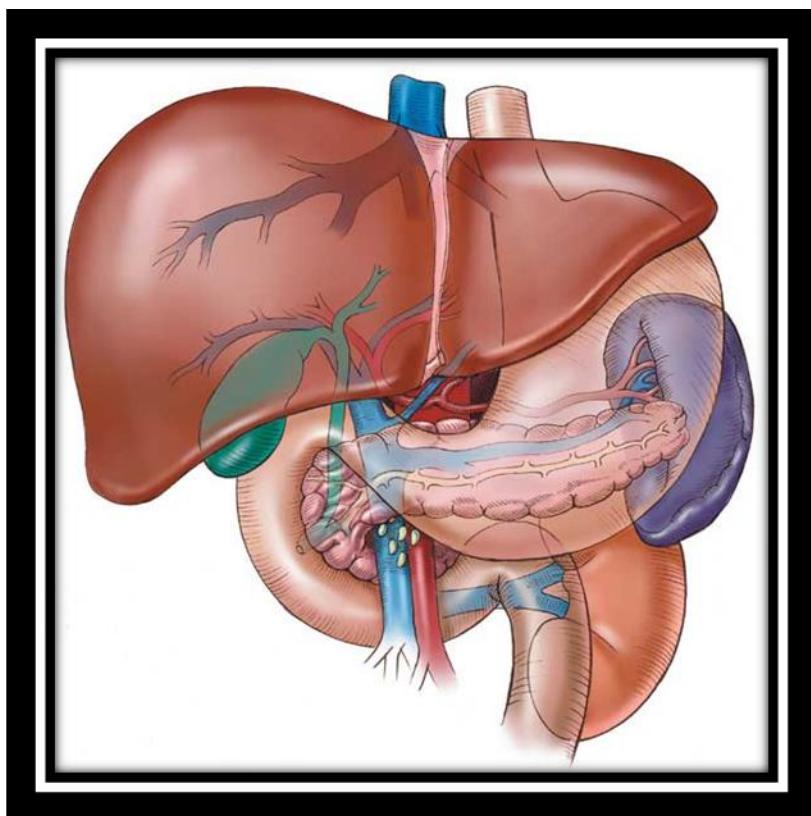


SIMPLY BIOLOGY



Z A S E

The letters Z, A, S, and E are displayed in large, bold, white serif font, each contained within its own black rectangular box. The boxes are arranged horizontally, with a thin white space between them.

IN CONJUNCTION WITH
ST. LISBON PUBLICATIONS

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Preface

The writing of this book was inspired by the desire of the author to make an indelible contribution to the educational system of our beloved country, Zambia.

The project started in the form of notes that the author was using to teach his Senior Secondary School Biology Classes over a period of nine years. The notes were widely researched and proven through the good grades his students were scoring in Zambian and International Examinations. In addition, they were frequently edited to make them conform to the demands of the Zambian Biology Syllabus produced by the Curriculum Development Centre (CDC).

It was not long before there was an outcry to have the notes converted into a book. By that time, the author had been setting examinations for the Examinations Council of Zambia (ECZ) for a considerable number of years. With the help of some of his students, notably Zameer and Shawn Banda, the first manuscript was typed in 2006 and produced in the form of pamphlet.

The pamphlet served two purposes. Firstly, it was used for instruction during classes. Most importantly, it was availed to several teachers and pupils who gave invaluable advice. This advice has been taken into account in producing the final copy of this first edition of the book.

In a nutshell, the book provides a very solid foundation to beginners and basic experience to those who wish to pursue further studies in Biological Sciences.

Acknowledgements

I wish to acknowledge the contribution of several individuals and organisation to the development of this publication. Firstly, I thank my former students, Shawn Banda and Zameer, who assisted type part of this work. I am also indebted to a number of former pupils of David Kaunda National Technical High School on whom this material was tried and tested between 2006 and 2009. They were so enthusiastic about the project and inspired me to keep working on it. Special thanks go to Mr. Severian Masesa, the Chief Examiner for the Biology Paper 2 Panel, for using his vast experience in editing this work

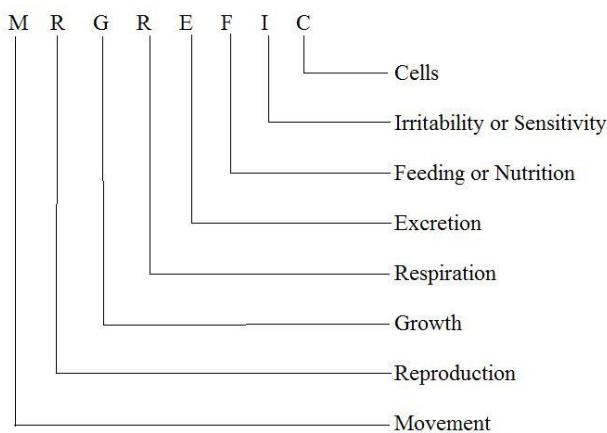
Introduction

INTRODUCTION: WHAT IS BIOLOGY?

Biology is defined as the study of living things (organisms). There are several branches of biology such as:
Botany (the study of plants)
Zoology (the study of animals)
Ecology (the study of interactions of organisms with each other and with their non-living environment)
Biochemistry (the study of chemical reactions that occur in living organisms)
Entomology (the study of insects)

CHARACTERISTICS OF LIVING THINGS

The characteristics of living things may be summarized by the mnemonic **MR. GREFIC**.



Movement is the process by which a living organism changes its location and posture without external help. The movement of an entire organism from one place to another is also called **locomotion**.

Respiration is the release of energy from food substances inside living cells. There are two types of respiration. These are **aerobic** and **anaerobic** respiration. Aerobic respiration is the release of energy from food substances inside living cells **in the presence of oxygen**. Anaerobic respiration is the release of energy from food substances inside living cells **in the absence of oxygen**. Aerobic respiration yields more energy than anaerobic respiration.

Growth is a permanent increase in size, mass, number of cells and complexity of an organism.

Reproduction is the process by which living organisms produce their young ones (offspring). There are two types of reproduction, **sexual** and **asexual**. In sexual reproduction offspring are produced by the fusion of male and female gametes (from one or two parents) and are genetically different from their parents. In asexual reproduction the offspring are produced from one parent without involving any gametes and are genetically identical to the parent and each other.

Excretion is the removal of toxic **metabolic wastes** from the cells of the body such as urea, excess salts, excess water, bile pigments and carbondioxide.

Feeding/nutrition is the process by which living organisms obtain food. There are two types of nutrition which are **autotrophic** and **heterotrophic**. Autotrophic nutrition is the type where an organism makes its own food e.g. green plants. Heterotrophic nutrition is the type where an organism takes in food present in bodies of others.

Irritability/sensitivity is the ability to detect and respond to stimuli (singular=stimulus). A stimulus is any change in the environment which causes a response from an organism.

Cells are the basic functional units of living organisms. Some organisms are made of single cells e.g. bacteria. Such organisms are called **unicellular organisms**. Other organisms are made of many cells e.g. fungi, plants and animals. Such organisms are called **multicellular organisms**.

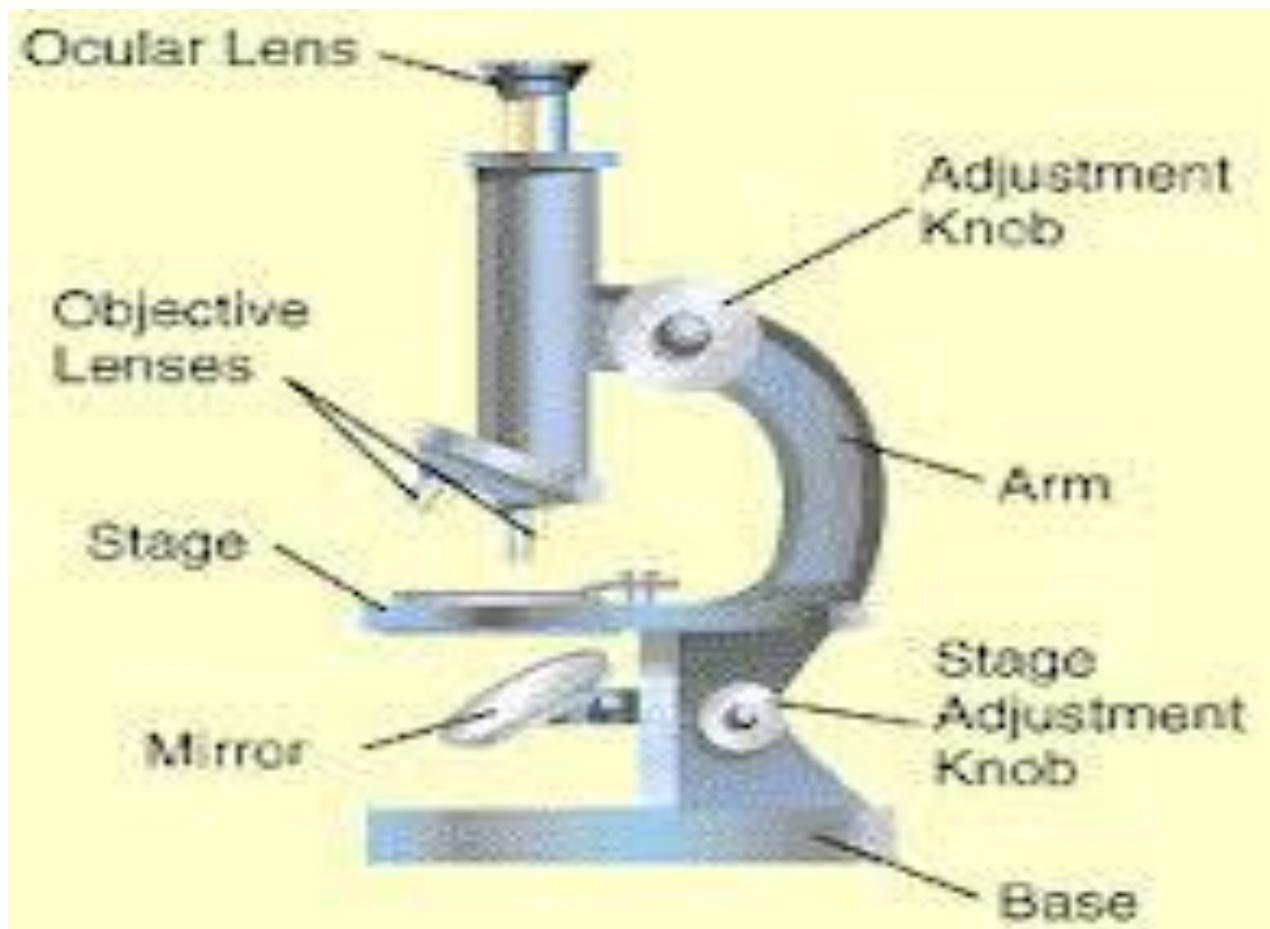
Metabolism/metabolic reactions

This is the sum total of chemical reactions that take place inside living cells. There are two types of metabolic reactions, namely **anabolic** and **catabolic** reactions. Anabolic reactions are metabolic reactions where large and complex molecules are synthesized from small and simple molecules e.g. photosynthesis, protein synthesis and synthesis of fats. Catabolic reactions are metabolic reactions where large complex molecules are broken down to simpler molecules e.g. respiration, digestion.

All metabolic reactions are catalyzed by **enzymes**. An enzyme is a biological catalyst (a catalyst inside a living organism).

MICROSCOPES

A microscope is an instrument which is used to make small objects look bigger or magnify small objects which are invisible to the naked eyes. Since most cells are invisible to the naked eye, a microscope is an essential tool in the study of cells. Cells were first discovered by an English scientist called Robert Hooke in 1665. There are several types of microscope. One type is a **hand lens**. It is a simple microscope made up of a convex lens fitted in a frame with a handle. Most hand lens have numbers such as $\times 2.5$ or $\times 5$. The numbers indicate the magnifying powers. In order to use a hand lens place the object to be viewed on a flat surface, a short distance from the lens itself. Look at the object through the lens. Then move the lens up and down until you see a distinct image. Another type is a **compound microscope**. It consists of two sets of lenses. The lenses are fitted at the opposite ends of a body tube. The lenses closer to the eye are called **eye piece** and the ones nearer the object are called the **objective lens**. The objective lenses are fitted into a revolving nose piece in the order of low power, medium power and high power. Some microscopes however may have only one or two sets of objective lenses. Figure below shows a typical microscope



USING A COMPOUND MICROSCOPE

In order to view an object, illuminate it first by light, then allow light to pass through the lenses and finally into the eye. The mirror directs the light to the object.

Place the microscope slide, with an object to be viewed on the stage and hold it in position by stage clips. Fix the objective lens to be used in line with the eye piece by turning the revolving nose piece. Ensure that a click sound is heard when the objective lens is set in position. Looking from one side of the microscope, keep the eyes at stage level. Then turn the coarse adjustment knob until the low power objectives lens and the object to be viewed are as close to each other as possible. To avoid breaking the slide, do not allow the objective lens to touch the cover slip. Turn the coarse adjustment knob slowly while looking through the eye piece. The turning increases or reduces the distance until a focussed image is obtained. When focussed, always start with low power, then turn to medium power before turning to high power objective lens. In order to obtain a sharp image, slowly turn the fine adjustment knob either clockwise or anti-clockwise. A compound microscope can magnify objects up to one thousand five hundred times ($\times 1500$).

MAGNIFICATION

Magnification is the number of times the image of the object is enlarged (magnified) as compared to the specimen. For example, a magnification of four ($\times 4$), means that the object is enlarged four times. Magnification has no units.

To obtain total magnification, multiply the number on the eye-piece lens by that on the objective lens; i.e.

M = power of eye-piece x power of objective lens

When the specimen is drawn magnification is calculated using the formula given below.

Magnification = $\frac{\text{size of drawing (image)}}{\text{actual size of specimen (object)}}$

Example: a pupil draw a specimen and the size of the drawing was 103 mm. If the size of the specimen was 53 mm, calculate the magnification.

Magnification = $\frac{\text{size of drawing (image)}}{\text{actual size of specimen (object)}}$

$$= \frac{103 \text{ mm}}{53 \text{ mm}}$$

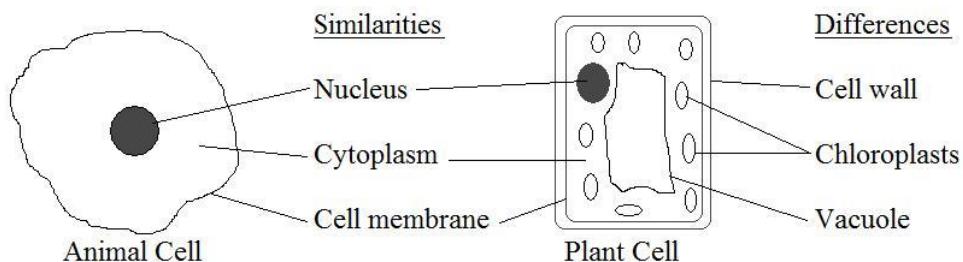
$$= 1.9433$$

Magnification = $\times 1.9$ or $1.9x$ or 1.9 times or times 1.9

CELLS

Cells are too small to be seen by the naked eye. Therefore they are observed using **microscopes**. A microscope is an instrument used to magnify images of objects that are too small to be seen with the naked eye. There are two groups of microscopes. These are **light** and **electron** microscopes. The light microscope shows a **simple structure** of a cell while the electron microscope shows a detailed or **ultrastructure** of a cell. A cell is a basic unit of life or basic unit of a living organism or functional unit of a living organism.

Simple Structure of a Plant Cell and an Animal Cell



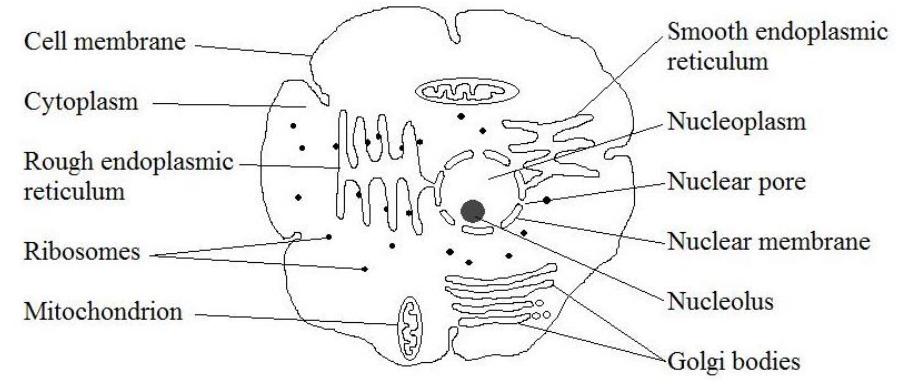
Similarities between animal and plant cells

They both have cell membranes, cytoplasm and nucleus

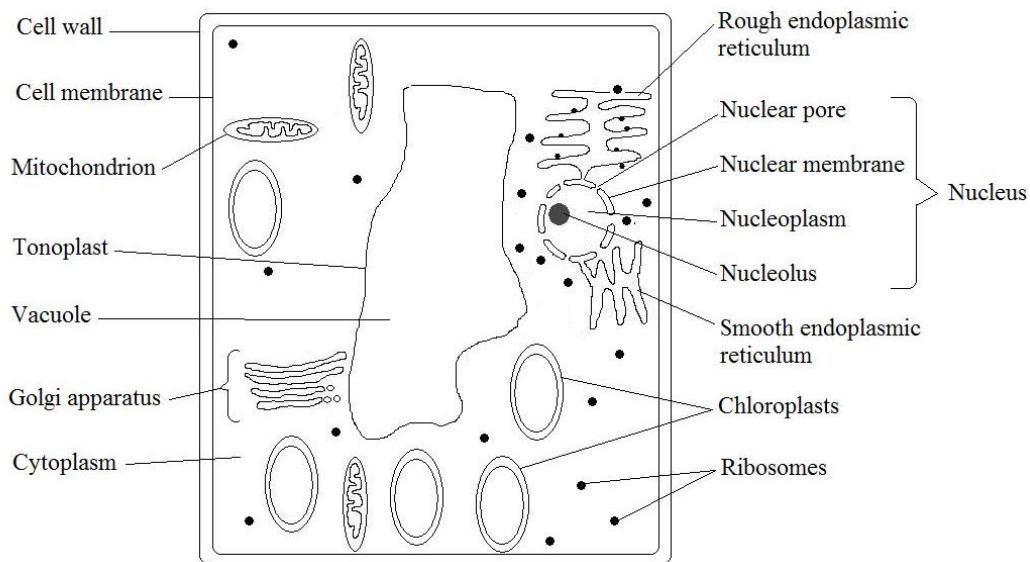
Differences between animal and plant cells

Plant Cell	Animal Cell
Has cellulose cell wall	Does not have cellulose cell wall
Has large permanent vacuole	Does not have large permanent vacuole
Has chloroplasts	Does not have chloroplasts
Has regular shape and bigger size	Has irregular shape and smaller size

Detailed structure/Ultrastructure of an Animal Cell



Detailed structure/Ultrastructure of a Plant Cell



Functions of Cell Parts

Nucleus: This part is responsible for controlling cell activities and storage of genetic information on threads of DNA called **chromosomes**. It is surrounded by a double membrane called the **nuclear membrane** which has openings called **nuclear pores**. The inside of the nucleus contains a fluid called the **nucleoplasm** and a dense body of DNA called the **nucleolus**.

Cell membrane: This part is made of **lipids** and **proteins** and is responsible for controlling the substances that enter and leave the cells. It is adapted for this function by being **selectively/partially permeable**. This means it allows some substances to pass through it but prevents others from passing through. The substances that cross the cell membrane freely include gases (such as oxygen and carbon dioxide) and water because their molecules have small sizes. On the other hand, substances such as urea whose molecules are large do not freely cross the cell membrane but use special carrier proteins to do so.

Cytoplasm: This is a jelly-like fluid made of water and dissolved substances such as proteins, salts and sugars. It contains suspended cell structures called **organelles** and is the site for cell activities.

Note: The three parts (nucleus, cytoplasm and cell membrane) are collectively called the **protoplasm**. The protoplasm is defined as the living part of the cell.

Mitochondrion (plural: mitochondria): These are rod-shaped or sausage-shaped structures in the cell. This is where respiration takes place. For this reason mitochondria are called the **power house** of the cell.

Ribosomes: These are small round structures in the cell where protein synthesis takes place. Some ribosomes float freely in the cytoplasm while others are attached to the rough endoplasmic reticulum.

Endoplasmic Reticulum: This is a network of membranes used for transportation of substances within the cytoplasm. There are two types of endoplasmic reticulum, namely smooth endoplasmic reticulum and rough endoplasmic reticulum. Rough endoplasmic reticulum has ribosomes on its surface and transports proteins. Smooth endoplasmic reticulum has no ribosomes on its surface and transports lipids.

Golgi Bodies: These are a pile of flattened vesicles which modify and carry proteins such as enzymes from the sites of synthesis to the sites of reaction. They are collectively called the Golgi apparatus.

Chloroplasts: These are oval-shaped structures found in plant cells. They carry out photosynthesis. They contain a green pigment called **chlorophyll** which absorbs light energy for photosynthesis.

Vacuole: This is a fluid filled space inside the cytoplasm of a plant cell. It contains a fluid called **cell sap** (a solution of sugars and salts in water) and is surrounded by a membrane called **tonoplast**. The concentration of the cell sap plays a role in the movement of water into and out of the cell.

Cell wall: This is the outermost boundary of the plant cell. It is made of a substance called **cellulose**. It is important for protection against damage and prevention of bursting when the plant cell gains a lot of water. It also gives shape to the plant cell. It is fully permeable to all substances.

Cell Specialization

New cells are formed from already existing cells by cell division in an organism. At first, they are all similar in structure. But in order to be suited for their functions they have to undergo cell specialization. This is a process by which a cell undergoes specific changes in structure and chemical composition of the cytoplasm in order to perform a specific function. Examples of specialized cells are ciliated cells, root hair cells, xylem vessels, guard cells, nerve cells, muscle cells, white blood cells and red blood cells.

Ciliated cells

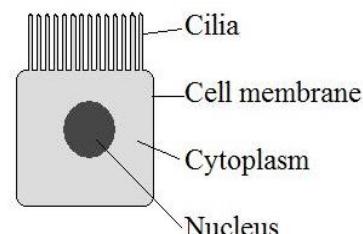
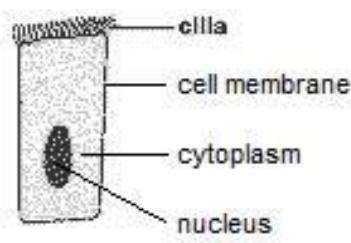
Functions

These are cells found in the inner lining of the respiratory tract and the oviducts.

- In the respiratory tract they sweep out mucus containing dust particles and germs.
- In the oviduct they move the ovum towards the uterus.

Adaptations

- Presence of cytoplasmic hairs called **cilia**
- A high concentration of mitochondria in the cytoplasm to generate energy for movements of the cilia



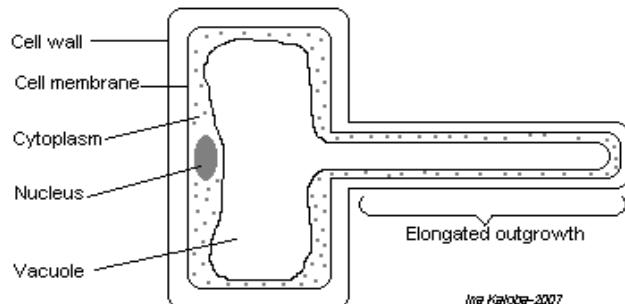
Root Hair cell: These are cells found near the tips of roots

Functions

- Absorption of water and mineral salts
- Anchor the plant in the ground

Adaptations

- Has an elongated outgrowth (long extension) which increases the surface area for faster diffusion during absorption.
- Absence of chloroplast to create more room for absorption.
- High concentration of mitochondria to provide energy for active absorption/transport of mineral salts. In addition, root hair cells are numerous which further increase their surface area.



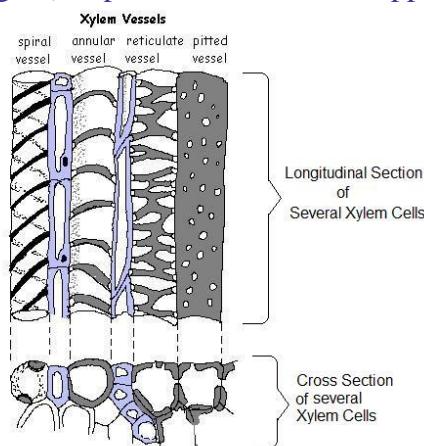
Xylem Cell

Functions

- Conduction of water and mineral salts
- Mechanical support of the plant.

Adaptations

- End walls of neighbouring cells broken to form continuous tubes
- Protoplasm is absent leaving a hollow space in the middle of the cell.
- Walls are lignified (filled with lignin) to provide mechanical support



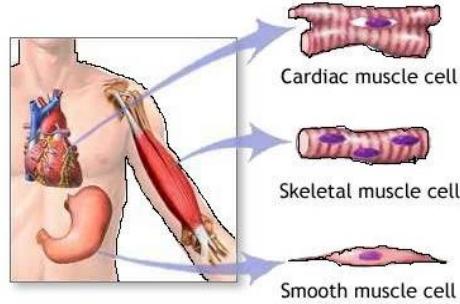
Muscle Cells

Functions

- Contraction to produce movement

Adaptations

- Abundance of mitochondria to release energy for contraction
- Presence of **actin** and **myosin** filaments in the cytoplasm which carry out contraction.



As seen from the diagram, the shapes of the different types of muscles are different from each other

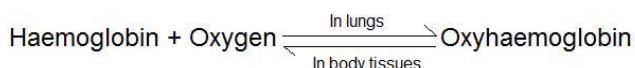
Red blood cell (Erythrocyte)

Functions

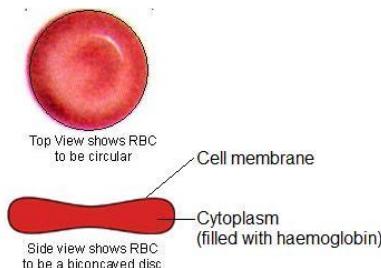
- Transportation of oxygen and small amounts of carbon dioxide.

Adaptations

- Biconcave disc shape to increase the surface area for diffusion of oxygen.
- Presence of a red pigment called **haemoglobin** which has a high affinity (attraction) for oxygen. Haemoglobin combines with oxygen to form **oxyhaemoglobin** when oxygen concentrations are high (e.g. in the lungs). When oxygen concentrations are low e.g. in the muscles, oxyhaemoglobin dissociates forming haemoglobin and oxygen.



- Absence of nucleus makes more room for haemoglobin



Nerve Cell (neurone)

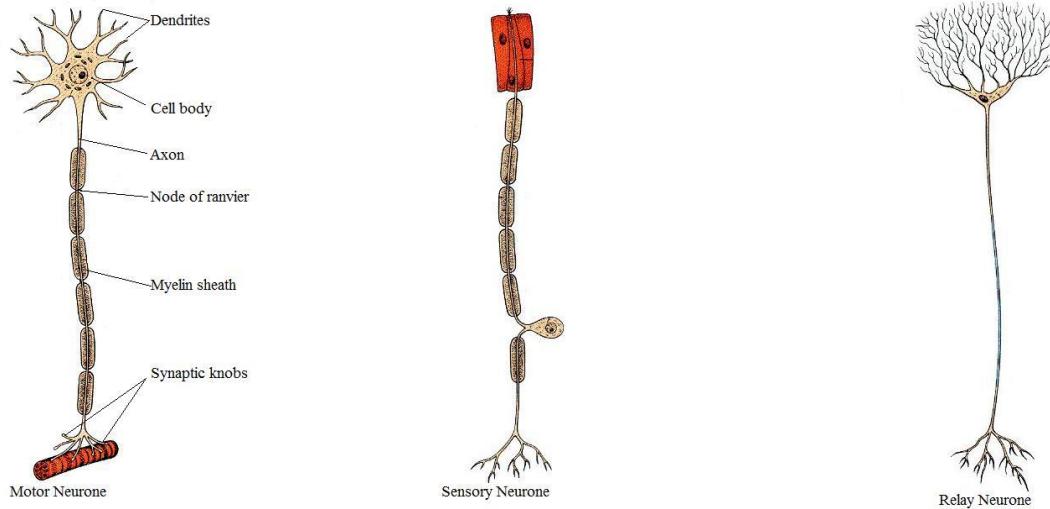
Functions

- To conduct electrical impulses (nerve impulses) from one part of the body to another.

Adaptations

- Presence of dendrites that collect impulses from neighbouring cells
- Presence of axon that carries impulses from one end of the neurone to another.
- Presence of synaptic knob that forms a link with other neurones.
- Presence of nodes of Ranvier that make impulses move faster

Note the part of the neurone having the nucleus and cytoplasm is called the cell body



White Blood Cells

These are cells that defend the body against infection (diseases). Two examples of white blood cells are **phagocytes** and **lymphocytes**.

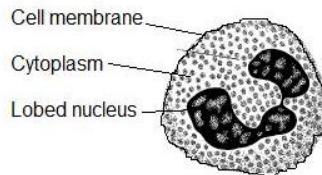
Phagocytes

Functions

- These defend the body against infection by **engulfing** and **digesting** germs (foreign bodies).

Adaptations

- Lobed nucleus which makes engulfing of germs easy.
- Amoeboid movement which makes it possible for them to move towards germs.
- They have no fixed shape but can change their shapes, making engulfing of foreign bodies possible.



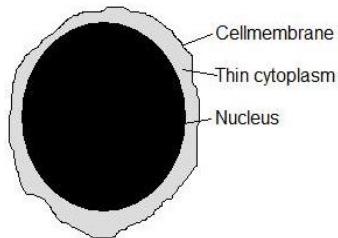
Lymphocytes

Functions

- To defend the body against infection by producing **antibodies** and **antitoxins**. Antibodies are proteins that destroy germs/foreign bodies while antitoxins are proteins that neutralize poisons from germs.

Adaptations

- Presence of a large nucleus and thin cytoplasm.



Guard Cells

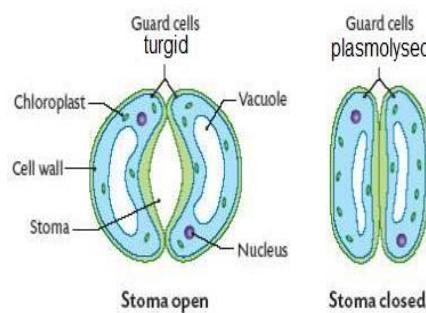
These are a pair of cells that surround each stoma.

Function

- To control the size of the stoma

Adaptations

- They occur in pairs and each cell has a semicircular (curved) shape when turgid and a straight shape when plasmolysed.
- Their cell walls are thicker around the stoma than anywhere else; this makes it possible for the stoma to open when these cells absorb water.



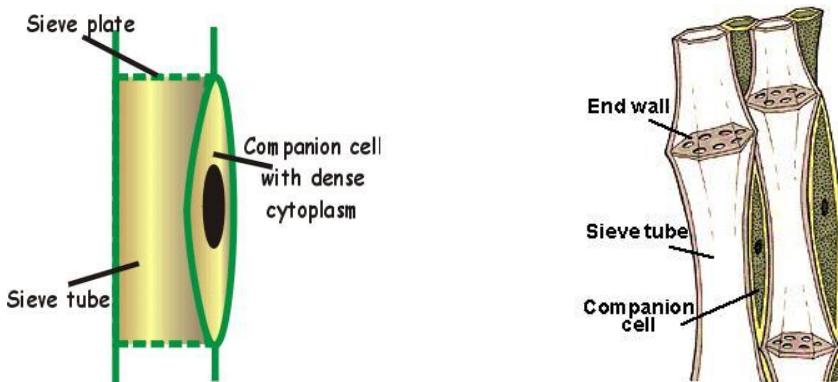
Phloem Cells

Function

- To transport manufactured food from one part of the plant to another

Adaptations

- End walls between neighbouring cells are perforated to form **sieve plates**
- Protoplasm is partly lost leaving behind some cytoplasmic strands
- Presence of companion cells which supply phloem cells with enzymes and ATP.



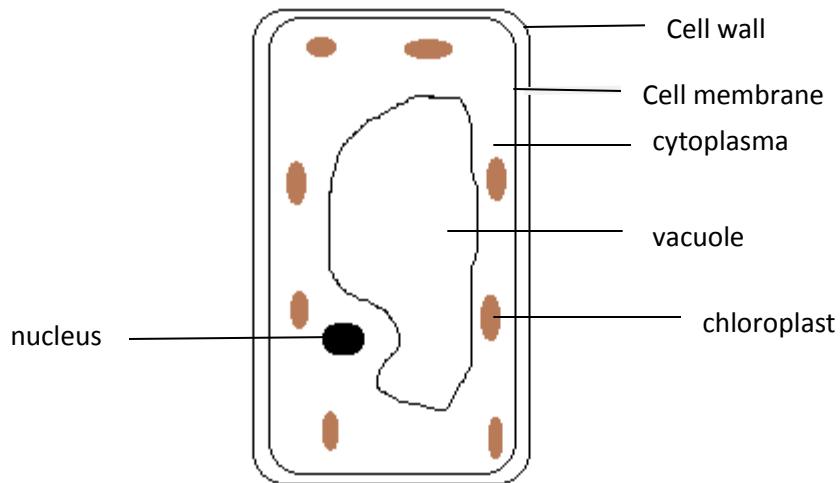
Palisade Cell

Functions

- Carrying out photosynthesis

Adaptations

- A high concentration of chloroplasts.
- The cells are longer vertically than horizontally. This allows chloroplasts to migrate upwards or downwards as light intensity changes so that they are not damaged by excess light.



Cell Organization

A group of specialized cells having the same shape/structure and function make up a **tissue**. Examples of tissues are epidermis, palisade tissue, spongy tissue, blood, epithelium and bone tissue.

A group of tissues performing a specific function make up an **organ**. Examples of organs are roots, stems, leaves, liver, skin, heart, brain, eyes, ears, kidneys and lungs. What tissues make up each of these organs?

A group of organs performing a specific function make up a **system**. Examples of systems are vascular system, digestive system, excretory system, endocrine system, nervous system, skeletal system, respiratory system and reproductive system. What organs make up each of these systems? A group of systems performing a specific function make up an organism. There are two types of organisms namely: unicellular which has only one cell e.g amoeba and multicellular which has many cells e.g a human being.

Levels of cell organization may be summarized as follows:

Cells → Tissues → Organs → Systems → Organism

TRANSPORT ACROSS THE CELL MEMBRANE (DIFFUSION, OSMOSIS AND ACTIVE TRANSPORT)

Substances enter or leave cells through the cell membrane using three main processes which are **diffusion**, **osmosis** and **active transport**.

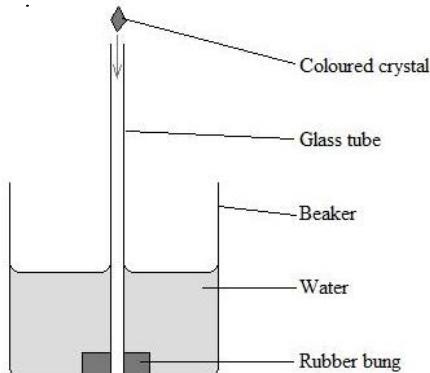
Diffusion

This is the movement of particles from their region of higher concentration to their region of lower concentration (down a concentration gradient).

Experiment to Demonstrate Diffusion

Materials: A 250 cm^3 glass beaker, a long glass tube, a holed rubber bung or stopper, a coloured crystal such as potassium permanganate or copper (II) sulphate and water

Method: Set up the experiment as shown in the following diagram



- First insert one end of the glass tube halfway into the rubber stopper.
- Place the rubber stopper and glass tube into the beaker, keeping the rubber firmly pressed to the bottom of the beaker.
- Introduce the coloured crystal of potassium permanganate down the tube.
- Close the open end of the glass tube with a finger and fill the beaker halfway with water.
- With one end of the glass tube still closed with a finger, gently lift the glass tube and rubber stopper out of the beaker without disturbing the crystal.
- Observe what happens in the beaker until there are no further changes.

Observations:

- At the beginning, the clear water and coloured crystal are each clearly visible
- After some time, the colour of the crystal starts spreading out but some of the water still remains clear.
- Eventually, all the water is evenly coloured by the colour of the crystal

Conclusion:

The particles of the potassium permanganate crystal spread out in the water by the process of diffusion.

Factors that affect the rate of Diffusion

The rate at which particles diffuse is affected by the following factors:

- Concentration gradient
- Surface area of diffusion surface
- Thickness/ distance of diffusion surface
- Temperature
- Size of diffusing particles

Concentration gradient: This refers to the difference in concentration of particles between two regions. The higher the concentration gradient, the faster the diffusion rate.

Surface area of Diffusion Surface: The larger the surface area of the diffusion surface, the faster the rate of diffusion.

Thickness of Diffusion Surface: The thinner the diffusion surface, the faster the diffusion rate.

Temperature: Increase in temperature increases the kinetic energy of particles causing them to diffuse at a faster rate.

Size of Diffusing Particles: The bigger the diffusing particles, the slower the diffusion rate; the smaller the diffusing particles, the faster the diffusion rate.

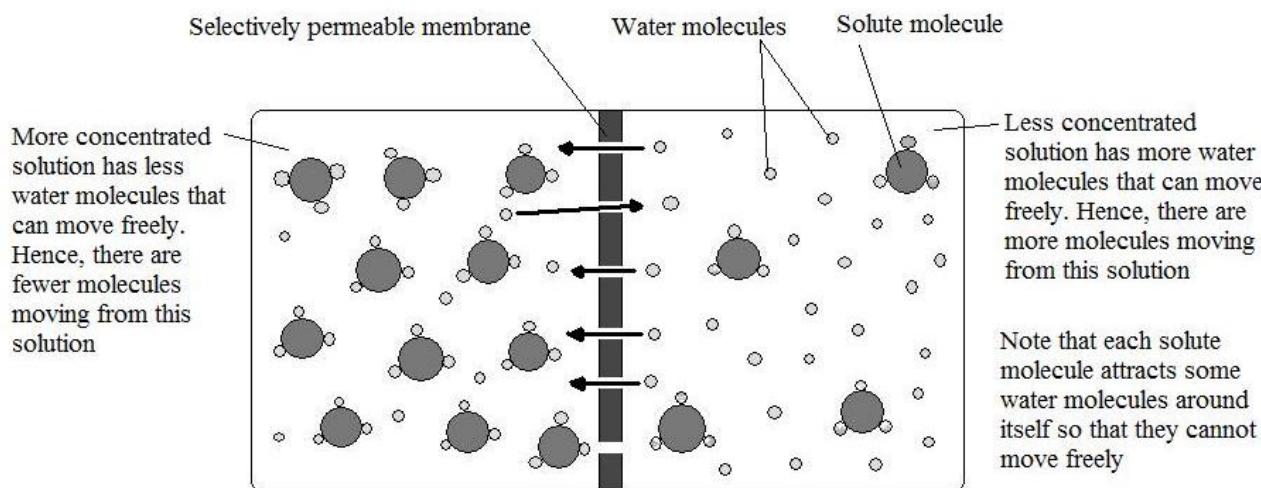
Importance of Diffusion

Diffusion is important in living organisms in the following ways:

- Oxygen moves from the lungs to the blood and from the blood to the tissue cells by diffusion.
- Carbon dioxide moves from the tissue cells to the blood and from the blood to the lungs by diffusion.
- Dissolved food moves from the blood into the tissue cells by diffusion.
- Metabolic wastes such as urea move from the tissue cells into the blood by diffusion.
- Carbon dioxide needed for photosynthesis by plants moves from the atmosphere into the leaves by diffusion.
- Oxygen produced during photosynthesis moves out of the leaves to the atmosphere by diffusion.
- Water vapour moves out of the air spaces of leaves to the atmosphere during transpiration by diffusion.

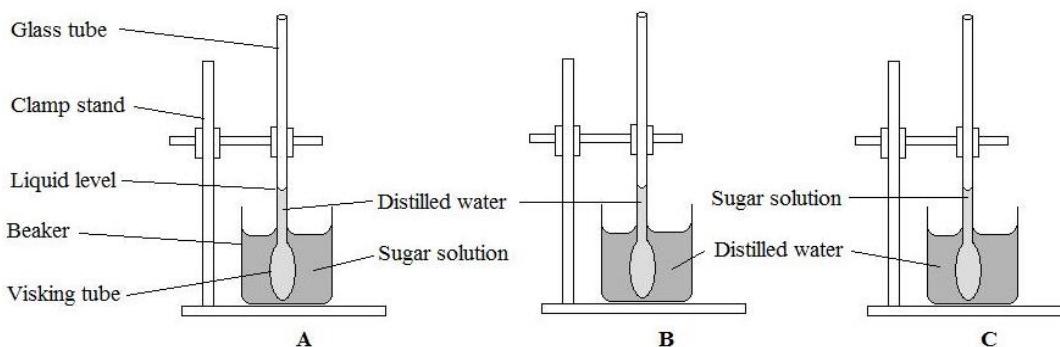
Osmosis

Osmosis is the movement of **water molecules** from a region of higher water potential to a region of lower **water potential** through a **selectively permeable membrane**. Water potential is a measure of the capacity or tendency of water molecules to move from one solution to another. Distilled water has the highest water potential. The more concentrated a solution becomes, the less its water potential becomes. A selectively permeable membrane can allow water molecules to pass through because of their small size but cannot allow solute molecules to pass through because of their big size. The following diagram illustrates what occurs during osmosis.



Experiment to Demonstrate Osmosis

Set up the experiment as shown in the following diagram



Mark the initial level of liquid in each of the three glass tubes. Record what happens to the liquid level in each glass tube after five minutes.

Observations

In A the liquid level drops. In B the liquid level stays the same. In C the liquid level rises.

Conclusion

During osmosis, water molecules move from a less concentrated solution to a more concentrated solution through a selectively permeable membrane until a dynamic equilibrium is reached. Equilibrium is a state where the number of water molecules moving to either side of the selectively permeable membrane is equal.

Osmosis is important in living organisms mainly in movement of water into and out of cells (absorption of water by plants, movement of water from cell to cell e.t.c)

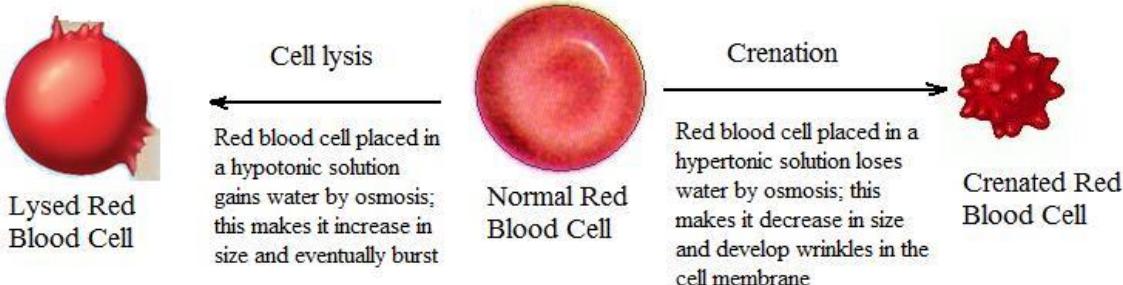
Effects of Osmosis in Living Organisms

The cells, tissues, organs and systems of living organisms are always exposed to body fluids or solutions of different concentrations. There are three types of solutions an organism may be exposed to, namely **hypotonic**, **isotonic** and **hypertonic** solutions. A hypotonic solution is one whose concentration is lower than the concentration inside a living cell. An isotonic solution is one whose concentration is equal to the concentration inside a living cell. Isotonic solutions have no net osmotic effects in living organisms because a dynamic equilibrium exists between them and the living cells. A hypertonic solution is one whose concentration is higher than the concentration inside a living cell.

a) Effects of Osmosis in Animals

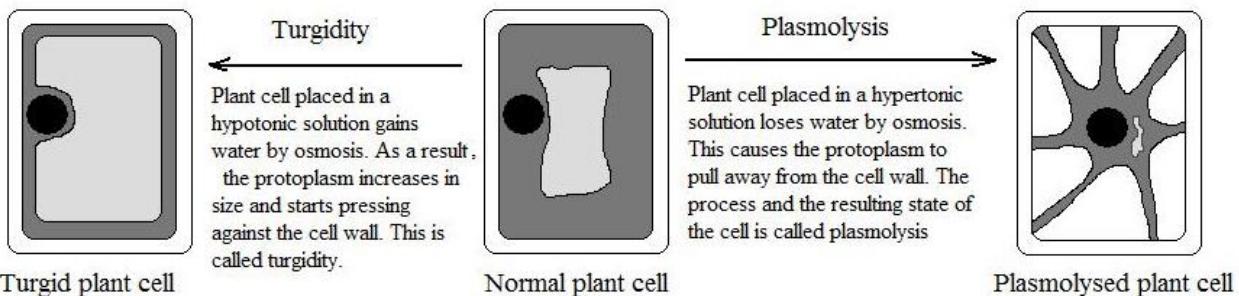
When an animal cell such as a red blood cell is placed in a hypotonic solution, it gains water by osmosis because the water potential of the hypotonic solution is higher than the water potential inside the cell. As a result, it swells and eventually bursts. The bursting of an animal cell due to osmotic gain of water is called **cell lysis**. When an animal cell is placed in a hypertonic solution, it loses water by osmosis because the water potential inside the cell is higher than the water potential of the hypertonic solution. As a result, it shrinks and wrinkles. The shrinking and wrinkling of an animal cell due to osmotic loss of water is called **crenation**. Osmotic loss of water by animal tissues leads to **dehydration** of the animal. The following diagrams illustrate cell lysis and crenation.

Cell lysis and crenation in a red blood cell



b) Effects of Osmosis in Plants

When a plant cell is placed in a hypotonic solution, it gains water by osmosis because the water potential of the hypotonic solution is higher than the water potential inside the plant cell. As a result, its protoplasm swells and eventually starts pressing against the cell wall. The condition where the protoplasm of a plant cell presses against the cell wall due to osmotic gain of water is called **turgidity**. A plant cell that is undergoing turgidity is said to be **turgid**. Why does the plant cell not burst? (Refer to structure of cell wall). When a plant cell is placed in a hypertonic solution, it loses water by osmosis because the water potential inside the cell is higher than the water potential of the hypertonic solution. As a result, its protoplasm shrinks and pulls away from the cell wall. The condition where the protoplasm of a plant cell pulls away from the cell wall due to osmotic loss of water is called **plasmolysis**. A plant cell that is undergoing plasmolysis is said to be **plasmolysed**. The following diagrams illustrate turgidity and plasmolysis.



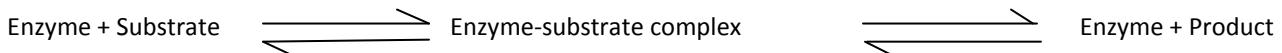
When a plant tissue such as a peeled potato tuber is placed in a hypotonic solution, it gains water by osmosis and becomes bigger and more firm. The presence of water in plant tissues forms a **hydrostatic skeleton** which renders mechanical support to the entire plant. When a plant tissue such as a peeled potato tuber is placed in a hypertonic solution, it loses water by osmosis and becomes **flaccid/flabby** (smaller and weaker). In a living plant, this leads to a condition called **wilting**. Wilting is the sagging of delicate plant parts such as leaves, flowers and young stems due loss of water. **Temporary wilting** is one which can be reversed by supplying a plant with water. **Permanent wilting** can not be reversed even if a plant is supplied with water the plant tissues have already died. Suggest why it is not advisable to apply too much fertilizer on plants.

Active Transport

The movement of particles against a concentration gradient using energy from ATP. It is the main process by which mineral ions move into and out of cells (e.g. ion uptake by root hairs and uptake of glucose by epithelial cells of the villi).

ENZYMES

Enzymes are defined as **biological catalysts**. A catalyst is any substance that speeds up the rate of a chemical reaction without itself being changed by the reaction. Enzymes catalyze chemical reactions in living organisms. Those that work inside of living cells are called **intracellular enzymes** while those that work outside living cells are called **extracellular enzymes**. The substances on which enzymes act to form products are called **substrates**. The part of an enzyme where the substrate fits during an enzyme-catalyzed reaction is called the **active site** while the other parts of the enzyme are called **allosteric sites**. A typical enzyme-catalyzed reaction may be represented as follows:

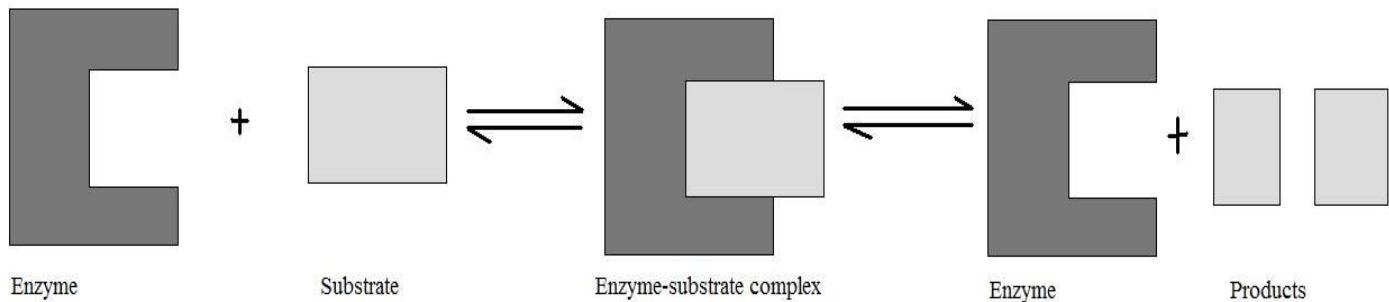


Characteristics of Enzymes

- Most of them are **protein in nature**
- They are **catalysts**
- They **catalyze both forward and reverse reactions**. That is why the reactants, intermediates and products in the equation above are linked by half arrows pointing forwards and backwards.
- They are **specific**. This means each enzyme acts on only one substrate or a narrow range of related substrates. Enzyme specificity is discussed latter in this booklet.
- Their activity is affected by temperature, PH, substrate concentration, enzyme concentration, inhibitors and cofactors (coenzymes and activators).Memory aid: SEPTIC

Explanation of Enzyme specificity

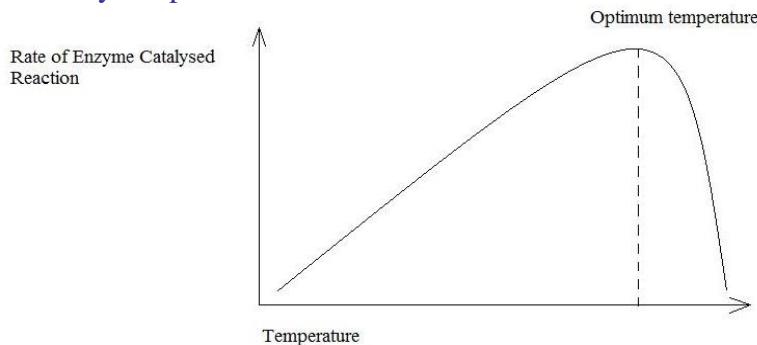
One of the theories used to explain enzyme specificity is called the **lock-and-key mechanism**. This theory states that each substrate fits into the active site of a particular enzyme in the same way a key fits into a specific lock because the two have complementary shapes. The following diagram illustrates the lock-and-key mechanism.



Factors that Affect Enzyme Activity

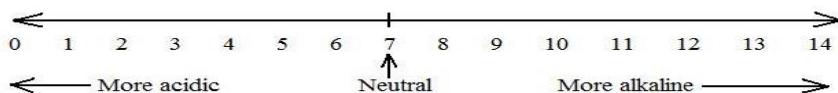
(i) Temperature

Enzyme activity increases with increase in temperature up to the **optimum temperature**. This occurs because an increase in temperature results in increase in the kinetic energy of both the enzyme and the substrate, leading to increased interaction between enzyme and substrate and formation of enzyme-substrate complex. At temperatures lower than the optimum, the rate of an enzyme-catalyzed reaction doubles with every increase of 10°C . The optimum temperature is the temperature at which an enzyme works best. The activity reduces after the optimum temperature because the enzyme gets **denatured** and loses its catalytic function. Enzyme denaturation is the disturbance of the shape of an enzyme and its active site such that the substrate no longer fits in the active site. Hence the enzyme can no longer carry out its catalytic function. The following graph shows how enzyme activity is affected by temperature.



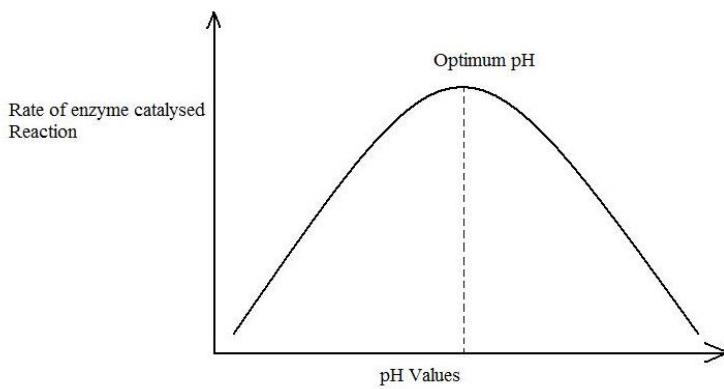
(ii) pH

pH is a measure of how acidic or alkaline a substance is. pH values range from 1 to 14. A pH value of 7 is said to be **neutral**. pH values lower than 7 are said to be **acidic** while values higher than 7 are said to be **alkaline**. This means that acidity increases as pH values get lower than 7 and alkalinity increases as pH values get higher than 7. The following diagram illustrates the pH scale.



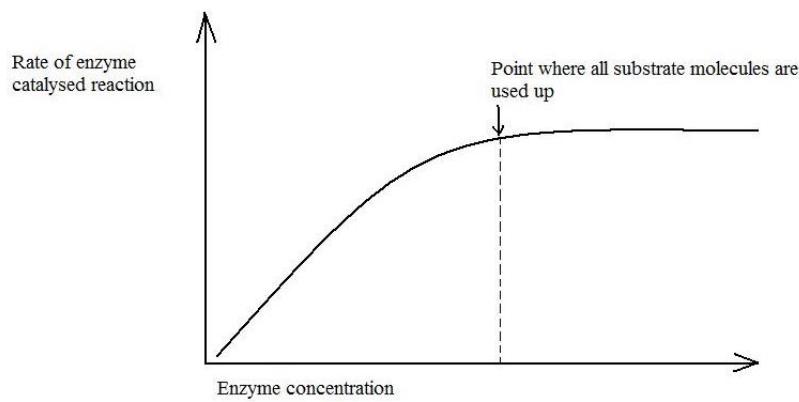
The pH value at which a given enzyme works best is called the **optimum pH**. Values lower or higher than the optimum pH lower enzyme activity. The optimum pH varies from enzyme to enzyme, depending on the enzyme's natural occurrence. For instance, the digestive enzymes of the stomach

work best at acidic pH values while those of the duodenum work best at alkaline pH values. A graph of enzyme activity against pH is always symmetrical and has its peak at the optimum pH, as illustrated by the following diagram.



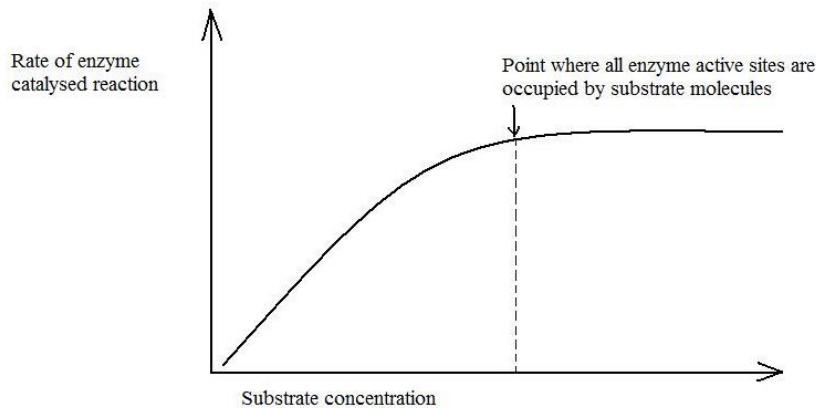
(iii) Enzyme Concentration

The rate of an enzyme-catalyzed reaction increases with increase in the concentration of the enzyme and remains constant when there are no more free substrate molecules for the enzyme to act on.



(iv) Substrate Concentration

The rate of an enzyme-catalyzed reaction increases with increase in the concentration of the substrate and levels off (remains constant) when all the enzyme active sites are occupied by the substrate molecules. Additional substrates have nowhere to fit on the enzymes.



(v) Inhibitors

An enzyme inhibitor is any substance that slows down or completely stops enzyme activity. **Competitive** inhibitors bind to the active site of an enzyme and block the substrate from binding there. **Non-competitive** inhibitors bind to allosteric sites of an enzyme and cause the shape of the active site to change so that the substrate fails to bind. All metabolic poisons are examples of enzyme inhibitors.

(vi) Cofactors

An enzyme co-factor is any non-protein substance whose presence makes an enzyme active. Organic cofactors are called **co-enzymes** e.g. vitamins. Inorganic cofactors are called **activators** e.g. mineral salts.

Naming of Enzymes

One way of naming enzymes is using the **first part of the substrate name** and the suffix **-ase**, as illustrated by the following table.

Name of Substrate	Name of Enzyme
Carbohydrates (i) Starch (amylose and amylopectin) (ii) Maltose (iii) Sucrose (iv) Lactose	Carbohydrase (i) Amylase (ii) Maltase (iii) Sucrase (iv) Lactase
Proteins (i) Peptide	Protease (i) Peptidase
Lipids	Lipase

NB: Most protease enzymes have names ending with **-in** e.g. pepsin, trypsin and rennin.

Some Industrial Applications of Enzymes

Enzymes have applications in many industries and professions. A few examples are discussed below.

(i) Making of Biological Detergents

Enzymes are included in biological detergents so that they can hydrolyze stains of biological origin. The most commonly used enzymes are proteases which breakdown protein stains such as blood and chlorophyll stains, forming colourless amino acids as products. Lipases and carbohydrases may be used to get rid of lipid and carbohydrate stains, respectively, but these are easy to wash even with ordinary detergents.

(ii) Brewing and Baking

Baking and brewing both make use of the enzyme **zymase** which is found in yeast.

When baking, flour, water, sugar and yeast are mixed to make **dough**. Yeast secretes **zymase** which breaks down sugars to form alcohol and carbon dioxide. The carbon dioxide forms bubbles which cause the dough to rise.

When brewing cereal seeds are soaked until they start germinating. During the process of germination, starch is broken down to maltose by the enzyme **amylase**. Maltose is broken down to glucose by **maltase**. The seeds are dried and ground to form a powder. The powder is boiled in hot water to form a paste. After the paste cools, yeast is added. The enzyme **zymase** from yeast acts on sugars to form alcohol and carbon dioxide. The alcohol is removed from the mixture by distillation.

(iii) Making Sweeteners for Food and Drinks

In sweetening of confectioneries, glucose is converted into fructose by the enzyme **glucose isomerase** because fructose is sweeter than glucose.

(iv) In the Dairy Industry

In the dairy industry, the enzyme rennin is used to coagulate milk during the making of yoghurt and cheese.

(v) Tanning of Leather

Tanning is a process by which leather is made soft and pliable. Trypsin is utilized to digest proteins in the leather during tanning.

(vi) Extraction and Processing of Fruit Juice

When extracting juices from fruits enzymes known as **cellulases** and **pectinases** are used to increase the juice yield and prevent jelling of the juices, respectively.

(vii) Tenderizing of Meat

The meat industry makes use of Trypsin to tenderize meat and predigest baby food.

CLASSIFICATION OF ORGANISMS

Classification is the placing of organisms in groups based on features they have in common. It involves taxonomy, nomenclature and the construction and usage of identification keys

Taxonomy

The branch of biology where each organism is placed in a series of groups arranged in a hierarchy is called **taxonomy**. The groups are called **taxa** (singular: **taxon**). A taxon is a group of organisms that have similar features. The highest taxon an organism can belong to is a **kingdom**. Each kingdom is made of related **phyla** (singular: **phylum**); each phylum is made of related **classes**; each class is made of related **orders**; each order is made of related **families**; each family comprises a number of related **genera** (singular: **genus**) and each genus is made of related **species**. The species is defined as a group of organisms having similar features and capable of interbreeding to produce fertile offspring. It is the lowest taxon an organism can belong to. The above hierarchy of taxa can be remembered using the following memory aid: **Kings Play Chess On Fine Gold Stools**. The taxonomies of the human being, lion and maize plant are given in the following table:

Taxon	Human being	Lion	Maize	Wolf
Kingdom	Animalia	Animalia	Plantae	Animalia
Phylum	Chordata	Chordata	Angiospermophyta	Chordata
Class	Mammalia	Mammalia	Monocotyledoneae	Mammalia
Order	Primates	Carnivora	Commelinaceae	Carnivora
Family	Hominid	Felidae	Poaceas	Canidae
Genus	<i>Homo</i>	<i>Panthera</i>	<i>Zea</i>	<i>Canis</i>
Species	<i>Homo sapiens</i>	<i>Panthera leo</i>	<i>Zea mays</i>	<i>Canis lupus</i>

Nomenclature

Nomenclature is the naming of organisms with scientific names. The system of naming used is called the **binomial system of nomenclature**. In this system, the biological/scientific name of each organism has two parts. The first part is the name of the genus (generic name) and always begins with a capital letter while the second part is the name of the species (specific epithet). If printed, the name is italicized (e.g. *Homo sapiens*) but if hand-written, the name is under-lined (e.g. *Homo sapiens*). This is to indicate that the name is scientifically accepted world-wide. The names are normally in Latin because it was the original scientific language and is universally accepted. When written for the first time, the name must be written in full (e.g. *Panthera leo*) but if mentioned afterwards, only the first letter of the generic name is written followed by the full specific epithet (e.g. *P. leo*).

Kingdoms

There are five kingdoms of living organisms, namely **Kingdom Prokaryota** (the prokaryotes or bacteria), **Kingdom Protoctista** (the protoctists or protists such as *Amoeba*, *Plasmodium* and *Trypanosoma*), **Kingdom Fungi** (the fungi such as yeasts, mushrooms, toadstools and *Penicillium*), **Kingdom Plantae** (the plants) and **Kingdom Animalia** (the animals). Viruses are not assigned a kingdom because they are considered to be on the border-line between living and non-living things. When independent, they behave like non-living particles because they do not metabolize or self-regulate. But once inside a host, they behave like living things by carrying out reproduction.

Kingdom Prokaryotae

No nucleus; no double-membraned organelles; unicellular; includes all bacteria (singular=bacterium)

Kingdom Protoctista

Have well defined nucleus; have double-membraned organelles; mainly unicellular (single-celled) or with a cellular level of organization; includes protozoa and algae.

Examples of protists are *Plasmodium*, *Amoeba* and *Trypanosoma*.

Kingdom Fungi

Multicellular; Have well defined nucleus; have double-membraned organelles; cell wall of chitin; non photosynthetic (no chloroplasts); saprophytic nutrition; examples are yeasts, moulds, mushrooms and toadstools.

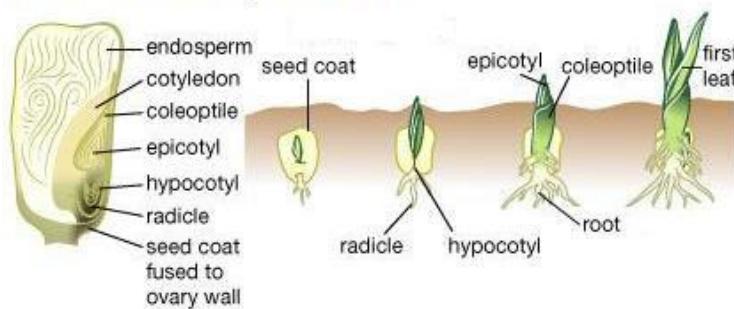
Kingdom Plantae

Multicellular; Have well defined nucleus; have double-membraned organelles; cellulose cell walls; photosynthetic (presence of chloroplasts); includes mosses, ferns, conifers and flowering plants.

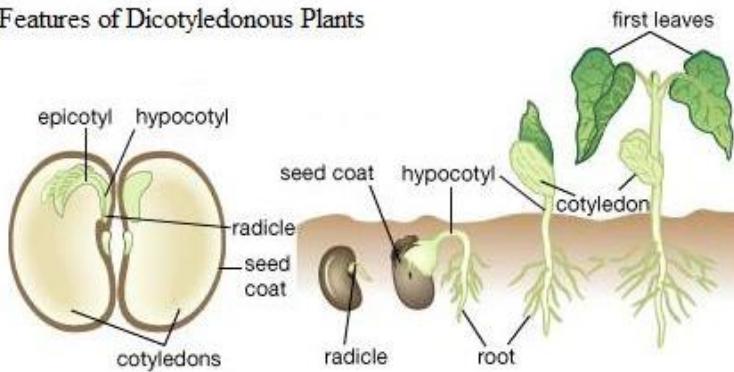
Flowering Plants

They have well developed roots, stem, vascular system and leaves; they bear flowers; they bear seeds which are enclosed in fruits. There are two classes: **monocotyledonous** and **dicotyledonous** plants.

Features of Monocotyledonous Plants



Features of Dicotyledonous Plants



Monocotyledoneae	Dicotyledoneae
Each seed has one cotyledon	Each seed has two cotyledons
Have fibrous root system	Have taproot system
Leaves are long and narrow and have parallel veins	Leaves are broad and have branched veins
Dull-coloured flowers having three floral parts	Brightly coloured flowers having four or more floral parts
Vascular bundles are scattered in the stem	Vascular bundles arranged in a circle in the stem
Examples include all grasses	Examples include all legume plants

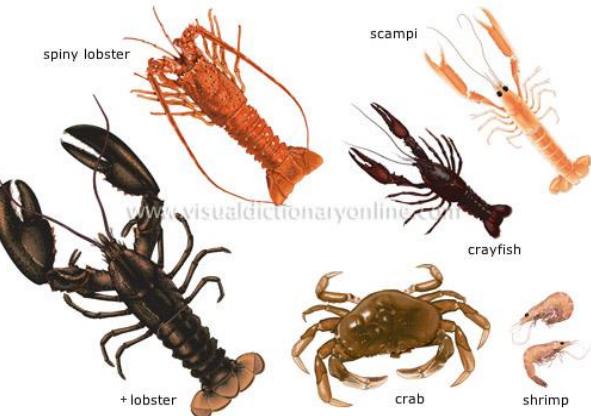
Kingdom Animalia

Multicellular; have well defined nucleus; have double-membraned organelles; no cell walls; heterotrophic nutrition; presence of nervous system; presence of anterior and posterior ends; presence of dorsal and ventral surfaces; presence of two lateral surfaces; presence of either radial or bilateral symmetry; includes invertebrates and vertebrates.

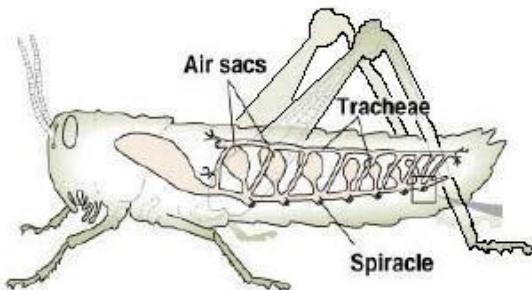
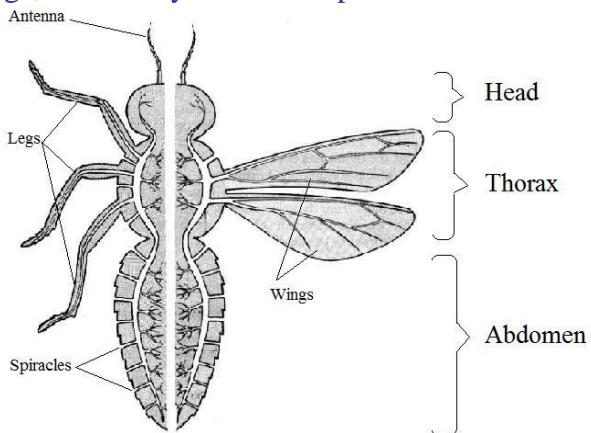
Invertebrates

These are animals without backbones. They include the following phyla:

- Cnidaria (e.g. sea anemones, corals, hydras and jellyfish): have radial symmetry; have tentacles.
- Mollusca (e.g. snails, slugs, squids, limpets, mussels and octopus): soft-bodied with a muscular foot; slimy covering; two pairs of tentacles, one with eyes and the other with smell receptors; usually have shells
- Nematoda (unsegmented roundworms): often microscopic, parasitic and extremely common.
- Platyhelminths (flatworms such as tape worm and liver fluke): flat, unsegmented and bilaterally symmetrical; mouth present but no anus.
- Annelida (truly segmented worms e.g. earthworms): long cylindrical bodies; bristle (chetae); clitellum
- Echinodermata (sea urchins and starfish)
- Arthropoda (Crustaceans, insects, myriapods and arachnids): theses are animals with jointed appendages, Exoskeleton, Bilateral symmetry, segmented body, Ventral notochord and dorsal heart. (Can be summarized JEBSDV).
 - Crustaceans (e.g. crabs, lobsters, crayfish and woodlice): aquatic or found in damp places; cephalothorax present; two pairs of antennae; three pairs of jaws; exoskeleton not water proof.

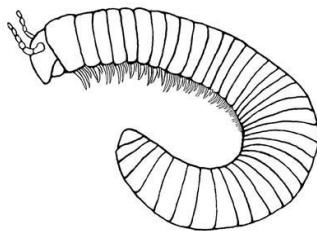


- Insects: 3 body regions (head thorax and abdomen), 2 pairs of wings, compound eyes, 3 pairs of legs, tracheal system for respiration.

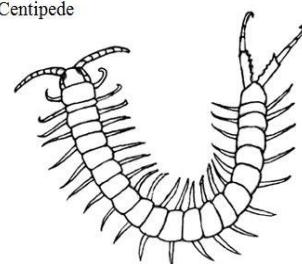


- Myriapods (centipedes and millipedes): terrestrial; herbivorous; one pair of antennae; one pair of jaws; many legs; centipedes have flattened bodies and one leg per segment; millipedes have cylindrical bodies and 2 pairs of legs per segment.

Millipede



Centipede



- Arachnids: 2 body regions (cephalothorax and abdomen); 4 pairs of legs; powerful jaws; spinneret (used for spinning webs in spiders); wings absent;

simple eyes; antennae absent; one pair of appendages; one pair of sensory appendages.



Identification Keys for the Kingdoms of Living Organisms

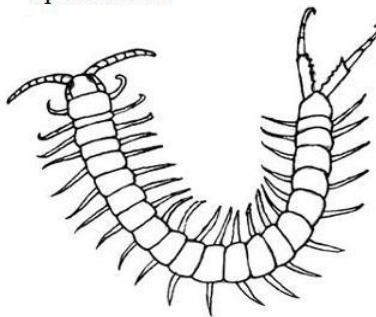
An identification key is a series of statements about characteristics of organisms which, if followed step by step, makes it possible for identification or classification of organisms. The type of key normally used in Biology called the **dichotomous key**. In this type of key, there is a series of paired contrasting statements or a branching tree diagram, leading to the identification of the organisms covered by the key. When constructing an identification key, one must always begin by listing the characteristics of the organisms they are trying to identify and then proceed with construction of the key based on the listed characteristics.

This presentation attempts to give some practice in the use of an identification key to place organisms in their kingdoms.

Exercise

You are provided with three specimens labelled A, B and C.

Specimen A



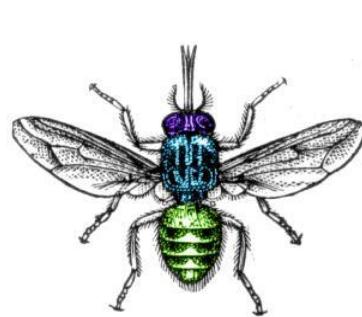
Scientific name:

Specimen B



Scientific name:

Specimen C



Scientific name:

Use the identification key provided below to write down the scientific name of each of the three specimens.

Identification Key for Specimens A, B and C

1. Organism has simple eyes (go to 2)
Organism has compound eyes (*Glossina fuscipes*)
2. Organism has four pairs of limbs (*Euscorpius carpathicus*)
Organism has more than four pairs of limbs (*Scolopendra subspinipes*)

DRAWING, MEASURING AND CALCULATION OF MAGNIFICATION

Observations made on specimens may be reported in the form of fully labelled drawings, depending on the nature of the specimen. The following considerations should be made when drawing specimens and labelling diagrams:

Drawing

The drawing must be **big enough**. This means it must be at least 6.0cm at its longest point or occupy about one-third of an A4 page. However, it must still fit within the space provided on the answer sheet and leave space for labels. The drawing must be **clean** (no dirty rubbings), **clear** (no double or disconnected lines and no shading) and **realistic** (a true reflection of the specimen provided and not a mere replica of a text book diagram)

Labelling

Label as many parts/structures on the diagram as possible. For this reason, is advisable to draw the specimen from the view/side that gives as many details as possible. Pointer lines must touch the part or structures being labelled on the diagram and must never cross each other or else the labels concerned are rejected. Arrowheads are not required on pointer lines.

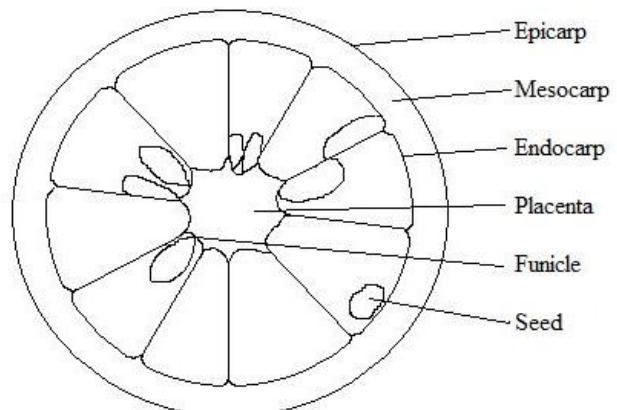
Measurements

Unless otherwise instructed, measurement of the specimen size must be taken along the longest part. For circular specimens, the longest line passing through the centre must be used. A line must be drawn along a corresponding part on the drawing/diagram. Measurements must be recorded to **one decimal place if in centimetres or no decimal place if in millimetres e.g.** it is correct to record 6.0 cm or 60 mm but wrong to record 6 cm or 60.0 mm.

The following diagram illustrates a drawing of a transverse section of an orange, taking into account the principles discussed above.



Orange Cross Section Specimen



Orange Cross Section Drawing

Magnification marks:

The formula must be correctly stated as:

$$\text{Magnification} = \frac{\text{Size of Image/Drawing}}{\text{Size of Object/Specimen}}$$

The substitution must be correctly done with identical units in the numerator and denominator. A substitution where size of specimen is swapped with size of drawing is wrong and makes the rest of the calculation wrong. When the units in the numerator and denominator are not identical, the substitution is rejected along with the rest of the calculation e.g. if an individual measures the specimen size as being 6.4 cm and the corresponding measurement on the diagram is 7.2 cm, the substitution will be correct if written as:

7.2 cm/6.4 cm or 72 mm/64 mm but will be wrong if written as: 7.2/6.4 or 72/64 or 7.2cm/64 mm or 72 mm/6.4 cm.

The final answer for magnification must be written to **one decimal place** with a **multiplication sign (X)** or the word ‘times’ either before or after the magnification and without units.
e.g. the answer for the substitution given above is 1.125 but should be written as:
X1.1 or 1.1X or times 1.1 or 1.1 times.

In summary, the magnification for the above given situation would be calculated as follows:

$$\text{Magnification} = \frac{\text{Size of Image}}{\text{Size of Object}} = \frac{7.2 \text{ cm}}{6.4 \text{ cm}} = X 1.1$$

Exercise:

- a) Measure the length of the orange cross section

specimen:.....

- b) Measure the length of the orange cross section

drawing:.....

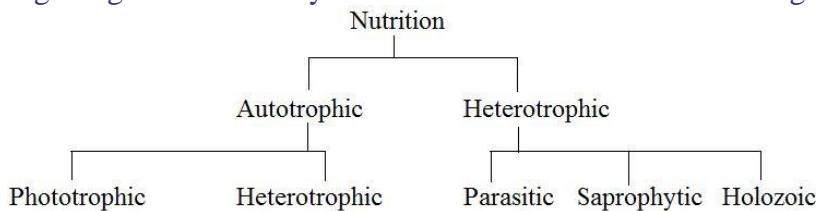
- c) Calculate the magnification of the drawing

NUTRITION

This is the process by which living organisms obtain food.

Modes of Nutrition

The following diagram gives a summary of the main modes of nutrition living organisms.



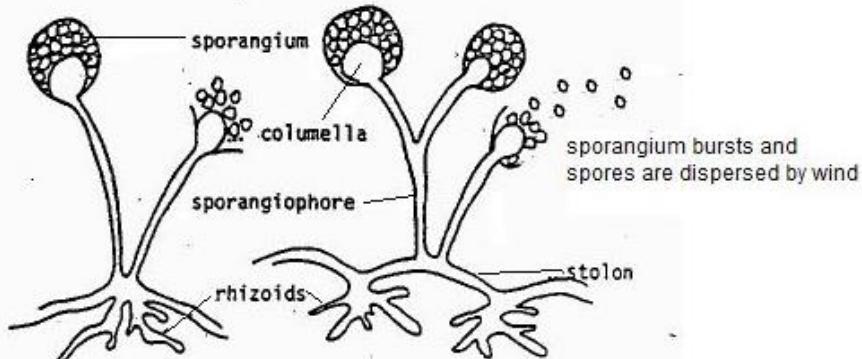
There are two main modes of nutrition namely **autotrophic** and **heterotrophic**. Autotrophic nutrition is a type of nutrition where an organism makes its own food. Organisms that carry out autotrophic nutrition are called **autotrophs**. Those that use energy from sunlight to make food are called **phototrophs** or **photoautotrophs** (e.g. green plants) while those that use energy from chemical reactions to make food are called **chemotrophs** or **chemoautotrophs** (e.g.

nitrifying bacteria). Heterotrophic nutrition is where an organism takes food present in the bodies of other organisms. It includes **parasitic**, **saprophytic** and **holozoic** nutrition. Organisms that carry out heterotrophic nutrition are called **heterotrophs**.

Parasitic nutrition is a type of nutrition where an organism known as the **parasite** lives and feeds off another organism called the **host**, often causing harm such as disease, physical injury or even death in the process. The parasite is always smaller than the host. There are two types of parasites which are **exoparasites** (those that live on external surfaces of the body e.g. lice) and **endoparasites** (those that live inside the body e.g. tapeworms and roundworms)

Saprophytic nutrition is a type of nutrition where an organism called the **saprophyte** feeds on dead and decaying organic matter known as the **substrate**. The saprophyte feeds by secreting **extracellular digestive enzymes** from its hyphae. These enzymes hydrolyze the substrate and the saprophyte absorbs the end products. Examples of saprophytic organisms are mould fungi such as *Mucor* and *Rhizopus*.

Structure of *Mucor* and *Rhizopus*



The bodies of *Mucor* and *Rhizopus* are made of threads called **hyphae**. A mass of hyphae is called a **mycelium**. Horizontal hyphae are called **stolons**; root like hyphae are called **rhizoids** while those that bear spore cases (sporangia) are called **sporangiophores**. Each spore case contains numerous **spores**. Spores are microscopic structures produced asexually which are capable of germinating under favourable conditions. Saprophytes are important in the following ways:

- They decompose dead organic matter, thereby preventing accumulation of dead bodies
- They play a role in the recycling of nutrients such as carbon and nitrogen
- Some saprophytes are used as food e.g. mushrooms.
- Some saprophytes such as yeast are important in brewing and baking

Holozoic Nutrition is a type of nutrition which occurs in animals in a specialized tube called the alimentary canal and involves five stages namely ingestion, digestion, absorption, assimilation and egestion. **Ingestion** is the intake of food into the mouth; **digestion** is the breaking down of food; **absorption** is the uptake of soluble food into the blood stream; **assimilation** is the usage and incorporation of food in living cells; **egestion** is the removal of undigested foods from the body through the anus.

Symbiosis/Mutualism: This is an association between two different species of organisms where each species benefits the other. Examples of mutualism are:

- The association between ruminants and the microbes which are found in their guts. The ruminants provide a habitat and gather food which is used by the microbes.

- The association between legumes and nitrogen-fixing bacteria (*Rhizobium sp*). The legumes provide a habitat to the *Rhizobium* while the *Rhizobium* fixes nitrogen into the legume plant.

Nutrients

A nutrient is any substance which provides the body with any or all of the following:

- Energy
- Material for growth
- Protection against diseases
- Proper functioning of the body

Classes of Nutrients

There are seven classes of nutrients namely: Carbohydrates, lipids, proteins, water, mineral salts, vitamins and roughage. Memory aid: **Calipro Wamiviro**.

Carbohydrates

These are nutrients that are made of carbon, hydrogen and oxygen and are a source of energy. Lack of carbohydrates in diet leads to **marasmus**. They are commonly obtained from plants. There are three classes of carbohydrates, namely **monosaccharides**, **disaccharides**, and **polysaccharides**.

(i) **Monosaccharides** are the simplest carbohydrates and make up the building blocks of carbohydrates. They are also called **simple sugars**. Groups of monosaccharides include trioses, tetroses, pentoses, hexoses, heptoses and so on. The hexoses are the most famous and include **fructose**, **glucose** and **galactose** (memory aid: **FGG**). The common name, occurrence and use of each of them are given in the following table.

Monosaccharide	Common name	Natural occurrence	Uses
Glucose	Blood sugar	In honey and blood	Main substrate of respiration
Fructose	Fruit sugar	In fruits, nectar and honey	Attracts and rewards to animals that pollinate flowers and disperse seeds
Galactose		In milk	Source of energy for young mammals

(ii) A **disaccharide** is made of **two monosaccharide units chemically combined by condensation**. Well-known disaccharides include **lactose**, **maltose** and **sucrose** (memory aid: **LMS= Lusaka Music Society**). The following table summarizes the common names, natural occurrence and uses of each of them.

Disaccharide	Common name	Natural occurrence	Uses	Constituent monomers
Lactose	Milk sugar	Milk	Source of energy for young mammals	Glucose and Galactose
Maltose	Malt sugar	Germinating seeds	Source of energy for germinating seeds	Glucose units only
Sucrose	Cane/table sugar	Stored in sugar cane, beet root and onions	Form in which plants transport	Glucose and fructose

		carbohydrates	
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NOTE: All monosaccharides and disaccharides are collectively called **sugars**. A sugar is a carbohydrate which has the following characteristics:

- **soluble in water**
- **has a sweet taste**
- **is crystalline**

Some of the sugars are also known as **reducing sugars** This is because they can reduce Cu^{2+} ions to Cu^+ ions. All monosaccharides and disaccharides except **sucrose** are reducing sugars. Sucrose is a non-reducing sugar.

(iii) **Polysaccharides** are complex carbohydrates made of more than two monosaccharides chemically combined by condensation. Common polysaccharides include **starch**, **glycogen** and **cellulose**.

Starch is the main **storage carbohydrate in plants**. Excess glucose in plants is converted to starch and stored in cell structures called **amyloplasts**. Starch is suited for the role of storage molecule in the following ways:

- It is **insoluble in water**; hence it cannot be lost from storage cells;
- It has **no osmotic effects**
- It is relatively **unreactive**
- It is **compact** and does not take up much space;
- It is **easily hydrolysed** by enzymes when glucose levels are low. The main sources of starch are **cereal seeds** and **tubers**, though all plants generally are a source of starch.

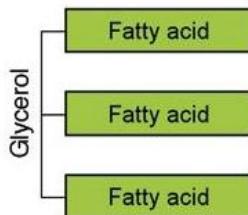
Glycogen is the main **storage carbohydrate in animals**. In humans, when there is excess glucose in the blood, the hormone **insulin** produced by the pancreas causes cells in the liver and muscles to convert the excess glucose into **glycogen** which is stored in the liver and muscles. The human body can store about 400g of glycogen (roughly 300g in the muscles and 100g in the liver). When glucose levels are low in the blood, the hormone **glucagon** produced by the pancreas causes muscle and liver cells to convert glycogen to glucose. Glycogen is sometimes called **animal starch** because its characteristics are similar to starch. It differs from starch by being more branched, making it less dense and easier to digest than starch. This is one reason why animals have a faster metabolic rate than plants.

Cellulose is a **structural carbohydrate** found in cell walls of plants. It has a **high tensile strength** (does not stretch easily), thereby protecting plant cells and preventing lysis when there is excessive osmotic inflow of water. Animals cannot digest cellulose on their own because they do not secrete the enzyme cellulase which digests cellulose. Those that depend on plant diets have symbiotic relationships with microbes which secrete cellulase. However, cellulose is still useful as roughage which stimulates peristalsis and prevents constipation.

Lipids

These are nutrients made of the elements carbon, hydrogen and oxygen. However the amount of oxygen in lipids is less than the one found in carbohydrates. They are insoluble in water but soluble in alcohol and organic solvents such as acetone, benzene and chloroform. Edible lipids include oils and fats. Oils are liquid at room temperature while fats are solid at room temp.

The building blocks of lipids are **glycerol** and **fatty acids**. Each molecule of a fat comprises one molecule of glycerol and three molecules of fatty acids.



Uses of Lipids

- Water proofing- certain organisms such as ducks secrete lipids which prevent their bodies from getting wet with water
- Insulation- animals have a layer of fat under their skins which prevents heat loss from the body
- Formation of cell membrane- the cell membrane is made of lipids called phospholipids which can be synthesized from fats and oils
- Energy source-lipids store a lot of energy which is made available when the supply of carbohydrates in the body is low. In fact lipids store twice as much energy as an equal amount of carbohydrates.

The uses of lipids can be summarized by the mnemonic **WIFE**.

Sources of lipids include vegetable oils and animal fats.

Proteins

All proteins contain carbon, hydrogen, oxygen and nitrogen. Most of them also contain sulphur or phosphorous and a small number of them contain metals such as iron (haemoglobin) and magnesium (chlorophyll). The building blocks of proteins are **amino acids**. There are twenty amino acids commonly found in living organisms and these may be divided into two groups namely **essential** and **non-essential** amino acids. Essential amino acids are those that the body cannot synthesize but must be part of the diet. Non-essential amino acids are those that the body can synthesize and so are not required in the diet.

Amino acids are linked by peptide **bonds** to make molecules known as **peptides**. A peptide molecule consisting of two amino acids is called a dipeptide while one with more than two is called a polypeptide. Most proteins are polypeptides. Sources of proteins include meat, fish, milk, eggs and legume seeds such as beans, ground nuts, peas e.t.c

Uses of proteins

- growth and repair of body tissues
- they are important for making body chemicals such as hormones, enzymes, antibodies, antitoxins, haemoglobin, keratin, melanin, collagen, actin and myosin

Water

It is an inorganic molecule made of the elements hydrogen and oxygen, its chemical formula is **H₂O**.

Uses of Water

- It is a **universal solvent**- where substances needed by the body are dissolved and transported
- **Thermoregulation**- water is a coolant when the body gets hot and also helps distribute body heat from active organs
- **Digestion**- involved in chemical breaking down of large molecules into smaller ones- also called hydrolysis.
- It is a **component of body fluids**- saliva, blood, lymph e.t.c
- It is a **participant in metabolic** reactions such as photosynthesis.
- It makes up the **hydrostatic skeleton** in some organisms such as worms.
- It prevents **constipation** (difficult defaecation due to dryness and hardness of faeces).

If water is lacking in the body, an organism suffers from **dehydration**. In humans insufficient water can also lead to constipation.

Mineral Salts

These are inorganic substances and are required by the body in small amounts and their absence causes serious deficiency diseases. They are absorbed into the body in the form of ions (charged particles formed when an atom gains or loses electrons). They function as enzyme activators. Examples of mineral salts are calcium and iron.

Calcium

This is a mineral salt important in the following ways:

- formation of strong bones and teeth
- conduction of nerve impulses
- contraction of muscles
- an activator of certain enzymes

Sources of calcium include milk, eggs, meat and bones. Calcium deficiency leads to a condition known as **rickets** (the formation of weak and deformed bones)

Iron

It is a mineral salt which is important in the formation of haemoglobin. Iron deficiency leads to **Anaemia**. Sources of iron include meat, green vegetables and fruits.

Iodine

important in the formation of hormone called thyroxine produced in the thyroid glands. This hormone controls metabolic reactions such as respiration.

Sources include iodised salt, sea foods, water. Iodine deficiency leads to goitre (swelling in the neck) and stunted growth (dwarfism).

Phosphorus

Important in the formation of chemical substances called **adenosine diphosphate** (ADP) and **adenosine triphosphate** (ATP). It is also responsible for the formation of strong bones and teeth. Sources include meat

Vitamins

Vitamins are organic molecules required by the body in small amounts and their absence leads to deficiency diseases. They function as co-enzymes. There are two groups of vitamins, namely water soluble (those that dissolve in water i.e. B and C) and fat soluble vitamins (those that dissolve in fats i.e. A, D, E and K)

Vitamin C (Ascorbic acid)

This is a water-soluble vitamin important for the formation of connective tissues of the body. Vitamin C deficiency leads to a disease called **scurvy** (characterized by swollen and bleeding gums, poor healing of wounds and painful muscles). Sources of vitamin C include fresh vegetables and fruits. Vitamin C tends to get destroyed by over-cooking and long periods of storage.

Vitamin D

It is a fat soluble vitamin which is required in the absorption and metabolism of calcium and phosphorous. Deficiency of vitamin D leads to **rickets**. Sources of vitamin D include fish liver oil, milk and eggs. The skin is also able to synthesize this vitamin when exposed to sunlight.

Roughage

This is the indigestible part of the diet made of cellulose. It adds bulk to faeces and stimulates peristalsis (wave like motion) along the alimentary canal, thereby preventing constipation. Lack of roughage leads to constipation (difficult defaecation due to hardness and dryness of faeces). The other name for roughage is **dietary fibre**. Sources include maize, unpolished cereals, fruits etc.

Exercise: Write a short essay about the uses, benefits and health hazards associated with food additives including colourings.

Food Tests

1. The Iodine Test for Starch

(a) If the sample is in solid /powder form

- Place a small amount of sample on a white tile
- Add a few drops/**2 drops of iodine solution** to the sample; then observe and record what happens.

(b) If the sample is in solution/suspension form

- Place 2 cm³ of sample solution into a clean and dry test tube.
- Add a few drops/**2 drops of iodine solution** to the test tube and shake; Then observe and record what happens.

The possible **observations** and corresponding **conclusions** are given in the table below:

Observation	Conclusion
Solution remains yellowish-brown	Starch absent
Solution turns blue-black	Starch present

2. The Benedict's test for Reducing Sugars

This test requires the sample to be in solution form and may be performed on suspensions. If the sample is in solid form, it will first need to be ground /crushed/cut into very small pieces and to be shaken with distilled water for extraction of reducing sugars if they are present. Filter and then proceed with the following test method on the filtrate:

- Place 2 cm³ of sample solution into a clean and dry test tube.
- Add 2 cm³/**an equal volume of Benedict's solution** to the sample solution and shake.
- **Gently heat the mixture using a water bath**; then observe and record what happens.

The possible **observations** and corresponding **conclusions** are given in the following table:

Observation	Conclusion
Solution remains blue	Reducing sugars absent
*Solution turns green/yellow/orange/brick red	Reducing sugars present

*Only state the final colour observed and not all the colours mentioned in the table. The extent of the colour change indicates the quantity of reducing sugars present i.e. green and yellow colours indicate that little/traces/small amounts of reducing sugars are present, orange indicates that reducing sugars are present and brick red indicates high concentrations of reducing sugars present.

3. The Benedict's test for Non-reducing Sugars

- First carry out the Benedict's test for reducing sugars. If the colour of the solution remains blue, proceed with the next steps.
- Place another 2 cm³ of sample solution into a clean and dry test tube.
- Add 1 cm³ of **dilute hydrochloric**, heat in water bath for 3 minutes and cool.
- Add **sodium hydrogen carbonate solution or sodium hydroxide solution** to the mixture, a little at a time until fizzing stops.
- Add **an equal volume of Benedict's solution** to the mixture.
- Gently heat the mixture using a water bath; then observe and record what happens.

The possible **observations** and corresponding **conclusions** are given in the following table:

Observation	Conclusion
-------------	------------

Solution remains blue	Non-reducing sugars absent
Solution turns green/yellow/ orange/brick red	Non-reducing sugar present

4. The Biuret Test for Proteins

This test also works best for solutions and suspensions. Extraction by grinding and shaking with distilled water is therefore necessary where samples are in solid form. The filtrate will then be tested as follows:

- Place 2 cm³ of sample solution into a clean and dry test tube.
- **Either** add **5 drops of sodium hydroxide solution** to the sample solution followed by a few/2 **drops of copper (II) sulphate solution**, drop by drop, shaking and observing after each drop.
- **Or** add **an equal volume of Biuret solution**; then observe and record what happens.

The possible **observations** and corresponding **conclusions** are given in following table:

Observation	Conclusion
Solution remains blue	Proteins absent
*Solution turns purple/violet/lilac/mauve	Proteins present

Only one of these options needs to be mentioned. Candidates are advised to use colour names which are commonly used e.g. it is better to use the name purple or violet instead of mauve or lilac.

5. Testing for Lipids (Fats and Oils)

(a) The Emulsion Test

- Shake a small sample/a drop of sample solution with 2 cm³ **absolute ethanol** in a test tube.
- Add **a few drops of distilled water** to the test tube; then observe and record what happens.

The possible **observations** and corresponding **conclusions** are given in the following table:

Observation	Conclusion
Solution remains clear	Fats/oils absent
Emulsion formed/solution turns cloudy	Fats/oils present

(b) The Grease Spot Test

- Place a drop of sample/sample solution on filter paper or brown paper.
- Place a drop of distilled water next to the drop of the sample.
- Hold the paper against light until the drop of water disappears; then observe and record what happens to the sample spot.

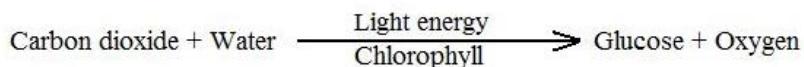
The possible **observations** and corresponding **conclusions** are given in the following table:

Observation	Conclusion
Sample spot disappears	Fats/oils absent
Permanent translucent/oily/greasy spot formed	Fats/oils present

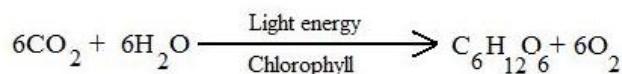
Photosynthesis

This is the process by which green plants manufacture glucose/ starch/ carbohydrates from carbon dioxide and water in the presence of light energy absorbed by chlorophyll. Oxygen is produced as a by product. This process takes place in leaves and may be summarised by the following word and chemical equations:

Word Equation



Chemical Equation

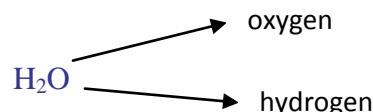


The products for photosynthesis are glucose and oxygen. The oxygen is released out of the plant while some of it is used for respiration. The glucose formed is metabolically active and takes part in the following reactions:

- Some of it is used for respiration
- Some of it is converted to cellulose and becomes part of cell walls
- Some of it is combined with nitrogen and used to synthesise amino acids
- Some of it is converted to sucrose in order to be transported
- Some of it is converted to fats and oils
- Some of it is converted to nucleic acids
- The excess is converted to starch for storage

LIGHT AND DARK REACTIONS

LIGHT REACTION- during this stage light energy absorbed by chlorophyll is used to split water molecules into oxygen and hydrogen. This is called photolysis. Oxygen diffuses into the atmosphere while hydrogen proceeds into the dark stage.



DARK REACTION- during this stage hydrogen from the light reaction combines with carbon dioxide forming glucose.

NOTE: carbon dioxide comes from the atmosphere by diffusion and water from the soil by osmosis.

To determine whether photosynthesis has taken place, the leaves of plants are tested for starch. The steps involved in testing a leaf for starch are:

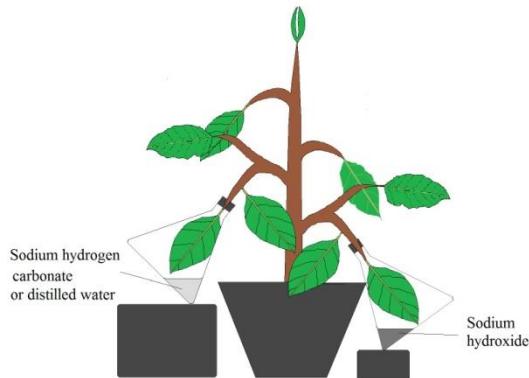
- Boil the leaf in water (to kill the protoplasm and make it permeable to Iodine solution)
- Boil the leaf in alcohol using a water bath. This is to extract the chlorophyll so that it does not interfere with colour changes; a water bath is used because alcohol is highly flammable. However the alcohol also makes the leaf brittle.
- Place the leaf in warm water to soften it.
- Spread the leaf on a white tile and add a few drops of Iodine solution this is to test for starch. If the Iodine solution turns blue-black, starch is present and if it remains yellowish brown, starch is absent.

Requirements for Photosynthesis

These factors that need to be present for photosynthesis to take place are **carbon dioxide**, **water**, **sunlight** and **chlorophyll**. Those that also affect the rate of photosynthesis are called **limiting factors of photosynthesis**. Carbon dioxide enters the plant by diffusing through small openings in the leaf called stomata (singular = stoma). Water enters the plant through the roots by osmosis and moves up the plant through xylem vessels. Light energy (mainly solar energy) is captured/trapped and stored by a green pigment called chlorophyll found in the chloroplasts. During photosynthesis, this solar energy is transformed into chemical energy. Since photosynthesis is an enzyme-catalysed reaction, its rate gets affected by **all factors that affect enzyme activity**.

Experiment to show that Carbon Dioxide is necessary for Photosynthesis

- Destarch a well-watered potted plant by placing it in the dark for at least 24 hours. During this time, all the starch present in the potted plant is used up.
- Set up the experiment as shown in the following diagram:



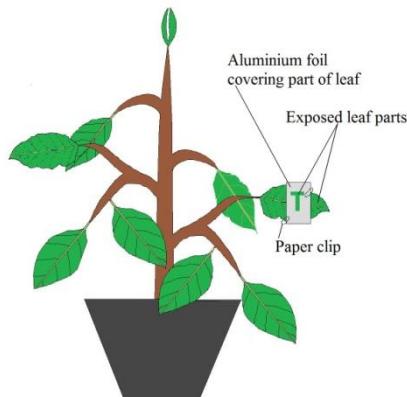
- Place the potted plant in sunlight for 4-6 hours.
- Test leaves A and B for starch

Leaf A turns blue-black (showing the presence of starch), while leaf B turns yellowish brown (showing the absence of starch). This shows that carbon dioxide is necessary for photosynthesis.

Exercise: What are the uses of sodium hydrogen carbonate, distilled water and soda lime in this experiment?

Experiment to show that light is necessary for Photosynthesis

- Destarch a well-watered potted plant by placing it in the dark for at least 24 hours. During this time, all the starch present in the potted plant is used up.
- Set up the experiment as shown in the following diagram:



- Place the potted plant in sunlight for 4-6 hours. While the plant is in sunlight, draw the selected leaf showing the exposed parts and the covered parts.
- Test parts A (exposed part) and B (covered part) for starch

Part A turns blue-black (showing the presence of starch), while part B turns yellowish brown (showing the absence of starch). This shows that light is necessary for photosynthesis.

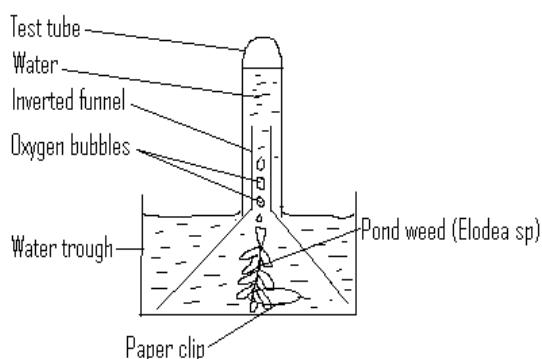
Experiment to show that Chlorophyll is necessary for Photosynthesis

- Destarch a well-watered potted plant which has variegated leaves by placing it in the dark for at least 24 hours. During this time, all the starch present in the potted plant is used up.
- Place the potted plant in sunlight for 4-6 hours. While the plant is in sunlight, draw a selected leaf showing the green parts and the white parts so that they can easily be identified even after chlorophyll has been removed from the leaf. Label the green parts as **A** and the white parts as **B**.
- Test the parts A (green part) and B (white part/ yellow) for starch.

Part A turns blue-black (showing the presence of starch), while part B turns yellowish brown (showing the absence of starch). This shows that chlorophyll is necessary for photosynthesis.

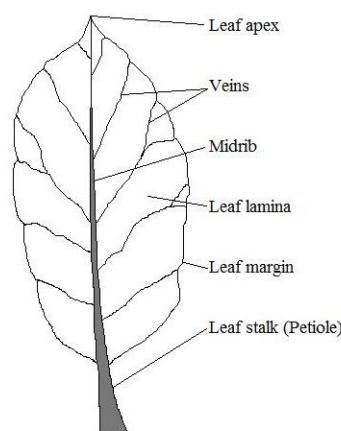
Measuring the Rate of Photosynthesis

This can be measured by counting the number of oxygen bubbles produced by an aquatic plant (e.g. pondweed/*Elodea* sp) per unit time. A typical setup for such an experiment is shown in the following diagram.

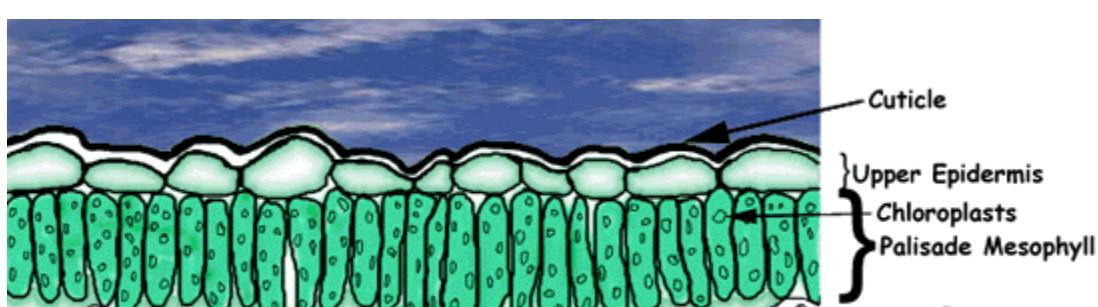


Leaf Structure

External Structure



Internal Structure (Cross Section)



Adaptations of the Leaf for Photosynthesis

- Thin lamina for easy penetration of light
- Large surface area to capture as much light as possible
- Presence of veins/vascular bundles to supply the leaf with water (the xylem) and to transport end products of photosynthesis (the phloem)
- Presence of stomata for entry of carbon dioxide and exit of oxygen
- Presence of chloroplasts to absorb light energy for photosynthesis. The highest concentration of chloroplasts is found in the palisade cells, followed by the spongy cells and finally the guard cells.

The Importance of Photosynthesis

- It produces food for all organisms directly or indirectly
- It maintains the balance (equilibrium) of oxygen and carbon dioxide in the atmosphere by using carbon dioxide from animals and producing oxygen for animals.
- It produces vast amount of energy in woods. Peat. Coal etc.

Applications of photosynthesis in Greenhouses

A greenhouse is an enclosure with walls of transparent glass or plastic where plants are grown. By having transparent walls, light and heat are allowed to reach the plants. In some green houses, plants are supplied with artificial light from electric bulbs. The walls minimize escape of heat from the greenhouse thereby keeping temperatures high inside the greenhouse for optimum enzyme activity. Sometimes the greenhouse is artificially supplied with carbon dioxide. These factors make a green house more productive than an open piece of land.

Plant Storage Organs

The food manufactured by plants is normally converted to starch and oils for storage. Oils are mainly stored in seeds e.g. in groundnuts and sunflower. Starch is stored in a range of modified plant organs, some of which are discussed below.

- (i) Root tuber: This is a fibrous root swollen with stored food e.g. sweet potato (*Ipomea batatas*) tuber
- (ii) Stem tuber: This is an underground stem swollen with stored food e.g. Irish potato (*Solanum tuberosum*)
- (iii) Bulb: A bulb is made of underground fleshy leaves growing from a short stem e.g. onion (*Allium sp*)
- (iv) Rhizome: This is a swollen underground horizontal stem e.g. ginger
- (v) Corm: This is swollen underground and vertical short stem e.g. *Crocus sp.*
- (vi) Seed: A sexually produced structure containing a plant embryo and its food store protected by a testa.

Mineral Nutrition in Plants

Plants require several elements in order to grow properly. These elements are absorbed by the roots from the soil in the form of mineral ions. There are two groups of elements needed by plants for proper growth namely major elements and minor elements. Major elements are required by plants in large quantities. Three examples of major elements are nitrogen, phosphorous and potassium (NPK). Minor elements are needed by the plant in small quantities. Examples of mineral ions needed by plants are magnesium and nitrates.

Magnesium

This forms part of the chlorophyll molecule. Deficiency causes **chlorosis** which is characterised by yellowing of leaves beginning from the bottom of the plant.

Nitrogen

This is absorbed from the soil in the form of nitrate ions (NO_3^-) or ammonium ions (NH_4^+). It is important for synthesis of proteins and amino acids. Deficiency leads to stunted growth, weak stems and yellowing of leaves.

Potassium

Potassium is important for flowering and fruit formation, ion transport and catalyst it is absorbed in the form of potassium ions (K^+). Deficiency of potassium causes poor flowering and fruit formation.

Phosphorous

It is absorbed in the form of phosphate ions (PO_4^{3-}). It is important for the formation of Nucleic acids and ATP. Deficiency leads to purple leaves, stunted growth and poorly developed roots.

Effects of Sulphur dioxide Pollution on Plant Nutrition

Sulphur dioxide is emitted in industrial and exhaust fumes which are released into the atmosphere. It dissolves in rain water forming sulphuric acid which falls as **acid rain**. The effects of acid rain on plant growth are:

- It dissolves away the waxy cuticle, thereby increasing the rate of transpiration and causing the leaves to wilt and die. This stops or reduces the rate of photosynthesis, leading to death of the plants.
- It damages the root hairs, thereby reducing the rate of water and mineral uptake.

In certain European countries, entire forests were wiped out after the industrial revolution due to increased emission of sulphur dioxide.

ANIMAL NUTRITION

Animals carry out **holozoic nutrition**. This is a type of nutrition which occurs in animals in a specialized tube called the **alimentary canal** or **digestive system** and involves five stages namely **ingestion, digestion, absorption, assimilation and egestion**.

Ingestion is the intake of food into the mouth.

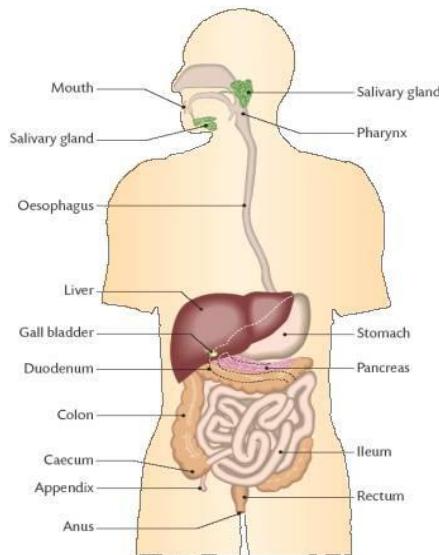
Digestion is the breaking down of food. There are two types of digestion, namely **physical digestion** and **chemical digestion**. Physical digestion is the break down of **large pieces of food** into smaller ones. In humans, this process is carried out by teeth in the mouth. It increases the surface area of the food for more efficient enzyme activity and makes food easy to swallow. Chemical digestion is the break down of **large molecules of food** into smaller ones by **enzymes**. It makes absorption of food more efficient.

Absorption is the uptake of soluble food into the blood stream.

Assimilation is the usage and incorporation of absorbed food in living cells.

Egestion is the removal of undigested food from the body through the anus.

The Human Alimentary Canal



Digestion of Carbohydrates, Lipids and Proteins

Digestion of food substances occurs in the mouth, stomach, duodenum and jejunum.

Digestion in the Mouth

The following events occur after food has been ingested into the mouth:

(i) **Chewing**: Also called **mastication**, this is the break down of **large pieces of food** into smaller ones by teeth. It increases the surface area of the food for more efficient enzyme activity and makes food easy to swallow.

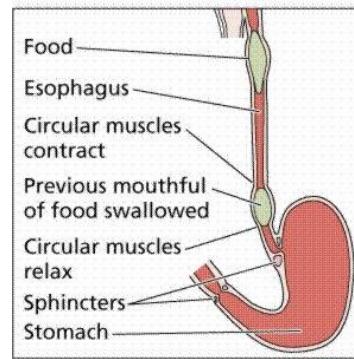
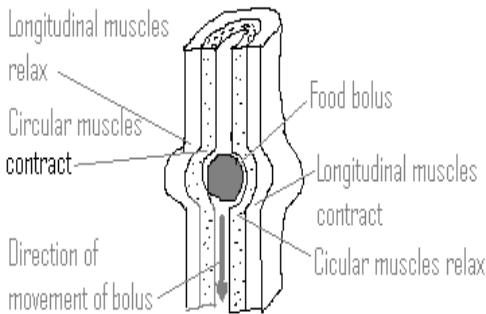
(ii) **Secretion of Saliva**: This is carried out by salivary glands. Saliva is a mixture of **water**, **mucus**, the enzymes **salivary amylase** and lysozyme in a **slightly alkaline medium**. The water helps in cooling food that is too hot and warming up food that is too cold so that its temperature is favourable for enzyme action. It also softens food for easy chewing e.g. it is easier to chew biscuits after they have been moistened by saliva. The mucus lubricates food for easier swallowing. The slightly alkaline pH is favourable or optimum for the activity of salivary amylase. Salivary amylase starts the digestion of cooked starch to produce maltose. However, only small amounts of starch are converted to maltose in the mouth because food stays for a short time in the mouth. Amylase does not work in the stomach because the pH there is acidic.

Mixing Food with Saliva and formation of Bolus

While food is being chewed, the tongue mixes it with saliva. Later, the tongue works with the palate (top of the mouth) to roll the chewed food up into a round semi solid mass called a **bolus**, in readiness for swallowing.

Swallowing and Peristalsis

Swallowing is the passage of food or liquids from the mouth to the stomach through the oesophagus. During swallowing, the food bolus moves by a process known as **peristalsis**. Peristalsis is the alternate contraction and relaxation of circular and longitudinal muscles in a wave-like manner in order to move food along the alimentary canal. Peristalsis is illustrated in the following diagram:



Behind the bolus, circular muscles contract while longitudinal muscles relax. Ahead of the bolus, circular muscles relax while longitudinal muscles contract.

Digestion in the Stomach

The stomach is an elastic bag with a muscular wall and a glandular lining. The entrance of the stomach is guarded by the cardiac sphincter. The exit is guarded by the pyloric sphincter. The following events take place in the stomach;

Secretion of gastric juice: Gastric juice is a mixture of pepsin, rennin, hydrochloric acid and mucus. Pepsin breaks down proteins to form peptides. Rennin coagulates milk by converting the soluble protein caesinogen into an insoluble form called casein. This delays the passage of milk to the duodenum giving chance for pepsin to digest milk protein. Both pepsin and rennin are secreted in inactive forms called pepsinogen and prorennin, respectively. Hydrochloric acid activates them into active enzymes and sets an acidic pH which is optimum. It also kills some bacteria and hydrolyses sucrose to glucose and fructose. Mucus protects the lining of the stomach against the acid and pepsin.

Churning: This is the mixing of food by rhythmic contraction of the muscles in the wall of the stomach to form a paste called **chyme**.

Temporal Storage of Food: Liquids can stay in the stomach for up to 30 minutes; carbohydrates are kept for about one hour; proteins and lipids stay up to 2 hours.

Digestion in the Duodenum

The duodenum receives digestive juices from the liver and the pancreas. The liver secretes bile which is temporarily stored in the gall bladder and carried to the duodenum by the bile duct. Bile contains **sodium hydrogen carbonate**, **bile salts** and **bile pigments**. Sodium hydrogen carbonate neutralizes the acidic chyme and then sets an optimum alkaline pH for the enzymes of the duodenum. The bile salts emulsify fats thereby increasing the surface area for the action of lipase. **Emulsification** is the break down of large drops of fats into small droplets. Bile pigments have no digestive function but add colour to the faeces.

The pancreas secretes pancreatic juice which contains sodium hydrogen carbonate, trypsin, lipase and pancreatic amylase. Sodium hydrogen carbonate neutralizes the acidic chyme and then sets an optimum alkaline pH for the enzymes of the duodenum. Trypsin breaks down proteins to form peptides. Lipase breaks down fat molecules to fatty acid and glycerol. Pancreatic amylase breaks down starch to form maltose.

Digestion in the Jejunum

This secretes **Intestinal Juice** (*succus entericus*) which contains **Lactase**, **maltase**, **sucrase** and **peptidase**. Lactase breaks down lactose to glucose and galactose. Maltase breaks down maltose to glucose. Sucrase breaks down sucrose to glucose and fructose. Peptidase breaks down peptides to amino acids. Digestion is completed in the jejunum.

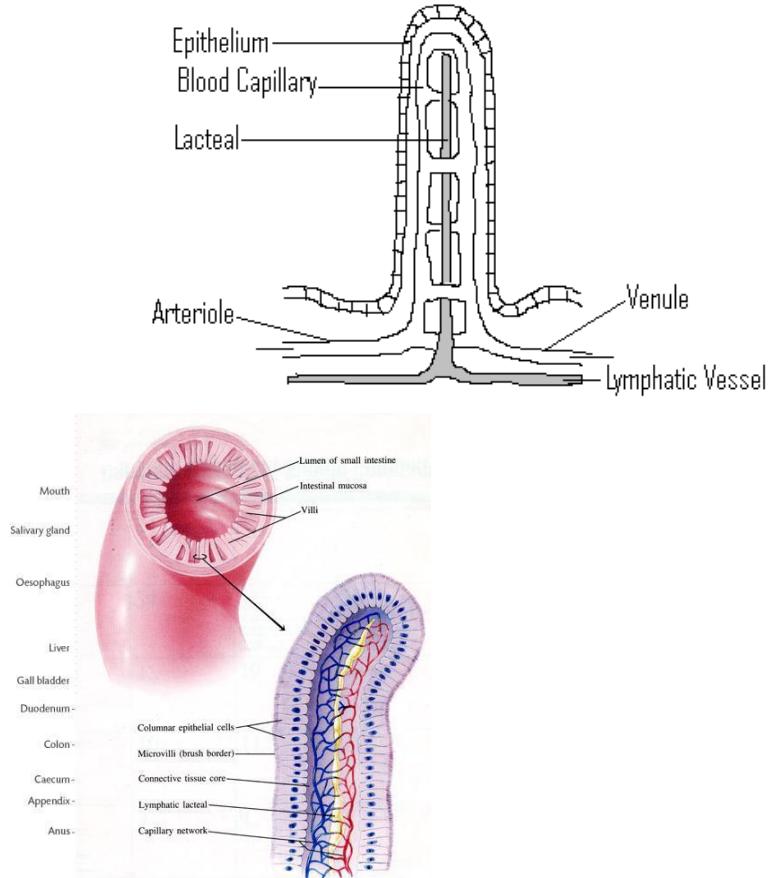
The ileum and Absorption

The ileum carries out absorption of digestive end products and is adapted for this function in the following ways:

- The ileum is **very long** thereby providing a large surface area for absorption.

- It has a **thin epithelium** for more efficient diffusion of food.
- It has finger like projections called **villi** (singular: villus) and microvilli which further increase the surface area for absorption.
- Each villus has a **network of capillaries** for absorption and transportation of monosaccharides and amino acids
- Each villus has a **lacteal** which absorbs and transports fatty acids and glycerol.

Diagram of a Villus



Assimilation of Digestive end Products

After absorption, the digestive end products are transported in the blood to the liver by the **hepatic portal vein**. The food is then assimilated as follows

a) Assimilation of Monosaccharides (Glucose, Fructose and Galactose)

Glucose is mainly used as a **substrate for tissue (cellular) respiration**. If it is in excess, the excess is converted to **glycogen** which is stored in the **muscles** and the **liver**. However the human body stores limited amounts of glycogen i.e. about 400g (300g in the muscles and 100g in the liver). If there is still some excess glucose, it is converted to **fat** and stored in the **adipose tissue** under the skin and **around delicate body organs** such as the brain, heart, liver, kidneys and intestine. These processes are influenced by a hormone called **insulin** which is secreted by the **pancreas**. Fructose and galactose are assimilated in the same way as glucose.

b) Assimilation of Amino Acids

Amino acids are assembled to make the proteins required by the body. Excess amino acids are **deaminated** by the liver. **Deamination** is the process by which the **amino group** of an amino acid is removed and eventually converted to urea by the liver. Ammonia is an intermediate during deamination and is highly toxic. It is quickly converted to urea which is less toxic. The

remaining part of the amino acid known as the **carbon skeleton** may be converted to glucose by a process called **gluconeogenesis**. Urea is toxic if allowed to accumulate in the body. It is carried from the liver by blood and is removed from the body by the **kidneys** by the process of **excretion**.

c) Assimilation of Glycerol and Fatty Acids

Glycerol and fatty acids are chemically combined to make fats which have the following uses in the body:

- Insulation- animals have a layer of fat under their skins which prevents heat loss from the body
- Formation of cell membrane- the cell membrane is made of lipids called phospholipids which can be synthesized from fats and oils
- Energy source-lipids store a lot of energy which is made available when the supply of carbohydrates in the body is low. In fact lipids store twice as much energy as an equal amount of carbohydrates.

Excess fats are stored in the **adipose tissue** under the skin and **around delicate body organs** such as the brain, heart, liver, kidneys and intestine. The fat under the skin is responsible for insulation while the fat around delicate organs cushions the organs against shocks.

Large Intestines

These are made of the caecum, the colon and the rectum. The caecum is the point where the ileum is linked to the large intestines. It has a projection at the base known as the **appendix**, which has no known use in the human body and is considered a **vestigial organ**. The colon carries out absorption of water from the faeces while the rectum stores faeces temporarily before they are egested and continues the absorption of water.

Functions of the Liver

The liver is the largest *internal organ* in the human body and performs a wide range of functions including the following:

- **Destruction of old red blood cells** resulting in **formation of bile** which is important in **emulsification of fats**.
- **Deamination of excess amino acids** resulting in **formation of urea**.
- **Detoxification of poisons** and **alcohol** by converting them to less toxic substances e.g. hydrogen peroxide is broken down to water and oxygen by the enzyme **catalase** in the liver. Excess intake of alcohol frequently can lead to a condition called **cirrhosis** (hardening liver tissue, leading to loss of function)
- **Conversion of excess glucose to glycogen and storage of glycogen**, thereby regulating the levels of blood sugar.
- **Manufacture of red blood cells in babies**
- **Transamination** (the conversion some amino acids to others)
- **Synthesis of plasma proteins** such as prothrombin, fibrinogen, globulins and albumin.
- **Storage of some vitamins** (e.g. vitamin A) and **some mineral ions** (e.g. iron)
- **Production of heat** through a wide range of exothermic/exergonic reactions.

Common Ailments of the Liver

Hepatitis: Inflammation of the liver which may result from infection hepatitis viruses.

Hepatomegaly: Enlargement of the liver.

Cirrhosis: Hardening of liver tissue resulting from poisoning or excessive intake of alcohol.

Common Ailments of the Alimentary Canal

Diarrhoea: The passage of watery stool, resulting in dehydration and loss of mineral ions from the body. It is caused by intake of food or drinks that are contaminated with pathogens. The pathogens cause inflammation of the intestinal lining leading to diarrhoea.

Constipation: Difficult defaecation due to hardness and dryness of faeces, resulting from insufficient roughage and water in diet. It may also result from keeping the faeces in the rectum

for too long which causes the rectum to absorb too much water, making the faeces hard and dry.

Stomach Ulcers: An ulcer is defined as an open sore that produces toxic matter. Stomach ulcers may result from over-production of pepsin and hydrochloric acid or when the mucus layer in the stomach is not sufficiently thin. This causes the lining of the stomach to be destroyed by the action of pepsin or hydrochloric acid.

Piles (haemorrhoids): This is a condition where the veins in the rectum become swollen and eventually burst causing pain and blood-stained stool. It may be caused by frequent constipation.

DENTITION

Dentition refers to the types, numbers and arrangement of teeth in the mouth of an animal. On the other hand, the term **dental formula** refers to the numbers and arrangement of teeth according to type on the upper and lower jaw in one half of the mouth.

Each tooth has a part that grows above the gum called the **crown**. The outer part of the crown is covered with a substance called **enamel**. Enamel is the hardest substance in the body of an animal. The part of the tooth found in the gum region is called the **neck** while the part that grows below the gum is called the **root**.



Types of Teeth

There are four types of teeth namely incisors, canines, premolars and molars.

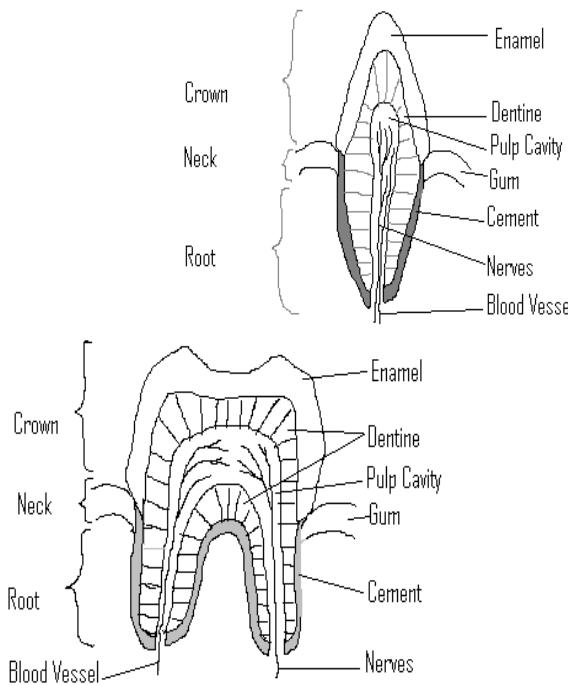
Incisors: These are chisel-shaped teeth used for cutting and biting. Each incisor only has one root.

Canine: These are dagger-shaped (pointed) teeth used for tearing flesh, suffocating prey and carrying young ones. Each canine only has one root. In carnivorous animals, the canines are very long and pointed.

Premolars: these are broad and ridged teeth used for grinding or crushing food. Each usually has two roots.

Molars: these are broad and ridged teeth used for grinding or crushing food. Each molar has from two to four roots. The projections on top of the crowns of premolars and molars are called **cusps or ridges**

Internal Structure of a Tooth



An Incisor

A Molar

Functions of tooth parts:

Enamel

This is the hardest substance in the body of an animal. It's made of Calcium and Phosphate salts and its functions are:

- Preventing wearing away of the tooth
- Protecting the tooth from damage
- It is used as a biting and grinding surface

However the enamel can be corroded (dissolved) by acids.

Dentine

This is a bone-like tissue below the enamel which is made of calcium and phosphate salts, collagen fibres and cytoplasmic strands. It contains fine canals which link the pulp cavity to the enamel.

Pulp Cavity

This is a space within the dentine which is made of tooth-producing cells, nerves and blood vessels. The nerves make the tooth sensitive to stimuli such as temperature, pH and pressure. The blood vessels supply the tooth with food and oxygen

Cement

This is a bone-like tissue with fibres that anchor the tooth to the jawbone.

Dental Formula (Plural: Dental Formulae)

The dental formula is the number and arrangement of teeth according to type on the upper and lower jaw in one half of the mouth of an animal. Examples of dental formulae are:

Human being

$$i = \frac{2}{2} c = \frac{1}{1} pm = \frac{2}{2} m = \frac{3}{3}$$

Cat

$$i = \frac{3}{3} c = \frac{1}{1} pm = \frac{3}{2} m = \frac{1}{1}$$

Cow

$$i = \frac{0}{3} c = \frac{0}{1} pm = \frac{3}{3} m = \frac{3}{3}$$

Rat

$$i = \frac{1}{1} c = \frac{0}{0} pm = \frac{0}{0} m = \frac{3}{3}$$

Where i=incisors, c=canines, pm=premolars and m=molars

Note that the dental formulae only show the number of teeth present in one half of the mouth. To get the total number of teeth, the numbers in the dental formula must be multiplied by two.

Relationship between Dentition and Type of Diet

a) Dentition in Carnivore

Carnivores are animals that feed predominantly on flesh e.g. lions. Their dentition is specialised in the following ways:

- **Canines are very long and pointed** to enable them to tear flesh and suffocate their prey.
- Presence of **carnassial teeth** (the last upper premolar and first lower molar) which work like the blades of a scissors to slice meat and shear flesh away from bones.

b) Dentition in a Herbivore

Herbivores are animals that feed predominantly on vegetation e.g. sheep. Their dentition is specialised in the following ways:

- Upper incisors are absent and replaced by a **horny pad** which works in conjunction with lower incisors to grip vegetation and wrench it.
- There is a space between the incisors and premolars called the **diastema**. It is used to manipulate food by separating the freshly eaten food from the one that is already being chewed.

c) Dentition in an Omnivore

Omnivores are animals that feed on both flesh and vegetation e.g. human beings. Their dentition is not specialised for any kind of diet.

Tooth Decay

Also called **dental decay** or **dental caries**, this is a condition where the enamel of teeth is dissolved (corroded) by **organic acids** produced by fermentation of **sugars** by **bacteria** in the mouth forming **cavities** in the teeth. When cavity reaches the dentine, the tooth starts getting painful. The pain increases further when the cavity reaches the pulp cavity. At this stage, the tooth pains each time the patient takes very hot or very cold foods, becomes infected and may even start having a bad smell due to accumulation of abscess (pus). The condition may be treated by filling the tooth in with cement or having a tooth extraction.

Prevention of Tooth Decay

- Brushing teeth with fluoride toothpaste after every meal
- Avoiding intake of sugary foods
- Regular visits to the dentist i.e. at least twice every year (once every six months)
- Taking foods that are rich in calcium, phosphorus and vitamins C and D
- Using dental floss to remove food particles from teeth
- Using teeth properly by avoiding using them for opening bottle tops and the like as this may crack the enamel.

TRANSPORT IN FLOWERING PLANTS

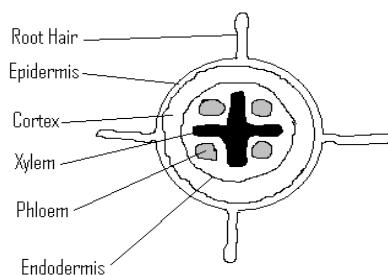
Plants need a transport system for the following reasons:

- To carry water and mineral salts from the roots to other parts of the plant
- To transport manufactured foods from the leaves to other parts of the plant
- To transport hormones from sites of synthesis to sites of usage

The transport system in flowering plants is called the **vascular system**. This consists of **xylem** and **phloem** which are closely associated with a meristematic tissue called **cambium**. Xylem conducts water and mineral salts from the roots to other parts of the plant and supports the plant mechanically. Phloem transports manufactured foods from the leaves to other parts of the plant. Cambium carries out cell division to produce new cells, including xylem and phloem cells.

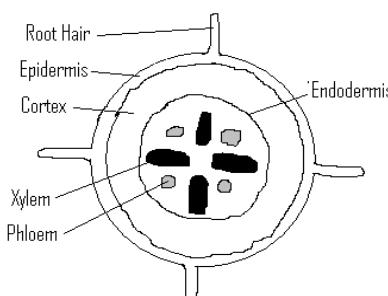
Arrangement of Vascular Tissues in Dicots and Monocots

(a) Cross-section of a Dicot Root

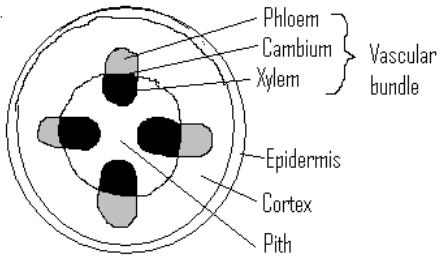


- Xylem is located in the centre and is star-shaped
- Phloem is located between the ‘arms’ of the xylem

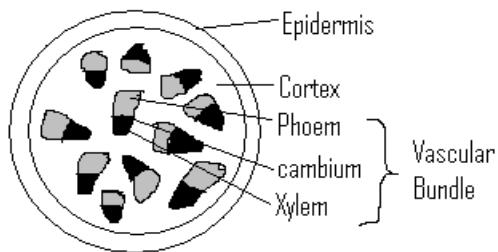
(b) Cross-section of a Monocot Root



(c) Cross-section of a Dicot Stem



(d) Cross-section of a Monocot Stem

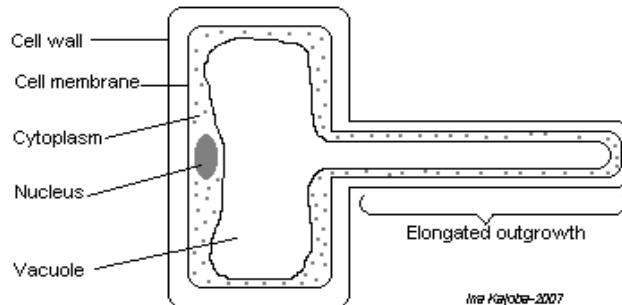


Uptake/Absorption of Water and Mineral Salts

Water and mineral salts are absorbed by **root hairs** which are found near the tips of roots. Root hairs are elongated outgrowths of epidermal cells of the roots. A root hair cell absorbs water by **osmosis** and mineral salts by **active transport** and is adapted for absorption in the following ways:

- Has an elongated outgrowth which increases the surface area for faster diffusion during absorption.
- Absence of chloroplast to create more room for absorption.
- High concentration of mitochondria to provide energy for active absorption/transport of mineral salts. In addition, root hair cells are numerous which further increase their surface area.

Structure of a Root Hair Cell



Movement of Water from the root hairs to the xylem

After being absorbed, water moves from the root hair cell to the xylem using three possible routes namely **apoplast** (from cell wall to cell wall), **symplast** (from cytoplasm to cytoplasm)

and **vacuolar route** (from vacuole to vacuole). The movement of water from cell to cell is due to **osmosis** and **transpiration pull**.

Movement of water up the Plant

Water moves up the plant through xylem vessels in a continuous stream known as the **transpiration stream**. The forces responsible for movement of water in the transpiration stream are transpiration, capillarity, root pressure and guttation.

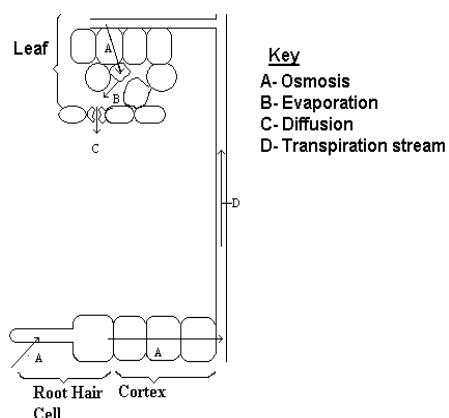
Transpiration (the diffusion of water vapour from plant leaves to the atmosphere through stomata). This creates a suction force that pulls water up the xylem vessels.

Capillarity: This is the movement of water into narrow tubes or openings as a result of cohesion (attractive forces between molecules of the same kind) and adhesion (attractive forces between molecules of different substances).

Root Pressure: This is the pressure created in xylem vessels due to osmotic gain of water by the roots. This pushes water up the xylem vessels.

Guttation: the loss of water drops from the tips and margins of leaves through openings called hydathodes. This creates a suction force that pulls water up the xylem vessels.

The following diagram summarises the transpiration stream.



Transpiration

This is the diffusion of water vapour from leaves to the atmosphere through stomata. In leaves of most plants, there are more stomata on the under-side than on the upper-side. The water moves from the xylem vessels to the mesophyll cells by **osmosis** then it **evaporates** from the surfaces of the mesophyll cells into the air spaces and finally **diffuses** out of the air spaces to the atmosphere through the stomata.

Excessive transpiration can lead to plasmolysis of plant cells causing wilting of the plant. Wilting is the sagging of delicate plant parts such as leaves, flowers and young stems due loss of water. **Temporary wilting** is wilting that can be reversed by supplying a plant with water. **Permanent wilting** can not be reversed even if a plant is supplied with water but leads to death of the plant. A plant undergoes wilting when the rate of transpiration is higher than the rate of water uptake.

Factors that affect the rate of transpiration

These include temperature, humidity, light intensity and wind.

Temperature: this is the degree of hotness or coldness of a substance. The higher the temperature, the higher the transpiration rate. This is because high temperatures increase the kinetic energy of the water molecules making them diffuse faster out of the leaf.

Humidity: this is the amount of water vapour in the atmosphere. The higher the humidity, the lower the transpiration rate because high humidity lowers the concentration gradient between the leaf and the atmosphere.

Light Intensity: This is the brightness or dimness of light. The higher the light intensity, the higher the transpiration rate because high light intensity causes opening of the stomata.

Wind: wind is moving air. The higher the wind speed, the greater the rate of transpiration. When the air is still, a layer of water vapour forms over the leaf and reduces the transpiration rate. But when there is wind, this layer of vapour is blown away thereby increasing the diffusion rate.

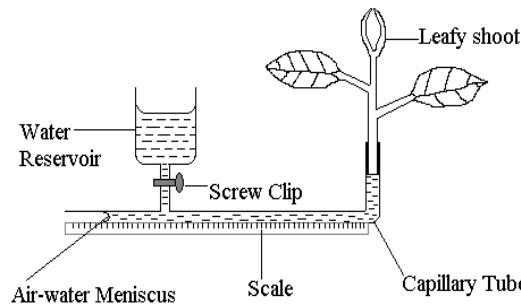
Plants can be adapted to reduce the rate of transpiration by having **xeromorphic features** which include the following:

- Presence of a thick waxy cuticle
- Sunken stomata
- Reduced size of leaves (needle-shaped leaves).
- Presence of hairs on the lower side of the leaf
- Leaves can roll up when water is scarce

Measuring the Rate of Transpiration

This can be measured using an instrument called the **potometer**.

Diagram of potometer



When using the potometer it is assumed that water uptake is equal to water loss through transpiration. The distance moved by the air bubble/meniscus, the cross sectional area of the capillary tube and the time taken need to be known in order to calculate the transpiration rate using the following formula:

$$\text{Rate of transpiration} = \frac{\text{Distance moved by meniscus}}{\text{Cross sectional area of tube}} \times \text{Time}$$

Time taken

Example

A student used a potometer to measure the transpiration rate of a leafy shoot of a plant. The water meniscus moved 30 cm in 30 minutes. If the cross-sectional area of the capillary tube was 0.25 cm^2 , what was the transpiration rate of the shoot?

Solution

$$\text{Rate of transpiration} = \frac{\text{Distance moved by meniscus} \times \text{Cross-sectional area of tube}}{\text{Time taken}}$$

$$= \frac{30 \text{ cm} \times 0.25 \text{ cm}^2}{30 \text{ minutes}} = 0.25 \text{ cm}^3/\text{minute}$$

Translocation

This is the movement of manufactured food from the **source** (point of origin/ manufacture) to the **sink sites** (the sites of usage or storage) through **phloem**. The organic solutes mainly include **sucrose** and **amino acids dissolved in water**. In most cases the leaves are the sources. In some cases, storage sites may also act as sources e.g. when food from a tuber is being translocated to points of growth.

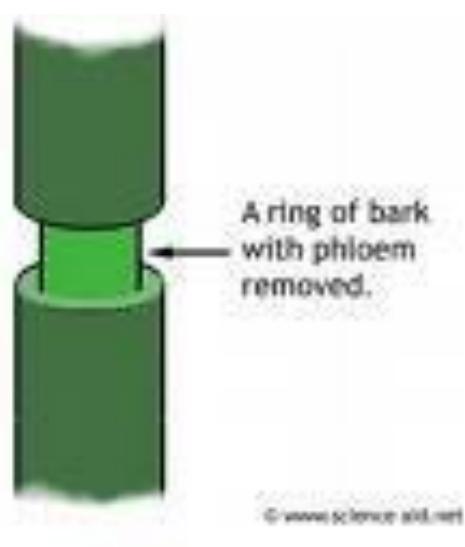
Evidence for Translocation

Using feeding aphids

When a feeding aphid is **anesthetised**, a chopped off leaving the mouth part attached to the plant, a drop of liquid is seen oozing out of the mouth part. Tests on the liquid reveal that it contains sucrose and amino acids. When a section of the plant is cut, the mouth part is found to be inserted in the phloem.

Ringing experiment

When a ring of **bark** is removed from a tree, phloem is removed together with the bark. If the tree is left to grow for several weeks, the bark above the ring swells because it continues receiving food coming from leaves through the phloem while the part below the ring stays the same. This shows that food is translocated through phloem.



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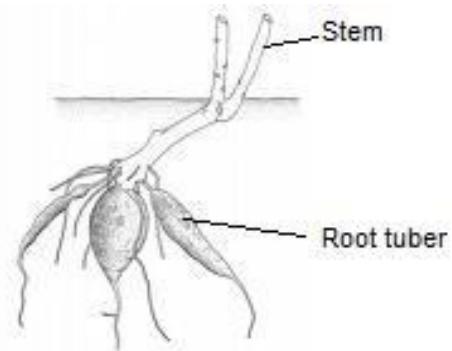
Using Radioactive Carbon

When plants are supplied with radioactive carbon dioxide and allowed to photosynthesise, they form radioactive sugars. Using photographic film, the path used by sugars moving from the leaf is found to be phloem.

Plant Storage Organs

The food manufactured by plants is normally converted to starch and oils for storage. Oils are mainly stored in seeds e.g. in groundnuts and sunflower. Starch is stored in a range of modified plant organs, some of which are discussed below.

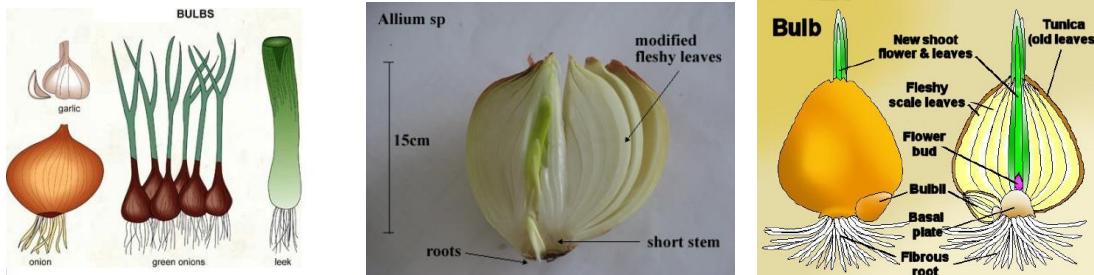
- Root tuber: This is a lateral root swollen with stored food e.g. sweet potato (*Ipomea batatas*) tuber



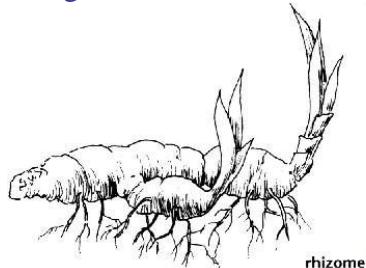
- Stem tuber: This is an underground stem swollen with stored food e.g. Irish potato (*Solanum tuberosum*)



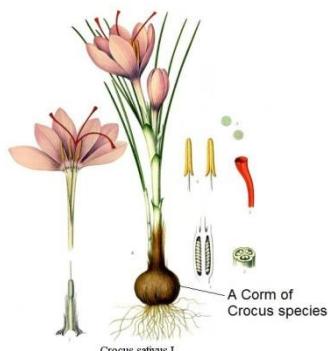
- Bulb:** A bulb is made of underground fleshy leaves growing from a short stem e.g. onion (*Allium sp*)



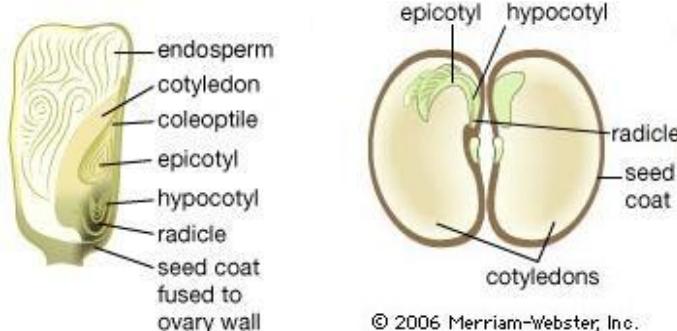
- Rhizome:** This is a swollen underground horizontal stem e.g. ginger



- Corm:** This is swollen underground and vertical short stem e.g. *Crocus sp.*



- Seed:** A sexually produced structure containing a plant embryo and its food store protected by a testa.



TRANSPORT IN ANIMALS

Animals need transport systems for the following reasons:

- To transport dissolved food substances from the intestines to the tissue cells.
- To transport oxygen from the lungs to the tissue cells.
- To transport hormones from endocrine (ductless) glands to target organs.
- To carry metabolic wastes from tissue cells to excretory organs.

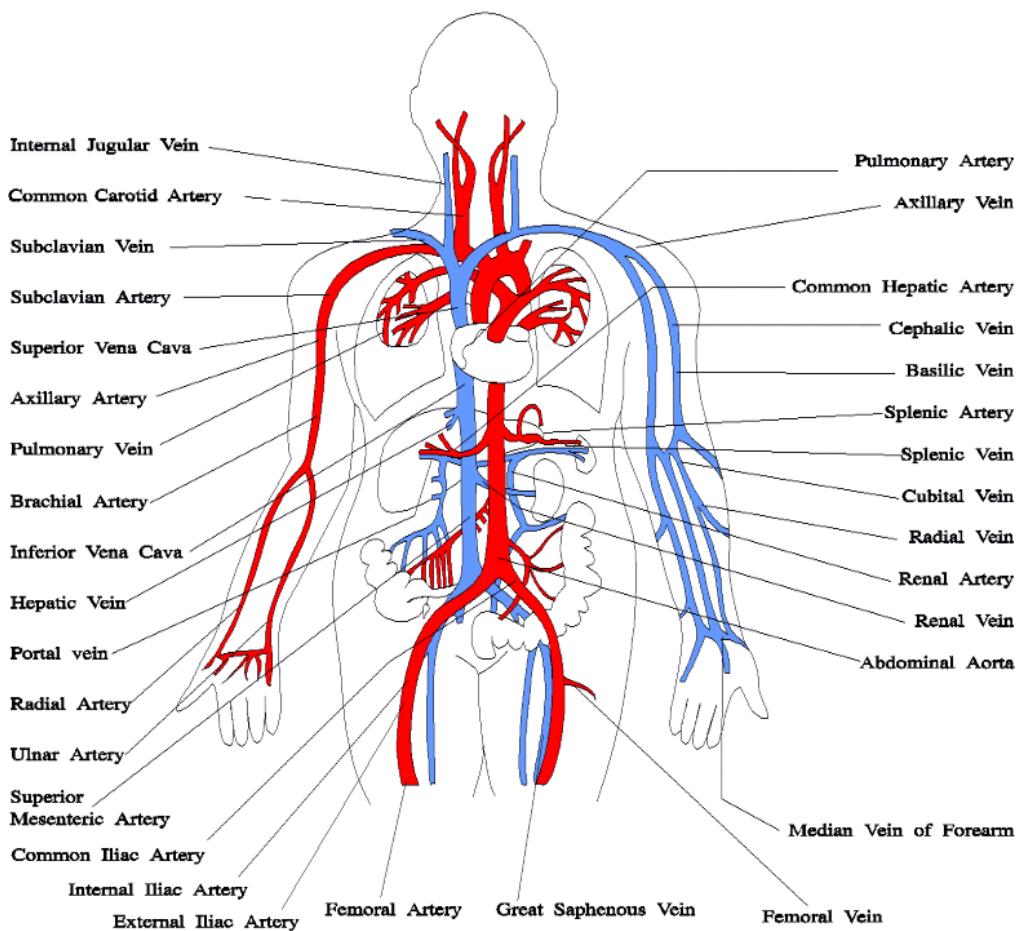
The transport systems of mammals are:

- The **blood circulatory system** (cardio-vascular system).
- The **lymphatic system**.

The Blood Circulatory System

This system is made of the *heart, blood vessels and the blood*.

Blood Circulation Principal Veins and Arteries



a) The Heart

This is a **muscular organ** that pumps blood around the body through blood vessels. The type of muscle found in the wall of the heart is known as **cardiac muscle**.

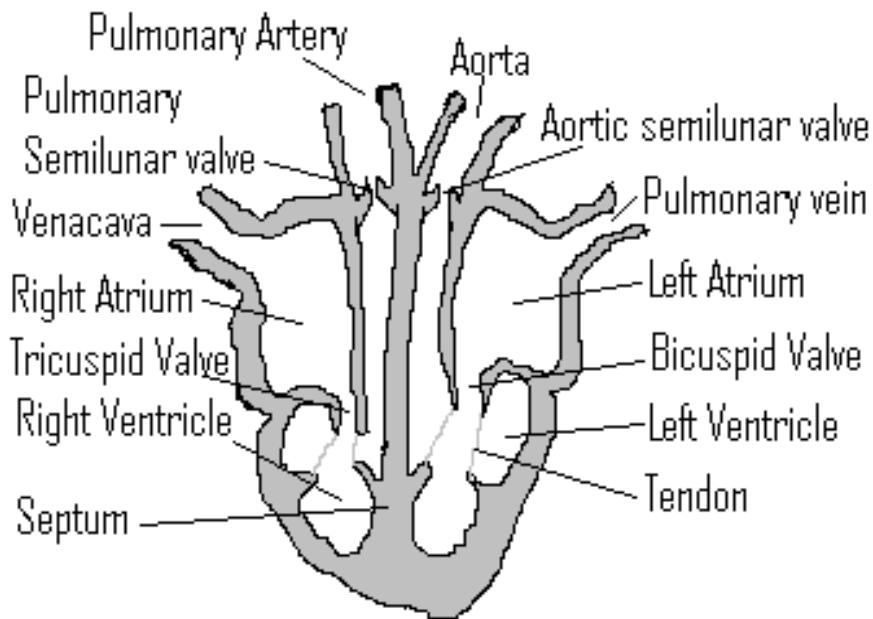
The heart is divided into left and right side by a middle wall called the **septum**. Each side has an upper chamber known as an **atrium** (*plural: atria*) and a lower chamber known as a

ventricle. The atria receive blood from the veins which they pump to the ventricles. The ventricles receive blood from the **atria** and pump it out of the heart through the **arteries**.

The heart receives blood from blood vessels called **veins**. These include the **venacava** (which carries blood from the rest of the body to the **right atrium**) and the **pulmonary vein** (which carries blood from the **lungs** to the **left atrium**). The heart pumps blood out through blood vessels called **arteries**. These include the **aorta** (which carries blood from the **left ventricle** to the rest of the body) and the **pulmonary artery** (which carries blood from the **right ventricle** to the **lungs**). The wall of the heart receives from the **coronary artery** which branches from the **aorta**.

The heart also contains valves which are responsible for keeping blood flowing in one direction by preventing back flow. The valves found between the atria and ventricles are called **atrio-ventricular valves**. The one on the right side is called the **tricuspid valve** while the one on the left is called the **bicuspid (mitral) valve**. Those found between the ventricles and arteries are called **semi-lunar valves**. The semi-lunar valve found at the beginning of the aorta is called the **aortic semi-lunar valve** while the one found at the beginning of the pulmonary artery is known as the **pulmonary semi-lunar valve**.

Diagram of the Mammalian Heart



Functioning of the heart

The wall of the heart is made of a type of muscle called **cardiac muscle** which has the following characteristics, among others:

- It is **myogenic** (it is self-stimulating, meaning that the stimulus for its contraction comes from the muscle itself). The stimulus for contraction originates from a special patch of cardiac muscle called the **pacemaker** or **sinoatrial node (SAN)** found in the right atrium.

- It does not develop fatigue
- Its cells are branched and have a single nucleus each.

Contraction of cardiac muscle is called **systole** while relaxation of cardiac muscle is called **diastole**. The sequence of events that occur during a single heart beat are called the **cardiac cycle**. The events of the cardiac cycle are summarised as follows:

- **Atrial Systole** (contraction of the walls of the atria)
- **Pause**
- **Ventricular Systole** (contraction of the walls of the ventricles)
- **Diastole** (relaxation of the walls of the entire heart)

Note that there is a pause between atrial systole and ventricular systole.

The following table gives the details of each event of the cardiac cycle:

Event	Atria	Ventricles	Bicuspid and Tricuspid Valve	Semi lunar Valves	Blood flow
Atrial Systole	Contract	Relax	Open	Close	From the atria to the ventricles
Ventricular Systole	Relax	Contract	Close	Open	From the ventricles to the arteries
Diastole	Relax	Relax	Open	Close	From veins into the atria

Double Circulation (Dual Circulation)

This is a type of circulation where blood passes through the heart **twice** during **one circulation** around the body. It involves two types of circulation, namely the **pulmonary circulation** and **systemic circulation**.

(i) Pulmonary Circulation

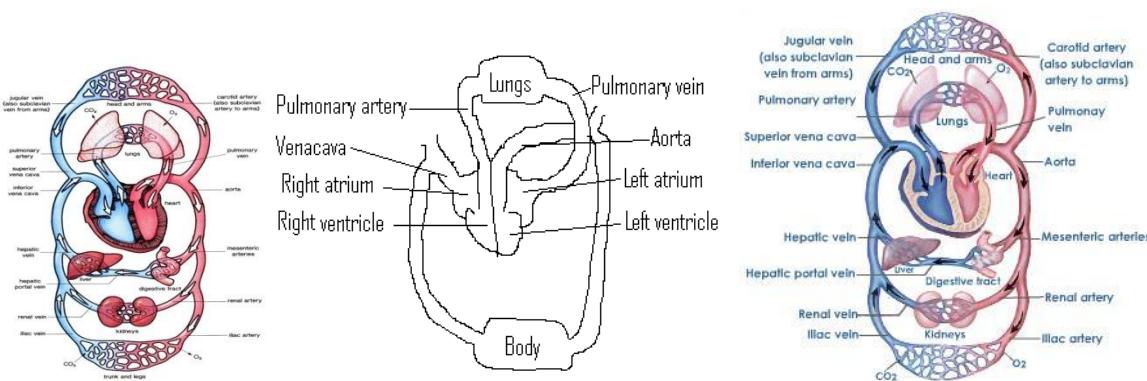
This is the flow of blood from the right ventricle to the lungs through the pulmonary artery and from the lungs to the left atrium through the pulmonary vein. In this circulation, blood is pumped over a short distance and at a low pressure. As a result, the walls of the right ventricle are relatively thin compared to those of the left ventricle. The purpose of this circulation is to oxygenate the blood and to remove carbon dioxide from the blood in the lungs.

(ii) Systemic Circulation

This is the flow of blood from the left ventricle to the rest of the body through the aorta and from the rest of the body to the right atrium through the venacava. In this circulation, blood is pumped over a long distance and at a high pressure. As a result, the walls of the left ventricle

are relatively thick compared to those of the right ventricles. The purpose of this circulation is to distribute oxygen around the body and to collect carbon dioxide from the body tissues.

The following diagram summarises double circulation.



Heart Rate and Pulse Rate

The term heart rate refers to the **number of heart beats per minute**. It can be measured using an instrument called the **stethoscope**. The heart rate of a normal adult human being at rest is about **72** beats /minute. Factors that affect and modify the normal resting heart rate are sleeping, emotional excitement, illness (e.g. fever) and physical exercise, as illustrated in the following table:

Factor	Heart Rate (beats per minute)
Rest	72
Sleeping	
Fever	
Emotional Excitement	
Physical Exercise	

Reference: Environmental Science Grade 8

A pulse is a wave of pressure created in the arteries by a heart beat. The number of pulses per minute is called the **pulse rate**. Measuring the pulse rate is an indirect way of measuring the heart rate. A pulse can be located using the index and middle fingers on any part of the body where arteries are very close to the skin surface such as

- on the wrist just near the base of the thumb
- on the sides of the head just next to the ears
- on the neck just below the jaws

Coronary Heart Disease (CHD)

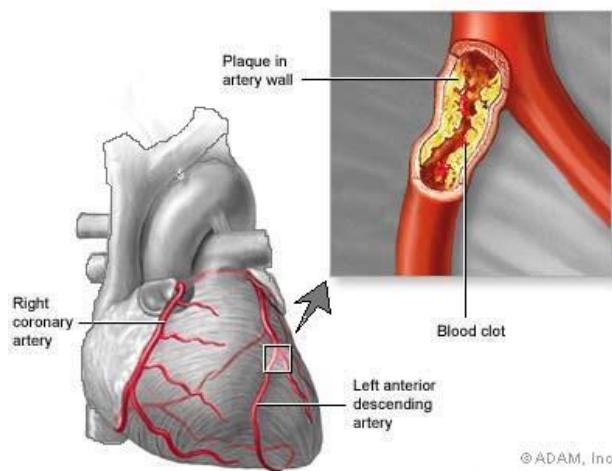
This is the occlusion (blockage) of coronary arteries with fatty material, mainly **cholesterol**. There are several conditions associated with coronary heart disease. Some of them are:

- **Atheroma** This is an accumulation of fatty material in the walls of the coronary arteries.
- **Sclerosis** This is the hardening of the walls of coronary arteries due to the presence of fatty material
- **Thrombosis** this is the blockage of the coronary arteries by a mixture of blood clots, fatty material and fibres. A blood clot within the blood vessels is called a **thrombus**.
- **Angina** This is a sharp pain experienced in the heart and left arm after exertion due to the presence of an atheroma or thrombus in the coronary artery.
- **Embolus** This is a moving clot that results when a thrombus is pushed out of place by heart beat. If it reaches the brain, it may cause bursting of blood vessels, resulting in stroke. An embolus in the lungs leads to **pulmonary embolism** which is characterized by sharp pains in the lungs.
- **Heart Failure** (myocardial infection), this is a condition where the heart fails to pump blood due to a limited supply of blood caused by blockage of the coronary arteries. The patient may black-out, collapse and die.

Causes of Coronary Heart Disease

Factors that increase the risk of coronary heart disease include the following:

- **Excessive intake of fatty foods.** Fatty foods are easily converted to cholesterol which in turn blocks the coronary arteries.
- **Smoking.** Cigarette smoke contains a **stimulant** called **nicotine** which tends to promote the accumulation of cholesterol in the blood.
- **Emotional stress.** The body secretes high levels of adrenaline during emotional stress. This also tends to promote accumulation of cholesterol in the blood stream.
- **Lack of exercise**



Prevention of Coronary Heart Disease

- Avoid excessive intake of fatty foods
- Avoid smoking
- Avoid emotional stress
- Exercise regularly

(b) Blood Vessels

These are tubes through which blood moves around the body. There are three types of blood vessels. These are Arteries, veins and capillaries.

(i) Arteries

These are blood vessels that carry blood away from the heart to other parts of the body. They have the following characteristics:

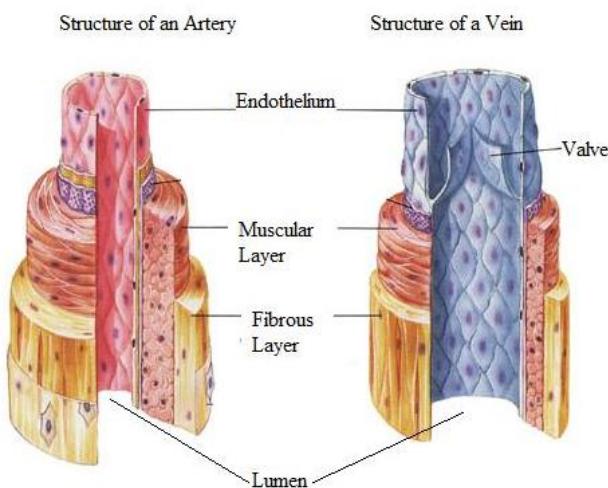
- They carry blood away from the heart
- They carry blood at high pressure
- They have thick walls and narrow lumens. The thick walls help them withstand the pressure from the heart.
- They have no valves since the pressure from the heart is enough to keep blood moving in one direction.
- They all carry oxygenated blood except the pulmonary artery.
- They appear round in cross-section
- They are located deeper under the skin than the veins.

(ii) Veins

These are blood vessels that carry blood towards the heart from other parts of the body. They have the following characteristics:

- They carry blood towards the heart.
- They carry blood at low pressure
- They have thin walls and wide lumens.
- They have valves to keep blood moving in one direction by preventing back flow.
- They all carry deoxygenated blood except the pulmonary vein.
- They appear irregular in cross-section
- They are located nearer to the skin surface than the arteries.

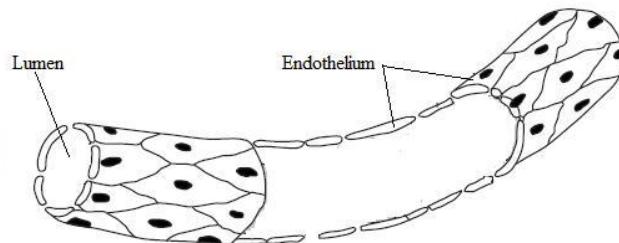
The following diagram illustrates the structure of an artery and a vein.



(iii) Capillaries

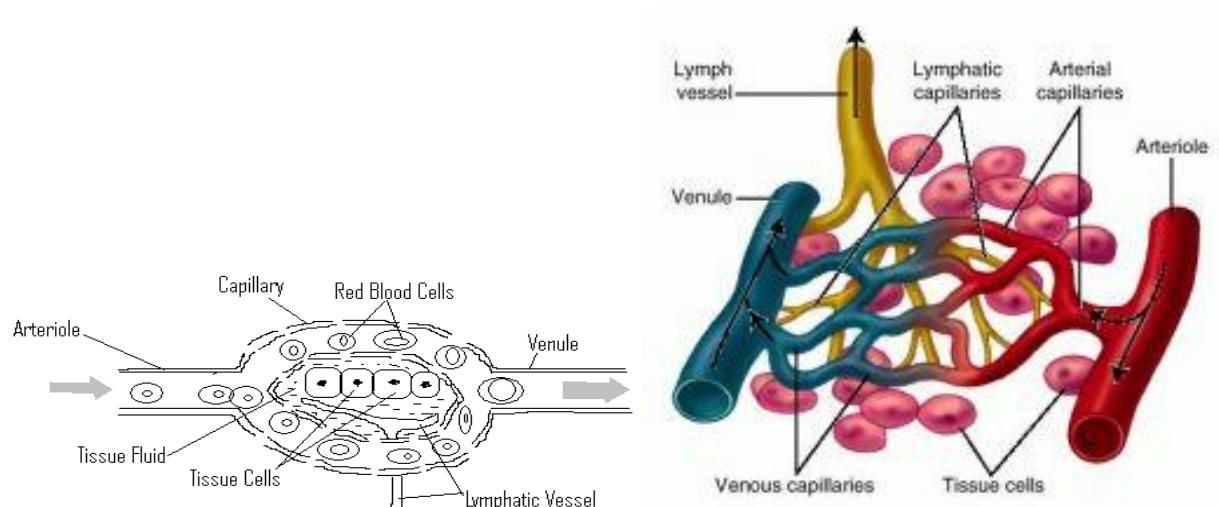
These are the **smallest blood vessels**. They form a **link between arteries and veins**. As arteries approach the organs of the body, they branch into smaller arteries called **arterioles**.

The arterioles keep on subdividing until they form the capillaries. The capillaries **have direct contact with the tissue cells**. This makes it possible for substances to be exchanged between the blood and tissue cells. In addition, the **walls of the capillaries are very thin** (just one cell thick) for easy diffusion of materials between the blood and the tissue cells. The network of capillaries in the tissue cells is called the **capillary bed**. The following diagram illustrates the structure of a capillary.



The exchange of materials between blood and the tissue cells is illustrated by the following diagram of the capillary bed.

Diagram of Capillary bed



When blood from the arterioles reaches the capillary bed, the plasma is filtered out of the capillaries into the spaces around the tissue cells. The fluid around the tissue cells is called **tissue fluid**. Tissue fluid has the following functions:

- Bathing the tissue cells
- Thermoregulation of the tissue cells
- Facilitating exchange of materials between the blood and tissue cells. Dissolved food and oxygen diffuse from the tissue fluid into the tissue cells while carbon dioxide and urea diffuse from the tissue cells into the tissue fluid.

The formation of tissue fluid from blood is caused by the following factors:

- The pressure of blood coming from the arterioles is higher than the pressure in the venule.
- The walls of the capillaries are very thin (one cell thick)

Red blood cells are not filtered out of the capillaries because they are large and rigid. However, phagocytes are able to change shape and squeeze out of the capillaries.

Names of Selected Blood Vessels

Name of Organ	Names of Blood Vessels
Heart	Coronary artery
Lungs	Pulmonary artery and pulmonary vein
Liver	Hepatic artery, hepatic vein and hepatic portal vein
Kidneys	Renal artery and renal vein

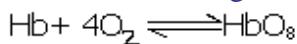
(c) Blood

This is a tissue made of red blood cells, white blood cells, plasma and platelets.

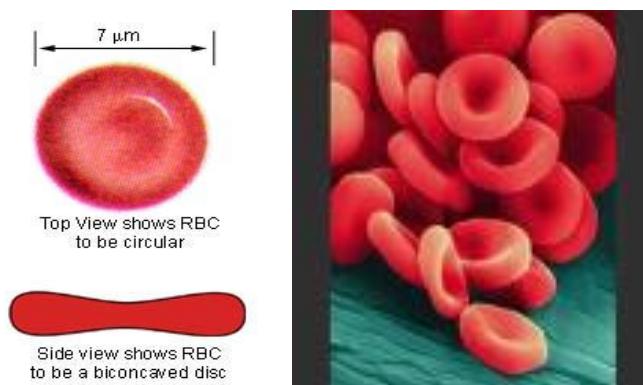
Red blood cell (Erythrocytes)

These are biconcave discs responsible for transportation of oxygen and small amounts of carbon dioxide. They are made in the bone marrow in adults but can also be made by the liver in babies. One milliliter of blood contains 5 to 6 million red blood cells. They have a lifespan of about 120 days and are destroyed by the liver. They are adapted for transportation of oxygen in the following ways:

- Biconcave disc shape to increase the surface area for diffusion of oxygen.
- Presence of a red pigment called **haemoglobin** which has a high affinity (attraction) for oxygen. Haemoglobin combines with oxygen to form **oxyhaemoglobin** when oxygen concentrations are high (e.g. in the lungs). When oxygen concentrations are low e.g. in the muscles, oxyhaemoglobin dissociates forming haemoglobin and oxygen.



- Absence of nucleus makes more room for haemoglobin



White Blood Cells (Leucocytes)

These are cells that defend the body against infection (diseases) and are made in the bone marrow, lymphoid tissue, lymph nodes, tonsils, thymus and spleen. Two examples of white blood cells are **phagocytes** and **lymphocytes**.

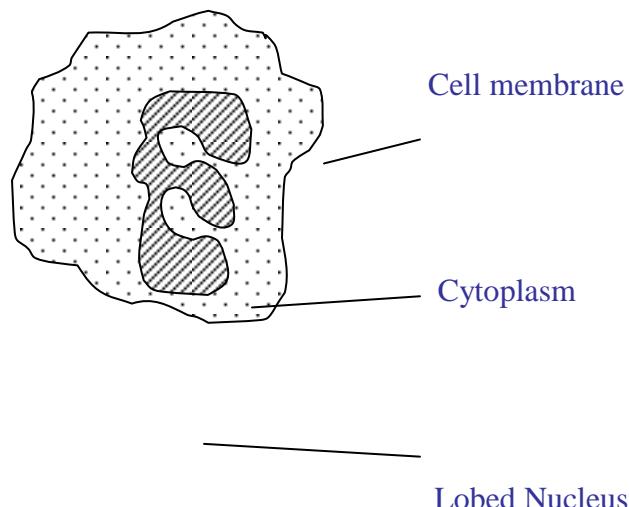
Phagocytes

Functions

- These defend the body against infection by **engulfing** and **digesting** germs (foreign bodies).

Adaptations

- Lobed nucleus which makes engulfing of germs easy.
- Amoeboid movement which makes it possible for them to move towards germs.
- They have no fixed shape but can change their shapes, making engulfing of foreign bodies possible.



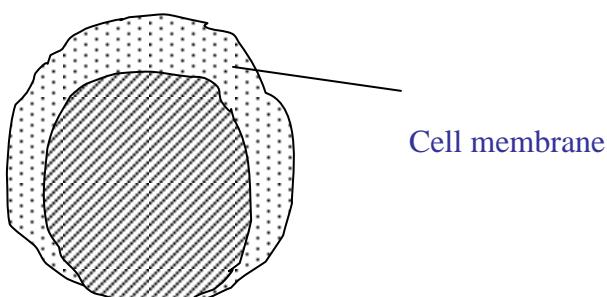
Lymphocytes

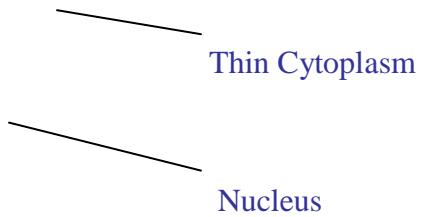
Functions

- To defend the body against infection by producing **antibodies** and **antitoxins**. Antibodies are proteins that destroy germs/foreign bodies while antitoxins are proteins that neutralize poisons from germs.

Adaptations

- Presence of a large nucleus and thin cytoplasm.



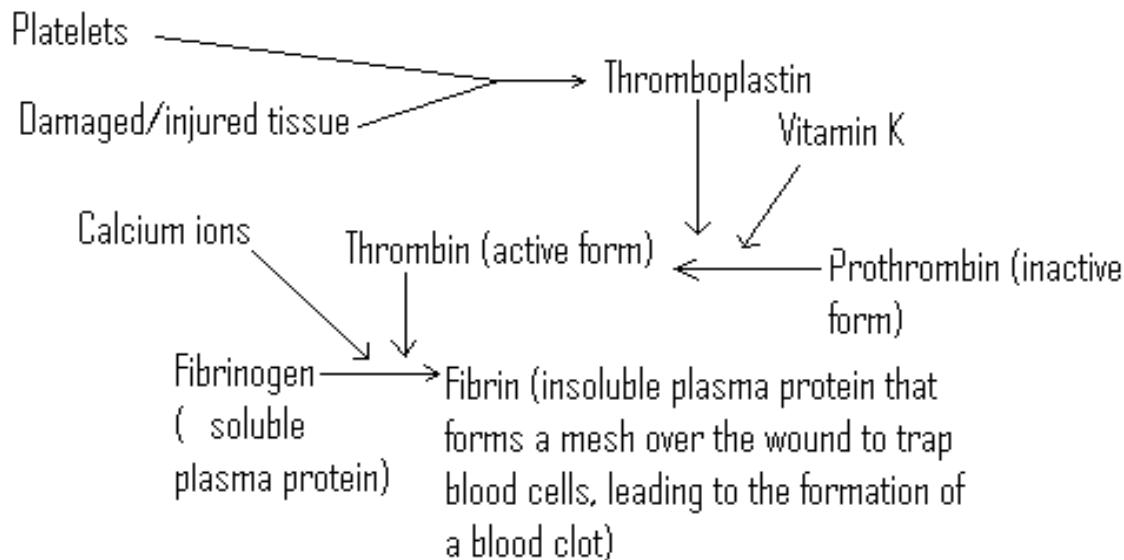


Platelets (Thrombocytes)

These are fragments formed during the manufacture of red blood cells. They are important for blood clotting. The steps involved in blood clotting are described below:

- When platelets are exposed to damaged/injured body tissues, they release an enzyme called **thromboplastin/thrombokinase**.
- Thromboplastin acts on a plasma protein called **prothrombin** changing it to an active form called **thrombin**.
- Thrombin acts on another plasma protein called **fibrinogen** changing it into an insoluble form called **fibrin**. This reaction occurs in the presence of calcium ions. The fibrin forms a mesh (net) over the wound. This mesh traps red and white blood cells, leading to the formation of a **clot** over the wound.

The following diagram summarizes the mechanism of blood clotting.



Blood clotting is important in the following ways:

- It prevents excessive loss of blood
- It prevents entry of germs into the body

- It is the first step in the healing of wounds. The clot eventually hardens, forming a **scab**. The scab eventually falls off, leaving behind a **scar**.

Blood Plasma

This is the liquid part of blood. It is made of water and dissolved substances. The dissolved substances include the following:

- dissolved food (monosaccharides, amino acids, fatty acids, glycerol, vitamins and mineral salts)
- dissolved metabolic wastes (urea and carbon dioxide in form of hydrogen carbonate ions)
- dissolved chemical substances such as hormones, antibodies, antitoxins and plasma proteins)

Plasma proteins include prothrombin, fibrinogen and albumin. The roles of plasma proteins include maintaining blood viscosity, causing blood clotting, maintaining a constant blood PH, maintaining osmotic balance e.t.c. The functions of blood plasma are:

- Transportation of dissolved food
- Transportation of metabolic wastes
- Transportation of hormones, antibodies and antitoxins
- Distribution of heat around the body. Most of the body heat is generated by the liver and muscles.

Note: The functions of blood may be summarised as transport and defence.

Blood Groups

The type of blood group in a human being is determined by the type of antigen present in the cell membrane of the red blood cell. There are two antigens, namely I^A and I^B , while the absence of either antigen is represented as I^O . This is called the **ABO** blood group system. There are four possible blood groups, namely group A, group B, group AB and group O. The lymphocytes in each type of blood produce antibodies against **non-self antigens** (antigens that are not present in the cell membranes of their red blood cells). These antibodies are released into the blood plasma. The following table shows the antigens and antibodies present in each of the four blood groups:

Blood Groups	Type of antigen(s) present in the cell membranes of red blood cells	Type of antibody present in the blood plasma
Group A	antigen A (I^A)	Anti B
Group B	Antigen B (I^B)	Anti A

Group AB	Both antigens A and B (I^A and I^B)	None
Group O	None	Anti A and anti B

Blood Transfusion

This refers to the transfer of blood from one individual called the **donor** to another one called the **recipient**. For a blood transfusion to be successful the blood of the donor has to be **compatible** with the blood of the recipient. **Blood compatibility** refers to the capacity of a blood recipient to receive the donor's blood without leading to **agglutination** or **clumping** of the blood received. Agglutination occurs when antibodies in the recipient's blood attack non-self antigens present in the donor's blood causing the red blood cells from the donor to stick together. This may cause blockage of blood vessels, kidney failure and stroke. Therefore, any blood groups that have different antigens are **incompatible**.

The following points must be noted when carrying out a blood transfusion:

- Blood group O can be given to any blood group because it has no antigens that can be attacked by antibodies in the recipient's blood. For this reason, blood group O is called the **universal donor**. However, blood group O can not receive blood from any other blood group.
- Blood group AB can receive blood from all other blood groups because it has no antibodies to attack the antigens in the donor's blood. For this reason, it is called the **universal recipient**. However, blood group AB can not give blood to any other blood group.
- A person can receive blood from another person of the same blood group without complications arising.
- Before a donor's blood is given to a recipient, it has to be screened. Blood screening is the testing of blood in order to determine the following: the blood group, the rhesus status and to check for infections such as hepatitis and HIV.

Rhesus Factor

This is a blood antigen first discovered in monkeys of the genus called **Rhesus**. A person whose blood has this antigen is said to be **rhesus positive** (Rh^+ or **Rh positive**), while a person whose blood does not have this antigen is said to be **rhesus negative** (Rh^- or **Rh negative**). The rhesus status of a child depends on the status of its two parents as described below:

- If both parents are Rh^+ , all their children will be Rh^+ .
- If one parent is Rh^+ and the other is Rh^- all children will be Rh^+ .
- If both parents are Rh^- , all their children will be Rh^- .

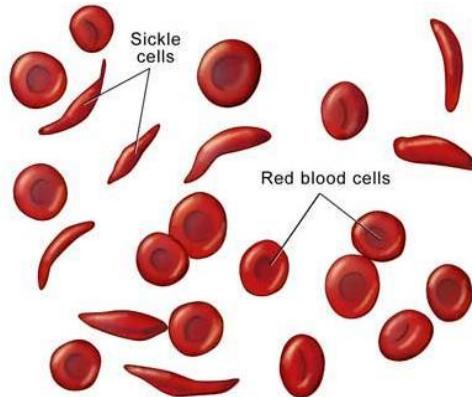
Having a rhesus negative mother and a rhesus positive father can cause serious complications in a foetus or baby. If some of the blood of the foetus enters the mother's blood stream during pregnancy or birth, the mother's blood begins making the **anti-rhesus antigens**. If the woman conceives another rhesus positive foetus, these antibodies will cross the placenta and attack the blood of the foetus. At the time of birth, the baby will suffer from **haemolytic disease**.

(**erythroblastosis foetalis**), which leads to death if the baby does not receive a comprehensive blood transfusion soon after birth. Any subsequent pregnancies are miscarried and fail to thrive up to the time of birth.

Blood Disorders

Examples of blood disorders in humans include sickle cell anaemia, haemophilia and leukemia.

Sickle Cell Anaemia: This is an inherited disease where a person has abnormal haemoglobin. As a result, the red blood cells become sickle-shaped, especially when oxygen levels are low in the body. The disease reduces the capacity of the body to transport oxygen.

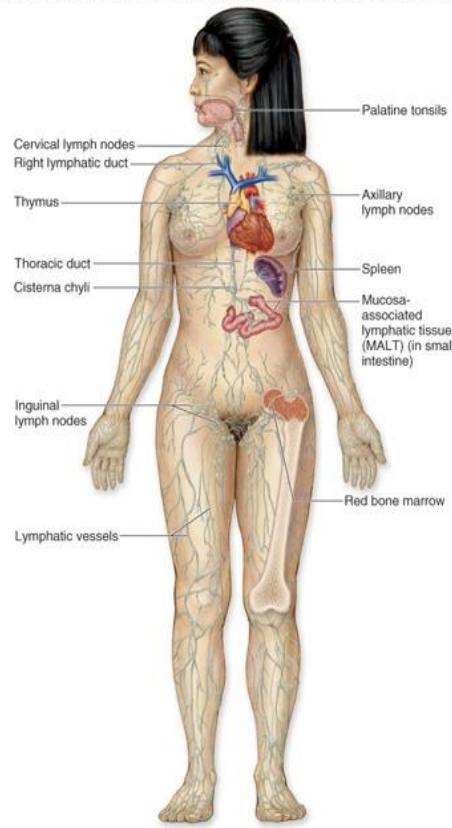
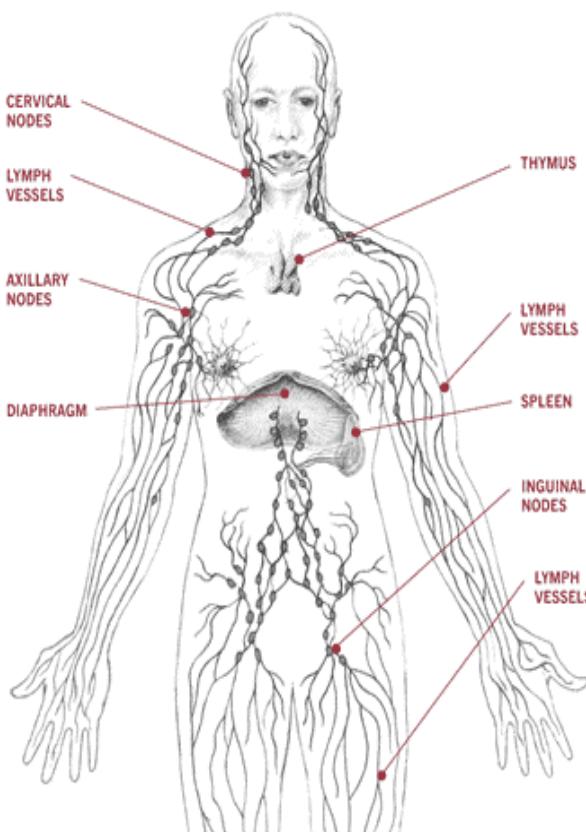


Haemophilia: This is an inherited disease where a person bleeds for longer periods than normal due to poor clotting of blood. It is caused by **absence of blood clotting proteins** known as **factor VIII and factor IX**.



Leukemia: This is defined as cancer of the white blood cells. The patient makes an abnormally high number of immature white blood cells.

The lymphatic System



This is a transport and defence system made of the following components:

- **Lymphatic vessels** (a network of vessels that have blind ends in the tissue cells)
- A fluid called **lymph** (derived from tissue fluid but having more glycerol, fatty acids, white blood cells, antibodies and antitoxins than tissue fluid)
- **Glands and organs** such as the **spleen**, **adenoids**, **tonsils**, **thymus**, **lymph nodes** and **appendix**. The largest organ of the lymphatic organ is the **spleen**. The thymus is a gland located on top of the heart and is large in infants but keeps getting smaller and eventually degenerates during early childhood.

The smallest vessels of the lymphatic system are called **lymphatic capillaries** and **lacteals** (in the villi of the small intestines). These small vessels join up to form bigger vessels called the **lymphatics** or **lymphatic vessels**. The lymphatics join up repeatedly to make bigger lymphatic vessels. The biggest lymphatic vessels are called **thoracic ducts**. Each thoracic duct drains lymph into a **subclavian vein** near the junction of the neck and the arm.

Two prominent features found along lymph vessels are **valves** and **lymph nodes**. Valves keep the lymph flowing in one direction by preventing backflow. The flow of lymph is assisted by contraction of muscles and breathing movements of the thorax and abdomen. Lymph nodes are important in the following ways:

- They produce and store lymphocytes which are added to the lymph as it passes through on its way to the subclavian vein.
- They filter foreign bodies, bacteria and dead tissue from the lymph before it joins the blood.
- They become very active when the body is invaded by foreign bodies, becoming swollen and tender in the process.

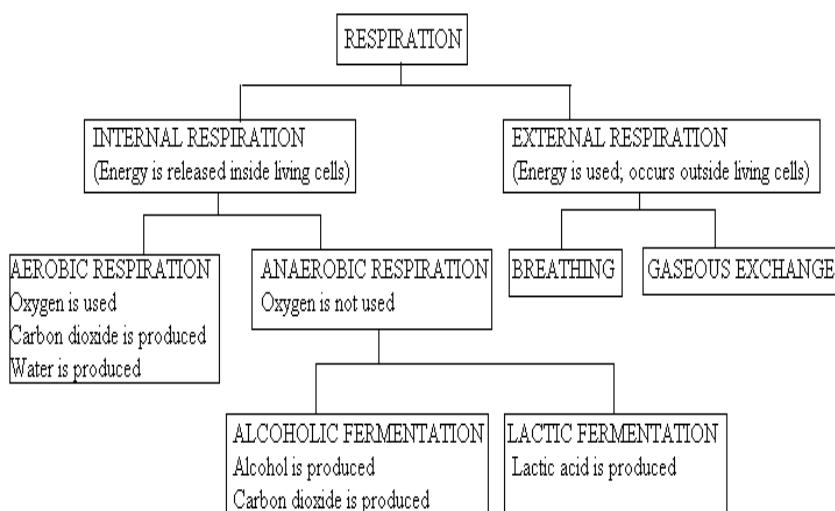
The functions of the lymphatic system may be summarised as follows:

- It drains excess tissue fluid and takes it back to the blood
- It adds lymphocytes to the blood
- It absorbs and transports cholesterol, fatty acids and glycerol to the blood.

RESPIRATION

Respiration is defined as the release of energy from food substances in living cells. This definition strictly applies to **tissue respiration** which is also called **cellular respiration** or **internal respiration**. However the term respiration is sometimes loosely applied to other processes that help make oxygen available to living cells. These are **breathing** (**ventilation**) and **gaseous exchange**. In this case, the term **external respiration** is used.

The following diagram summarises the terms associated with respiration.



Internal Respiration

Internal respiration occurs inside living cells in organelles called **mitochondria** (singular: **mitochondrion**). The main substrate for internal respiration in most organisms is **glucose**. There are two types of internal respiration, namely **aerobic** and **anaerobic respiration**.

Aerobic Respiration

This is the release of energy from food in living cells in the **presence of oxygen**. This process releases a **relatively high amount of energy** (about 2880 KJ from one mole of glucose) and the by products produced are **carbon dioxide** and **water**. This type of respiration occurs in tissue cells of animals and plants when there is a sufficient supply of oxygen. The word and chemical equations for aerobic respiration are given below:

Word Equation



Chemical Equation



Anaerobic Respiration

This is the release of energy from food substances in living cells in the **absence of oxygen**.

Types of anaerobic respiration include **alcoholic fermentation** and **lactic fermentation**.

Alcoholic Fermentation

This is the release of energy from food substances in living cells in the **absence of oxygen**, producing **alcohol (ethanol)** and **carbon dioxide** as by products. This process releases a **relatively low amount of energy** (about **210 KJ** from one mole of glucose). The reaction is catalysed by an enzyme called **zymase** which is naturally found in yeast. The word and chemical equations for alcoholic fermentation are given below:

Word Equation:

Zymase



Chemical Equation:

Zymase



Alcoholic fermentation takes place in yeast.

Alcoholic fermentation is important in **brewing** and **baking**. In both cases yeast is the organism that is used to carry out the alcoholic fermentation.

When brewing, germinating seeds are used because they contain the sugar maltose. The seeds are dried and ground to form a powder. This powder is then boiled in water to form a paste. The paste is cooled and yeast is added. Yeast contains an enzyme called **zymase** which converts glucose to carbon dioxide and alcohol, releasing energy in the process. The glucose is formed from the action of maltase on maltose. The alcohol is removed from the mixture by **simple distillation**.

When baking, flour is mixed with water, salt, sugar and yeast to form a paste called **dough**. When there is insufficient oxygen, zymase from yeasts acts on sugars to form carbon dioxide and alcohol. But if oxygen is sufficient, yeast carries out aerobic respiration. The carbon dioxide begins to form bubbles in the dough causing it to rise. The dough is often placed in a

warm place to provide an **optimum temperature** for enzyme activity. After this the dough can be baked.

Lactic Fermentation

This is the release of energy from food substances in living cells in the **absence of oxygen**, producing **lactic acid** as the only by product. The amount of energy released is very little (about 150 KJ from one mole of glucose).

Word Equation:



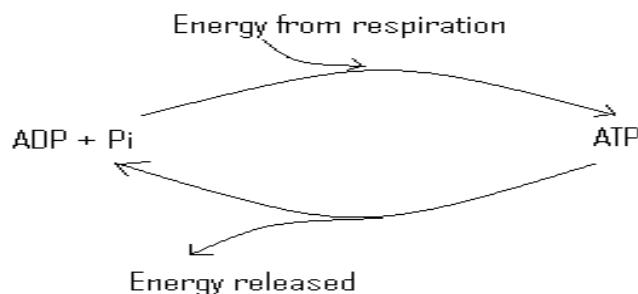
Chemical Equation:



This process takes place in the muscles of animals during exercise. This is because the extra energy required by the animal during exercise cannot all be generated by aerobic respiration since there is a limited supply of oxygen. This energy is therefore generated by lactic fermentation. However the lactic acid formed has harmful effects on the body such as causing fatigue, muscle cramp and fainting. Blood flowing through the muscles carries some lactic acid with it to the brain and the brain detects its presence. It then sends impulses to the ribcage (to increase the breathing rate and depth) and to the heart (to increase the heart rate). This increases oxygen supply to the muscles. This oxygen is needed to break down lactic acid to water and carbon dioxide. The total amount of oxygen needed to break down the lactic acid produced during exercise is called the **oxygen debt**.

ATP and its Significance

Energy from respiration is not used directly by organisms but is used to produce **ATP** (adenosine triphosphate) by combining adenosine diphosphate (ADP) and inorganic phosphate (P_i). Energy from ATP is then used by living organisms. When the energy is needed, ATP breaks down to ADP and inorganic phosphate, releasing energy in the process. The formation and breakdown of ATP can be illustrated as follows:



ATP is important in the following ways:

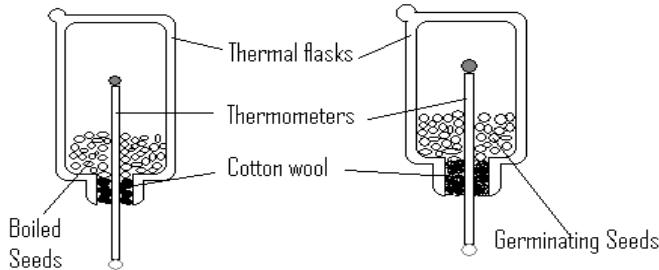
- It makes it possible for energy to be stored and transported
- It makes energy available when and where it is needed.

Experiment to Demonstrate Respiration in Germinating Seeds

Materials: two thermal flasks, two thermometers, cotton wool, two sets of bean seeds.

Method

- Soak one set of seeds until they start germinating and boil the other set of seeds
- Soak both sets of seeds in disinfectant to kill micro organisms and place each set in a separate thermal flask.
- Set the experiment as shown in the following diagram.



- Read the initial temperature from each of the two thermometers.

- Leave the setup for four days and read temperatures from the two thermometers again.

Exercise: Suggest why the seeds need to be soaked in a disinfectant before being put into the flasks.

Observations

- The temperature in the flask containing boiled seeds will remain the same while the temperature in the flask containing germinating seeds will increase.

Conclusion

Energy is produced during respiration. Germinating seeds carry out respiration while boiled seeds do not.

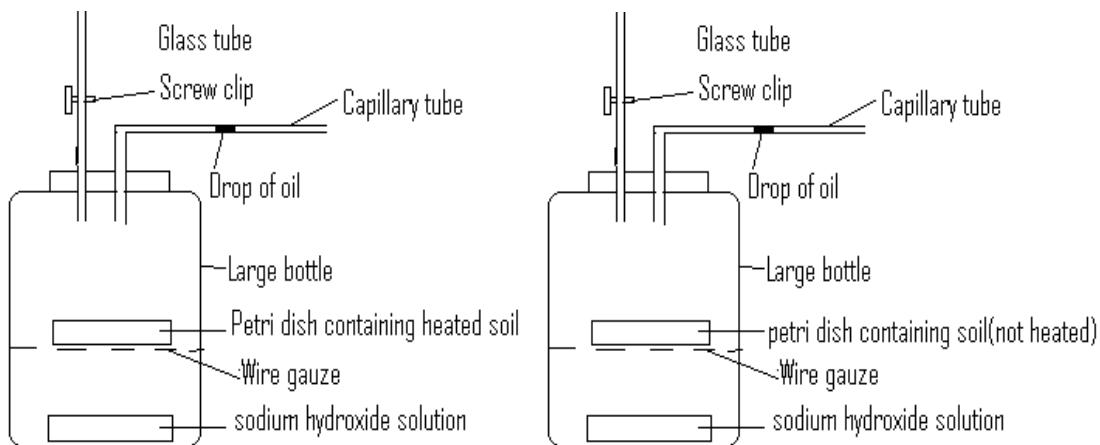
Experiment to Demonstrate Respiration in Soil Organisms

Materials

Two large bottles, wire gauze, sodium hydroxide solution, two capillary tubes, two glass tubes, two petri dishes, two samples of soil, two screw valves.

Method

- Heat one of the soil samples and leave the other one without heating.
- Set up the experiment as shown in the following diagram



- Leave the setup for five hours and observe what happens to the position of the drop in the capillary tube.

Observations

- The oil drop in the container having heated soil remains at the same position while the one in the container having unheated soil moves inwards

Conclusion

Soil contains living organisms that carry out respiration and use up oxygen in the process.

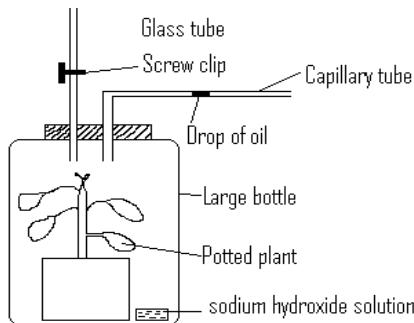
Experiment to Demonstrate Respiration in Green Plants

Materials

A large bottle, sodium hydroxide solution, a capillary tube, a glass tube, a petri dish, a potted plant, a screw valve.

Method

- Set up the experiment as shown in the following diagram and place the setup in a dark place.



- Leave the setup for five hours and observe what happens to the position of the drop in the capillary tube.

Observations

- The oil drop in the capillary tube moves inwards

Conclusion

The plant carries out respiration and uses up oxygen in the process.

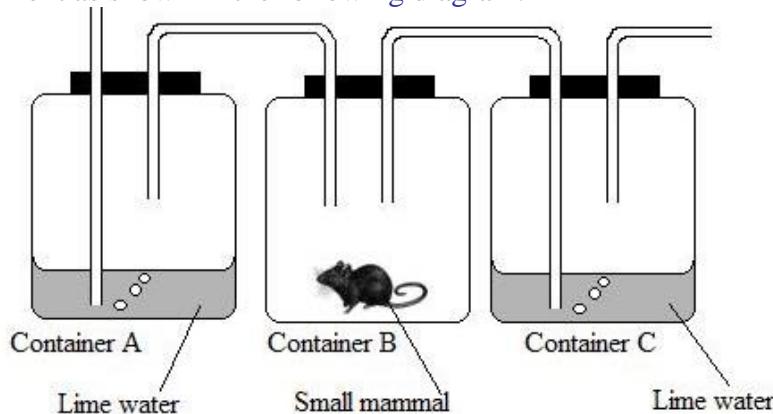
Experiment to Show that Carbon Dioxide is Produced During Respiration

Materials

Three large bottles, lime water, glass tubes and a small mammal e.g. a rat.

Method

- Set up the experiment as shown in the following diagram.



- Observe and record what happens to the lime water in containers A and C.

Observation

The lime water in the container C turns milky earlier than the one in A.

Conclusion

Exhaled air contains more carbon dioxide than inhaled air. That is why the lime water in C turns milky earlier than in A.

The Importance of Respiration

The energy released during respiration is used in the following processes: **maintenance of a constant body temperature, reproduction, cell division, active transport and growth /synthesis of macromolecules** (memory aid: **MR. CAG**).

Breathing and gaseous Exchange

Breathing in **terrestrial animals** (such as human beings) is defined as the movement of air into and out of the lungs. In **aquatic animals** such as fish, breathing is the movement of water into and out of the **gill chamber**. Another term used to refer to breathing is **ventilation**. Breathing involves two stages known as **inspiration (inhalation)** and **expiration (exhalation)**.

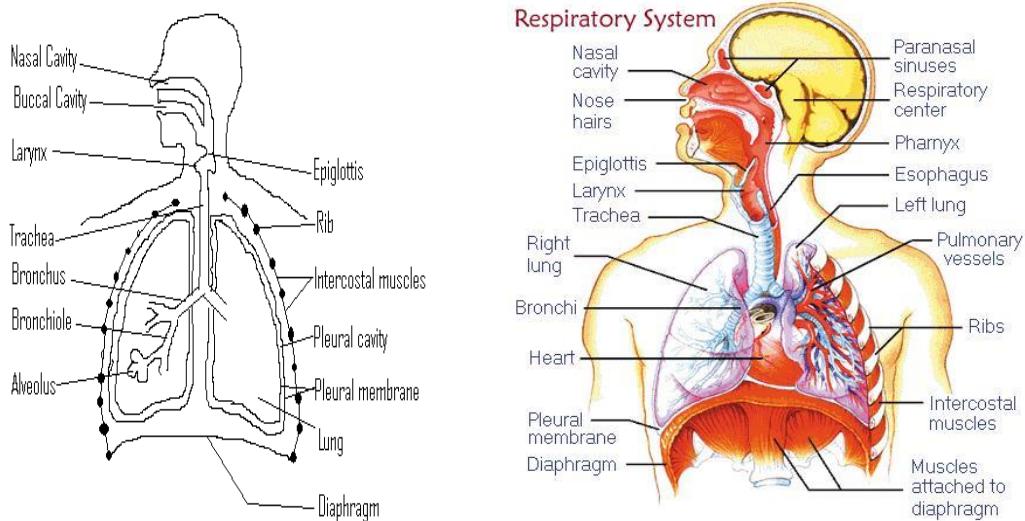
Gaseous exchange is the diffusion of oxygen into the blood and carbon dioxide out the blood across a **gaseous exchange surface**. In humans the gaseous exchange surfaces are the alveoli

found in the lungs while the gaseous exchange surfaces in fish are the gills. Gaseous exchange surfaces have the following characteristics:

- **Large surface area** to maximise the exchange of gases
- **Moist surface** because gases need to dissolve before they can diffuse across a surface.
- **Thin surface** to minimise the distance of diffusion so that there is faster diffusion
- **Close association with a transport system** to transport the gases to and from the gaseous exchange surface, thereby maintaining a constant diffusion gradient for the gases
- **Well-ventilated** to maintain a constant diffusion gradient.

Breathing in Humans

The following diagram illustrates the breathing system (respiratory system) of a human being.



The events associated with breathing in human beings are summarised in the following table:

	Inpiration	Expiration
Diaphragm	Contracts and moves downwards (flattens)	Relaxes and moves upwards (becomes dome-shaped)
External intercostal muscles	Contract	Relax
Internal intercostals muscles	Relax	Contract
Ribcage	Moves upwards and outwards	Moves downwards and inwards
Volume of lungs	Increases	Decreases
Pressure in lungs	Decreases lower than atmospheric pressure	Increases higher than atmospheric pressure
Air flow	Into the lungs	Out of the lungs

Terms Associated with Breathing in Humans

Breathing Rate

This refers to the number of breaths taken by an individual per minute. The normal breathing rate of an adult human being at rest is about **18**. However, this can be altered by factors such as

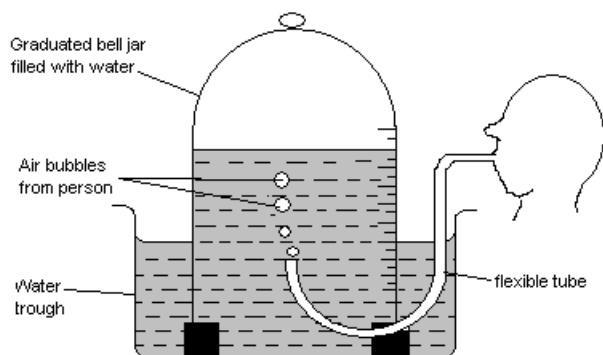
sleeping, illness (e.g. fever), emotional excitement and physical exercise. Sleeping lowers the breathing rate, while the other factors mentioned increase it.

Tidal Volume/Tidal Air

This is the volume of air breathed in or out in one breath when resting. The tidal volume in humans is about **0.5 dm³** (500 cm³).

Vital Capacity

This is the **maximum** volume of air breathed out after forced inspiration. The vital capacity in humans is about **3.5 dm³** (3500 cm³). The vital capacity can be measured using an instrument called the **spirometer**. When using a spirometer, a person must first completely fill the lungs with air and then breathe out through a tube connected to a spirometer as shown in the following diagram until no more air can be exhaled. The vital capacity is equal to the volume of water displaced

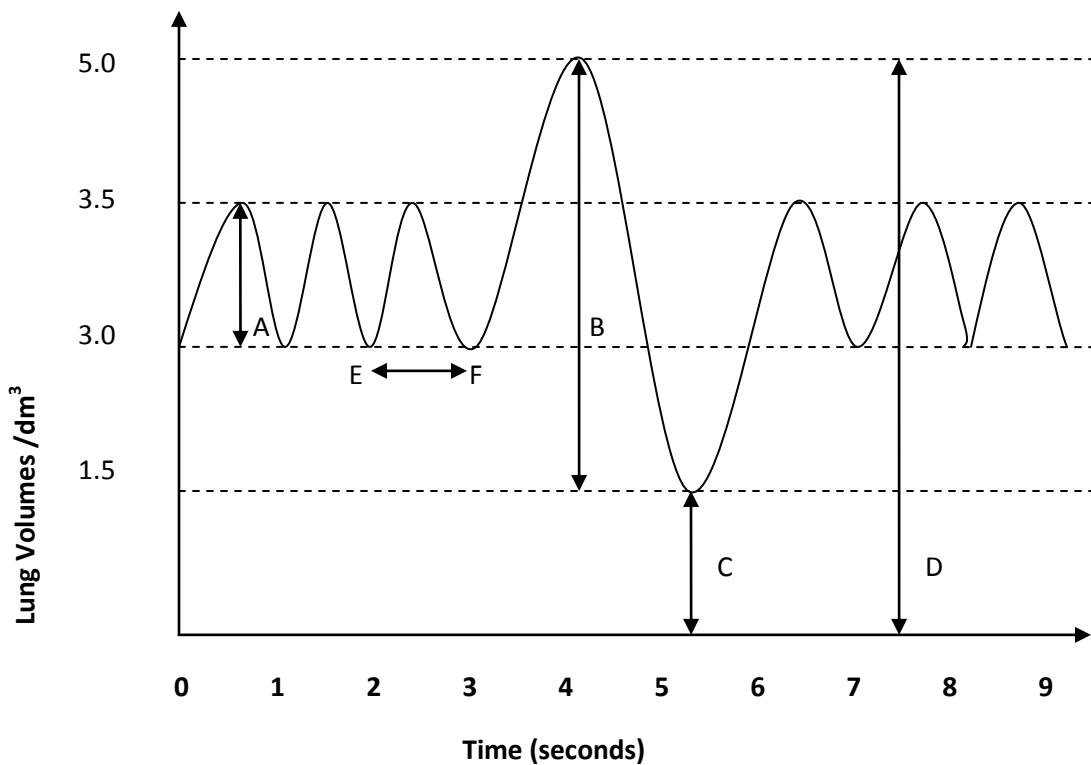


Residual Volume

This is the volume of air that never comes out of the lungs after forced expiration. It keeps the lungs from collapsing. It has a value of about **1.5 dm³**.

Exercise

The following diagram shows the pattern of breathing in an animal over a period of nine (9) seconds.



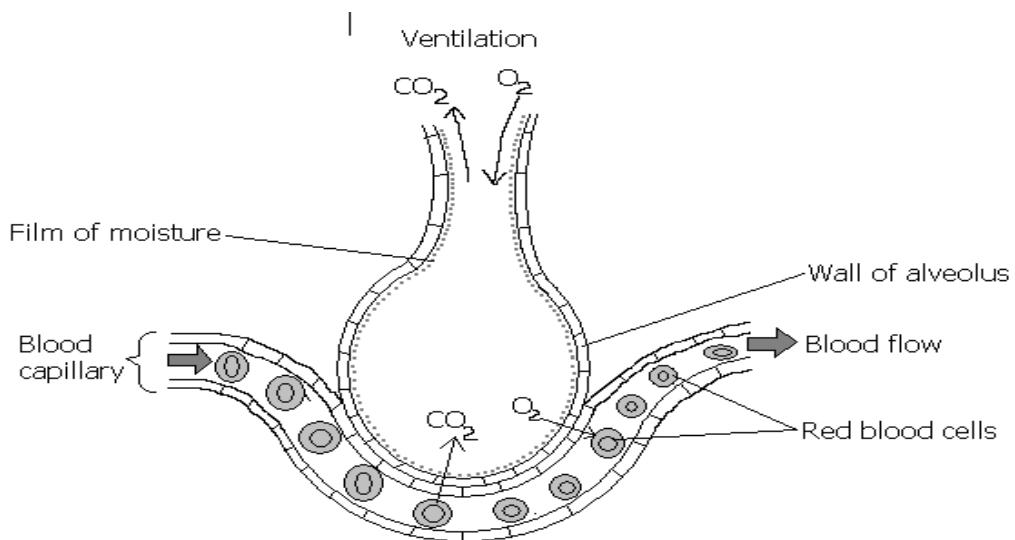
- (a) What do the letters A, B, C and D stand for?
- (b) What was the animal's breathing rate between 0 and 3 seconds?
- (c) What would happen to distance EF if the animal undergoes a period of physical exercise?

Composition of inspired and expired air

Gases	Inspired air	Expired air
Oxygen	21%	16%
Carbon dioxide	0.03%	4%
Nitrogen	78%	78%
Water vapour	Variable	Saturated
Other gases	Traces	Traces

Gaseous Exchange in Humans

In humans, gaseous exchange is the diffusion of oxygen from the lungs into the blood and carbon dioxide from the blood into the lungs across the walls of the **alveoli**. The following diagram illustrates gaseous exchange in humans.



Effects of Smoking on the Respiratory System

Cigarette smoke contains three major toxic substances, namely **nicotine**, **tar** and **carbon monoxide**. Tar is responsible for causing respiratory diseases such as bronchitis, emphysema and lung cancer.

Bronchitis: This is the inflammation of the air passages. Tar immobilizes (stops movement of) the cilia, causing mucus to accumulate in the air passages. This gives chance to the germs in the mucus to infect the lining of the air passages, causing coughing. The overall effect of bronchitis is that it reduces the amount of oxygen reaching the lungs.

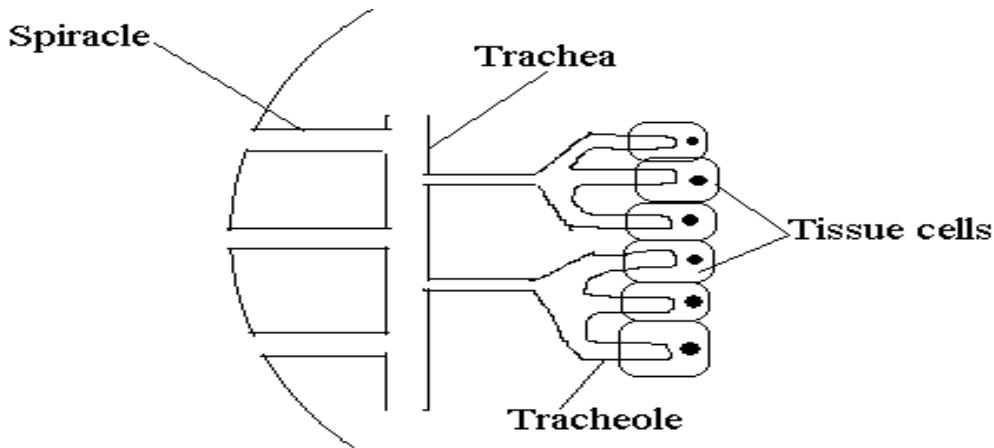
Emphysema: This is the weakening and bursting of the alveoli. When tar reaches the alveoli it weakens them and irritates them. The irritation causes coughing which makes the alveoli burst. Emphysema reduces the surface area available for gaseous exchange.

Lung Cancer: This is the uncontrolled or abnormal division of cells in the lungs. Smoking increases the risk of lung cancer because tar which is present in cigarette smoke is a **carcinogen** (a cancer-causing agent)

Breathing and Gaseous Exchange in Insects

Insects breathe in using the **tracheal system**. The tracheal begins with **spiracles** which are located in the **thorax** and **abdomen**. The spiracles are joined to tubes known as **tracheae** (singular= **trachea**). The tracheae are divided into smaller tubes called **tracheoles**. Gaseous exchange occurs across the walls of the tracheoles. Small insects normally do not make any breathing movements. However, large and active insects such as grasshoppers and bees make breathing movements by pushing their abdomens in and out. Note that insects do not use blood to transport gases since gases diffuse from the atmosphere to the tissue cells and vice versa through the tracheal system.

The following diagram illustrates the tracheal system of an insect.



Breathing and Gaseous Exchange in Fish

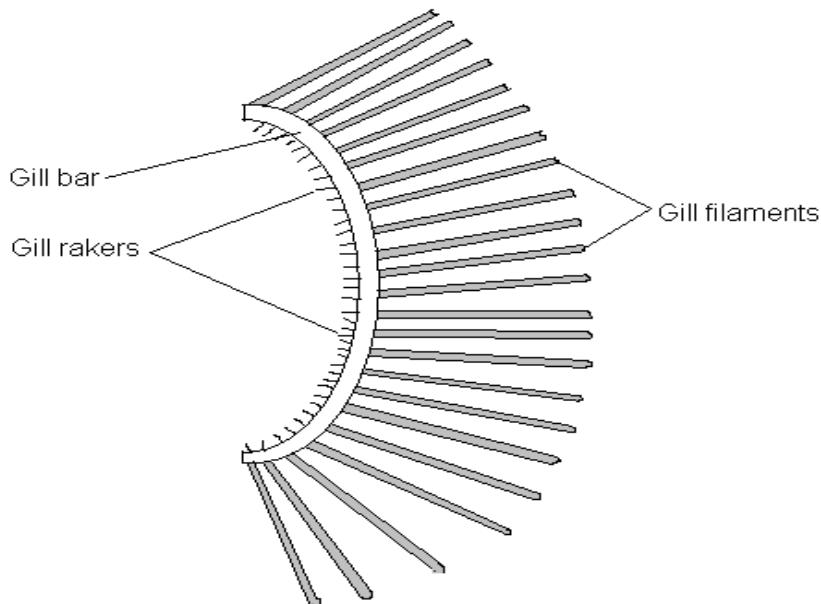
Gaseous exchange in **bony fish** occurs across the surfaces of the **gills**. The gills of bony fish are attached to structures known as **gill bars** (gill arches). There are four gill bars on each side of the gill chamber of a bony fish. There is a series of **gill filaments** attached to each gill bar. Each gill filament has structures known as **gill lamellae** (singular=gill lamella) where gaseous exchange takes place. The other side of the gill bars has structures known as **gill rakers** whose function is to remove solid particles from the water before it passes across the gills.

Water enters the gill chamber of a fish through the **mouth** (buccal cavity) and comes out through the **operculum** when it opens (note that there is an operculum on each side of the head).

The following table summarises the events associated with inspiration and expiration in fish.

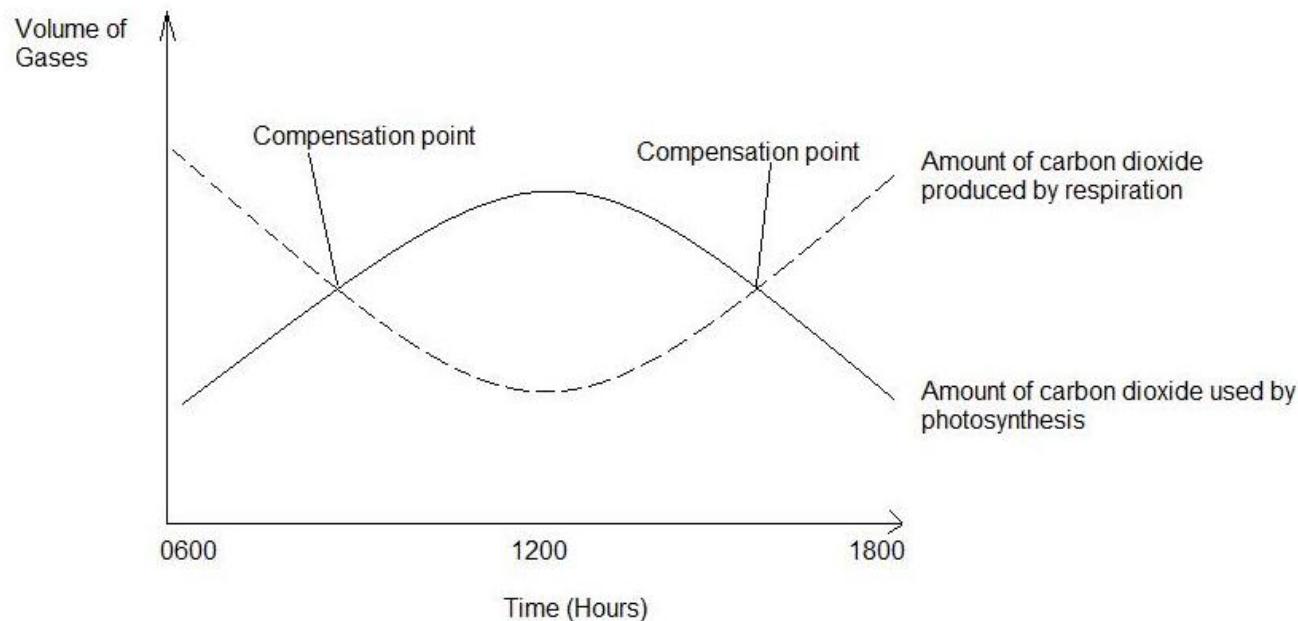
		Inpiration	Expiration
1	Floor of mouth	Lowered	Raised
2	Mouth	Open	Closed
3	Operculum	Closed	Open
4	Volume of mouth and gill chamber	Increases	Decreases
5	Pressure in mouth and gill chamber	Decreases	Increases
6	Water movement	Enters the gill chamber	Leaves the gill chamber

Structure of Bony Fish Gills

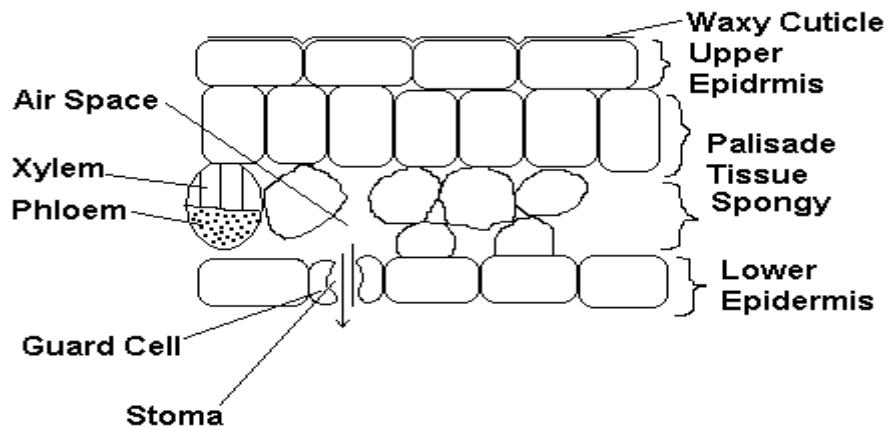


Gaseous exchange in plants

Gaseous exchange in plants occurs in the spongy layer of the leaf. When photosynthesis is actively taking place e.g. during day time), a plant leaf takes in carbon dioxide and releases oxygen. Note that during such periods, respiration also takes place. When respiration is the only process taking place (e.g. at night), the plant leaf takes in oxygen and releases carbon dioxide. The changes in amounts of oxygen and carbon dioxide used by the plant at different times of the day may be illustrated as follows:



The following diagram illustrates gaseous exchange in the leaf of a plant.



EXCRETION

This is the removal of toxic **metabolic** waste products from the bodies of living organisms. The products of excretion are called **excretory products** while the organs used to remove them are called **excretory organs**.

Excretion in Mammals (e.g. Humans)

The main excretory organs and products of a mammal are summarised in the following table:

Excretory Organs	Excretory Products
Kidney	Urea, excess salts and excess

	water
Skin	Urea, salts and water
Lungs	Carbon dioxide
Liver	Bile pigments

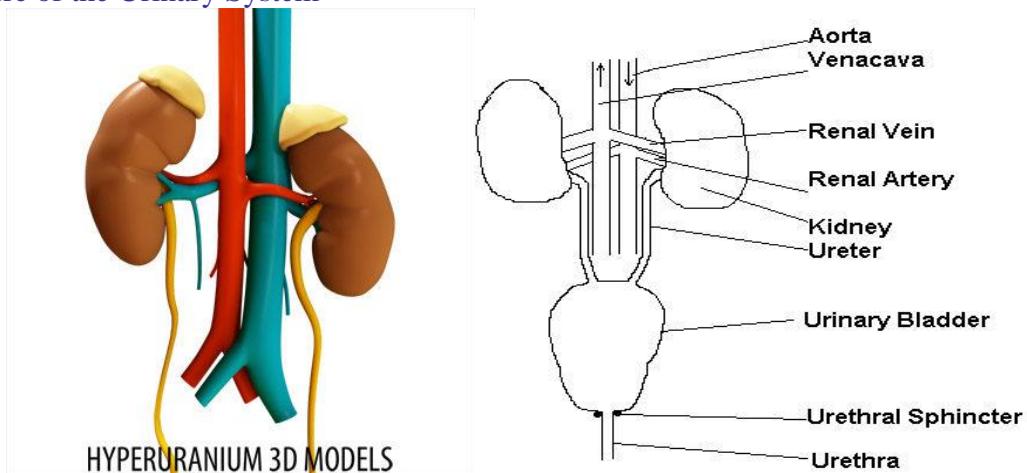
The sources of the major excretory products in the human body and the organs used to remove them are summarised in the following table.

Excretory Product	Excretory Organ	Source of Excretory Product
Urea	Kidneys and skin	Deamination in the liver
Carbon dioxide	Lungs	Cellular respiration
Bile pigments	Liver	Destruction of old red blood cells

a) The Kidneys

The kidneys are a pair of bean shaped organs found in the lower abdomen. They are part of a system called the **excretory system** or **urinary system** or **renal system**.

Structure of the Urinary System



Functions of parts of Renal System

Aorta: Carries oxygenated blood from the heart to other parts of the body.

Venacava: Carries deoxygenated blood from different body organs towards the heart.

Renal Vein: Carries deoxygenated blood away from the kidneys towards the venacava.

Renal Artery: Carries oxygenated blood from the aorta to the kidneys.

Ureter: This transports urine from the kidneys to the urinary bladder.

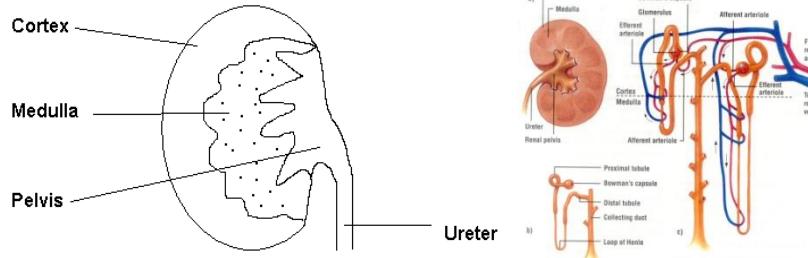
Urinary Bladder: Temporal storage of urine.

Urethral Sphincter: This is a ring of muscle found at the exit of the urinary bladder. It controls the flow of urine out of the urinary bladder. When closed, it prevents urine from coming out; when open, it allows urine to flow out of the bladder.

Urethra: It is a passage through which urine leaves the body. In males, it is also the outlet for semen.

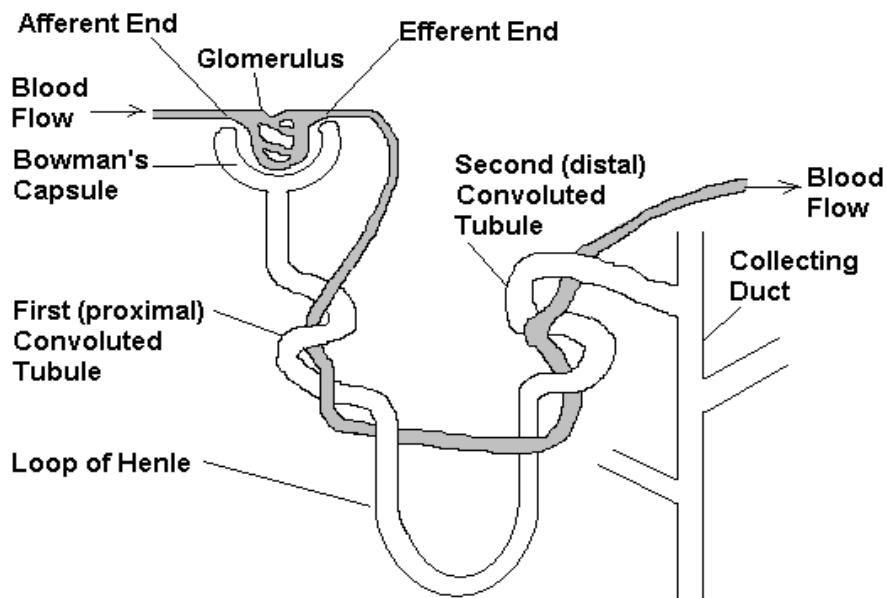
Kidney: Removes urea, excess salts and excess water from the blood and forms urine.

Structure of a Kidney



The basic functional unit of the kidney is the **nephron**.

Structure of a Nephron



How the Kidney Functions

Excretion in the kidney nephron occurs in four stages, namely, **ultrafiltration** (pressure filtration) **selective reabsorption**, **osmoregulation** and **secretion**.

Ultrafiltration

This is the filtration of small molecules such as water, mineral salts, glucose and urea from the glomerulus into the Bowman's capsule of a nephron. It is caused by a build up of pressure in the glomerulus. The pressure builds up due to the following reasons:

- The afferent end of the glomerulus is wider than the efferent end.
- Blood from arteries is under high pressure.

During ultrafiltration, the red blood cells and large molecules such as plasma proteins remain inside the glomerulus. The liquid that collects in the Bowman's capsule is called the **glomerular filtrate**. The glomerular filtrate is drained from the Bowman's capsule by the renal tubule.

Selective Reabsorption

This is the reabsorption of useful substances from the glomerular filtrate in the renal tubule into the blood stream. It occurs mainly in the folded regions (convolutions) of the tubule where the tubule is entangled with blood vessels to facilitate reabsorption. The first (proximal) convolution reabsorbs **all glucose**, **some water** and **some salts**. The second convolution reabsorbs salts and water. Water is reabsorbed by osmosis; glucose by diffusion and mineral salts by active transport.

Osmoregulation

This is the regulation of water levels in body fluids. Osmoregulation takes place in the loop of Henle. If the body has little water in it, a hormone called **antidiuretic hormone (ADH)** also called **vasopressin** is secreted by the **pituitary gland** in the brain. It causes water to be absorbed from the glomerular filtrate into the surrounding cells. This results in the production

of small volumes of concentrated urine. But if the body has enough water, ADH is not secreted and huge volumes of dilute urine are produced.

Secretion

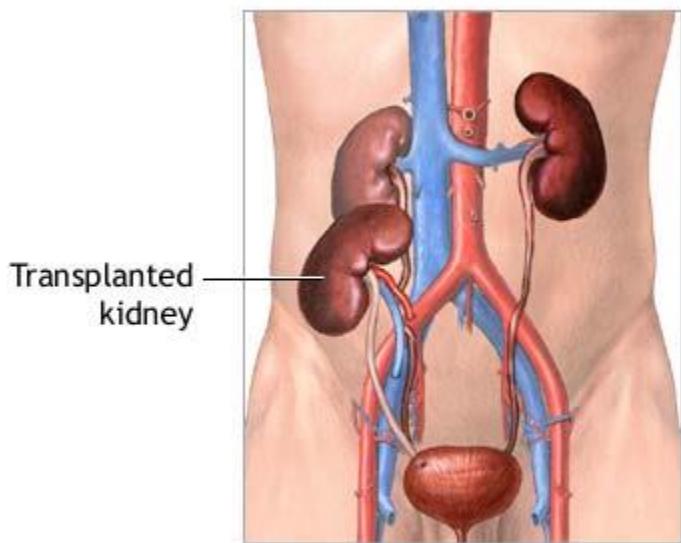
The removal of urine from the kidney through the **collecting duct** and **ureter**. Urine is a mixture of urea, excess salts and excess water. The urine is passed on to the **urinary bladder** where it is temporarily stored before being passed out.

Kidney Failure and Treatment

Kidney failure may be caused by poisoning, accidents (injuries to the kidneys), infection and drug abuse.

Kidney failure may be treated in two ways:

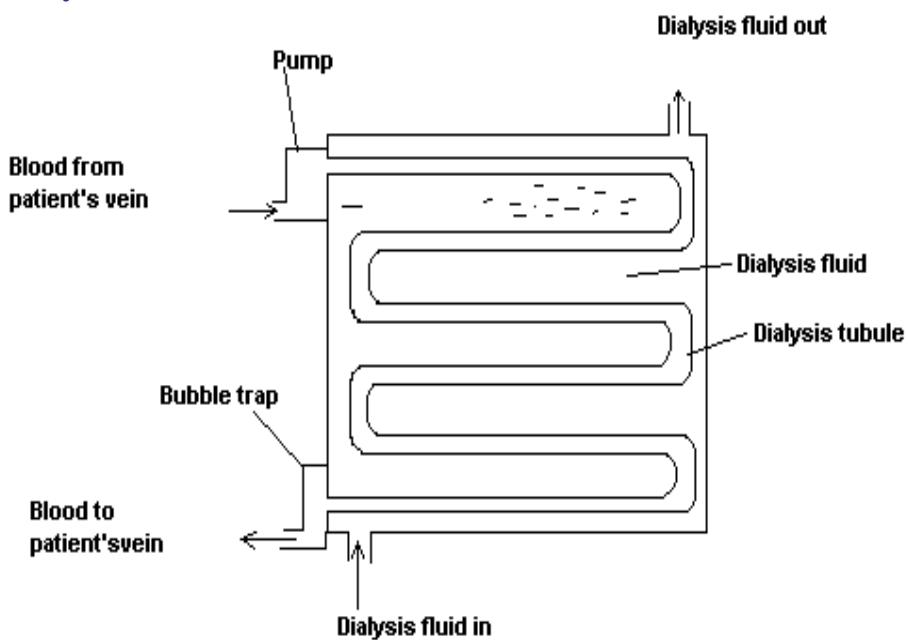
- Kidney transplant: This is a surgical operation during which a normal kidney from another person called a donor is added to an individual experiencing kidney failure. The transplanted kidney must be compatible with the recipient; otherwise there will be tissue rejection.



ADAM.

- Using the dialysis machine (kidney machine).

Diagram of a Dialysis Machine



A kidney machine is made of a **thin coiled tubule** called the **dialysis tubule** through which a patient's blood passes. The tubule is **long** and **coiled** in order to increase the surface area for diffusion. The tubule is also **thin** and **selectively permeable**. Thus it allows small molecules such as glucose, urea, salts and water to pass through but prevents large ones from doing so. The dialysis machine also contains **dialysis fluid** which is a solution of salts and glucose in water and its concentration is equal to the normal concentration of blood.

The patient's blood is drawn from a vein on the patient's arm and taken into the dialysis machine through a tube with the help of a pump. After passing through the machine, blood is returned to a different point on the same patient's vein. The dialysis fluid is introduced into the machine using an inlet and removed using an outlet at a different location. The flow of the dialysis fluid through the machine is opposite to the flow of the patient's blood through the dialysis tubing. This is called **counter-current flow** and helps make diffusion faster by maintaining a constant diffusion gradient.

Normally, only urea, excess salts and excess water diffuse from the patient's blood into the dialysis fluid. A patient needs to be on the machine at least twice a week and each session lasts about 8 hours.

Exercise:

1. Does active transport take place in the dialysis machine? Give reasons for your answer.
2. An **anticoagulant** called heparin is added to the blood as it enters the machine during the early stages of dialysis. Why is this important? Why is the addition of heparin discontinued towards the end of a dialysis session?

Excretion in Plants

Plants excrete a wide range of metabolic waste products. These are removed from plants through different parts of the plant such as leaves, flowers, the barks of stems and roots. The method of excretion varies according to the nature of the metabolic waste products. Examples of plant excretory products are discussed below:

- **Alkaloids** such as **morphine** (in opium plants), **quinine** (in cinchona plants) and **cocaine** (in coca plants). Alkaloids are nitrogen-containing metabolic wastes in plants.
- **Tannins** which are reddish and are usually deposited in the barks of trees e.g. *Acacia* and red mangrove.
- **Anthocyanins**. These wastes are red and blue in colour and are deposited in the petals and are responsible for the red, blue and purple colours of the petals. They are removed from the plant when petals are shed off.
- **Oils** are deposited in fruits and seeds and are got rid of when the fruit or seed is dispersed from the plant. Sugar compounds in fruits also are removed when the fruits fall off from the plants.
- **Latex** is a milk-like whitish liquid which is excreted by plants such as *Euphorbia* and *Ficus elastica*.
- **Resins, gums and mucilages**.
- **Carbon dioxide** produced during respiration and released from the plant through the stomata in the leaves.
- **Oxygen** produced during photosynthesis and released from the plant through the stomata in the leaves.
- **Water** may be released from pores on the margins or tips of leaves in liquid form by a process called **guttation**.

HOMEOSTASIS

This is defined as the maintenance of a constant internal environment. It involves the regulation of body temperature (thermoregulation), regulation of the amount of water in body fluids (osmoregulation), regulation of blood sugar and removal of toxic metabolic wastes (excretion).

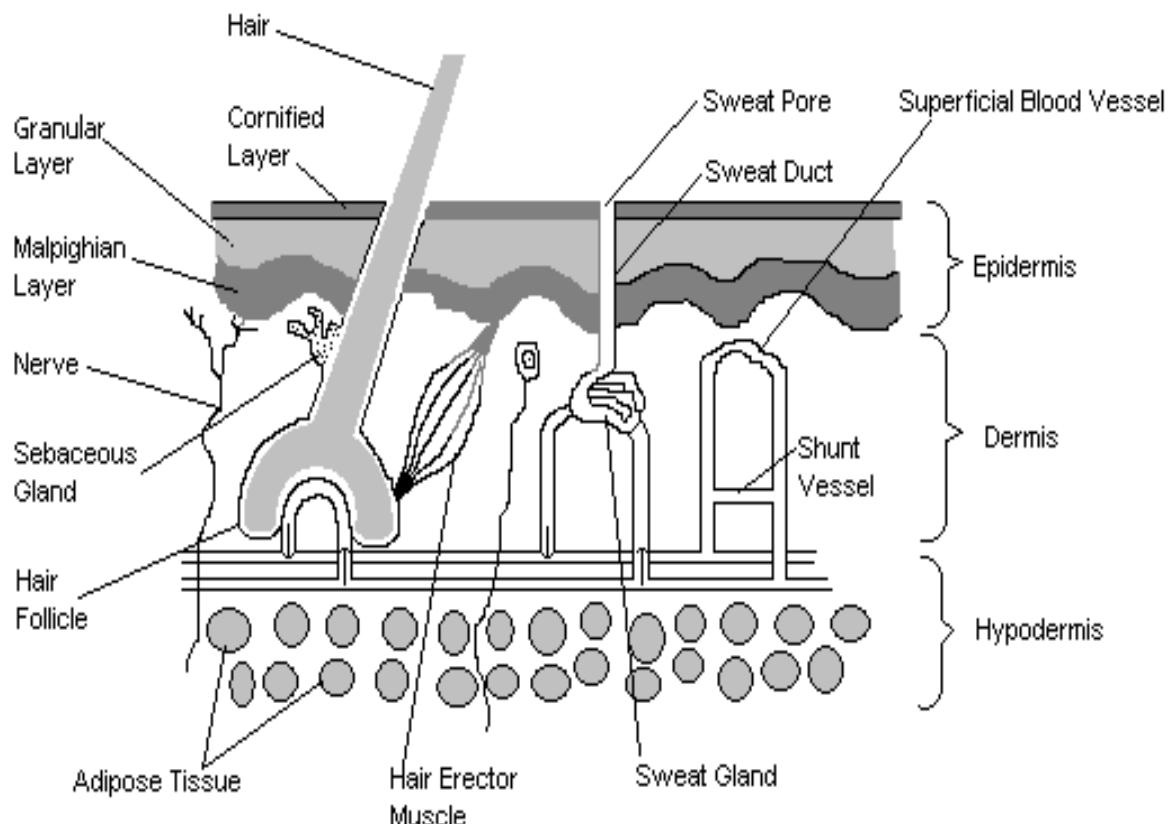
Thermoregulation

This is the maintenance of a constant body temperature. The temperature of the human body must be kept around 37°C because that is the **optimum temperature** for its enzymes. If the temperature goes lower than 37°C , the enzymes become less active and if the temperature is too high, the enzymes become denatured.

Body heat is normally generated by metabolic reactions in the liver and through shivering in the muscles. Body heat may be lost through the following processes: expiration (heat is lost from the surfaces of the lungs), sweating, conduction, radiation, excretion and egestion.

The regulation of body temperature is mainly carried out by the **skin** under the control of the **hypothalamus**, which is found in the fore brain.

Structure of the Skin



Mechanism of Thermoregulation by the Skin

In Cold Temperatures

The skin reduces loss of heat in the following ways:

- **Erector muscles contract**, pulling the hairs upright. The erect hair traps a layer of air which insulates the skin against heat loss. The contraction of hair erector muscles leads to development of goose bumps on the skin in cold weather.
- **Vasoconstriction** (narrowing of skin arterioles) occurs to reduce the amount of blood passing through the skin. This reduces heat lost.
- **Shunt vessels open**, reducing the amount of blood passing through superficial vessels near the skin surface. This reduces heat loss.
- **Sweat glands become less active or inactive** to minimise loss of heat which might occur through sweating.

In Hot Temperatures

The skin promotes loss of heat in the following ways:

- **Erector muscles relax**, causing the hair to lie on the skin. This increases heat loss from the body by conduction since no layer of still air forms

- **Vasodilation** (widening of skin arterioles) occurs, increasing the amount of blood passing through the skin. This allows more heat to be lost from the blood by conduction.
- **Shunt vessels close**, allowing more blood to pass through superficial vessels near the skin surface. This increases heat loss from the body.
- **Sweat glands become more active and produce more sweat.** The water in sweat absorbs heat from the body in order to evaporate, thereby cooling the body.

Blood Sugar Regulation

The term ‘blood sugar’ refers to glucose. The maintenance of constant glucose levels in blood is carried out by the **pancreas**. It has cells known as the **Islets of Langerhans** which produce hormones involved in blood sugar regulation. These cells are of two types, namely **alpha cells** (α -cells) and **beta cells** (β -cells). Alpha cells secrete a hormone called **glucagon**. Beta cells secrete a hormone called **insulin**.

When glucose levels are too high in blood, the pancreas secretes insulin which lowers the levels of glucose in the following ways.

- It causes the cells of the liver and muscles to convert excess glucose to **glycogen** which is stored in the liver and muscles. The body can only store about 400g of glycogen (about 100g in the liver and 300g in the muscles).
- It causes the cells of the **adipose tissue** to convert excess glucose to fats. The fats are stored under the skin and around delicate body organs such as the heart, liver, kidneys, intestines and brain.
- It enables body cells to absorb and use glucose from the blood.

Lack or insufficient production of insulin leads to the disease called **diabetes mellitus** whose signs and symptoms include the following:

- High levels of glucose in blood (**hyperglycaemia**)
- Glucose in urine (**glucosuria**)
- Persistent thirst leading to excessive intake of water
- Drastic loss of weight
- Loss of sensation in some body parts.

When glucose levels are too low in blood, the pancreas secretes **glucagon** which increases glucose levels in blood in the following ways:

- It causes the cells of the liver and muscles to convert glycogen to glucose.
- It causes fat to be changed into glucose and may cause proteins to be modified so that they are utilised for energy production.

(For more details, refer to notes on the pancreas under the endocrine system)

GROWTH AND DEVELOPMENT

Growth is defined as a permanent increase in **size, mass, number of cells** and **complexity** of a living organism. Growth of multicellular organisms involves life cycles. A life cycle is a sequence of stages that an organism passes through during its development from the embryonic stages to maturity.

Growth in Plants

Plants undergo two types of growth, namely, **primary growth** and **secondary growth**. Primary growth is the **increase in the length** of the shoots and roots while secondary growth is the **increase in the width or girth** of shoots and roots. Primary growth enables the roots to penetrate the ground and the shoots to grow towards sunlight.

Plant growth involves three stages. These are **cell division**, **cell vacuolation (cell elongation)** and **cell specialisation (cell differentiation)** which may be described as follows:

Cell division: The process by which new cells (daughter cells) are formed from cells that are already existing (parent cells). The type of cell division involved in growth is called **mitosis**. This is a type of cell division where one parent cell produces **two daughter cells** that are **genetically identical** to the parent cell. Immediately after cell division, all cells look alike.

Regions of active cell division are known as **meristems**, or **meristematic tissues**. There are two types of meristematic tissues in plants, namely **apical meristems** and **cambial meristems** (or simply cambium). Apical meristems occur at the tips of shoots and roots and are responsible for primary growth. There are two types of cambium, namely, **vascular cambium** and **cork cambium**; both are responsible for secondary growth.

Cell Elongation: This is a process by which cells grow bigger and develop their vacuoles by absorbing a lot of water. The greatest increase in length occurs in the region of cell elongation during growth. After being vacuolated all cells still look identical.

Cell Differentiation: This is a process by which cells become suited for specific functions by developing specific shapes and undergoing specific chemical changes in their cytoplasms. After specialisation, plant cells may develop into any of the following cell types: **collenchyma**, **parenchyma**, **sclerenchyma**, **cambium**, **phloem** or **xylem**.

Growth at the Apices (Tips) of Roots and Shoots

There are three regions of growth at the apices of shoots and roots in plants. These are

- Region of cell division
- Region of cell elongation or vacuolation
- Region of cell differentiation or specialisation.

Diagram Illustrating Regions of Growth at the Shoot Apex

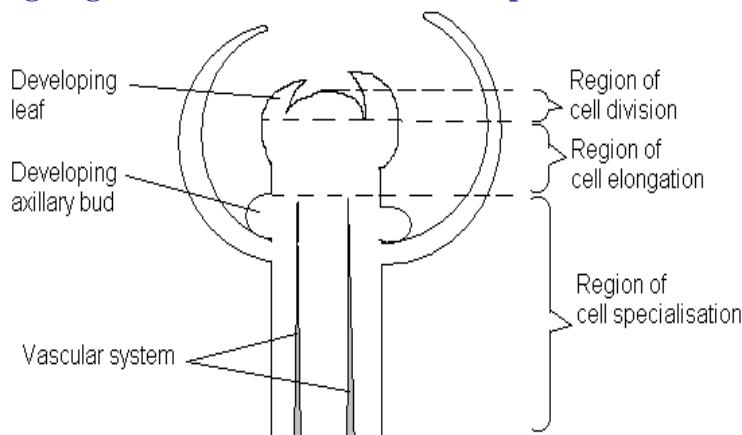
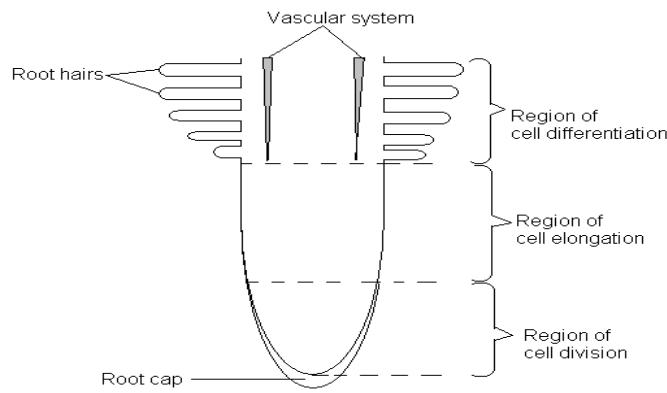


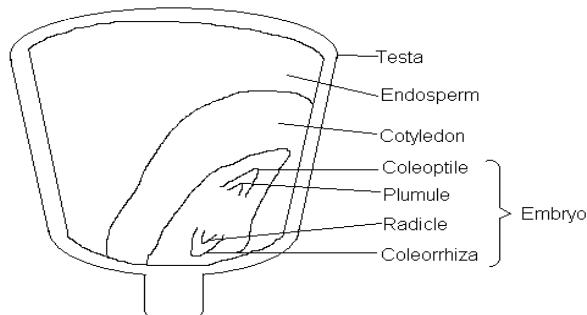
Diagram Illustrating Regions of Growth at the Root Apex



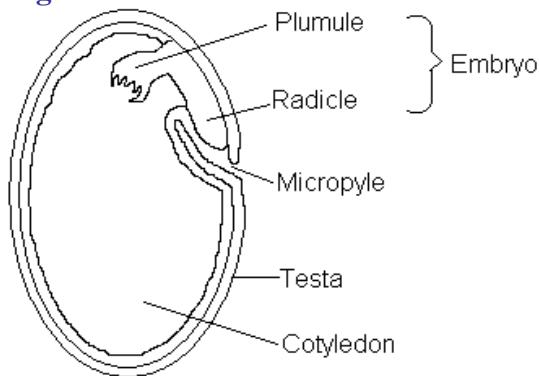
Germination

This is the process by which seedlings develop from seed embryos. To fully understand germination, it is important to first understand the structure of seeds in monocotyledonous and dicotyledonous plants.

Structure of a Monocot Seed e.g. Maize Seed.



Structure of a Dicot Seed e.g. Bean Seed



Functions of Seed Parts

Testa (seed coat): This is the outer-most layer of seed and is responsible for **protecting** the seed against physical damage and infection. It is also responsible for **dormancy** in certain seeds where it prevents **imbibition** (entry of water into the seeds)

Plumule: This is the **embryonic shoot**. It develops into a shoot after germination

Radicle: This is the **embryonic root**. It develops into roots after germination

The plumule and radicle together make up the **embryo** of the seed. The region of the embryo next to the plumule is called the **epicotyl** while the region next to the radicle is called the **hypocotyl**.

Cotyledons: These **store food** and **enzymes** in non-endospermic seeds, mainly dicot seeds. In most monocot seeds, food is stored in another tissue known as the **endosperm**. Seeds, which have the endosperm, are called **endospermic seeds** while those without the endosperm are called **non-endospermic seeds**. The main forms of foods stored in seeds include **starch, oils and proteins**.

In some monocot seeds such as maize, the plumule is protected by a sheath called the **coleoptile** while the radicle is protected by a sheath called the **coleorrhiza**. These prevent damage during germination.

Conditions Necessary for Germination

The conditions necessary for the germination of seeds include **oxygen**, **water (moisture)** and a **suitable temperature**.

Experiment to Show that Oxygen is Necessary for Germination of Seeds

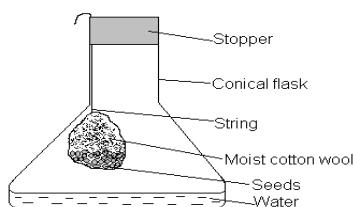
Suggested materials:

Soaked maize seeds, cotton wool, two conical flasks, alkaline pyrogallol, two strings and two stoppers.

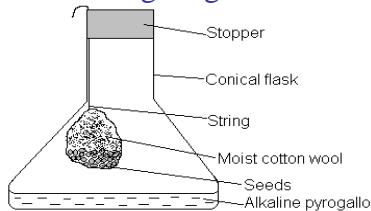
Method:

- Label two conical flasks, A and B
- Put 10 cm³ of water in flask A and 10 cm³ of alkaline pyrogallol in flask B
- Wrap two sets of maize seeds in moist cotton wool
- Hang one set of seeds in flask A and the other in flask B as shown below
- Leave the seeds for about seven days.

The set up of the experiment is shown in the following diagram:



Conical flask A



Conical flask B

Observation

The seeds in flask A germinate. However, the seeds in flask B fail to germinate because the alkaline pyrogallol absorbs oxygen from the air inside the flask. As such, the seeds lacked oxygen for respiration.

Conclusion

Oxygen is necessary for germination of seeds. It is required for respiration which provides energy for germination.

Experiment to Show that Water is Necessary for Germination

Suggested Materials:

Soaked maize seeds, dry maize seeds, cotton wool, three petri dishes

Method:

- Label the petri dishes A, B, and C
- Put five soaked seeds in petri dish A
- Put another five soaked seeds on top of moist cotton wool in petri dish B
- Put five dry seeds in petri dish C
- Cover the seeds in dish A completely with water
- Keep the cotton wool in petri dish B moist all the time by sprinkling it with water.
- Leave the seeds for at least seven days.

Observation:

Seeds in petri dish A do not germinate; seeds in petri dish B germinate while those in petri dish C do not germinate.

Conclusion

Seeds require suitable amounts of water (moisture) in order to germinate. The water is imbibed (absorbed) by the seed and is important in the following ways:

- It softens the testa so that it can split to release the plumule and radicle.
- It activates enzymes and provides an aqueous medium for metabolic reactions to take place.
- It is involved in hydrolysis of complex nutrients in a seed e.g. hydrolysis of starch to maltose.

Too much water makes the seeds rot. For this reason the seeds in dish A do not germinate. Seeds in dish C do not germinate because no water is provided for them to soften the testa and activate enzymes.

Experiment to Show that a Suitable/Favourable Temperature is Necessary for Germination of Seeds

Suggested Materials:

Soaked seeds, cotton wool, 3 pyrex beakers, a fridge and an oven.

Method

- Label the beakers A, B, and C
- Wrap three sets of five seeds in moist cotton wool.
- Place one set in beaker A, one in B and the other in beaker C
- Put beaker A in a refrigerator at a temperature of 0°C, beaker B at room temperature (about 25°C) and beaker C in an oven at a temperature of 50°C
- Leave the set up for at least seven days ensuring that the cotton wool remains moist.

Observation

The seeds put in the refrigerator at 0°C (in beaker A) and those put in the oven at 50°C (in beaker C) fail to germinate while those left at room temperature (in beaker B) germinate.

Conclusion

Very low and very high temperatures are not favourable for seed germination. Seeds at very low temperature fail to germinate because the enzymes in the embryo become inactive or less active and as such they do not catalyse the metabolic reactions necessary for germination. High temperatures (temperatures above optimum) denature the enzymes and as such no metabolic reactions take place. Hence seeds require a favourable temperature in order to germinate.

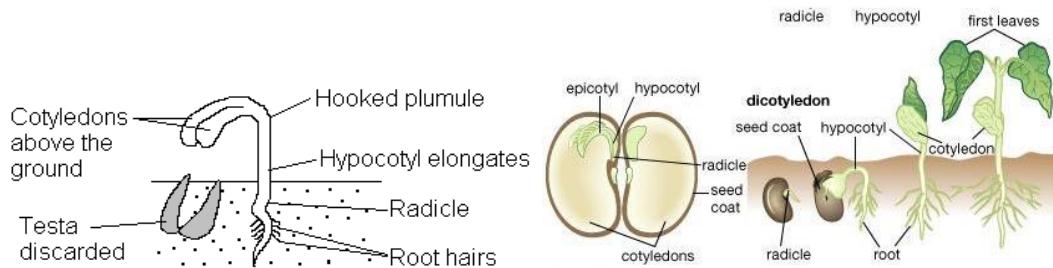
Types of Germination

There are two types of germination, namely **epigeal** and **hypogea** germination.

Epigeal Germination

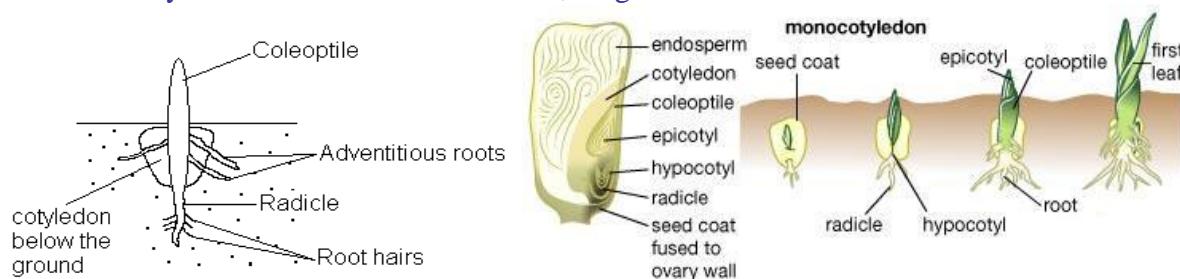
This is a type of germination where the cotyledons are pushed above the ground by **elongation of the hypocotyl**. The plumule is covered by cotyledons and comes out of the ground with a hooked shape in order to protect the delicate shoot. The cotyledons also carry out photosynthesis during the first few days before the leaves develop fully. Examples of seeds that carry out this type of germination are beans (*Phaseolus vulgaris*), sunflower, castor oil and groundnut seeds. This type of germination is commonly associated with dicotyledonous seeds but there are exceptions such as the broad bean.

Diagram Illustrating Epigeal Germination



Hypogea Germination

This is a type of germination where the cotyledons remain underground, due to elongation of the epicotyl. The plumule is covered with a sheath called the **coleoptile** to protect it from abrasion as it pushes out of the soil. Examples of seeds which undergo this type of germination are monocotyledonous seeds such as maize, sorghum and millet seeds.



In non-endospermic seeds the cotyledons are the food store. However, the function of the cotyledon/scutellum in endospermic seeds is to a) synthesise GA and b) absorb the digested products of the endosperm and pass them on (via vascular tissue) to the embryo.

Seed Dormancy

Seed dormancy is the state/condition during which a **seed carries out minimum metabolism** and **does not germinate**. Seed dormancy is important in the following ways:

- It gives time for seeds to reach full maturity.
- It prevents the seed from germinating when conditions are harsh. Hence it is a survival mechanism

Causes of Seed Dormancy

- **Hard Testas:** In some seeds, the testas are hard and impermeable to water and oxygen, thereby preventing germination of the seeds.
- **Chemical Substances:** Some seed embryos have hormones, such as **abscicic acid (ABA)** which keep them from germinating
- **Physiological Conditions:** Some plant seeds can only germinate if first exposed to certain conditions of the environment such as cold temperatures, light or darkness.

Dormancy may be broken in the following ways:

- **Scarification:** This is the physical destruction of hard testa so that a seed becomes permeable to water and oxygen. It can be done manually or by the action of digestive juices or gizzards of some animals.
- **Soaking Seeds in Water:** This softens hard testas in some seeds
- **Fire:** The resistant testas of some seeds are only made permeable to water and oxygen through burning them.
- Exposure to **appropriate environmental conditions** such as light, darkness and cold temperatures.
- Exposure to **appropriate chemical substances** which reverse the effects of chemical inhibitors of germination e.g. **gibberellic acid** is thought to reverse the effects of **ABA** in some cereals.

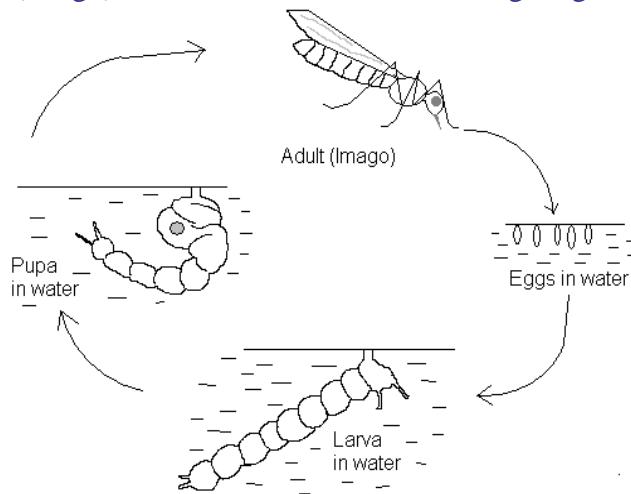
Seed Viability

Seed viability is the ability of a seed to germinate into a seedling. It may be reduced by prolonged periods of storage, high temperatures, physical damage, parasites and pests.

Growth in Animals

1. Life cycle of a Mosquito

The mosquito undergoes **complete metamorphosis**. This is a type of life cycle where the different stages of the cycle have different body forms (morphologies) from each other and different behaviours and nutritional requirements. The stages of a mosquito life cycle are **egg**, **larva**, **pupa** and **adult** (imago) as summarised in the following diagram.



Eggs are laid in water by female mosquitoes after mating and they hatch into larvae (singular: larva). Larvae can swim and they feed on **phytoplankton** and **zooplankton**. They eventually develop into pupae (singular: pupa) which are a less active stage that continually undergo internal changes. After some time, the adult insect emerges out of the pupa case (**puparium**). The adult flies and feeds mainly on plant juices. However, when female mosquitoes are carrying fertilized eggs, they develop a desire for animal blood which they need for egg development.

Because of blood sucking, the female *Anopheles* mosquito is a **vector** for malaria in humans. A vector is any organism that transmits parasites from one host to another. Mosquitoes are said to be **biological vectors**. A biological vector is one that carries parasites inside its body systems and the parasite undergoes part of its life cycle inside the vector.

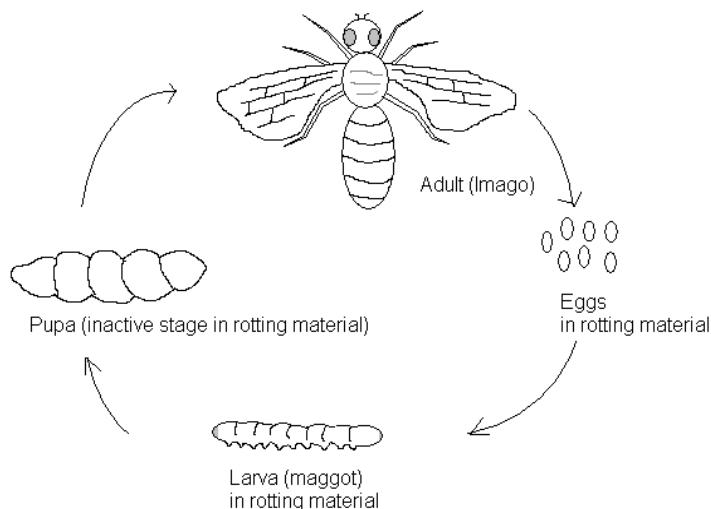
Control of mosquitoes (in order to control malaria) can be targeted against the different stages of the life cycle in the following ways:

- (i) Draining all stagnant pools of water to eliminate eggs, larvae and pupae
- (ii) Spraying stagnant water with insecticides and/or oil. Insecticides such as DDT kill the eggs, larvae and pupae directly. Oil blocks the oxygen supply from the eggs, larvae and pupae, thereby killing them.
- (iii) Biological control (the use of one type of organism called the **control agent** to get rid of another – called the **target organism** – which is a nuisance). The control agent must be a natural enemy (predator or parasite) of the target organism. Biological control may also involve interfering with reproduction by use of radiation or chemicals and the artificial synthesis of chemical substances normally produced by the target organism to be used in traps. Examples of biological control against mosquitoes include:
 - Use of a bacterium called ***Bacillus thuringiensis*** which infects and kills mosquito larvae.
 - Use of insectivorous fish from the Genus ***Gambusia*** that feeds on mosquito pupae and larvae.
- (iv) Use of insecticide – treated mosquito nets to trap and kill adult mosquitoes
- (v) Clearance of bushes and tall grass where adults normally live before entering houses

(vi) Physical killing of adult mosquitoes

2. Life Cycle of a House Fly

Like the mosquito, the housefly also undergoes complete metamorphosis during its life cycle. Its life cycle is summarised in the following diagram:



The female housefly lays eggs in rotting material after mating. The eggs normally hatch into larvae (commonly called **maggots**) 8-24 hours after being laid. The larvae feed on rotting material by sucking the nutrients and move using pads on the lower side of their bodies. After 4-5 days, the larvae develop into pupae which are immobile and do not feed. Although the pupae are immobile, a lot of metabolism occurs inside of them and the imago takes shape within the pupa case known as the puparium. 3 to 4 days later, the imago breaks out of the puparium. It takes an imago 14 days to reach sexual maturity and the cycle starts all over again.

Importance of Houseflies

Houseflies are vectors for pathogens that cause cholera, dysentery and typhoid among others. The adult stage is able to fly. This makes it a very efficient vector. A housefly is a **mechanical vector**. A mechanical vector is a vector that carries pathogens on the external surface of its body.

Control of Houseflies

Houseflies may be controlled using the following methods;

- Sanitary disposal of refuse and faeces (this reduces the breeding sites for houseflies)
- Spraying with insecticide (to kill adult flies)
- Use of fly traps e.t.c.
- Covering the 'mouths' of pit latrines.

RESPONSES

A response is an action or process that occurs in an organism due to the presence of a stimulus (plural – stimuli). A stimulus is any substance or factor that causes a response from an organism. Examples of responses in living organisms are **tropic responses (tropisms)** and **taxic responses (taxism)**.

The following table compares tropic and taxic responses:

Tropic response	Taxic response
Occurs in plants	Occurs in invertebrates

Involves growing either towards or away from the stimulus	Involves moving either towards or away from the stimulus
Only part of the plant responds	The entire organism responds
Slower	Faster

1. Tropic Responses

A tropic response or tropism is the response of a **plant part** to a stimulus by either **growing** towards or away from the stimulus. When a plant part grows towards a stimulus, the response is called a **positive tropic response**, but when a plant part grows away from a stimulus, the response is called a **negative tropic response**. The name of a tropic response depends on the type of stimulus causing it.

Examples of tropisms, corresponding stimuli and the plant parts involved are given in the following table:

Tropism	Stimulus	Positively Tropic Part	Negatively Tropic Part
Geotropism	Gravity	Roots	Shoots
Phototropism	Light	Shoots	Roots
Hydrotropism	Water	Roots	_____
Chemotropism	Chemicals	Roots, pollen tube	_____

Phototropism

This is the response of a plant part to light by growing either towards or away from the light. Growth towards light is called **positive phototropism** while growth away from light is called **negative phototropism**. Generally, plant shoots are positively phototropic while roots are negatively phototropic.

Experiment to Investigate the Effect of Light on Growth of Maize Coleoptiles

Materials:

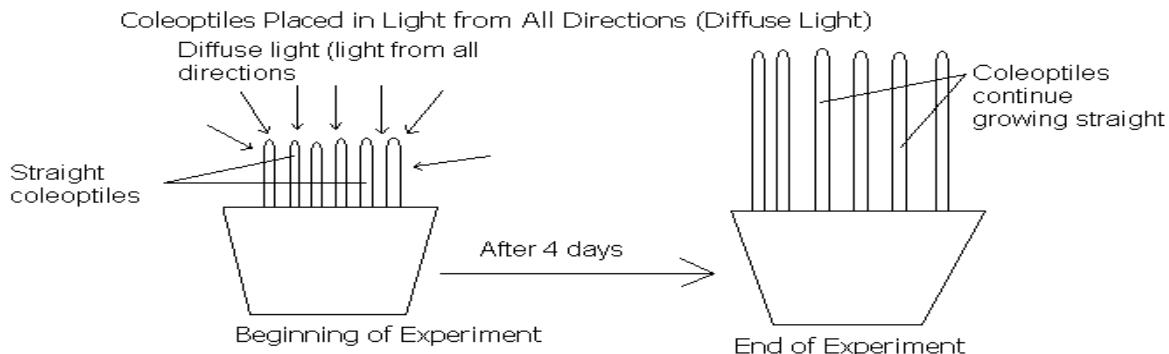
Maize seedlings, cardboard box with a hole on one side and two tins.

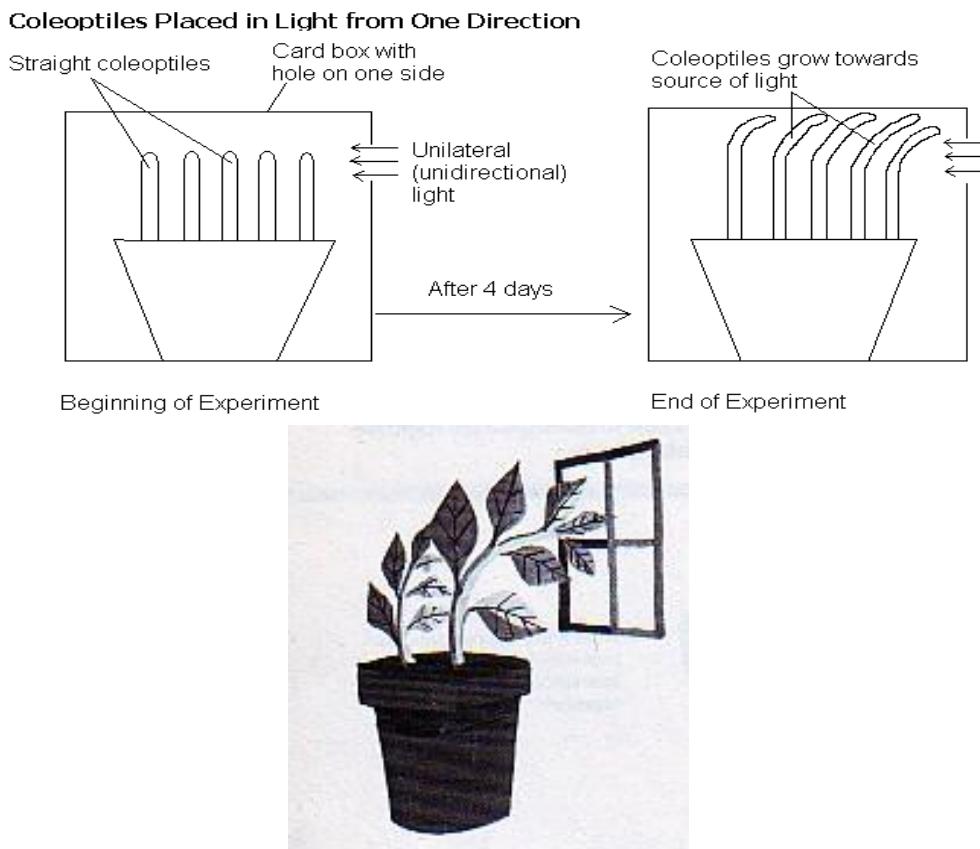
Method:

- Select seedlings with straight coleoptiles and place them in two separate tins.
- Place one tin of seedlings in the box with a hole on one side and put the box in the sunlight.
- Leave the other tin of seedlings in sunlight to act as a control.
- Observe and record what happens after four days.

Observations:

The coleoptiles placed in the box with a hole on one side grow towards the source/direction of light; those placed in sunlight continue growing straight upward as illustrated by the following diagram:





Conclusion:

Plant shoots are positively phototropic

Significance of Phototropism

Positive phototropism in plant shoots ensures that the leaves are exposed to sunlight in order for photosynthesis to take place.

Geotropism

This is the response of a plant part to gravity by growing either towards or away from the gravity. Growth towards gravity is called **positive geotropism** while growth away from gravity is called **negative geotropism**. Generally, plant roots are positively geotropic while shoots are negatively geotropic.

Experiment to Investigate the Effect of Gravity on Growth of Roots and Shoots

Materials:

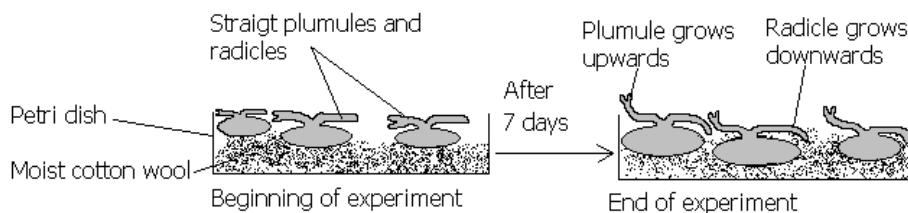
Germinating bean seeds, petri dish, moist cotton wool and clinostat

Method:

- Place three or more germinating bean seeds on moist cotton wool in a still petri dish, making sure that their radicles and plumules are horizontal.
- Place another set of germinating bean seeds on a petri dish and mount it on a rotating clinostat
- Observe what happens to each set of bean seeds after one week.

Observation:

For the seedlings placed on a still petri dish, the radicles grow towards gravity and the plumules grow away from gravity. For those where the petri dish is placed on a rotating clinostat, both the plumules and radicles continue growing straight. This is illustrated in the following diagrams:



Conclusion:

Plant roots are positively geotropic while plant shoots are negatively geotropic.

Significance of Geotropism:

Positive geotropism in the roots makes it possible for roots to grow towards water and nutrients in the ground.

Hydrotropism

This is the response of a plant part to water by growing either towards or away from the water. Growth towards water is called **positive hydrotropism** while growth away from water is called **negative hydrotropism**. Plant roots are generally positively hydrotropic. This ensures that the roots absorb the water the plant needs.

Experiment to Investigate the Effect of Water on the Growth of Radicles

Materials:

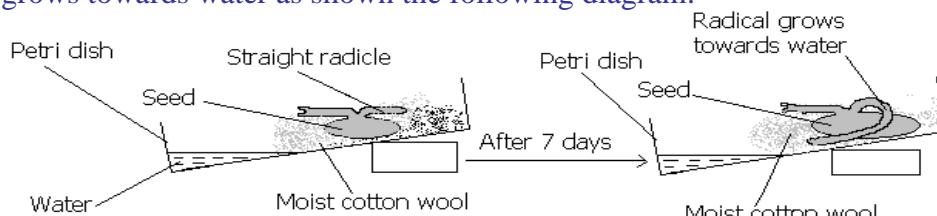
Germinating bean seed, petri dish and cotton wool

Method:

Wrap the seed in wet cotton wool and place it on a tilted petri-dish with water on one side.

Observation:

The radicle grows towards water as shown the following diagram:



Conclusion:

Plant roots are positively hydrotropic

Chemotropism

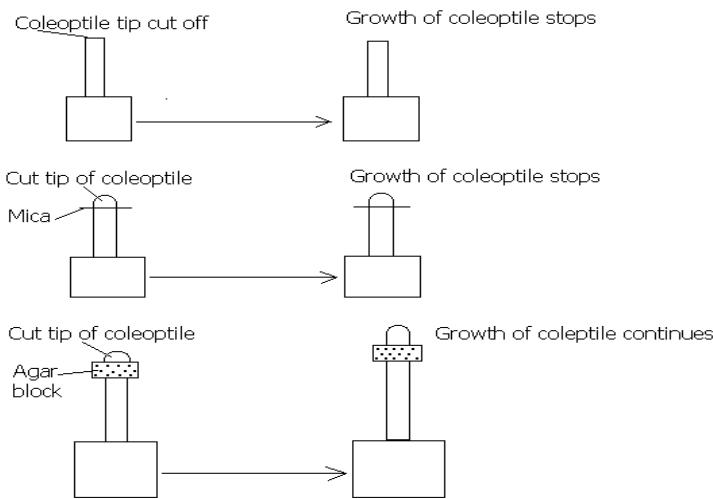
This is the response of a plant part to chemicals by growing either towards or away from the chemicals. Growth towards chemicals is called **positive chemotropism** while growth away from chemicals is called **negative chemotropism**. Plant parts grow towards chemicals relevant to them e.g. the pollen tube grows towards the ovary in response to chemicals secreted in the ovary to bring about fertilization.

The Role of Auxins in Tropisms

Tropisms in plants are controlled by growth substances called **auxins** that are produced by the tips of shoots and roots. Auxins promote growth in shoots while they inhibit growth in roots.

Experimental Evidence to Show that Auxins Promote Growth of Shoots

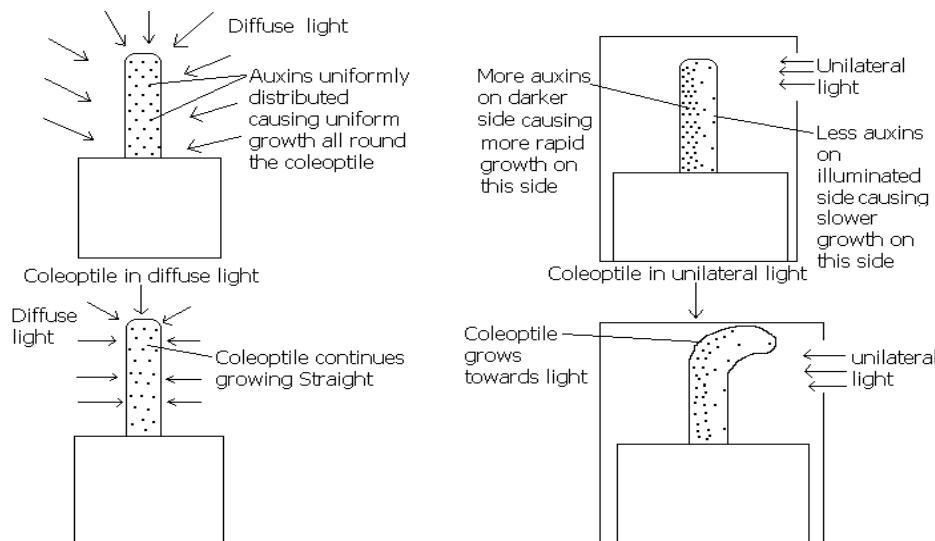
In one experiment, the tips of maize coleoptiles were cut off. After a few days, the shoots stopped growing because of the absence of auxins. In another experiment, a piece of mica was placed between the cut tip and the rest of the coleoptile and growth stopped after a few days because mica is impermeable to auxins. In yet another experiment, an agar block was placed between a cut tip and the rest of the coleoptile and the tip continued growing because auxins are able to diffuse from the cut tip to the rest of the coleoptile through the agar block. The results of these experiments are illustrated in the following diagrams:



Homework: Suggest what would happen if the tips of the coleoptiles are covered with aluminium foil (which is opaque) and the coleoptiles are exposed to unilateral light.

The Role of Auxins in Phototropism

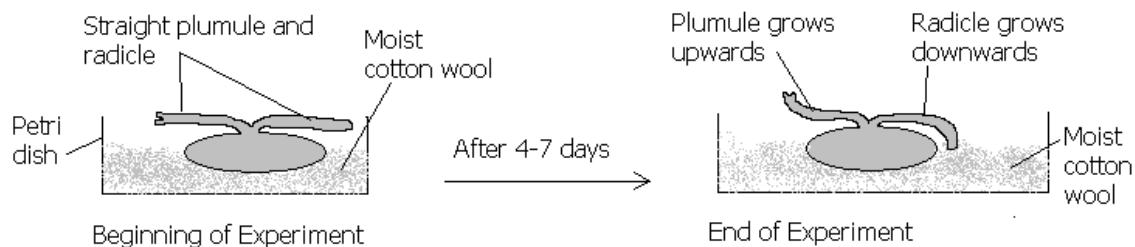
When a plant shoot is exposed to diffuse light (light from all directions), the auxins are evenly/uniformly distributed all round the shoot tip. As a result, growth is uniform all round the shoot tip, causing the shoot to grow straight. But when a plant shoot is exposed to unilateral light (light from one direction), the auxins are more concentrated on the darker side than the illuminated side. Since auxins promote growth of in shoots, growth is faster on the darker side than the illuminated side, causing the shoot to grow towards the light. This is illustrated in the following diagrams:



The Role of Auxins in Geotropism

When germinating bean seeds are placed on moist cotton wool in a dark place, with their plumules and radicles horizontal, the following observations are made after several days:

- The plumules grow away from gravity
- The radicles grow towards gravity



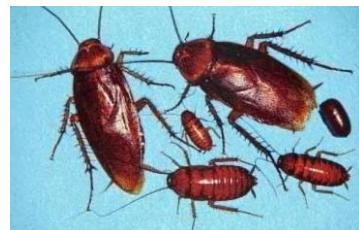
The above observation may be explained as follows:

- Gravity pulls the auxins to the lower side of the radicle and plumule; hence the concentration of auxins is higher on the lower sides than the upper sides.
- In the plumule, growth is faster on the lower side than the upper side, causing it to grow upwards (away from gravity)
- In the radicle, growth is faster on the upper side than the lower side, causing it to grow downwards (towards gravity)

Taxic Responses

A taxic response is a response of **an invertebrate animal** to a stimulus by **moving** either towards or away from the stimulus. Movement towards the stimulus is called **positive taxism** (positive taxic response) while movement away from the stimulus is called **negative taxism** (negative taxic response). Examples of taxic responses in invertebrates are:

- Woodlice are **positively hydrotaxic** and **negatively phototaxic**
- Earthworms are **positively hydrotaxic** and **positively geotaxic**
- Cockroaches are **negatively phototaxic**



COORDINATION AND RESPONSE IN ANIMALS

Coordination is the process by which different organs and systems of the body work together efficiently.

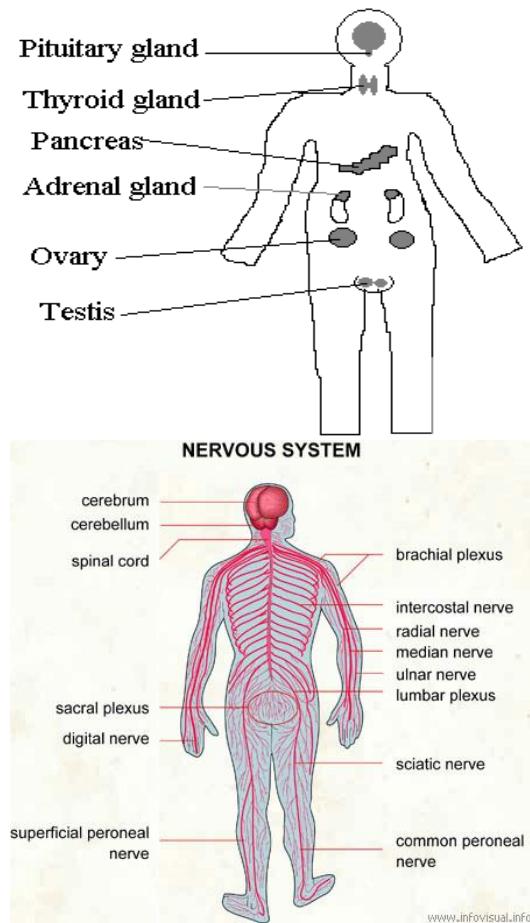
There are two main systems of coordination in animals. These are the endocrine system and the nervous system.

The Endocrine System

This is a system of coordination that is made of ductless glands that produce hormones. A hormone is a chemical secreted by a **ductless gland**, transported by **blood** and has effects on one or more **target organs** before being destroyed by the **liver**. A target organ is any organ that carries out an appropriate response to a stimulus under the influence of hormones. Any hormone can only have effects on an organ that has receptor sites for it.

The following diagram illustrates the main endocrine glands of the human body.

Human Endocrine System



Pituitary Gland

The pituitary gland is also called the **master gland** of the endocrine system. This is because it secretes hormones that stimulate other endocrine glands to function. These hormones include the following:

- **Thyroid Stimulating Hormone (TSH)**: This stimulates the thyroid gland to function
- **Adrenocorticotropic Hormone (ACTH)**: This stimulates the adrenal cortex to secrete hormones
- **Interstitial Cell Stimulating Hormone (ICSH)** : This stimulates the testes to function
- **Follicle Stimulating Hormone (FSH)**: This stimulates formation of follicles in the ovaries.
- **Luteinising Hormone (LH)**: This causes **ovulation** and formation of the **corpus luteum**.

There are other hormones produced by the pituitary gland which are not involved in stimulating other endocrine glands. These include:

- **Antidiuretic Hormone (ADH)**: Also called **vasopressin**, this hormone stimulates re-absorption of water from the renal tubule and loop of Henle in the kidneys when the body has little water. Insufficient or lack of ADH leads to **diabetes insipidus** (a condition where an individual passes out large volumes of dilute urine)
- **Growth Hormone**: This stimulates growth by stimulating synthesis of macromolecules such as proteins, carbohydrates and lipids. Too much secretion of growth hormone leads to **giantism/gigantism** and **acromegaly**. Gigantism or giantism is a condition where an individual is abnormally tall and huge. Acromegaly is enlargement of bones often accompanied by protrusion of the lower jaw. Little secretion of growth hormone

leads to **dwarfism**, a condition where an individual has physically stunted growth and appears too small for their age.

- **Oxytocin:** This causes rhythmic contractions of the uterus wall during child birth and also stimulates release of milk from mammary glands in the breasts.
- **Prolactin:** This stimulates milk production by the mammary glands in the breasts.

The Thyroid Gland

This is an H-shaped gland located in the neck near the larynx. It produces a hormone called **thyroxine**. Thyroxine controls the **basal metabolic rate** (BMR) of the body, stimulates respiration of glucose and fats as well as controlling the growth and differentiation of cells. The formation of thyroxine by the thyroid gland requires iodine. Over production of thyroxine causes **hyperactivity** which is characterised by an increased metabolic and heart rate, loss of body mass and extreme irritability. Under production of thyroxine causes **myxoedema** and **cretinism**. Myxoedema is a condition where the basal metabolic rate and mental development are slow. Cretinism is a condition where the physical, mental and sexual developments of a child are retarded. A person who suffers from cretinism is called a **cretin**. Iodine deficiency causes swelling of the thyroid gland, a condition known as **goitre**.

The Adrenal Gland

This is a pair of glands, each located just above each kidney. The **medulla** of the adrenal glands produces a hormone called **adrenaline**. This hormone is called the "**fight or flight hormone**" and is produced when an individual is angry, scared, emotionally excited or under stress. It prepares the body for action in the following ways:

- It boosts the changing of glycogen to glucose, thereby increasing glucose levels in the blood to be used for respiration
- It increases the breathing rate so that more oxygen is taken in to be used for energy production
- It increases the heart rate so that more blood containing glucose and oxygen can be carried to the muscles
- It diverts blood from the gut to the muscles by constricting the blood vessels of the gut and dilating the blood vessels of the muscles.
- It **dilates** the pupils in the eyes for increased alertness
- It dilates the bronchi and increases the volume of the thorax so that more air containing oxygen may be taken in
- It increases the sensitivity of the nervous system for faster response to stimuli
- It raises hair in furry animals and causes the appearance of 'goose bumps'.
- It causes shivering.

Pancreas

The pancreas is both an endocrine and exocrine gland. It is considered as an exocrine gland in the digestive system where it secretes pancreatic juice through a duct called the pancreatic duct.

In the endocrine system it plays a major role in maintaining normal glucose levels in blood. It has cells known as the **Islets of Langerhans** which produce hormones involved in blood sugar regulation. These cells are of two types, namely **alpha cells** (α -cells) and **beta cells** (β -cells). Alpha cells secrete a hormone called **glucagon**. Beta cells secrete a hormone called **insulin**.

When glucose levels are too high in blood, the pancreas detects the change and secretes insulin which lowers the levels of glucose in the following ways.

- It causes the cells of the liver and muscles to convert excess glucose to **glycogen** which is stored in the liver and muscles. The body can only store about 400g of glycogen (about 100g in the liver and 300g in the muscles).
- It causes the cells of the **adipose tissue** to convert excess glucose to fats. The fats are stored under the skin and around delicate body organs such as the heart, liver, kidneys, intestines and brain.

- It enables body cells to absorb glucose from the blood and use it.

Lack or insufficient production of insulin leads to the disease called **diabetes mellitus** whose signs and symptoms are:

- Abnormally high levels of glucose in blood
- Presence of glucose in urine
- Persistent thirst leading to excessive intake of water
- Drastic loss of weight
- Loss of sensation in some body parts.

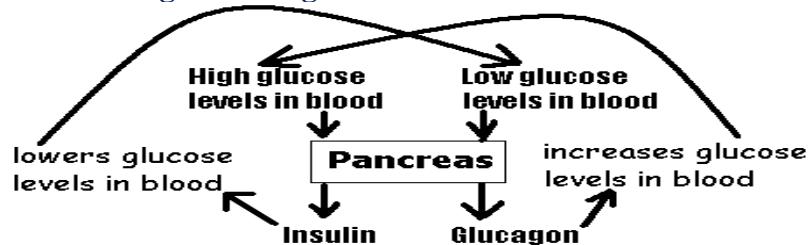
When glucose levels are too low in blood, the pancreas detects and secretes glucagon which increases glucose levels in blood in the following ways:

- It causes the cells of the liver and muscles to convert glycogen to glucose.
- It causes fat to be changed into glucose and may cause proteins to be modified so that they are utilised for energy production.

Negative Feedback Mechanism

A negative feedback mechanism is a mechanism whereby levels of substances in the body are brought back to normal. When there are changes in the internal environment, they are detected by a monitor (detector) which produces a hormone to return the condition to normal. The following diagram illustrates negative feedback mechanism in the production of insulin and glucagon by the pancreas.

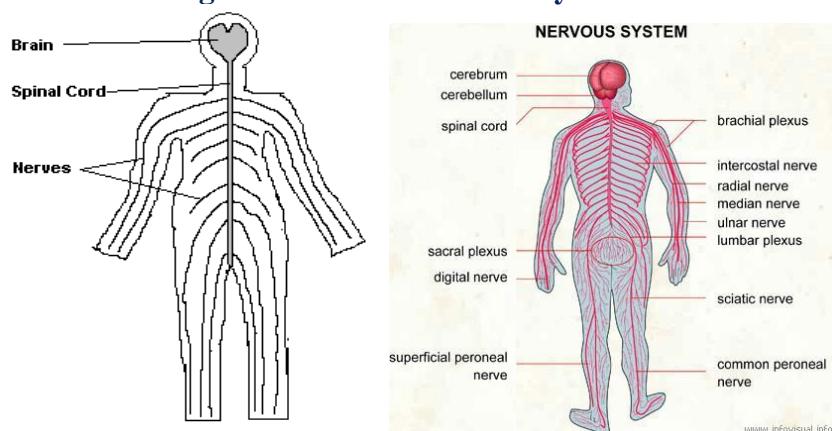
Figure 1: Negative Feedback Mechanism



The Nervous System

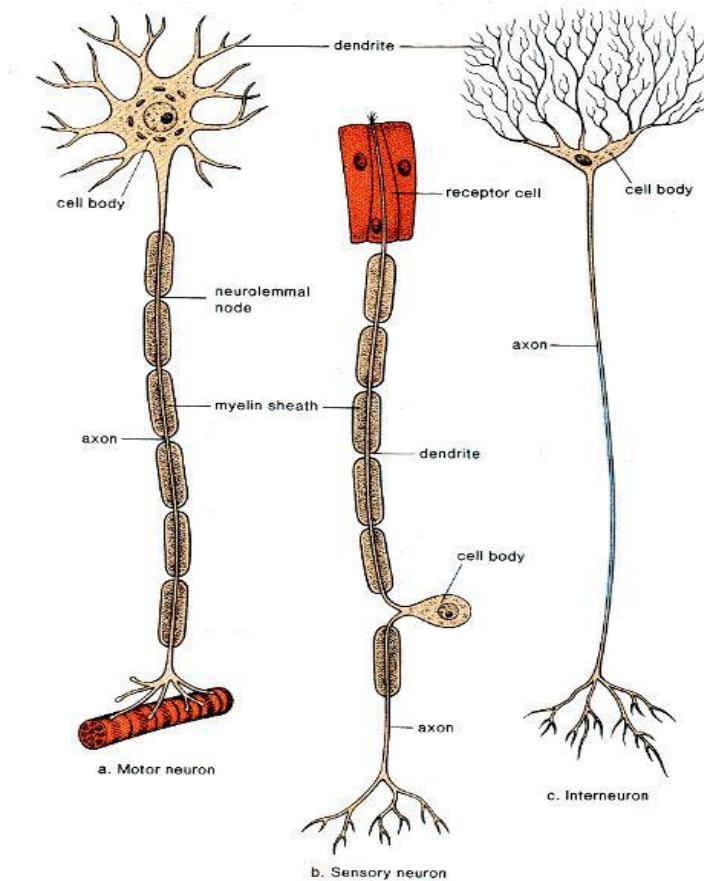
This is a system of coordination in animals made up of the **brain**, **spinal cord** and **nerves**. The brain and the spinal cord together make up the **central nervous system** (CNS) while the nerves make up the **peripheral nervous system** (PNS). Nerves that are joined to the brain are called **cranial nerves** while those that are joined to the spinal cord are called **spinal nerves**. In the nervous system messages are transmitted in the form of **electric impulses** also called **nerve impulses**.

Figure 2: Human Nervous System



Neurones

The basic functional units of the nervous system are **neurones** or **nerve cells**. Types of neurones include **sensory**, **relay** (connector, intermediate, multipolar, pyramidal) and **motor** neurones

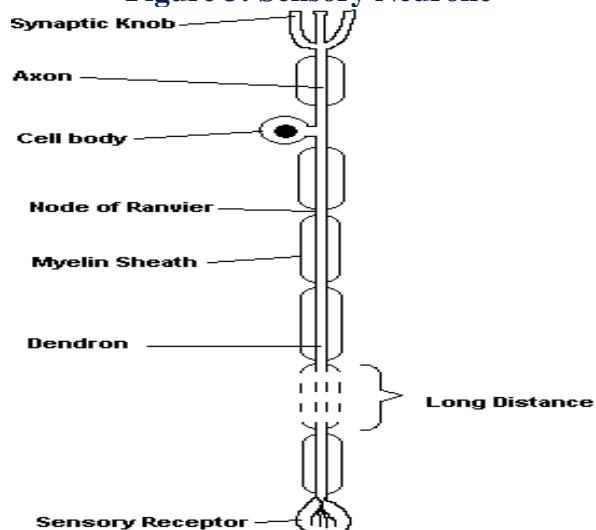


Sensory Neurones

These are neurones that carry impulses from sense organs (receptors) to the central nervous system. A receptor is any organ that detects a stimulus and converts information about it to electrical impulses. Characteristics of sensory neurones include the following:

- They carry impulses from sense organs to the central nervous system.
- They have **long dendrons** and **short axons**.
- Their cell bodies are not terminally located but are **axillary**.

Figure 3: Sensory Neurone



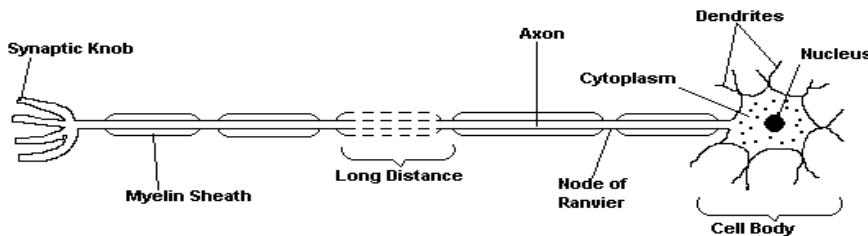
Motor Neurones

These are neurones that carry impulses from the central nervous system to effectors. An **effector** is any part of the body that carries out a response to a nervous impulse. Most effectors are glands or body organs such as muscles.

Motor neurones have the following characteristics:

- They carry impulses from the central nervous system to the effectors.
- They have **long axons** and **short dendrites**.
- Their cell bodies are **terminally located** (located at the end).

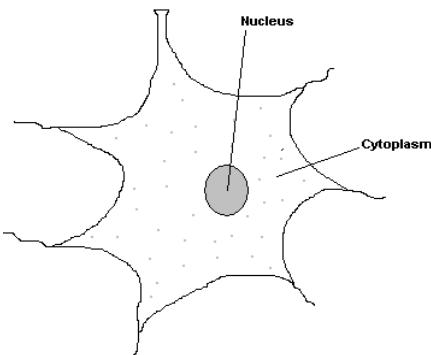
Figure 4: Motor Neurone



Relay Neurone

These are neurones that form a link between sensory neurones and motor neurones. They are located in the central nervous system and are multipolar so as to provide many alternative paths for impulses.

Figure 5: Relay Neurone



Synapses

A synapse is a junction between two neurones. The neurones at the synapse are not joined to each other but have gaps between them called synaptic gaps (synaptic clefts).

The following passage describes how a nerve impulse moves across a synaptic gap:

- 1 An impulse arrives at the synapse
- 2 At the end plates, there are vesicles (tiny sacs) containing a chemical (**neurotransmitter**).
- 3 The vesicles fuse with the cell membrane (presynaptic membrane) and the chemical is released into the synaptic gap.
- 4 The chemical diffuses across the gap and the impulse restarts at the other side.

Reflex Actions

A reflex action is an **automatic** and **stereotyped** response to a stimulus. Reflex actions are often quick, but some of them are slow. Examples of quick reflex actions include:

- Withdrawing of a hand from a hot object
- Jumping up after sitting on a pin
- Blinking when an object approaches the eye
- Knee-jerk reflex
- Shedding of tears when an object enters the eye.



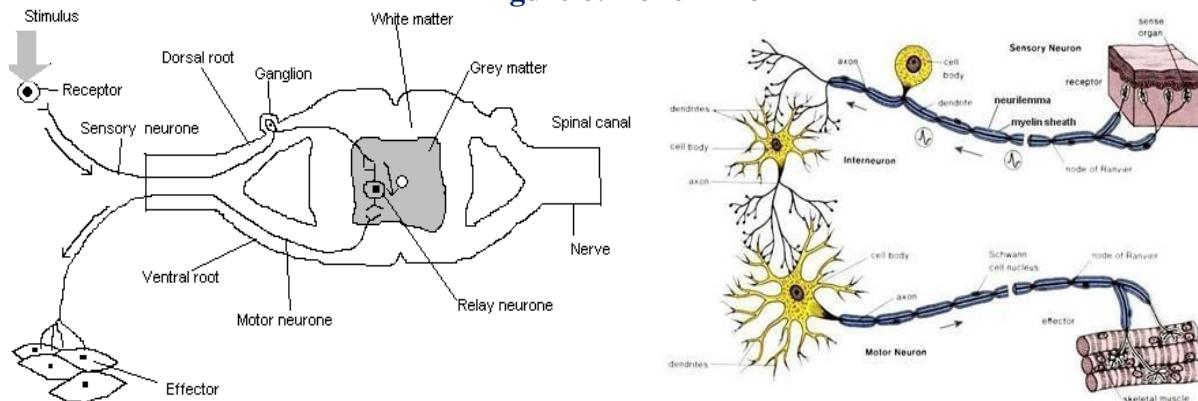
An example of a slow reflex action is the pupil reflex (iris reflex). Each reflex action has a survival value which protects an animal from dangerous factors. What is the survival value of each of the reflex actions stated above? Other examples of reflex actions are sneezing, salivating, peristalsis, vasoconstriction and vasodilation.

There are two types of reflex actions, namely **spinal** and **cranial reflexes**. During a spinal reflex impulses pass through the spinal cord, whereas during a cranial reflex impulses pass through the brain.

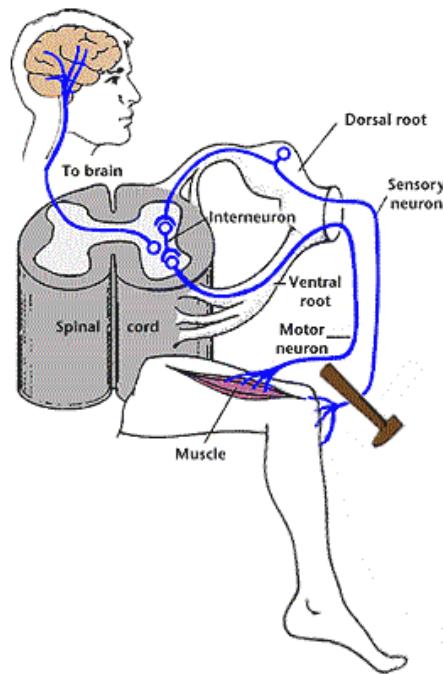
Reflex Arc

The path travelled by a nerve impulse during a reflex action is called a **reflex arc**.

Figure 6: Reflex Arc



The following diagram illustrates the knee-jerk reflex arc:



Conditioned Reflex

A conditioned reflex is a response that results from learning or training. The response given during a conditioned reflex is not related to the stimulus but the animal associates it with a related stimulus after being trained to do so. This may be illustrated by Pavlov's experiment.

Pavlov's Experiment

Pavlov observed that dogs always salivated when they saw, smelled or tasted food. For some days, Pavlov would ring a bell each time before giving the dogs food. Eventually, the dogs started salivating at the sound of the bell alone. In this case, the salivation of the dogs is an example of a **conditioned reflex** and the sound of the bell may be referred to as a **conditioned stimulus**.

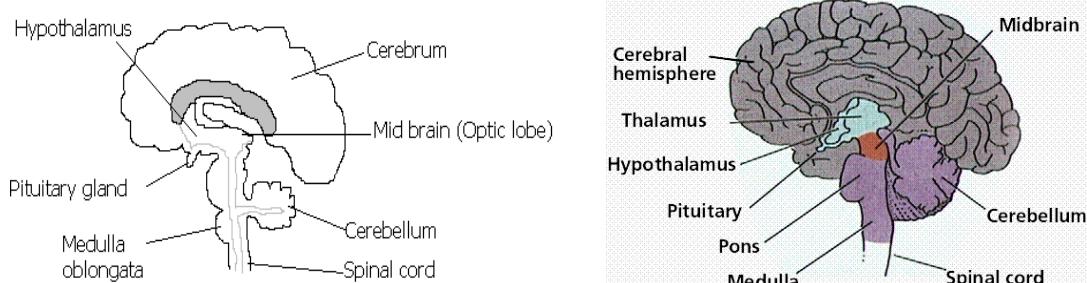
Conditioning is used in training of animals for different tasks. In humans, activities such as walking, responding to a name, cycling and driving are examples of conditioned reflexes.

The Brain

The brain is the enlarged anterior end of the spinal cord. It is made of three regions which are:

- (i) **Fore brain** (cerebrum, hypothalamus, pituitary gland and olfactory lobe)
- (ii) **Mid brain** (optic lobe)
- (iii) **Hind brain** (medulla oblongata and cerebellum)

Figure 7: The Human Brain



Functions of Brain Parts

Medulla Oblongata: This links the spinal cord and the brain and conducts nerve impulses between these two parts. It controls automatic processes such as heart rate, breathing rate, swallowing, salivating, sneezing and coughing.

Cerebellum: This controls co-ordinated movement, helps maintain posture and also controls the sequence of activities involved in dancing, acrobatics and playing of musical instruments.

Hypothalamus: Sometimes regarded as the centre of homeostasis, this contains centres which control thirst, hunger and thermoregulation.

Pituitary Gland: This links the central nervous system and the endocrine system. (Refer to notes on the endocrine system for the hormones it secretes and their functions)

Cerebrum: This is the largest part of the brain and is the centre of intelligence, memory, language and consciousness. It has both motor and sensory areas. The motor areas control voluntary movement. The sensory areas interpret sensations and are linked by association areas. Injury to the cerebrum lowers intelligence. It occupies three quarters of the brain. Human beings have got the largest cerebrum of all animals. It is divided into two halves which are known as **cerebral hemispheres**. The outer part (cortex) is folded and wrinkled to give a very large surface area. The cortex is grey in colour because it contains cell bodies of neurones. The inner part is white in colour as it is made up of axons of neurons.

Differences between Endocrine and Nervous System

Nervous System

Messages are electrical (nerve impulse)

Responses are localised

Responses are short-lived (temporary)

Responses are often quick

Endocrine System

Messages are chemical (hormones)

Responses are widespread and affect more than one target organ

Responses are either temporary or permanent

Responses are either quick (e.g. for adrenaline or slow (e.g. for sex hormones)

Drugs and Drug Abuse

A drug is any **externally administered substance** which **modifies/alters the rate of metabolic reactions** in the body. Drugs may be administered in several ways including

- **Ingestion** (taking through the mouth).
- **Injection** (use of needles and syringes to introduce drugs into blood).
- **Sniffing** (taking a powdery drug in through the nostrils) e.g. snuff
- **Inhalation** (taking a vaporised drug in through the respiratory)

The term drug refers to useful substances such as medicine as well as harmful substances. Harmful drugs are also called drugs of abuse and are classified into the following groups, among others: **stimulants, depressants, hallucinogens, narcotics and inhalants/solvents**.

Some terms associated with drug abuse include:

- **Dependency (addiction):** A condition where an individual's body fails to function normally in the absence of a particular drug. A person who dependent on a drug is also said to be addicted. Dependency can be **psychological** or **physiological**. Psychological dependency is where a person believes that they need a particular drug to function normally.
- **Tolerance:** This is a condition where an individual needs a higher dosage of a drug to produce an effect that was initially being produced by a smaller dosage of the drug.
- **Withdrawal symptoms:** These are the symptoms or signs an individual experiences when they discontinue using a drug which they are addicted to.

Classes of Abused Drugs

(i) **Stimulants:** These are drugs that accelerate/increase the rate of impulse transmission in the nervous system. Examples of stimulants are **cocaine, caffeine, nicotine and amphetamines**. Their effects include:

- Increasing alertness
- Increasing heart rate and breathing rate
- Reducing the desire to sleep

- Reducing the desire for food (lack of appetite)
- Making someone feel energetic
- Euphoria (feeling of well being)

However, stimulants increase the risk of cardiovascular diseases such as hypertension and coronary heart disease. Prolonged use can lead to dependency and liver damage. Overdoses can cause death.

(ii) **Depressants:** These are drugs that slow down the rate of impulse transmission in the nervous system. Examples of depressants are **alcohol** and **heroin**. Their effects include:

- Reduced anxiety and tension
- Increased desire for sleep and drowsiness
- In small amounts, some cause an increased desire for food
- Euphoria
- Numbing of pain by inhibiting pain and emotion centres.

The dangers associated with abuse of depressants include the following:

- Overdoses can lead to instant death
- Injectable drugs such as heroin increase the risk of HIV infection resulting from sharing of needles.
- Addiction/dependency is quickly established
- They have severe withdrawal symptoms e.g. vomiting, diarrhoea and dizziness
- They slow down the time taken to respond to stimuli, leading to accidents
- Damage to vital body organs such as the liver, kidneys and brain
- Social problems such as crime and prostitution committed by addicts who need money for the drugs.

Harmful Effects of Alcohol

The harmful effects of alcohol can be classified as either **short term** or **long term**. Short term effects are those that are experienced immediately after taking the drug and do not last for a long time. These include:

- Staggering (loss of coordination)
- Slurred speech
- Anti-social behaviour e.g. shouting
- Slowing down the transmission of nerve impulses, thereby slowing down reactions to stimuli
- Poor judgment
- Hangover

Long term effects are the effects someone experiences after using a drug for a long time. For alcohol, the long term effects are:

- Permanent damage to internal organs such as the liver, brain and kidneys. The hardening of liver tissue resulting from alcohol abuse is called **liver cirrhosis**.
- Social problems such as poverty, lack of food in homes, failure to sponsor children to school e.t.c.
- Stomach ulcers
- Uncontrolled shaking (delirium tremens) and hallucinations in some cases.
- Expectant mothers who take alcohol have a risk of giving birth to underweight babies having **foetal alcoholic syndrome** (FAS). This is a condition where a child is deformed and mentally retarded.

Note: Some effects of depressants are closely associated with those of **sedatives** and **tranquillisers**.

(iii) **Hallucinogens:** These are drugs that distort the perception of an individual e.g. marijuana and LSD (lysergic acid diethylamide).

The Effects of Tetanus Infection

This is an infection caused by a bacterium called *Clostridium tetanus*. It is characterised by sustained contractions of muscles which leads to stiffening of the body and death. Individuals who have deep cuts with dirty objects on their bodies (e.g. accident victims) are at high risk of tetanus infection. As a result they are given anti-tetanus injections which contain antibodies that counter the effects of tetanus toxins.

Sense Organs

A sense organ is any body organ responsible for detecting one or more stimuli. Examples of human sense organs and the stimuli they detect are summarised in the following table:

Sense Organ	Stimulus/stimuli detected
The eye	Light/light energy
The skin	Touch, temperature, pressure and pain
The nose chemoreceptors	Chemicals in air
The tongue chemoreceptors	Chemicals in food
The ear	Sound energy, balance/posture and pressure

1. The Eye

This is a sense organ responsible for detecting light energy

Figure 8: External Structure of Eye

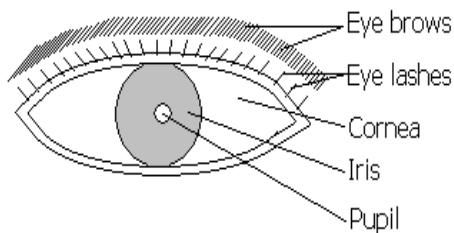
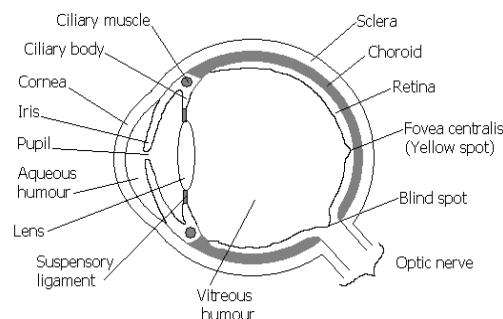


Figure 9: Longitudinal Section of Eye



Functions of Eye Parts

Sclera:

This is the **tough** fibrous outer coat which maintains the spherical shape of the eyeball protects the eye against damage and provides attachment for external eye muscles (rectus and oblique muscles) which move the eye in its sockets. This layer is **white** and **opaque**

Cornea:

This is the **transparent** section of the sclera found in front of the eye. It does most of the **refraction of light rays** from an object. This leads to the formation of an **inverted** and **diminished** image on the retina.

Choroid:

This is a **dark layer** that also **contains blood vessels**. The dark colour **limits internal reflections** so that clear images are formed. The blood vessels **provide food and oxygen** to the cells of the retina.

Retina:

This is a layer containing light-sensitive cells where images form and light energy is converted to nerve impulses. There are two types of light sensitive cells found on the retina, namely **cones** and **rods**. The cones form **clear** (detailed) **colour images** when there is **high light intensity** (bright light). The portion of the retina having the higher concentration of cones is called **fovea (yellow spot)** and forms the most detailed colour images. The rods form **blurred, black and white images at low light intensity** (dim light).

Blind spot:

A portion corresponding to the exit point for the optic nerve, where there are no light-sensitive cells. Hence, light falling there cannot be detected.

Optic nerve:

A nerve having sensory neurones that transmit nerve impulses from the retina to the visual centre of the brain.

Vitreous humour:

It's a jelly-like fluid which keeps the eyeball in shape, refracts light rays, supports the lens and keeps the retina in place at the rear of the eye.

Aqueous humour:

It is a watery fluid which supports the cornea and keeps it in shape.

Some Functions of the Eye

- Image formation
- Focusing and accommodation
- Pupil/iris reflex

Formation of Images

The part of the eye where images form is the **retina**. The images formed have the following characteristics:

- They are **inverted** (upside down)
- They are **diminished** (smaller than the object)
- They are **real** (can be produced on screens)

Though the images on the retina are inverted, they are seen the right way up because the brain gives the correct interpretation of the images. Information about the image is carried from the retina to the brain by the **optic nerve**.

Focusing and Accommodation

Focusing is the formation of a clear image on the retina. Accommodation is the process by which the eye forms a focused image on the retina by adjusting the thickness and length of the lens using suspensory ligaments and ciliary muscles in response to the distance of the object away from the eye.

Accommodation of a Close (Nearby) Object

Rays from close objects are **divergent**. To focus the images on the retina the following events take place:

- Ciliary muscles contract
- Suspensory ligaments become slacken
- The lens becomes short and thick
- The light rays are more refracted, thereby focusing the image on the retina

Accommodation of a Distant (Far) Object

Rays from distant objects are more or less **parallel** to each other and do not require much refraction to be focused on the retina. The following events occur to focus the image on the retina:

- Ciliary muscles relax
- Suspensory ligaments become taut, making the lens long and thin
- Light rays are less refracted, thereby focusing the image on the retina

Pupil/Iris Reflex

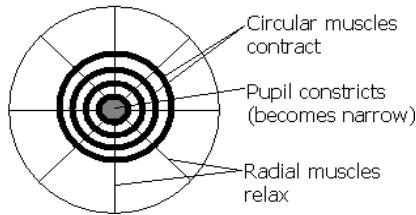
This is the adjustment of the diameter of the pupil by circular and radial muscles of the iris in response to changes in light intensity.

In Bright Light (High Light Intensity)

Excess light may damage the retina by bleaching it. To prevent this, the following events take place:

- Circular muscles contract
- Radial relax

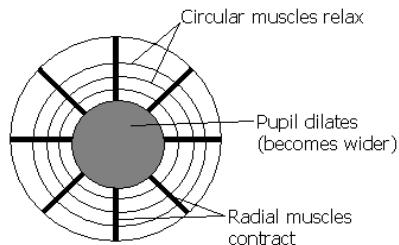
- Pupil constricts (becomes smaller) to prevent bleaching of the retina by excess light.



In Dim Light (Low Light Intensity)

The light reaching the retina is not enough for image formation. To correct this situation, the following events take place:

- Radial muscles contract
- Circular muscles relax
- Pupil dilates (becomes wider) to allow as much light as possible to enter the eye for image formation



Defects of the eye

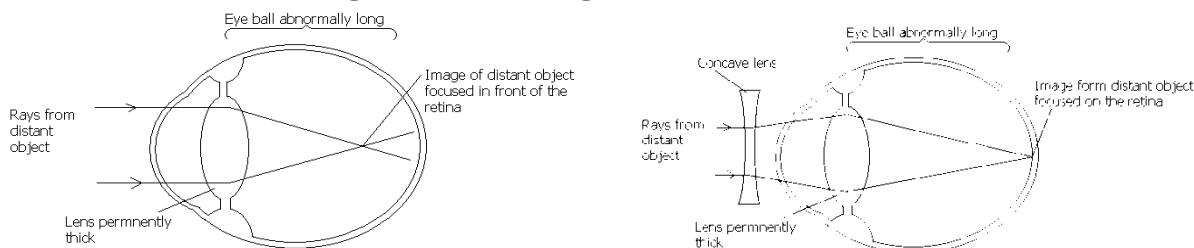
- Short sight (Myopia)
 - Long sight (Hypermetropia)
 - Blindness
- Night blindness
 - River blindness
 - Blindness due to injury
 - Colour blindness

a) Short Sight (Myopia)

This is an eye defect where an individual can clearly see close objects but distant objects appear blurred.

This is because rays from distant objects are brought into focus before (in front of) the retina. It is caused by an abnormally long eyeball or a permanently thick lens. It can be corrected by using concave lenses, as illustrated in the following diagrams:

Figure 10: Short Sight and its Correction

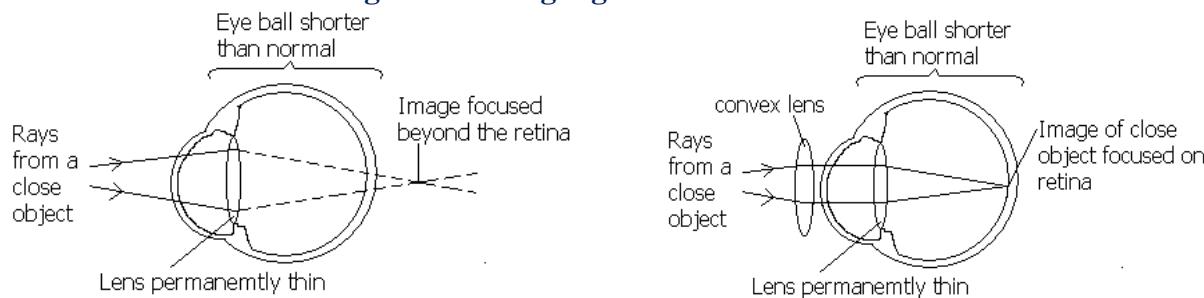


b) Long Sight (Hypermetropia)

This is an eye defect where an individual can clearly see distant objects but close objects appear blurred. It is caused by an abnormally short eyeball or a permanently thin lens. In this case, rays from close objects are focused beyond the retina. Stiffening of the lens in its thin

position can be caused by old age. Long sight is corrected by using convex lenses, as illustrated in the following diagrams:

Figure 11: Long Sight and its Correction



c) **Blindness**

This is defined as lack or loss of visual perception. There are different forms of blindness, some of which are discussed below.

- (i) Blindness due to Injury
- (ii) Night Blindness

This is a condition where vision becomes diminished in dim light. It is caused by deficiency of vitamin A. Vitamin A is required by the eye to form a visual pigment called **rhodopsin** that is required for vision at low light intensities. Hence vitamin A deficiency initially leads to night blindness which may later develop **xerophthalmia** (a condition where there is abnormal dryness of the conjunctiva, leading to blindness).

- (iii) River Blindness

This is a type of blindness caused by a **filarial worm** known as *Onchocerca volvulus*. Adult worms of this kind produce tiny larvae known as **microfilariae** that attack the eyes, causing **glaucoma**, **cataracts** and **conjunctivitis**, thereby causing blindness.

River blindness is common in tropical regions that have rivers and lakes. This is because the vectors of this worm are flies of the genus *Simulium* that require aerated fresh water to breed. The flies transmit the larvae of the worms from one person to another through bites. These reach their maturity under the skin of the human body. Then they begin mating and produce large numbers of **microfilariae** which migrate to the eyes and cause harm.

Methods of preventing and/or treating river blindness are:

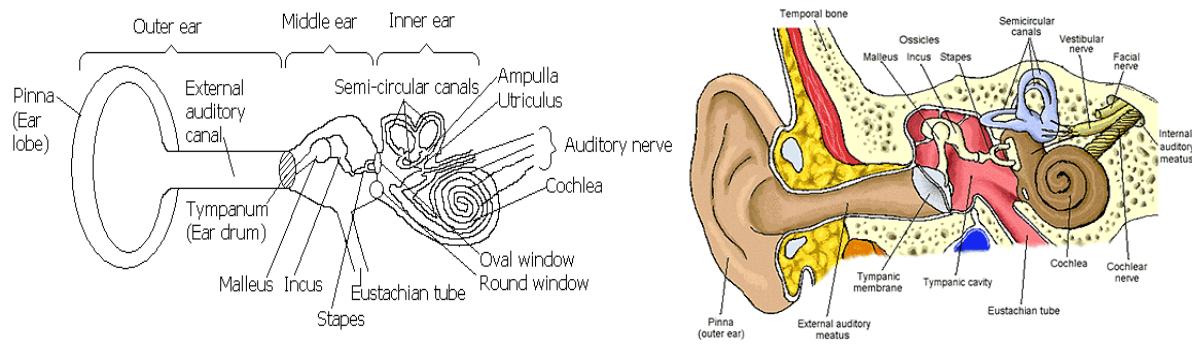
- Spraying rivers with insecticides to kill the larval stages of the *Simulium* flies.
- Application of **dimethylphthalane** to clothing or the skin in order to repel the flies for several hours.
- Dosage of **diethylcarbamazine** to kill the microfilariae
- Injections of **suramin** to kill adult worms in the body.
- Long clothing to prevent bites by *Simulium* flies

2. The Ear

This is a sense organ that is responsible for detection of sound. The ear is divided into the following regions:

- Outer Ear or External Ear (an air-filled cavity made of the **pinna/ear lobe** and **external auditory meatus**)
- Middle Ear (an air-filled cavity made of the **tympanum/ear drum**, **ossicles** and **eustachian tube**)
- Inner Ear or Internal Ear (a fluid-filled cavity made of the **cochlea**, **semicircular canals** and **vestibules or vestibular apparatus**)

Figure 12: Structure of the Ear



Functions of Ear Parts

Pinna

This collects sound waves and passes them on to the external auditory canal.

External Auditory Canal (Ear Canal)

- Carries sound waves from the pinna to the tympanum.
- Produces wax to keep the ear drum supple and trap particles that enter the ear
- Contains hair to trap particles entering the ear

Ear Drum (Tympanum)

This is a membrane that vibrates when hit by sound waves in order to transmit sounds to the ossicles that are found in the middle ear.

Ossicles

This are a set of three small bones found in the middle ear and are responsible for:

- Transmitting sounds from the ear drum to the oval window.
- Amplifying sounds by about 20 times.

The names of the three bones are related to their shapes. The first one after the ear drum is the **malleus** (hammer); the next one is the **incus** (anvil) and the last one is **stapes** (stirrup).

Eustachian Tube

This is a tube that connects the middle ear to the back of the pharynx. It opens during swallowing and yawning in order to equalize pressure between the middle ear and the atmosphere. This prevents the ear drum from bursting when atmospheric pressure changes drastically e.g. during an aeroplane flight or deep-sea diving.

Oval Window (Fenestra ovalis)

This picks up vibrations from the stapes and transmits them to the perilymph in the inner ear.

Round Window

This relieves the pressure that builds up in the perilymph during vibrations of the oval window. It moves outwards as the oval window moves inwards and moves inwards when the round window moves outwards.

Vestibules (Vestibular Apparatus).

This is made of the **sacculus** (saccule), **utriculus** (utricle), **ampullae** (singular=ampulla) and three **semi-circular canals**. The sacculus links the rest of the vestibules to the cochlea. The utriculus contains receptors that are sensitive to **gravity and body posture**. The semicircular canals are responsible for balancing the body during **rotational movements** of the head. Each semicircular canal is at right angles to the other two. The ampullae are the swollen ends of the semicircular canals. They contain hair cells that are connected to nerves. When the head twists, the fluid inside the semicircular canal moves and causes movement of the cupula and bending of the hair cells. This makes the hair cells generate impulses that are transmitted to the brain to control balance.

Cochlea

This is a coiled structure that detects sound intensity and frequency and transduces sounds to generate nerve impulses. Nerve impulses from the ear are carried to the brain by the **auditory nerve**.

Deafness

This is an ear disorder where hearing is impaired or diminished. Causes of deafness include the following:

- Over-production of wax which leads to blockage of the external auditory canal.
- Exposure to loud sounds which might damage the ear ossicles.
- Inserting hard and sharp objects into the ears, causing damage to the ear drum.
- Infections of the inner ear or the throat. Some throat infections are able to affect the middle ear by getting transmitted through the eustachian tube.

Proper Care for Ears

- Clean the ears regularly with soft materials to remove excess wax
- Avoid exposure to loud sounds. This can be done by covering the ears when exposed to loud sounds. Soldiers are advised to keep their mouths open when firing guns; suggest a reason for this.
- Treat all infections of the inner ear and throat.

LOCOMOTION

Locomotion refers to movement of an entire organism from one place to another. Only animals can carry out locomotion. Other types of organisms such as trees can only move parts of their bodies while remaining fixed.

Locomotion in animals is done with the help of skeletons and muscles.

Skeletons

A skeleton is any firm structure that gives mechanical support to the body and provides protection to the softer parts of the body.

There are three types of skeletons in multicellular organisms. These are **hydrostatic skeletons, exoskeletons and endoskeletons**.

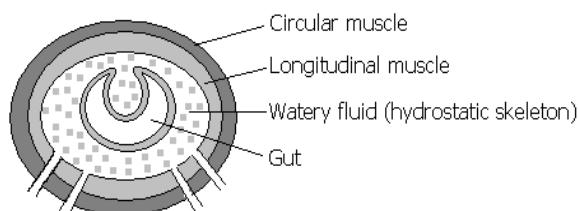
1) Hydrostatic Skeleton

This is a type of skeleton made of **watery fluids found inside the body**. These watery fluids offer mechanical support and help in movement. This type of skeleton occurs in **soft-bodied invertebrates** such as earthworms, hydra, snails, slugs and sea anemones.

Water has three important characteristics that make it suitable to act as a skeleton.

- It is relatively incompressible (cannot be easily compressed)
- It can transmit pressure changes equally in all directions
- It takes up the shape of its container.

Figure 13: Cross-Section of an Earthworm



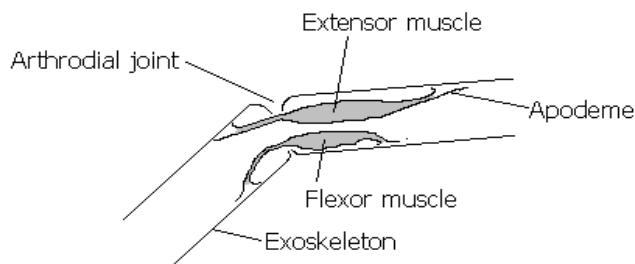
During locomotion in an earthworm, the circular and longitudinal muscles contract in turns to produce peristaltic waves along the body, beginning at the front end and working backwards.

2) Exoskeleton

This is a type of skeleton located **outside the muscles of the body** and occurs in all **arthropods** (crustaceans, insects, myriapods and arachnids). In insects, this skeleton is also

known as the **cuticle** and is largely made of a polysaccharide called **chitin** covered with small amounts of wax outside. The cuticle is made of a waxy thin outer layer called the **epicuticle** and an inner layer of chitin called the **procuticle**. The procuticle is made of two layers called **exocuticle** and **endocuticle**.

Figure 14: Insect Joint Showing Location of Exoskeleton and Muscles



Exercise

1. State the functions of each of the parts labelled in the diagram above.
2. Draw the hind leg of a grasshopper, showing the following parts: femur, spines and claws.

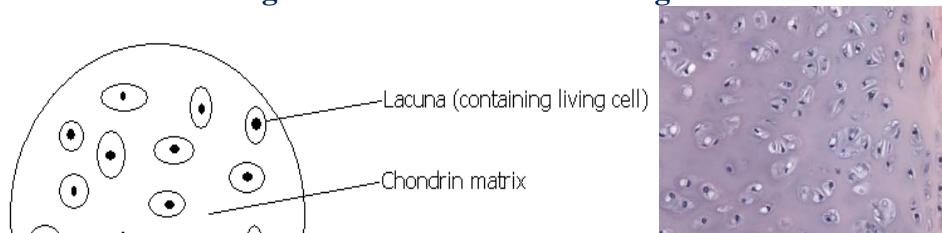
3) Endoskeleton

An endoskeleton is located **inside the body** and is made of **bones** and **cartilage**. This type of skeleton is found in all **vertebrates** i.e. fish, amphibians, reptiles, birds and mammals. The endoskeleton of a vertebrate foetus is largely made up of **cartilage** while that of an adult is made of bones with small amounts of cartilage in areas that need flexibility. However, some adult vertebrates have entire skeletons made of cartilage e.g. **cartilaginous fish** such as sharks.

Cartilage

Cartilage is a firm and flexible rubber-like tissue which is made of **living cells** and **collagen fibres** embedded in a matrix of **chondrin**. The structure of cartilage is illustrated in the following diagram.

Figure 15: Structure of Cartilage



Cartilage is found in firm but flexible parts of the vertebrate body such as the trachea, the nose, ear lobes, larynx and at the ends of bones. Some functions of cartilage are:

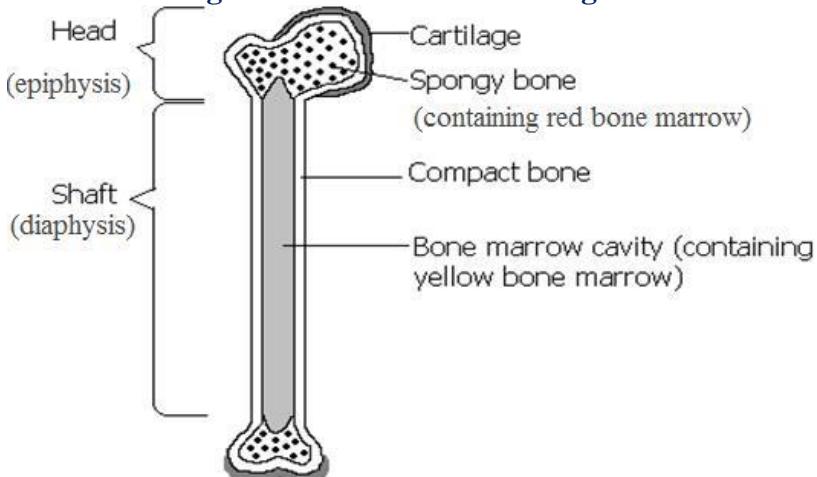
- It is found between the vertebrae in the spine, allowing bending of the spine.
- It is found in the trachea and allows it to remain open even when the neck bends
- It is found in the pinna and the end of the nose and helps keep them firm.
- It is found at the ends of bones at the joints, where it reduces friction, cushions the ends of bones and bears loads.
- It is the main skeletal material of vertebrate embryos

Bones

Bone is a tissue made of **living cells** and **collagen fibres** in a **matrix of calcium phosphate** and magnesium salts. The living cells occur in structures known as **lacunae** (singular=lacuna). The matrix is laid up in several concentric rings forming a system known as the **Haversian system**. The lacunae are linked to each other by channels of cytoplasm known as **canliculi** (singular=canalculus). The central space of the Haversian system is called the **haversian canal** and contains blood vessels, nerves and lymphatic vessels. A transverse extension from the haversian canal called the **Volkmann canal** links it to the bone marrow.

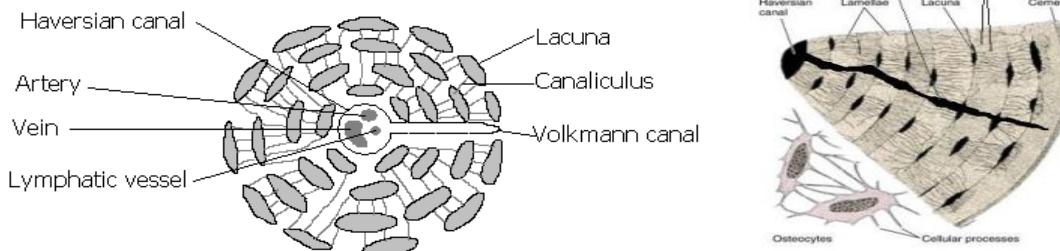
The long bones of a vertebrate have **spongy bone** at the ends and **compact bone** in the shaft.

Figure 16: Structure of a Long Bone



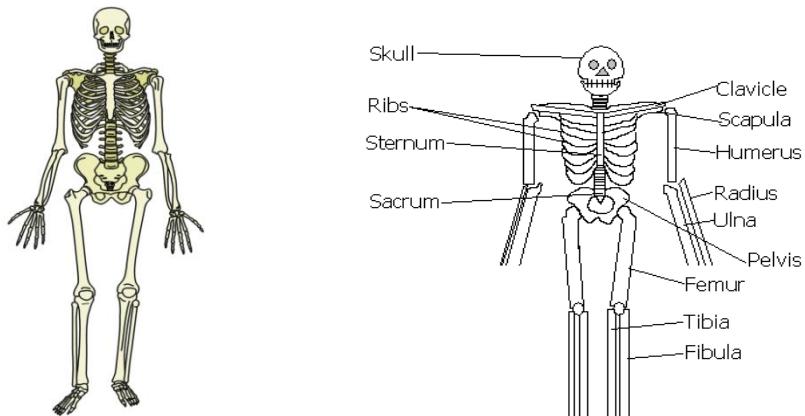
Compact bone is made of a lot of haversian systems grouped together. The following diagram illustrates the structure of Haversian system in compact bones

Figure 17: Haversian System



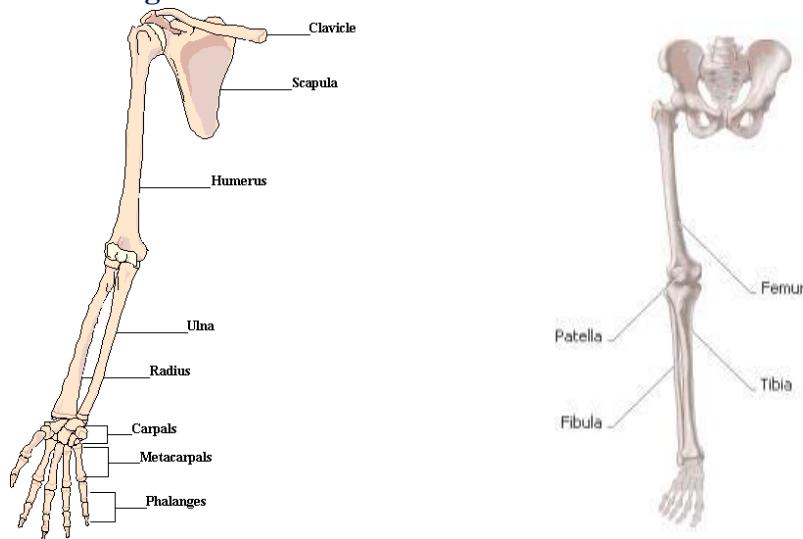
The Human Skeleton

Figure 18: Human Skeleton



The human skeleton is divided into two regions, namely **axial skeleton** and **appendicular skeleton**. The axial skeleton is made of the **skull**, **vertebral column (spine)**, **ribs** and **sternum** while the appendicular skeleton is made of the **limbs** and **girdles**. There are two sets of limbs i.e. **two fore limbs** (arms) and **two hind limbs** (legs). The girdles form a link between the axial skeleton and the limbs. There are **two girdles**, namely, the **pectoral girdle** and the **pelvic girdle**. The pectoral girdle links the fore limbs to the axial skeleton. It is made of the **shoulder blades** (scapulas) and **collar bones** (clavicles). The pelvic girdle links the hind limbs to the axial skeleton. It is also called the **pelvis** and is made of the **pubis**, **ilium** and **ischium**, among other bones.

Figure 19: Bones of the Forelimb and Hindlimb



Bones of the Spine

The bones that make up the vertebral column (spine) are called **vertebrae** (singular=vertebra). Their names, structures and numbers vary depending on the region of the spine in which they occur. The following table gives the names, locations and numbers of different vertebrae in the human being.

Name	Region where located	Number
Cervical vertebrae	Neck region	7
Thoracic vertebrae	Chest region	12
Lumbar vertebrae	Abdominal region or loin	5
Sacral vertebrae	Hip region	5
Caudal vertebrae or Coccyx	Tail region	4

Figure 20: Generalized Structure of Vertebra

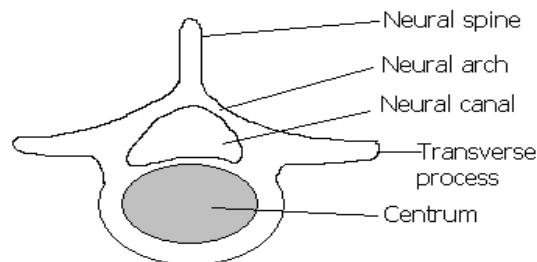
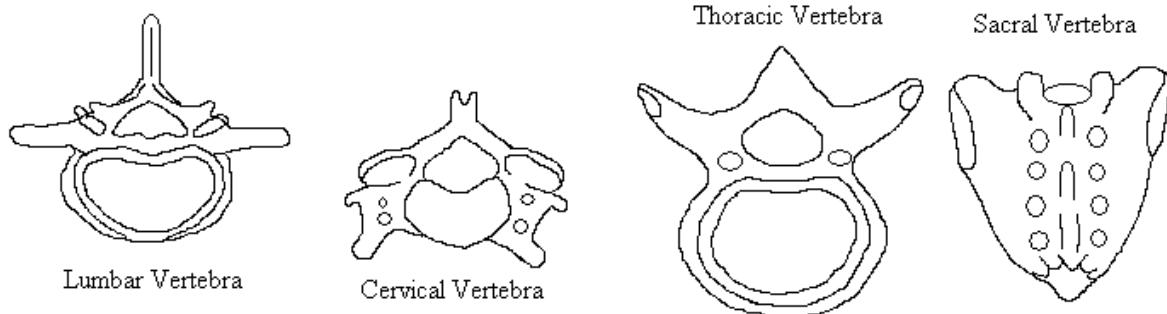


Figure 21: Structures of Some Selected Types of Vertebrae



The functions of the different parts of a vertebra are discussed below:

Neural spine: This is a projection on top of the neural arch that provides a surface for attachment of muscles and ligaments.

Neural arch: This is a curved bony structure arising from the centrum and has an opening in the centre called the **neural canal**. The neural arch protects the spinal cord while the neural canal is the passage for the spinal cord.

Transverse process: These are projections on the sides of the centrum that provide surfaces for attachment of muscles and ligaments.

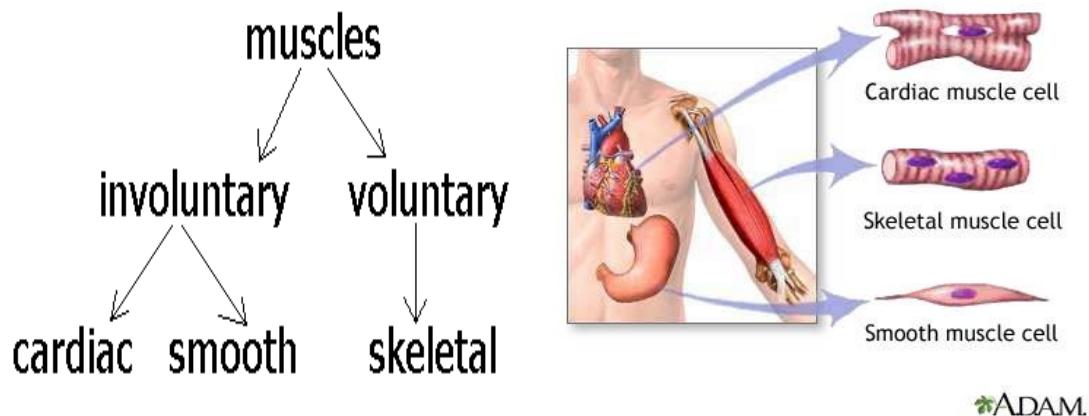
Centrum: This is the solid central part of the vertebra whose function is to bind to the intervertebral disc and form a cartilaginous joint with the next vertebra.

The functions of vertebral column are:

- Protecting the spinal cord from mechanical damage
- Providing attachment for ribs and girdles
- Supporting the body trunk
- Imparting flexibility to the body trunk due presence of cartilaginous joints.

Muscles

A muscle is a tissue which contracts to produce movements in parts of the body or the entire body. There are three types of muscles, namely, **cardiac muscle**, **smooth muscle (visceral muscle)** and **skeletal muscle (striated muscle)**.



ADAM.

Cardiac muscle is found in the heart and has the following characteristics:

- It is **myogenic** (self-stimulating), meaning that the stimulus for contraction originates from the muscle itself
- It does not get fatigued
- The muscle cells (muscle fibres) are **branched and interconnected** forming a net-like structure
- The muscle cells die easily when deprived of oxygen and food or exposed to toxins.

Smooth muscles (visceral muscles) are made of long, **spindle-shaped** cells and are found in the walls of several body tubes and organs. Rings of smooth muscles are called **sphincters**.

Skeletal muscles are muscles which are attached to the skeleton and play a major role in locomotion. When viewed under the microscope they look striped (striated) and are therefore called **striated muscles**. They are **multinucleated** (each muscle cell has several nuclei).

Skeletal muscles are **voluntary** while cardiac and smooth muscles are **involuntary**. A voluntary muscle is a muscle whose contraction is **consciously** controlled by the brain.

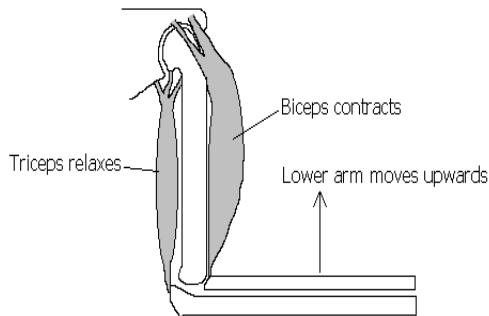
Skeletal muscles occur in pairs known as **antagonistic muscles**. Antagonistic muscles are **pairs of muscles** which produce **movement in opposite directions** at the **same joint**. The muscle that causes bending of the joint when it contracts is called a **flexor muscle** while the one that causes extending of the joint when it contracts is called the **extensor muscle**. Skeletal muscles occur in antagonistic pairs because each muscle can only contract but requires the contraction of another muscle to relax or lengthen it. Examples of antagonistic muscles are the **biceps** and **triceps** which act on the elbow joint. The biceps are the **flexor muscles** while the triceps are the **extensor muscles**.

The events involved in bending and straightening the elbow joint are summarised below:

(a) To bend the elbow joint

- The brain sends impulses to stimulate contraction of the biceps and inhibit contraction of the triceps.
- Biceps contract, thereby pulling the radius upwards and towards the humerus.
- Triceps relax and are stretched by the action of the biceps.
- The lower arm moves upwards thereby bending the elbow joint

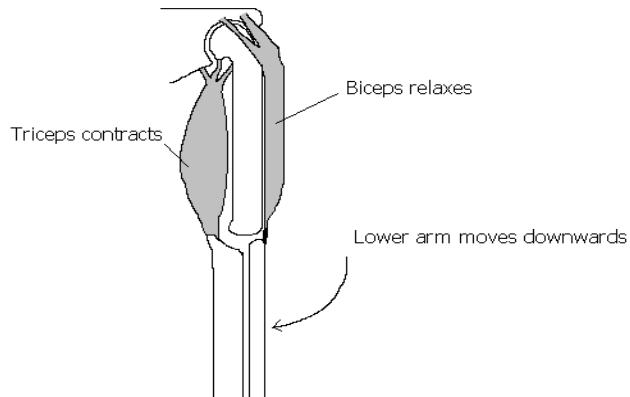
Figure 22: Flexing the Elbow Joint



(b) To straighten the elbow joint

- The brain sends impulses to stimulate contraction of the triceps and inhibit contraction of the biceps.
- Triceps contract and pull the ulna.
- The biceps are stretched by the contraction of the triceps
- The lower arm moves downwards, thereby extending the elbow joint.

Figure 23: Extending the Elbow Joint



Joints

A joint is defined as a point where two or more bones meet. There are three main types of joints, namely **fibrous**, **cartilaginous** and **synovial** joints. The names of these types of joints are based on their structures and the type of movement they permit

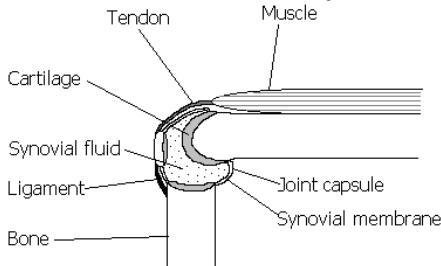
Fibrous Joints: These are joints where the bones are tightly held together by short and tough fibres. They permit no movement and are therefore called **immovable joints** e.g. the **sutures** between the bones of the skull (cranium).

Cartilaginous Joints: These are joints in which bones are held together by cartilage. They only permit slight movements and are therefore said to be **slightly movable joints** e.g. the **intervertebral discs** that hold the vertebrae together in the spine.

Synovial Joints: These are joints made of cavities containing a fluid called **synovial fluid** and they allow movement in one or more planes. They are said to be **movable joints**. There are several types of synovial joints. Two examples are **ball-and-socket joints** and **hinge joints**.

- **Ball-and-socket joints:** These are synovial joints where one bone has a round head (ball) and another has a depression (socket). These joints **allow movement in three planes** e.g. **hip joint** and **shoulder joint**.
- **Hinge joints:** These are synovial joints which **allow movement in only one plane**, usually through an angle of 180° e.g. the **elbow joint**, **knee joint**, **knuckle joints** and **joints of the phalanges**.

Figure 24: Structure of a Synovial Joint



The main parts of a synovial joint and their roles are summarised in the following table

Structure	Main Function	Description (where necessary)
Ligament	Joins bone to bone and keeps the joint stable by preventing dislocation	Elastic fibrous tissue made of an elastic protein called yellow elastin
Tendons	Joins muscle to bone; translate muscle contraction into movement of bone	Tough and inelastic fibrous protein largely made of a protein called collagen
Joint Capsule	Encloses the joint membrane	
Synovial fluid	Supplies nutrients and acts as a lubricant that reduces friction	
Synovial membrane	Secretes synovial fluid	
Cartilage	Reduces friction at ends of bones, absorbs mechanical shocks and spreads forces	Firm and flexible rubber-like tissue made of living cells and collagen fibres embedded in a matrix of chondrin

Disorders of Joints

(a) Gout

This is a condition characterised by formation of uric acid crystals at the joints. It leads to swelling and pain of joints. It can be controlled by reducing the intake of meat and meat products whose amino acids are easily converted to uric acid.

(b) Arthritis

This is inflammation of joints characterised by painful and swollen joints. The inflammation initially affects the synovial membranes but eventually causes damage to cartilage and bone, making movement difficult.

(c) Dislocation

This is a condition where one or more bones move out of place at a joint.

(d) Tuberculosis of the Bones: Formation of tubercles in the bones due to infection by *Mycobacterium tuberculosis*.

(e) Bone marrow cancer: the uncontrolled division of cells in the bone marrow.

Importance of the Skeleton

The human skeleton is important in the following ways:

- Supporting the body and providing the frame work of the body
- Movement and locomotion
- Protection of delicate body parts e.g. the brain is protected by the skull (cranium) while the heart and lungs are protected by the ribcage

- Production of blood cells i.e. some white blood cells are produced in the yellow bone marrow while red blood cells are produced in the red bone marrow.
- Transmission of sound from the ear drum to the oval window by ear ossicles
- The ribcage contributes to breathing by moving upwards and outwards (during inspiration) or downwards and inwards (during expiration)

REPRODUCTION

This is the process by which living organisms produce offspring (young ones of the same kind). There are two types of reproduction, namely **sexual** and **asexual** reproduction.

Asexual Reproduction

This is a type of reproduction where **one parent** produces one or more **genetically identical offspring** by **mitosis** without involving the fusion of gametes.

Advantages of asexual reproduction include:

- A mate is not required for offspring to be produced
- Large numbers of offspring can be produced in a short time
- Desirable features of parents are passed on to the offspring unchanged.
- It makes it possible to grow new plants of certain species even when seeds fail.
- It can take place even in harsh environmental conditions e.g. fungi such as *Mucor* switch to asexual reproduction when environmental conditions are harsh.
- No pollination and dispersal agents required for plants

Examples of plants produced using asexual reproduction are sugar cane (using stem cuttings), bananas (using suckers) and pineapples.

Disadvantages of asexual reproduction include:

- Undesirable features of parents are passed on to the offspring unchanged
- Lack of genetic variation makes it difficult to adapt to a variety of habitats.
- It often leads to overcrowding and competition for resources

Examples of asexual reproduction include **binary fission**, **multiple fission**, **budding**, **fragmentation**, **spore formation** and **vegetative propagation**.

Binary Fission

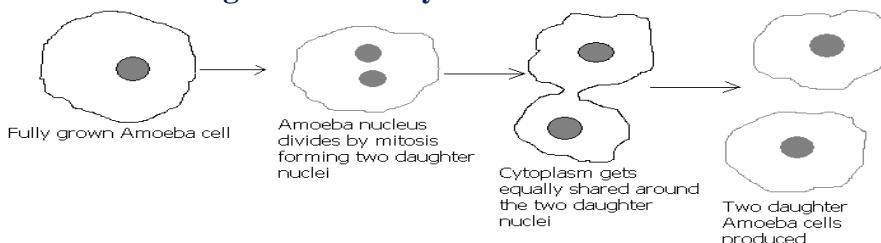
This is a type of asexual reproduction where one parent cell divides into two daughter cells.

The stages involved in binary fission are:

- The parent cell first grows bigger by increasing the amount of cytoplasm
- The DNA replicates and the nucleus undergoes mitosis, resulting in the formation of two daughter nuclei
- The cell membrane constricts thereby dividing the cytoplasm in two so that each nucleus is surrounded by its own cytoplasm
- The two daughter cells separate.

This type of reproduction occurs in **bacteria** and **Amoeba**.

Figure 25: Binary Fission in Amoeba

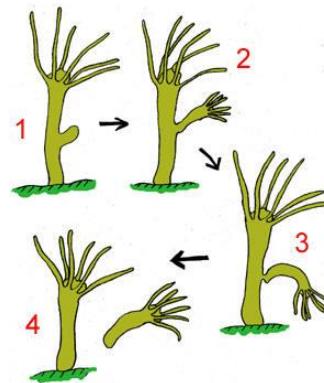
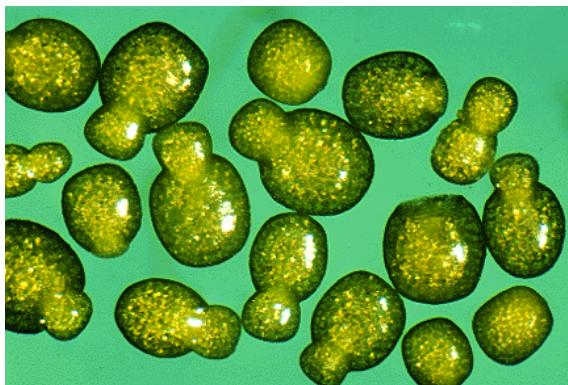
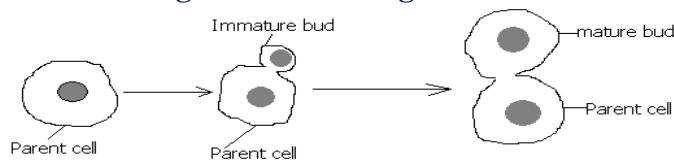


Budding

This is a type of asexual reproduction where a parent cell or body of an organism develops an outgrowth called a bud which increases in size and eventually detaches from the parent to

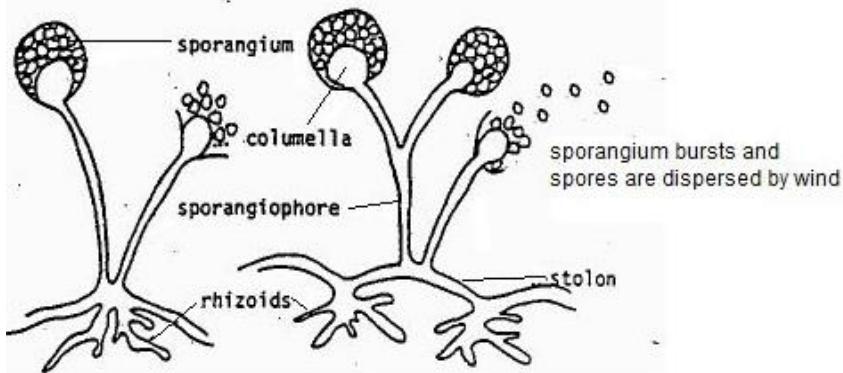
become an independent organism. Examples of organisms that carry out budding are **yeast** and **hydra**. A group of undetached buds is called a **colony**.

Figure 26: Budding in Yeast



Spore formation

This is a type of asexual reproduction where an organism forms spores. Spores are microscopic round structures produced asexually in very large numbers and are capable of germinating when conditions are favourable. They are normally produced when conditions are not favourable for sexual reproduction and are dispersed by wind. Examples of organisms that produce spores are the fungi *Mucor* and *Rhizopus*.



Note: *Mucor* and *Rhizopus* can also reproduce sexually by **conjugation** which results in formation of **zygospores**. They only carry out asexual reproduction when environmental conditions are harsh e.g. when the temperature is extremely low or high and when there is insufficient moisture.

Fragmentation

This is a type of asexual reproduction where pieces cut from an organism develop into independent organisms e.g. in **Spyrogyra**, some **flat worms** and **sponges**.

Vegetative Propagation

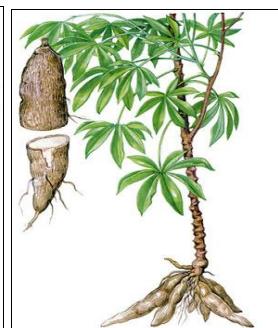
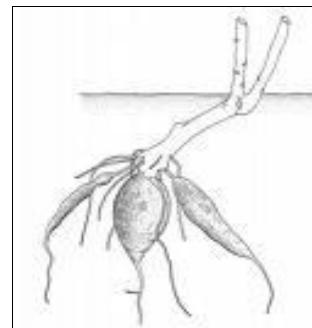
This term refers to asexual reproduction in flowering plants where new plants are grown from **vegetative parts** of a plant such as **roots**, **stems** and **leaves**, without involving seeds.

Vegetative propagation can be either natural or artificial.

(a) Natural vegetative propagation

A lot of flowering plants can naturally propagate themselves vegetatively using underground structures called **perennating organs** which enable plants to survive from year to year. The features possessed by perennating organs include **buds**, **adventitious roots** and **stored food**. Each **bud** can grow to form a single shoot. Buds that are located at the end of the stem are called **apical buds** while those located on the sides of the stems are called **lateral or axillary buds**. The buds are protected by structures called **scale leaves**. Adventitious roots are either present on the perennating organ or they quickly develop when conditions are favourable. Examples of perennating organs are **root tubers**, **stem tubers**, **corms**, **suckers**, **bulbs** and **rhizomes**.

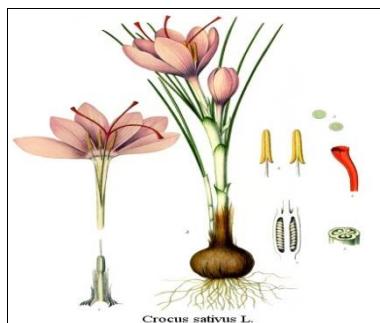
- **Root tuber:** This is a root that has become swollen because of stored food and is able to grow into a new plant e.g. sweet potatoes and carrots.



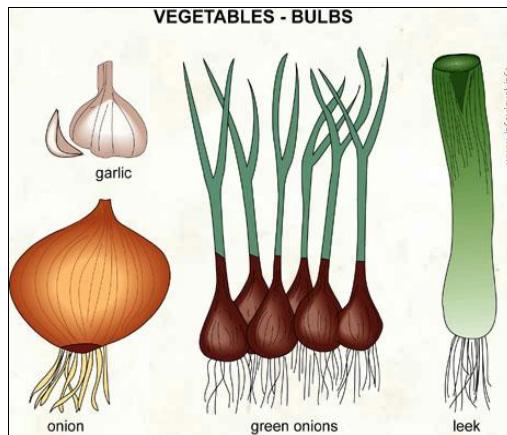
- **Stem tuber:** This is an underground stem that has become swollen because of stored food and contains eye buds that are able to grow into new plants e.g. Irish potatoes.



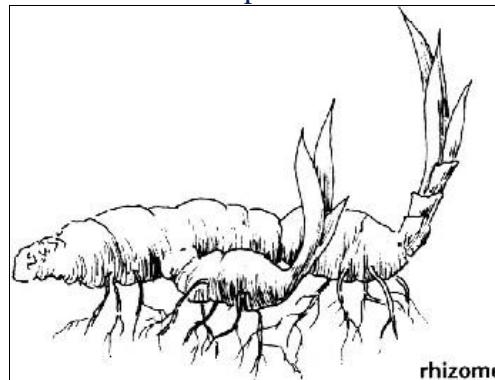
- **Corm:** This is swollen underground and vertical short stem with **apical** and **axillary buds** that can grow into new shoots e.g. *Crocus sp.*



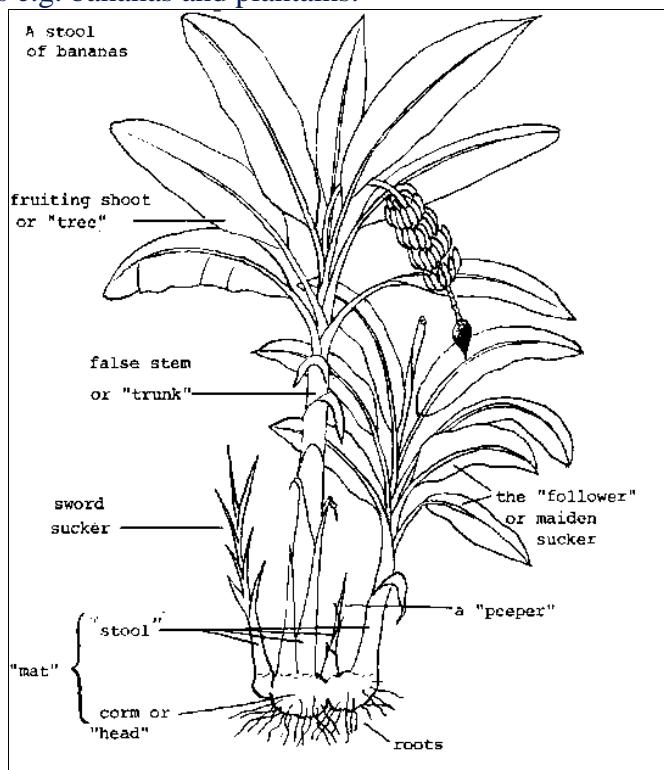
- **Bulb:** A bulb is made of underground fleshy leaves growing from a short stem e.g. garlic and onion (*Allium sp.*). The fleshy leaves contain food in them.



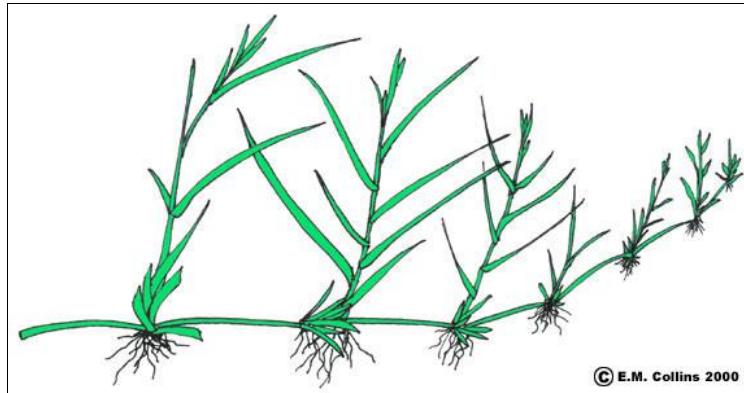
- **Rhizome:** This is a swollen underground horizontal stem e.g. ginger. A rhizome has adventitious roots and buds that can develop into new shoots at the nodes.



- **Suckers:** These are underground lateral branches of stems having terminal buds and adventitious roots e.g. bananas and plantains.



- **Runners, stolons and vines:** These are horizontal stems growing above the ground and have adventitious roots and buds at the nodes e.g. lawn grass, sweet potato vines.



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- **Leaves:** Certain plants such as *Bryophyllum* have leaves that are swollen with stored food and have buds and adventitious roots that can develop into new plants.

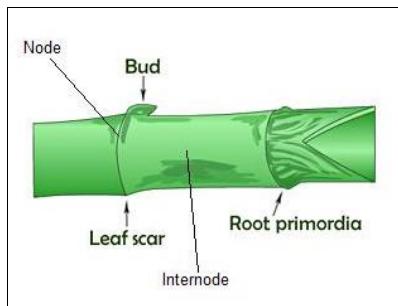


Exercise: Draw labelled drawings of a root tuber, stem tuber, corm, rhizome, bulb and stolon. Your drawings must show buds, adventitious roots and scale leaves, where necessary.

(c) Artificial Vegetative Propagation

Examples of artificial vegetative propagation are discussed below:

- **Stem Cuttings:** These are stems cut just below the node and planted to produce new plants. Adventitious roots develop from the node and the buds on the stem develop into shoots, giving rise to new plants. This method is enhanced by applying rooting powder to stimulate development of adventitious roots. Leaves are also removed from the stem to reduce the rate of transpiration. If there is a cut end exposed to the air, it is coated with paint or another substance to reduce water loss. Sugar cane and cassava can be propagated this way.

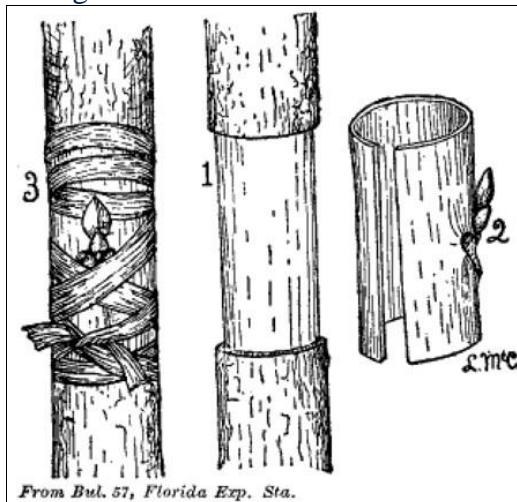


- **Grafting:** This involves bringing together a **stock** and a **scion** coming from two closely related plants i.e. plants of the same species or genus. The stock is the part whose aerial (upper) parts have been cut off and it provides an already established root system that is responsible for absorbing water and mineral salts. The scion is the aerial part that bears buds which later form the shoot. This is the part that has the desired stem, leaves, flowers or fruits. The stock and scion are cut with complementary shapes that fit into

each other before being tied together. The method works well if the stock and scion have identical diameters. Roses can be propagated using this method.

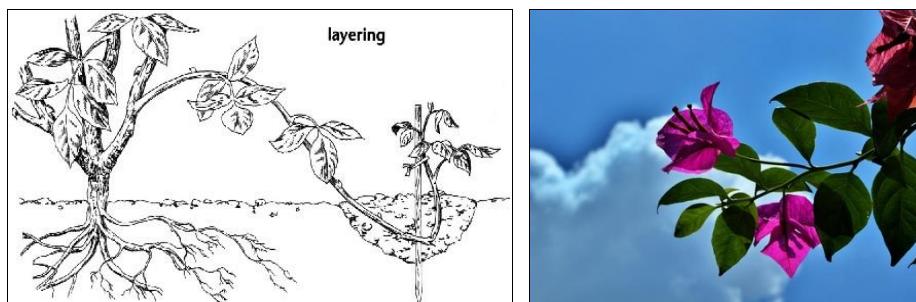


- **Budding:** This is a type of vegetative propagation where a **bud** is used as **scion** and the **bark** of an entire plant used as a **stock**. The bud is cut in such a way that it has some cambium. A **T-shaped cut** is made in the scion reaching up to the cambium. Then the bud (scion) is inserted into the T-shaped part of the stock in such a way that the cambium from the two parts is in contact. The two parts are tied together and sealed with wax, leaving the bud exposed. The wax prevents excessive transpiration. Citrus fruits can be propagated using this method.



- **Layering:** The involved in layering are:
 - Removing a ring of bark from a low-lying branch of plant to expose the cambium
 - Covering the wounded part of the branch with moist soil to stimulate the development of adventitious roots.
 - Separating the branch from the parent plant once it has developed new roots and shoots.

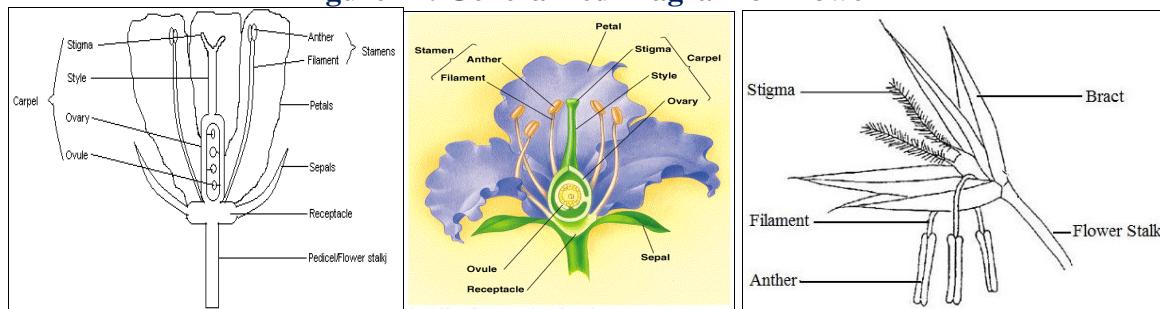
Bougainvillea and strawberry plants can be propagated using this method.



Sexual Reproduction in Plants

The sexual organs of plants are **flowers**. The following diagram illustrates a generalized structure of a flower.

Figure 27: Generalized Diagram of Flower



Flowers have male parts (**stamens** or **androecium**) and female parts (**carpels** or **pistil** or **gynoecium**). The male parts of a flower include the **filament** and **anther** while the female parts include the **stigma**, **style** and **ovary**.

Functions of Flower Parts

Pedicel or Flower Stalk: This part links the flower to the stem and conducts water, nutrients and hormones between these two parts.

Receptacle: This is the swollen end of the pedicel where other parts of the flower are attached.

Sepals: These are leaf-like structures that enclose the flower in the bud stage and protect it from desiccation (drying up) and damage by pests and harsh weather conditions. A group of sepals from the flower is called a **calyx**

Petals: These are structures that are **brightly coloured** and **scented** in insect-pollinated flowers to attract insects. In some flowers, the petals have **nectar guidelines** that lead to the nectaries in the flowers.

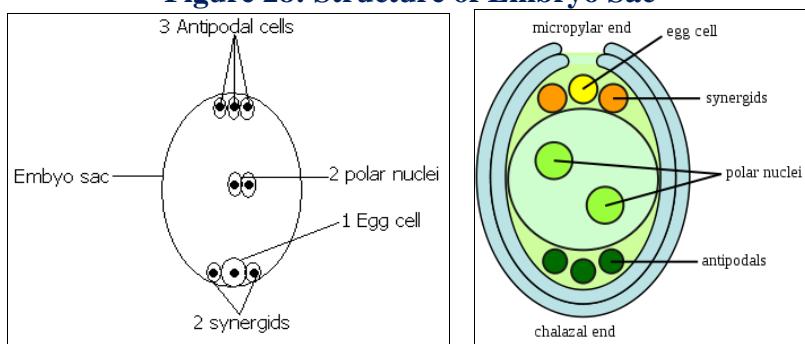
Stigma: This is the part that where pollen grains are deposited during pollination.

Style: This holds the stigma in position and links it to the ovary. It is also used as a passage for the pollen grain on its way from the stigma to the ovary through the pollen tube.

Ovary: This is the part that makes and contains ovules. It becomes the fruit after fertilization.

Ovule: Ovules contain female gametes and they develop into seeds after fertilization. Each ovule has an embryo sac containing eight haploid nuclei as illustrated in the following diagram:

Figure 28: Structure of Embryo Sac



Anther: A structure made of pollen sacs where pollen grains are made and stored.

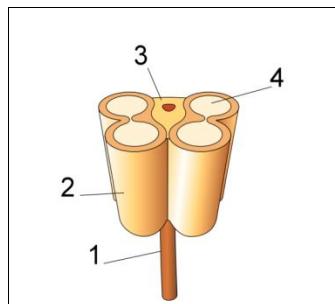
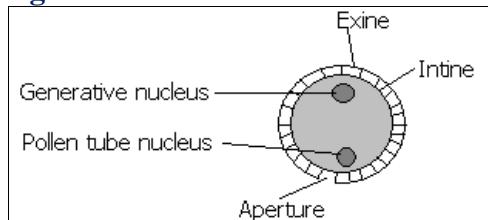


Figure 29: Structure of Pollen Grain



Filament: This supports the anther and supplies it with water and nutrients.

Pollination

This is the transfer of pollen grains from the anther to the stigma on the same plant or different plants of the same species. There are two types of pollination, namely **self pollination** and **cross pollination**. Self pollination is the transfer of pollen grains from the anther to the stigma on the same plant while cross pollination is the transfer of pollen grains from an anther present on a given plant to a stigma on another plant of the same species.

Exercise: Most species of plants favour cross pollination.

- (a) Suggest the advantages of cross pollination over self pollination.
- (b) What mechanisms in plants favour cross pollination?

Agents of pollination include mainly **insects** and **wind**. Insect-pollinated flowers are also called **entomophilous flowers** while wind pollinated flowers are also called **anemophilous flowers**. The following table compares the structures present in insect and wind pollinated flowers:

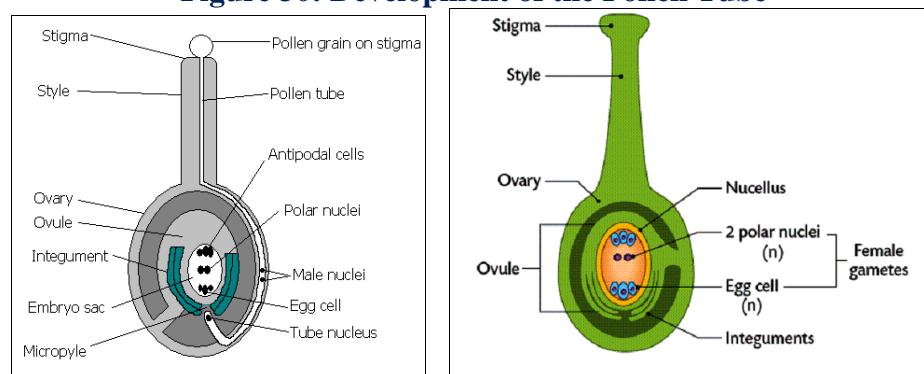
Structure	Insect-pollinated flower	Wind-pollinated flower
Petals	Brightly-coloured, scented, large and have nectaries	Dull-coloured, non-scented, small, and have no nectaries
Anthers	Small, firm and enclosed within petals	Large, pendulous and exposed.
Filaments	Short and firm	Long and dangling outside the flower
Stigmas	Short, firm, lobed and enclosed in petals to ensure insects brush against them	Long, feathery and exposed so as to easily trap pollen grains from air
Pollen grains	Large, few and sticky	Small, numerous and smooth

The Pollen Tube and Fertilization

After pollination, the pollen grain absorbs water from the stigma and becomes swollen. Then the **pollen tube nucleus** (tube nucleus) germinates to form a pollen tube which grows through the stigma, style and ovary until it reaches the embryo sac inside the ovule. To form the pollen tube, the pollen tube nucleus secretes enzymes that break down part of the stigma, style and ovary. Growth of the tube nucleus towards the ovule is guided by chemicals secreted by the **synergids** that are found in the ovule. This is an example of **positive chemotropism**. After reaching the **micropyle** (an opening in the wall of the ovule), the tube nucleus disintegrates.

The generative nucleus follows the tube nucleus behind and divides into two haploid cells called **male nuclei** (singular=male nucleus). The first male nucleus fuses with the egg cell to form a **diploid zygote** which later develops into the embryo. The second male nucleus fuses with two polar nuclei to form a **triploid cell** which later develops into the **endosperm**. The function of the endosperm is to act as a food storage tissue. This type of fertilization where one male nucleus fuses with the egg cell to form a diploid zygote and the other male nucleus fuses with two polar nuclei to form a triploid cell is called **double fertilization**.

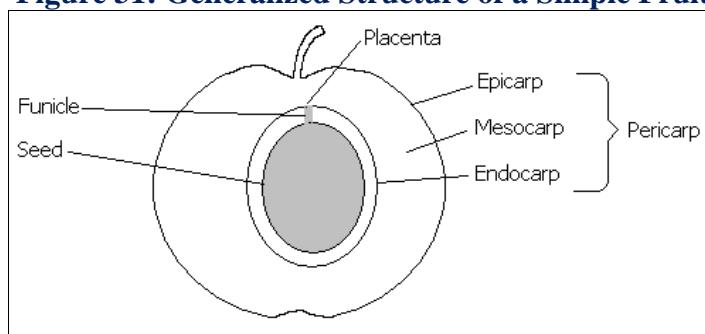
Figure 30: Development of the Pollen Tube



After fertilization, the ovule develops into a seed while the ovary develops into a fruit. Refer to notes on plant growth and development for seed structure.

Fruit Structure

Figure 31: Generalized Structure of a Simple Fruit



Fruit and Seed Dispersal

This refers to the scattering of fruits or seeds from the parent plant to others places. The advantages of seed dispersal are:

- It reduces competition for light, space, gases and nutrients

- It allows plants to colonize new areas
 - It reduces the chances of extinction in case the plants in one location are destroyed
- The adaptations of fruits and seeds to their methods/agents of dispersal are discussed below:

(i) Animal-dispersed Seeds

Animal-dispersed seeds have the following characteristics:

- Presence of **hooks** to cling to the fur of animals e.g. black jack (*Bidens pilosa*). The hooks irritate the animal causing it to shake the seeds off some distance away from the parent plant.

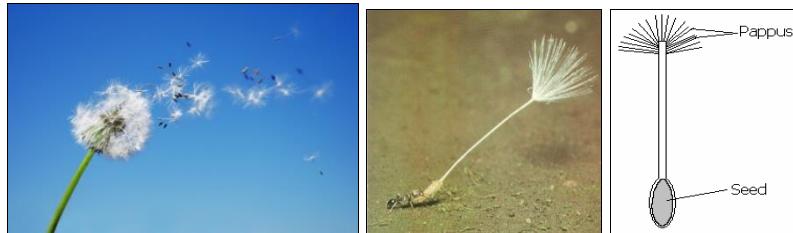


- **Succulent** (juicy) mesocarps to attract and reward animals e.g. mangoes.
- **Brightly coloured** epicarps to attract animals to fruits, especially when ripe e.g. oranges.
- Seeds have hard testas that are **resistant to digestive enzymes** found in the guts of animals e.g. guavas.
- **Scented fruits** to attract animals e.g. oranges.

(ii) Wind-dispersed Fruits

Wind-dispersed seeds have the following characteristics:

- '**Parachute**' of hairs (**pappus**) formed from sepals after fertilization causes the fruit to float thereby delaying landing and encouraging dispersal. An example of a seed that has a pappus is the dandelion seed.



- **Wing-like Structures** that cause the fruit to float thereby delaying landing and encouraging dispersal. An example of a seed that has wing-like structures is the sycamore seed as illustrated in the following diagram.



Figure 32: Wind-dispersed Fruits

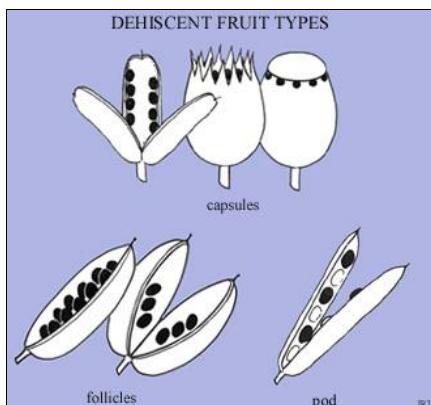
(iii) Water-dispersed fruits

Water-dispersed fruits have **fibrous pericarps** that enable them to float in water e.g. coconut fruits.



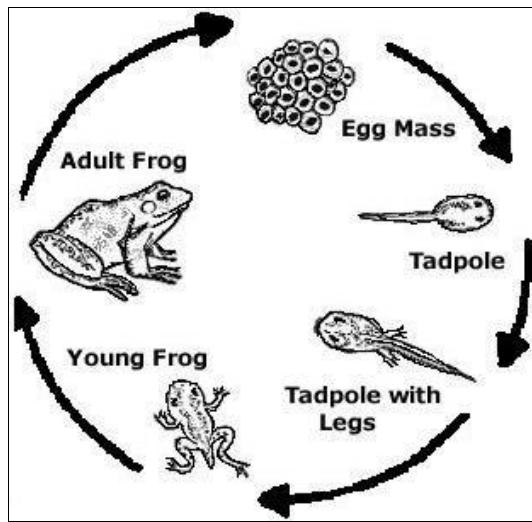
(iv) Self-dispersed fruits (Explosive mechanism of Dispersal)

Such fruits have fruit walls that develop tension and split to scatter seeds when dry. Such pods (fruit walls) are said to be **dehiscent pods**. This mechanism of dispersal is common in legume fruits e.g. beans.



Sexual Reproduction in Frogs

Frogs require water in order to reproduce. This is because their eggs and larval stages are adapted to obtain their oxygen from water. Mature male frogs attract females for mating by making croaking sounds. The male mounts the female in water to start the copulation process. During copulation, the female produces **a large number of eggs** which are then fertilized by spermatozoa from the male outside of the female's body. This is called **external fertilization**. Once the eggs have been laid, there is **no parental care** but they are left to develop on their own. Each egg contains egg yolk which is rich in food needed for development of the embryo until it hatches to produce a **tadpole**. The tadpole moves through water by propelling itself using a tail and obtains oxygen from water using gills.

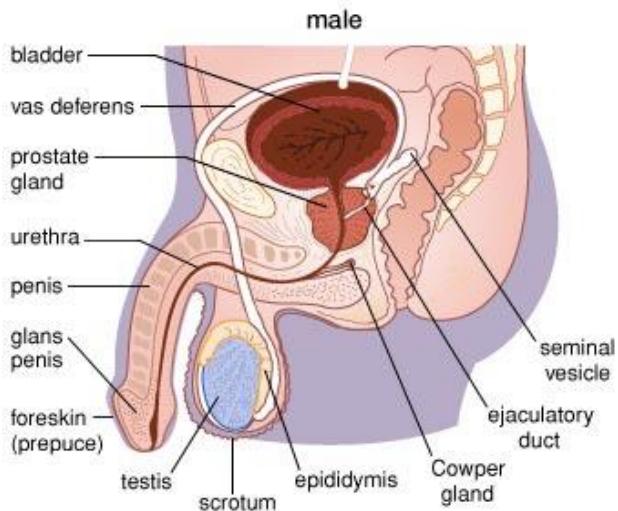


Sexual Reproduction in Humans

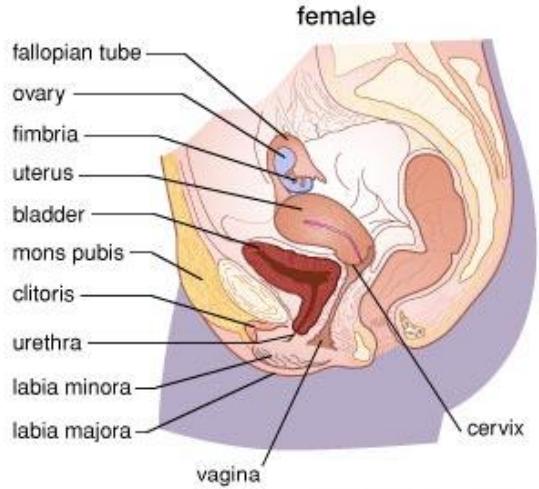
Human bodies are equipped with **sexual organs** (gonads) that are used for sexual reproduction. The male gonads are called **testes** (singular= testis) while the female gonads are called **ovaries**. The female and male gonads occur on separate bodies and are part of the **reproductive system**.

Figure 33: Male and Female Reproductive Systems

Male Reproductive System-Side view Side view



Female Reproductive System- Side view



Functions of Parts of the Male Reproductive System

Testes (singular= testis): These are a pair of structures that produce spermatozoa (sperm) and secrete the hormone called **testosterone**. They are found in a sac of skin called the scrotum located outside the lower abdomen. The scrotum holds the testicles outside the body to keep them at a temperature slightly lower than that of the body for more effective production of spermatozoa.

Epididymis: This is made of coiled tubes where sperms are stored.

Sperm duct (vas deferens): This is the tube that carries spermatozoa from the epididymis to the urethra.

Urethra: This is the tube that carries semen from the sperm duct and urine from the bladder.

Penis: This is an erectile organ that is used to deposit semen into the vagina during sexual intercourse. The semen is deposited into the vagina by a process called **ejaculation**.

Functions of Parts of the Female Reproductive System

Ovaries: These are a pair of gonads responsible for formation of eggs and for secretion of oestrogen and progesterone.

Oviduct: This is the tube through which the ovum travels from the ovary to the uterus. It is also the site where fertilization occurs.

Uterus: This is the site for implantation and development of the foetus.

Cervix: This connects the vagina to the uterus and forms part of the birth canal. It is the point where semen is deposited during sexual intercourse. The cervix also secretes fluids that lubricate the vagina during sexual intercourse.

Vagina: This is the part where an erect penis is inserted during sexual intercourse. It also forms part of the birth canal.

Secondary Sexual Characteristics

During sexual development, the human being first develops the **primary sexual characteristics** which include the sexual organs and the reproductive systems. To complete its sexual development, the human body must develop **secondary sexual characteristics**. These are characteristics that a human body develops after reaching **puberty**. They make the body more adapted to carry out reproduction and are influenced by hormones. In males, their development is influenced by the hormone called **testosterone** which is secreted by the **testicles**. In females, their development is influenced by the hormone called **oestrogen** which is secreted by the **ovaries**.

Female Secondary Sexual Characteristics

- Menstrual cycle commences
- Enlargement of breasts
- Widening of hips
- Development of pubic hair and hair in the armpits
- Enlargement of vagina
- Skin becomes more tender and supple

Male Secondary Sexual Characteristics

- Sperm production
- Enlargement of testicles and penis
- Development of pubic hair, beards, hair on the chest and in the armpits
- Deepening of voice
- The body becomes more muscular

Note: Females stop their menstrual cycles when they reach a stage of sexual development called **menopause** (at 45 to 50 years of age)

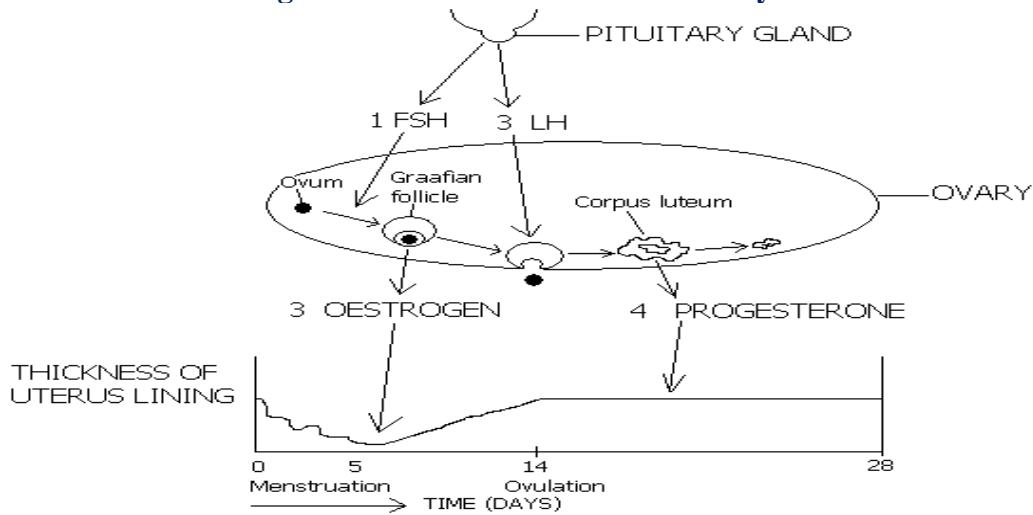
The Menstrual Cycle

This is a cycle of about **28 days** during which a woman experiences **ovulation** and **menstruation**, one after the other. Ovulation is the release of an ovum from the ovary. Menstruation is the shedding of the uterus lining together with some blood through the vagina which occurs when an ovum does not get fertilized. It lasts three to five days. Ovulation and menstruation occur approximately 14 days (two weeks) after each other.

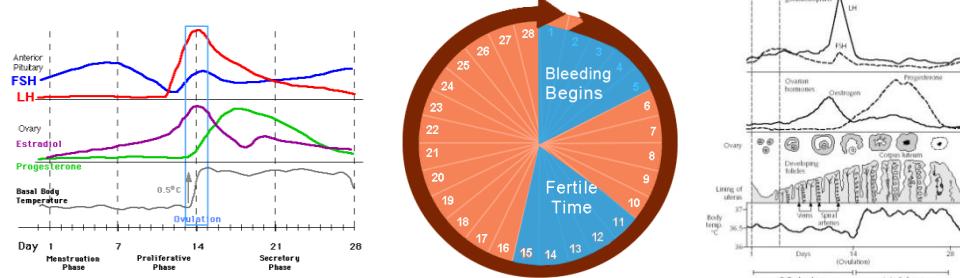
The menstrual cycle is controlled by hormones secreted by the **pituitary gland** and the **ovaries**. The hormones from the pituitary gland (**follicle stimulating hormone** and **luteinising hormone**) act on the ovaries while those from the ovaries (**oestrogen** and **progesterone**) act on the lining of the uterus (endometrium). The roles of these hormones are summarized below:

- (i) Follicle Stimulating Hormone (FSH) is secreted by the pituitary gland and causes ripening of the eggs in the ovaries by stimulating the development of Graafian follicles around them.
- (ii) Oestrogen is secreted by the Graafian follicle in the ovary. It builds up the lining of the uterus, inhibits further secretion of follicle stimulating hormone and stimulates secretion of luteinising hormone.
- (iii) Luteinising Hormone (LH) is secreted by the pituitary gland. It stimulates ovulation and the development of the corpus luteum (yellow body) from the remains of the Graafian follicle.
- (iv) Progesterone is secreted by the corpus luteum in the ovaries. It maintains the growth of the uterus lining and increases blood supply to it in readiness for implantation in case fertilization occurs. It also inhibits secretion of FSH and LH by the pituitary gland. However, the corpus luteum gets progressively smaller until it completely degenerates and there is no more progesterone being secreted. When this happens, lining of the uterus breaks down and the pituitary gland starts secreting FSH to begin the cycle all over again. On the other hand, if the egg gets fertilized, the corpus luteum takes longer to degenerate until the placenta has developed in the uterus.

Figure 34: Events of the Menstrual Cycle



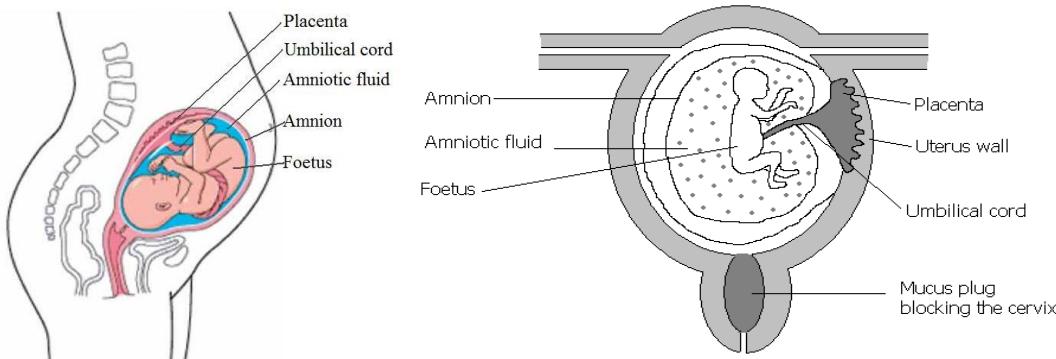
The Menstrual Cycle



Fertilization, Implantation and Foetal Development

Fertilization is the fusion of the nucleus of a male gamete with the nucleus of a female gamete to form a single cell called a **zygote**. It normally occurs in the oviduct. After fertilization, the zygote travels through the oviduct towards the uterus and divides repeatedly by **mitosis** to form an **embryo**. Upon reaching the uterus, the embryo undergoes **implantation**. Implantation is the process by which an embryo gets attached to the wall of the uterus (about 11 or 12 days after fertilization). As the embryo develops, it forms temporal organ known as the **placenta**. As soon as vital organs begin developing, the embryo's name changes to **foetus**. This occurs 6 to 8 weeks after fertilization.

Figure 35: Ten-week Old Foetus



The Placenta: The placenta performs the roles normally performed by the intestines, kidneys and lungs in adult human being. These include absorption of food, excretion and gaseous exchange, respectively. The functions of the placenta are summarized as follows:

- Attaching the foetus to the uterus of the mother
- Protecting the foetus from the mother's immune system, mother's blood pressure and pathogens. It does this by forming a barrier that prevents mixing of the blood of the mother and the blood of the foetus.
- Exchange of materials between foetus and mother by the process of diffusion. Dissolved food and oxygen diffuse from the mother's blood to the blood of the foetus while carbon dioxide and urea diffuse from the blood of the foetus to the mother's blood. The placenta has finger-like projections called villi that increase the surface area for exchange of substances.
- Secretion of hormones. It secretes progesterone to maintain the thickness of the uterus lining during pregnancy. It also secretes **human chorionic gonadotrophin** (HCG) which prolongs the activity of the corpus luteum. The presence of HCG in the urine of a woman is a sign that she is pregnant.

Besides the useful materials that cross the placenta from the mother's blood to the blood of the foetus, some harmful substances that are made of small molecules also manage to cross the placenta and affect the baby negatively. These substances include **carbon monoxide from cigarette smoke**, **drugs such as alcohol** and **viruses**. Carbon monoxide combines with haemoglobin irreversibly, thereby reducing the amount of oxygen available to the cells of the foetus. This leads to low birth weights. Alcohol makes a baby be born with a condition called **foetal alcoholic syndrome** (FAS) which is characterized by mental retardation and deformation of the baby.

Umbilical Cord: The umbilical cord contains blood vessels (umbilical artery and umbilical vein) that transport blood between the foetus and the placenta. The umbilical artery carries blood rich in metabolic wastes (mainly carbon dioxide and urea) from the foetus to the placenta while the umbilical vein carries blood rich in dissolved food and oxygen from the placenta to the foetus.

Amnion and Amniotic Fluid: The amnion is the membrane responsible for enclosing the amniotic fluid. The amniotic fluid protects the foetus from mechanical shocks, drying up and also maintains a constant temperature around the environment of the foetus.

NB: The mucus plug blocks the cervical canal to keep away foreign substances from the uterus during pregnancy.

Exercise: Write a short essay to describe the special dietary needs of a pregnant woman.

Gestation Period and Birth

Gestation period refers to the period of time between fertilization and birth. In human beings, the gestation period lasts for about nine months for a boy child and about eight months for a girl child. The process of birth is made of three main stages, namely **dilation**, **delivery** and **afterbirth**. Dilation is the first major stage of birth and involves widening of the cervix in readiness for expulsion of the baby from the uterus. Before dilation, a woman experiences intermittent contractions of the uterus which are called **labour pains**. Labour pains are initiated by a hormone called **oxytocin**, which is secreted by the pituitary gland. After dilation, the amnion bursts to release amniotic fluid. This is called the **breaking of the waters**. The second major stage is delivery which is the expulsion of the baby from the uterus. This is brought about by strong contractions of the uterus, coupled with voluntary contractions of the abdominal muscles by the woman. During a normal delivery, the head of the baby comes out first. If the legs come out first, the birth is called a **breach**. The third and final stage of birth is the expulsion of the placenta from the uterus through the vagina. This is called the after-birth.

Birth Control (Family Planning)

This involves limiting the number of children and spacing their births so as to get the following benefits:

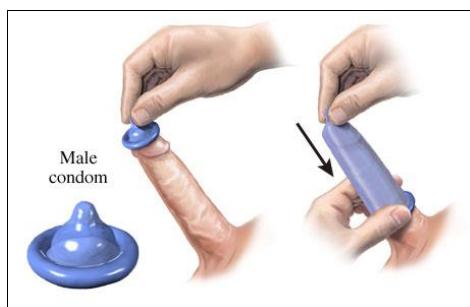
- Give the mother time to recover from the effects of giving birth before she can have another child.
- Ensuring each child receives enough nutrition, shelter, clothing, education and attention.

The methods of birth control are also called **contraceptive methods** because they are used to prevent conception (fertilization and implantation). Contraceptive methods are divided into two groups, namely **natural methods** and **artificial methods**. Natural methods include the **withdrawal method** (coitus interruptus) and the **rhythm** (safe period) method. The main advantage of natural methods is that they cost no money. Otherwise, they are unreliable and require a lot of discipline. Artificial methods include **barrier methods** (condom, diaphragm and intra-uterine device), **chemical methods** (spermicides and hormones such as those found in the oral contraceptive pill) and **surgical methods** (vasectomy and tubal ligation or laparotomy)

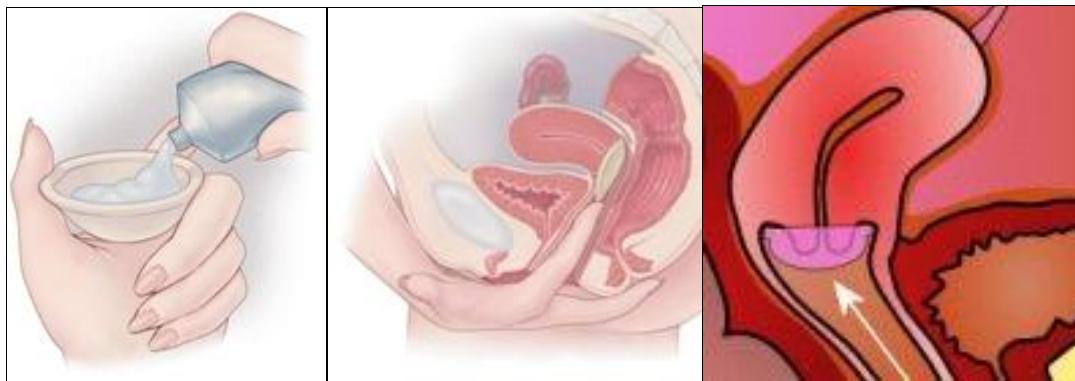
Withdrawal Method: This is the removal of the penis from the vagina just before ejaculation. It is an unreliable method because the fluids that a man releases before ejaculation contain traces of spermatozoa that may still fertilize an ovum.

Rhythm Method: This is a contraceptive method where a couple only copulates during the safe period of the menstrual cycle when fertilization is less likely to occur. This method is also unreliable because the length of the menstrual cycle is modified by factors such as type of diet, stress and physical exercise.

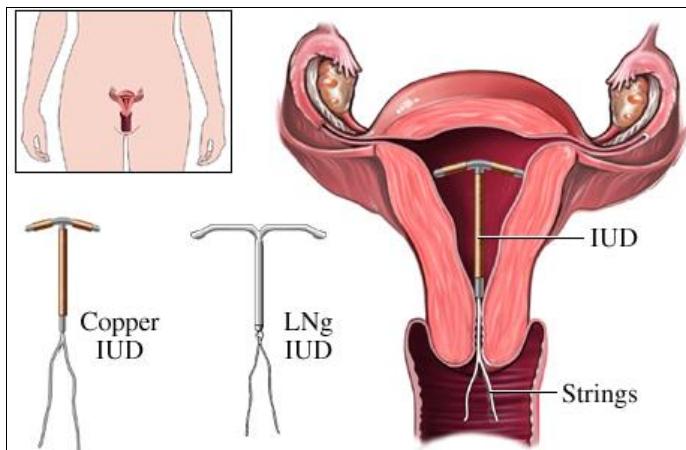
Condoms: A condom is a thin latex sheath that is fitted around an erect penis or inserted into the vagina before intercourse so as to keep semen from being deposited directly into the vagina. It is the only contraceptive method that prevents the transmission of sexually transmitted infections (STI's) such as syphilis, gonorrhoea and AIDS. However, if expired or not properly used, they can break or leak. Some people complain that they reduce enjoyment of sex and cannot be used spontaneously.



Diaphragm (cap): This is a thin latex cap fitted over the cervix before intercourse so as to block spermatozoa from entering the uterus. It is more reliable if used in conjunction with spermicides. Initially, the diaphragm must be fitted by a doctor.



Intra-uterine Device (IUD): This is a device made of plastic and copper wire that is inserted into the uterus to prevent implantation by irritating the lining of the uterus. The device can only be fitted by experts and it may cause discomfort if wrongly placed.

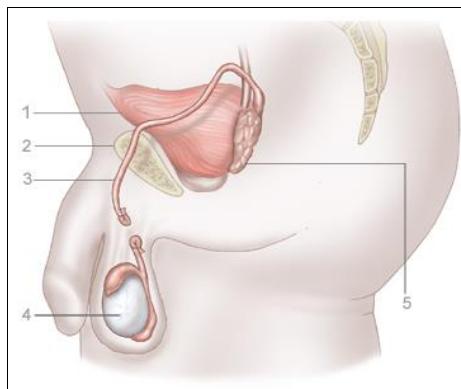


Spermicides: These are chemical substances that are applied inside the vagina before sexual intercourse in order to kill spermatozoa. They are normally used together with the diaphragm.

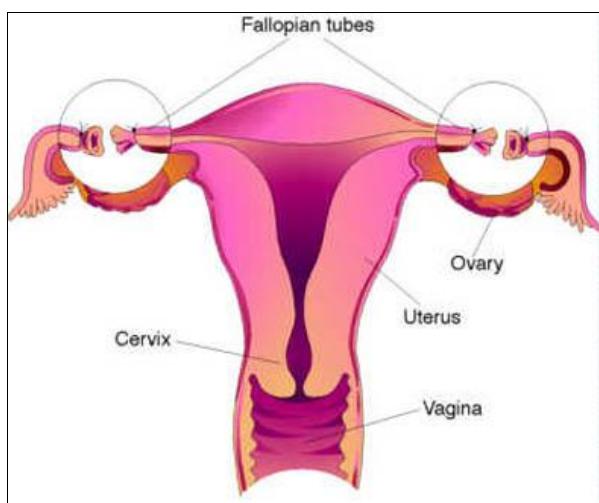
Hormones: Hormones such as oestrogen and progesterone are administered in the form of pills or injections to prevent ovulation and implantation. They are only reliable if taken according to prescription and may have side effects such as interfering with the pattern of the menstrual cycle, nausea and weight gain.



Vasectomy: This is the cutting and tying of sperm ducts to block passage of spermatozoa from the testicles. The man is still able to engage in sexual intercourse but ejaculates seminal fluids that have no spermatozoa. The method is highly reliable but may be irreversible.



Tubal Ligation (Laparotomy): Oviducts are cut and tied to prevent passage of eggs from the ovaries to the uterus. This method is also highly reliable and usually irreversible.



HUMAN HEALTH AND DISEASE

Health is defined as a state of physical and mental well-being. A **disease** is any physical or mental disorder that interferes with normal functioning of the body and has a characteristic set of signs and symptoms. A **sign** is any indication of a disease which can be observed or measured e.g. a rash, a high temperature and loss of weight.

A **symptom** is any indication of a disease that can only be felt and described by a patient e.g. headache and other kinds of pain, nausea and dizziness.

Groups of Diseases

There are two main categories of diseases which are **infectious diseases** (transmissible diseases) and **non-infectious diseases** (non-transmissible diseases).

Infectious Diseases

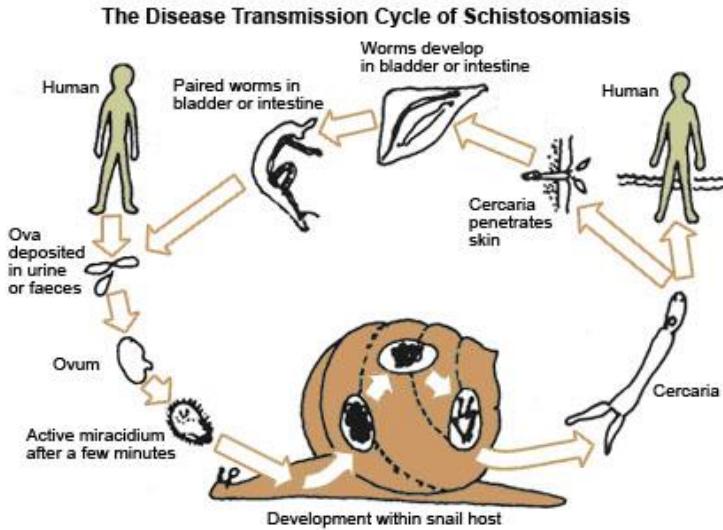
Infectious diseases are those diseases that can be transmitted from person to person. They are also called **pathogenic** diseases because they are all caused by **pathogens**. Pathogens are disease-causing organisms, mainly microorganisms. Pathogens include viruses, bacteria, protozoa, fungi and worms. Methods by which infectious diseases spread include the following:

- **Through vectors.** A vector is an organism that transmits a pathogen from one organism to another. There are two types of vectors, namely **mechanical vectors** and **biological vectors**. A mechanical vector is one that carries pathogens on its body surface e.g. the house fly is a mechanical vector for the cholera pathogen. A biological vector is one that carries the pathogen inside its body and the pathogen undergoes part of its life cycle inside its body. For this reason, the biological vector is considered to be a **secondary host** of the pathogen. The mosquito is a biological vector for the malaria parasite known as *Plasmodium*. Insects tend to be very effective vectors because their capacity to move fast by flying and their ability to occupy different types of habitats.
- **Inhalation of infected air droplets.** A number of respiratory diseases are spread when a healthy person inhales infected droplets released into the air when an infected person coughs or sneezes. Examples of such diseases are tuberculosis, pneumonia, influenza, measles and diphtheria.
- **Taking contaminated food and water.** Transmission by this method occurs for diseases such as cholera, typhoid, dysentery, intestinal worm infections and hepatitis (A and B).
- **Contact with infected water** e.g. bilharzia and hook worms.
- **Contact with infected organisms** e.g. ringworm, athlete's foot and thrush.
- **Sexual Intercourse** e.g. gonorrhoea, syphilis and AIDS. Such diseases are called **sexually transmitted infections (STI's)** or **sexually transmitted diseases (STD's)**.

The following table summarizes the causative agents, signs, symptoms, methods of transmission and methods of control for selected pathogenic diseases.

Disease	Causative Agent	Signs and Symptoms	Methods of Transmission	Treatment and Methods of Control
Bilharzia (Schistosomiasis)	<i>Schistosoma</i> (<i>S. mansoni</i> , <i>S. haematobium</i> & <i>S. japonicum</i>)	Anaemia, tiredness, blood in urine and in faeces (eggs of <i>Schistosoma</i> have hooks that damage blood vessels of bladder and gut)	Exposure to cercaria larvae in water	Sanitary disposal of urine and faeces; boiling or treatment of water before use; treatment with drugs
AIDS (Acquired Immune Deficiency Syndrome)	A virus called human immunodeficiency virus (HIV)	Loss of weight; skin cancer; tiredness; opportunistic infections such as pneumonia, tuberculosis and diarrhoeal diseases	Sexual intercourse with an infected partner; contact with infected blood; mother to child transmission	Avoid unprotected casual sex; be faithful to one sexual partner; avoid sharing piercing and cutting utensils; screening of blood before transfusion; no cure yet
Malaria	A protozoon called <i>Plasmodium</i>	Headache; fever; anaemia; pain in muscles and joints; shivering and sweating	Bite from female <i>Anopheles</i> mosquito	Treatment with anti-malarial drugs; controlling or killing of mosquitoes; preventing mosquito bites

Cholera	A bacterium called <i>Vibrio cholera</i>	Vomiting and diarrhoea (rice water like stool) ; dehydration	Taking contaminated food and water; contact with infected person	Sanitary disposal of faeces; boiling or chlorination of drinking water; warming and covering of food; quarantine of patients; treatment with antibiotics and replacement of salts and water using oral rehydration salt (ORS)
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Non-transmissible Diseases

These are diseases that cannot be passed from one individual to another. They are divided into the following categories:

(i) Nutritional Deficiency Diseases: Diseases caused by poor diets lacking one or more essential nutrients.

Examples of such diseases are marasmus, kwashiorkor and rickets.



(ii) Genetic (inherited) Diseases: Diseases that are passed through genes from parents to their offspring e.g. sickle

cell anaemia, haemophilia and down's syndrome.



(iii) Degenerative Diseases: Diseases characterized by a gradual decline in the function of an organ as a result of ageing or too much stress on the organ e.g. arthritis and coronary heart disease.

(iv) Environmental Diseases: Diseases resulting from the presence of pollutants in the environment e.g. bronchitis,

emphysema and lung cancer resulting from the presence of tar in the air.

(v) Mental Disorders: Disorders of the mind caused by chemical or physical factors e.g. schizophrenia.

(vi) Self-inflicted and Social Diseases: These include conditions like drug addiction.

IMMUNITY

This refers to resistance of the body to infection due to the presence of antibodies in the blood. Antibodies are proteins produced by lymphocytes are responsible for destroying antigens produced by infectious or foreign bodies. Each type of antibody is only effective against one particular type of antigen. The body can only produce antibodies against an antigen that it has been exposed to.

Types of Immunity

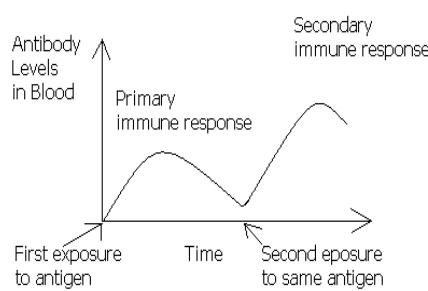
Immunity is said to be **active** if the body is involved in the production of antibodies and **passive** if the body receives ready made antibodies from an external source. Both active and passive immunity can be **natural** (if acquired through natural means such as getting infected, breast feeding or across the placenta from a mother to an unborn baby) or **artificial** (if acquired through man-made means such as vaccination or immunization). The following table gives examples of different types of immunity:

Type of immunity	Definition or Description	Examples
Natural Active Immunity	The body gets naturally infected and gets stimulated to produce antibodies against the infection	A person becomes permanently immune to measles if they have suffered from it before
Artificial Active Immunity	Introducing dead or weakened (attenuated) germs or antigens into the blood stream of a person so as to stimulate production of antibodies by the body. This process is called vaccination	BCG vaccination against tuberculosis; polio vaccine ; cowpox vaccine e.t.c.
Natural Passive Immunity	Ready-made antibodies are introduced into the blood stream of a person through natural means such as breast feeding or across the placenta from a mother to an unborn baby to give immediate but temporal protection against particular antigens.	

Artificial Passive Immunity	Immune serum containing ready-made antibodies is injected into the blood stream of a person to give immediate but temporal protection against a particular antigen.	Anti-venom or anti-tetanus injections
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Note: The immunity of a person may be determined by determining the levels of antibodies in the blood stream. In passive immunity, the levels of antibodies shoot up immediately after the person has received them. However the levels go down with time because the antibodies are destroyed by the spleen and the liver. It takes another introduction of antibodies to raise the levels again. For active immunity, the immune response that occurs after being exposed to an antigen for the first time is called the **primary response**. After the primary response, the body makes memory cells that produce antibodies more rapidly the next time there is a similar infection. The immune response that occurs after being exposed to an antigen for the second time is called the **secondary response**. The secondary response is always greater and more rapid than the primary response. The next two diagrams illustrate passive immunity and active immunity:

Active Immunity



Passive Immunity

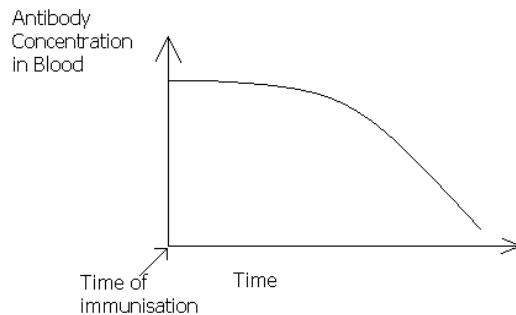


Figure 36: Changes in Levels of Antibodies with Time in Active and Passive Immunity

Immunity is important for prevention of diseases. Factors that reduce immunity include **poor diet**, **development of resistant strains of pathogens**, **repeated invasions by pathogens**, **intake of immuno-depressant drugs** and **infection by HIV** that destroys the lymphocytes.

GENETICS

Genetics is the study of the mechanisms involved in the **control**, **transmission** and **expression** of inherited characteristics.

Variation

This refers to the differences in characteristics among organisms of the same species. There are two types of variation, namely **continuous variation** and **discontinuous variation**.

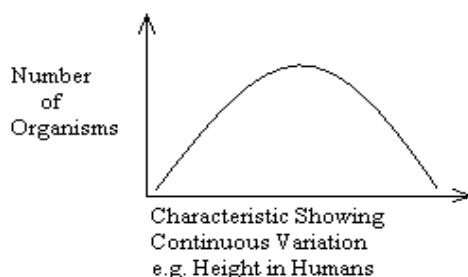
Continuous variation

This is a type of variation where a characteristic has **many intermediate forms** between **two extremes**. Examples of characteristics that show continuous variation in humans are **height**, **complexion** and **body mass/size**. The causes of continuous variation include:

- **Control by many genes**/control by many pairs of alleles/polygenic control
- **Influence by environmental factors** such as diet, climate e.t.c

When the number of individuals is plotted against a characteristic that shows continuous variation, a **normal distribution curve** (bell-shaped curve) is produced, as illustrated in the following diagram:

Figure 37: Graph Illustrating Continuous Variation



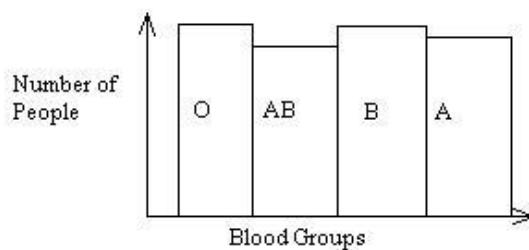
Discontinuous variation

This is a type of variation where a characteristic has **clear-cut different groups (distinct groups)**, with **no intermediate forms**. Examples of characteristics which show discontinuous variation in humans are **sex, blood groups and colour of eyes**. The causes of discontinuous variation include:

- Control by one or few genes (control by one or few pairs of alleles)
- Lack of environmental influence.

Characteristics which show this kind of variation are normally plotted on histograms, bar-charts or similar types of graphs, as illustrated in the following diagram:

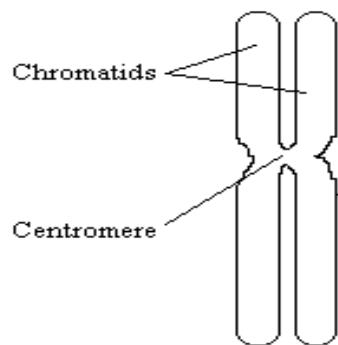
Figure 38: Chart Illustrating Discontinuous Variation



Chromosomes and Genes

Chromosomes are DNA threads found in the nucleus and responsible for storage of inherited information in the form of genes. Each chromosome is made of two strands called **chromatids** which are linked to each other at the **centromere**. Chromatids found on the same chromosome are called **sister chromatids**.

Figure 39: Simplified Structure of a Chromosome



Chromosome Numbers

The number of chromosomes in **each cell** of a particular species of organisms is fixed. Note that there are two kinds of cells in organisms that reproduce sexually, namely **somatic cells** (body cells) and **gametes** (sex cells)

The number of chromosomes in each **somatic cell** is called the **diploid number** and its symbol is **$2n$** . The number of chromosomes in each **gamete** is called the **monoploid** or **haploid number** and its symbol is **n** . The haploid number is always half of the diploid number in a given species.

The following table gives examples of species and their diploid and haploid numbers.

Species	Diploid Number ($2n$)	Haploid number (n)
Human being	46	23
Rat	40	20
Fruit fly	8	4
Onion	16	8
Tomato	24	12

Chromosome Types

There are two types of chromosomes, namely **sex chromosomes** and **autosomes** (non-sex chromosomes). Every somatic cell has two sex chromosomes while every gamete has only one sex chromosome.

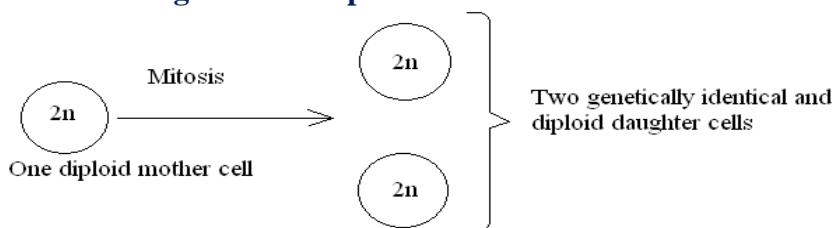
Nuclear Division (Mitosis and Meiosis)

Nuclear division or cell division is the process by which new cells (**daughter cells**) are formed from existing cells (**parent/mother cells**). There are two types of nuclear division, namely **mitosis** and **meiosis**.

(a) Mitosis

This is a type of cell division that results in the formation of **two daughter cells** that are **diploid** and **genetically identical** from one diploid parent cell

Figure 40: Simple Illustration of Mitosis



Stages of Mitosis

Mitosis involves four stages, namely **prophase**, **metaphase**, **anaphase** and **telophase**.

Prophase

The following events take place during prophase

- Movement of centrioles to opposite poles of the cell
- Appearance of spindle fibres from the centrioles
- Disappearance of the nuclear membrane and nucleolus

- Chromosomes become visible by coiling and shortening

Metaphase

During metaphase the following events take place

- Centromeres of chromosomes line up along the equator of the cell
- Spindle fibres from the centrioles attach themselves to the centromeres of the chromosomes

Anaphase

During anaphase the sister chromatids are separated from each other and pulled to opposite poles, centromere first.

Telophase

The following events take place

- The chromatids arrive at the poles and each of them becomes a complete chromosome
- The spindle fibres disappears
- Chromosomes disappear by unwinding and becoming longer
- The nucleolus and nuclear membrane reappear

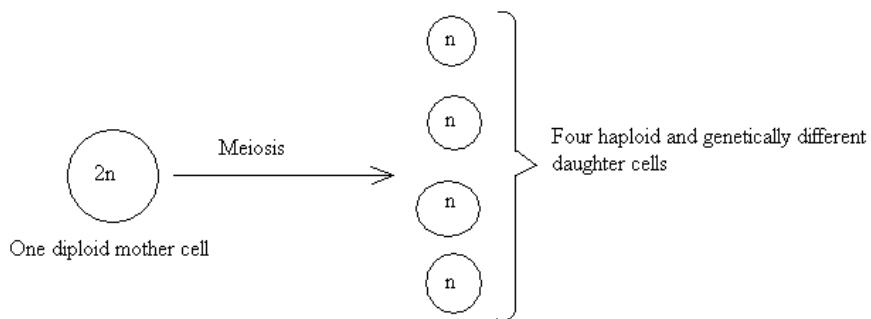
Importance of mitosis (MR. RAG)

- Growth
- Regeneration
- Asexual reproduction e.g. binary fission in Amoeba
- Maintaining genetic stability
- Replacement of cells

(b) Meiosis (reduction division)

This is a type of nuclear division where one diploid parent cell produce four daughter cells that haploid and genetically different from the parent cell. There are two divisions that take place during meiosis. These are **meiosis I** (first meiotic division) and **meiosis II** (second meiotic division). Each of the two divisions is made of prophase, metaphase, anaphase and telophase.

Figure 41: Simple Illustration of Meiosis

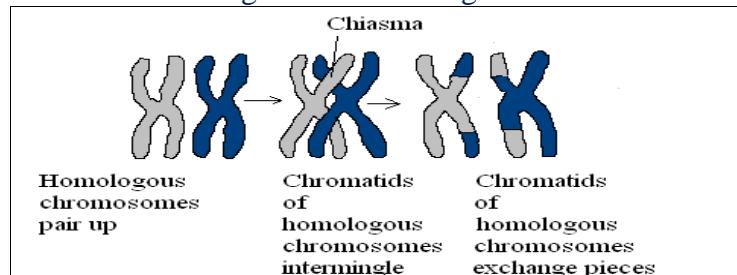


Meiosis I

Prophase I

- Movement of centrioles to the poles of the cell

- Appearance of spindle fibres from the centrioles
- Disappearance of the nuclear membrane and nucleolus
- Chromosomes become visible by coiling and shortening
- **Homologous chromosomes pair up.** These are chromosome pairs having the same length, same gene loci and an identical position of the centromere. Each member of this pair comes from a different parent.
- **Crossing over** takes place between chromatids of homologous chromosomes. This is a process during which the chromatids of homologous chromosomes get entangled and exchange pieces. The point of crossing over is called a **chiasma** (plural=**chiasmata**). This process contributes to genetic variation. The following diagram demonstrates crossing over in homologous chromosomes



Metaphase I

- Centromeres of homologous chromosomes line up along the equator of the cell
- Spindle fibres from the centrioles attach themselves to the Centromeres of the homologous chromosomes

Anaphase I

During anaphase I the homologous chromosomes are separated from each other and pulled to opposite poles, centromere first. The chromosomes are separated randomly. This is called **random assortment** of chromosomes and is one of the processes that contributes to genetic variation.

Telophase I

- The chromosomes arrive at the poles
- The spindle fibres disappear
- Chromosomes disappear by unwinding and becoming longer
- The nucleolus and nuclear membrane reappear

Meiosis II

The events that take place during meiosis II are similar to those in mitosis.

Importance of meiosis

- Formation of gametes (sex cells)
- It contributes to genetic variation due to crossing over and random assortment of chromosomes

Monohybrid Inheritance

This is the study of one characteristic controlled by only one gene.

The Language of Genetics

Chromosome: A chromosome is a DNA thread wrapped in protein. Chromosomes carry inherited information from one generation to the next

Gene: This is a portion/segment of DNA controlling one particular characteristic e.g. the portion of DNA controlling the inheritance and expression of eye colour is called the gene for eye colour. Note that some

characteristics are controlled by more than one gene. This is called **Polygenic inheritance**. Generally, each gene controls the synthesis of one polypeptide molecule.

Allele: This is an alternative form of a given gene. Each sexually-reproducing organism has two alleles for each of its characteristics. The alleles may be similar or different. One of the alleles is inherited from the male parent while the other one is from the female parent. Alleles which have more than two alternative forms are called **multiple alleles** e.g. the gene for blood group in humans has three alleles, namely I^A , I^B and I^O . Even in this case, each human being can have only two of the alleles.

Genotype: This is the combination of alleles an organism has for a given characteristic. It is also defined as the genetic composition of an organism for a particular characteristic. The genotype is normally written using a pair of letters, each representing one allele e.g. AA , Aa and aa .

Phenotype: This is the out-ward expression of the genotype in the form of physical characteristics of an organism.

Dominant: A dominant allele is one that gets expressed in the phenotype to the exclusion of another. It is always represented by a capital letter e.g. A, B, T and so on

Recessive: A recessive allele is one that is over-shadowed in the phenotype by the presence of a dominant allele. It is always represented by a small/lowercase letter e.g. a, b, t and so on.

Codominance: Codominant alleles are two different alleles which are equally expressed in the phenotype when present together e.g. the alleles I^A and I^B for blood group

Homozygous: This a type of genotype where both alleles are the same i.e. both dominant or both recessive e.g. AA , aa , BB , bb and so on. Organisms which are homozygous are called **homozygotes or pure breeds**.

Heterozygous: This is a type of genotype where the two alleles are different, such as one allele is dominant while the other is recessive e.g. Aa , Tt and Bb . Organisms which are heterozygous are called **heterozygotes or hybrids**.

Mendel's Experiments

Mendel used garden peas because:

- (i) They have a short life cycle
- (ii) They show contrasting characteristics e.g. short plants are always below 1 meter while tall plants always grow above 1 meter

Experiment 1

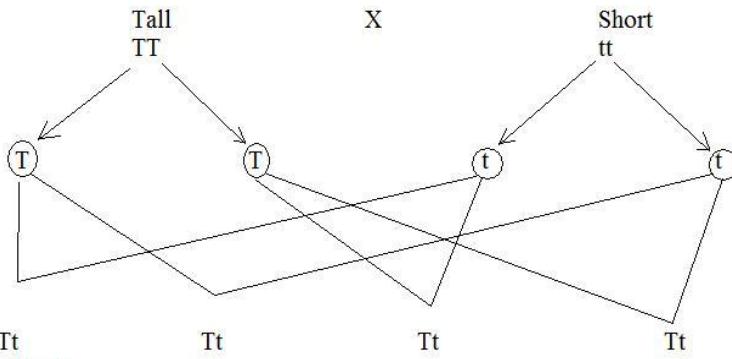
Mendel crossed homozygous tall plants with homozygous short plants. The seeds produced all grew into tall plants. From this Mendel concluded that the allele for tallness was dominant to the allele for shortness. This experiment can be explained using the following genetic diagram:

Let T = allele for tallness and t = allele for shortness

Let T= allele for tallness and t=allele for shortness

Parent Phenotypes:
Tall TT
Short tt

Gametes:



Offspring Genotypes: Tt
Offspring Phenotypes: All tall

Note: The parents used at the beginning of any genetic experiment are called the **first parental generation** (P1-generation). The offspring of the P1 generation are called the **first filial generation** (F1-generation). The offspring of the F1 generation are called the **second filial generation** (F2-generation) and so on.

Experiment 2

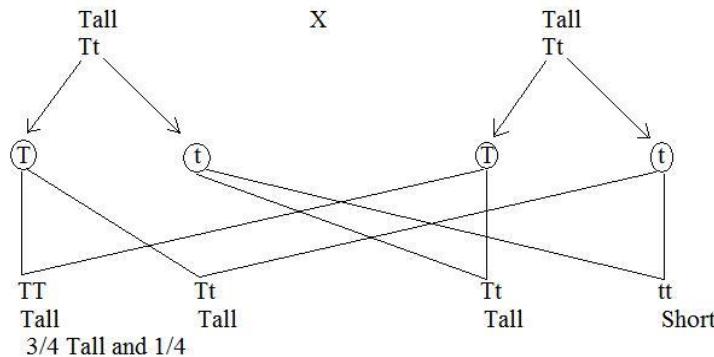
Mendel allowed the F1 plants to self pollinate. $\frac{3}{4}$ of the offspring were tall while $\frac{1}{4}$ were short. This is explained by the following genetic diagram:

Let T= allele for tallness and t=allele for shortness

Parent Phenotypes:
Tall Tt

Gametes:

Offspring Genotypes:
Offspring Phenotypes:



NB The fractions of the offspring phenotypes (which also represent the chances of each phenotype) may be converted into ratios or decimal numbers, in this case the ratio is 3:1 while the decimal numbers are 0.75 and 0.25. This information may also be converted into actual numbers e.g. if the total number of offspring is 1000, the number of short plants will be calculated as follows:

$$\text{Number of short plants} = \frac{1}{4} \times 1000 = 250$$

Exercise: In garden peas, the allele for smooth seeds (**R**) is dominant to the allele for wrinkled seeds (**r**). Use a genetic diagram to show the result of crossing a **heterozygous** plant with a **homozygous recessive** one.

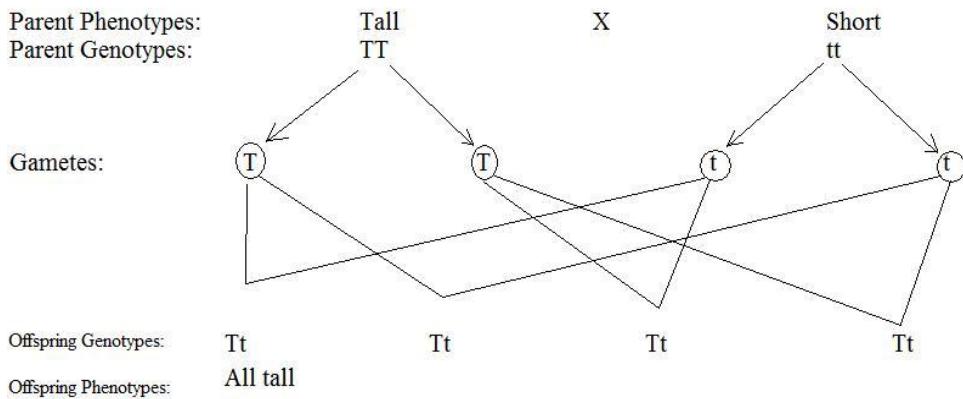
Back Cross (Test Cross)

This is when an organism having a dominant phenotype is crossed with a homozygous recessive one in order to determine its genotype. The phenotypes of the offspring are used to conclude what the genotype of the tested organism is. If all the offspring still show the dominant phenotype, it is concluded that the tested organism is homozygous dominant. If some of the offspring show the dominant phenotype while others show the recessive phenotype, it is concluded that the tested organism is heterozygous. This is illustrated by the following genetic diagrams, using height in garden peas.

(a) If the organism is homozygous dominant (TT)

Let T= allele for tallness and t=allele for shortness

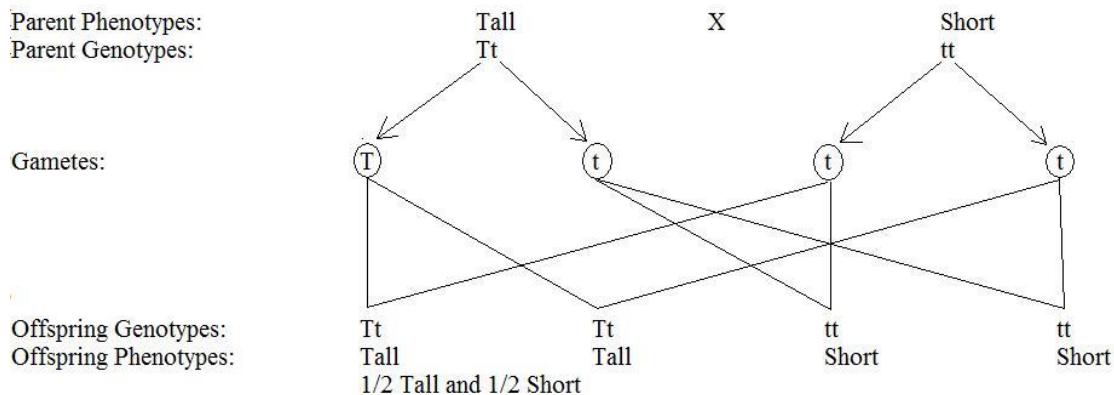
Parent Phenotypes:
Parent Genotypes:



(b) If the organism is heterozygous (Tt)

Let T= allele for tallness and t=allele for shortness

Parent Phenotypes:
Parent Genotypes:



Common Crosses and their expected Phenotypic ratios of Offspring

- When one of the parents is homozygous dominant all the offspring will have the dominant phenotype, regardless of the genotype of the other parent.
- When both parents are heterozygous, the phenotypic ratio of the offspring is 3:1
- When one parent is heterozygous and the other homozygous recessive the phenotypic ratio of the offspring is 1:1
- When both parents are homozygous recessive, all the offspring will have the recessive phenotype.

Type of Cross	Phenotypic ratio of Offspring
TT X TT	All offspring have dominant phenotype
TT X Tt	All offspring have dominant phenotype
TT X tt	All offspring have dominant phenotype
Tt X Tt	3:1
Tt X tt	1:1
tt X tt	All offspring have recessive phenotype

Exercise:

In maize plants, the allele **M**, for white seeds is dominant over the allele **m** for yellow seeds. 100 heterozygous plants were self pollinated and 250 yellow seeds were collected.

- (a) What is the expected ratio of white seeds to yellow seeds [1]
- (b) What is the expected total number of seeds [2]
- (c) What is the expected number of white seeds [2]

Blood Group inheritance in Humans

Blood group inheritance in humans is controlled by three alleles, namely **I^A**, **I^B** and **I^O**.

Both **I^A** and **I^B** are dominant over **I^O** but are codominant to each other. There are six possible genotypes and four possible phenotypes, as shown in the following table:

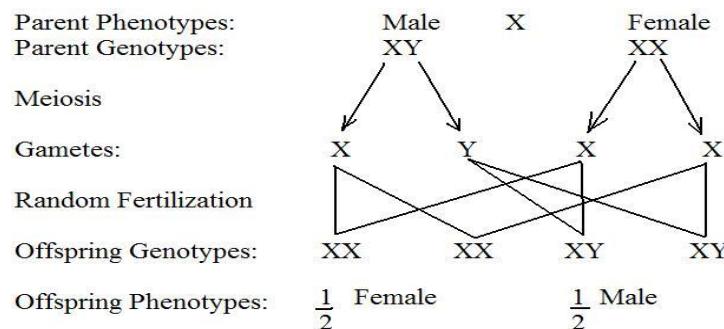
Genotypes	Phenotypes
I^AI^A	Group A
I^AI^O	Group A
I^BI^B	Group B
I^BI^O	Group B
I^AI^B	Group AB
I^OI^O	Group O

Points to take note of

- When one parent is group AB, a couple can never have a group O child.
- When one parent is group O, a couple can never have a group AB child.
- When one parent is homozygous group A (**I^AI^A**) or homozygous group B (**I^BI^B**), a couple can never have a group O child.
- Group A and group B parents can have a group O child as long as they are heterozygous (**I^AI^O** or **I^BI^O**).
- A couple where one parent is heterozygous group A (**I^AI^O**) and the other heterozygous group B (**I^BI^O**) can have a child of any blood group.

Sex Inheritance in Humans

Sex inheritance in humans is controlled by two chromosomes, X and Y, which are called sex chromosomes. The X chromosome is longer than the Y chromosome. A person with genotype **XX** is female while a person with genotype **XY** is male. At each conception, the chances of having either a male or a female child are equal, as illustrated by the following diagram.



Sex Linkage

This is the occurrence of a non **sex gene** on a sex chromosome. A non-sex gene found on a sex chromosome is said to be **sex-linked**. If the gene is on the X chromosome, it is said to be X-linked. Examples of X-linked conditions in humans are haemophilia and red-green colour blindness. These X-linked conditions do not occur on the Y chromosome because they are found on the extra (non-homologous) portion of the X chromosome.

Haemophilia

This is an inherited disease where a human being bleeds for longer periods than normal due to poor clotting of blood. It is caused by lack of blood clotting factors known as **factor VIII** and **factor IX**. The allele for haemophilia (h) is recessive while the allele for normal blood clotting (H) is dominant. There possible genotypes and phenotypes for haemophilia are given below:

- $X^H X^H$ normal female
- $X^H X^h$ normal carrier female
- $X^h X^h$ haemophilic female
- $X^H Y$ normal male
- $X^h Y$ haemophilic male

Red-green Colour Blindness

This is a genetic disorder where a person can not distinguish between the colours red and green. The allele for red-green colour blindness(r) is recessive while the allele for normal vision (R) is dominant. There possible genotypes and phenotypes for red-green colour blindness are given below:

- $X^R X^R$ normal female
- $X^R X^r$ carrier female
- $X^r X^r$ colour blind female
- $X^R Y$ normal male
- $X^r Y$ colour blind male

Exercise A red-green colour blind male is married to a woman who has normal vision but carries the allele that causes red-green colour blindness. Use a genetic diagram to predict their chances of having the following types of offspring:

- (a) a colour blind male
- (b) a carrier female
- (c) a normal male
- (d) a normal female (not carrier)

Mutations

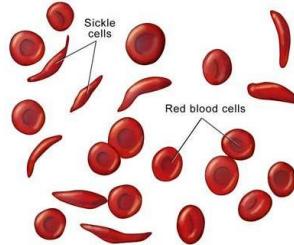
A mutation is a sudden spontaneous change in the structure of a gene or number of chromosomes. A gene, chromosome or an organism which has undergone a mutation is called a **mutant**. Any substance that causes a mutation is called a **mutagen** or **mutagenic factor**. All mutagens are also **carcinogens** (cancer-causing agents). Examples of mutagens are chemicals, radiation and viruses. There are two types of mutations, namely gene mutations and chromosome mutations.

Gene Mutation: This is a change in the chemical structure of a gene. Examples of gene mutations in humans are albinism, sickle cell anaemia, red-green colour blindness and haemophilia.

Albinism: This is an inherited disease where an organism lacks the capacity to synthesize melanin. As a result, the skin, hair, eyebrows and eyelashes all have a white colour. Even the iris does not contain melanin in albinos. This causes internal reflections in the eye, making it difficult for albinos to see clearly.



Sickle Cell Anaemia: This is an inherited disease where a person has abnormal haemoglobin, making the red blood cells sickle-shaped, especially when oxygen levels are low in the body. The disease reduces the capacity of the body to transport oxygen.



One advantage of sickle cell anaemia is that it reduces the incidence of malaria. This is because the malaria parasite fails to reproduce inside abnormal red blood cells due to small amounts of oxygen. The other reason is that sickle-shaped red blood cells infected with the malaria parasite are destroyed in the spleen.

Chromosome Mutation: This is a spontaneous change in the number of chromosomes. An example of chromosome mutation in humans is **Down's syndrome**. Down's syndrome is a genetic disorder where a human being has 47 chromosomes instead of 46. The signs and symptoms of Down's syndrome are:

- Mental retardation
- Round face with squinty eyes, rather like a Mongolian. That is why the disease is sometimes called **mongolism**.
- Abnormally short limbs.
- Six digits (toes or fingers) on the limbs.

Chances of having Down's syndrome babies are higher in women who have children when they are old (over 35 years).

NB Mutation is a source of variation within a population.

Selection

This is a process by which a selection pressure acts on population, eliminating some individuals while allowing the fittest individuals to survive. The organisms who survive the selection process pass on their genes to their offspring, thereby ensuring continuity of their characteristics. There are two types of selection, namely **natural** and **artificial** selection. Natural selection occurs through natural means such as disease, competition, predation and climatic changes. Artificial selection is carried out by human beings e.g. selective breeding of animals. Natural selection is a possible mechanism for evolution. An example of evolution brought about by selection is the development of antibiotic-resistant bacteria.

Genetic Engineering

This is the transfer of genes from one organism to another one of the same species or different species. An organism carrying a modified gene or a gene transferred from another organism is called a **genetically modified organism (GMO)**. An example of the application of genetic engineering is the making of human insulin using

bacteria. In this case, the gene for human insulin is transferred to the bacteria and the bacteria begin making the human insulin. This insulin is then isolated, purified and put in appropriate containers for diabetics to utilize.

ECOLOGY

Synopsis

Ecosystem; Community; Populations; Species; Niche (Producers, Consumers and Decomposers); Habitat; Energy Flow; Food Chains; Trophic Levels; Food Webs; Ecological Pyramids; Nutrient Cycles; Effects of Human Activities on Ecosystems (Pollution, Deforestation, Desertification and Conservation); Biodiversity; Populations

Ecology is the study of interactions of living things with each other and the environment. The following terms are associated with the study of ecology:

- **Ecosystem**- a definable area made of communities of living things that interact with each other and their non living environment e.g. a pond, Game Park.
- **Community**- a group of populations found in the same area and interact with each other.
- **Population**- a group of organisms of the same species living in the same area at the same time.
- **Species**- a group of living things that have similar features and can inter-breed to produce fertile offspring.
- **Habitat**- a place where an organism lives. Examples of habitats are aquatic habitats (found in water), terrestrial habitats (found on land)
- **Niche**- the specific role a given organism plays in an ecosystem e.g. some organisms such as algae and green plants are producers; other such as animals are consumers; and other such as bacteria and fungi are decomposers.

Energy Flow

The principal source of energy for ecosystems is the sun. Energy from the sun is called **solar energy**. Solar energy is captured by green plants during the process of **photosynthesis** and converted to chemical energy (food) which living organisms are able to use. Because of their capacity to produce food for other living organisms in an ecosystem, plants are called **producers**. Animals that feed on plants are called **primary consumers** or herbivores. Those that feed on primary consumers are called **secondary consumers** and those that feed on secondary consumers are called **tertiary consumers**.

The flow of energy from the sun is non cyclic (the energy can never be returned to the sun).

The following diagram illustrates an energy flow chain:

Sun → Producer → Primary consumer → Secondary consumer → Tertiary consumer

Food Chains and Food Webs

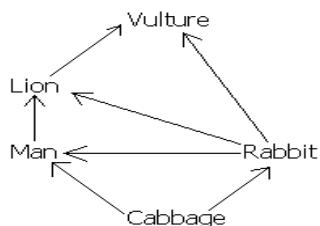
A food chain is a sequence of feeding relationships that begins with the producers and involves at least three organisms. The feeding level of an organism in a food chain is called the **trophic level**. In every food chain the producers occupy the **first trophic level**; the primary consumers occupy the **second trophic level**; the secondary consumers occupy the **third trophic level** and so on. In a food chain the organisms are linked by a series of arrows which always point towards the organism that is feeding on another. An example of a food chain is given below:

Cabbage → Rabbit → Man → Lion

Food chains can rarely go beyond the fourth trophic level. This is because only 10% of the energy present in one trophic level is passed on to the next. 90% of the energy is lost through respiration, egestion and excretion. By the time a food chain reaches the fourth trophic level there is very little energy available for any higher trophic level. There is more energy gained by feeding on vegetation than feeding on meat.

Food Webs

This is a group of interlinked food chains. The following diagram illustrates a food web:



The following table compares a food web to a food chain:

Food chain	Food web
One sequence of feeding relationships	Several inter-linked sequences of feeding relationships
Each organism occupies only one trophic level	Each organism may occupy more than one trophic level except the producer
Usually involves fewer organisms than a food web	Usually involves more organisms than a food chain

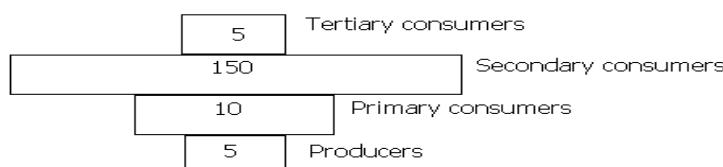
Ecological Pyramids

These are diagrammatic ways of showing feeding relationships in an ecosystem. Each ecological pyramid is made of a pile of rectangular blocks on top of each other. There are three types of ecological pyramids which are:

- Pyramids of numbers,
- Pyramids of biomass
- Pyramids of energy

Pyramids of numbers

This shows the numbers of organisms at each trophic level in a food chain. The length of each rectangular block is proportional to the number organisms at the trophic level it represents. For example the following pyramid of numbers may represent an ecosystem where there are 5 producers, 10 primary consumers, 150 secondary consumers and 5 tertiary consumers



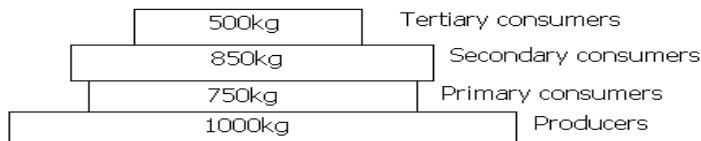
Pyramids of numbers are not always upright but maybe **inverted**. This results when a small number of large organisms is supplying food to a large number of small organisms e.g. Parasites feeding on a host.

Pyramids of Biomass

This shows the biomass of organisms at each trophic level in a food chain. Biomass is the **total dry mass** of an organism. It is also defined as the total amount of organic matter in an organism. It is measured in kilograms (Kg). The length of each rectangular block is proportional to the biomass of organisms at the trophic level it represents.

Example

Construct a pyramid of biomass for an ecosystem where the producers have a biomass of 1000Kg, primary consumers 750Kg, secondary consumers 850 Kg and Tertiary consumers 500 Kg.



Pyramids of biomass are usually upright but may sometimes be inverted. This is because the measurements used for constructing the pyramids are based on the **standing crop**, rather than the total biomass per growing season.

Pyramids of Energy

This shows the energy of organisms at each trophic level in a food chain. The length of each rectangular block is proportional to the energy of organisms at the trophic level it represents. The units used for measuring energy are Joules (J) or Kilojoules (KJ). This is the best way of showing feeding relationships as the pyramids are always upright.

Food cycles

A food cycle is a food chain or food web that includes decomposers. The decomposers break down complex organic molecules to simple inorganic molecules that can be used by producers hence completing the cycle.

Nutrient Cycles

A nutrient cycle shows the different forms of a particular element or nutrient in different parts of the environment and the processes involved in converting it from one form to another.

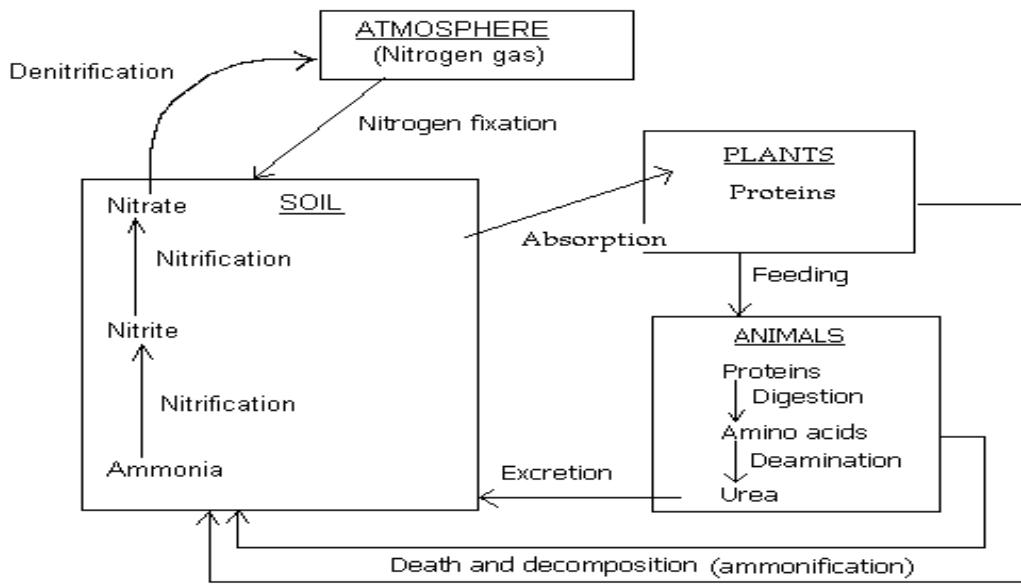
Nitrogen Cycle

Nitrogen occurs in the following parts and forms in the environment:

- **Atmosphere** (in the form of nitrogen gas)
- **Soil** (in the form of ammonia/ammonium ions, nitrite and nitrate)
- **Plants** (in the form of proteins and nucleic acids)
- **Animals** (in the form of proteins, amino acids, urea and nucleic acids)

Note: Nucleic acids are molecules responsible for storage of genetic information i.e. deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

The processes involved in converting nitrogen from one form to another are summarised in the following diagram of the nitrogen cycle.



Bacteria are involved in the following processes of the nitrogen cycle:

- **Nitrogen fixation**: The process by which nitrogen gas from the atmosphere is converted to absorbable nitrogen compounds by the action of **nitrogen fixing bacteria** such as *Rhizobium*, *Azotobacter*, *Clostridium* and *Anabaena*. *Rhizobium* is a symbiotic bacterium found in the root nodules of leguminous plants such as beans, peas, groundnuts and clover. *Clostridium* and *Azotobacter* are free-living in the soil while *Anabaena* is aquatic. All nitrogen-fixing bacteria contain an enzyme called **nitrogenase** which catalyses the reaction between nitrogen gas and hydrogen to form ammonia.
- **Nitrification**: The process by which ammonia is oxidised to form nitrite (NO_2^-) by the bacterium *Nitrosomonas* and nitrite is oxidised to form nitrate (NO_3^-) by the bacterium *Nitrobacter*. Oxygen is required in order for nitrification to take place. The bacteria that carry out nitrification are called **nitrifying bacteria**.
- **Decomposition**: The process by which complex organic molecules are broken down into simple inorganic molecules by the action of micro organisms known as **decomposers**. Decomposers include not only bacteria but also fungi. The decomposition of nitrogen-containing organic compounds is also called **ammonification** because it leads to the formation of ammonia or ammonium ions.
- **Denitrification**: The process by which nitrate is converted to nitrogen gas by **denitrifying bacteria** such as *Pseudomonas denitrificans* and *Thiobacillus denitrificans*. The process occurs in water-logged soils, lacking oxygen. It makes the soil less fertile and adds nitrogen gas to the atmosphere.

Other processes that have an effect on the nitrogen cycle discussed below:

- **Lightning**: This carries out nitrogen fixation by causing nitrogen to react with oxygen to form nitrogen oxides. The nitrogen oxides dissolve in rain water to form nitric acid which has nitrate that the plants are able to absorb.
- **Harber Process**: This is an artificial process where nitrogen gas and hydrogen are made to react with each other at high temperature and pressure to form ammonia. It reduces the amount of nitrogen gas in the atmosphere.
- Application of **nitrogen-containing fertilisers** increases the amount nitrogen-containing compounds in the soil.

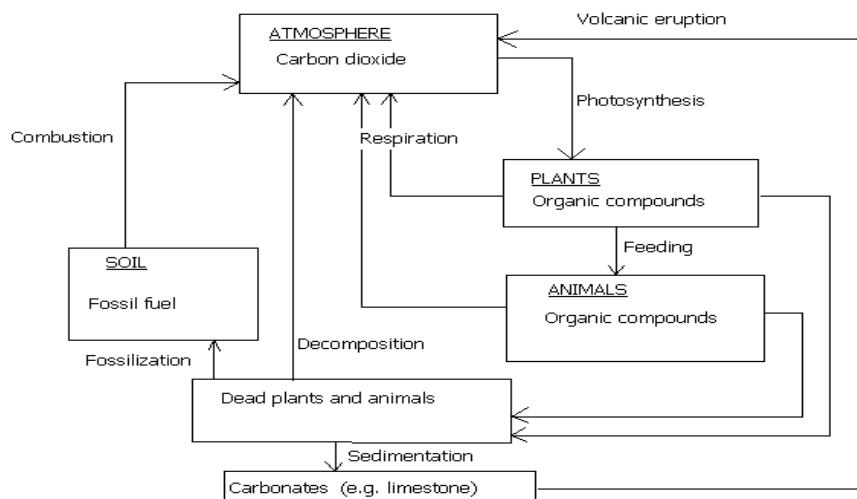
Carbon Cycle

Carbon occurs in the following parts and forms in the environment:

- **Atmosphere** (in the form of carbon dioxide gas)

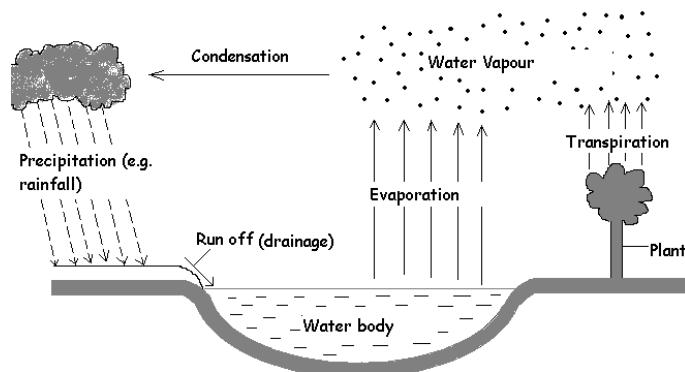
- **Plants** (in the form of organic molecules)
- **Animals** (in the form of organic molecules)
- **Soil** (in the form of fossil fuels and carbonates)

The processes involved in converting carbon from one form to another are summarised in the following diagram of the carbon cycle.



Water Cycle

Water exists in three states, namely solid (ice), liquid (water) and gas (water vapour). The processes that take place during the water cycle are summarised in the following diagram:



Effects of Human Activity on the Environment

Human activities such as agriculture, construction, waste disposal, industrialization and burning of fossil fuels have produced negative effects on the environment. These negative effects include **pollution**, **deforestation** and **desertification**. One way humans try to address some of these effects is through **conservation**.

Agriculture and the Soil

Agriculture

Agriculture may be defined as the use of land for growing crops. The type of agriculture where only one type of crop is grown is called **monoculture**. Some advantages of agriculture are:

- It ensures that there is enough food and cash crops for increasing populations of human beings.

- It makes it possible for newly developed varieties of crops and breeds of livestock to be nurtured with little competition from wild types.

Some disadvantages of agriculture are:

- It contributes to deforestation as forests are cleared to make room for growth of crops or rearing of livestock.
- The clearance of forests for agriculture leads to reduction in biodiversity
- Some chemicals used in agriculture e.g. herbicides, pesticides and fertilizers cause pollution of the environment
- Mechanised agriculture relies on combustion of fossil fuels which cause more pollution.

Soil

Soil is the weathered top layer of the earth's crust. The components of soil are divided into two groups, namely **inorganic components** and **organic components**. The inorganic components of soil are:

- **Mineral particles:** These are particles formed from surface rocks by the process of weathering and have diameters ranging from 0.002 mm to 2 mm. They are classified into four types, namely clay, silt, sand and gravel, depending on their size. The following table shows the diameters of the different types of mineral particles found in soil:

Type of Mineral Particle	Diameter (mm)
Clay	< 0.002
Silt	0.002-0.02
Sand	0.02-2.0
Gravel	>2.0

- Water
- Air
- Dissolved mineral salts and PH

Pollution

This is the contamination of the environment with substances that are harmful to living organisms. Any substance that causes pollution of the environment is called a **pollutant**. There are three types of pollution, namely **land**, **air** (atmospheric) and **water** pollution.

(i) Land pollution

The following table discusses some pollutants of the land, their sources and effects:

Name of Pollutant	Source(s)	Effects
Non-biodegradable materials: materials that can not be decomposed by microorganisms e.g. plastic	-Disposable packaging for a number of man-made products	-They make the soil less fertile
Garbage/Refuse/	-Domestic and industrial waste	-Act as breeding sites for pathogens and their vectors

Rubbish		<ul style="list-style-type: none"> -May contain poisonous substances -Giving the air an unpleasant smell
Heavy metals: metals with a relative atomic mass higher than 100 e.g. lead and mercury	-Industrial emissions	<ul style="list-style-type: none"> -They cannot be excreted by bodies organisms and are poisonous when they reach certain levels. - Bioaccumulation (a substance becoming more concentrated in higher trophic levels of a food chain) may result, leading to death of higher predators.

(ii) Air Pollution

The following table discusses some pollutants of the atmosphere, their sources and effects:

Name of Pollutant	Source(s)	Effects
Sulphur dioxide	-Burning of fossil fuels	<p>Dissolves in rain water forming sulphurous acid and sulphuric acid. Such rain is called acid rain. The effects of acid rain are:</p> <ul style="list-style-type: none"> -It breaks down the waxy cuticle on plant leaves, leading to excessive transpiration and leaching of nutrients. This may lead to death of trees and destruction of forests. -It destroys the root hairs of plants, leading to reduced uptake of nutrients and water. -It kills or inhibits the activity of soil organisms, thereby slowing down decomposition of organic matter -It mobilises ions that are normally bound to soil particles, leading to leaching of such ions. When some of the leached ions flow into rivers, they may accumulate to toxic levels. -It corrodes and damages buildings
Carbon dioxide	<ul style="list-style-type: none"> -Burning of fossil fuels and organic matter. -Deforestation promotes increase in CO₂ concentrations because it reduces the number of plants carrying out 	<ul style="list-style-type: none"> -It contributes to the greenhouse effect i.e. it slows down the escape of heat (long-wave radiation) from the atmosphere into space. This has led to an effect known as global warming i.e. a rise in global temperatures. Global warming is believed to cause drastic climatic changes, resulting in droughts and floods. <p>NB: There are other greenhouse gases besides carbon dioxide. Examples are methane, water vapour, chlorofluorocarbons (CFC's) and nitrous oxide (N₂O)</p>

	photosynthesis NB: The gas is also added to the atmosphere naturally by respiration and volcanoes	
Carbon monoxide	-Incomplete combustion of fossil fuels and organic matter.	<p>-When inhaled, it gets into the blood and combines irreversibly with haemoglobin to form carboxyhaemoglobin. This reduces the capacity of the blood to transport oxygen. This may cause breathlessness, headache and suffocation to death in humans.</p> <p>-Babies born from mothers that have been frequently exposed to the gas have a low birth weight.</p>
Nitrogen oxides	<p>-Exhaust fumes -Industrial fumes In both cases the nitrogen is initially from the atmosphere, but reacts with oxygen under intense heat to form oxides. NB: oxides of nitrogen are formed naturally when there is lightning</p>	<p>-Formation of acid rain (refer to effects of acid rain under sulphur dioxide)</p> <p>-Formation of photochemical smog, which reduces visibility and may lead to road and air traffic accidents.</p> 

(iii) Water Pollution

The following table discusses some pollutants of water, their sources and effects:

Name of Pollutant	Source(s)	Effects
Raw (untreated) sewage: This is a mixture of human faeces, urine, kitchen waste and detergents	<ul style="list-style-type: none"> -Leaking of sewer pipes. -Direct discharge of untreated sewage into water bodies i.e. rivers and lakes. 	<ul style="list-style-type: none"> -Some microorganisms present in sewage are pathogenic and may cause diseases such as cholera, dysentery and typhoid -Decomposition of the organic components of sewage leads to high levels of phosphates and nitrates. The presence of high levels of phosphates and nitrates in water is called eutrophication. It leads to algal blooms (the rapid multiplication of algae in water) and multiplication of water weeds. The algae use up a lot of oxygen for respiration and during their

		<p>decomposition after death. This lowers the amount of oxygen in water and may result in death of fish. In addition, nitrates are poisonous to both fish and humans.</p> <p>-Suspended particles present in the sewage reduce penetration of light, slowing down photosynthesis in aquatic plants.</p> <p>-Detergents in sewage lead to formation of foams which block oxygen and light from getting into the water.</p>
Agricultural run-off containing fertilisers, herbicides and pesticides.	-Farms located near water bodies	<p>-Fertilisers in water cause eutrophication (see explanation above)</p> <p>-Herbicides and pesticides are poisonous to aquatic organisms and to humans who may drink the water.</p>
Oil spills: These normally affect marine water bodies i.e. seas and oceans	-Accidental spillages from tankers	<p>-Oil floats on top of water, thereby blocking oxygen supply to aquatic organisms.</p> <p>-It kills aquatic organisms</p> <p>-It sticks to the feathers of some aquatic birds, making it difficult for them to swim.</p>

Deforestation

This is defined as the permanent removal of trees and their undergrowth from a forest.

Some causes of deforestation are:

- Clearance of land for agriculture
- Use of trees in the paper-making industry
- Harvesting timber for construction
- Clearance of land for construction of human settlements, roads, rail lines, and dams
- Destruction of forest trees by acid rain.
- Late forest fires

The effects of deforestation on the environment are:

- Reduction in biodiversity
- It interferes with the carbon cycle because there is reduced photosynthesis, leading to accumulation of carbon dioxide in the atmosphere. This in turn contributes to the **greenhouse effect**.
- It interferes with the nitrogen cycle because some of the trees removed are legumes that harbour nitrogen-fixing bacteria.
- It promotes soil erosion by wind and rain water. The soil eroded by water is often deposited in rivers, leading to flooding.
- It promotes **leaching** of nutrients
- It promotes desertification

Desertification

This is the degradation of arid and semi-arid land to form a desert. Causes of desertification include:

- Deforestation
- Overgrazing
- Trampling of the ground by animals
- Overpopulation

Effects of Desertification

- Land becomes less productive because it cannot support growth of plants. People staying on desert land are in danger of starvation and famine
- Desert lands are prone to extremes of temperature (very high temperatures during day time and very low temperatures during night time)
- Very low rainfall
- Low biodiversity

Conservation

Conservation is the protection of species, their habitats and ecosystems from extinction. **Extinction** is the end of a species or group of taxa. The moment of extinction is generally considered to be the death of the last individual of that species (although the capacity to breed and recover may have been lost before this point).

Examples of conservation efforts made by human beings include:

- Creation of game reserves to conserve wild animals
- Creation of forest reserves to conserve forests
- Creation of botanical gardens and zoos
- Fishing and hunting bans during the breeding seasons of animals
- Creation of gene banks, seed banks and sperm banks for endangered species
- Formulation of legislation (laws) that govern the utilization of natural resources
- Recycling of products made from natural resources

Populations

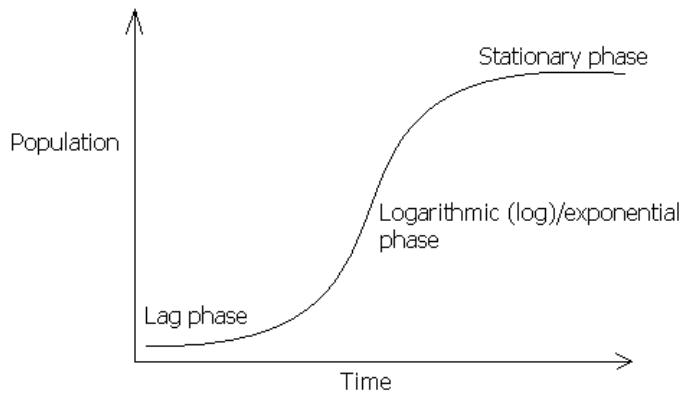
A population is a group of organisms of the same species living in the same area at the same time.

Population size is the number of organisms in a population.

Population density is the number of organisms of the same species per unit area.

Population growth rate is the increase in the size of a population per unit time. Population growth of organisms follows an S-shaped pattern (sigmoid curve). This curve is made of three phases:

- **Lag phase** (this is when there is very little increase in population size because the organisms are not yet fully adapted to the environment)
- **Exponential/logarithmic phase** (this is when the organisms are fully adapted to the environment and are reproducing at a fast rate)
- **Stationary phase** (this is when the birth rate equals the death rate). At this point the carrying capacity of the environment has been reached. The carrying capacity is the maximum number of organisms an environment can support.



Note: A **decline phase** may be experienced after the stationary phase if there is an increase in factors like competition, disease, pollutants/toxins. Such factors limit increase in population size and are called **environmental resistance**.

Factors Affecting Population Growth Rate

The growth rate of a population is affected by the following factors:

- **Birth rate:** the number of births per unit number of adults in a population.
- **Immigration:** the movement of more organisms into a population.
- **Death rate:** the number of deaths per unit number of adults in a population.
- **Emigration:** the movement of organisms out of a population.

These four factors are affected by two sets of factors called **biotic factors** and **abiotic factors**. The biotic factors include **food availability**, **predators**, **parasites**, **disease** and **competition**. The abiotic factors include **climate change**, availability of **water**, **oxygen**, **light** and **pollutants**. Suggest how each of these biotic and abiotic factors affect the four factors mentioned above.

A high **birth rate** and high rate of **immigration** leads to a **positive population growth rate** (increase in the size of a population per unit time). A high **death rate** and high rate of **emigration** leads to a **negative population growth rate** (decrease in the size of a population per unit time).

Biodiversity

This refers to the variety of living organisms in an ecosystem.

There are five kingdoms of living organisms. These are:

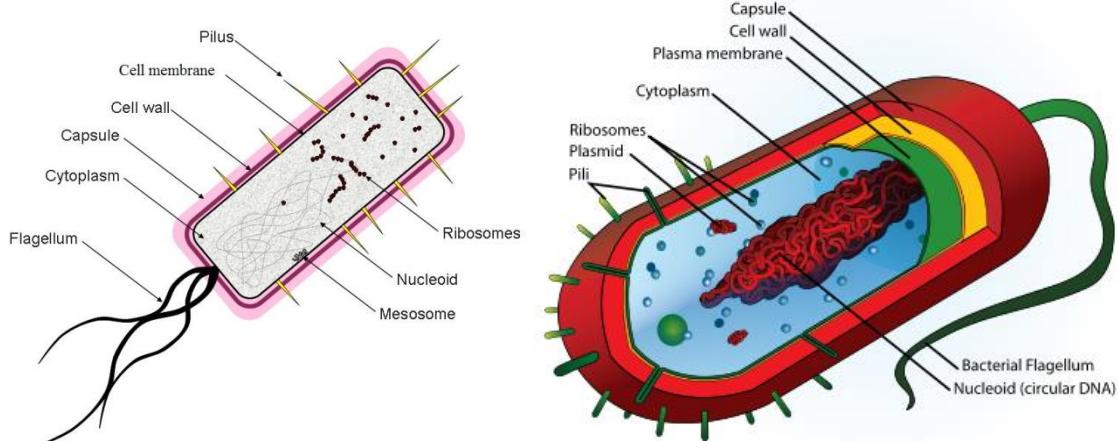
- Kingdom Prokaryota (The Bacteria)
- Kingdom Protocista (The Protists)
- Kingdom Fungi (The Fungi)
- Kingdom Plantae (The Plants)
- Kingdom Animalia (The Animals)

1. Kingdom Prokaryota

Members of this kingdom have the following characteristics:

- They are unicellular (single-celled)
- They have no true nucleus; only naked circular DNA called **nucleoid** or **bacterial chromosome**
- They have no double-membraned organelles, but small (70s) ribosomes are present
- They reproduce asexually by **binary fission**. Some members exhibit **conjugation** (the transfer of genetic material from one bacterial cell to another through structures known as **pili**)
- They carry out heterotrophic nutrition

- The kingdom includes **all bacteria**
- Some members are pathogenic i.e. cause diseases e.g. *Vibrio cholera*, *Mycobacterium tuberculosis*, *Treponema*, *Gonococcus neisseria*.
- Some types of bacteria are useful e.g. decomposers, nitrogen fixing bacteria, nitrifying bacteria and denitrifying bacteria. Others are used in the dairy industry during the making of cheese and yoghurt.

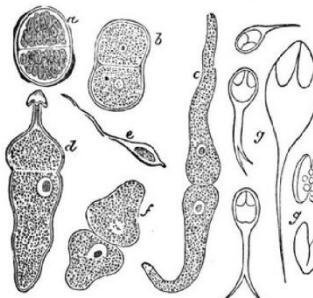


2. Kingdom Protostista

Members of this kingdom have the following characteristics:

- Most are unicellular (single-celled), but some are multicellular.
- Cells have a true nucleus with a membrane around it (eukaryotic cells)
- Some are heterotrophic (i.e. the protozoa) while others are autotrophic (i.e. the algae)
- Most reproduce by binary fission
- Examples are paramecium, amoeba, and kelp

Protozoa



3. Kingdom Fungi

Members of this kingdom have the following characteristics:

- They are multicellular, but a few of them such as yeasts are unicellular.
- They have well-developed nuclei with nuclear membranes around
- They have cell walls made of **chitin**.
- Most members carry out saprophytic nutrition, but some are parasitic.
- Most reproduce by **spores**.
Examples are yeast, mushrooms, bread moulds, and lichens



4. Kingdom Plantae

Members of this kingdom have the following characteristics:

- They are multi-cellular
- They have a well developed nucleus with a membrane around
- Their cells contain chlorophyll in the chloroplasts, hence they are photosynthetic.
- They have cellulose cell walls
- Most reproduce from seeds; some reproduce from vegetative parts such as stems, roots and modified leaves.
- Examples are mosses, ferns, gymnosperms (conifers) and angiosperms (flowering plants)



5. Kingdom Animalia

Members of this kingdom have the following characteristics:

- They are multicellular
- They have a true nucleus and membrane-bound organelles
- They carry out holozoic nutrition
- They have a nervous system
- Their bodies have symmetry (either bilateral or radial symmetry)
- Their bodies have anterior and posterior ends; dorsal and ventral surfaces; and lateral surfaces
- Examples are bears, fish, frogs, butterflies, and starfish