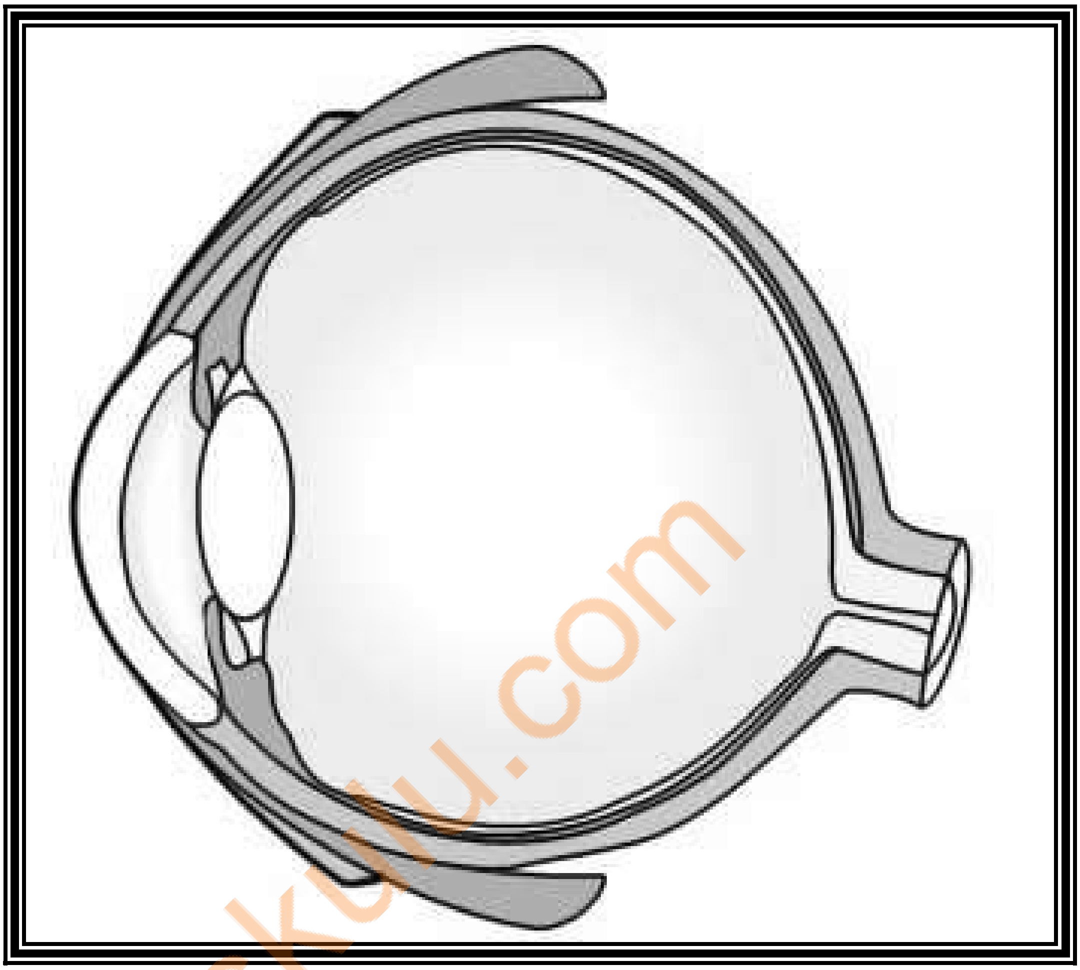
BASICS OF BIOLOGY

FOR GRADE 11



COVERING ALL THE GRADE 11 TOPICS IN THE ZAMBIAN 'O' LEVEL SYLLABUS:

- TRANSPORT IN FLOWERING PLANTS
- TRANSPORT IN ANIMALS
- RESPIRATION
- EXCRETION
- HOMEOSTASIS
- GROWTH AND DEVELOPMENT
- RESPONSES

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TRANSPORT IN FLOWERING PLANTS

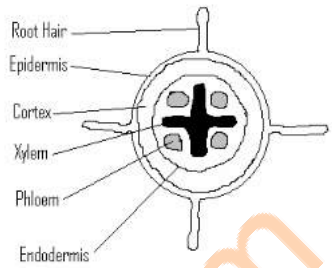
Plants need a transport system for the following reasons:

- 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.

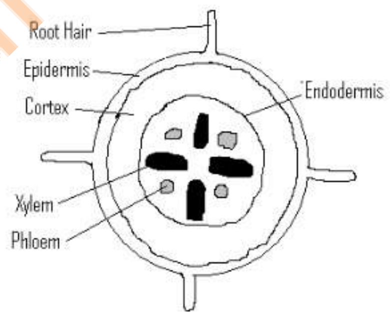
Arrangement of Vascular Tissues in Dicots and Monocots

(a) Cross-section of a Dicot Root

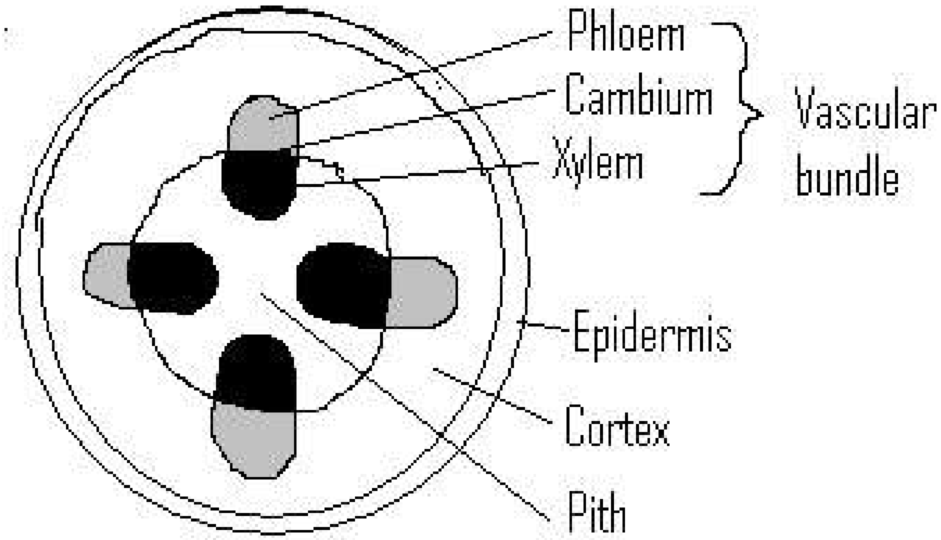


- Xylem is located in the centre and is star-shaped
- Phloem is located between the 'arms' of the xylem

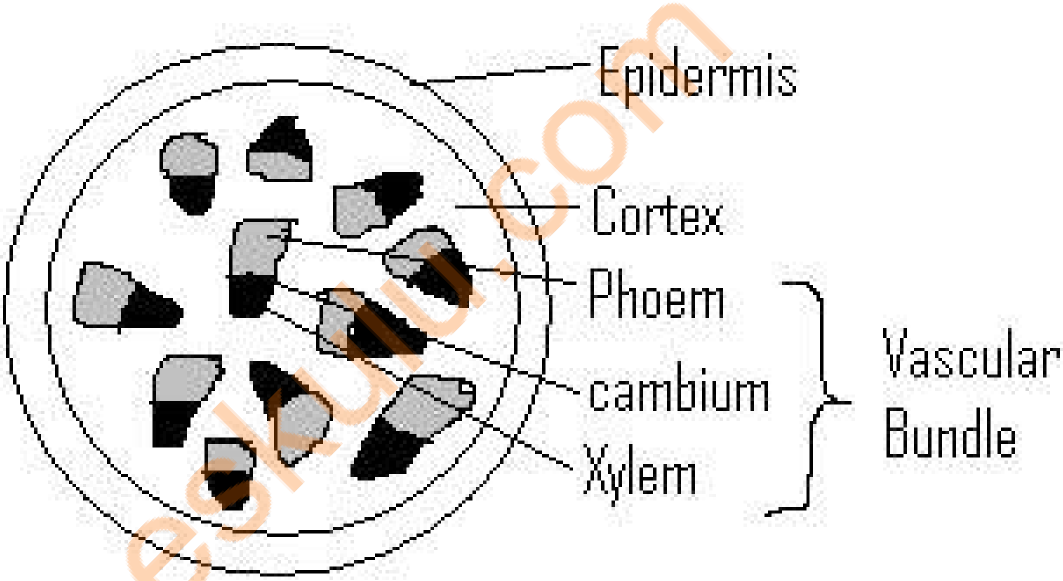
(b) Cross-section of a Monocot Root



(c) Cross-section of a Dicot Stem



(d) Cross-section of a Monocot Stem

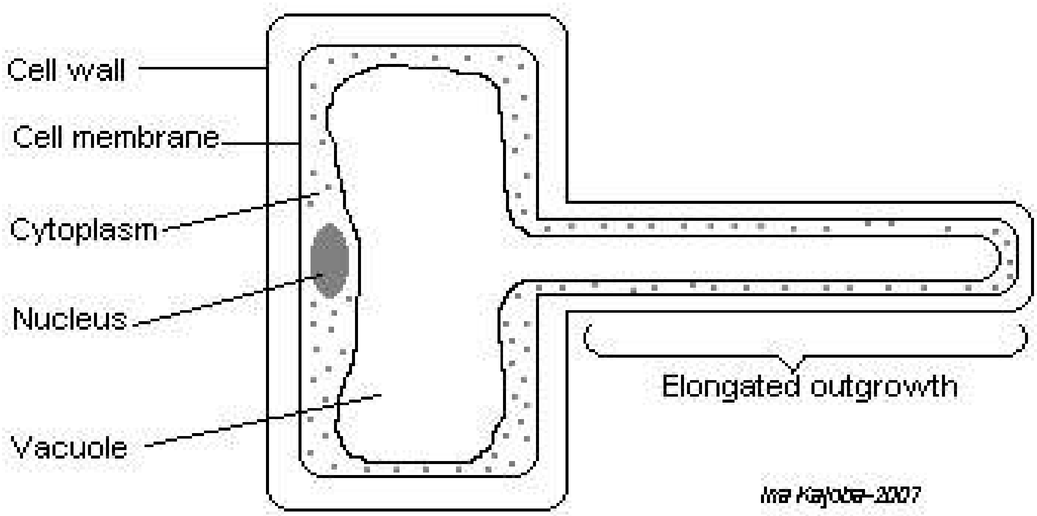


Uptake/Absorption of Water and Mineral Salts

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.

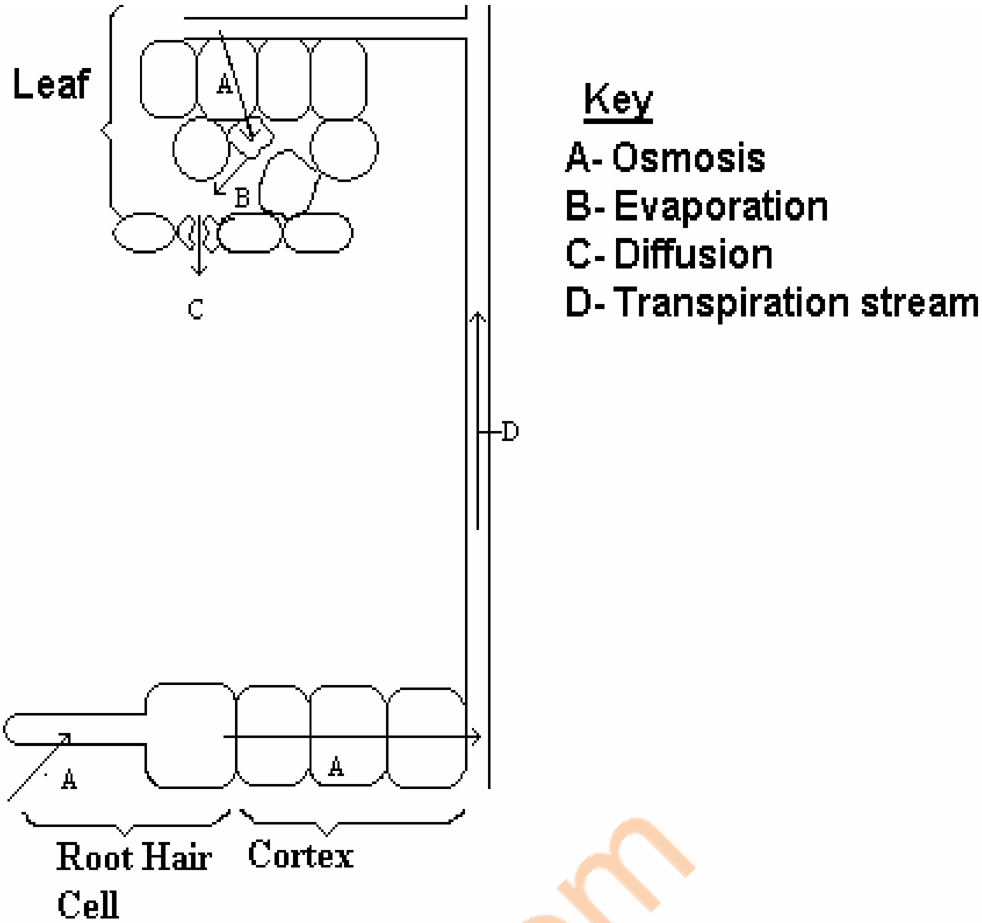
<u>Transpiration</u> (the diffusion of water vapour from plant leaves to the atmosphere through stomata). This creates a suction force that pulls water up the xylem vessels.

<u>Capillarity:</u> 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).

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

<u>Guttation</u>: 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.

<u>Temperature</u>: 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.

<u>Humidity</u>: 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.

<u>Light Intensity</u>: 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.

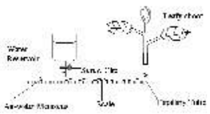
Plants can be adapted to reduce the rate of transpiration by having **xeromorphic features** which include the following:

- 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:

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

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

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

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

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.

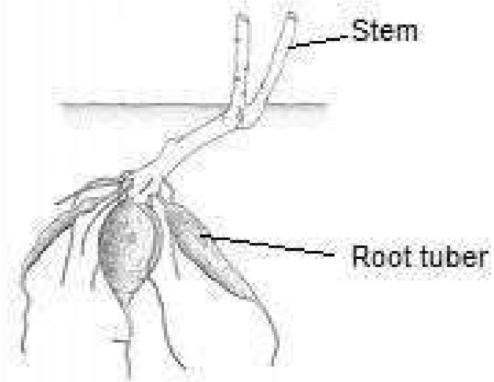
Using Radioactive Carbon

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

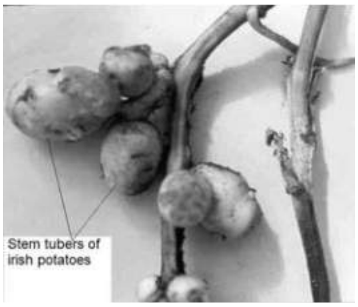
Plant Storage Organs

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.

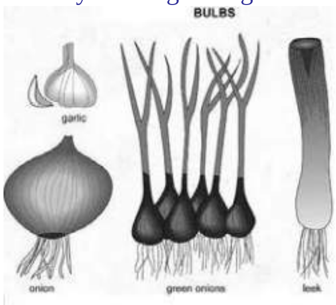
- Root tuber: This a fibrous root swollen with stored food e.g. sweet potato (*Ipomea batatas*) tuber



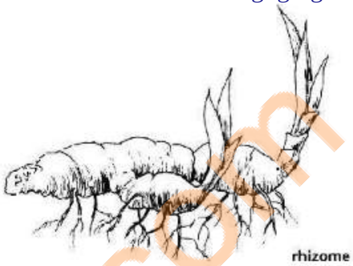
- <u>Stem tuber</u>: This is an underground stem swollen with stored food e.g. Irish potato (*Solanum tuberosum*)



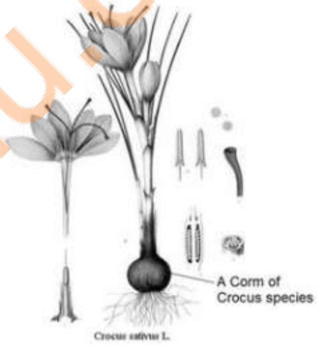
- <u>Bulb</u>: A bulb is made of underground fleshy leaves growing from a short stem e.g. onion (*Allium sp*)



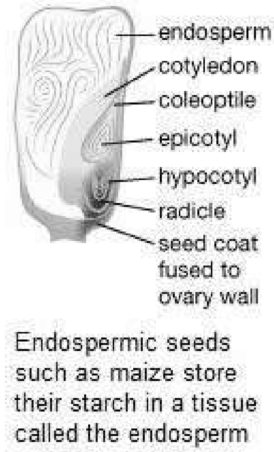
- <u>Rhizome</u>: This is a swollen underground horizontal stem e.g. ginger

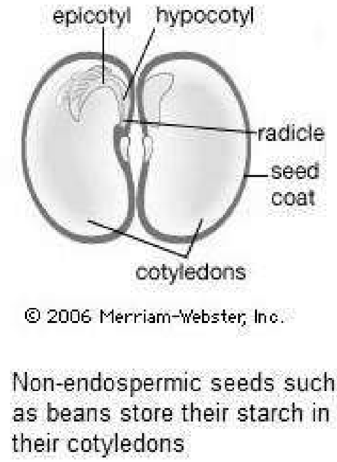


- <u>Corm</u>: This is swollen underground and vertical short stem e.g. *Crocus sp.*



- <u>Seed</u>: 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:

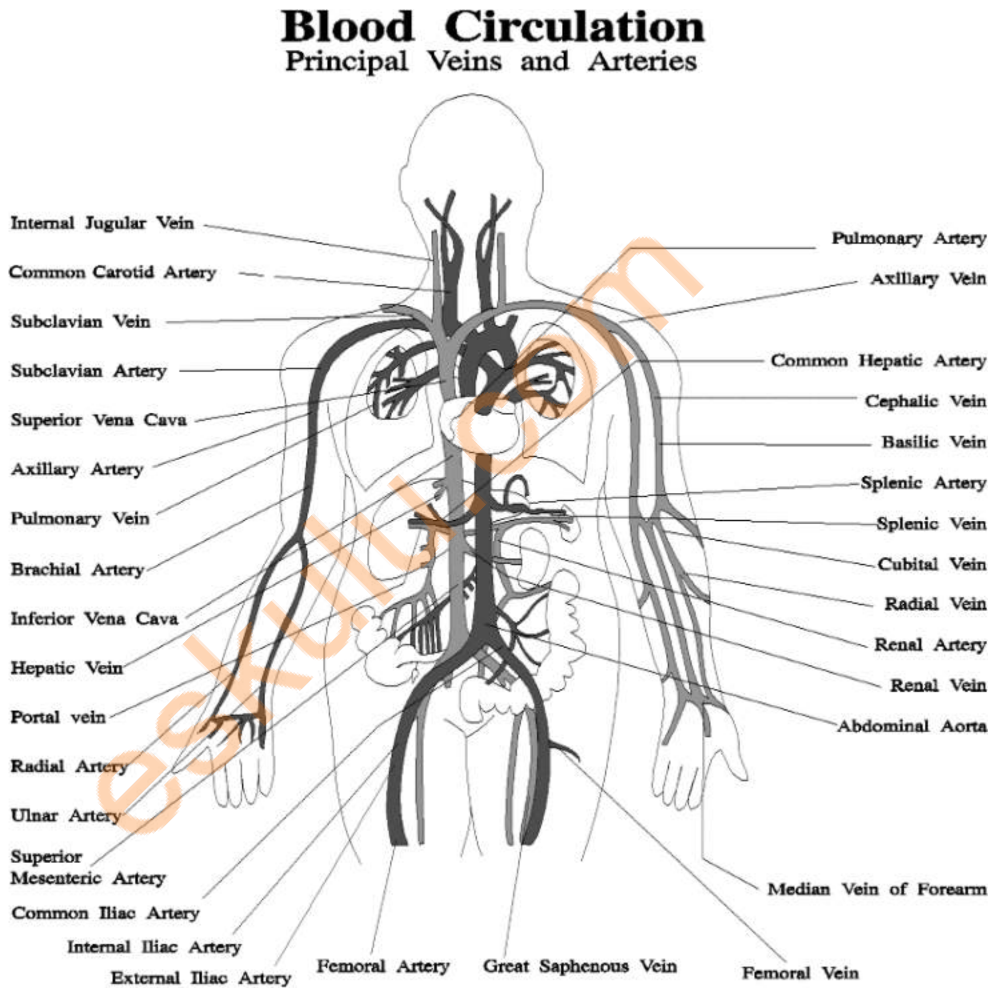
- To transport dissolved food substances from the intestines to the tissue cells.
- To transport oxygen from the lungs to the tissue cells.
- To transport hormones from endocrine (ductless) glands to target organs.
- To carry metabolic wastes from tissue cells to excretory organs.

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.*



a) The Heart

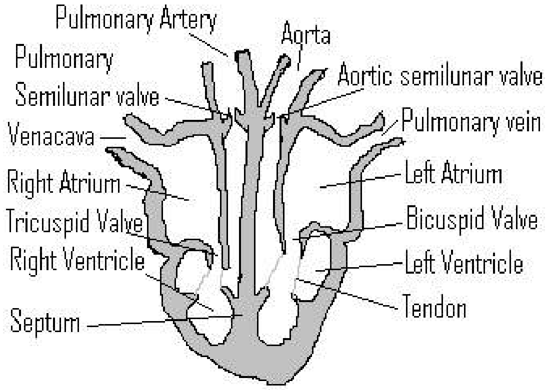
This is a **muscular organ** that pumps blood around the body through blood vessels. The type of muscle found in the wall of the heart is known as **cardiac muscle.**

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 form the veins which they pump to the ventricles. The ventricles receive blood from the a*tria* 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**.

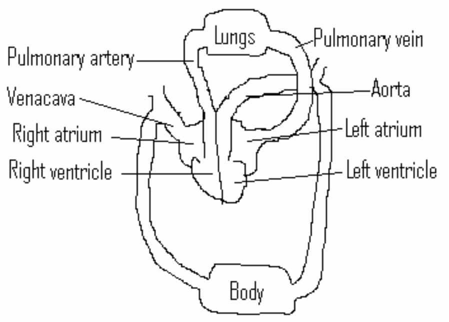
(i) Pulmonary Circulation

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 ventricles. 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 infarction) 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

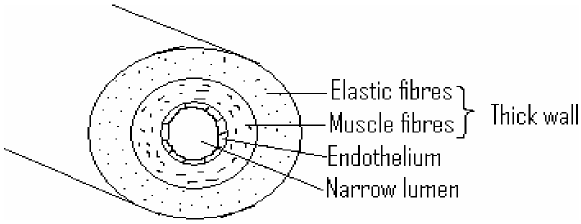
These are tubes through which blood moves around the body. There are three types of blood vessels. These are Arteries, veins and capillaries.

(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.

The following diagram illustrates the structure of an artery.

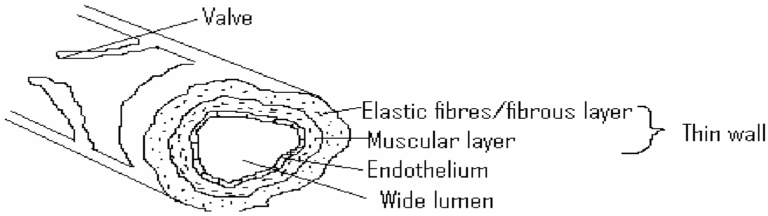


(ii) Veins

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

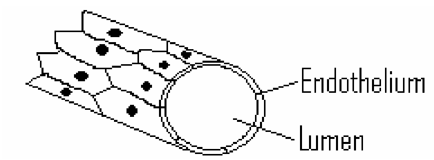
- They carry blood towards the heart.
- They carry blood at low pressure
- They have thin walls and wide lumens.
- They have valves to keep blood moving in one direction by preventing back flow.
- They all carry deoxygenated blood except the pulmonary vein.
- They appear irregular in cross-section
-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

The following diagram illustrates the structure of a vein.



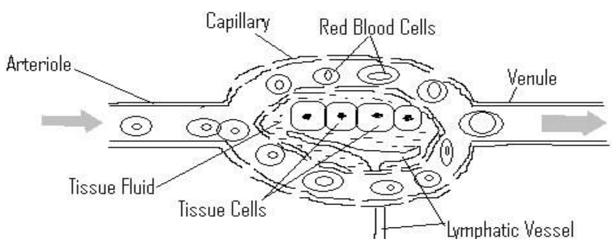
(iii) Capillaries

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:

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- 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)

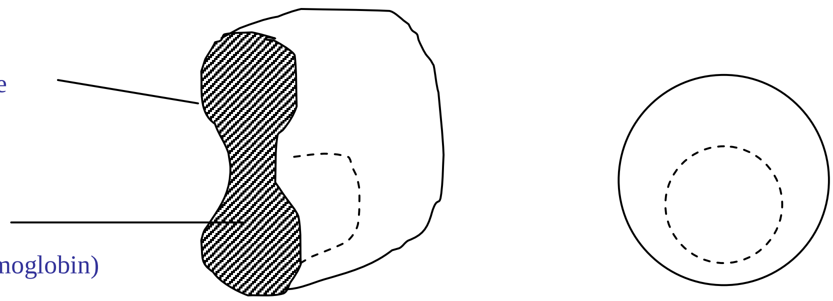
These are biconcave discs responsible for transportation of oxygen and small amounts of carbon dioxide. They are made in the bone marrow in adults but can also be made by the liver in babies. One milliliter of blood contains 5 to 6 million red blood cells. They have a lifespan of about 120 days and are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

$$Hb + 4O_2 \rightleftharpoons HbO_8$$

- Absence of nucleus makes more room for haemoglobin

Diagram of Red Blood Cell



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**.

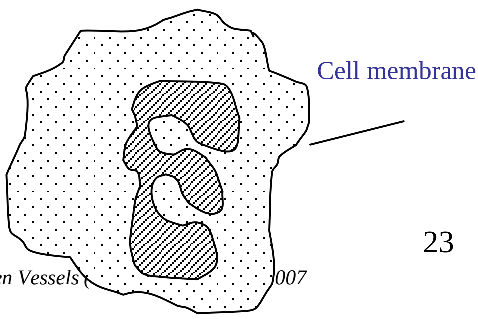
Phagocytes

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.



Cytoplasm

Lobed Nucleus

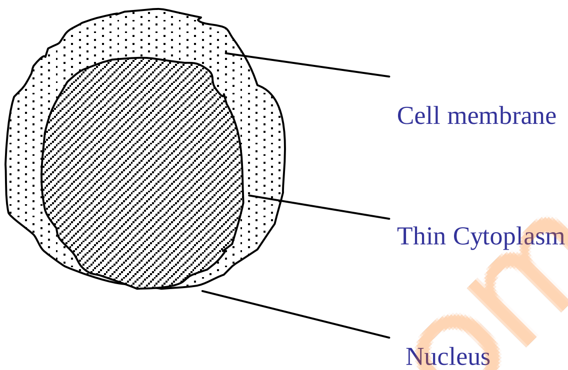
Lymphocytes

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.



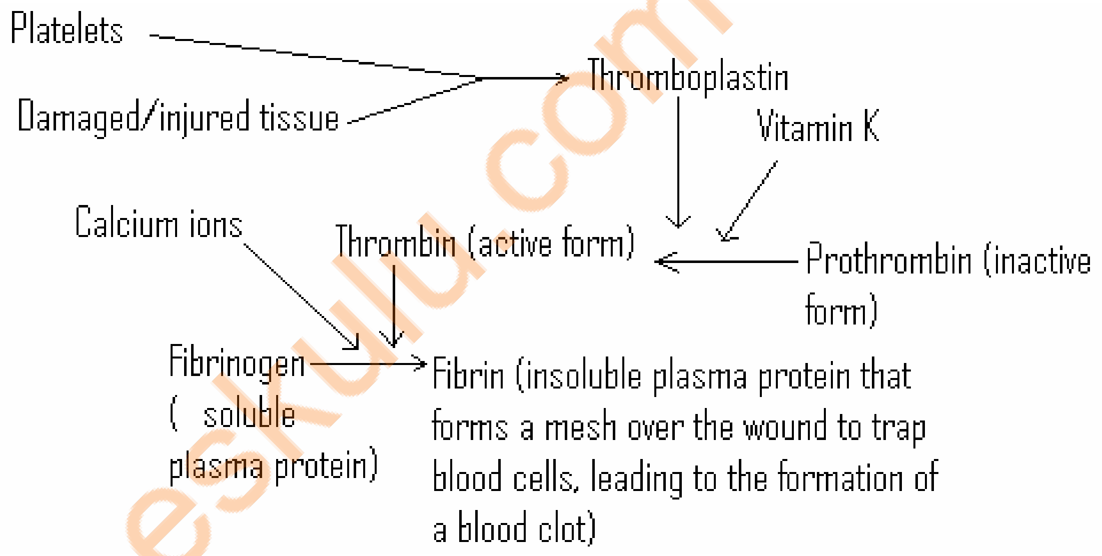
Platelets (Thrombocytes)

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 $\mathbf{I^A}$ and $\mathbf{I^B}$, while the absence of either antigen is represented as $\mathbf{I^O}$. 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.

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- 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.

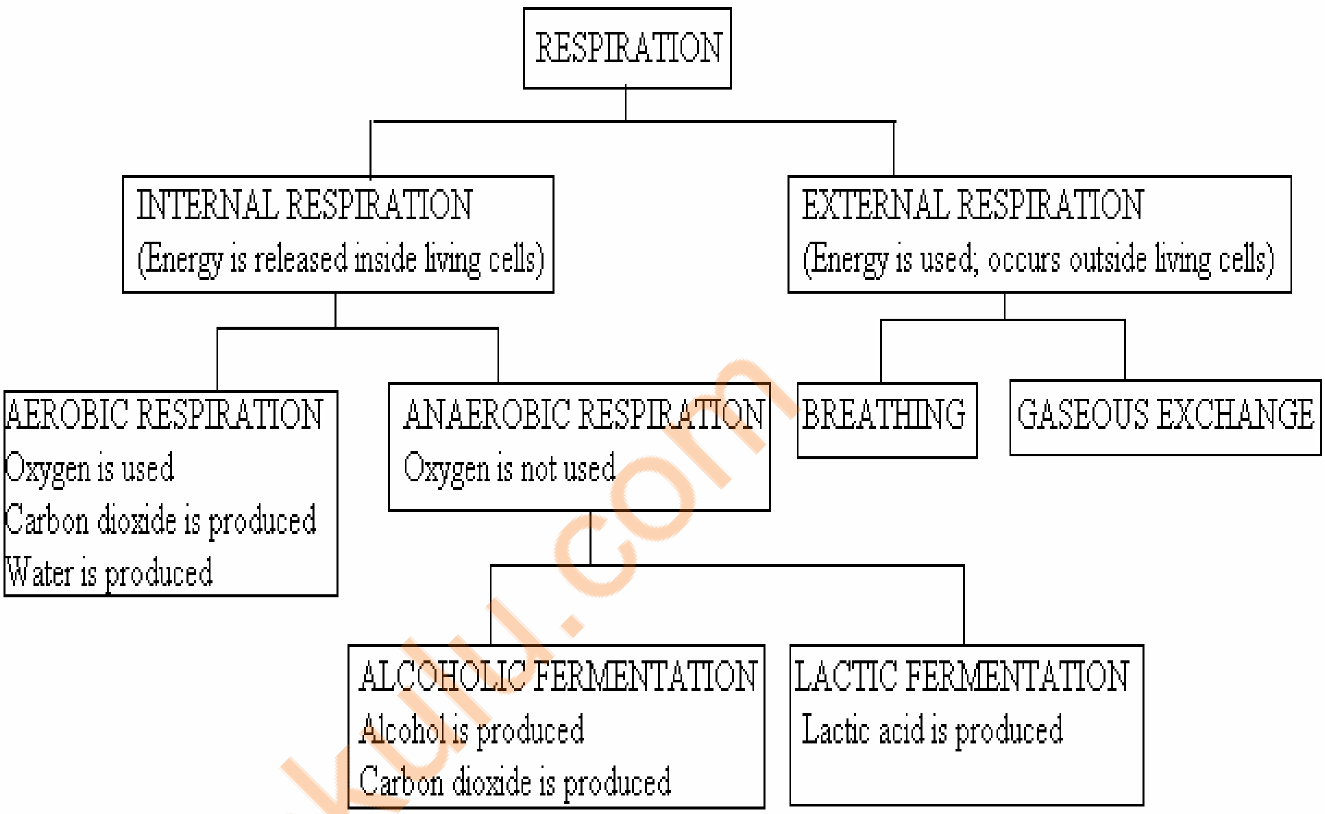
The functions of the lymphatic system may be summarised as follows:

- 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:

<u>Word Equation</u>

Glucose + Oxygen $\longrightarrow$ Carbon dioxide +Water +Energy

<u>Chemical Equation</u>

$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$ + Energy (2880KJ)

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**.

<u>Alcoholic Fermentation</u>

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:

$$\text{Glucose} \xrightarrow{\text{Zymase}} \text{Carbon dioxide} + \text{Alcohol} + \text{Energy}$$

Chemical Equation:

$$C_6H_{12}O_6 \xrightarrow{\text{Zymase}} 2CO_2 + 2C_2H_5OH + \text{Energy (210 KJ)}$$

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:

Glucose $\longrightarrow$ lactic acid + energy

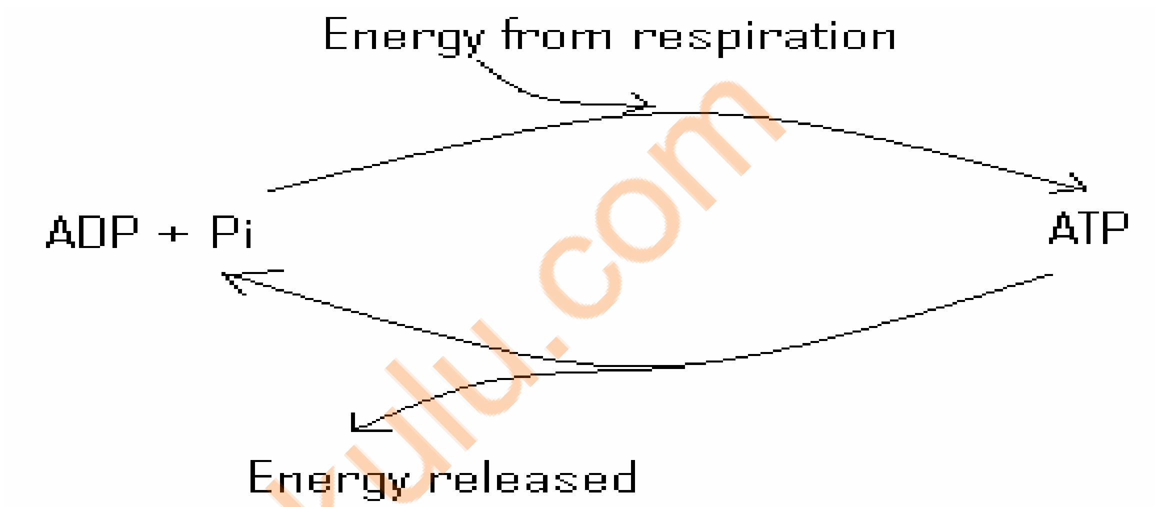
Chemical Equation:

$C_6H_{12}O_6 \longrightarrow 2C_3H_6O_3$ + Energy (150 KJ)

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:

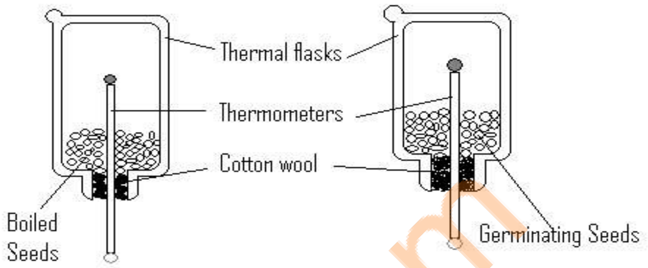
- It makes it possible for energy to be stored and transported
- It makes energy available when and where it is needed.

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.

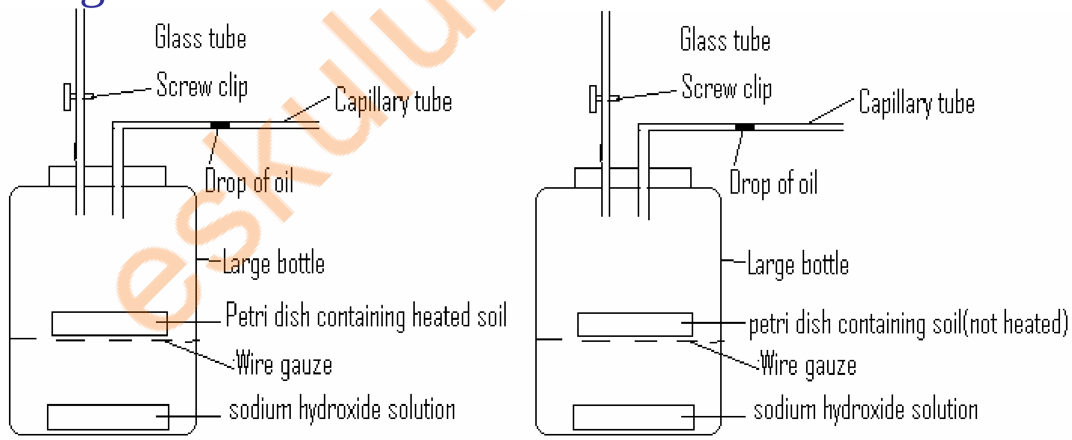
Experiment to Demonstrate Respiration in Soil Organisms

<u>Materials</u>

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

<u>Method</u>

- 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.

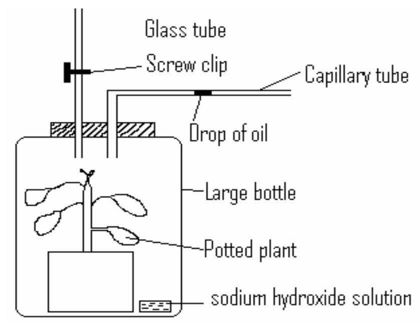
Experiment to Demonstrate Respiration in Green Plants

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.

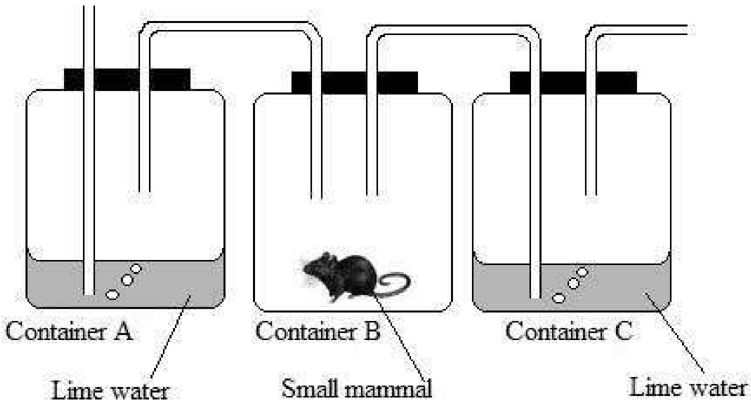
Experiment to Show that Carbon Dioxide is Produced During Respiration

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.



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- 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

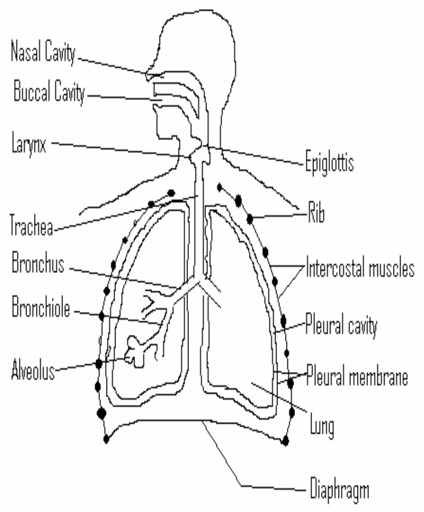
Breathing in **terrestrial animals** (such as human beings) is defined as the movement of air into and out of the lungs. In **aquatic animals** such as fish, breathing is the movement of water into and out of the **gill chamber**. Another term used to refer to breathing is **ventilation**. Breathing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

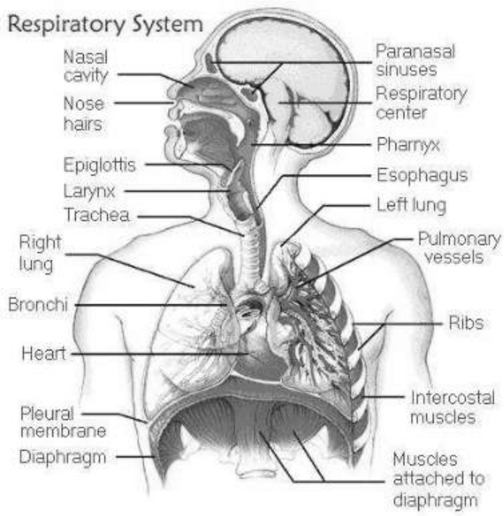
Gaseous exchange is the diffusion of oxygen into the blood and carbon dioxide out the blood across a **gaseous exchange surface**. In humans the gaseous exchange surfaces are the alveoli found in the lungs while the gaseous exchange surfaces in fish are the gills. Gaseous exchange surfaces have the following 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:

	Inspiration	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

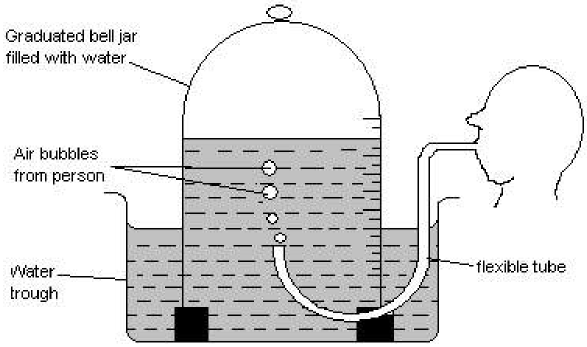
This refers to the number of breaths taken by an individual per minute. The normal breathing rate of an adult human being at rest is about **18**. However, this can be altered by factors such as sleeping, illness (e.g. fever), emotional excitement and physical exercise. Sleeping lowers the breathing 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 dm^3** (500 cm^3).

Vital Capacity

This is the **maximum** volume of air breathed out after forced inspiration. The vital capacity in humans is about **3.5 dm^3** (3500 cm^3). 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

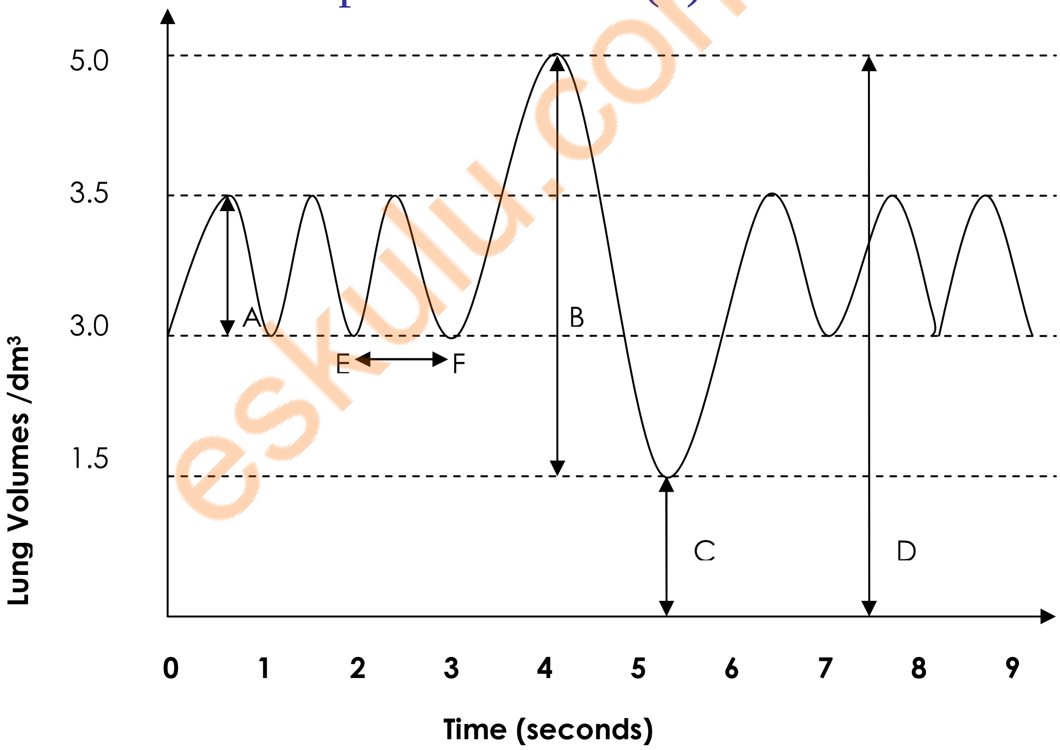


Residual Volume

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 dm^3**.

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 after 3 seconds?

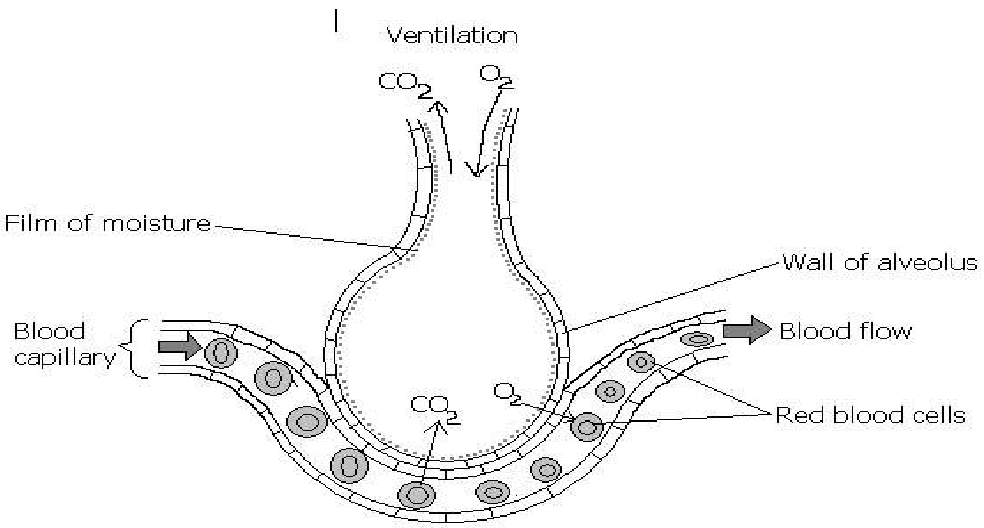
(c) What would happen to distance EF if the animal undergoes a period of physical exercise?

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.

<u>Bronchitis</u>: 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.

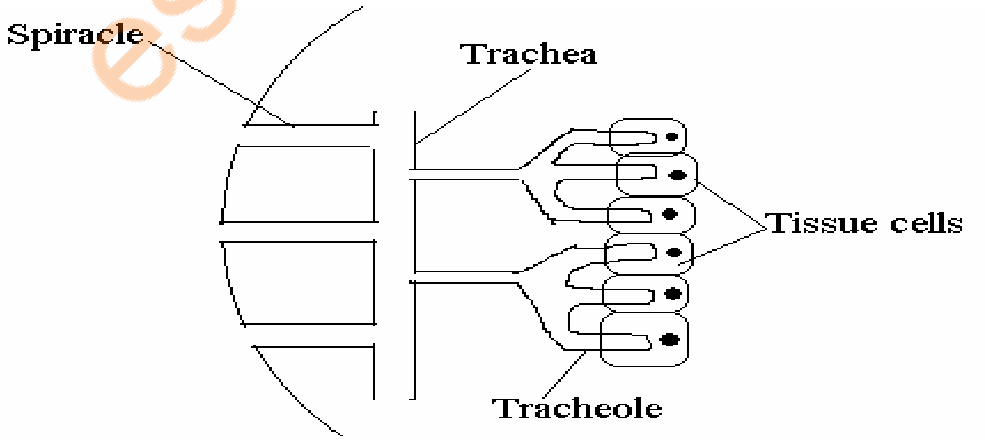
<u>Emphysema</u>: This is the weakening and bursting of the alveoli. When tar reaches the alveoli it weakens them and irritates them. The irritation causes coughing which makes the alveoli burst. Emphysema reduces the surface area available for gaseous exchange.

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.



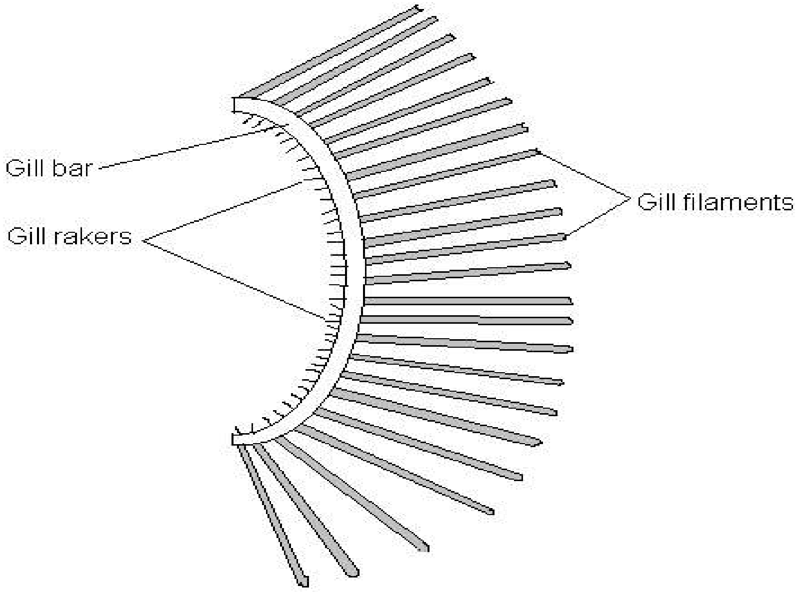
Breathing and Gaseous Exchange in Fish

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.

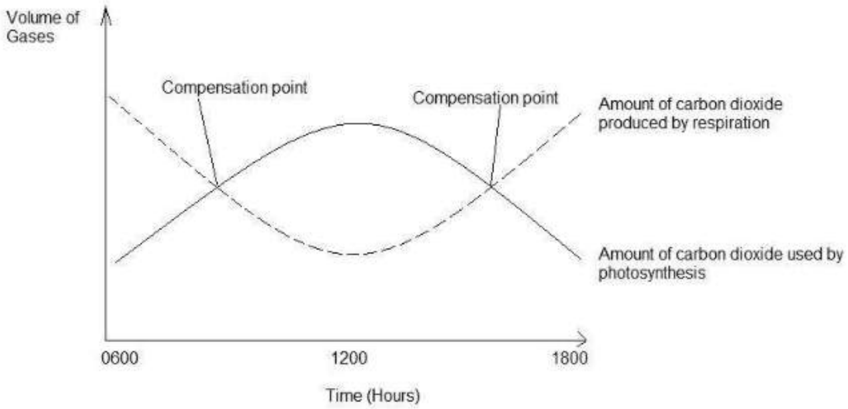
		Inspiration	**Expiration**
1	Floor of mouth	Lowered	Raised
2	Mouth	Open	Closed
3	Operculum	Closed	Open
4	Volume of mouth and gill chamber	Increases	Decreases
5	Pressure in mouth and gill chamber	Decreases	Increases
6	Water movement	Enters the gill chamber	Leaves the gill chamber

Structure of Bony Fish Gills

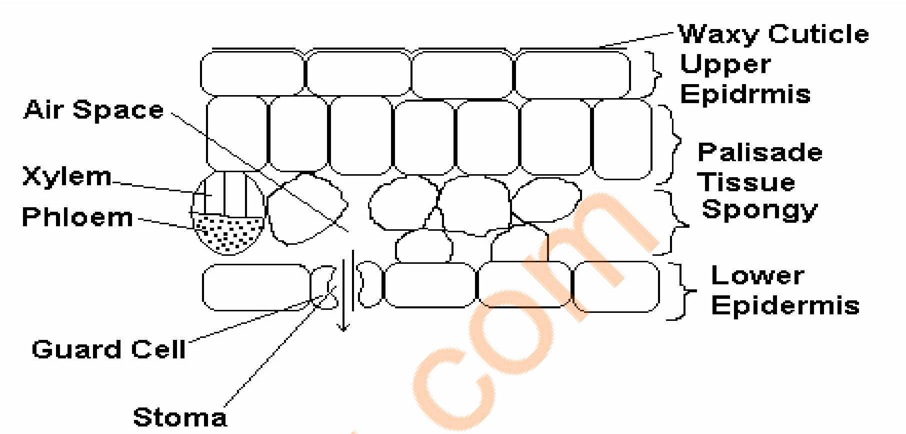


Gaseous exchange in plants

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:

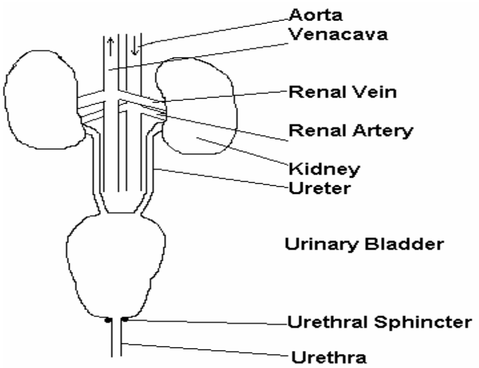
Excretory Organs	**Excretory Products**
Kidney	Urea, excess salts and excess water
Skin	Urea, salts and water
Lungs	Carbon dioxide
Liver	Bile pigments

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

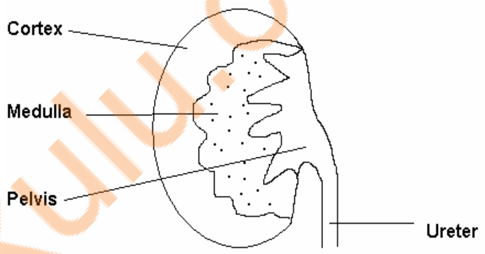
Bile pigments	Liver	Destruction of old red blood cells

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

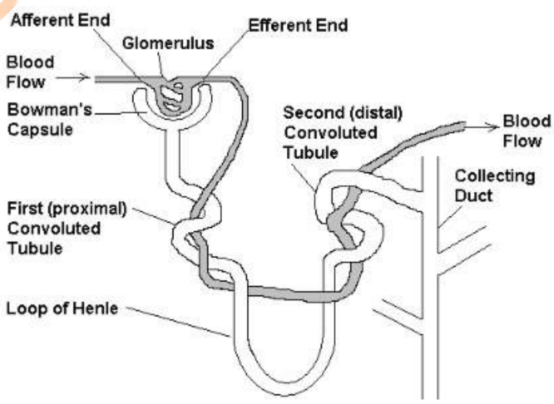


Functions of parts of Renal System
Aorta: Carries oxygenated blood from the heart to other parts of the body.
Venacava: Carries deoxygenated blood from different body organs towards the heart.
Renal Vein: Carries deoxygenated blood away from the kidneys towards the venacava.
Renal Artery: Carries oxygenated 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.

<u>Osmoregulation</u>

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.

<u>Secretion</u>

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.

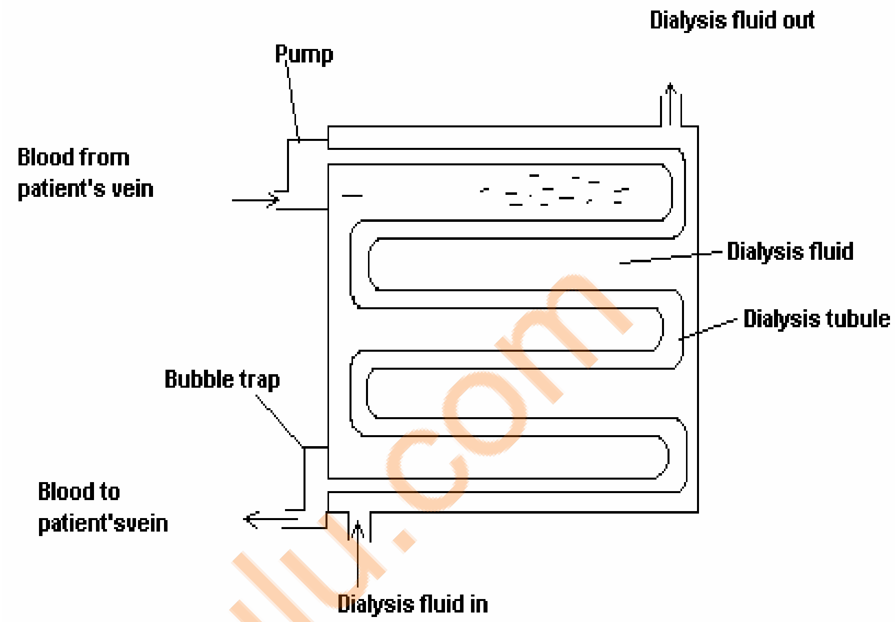
Kidney Failure and Treatment

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 damaged kidney is replaced with a normal one from another person called a donor. The transplanted kidney must be compatible with the recipient; otherwise there will be tissue rejection.
- 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.

<u>Exercise</u>:

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 plant excretory products are discussed below:

- **Alkaloids** such as **morphine** (in opium plants), **quinine** (in cinchona plants) and **cocaine** (in cocoa 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).

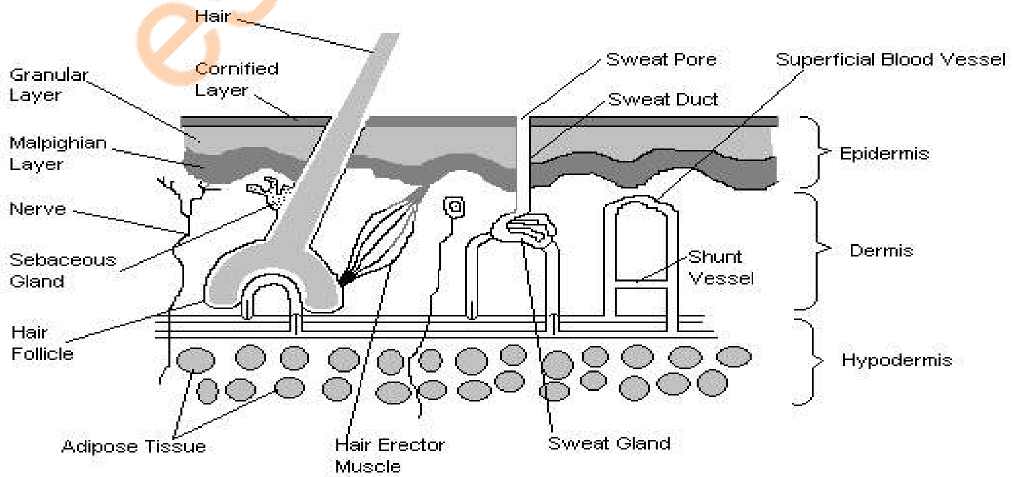
Thermoregulation

This is the maintenance of a constant body temperature. The temperature of the human body must be kept around **37^{o}C** because that is the **optimum temperature** for its enzymes. If the temperature goes lower then 37^{o}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 prevents 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 (about100g 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 cell division
- Region of cell elongation or vacuolation
- Region of cell differentiation or specialisation.

Diagram Illustrating Regions of Growth at the Shoot Apex

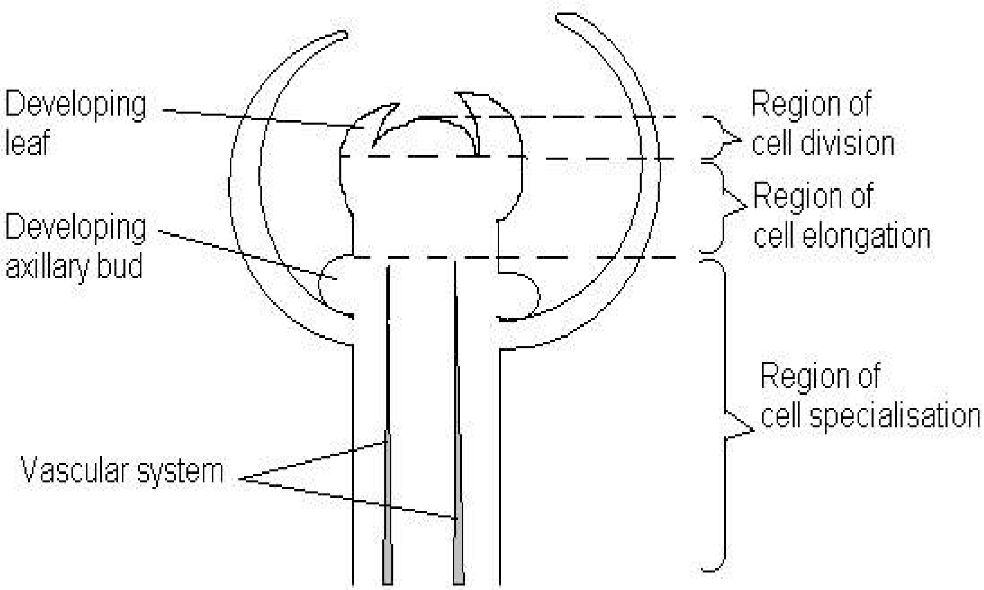
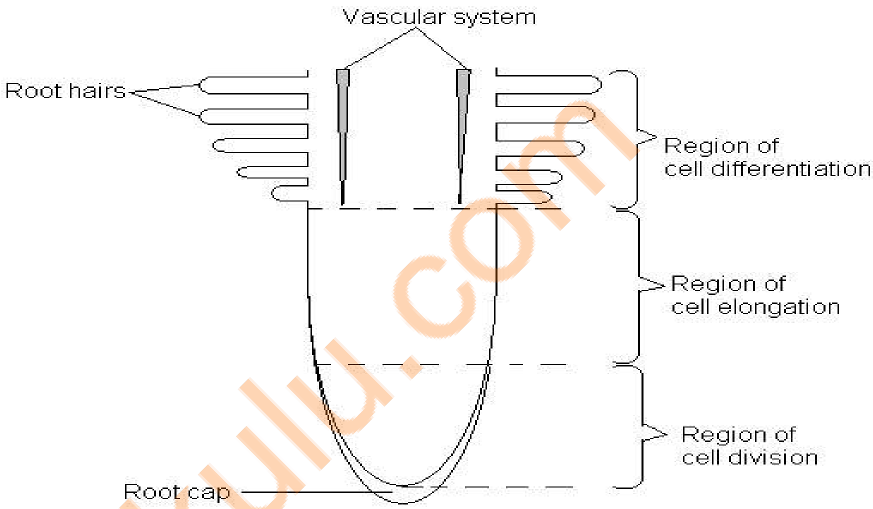


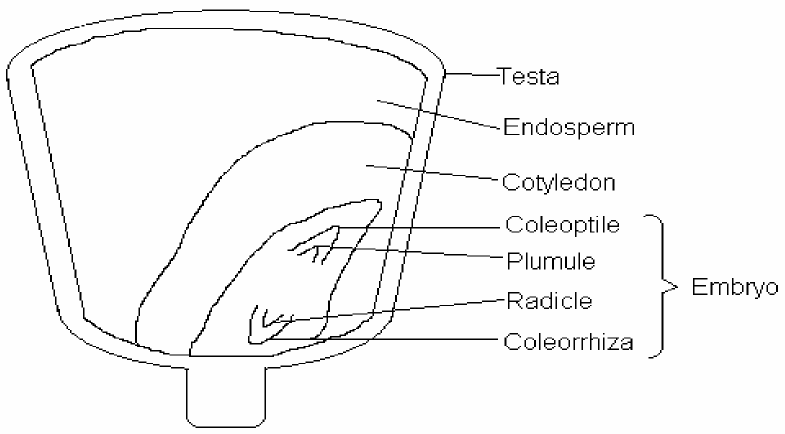
Diagram Illustrating Regions of Growth at the Root Apex



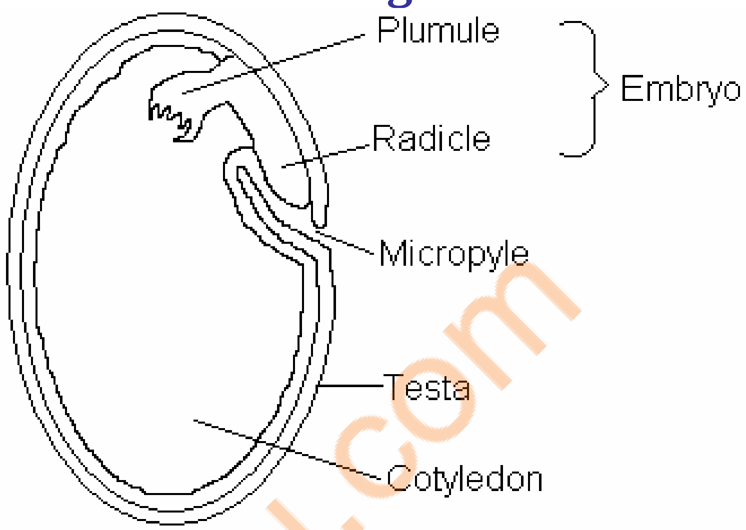
Germination

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.

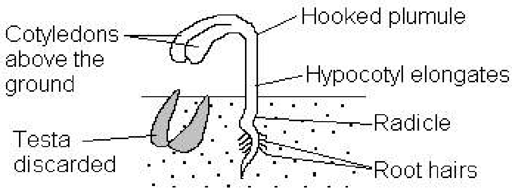
Types of Germination

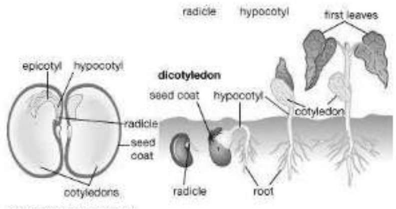
There are two types of germination, namely **epigeal** and **hypogeal** germination.

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, sunflower, castor oil and groundnut seeds. This type of germination is commonly associated with dicotyledonous seeds.

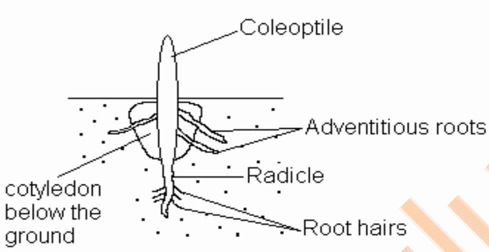
Diagram Illustrating Epigeal Germination

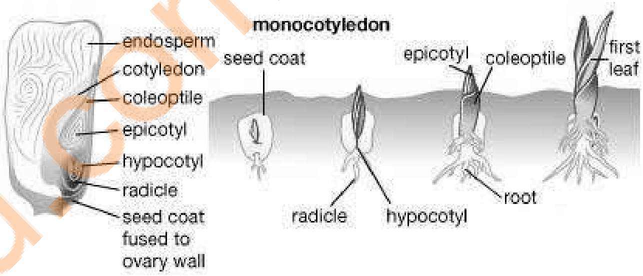




Hypogeal Germination

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.





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.

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

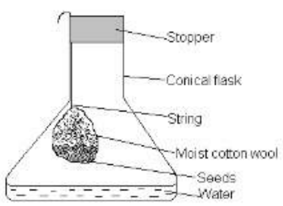
Suggested materials:

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

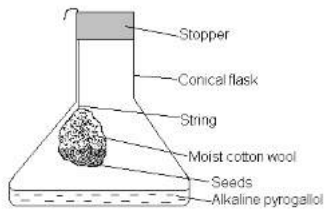
Method:

- Label two conical flasks, A and B
- Put 10 cm^3 of water in flask A and 10 cm^3 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 a 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^oC, beaker B at room temperature (about 25^oC) and beaker C in an oven at a temperature of 50^oC
- 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^oC (in beaker A) and those put in the oven at 50^oC (in beaker C) fail to germinate while those left at room temperature (in beaker B) germinate.

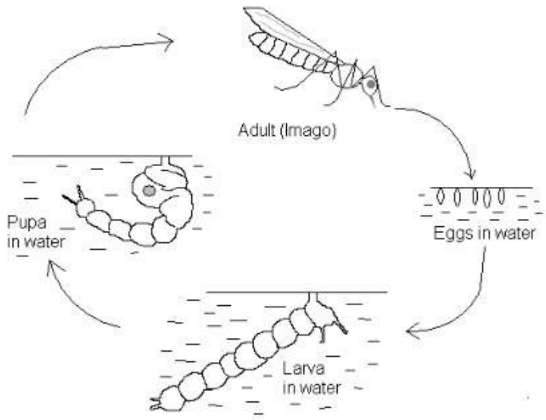
Conclusion

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.

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 undergoing 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.

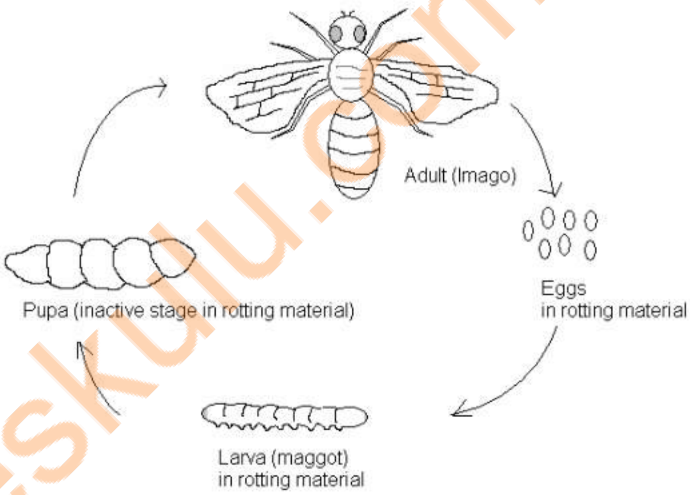
(iv) Use of insecticide – treated mosquito nets to trap and kill adult mosquitoes

(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:

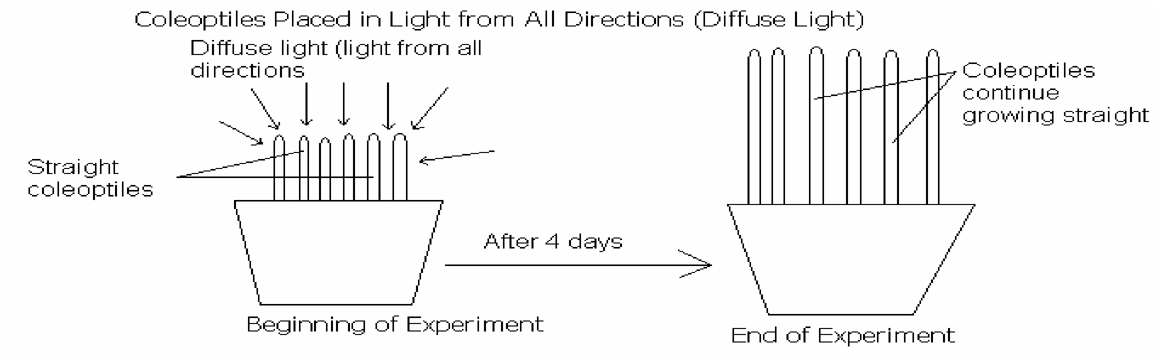
Maize seedlings, cardboard box with a hole on one side and two tins.

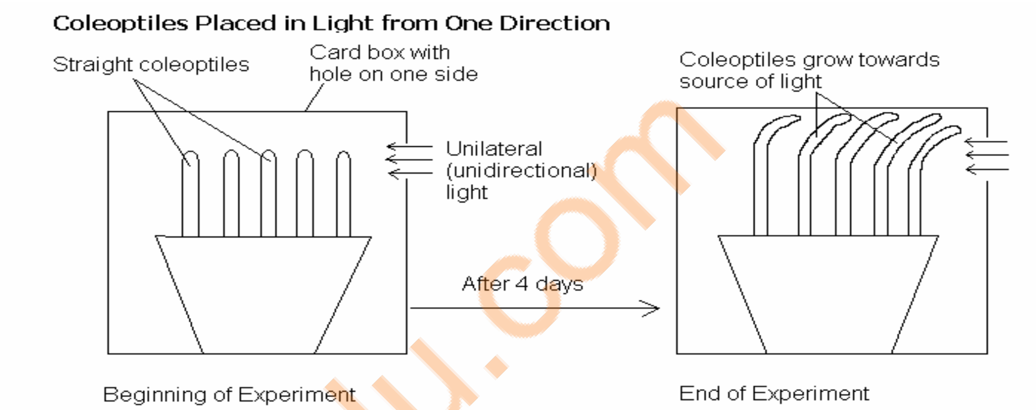
Method:

- 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:

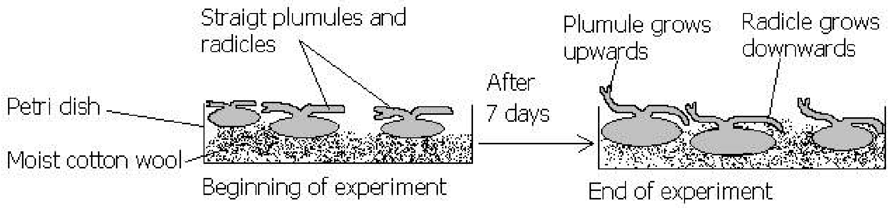
Germinating bean seeds, petri dish, moist cotton wool and clinostat

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:

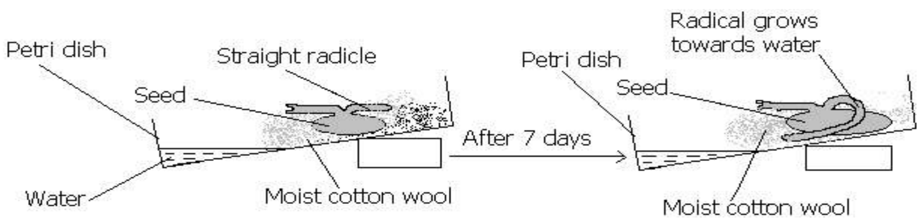
Germinating bean seed, petri dish and cotton wool

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

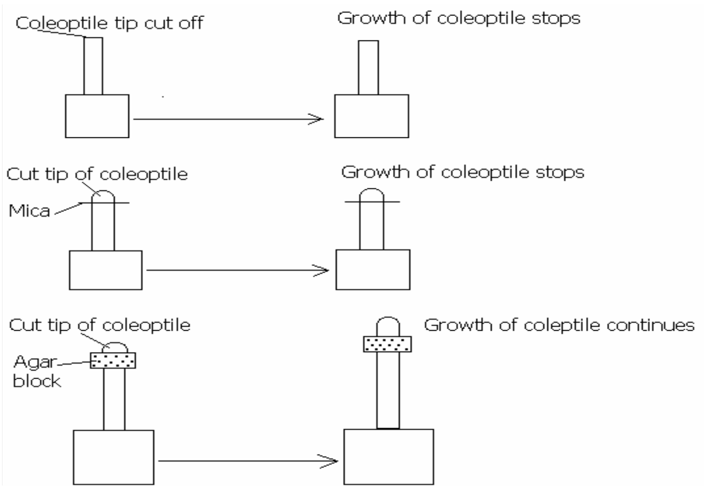
This is the response of a plant part to chemicals by growing either towards or away from the chemicals. Growth towards chemicals is called **positive chemotropism** while growth away from chemicals is called **negative chemotropism**. Plant parts grow towards chemicals relevant to them e.g. the pollen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

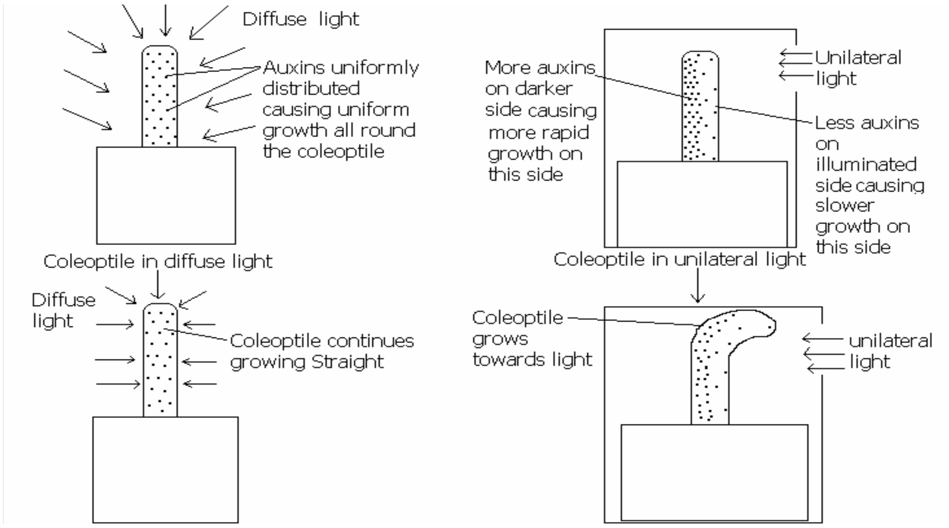
In one experiment, the tips of maize coleoptiles were cut off. After a few days, the shoots stopped growing because of the absence of auxins. In another experiment, a piece of mica was placed between the cut tip and the rest of the coleoptile and growth stopped after a few days because mica is impermeable 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

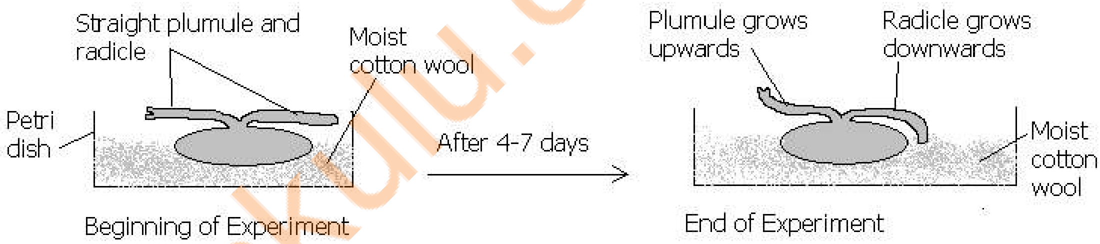
When a plant shoot is exposed to diffuse light (light from all directions), the auxins are evenly/uniformly distributed all round the shoot tip. As a result, growth is uniform all round the shoot tip, causing the shoot to grow straight. But when a plant shoot is exposed to unilateral light (light from 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)

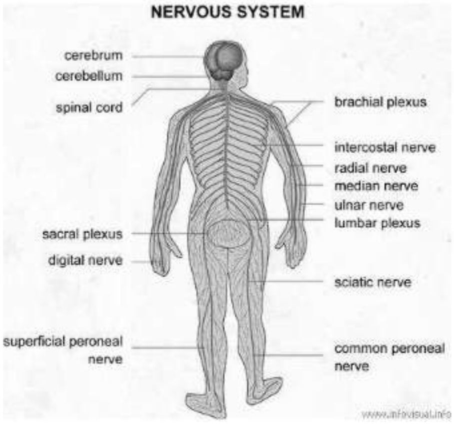
Taxic Responses

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**

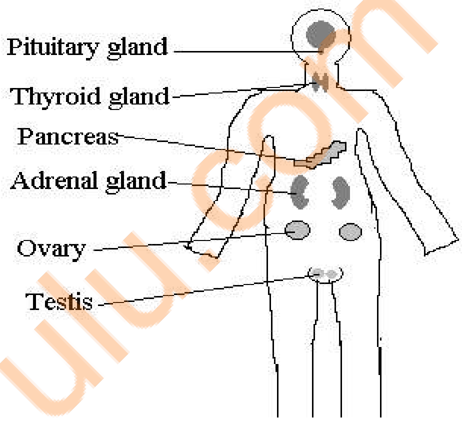
COORDINATION AND RESPONSE IN ANIMALS

Coordination is the process by which different organs and systems of he 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.



Pituitary Gland

The pituitary gland is also called he **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
- **Adrenocorticotrophic Hormone** (ACTH)): This stimulates the adrenal cortex to secrete hormones
- **Intestinal Cell Stimulating Hormone** (ICSH)): This stimulates the tests 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 e.g. when it is hot or after sweating. 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 cotrolling 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 Glands

This is a pair of glands, each located just above each kidney. The cortex 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 increase 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'.

Pancreas

The pancreas 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 produces 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 (about100g 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 are:

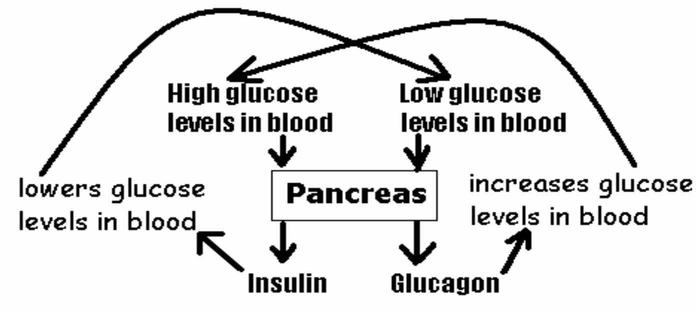
- High levels of glucose in blood
- Glucose in urine
- Persistent thirst leading to excessive intake of water
- Drastic loss of weight
- Loss of sensation in some body parts.

When glucose levels are too low in blood, the pancreas 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

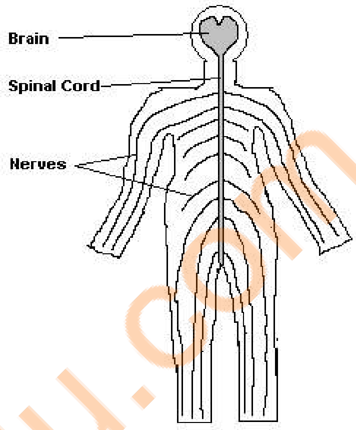
A negative feedback mechanism is a mechanism whereby changes in the internal environment are detected by a monitor/detector which produces a hormone to return the condition to normal. In the regulation of blood sugar, the pancreas plays the role of detector, as illustrated in the following diagram:



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**.

Diagram of the Human Nervous System



Neurones

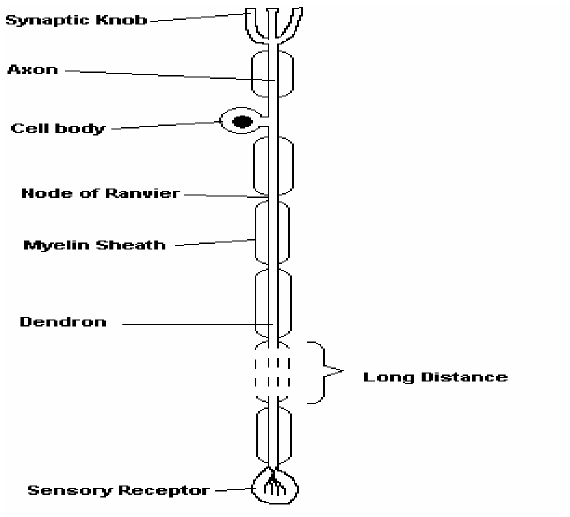
The basic functional units of the nervous system are **neurones** or **nerve cells**. Types of neurones include **sensory**, **relay** (connector, intermediate, multipolar, pyramidal) and **motor** neurones

<u>Sensory Neurones</u>

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**.

Diagram of Sensory Neurone

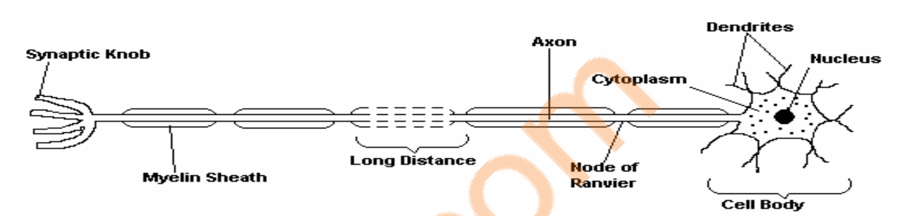


Motor Neurones

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).

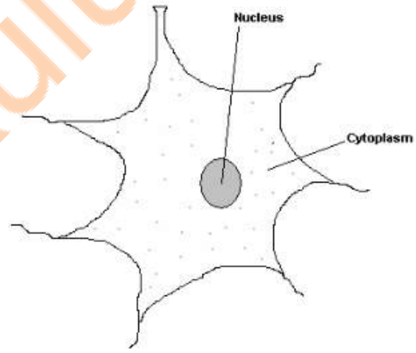
Diagram of a Motor Neurone



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.

Diagram of a Multipolar Neurone



Synapses

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

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.

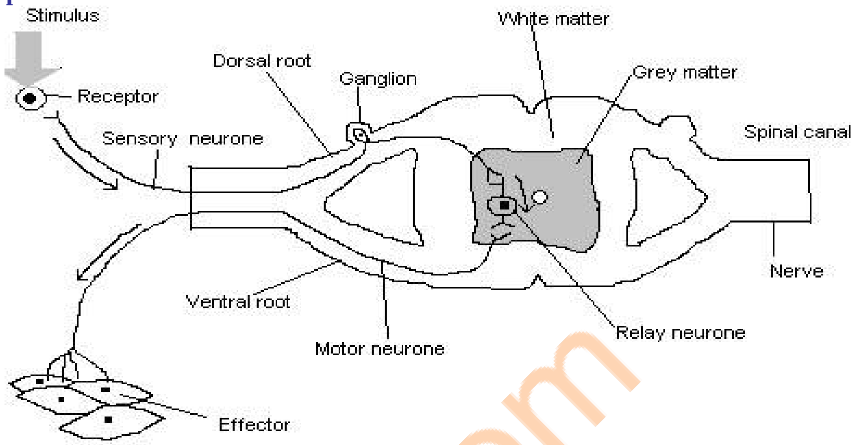
An example of a slow reflex action is the pupil reflex (iris reflex). Each reflex action has a survival value which protects an animal from dangerous factors. What is the survival value of each of the reflex actions stated above? Other examples of reflex actions are sneezing, salivating, peristalsis,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

Diagram of a Spinal 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**.

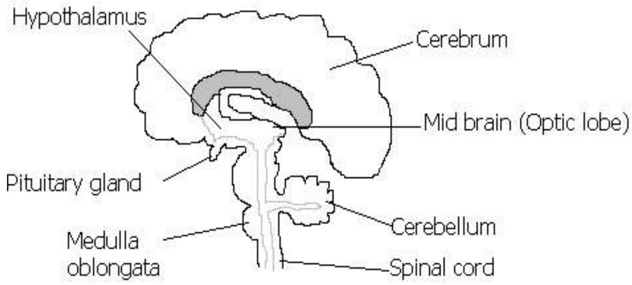
Conditioning is used in training of animals for different tasks. In humans, activities such as walking, responding to a name, cycling and driving are examples of conditioned reflexes.

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)

Diagram of the Brain



Functions of Brain Parts

Medulla Oblongata: This is located between the spinal cord and the brain and conducts nerve impulses between these two parts. It controls automatic processes such as heart rate, breathing rate, vasodilation, vasoconstriction, 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 controls thirst, hunger and thermoregulation.

Pituitary Gland: This belongs to both 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 occupies three quarters of the brain and 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. 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 (cerebral 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 because it is made up of axons of neurons.

Differences between Endocrine and Nervous System

Nervous System	**Endocrine System**
Messages are electrical (**nerve impulses**)	Messages are chemical (**hormones**)
Impulses conducted by nerves	Hormones carried by blood.
Responses carried out by **effectors**	Responses carried out by **target organs**
Responses are localised	Responses are widespread and affect more than one target organ
Responses are short-lived (temporary)	Responses are either temporary or permanent
Responses are often quick	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 to introduce drugs into blood).
- **Sniffing** (taking a vaporised drug in through the respiratory system).

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**: A condition where an individual's body fails to function properly in the absence of a particular drug. Such a person 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, which 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 to which they are addicted.

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.

(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:

- Overdoses can lead to instant death
- 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.

Note: The 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 L.S.D.

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 ant-tetanus infections which contain antibodies that counter the effects of tetanus toxins.