COMPLETE S.3 & S.4 BIOLOGY CLASS NOTES BY KUGONZA H. ARTHUR||2022

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GASEOUS EXCHANGE

This is the exchange of respiratory gases between the organism and the environment. It takes place across specialized surfaces called respiratory surfaces. Gaseous exchange helps an organism to get rid of CO_2 produced during respiration within cells and at the same time obtain oxygen needed for aerobic respiration to occur.

Gaseous exchange in plants

Plants do not have a special respiratory surface for exchange of gases. They do not breathe, and have no organs which are only used for respiration. The gases enter the tissues through openings called stomata in leaves and lenticels in roots and stems. The exchange of the gases takes place by diffusion where gases circulate in the plant tissues by simple diffusion due to large intercellular spaces between the cells that make air movement faster.

For example, if there is a deficit of oxygen in any part of the plant, oxygen will diffuse into the part from the surrounding air. Like ways, if there is a surplus of carbon dioxide, carbon dioxide will diffuse out to the air.

Plants do not need special respiratory organs because:

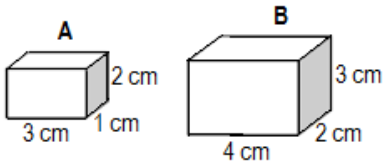
- They utilize CO_2 produced by the plant cells for photosynthesis thus preventing accumulation.
- Plants produce oxygen as a bi-product of photosynthesis which is then used in respiration.
- Plants have numerous stomata and lenticels that allow faster diffusion of gases to the tissues.
- They have large intercellular spaces between cells that allow faster circulation of gases to cells.
- They have low demand for oxygen due to their low metabolic rate because they are less active since they are immobile.

Gaseous exchange in simple organisms

Small organisms like amoeba, paramecium, hydra and jellyfish have a large surface area to volume ratio. In such organisms, gaseous exchange takes place over the whole-body surface. Because of their small body volume, diffusion alone is enough to transport oxygen and carbon dioxide into, around and out of their bodies.

Larger organisms such as insects and vertebrates have a small surface area to volume ratio. In these organisms, gaseous exchange takes place in a specialized region of the body known as a respiratory surface. The respiratory surface is part of the respiratory organ. It is the actual site where gaseous exchange takes place.

Note: Surface area to volume ratio is an important aspect in gaseous exchange. It is obtained by calculating the total surface area and dividing it by the volume of the object in question. For example, consider two boxes ***A*** and ***B*** below:



Box A is smaller than box B. We can work out the surface area to volume ratio of each box to prove that smaller objects have a larger surface area to volume ration than big ones.

Box A

Total surface area.

A = 2(2X1) + 2(3X2) + 2(1X3)

A = 4 + 12 + 6

A = 22 cm^2

Volume of A

V = L *x* W *x* H

V = 3 *x* 1 *x* 2

V = 6 cm^3

Surface area to volume ratio of A

$= \frac{22}{6}$

= 3.67

Box B

Total surface area.

A = 2(3X2) + 2(2X4) + 2(3X4)

A = 12 + 16 + 24

A = 52 cm^2

Volume of B

V = L *x* W *x* H

V = 4 *x* 2 *x* 3

V = 24 cm^3

Surface area to volume ratio of B

$= \frac{52}{24}$

= 2.3

The surface area to volume ratio of A is larger than that of B.

Therefore, the surface area to volume ratio of smaller organisms is larger than that of larger organisms. This facilitates a faster rate of diffusion of respiratory gases to all body tissues. Most of these organisms are single celled and some have only one layer of cells.

Larger organisms on the other hand have a smaller surface area to volume ratio. This reduces the rate of diffusion and diffusion alone cannot meet the respiratory demands of their large bodies. They also have a large diffusion distance because they have very many layers of cells. Due to this, large organisms have developed mechanisms, which reduce on the diffusion distance and increase the surface area to volume ratio. For instance;

- Mammals have developed a blood circulatory system which transports respiratory gases through highly branched blood vessels to all cells of the body.
- Insects have developed a tracheal system, which has finely divided tubes known as tracheoles which carry respiratory gases to and from all cells in the body of the insect.

Respiratory surfaces and corresponding respiratory organs

Animal	Respiratory organ	Respiratory surface
Amphibians	Lungs	Alveolus
	Skin	Skin surface
	Buccal cavity	Buccal cavity epithelium
Fish	Gills	Gill filaments
Insects	Tracheal system	Tracheoles
Mammals	Lungs	Alveolus
Tadpoles	Gills	Gill filaments

Note: the movement of gases and water to and from respiratory surface is called ventilation (breathing).

*Breathing is an **active process** involving movement of air in and out of the body whereas gaseous exchange is a **passive process** involving passage of air through respiratory surfaces/gaseous exchange surfaces.*

Respiratory surfaces are sites where gaseous exchange takes place in the body of the organism.

Characteristics of a good respiratory surface

i) They have a ***large surface area to volume ratio*** to enable rapid diffusion of gases. This is achieved by folding or branching of structures to form alveoli in lungs, gill filaments in the gills and tracheoles in insects.
ii) They are ***kept moist*** to dissolve gases for easy diffusion.
iii) They are ***thin walled*** to reduce on the distance over which diffusion has to take place.
iv) They have ***many blood capillaries*** to transport oxygen and carbon dioxide gases to and from the respiring tissues to maintain a high concentration gradient.
v) They are ***well ventilated*** to supply oxygen to the respiratory organ from the atmosphere and remove carbon dioxide from the respiratory organ to the atmosphere. This also maintains a high concentration gradient.

Gaseous exchange in a bony fish

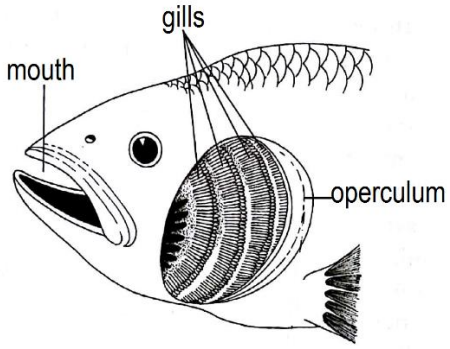
A bony fish such as Tilapia uses water as a medium of gaseous exchange and its respiratory surface are the internal gills.

The gaseous exchange system comprises of a mouth, gills, gill chamber, operculum and opercular opening.

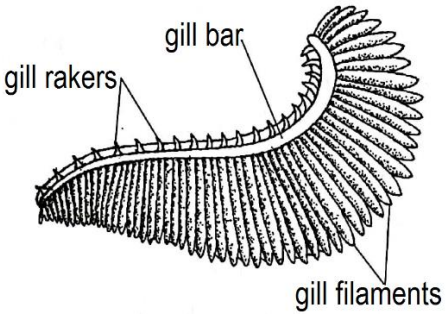
The operculum is a bony structure which covers the gills from the outside.

A gill chamber contains four gills on either side of the head of the fish.

Gaseous exchange structures in a bony fish



A gill of a bony fish



Parts of the gill:

Gill bar: this is a curved bony structure which supports gill rakers and filaments.

Gill rakers: These filter and prevent solid particles from reaching the delicate gill filaments.

Gill filaments: these are membranous projections on the gill bar. Each gill bar has two rows of gill filaments which are further subdivided into gill lamellae. The two rows of the gill filaments provide a large surface area for gaseous exchange. Blood vessels enter the gill filaments as capillaries to deliver carbon dioxide to the gills for removal take oxygen from the water to the rest of the body.

Water flows through the gills in the opposite direction to the flow of blood in the capillaries in the gills. This arrangement is known as ***countercurrent flow***. It ensures that there is maximum extraction of oxygen from water to blood. If blood and water were to flow in the same direction, this arrangement would be called ***parallel flow*** which is less efficient hence less oxygen would diffuse into the blood.

Gaseous exchange in amphibians

Amphibians include frogs and toads. They live both in water and on land. The early stage of growth and development occur in water, while an adult frog/toad lives partly in water and on land. They therefore, have gaseous exchange structures for breathing on land and in water. They are ***external*** and ***internal gills*** in tadpoles, ***skin, mouth lining*** and ***lungs*** in adult frogs/toads.

Gaseous exchange in Man

The respiratory organs in man are lungs and the respiratory surfaces are the sac like structures called alveoli.

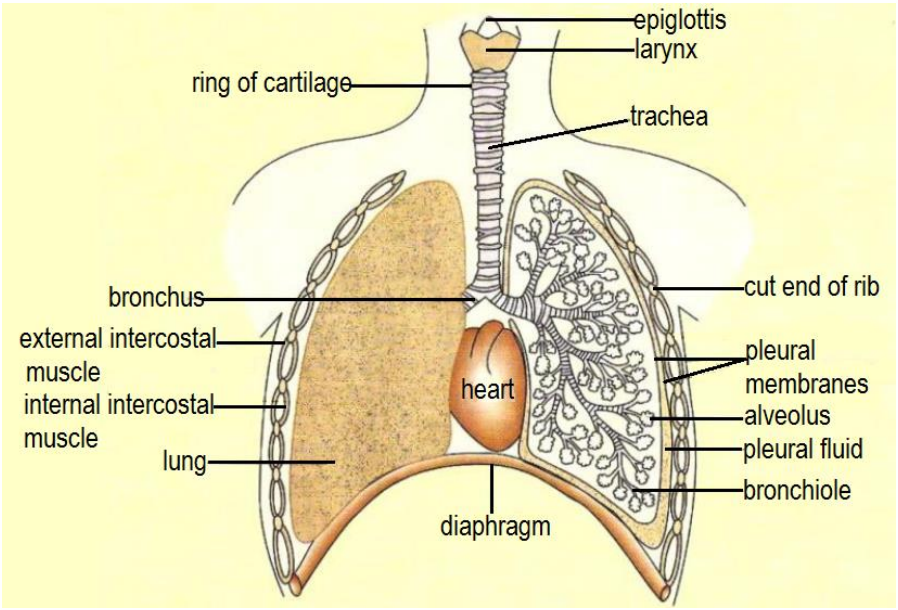
The respiratory tract (air passage)

Air enters through the ***nostrils*** into the nasal cavity where it is warmed to body temperature. The nasal cavity is lined with mucus secreting cells and hairs. The mucus and hairs filter and trap dust and micro-organisms from the air.

The air is then passed to the ***pharynx*** from which it goes into the ***larynx*** through a small opening called ***glottis*** which has a flap known as the ***epiglottis*** which closes when a person is swallowing to prevent food from entering the trachea. The air then enters the ***trachea***. Choking and coughing are reflex actions which remove any liquid or solid particles which accidentally enter the trachea.

From here, air travels to the lungs through the bronchus, bronchioles and lastly to the alveolus.

The respiratory tract system



The trachea: This is a tube made up incomplete rings of cartilage along its length which resist collapse whenever there is decreased pressure in the chest cavity. The inner lining has cilia and also produces mucus to trap and filter microorganisms and dust particles, preventing them from entering the lungs. The ***cilia*** beats moving mucus upwards towards the pharynx at the back of the mouth where they are swallowed.

The bronchus: At the lower end, the trachea divides into two tubes called ***bronchi***, which penetrate further into the lungs and divide repeatedly to form small tubes called ***bronchioles***.

The bronchioles have no rings of cartilage and divide into many small tubes called ***alveolar ducts***, which ends up into a tiny sac called ***alveoli***.

The alveoli: An alveolus is a sac-like structure. Each alveolus is kept moist and thin walled surrounded by an extensive a network of blood capillaries.

The lungs: These are two elastic spongy-like structures located within the ***thoracic cavity*** and protected by the ***rib cage***. Each lung is enclosed by two membranes called the ***pleural membranes***. The space between the membranes is the ***pleural cavity*** filled with ***pleural fluid***.

In between the ribs are internal and external ***intercostal muscles***, which move the rib cage and below the lungs is a muscular sheet of tissue called the ***diaphragm.***

Mechanism of breathing in mammals

Breathing in:

- The external intercostal muscles contract while the internal intercostal muscles relax.
- This makes the rib cage to move outwards and upwards. The diaphragm contracts and flattens.
- This increases the volume of the thoracic cavity and reduces the pressure in it below that of the atmosphere.
- Air moves into the lungs through the nostril, trachea, bronchi, and bronchioles until it reaches the alveoli.

Breathing out:

- The internal intercostal muscles contract and the external intercostal muscles relax.
- This makes the rib cage to move downwards and inwards.
- The diaphragm muscles relax and the diaphragm returns to its dome shape.
- The volume of the thoracic cavity reduces and pressure increases beyond atmospheric pressure.
- This forces the lungs to contract and release air out of the lungs through the bronchi, trachea and nostrils.

Gaseous exchange in the alveolus

This takes place across walls of alveoli and blood capillaries by diffusion.

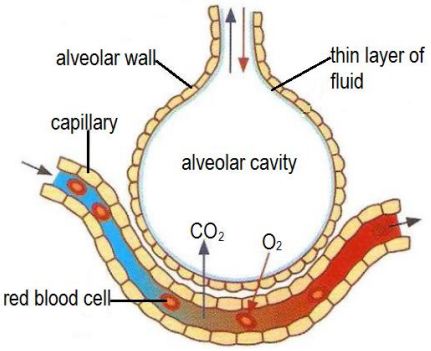
During inspiration, air is taken into the lungs filling the alveoli. When there is a high concentration of oxygen in the air spaces of alveoli than in the blood, oxygen diffuses across the membranes of the alveoli and capillaries into the blood stream in the capillaries.

The oxygen combines with haemoglobin to form ***oxyhaemoglobin***. Some oxygen dissolves in the plasma. The oxygen is transported to the tissues and body organs. Oxyhaemoglobin releases oxygen to the tissues which use it during respiration and produce carbon dioxide.

When tissues have a high concentration of carbon dioxide than the blood in the capillaries, the carbon dioxide diffuses from the tissue cells across the membranes of the capillaries into the blood.

Some carbon dioxide dissolves in plasma to form carbonic acid and some of the gas combines with haemoglobin to form ***carbaminohaemoglobin***.

Gaseous exchange in the alveolus



Some carbon dioxide dissolves in plasma to form carbonic acid and some of the gas combines with haemoglobin to form ***carbaminohaemoglobin***.
Carbon dioxide diffuses across the membranes of capillaries and alveoli into the alveolar space

Carbon dioxide is released from the alveolar space through the nostrils as a person is breathing out

Revision questions

1. *Outline five ways how alveoli are adapted for gaseous exchange.*
2. *What are the functions of cilia and mucus found in the mammalian trachea?*
3. *Describe how carbon dioxide is transported in blood.*
4. *The table below shows the composition of three gases during breathing in humans.*

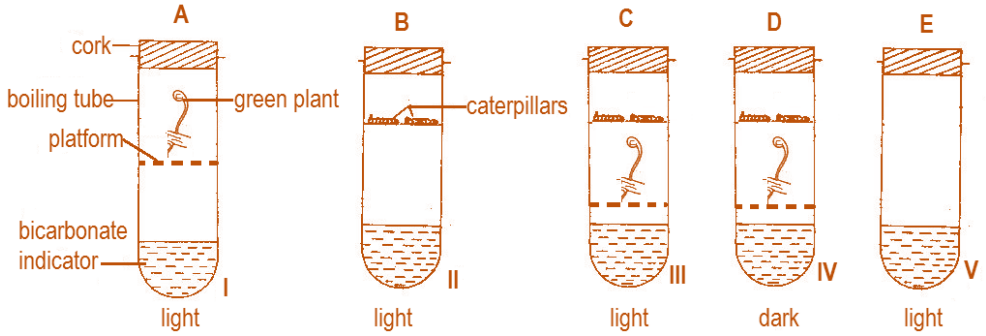
Gas	***Inhaled air***	***Exhaled air***
Oxygen	*21*	*16*
Carbon dioxide	*0.04*	*4.0*
Nitrogen	*79*	*79*

Explain the differences in the composition of the gases between inhaled air and exhaled air.

5. *A bicarbonate indicator changes colour depending on the amount of carbon dioxide present:*

Yellow	***Red***	***Purple***
Much CO_2	*Normal amount of CO_2*	*Very little CO_2*

*Five test tubes were set up as shown in the figure below. Each one contained red bicarbonate indicator at first, and they were left for **four** hours. With a reason in each case, state the colour you would expect the indicator to be in each test tube.*



Changes in the composition of gases in blood capillaries across the alveolus

	Volume of gas carried by 100 cm^3 of blood	
Gas	**Entering lungs**	**Leaving lungs**
Nitrogen	0.9 cm^3	0.9 cm^3
Oxygen	10.6 cm^3	19.0 cm^3
Carbon dioxide	58.0 cm^3	50.0 cm^3

The blood that flows towards the lungs contains a larger volume of carbon dioxide and less oxygen. But as it leaves the lungs, oxygen is added to it and some CO_2 is removed from the lungs. This indicates exchange of gases within the lungs.

Changes in approximate air composition during breathing

Component	Inhaled air	Exhaled air
Nitrogen	79%	79%
Oxygen	21%	17%
Carbon dioxide	0.03%	4%
Water vapour	Less saturated (variable)	Saturated
Temperature	Atmospheric temperature	Body temperature

Although nitrogen is exchanged within the lungs and blood plasma, it plays no part in chemical reactions of the body hence its composition remains the same in inspired and expired air.

Inhaled air has more oxygen compared to exhaled air because it is taken up for the process of respiration, which produces out CO_2. Hence exhaled air contains more CO_2 than inhaled air. However, the process of gaseous exchange in alveoli does not remove all the carbon dioxide and oxygen in air.

How CO_2 is removed from the mammalian body tissue to atmosphere

- CO_2 in the tissues diffuse through the thin cavity membranes of capillaries into blood and then across thin membrane of a red blood cell into the cytoplasm.
- In the cytoplasm, CO_2 combines with water to form carbonic acid.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

- The carbonic acid formed dissociates to form hydrogen ion and hydrogen carbonate ion as shown below.

$$H_2CO_3 \longrightarrow H^+ + HCO_3^-$$

- The cell membrane of a red blood cell is permeable to negative ions but impermeable to positive ions. Thus, hydrogen carbonate ion diffuses out of a red blood cell into blood plasma.
- The blood is transported to the lungs where there is high concentration of O_2. In the lungs, the reactions above are reversed which results into formation of CO_2.
- CO_2 diffuse across the blood capillaries in the lungs to the alveoli and then expelled out of the lungs to the atmosphere.

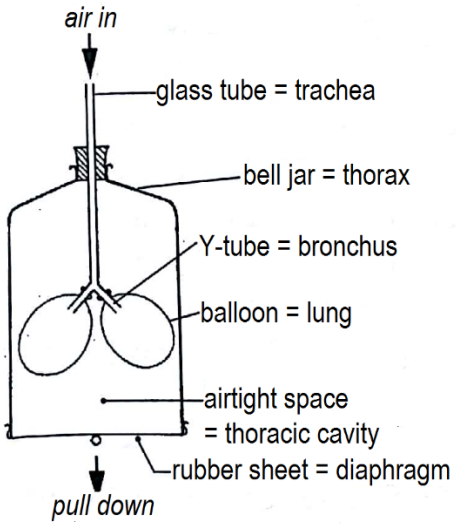
$$HCO_3^- + H^+ \longrightarrow H_2O + CO_2$$

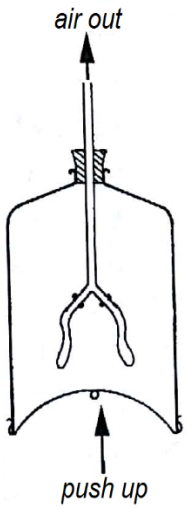
Experiment to demonstrate breathing mechanism in a model thoracic cavity

Materials: Glass tubing, cork, rubber tubing, Y-tube, bell jar, two balloons, rubber sheet and thread.

Procedure:

- Set up the apparatus as shown in the figure below. Make the jar airtight by filling the gaps using petroleum jelly.
- Pull down the rubber sheet at the base of the bell jar.
- Observe what happens to the balloons.
- Then release the rubber sheet slowly and observe what happens to the balloons.
- Identify and label the parts in the set up that are similar to the breathing mechanism in a living mammal.





Observation:

When the thread is pulled, the rubber sheet stretches. This increases the volume in the bell jar and reduces the pressure. Air enters from out through the glass tube to the Y-tube and inflates the balloons.

- When the thread is released, the rubber sheet returns to its normal flat shape. This reduces the volume in the bell jar and increases the pressure. Air is forced out of the balloons through the Y-tube and glass tubing. This deflates the balloons.

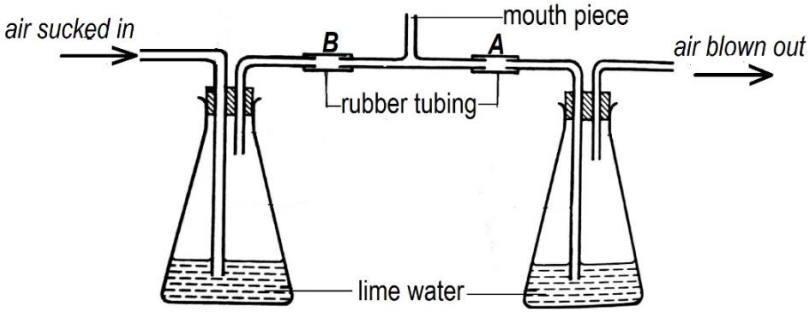
Conclusion: Pulling of the thread represents inspiration and its release represents expiration.

An experiment to show the composition of exhaled air and inhaled air

Materials: thistle funnel, soda lime, cotton wool, two conical flasks, lime water, two rubber tubings, a T-tube and three delivery tubes.

Procedure:

- Prepare the apparatus as shown in the figure below:
- Hold tight to close rubber tubing ***A*** and breathe in through the mouthpiece, release the rubber tubing ***A*** and hold to close



rubber tubing ***B*** and breathe out still through the mouthpiece.

- Repeat the procedure three times while observing the changes on the lime water.

Observation: The lime water in the conical flask where air blown out passes turns milky whereas the lime water in the conical flask where air sucked in passes remains clear.

Conclusion: Exhaled air contains carbon dioxide gas.

Revision questions

1. *What are the advantages of breathing through the nostril rather than the mouth in human beings?*
2. *Describe a laboratory experiment to demonstrate the breathing mechanism in humans.*
3. *Explain the following observations:*
   a) Waterlogging of the soil may lead to death of plants.
   b) Mouth-to-mouth resuscitation is more effective with breathed out air than with breathed in air.
   c) People living in high altitudes have a higher red blood cell count and more haemoglobin than people living in low altitudes.

TISSUE RESPIRATION

Respiration is the process by which food substances are broken down by enzymes in cells to provide energy. During respiration carbon dioxide, water and alcohol or lactic acid are formed. When there is enough oxygen during respiration, alcohol or lactic acid is not formed. The organelle in which respiration takes place is the ***mitochondrion***.

The excess energy is stored as Adenosine tri phosphate (ATP), later broken down to release the energy when needed by the body.

The energy released is used by the body for the following activities:

- Contraction of the heart muscles to maintain blood flow.
- Contraction of the thoracic muscles to bring about breathing.
- Muscle contraction to bring about movements.
- Transmission of nerve impulses.
- Maintenance of a constant body temperature.
- Cell division to bring about growth.
- Excretion.
- Secretion of substances like hormones and enzymes.

Aerobic respiration

This is the breakdown of glucose using oxygen to release energy, carbon dioxide and water. This type of respiration produces energy, Carbon dioxide and water. This is the most efficient process by which energy is produced because there is complete breakdown of glucose and it therefore produces more energy.

The overall equation for aerobic respiration is:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + energy$$

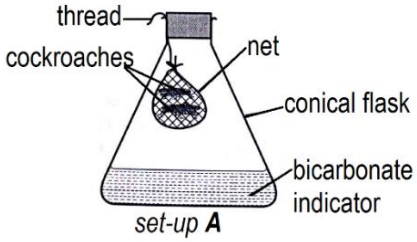
Glucose oxygen carbon dioxide water

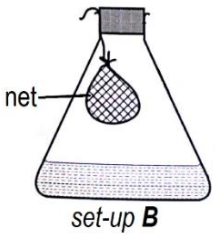
An experiment to show aerobic respiration in animals

Materials: grasshoppers or cockroaches, two pieces of muslin cloths or net, bicarbonate indicator solution, two conical flasks, measuring cylinder, two rubber bungs and threads.

Procedure:

- Put 3 cm^3 of bicarbonate indicator solution in the two conical flasks.
- Label conical flasks, ***A*** and ***B***
- Put about two grasshoppers on a muslin cloth or net and place them in conical flask ***A***. Cover the conical flask immediately with a cork as shown in the figure below.
- Place only a muslin bag or net in the conical flask labelled ***B*** and cover it also with a cork immediately.





- Leave the set up for 30 minutes.
- After 30 minutes, observe the bicarbonate indicator solution in both flasks ***A*** and ***B***.

Observation: The bicarbonate solution in flask ***A*** turns from red to yellow. This shows that cockroaches are releasing carbon dioxide through respiration. The bicarbonate solution in flask ***B*** remains red.

Conclusion: Aerobic respiration takes place in animals where carbon dioxide is released. Carbon dioxide gas changes the colour the colour of the bicarbonate indicator.

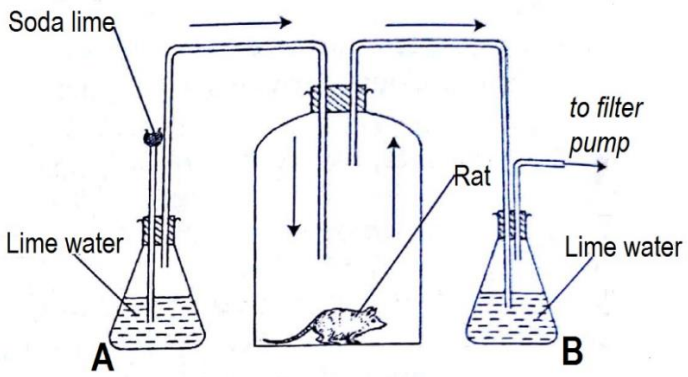
1. *What changes occur in conical flasks A and B*
2. *Explain your observations above.*

An experiment to show that respiration takes place in animals

Materials: Soda lime (sodium hydroxide pellets), lime water, filter pump, rat, delivery tubes, two conical flasks, corks, bell jar and petroleum jelly or wax.

Procedure:

- Set up the apparatus and materials as shown in the figure below.
- Use the petroleum jelly or wax to seal off any gaps to prevent air from entering into the apparatus.
- A stream of air should be drawn slowly through the apparatus by a filter pump.
- Observe any changes in the conical flasks ***A*** and ***B***.



Observation:

Limewater in *flask* ***B*** turned milky while that in *flask* ***A*** remained clear.

Conclusion:

Respiration takes place in animals during which carbon dioxide gas is released.

Note:

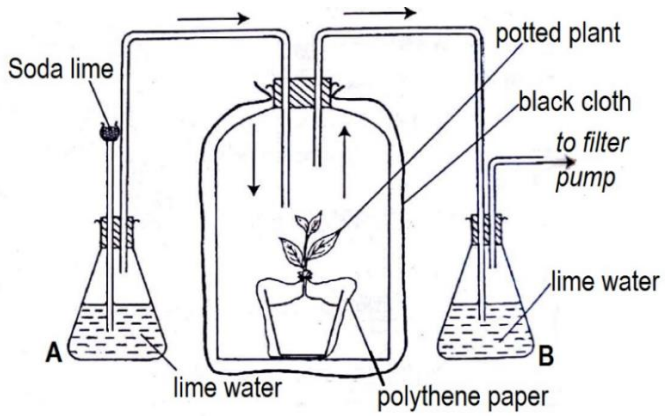
- The purpose of sodium hydroxide is to absorb CO_2 from the incoming air.
- Lime water in *flask* ***A*** is used to confirm the absence of CO_2 in the incoming air.
- Lime water in *flask* ***B*** is used to test for the presence of CO_2 in exhaled air. Carbon dioxide reacts with lime water to form a white precipitate which makes the solution appear milky.
- The filter pump ensures one direction of air.

An experiment to show that respiration takes place in plants

Materials: Soda lime (sodium hydroxide pellets), lime water, filter pump, black cloth, potted plant, delivery tubes, conical flasks, corks, bell jar and petroleum jelly or wax.

Procedure:

- Set up the apparatus and materials as shown in the figure below.



- Use the petroleum jelly or wax to seal off any gaps to prevent air from entering into the apparatus.
- Place the potted plant under the bell jar and cover the bell jar with a black cloth. The black cloth prevents the green plant from carrying out photosynthesis. The soil is also covered with polythene paper to exclude any gas from the soil.

- A stream of air should be drawn slowly through the apparatus by means of a filter pump.
- Observe any changes in the conical flasks ***A*** and ***B***.

Observation: Limewater in *flask **B*** turned milky while that in *flask **A*** remained clear.

Conclusion: Respiration takes place in plants during which carbon dioxide gas is released.

Revision questions

1. *Why is the bell jar covered with a black cloth?*
2. *Where does carbon dioxide in the soil come from?*
3. *State the role of the following in the set up?*
   i) *Soda lime.*
   ii) *Lime water in flask **B.***
4. *Explain how soda lime removes carbon dioxide from the air coming into the apparatus.*
5. *Explain what was observed in flask **A** and **B.***

Anaerobic respiration

This is the breakdown of glucose to release energy in absence of oxygen. In this process, glucose is not completely broken down.

In plants, glucose is oxidized in the absence of oxygen to release ***carbon dioxide, energy*** and ***ethanol*** as shown in the equation below:

$$\underset{\text{glucose}}{C_6H_{12}O_6} \longrightarrow \underset{\text{ethanol}}{2C_2H_5OH} + \underset{\text{carbon dioxide}}{2CO_2} + \text{Energy}$$

Anaerobic respiration in a solution leading to release of bubbles of gas is called ***fermentation***. Fermentation occurs when bacteria or fungi like yeast break down glucose in sugar solutions to form alcohol, carbon dioxide and heat energy. Such organisms only respire anaerobically because they live where oxygen is absent or in short supply. Yeasts, for example have respiratory enzymes which catalyze the breakdown of sugars to carbon dioxide and alcohol known as ethanol.

In animals, glucose is broken down in absence of oxygen to form lactic acid and energy only as shown in the equation below:

$$\underset{\text{glucose}}{C_6H_{12}O_6} \longrightarrow \underset{\text{lactic acid}}{2CH_3CH(OH)COOH} + \text{Energy}$$

The incomplete break down of glucose results into less energy being released from the same amount of glucose compared to aerobic respiration.

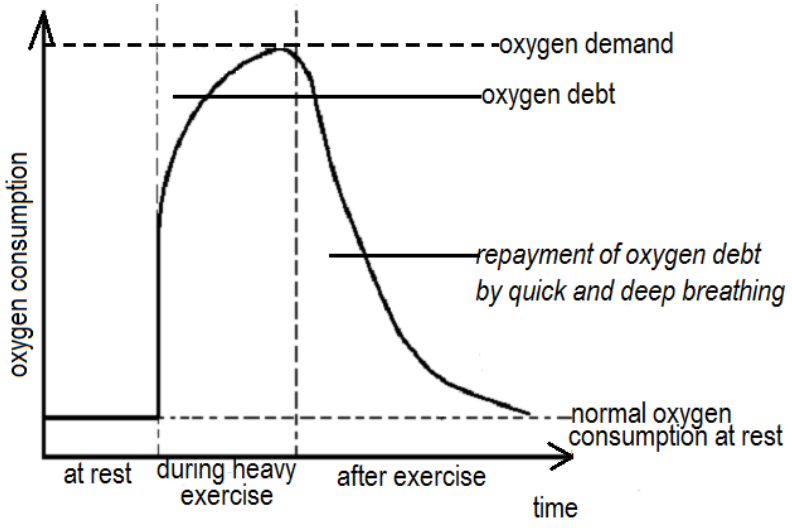
Most of the energy remains blocked in the intermediate substances (ethanol and lactic acid). When oxygen is provided lactic acid can be further broken down to release the remaining energy.

Anaerobic respiration occurs in animals during strenuous exercises such as flying in birds and running in animals. This leads to build up of lactic acid in the muscles. Lactic acid is toxic to body cells. During vigorous exercises, the energy demand increases and the oxygen consumption in the animal exceeds the oxygen supply, leading to an ***oxygen debt***.

Oxygen debt

During vigorous activities, the oxygen supply to muscles may not be enough to meet the energy demands of the organism. In the process, the muscle cells respire anaerobically to provide more energy leading to accumulation of lactic acid in the muscles which has to be oxidized when the race is over.

A graph showing the rate of oxygen consumption before exercise, during exercise and after exercise

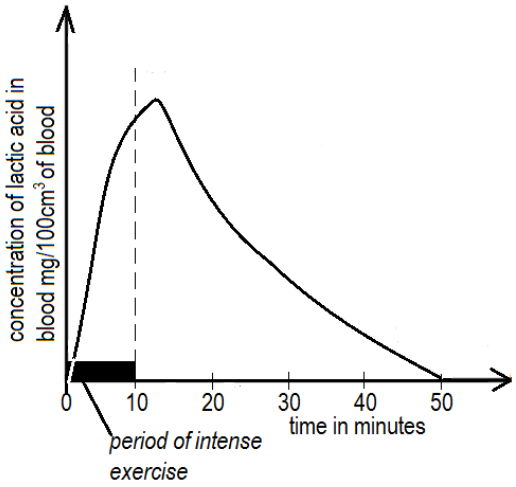


As a result, the supply of oxygen into the body increases by breathing more quickly and deeply after an exercise to provide the extra oxygen required to oxidize the accumulated lactic acid to CO_2, water and energy.

Oxygen debt therefore is the amount of oxygen needed to break down the accumulated lactic acid in muscles after vigorous exercises.

Discussion question: *Describe and explain the changes shown in the graph above.*

Graph showing change in lactic acid and concentration during and after exercise



Lactic acid increases rapidly during an exercise till the end. This is due to increased rate of anaerobic respiration due to limited supply of oxygen.

At the end of the exercise, lactic acid content in muscles decreases rapidly because it is being oxidized to CO_2, water and more energy in the liver. The oxygen used in breaking down this lactic acid is attained by breathing quickly and deeply.

Application of anaerobic respiration

- Brewing to produce beer, wines and spirits though fermentation using yeast.
- It is also used in baking of bread to raise dough.
- Sewage and industrial effluent treatment to reduce any harmful effects to living organisms.
- Manufacture of dairy products such as butter, cheese and yoghurt.

Revision questions

1. *An experiment was carried out on a young man in which the volume of air taken in at each breath and the number of breaths per minute were measured at rest and after running.*

	Volume of air per breath	***Breaths per minute***
At rest	*450 cm^3*	*20*
After running	*1000 cm^3*	*38*

   a) *What is the total volume of air breathed in per minute at rest and after running?*
   b) *20% of the air breathed in consisted of oxygen, but only 16% of the air breathed out consisted of oxygen. Assuming that these figures remain constant, work out the volume of oxygen entering the blood per minute at rest after exercise.*
   c) *Why does the amount of oxygen taken up into the blood increase after exercise?*

2. *The table below represents percentages of oxygen and carbon dioxide in two samples of air. Study the table and answer the questions that follow.*

Gas	*Atmospheric air*	*Alveolar air*	*Exhaled air*
Oxygen	*20.96%*	*13.8%*	*16.4%*
CO_2	*0.03%*	*5.5%*	*4.1%*

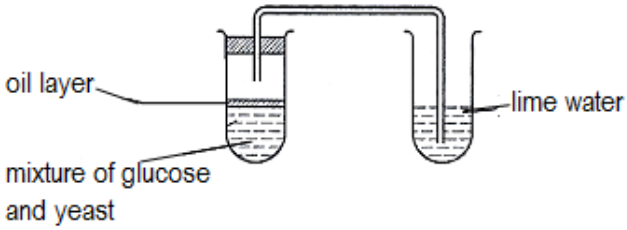
   a) *What is the difference between the percentage of oxygen in the alveolar air and that in the exhaled air?*
   b) *What is the reason for this?*
   c) *Why does alveolar air contain more carbon dioxide than atmospheric air?*
   d) *Why does a person breathe fast after a race?*
   e) *State one situation in which the percentage of oxygen in alveolar air can become higher than given above.*
   f) *Living organisms require energy for various activities taking place in their bodies. State two ways in which energy is used by animals.*
   g) *Why would you give an athlete glucose and not sucrose after a race?*
   h) *A man who normally lives at sea level moves to a place which is 2000 meters above sea level. He finds that his breathing rate is increased. Explain why this happens.*
   i) *Give five characteristics of an efficient respiratory organ of an animal.*

Experiment to show that carbon dioxide is given off during fermentation of glucose solution by yeast

Materials: Two test tubes, delivery tubes, yeast, glucose, oil and lime water.

Procedure:

- Boil about 10 cm^3 of glucose solution in one test tube ***to drive off oxygen*** from it and allow it to cool to room temperature.
- Add a layer of oil over glucose solution to prevent oxygen from dissolving in it.
- Introduce a small quantity of yeast suspension to the glucose solution using a pipette.
- Pour limewater in another test tube.
- Using a delivery tube and rubber bangs fix the delivery tube in the test tube and lime water as shown below.
- Leave the experiment to stand in a warm place for an hour. Ensure that the delivery tube dips into the lime water.



Set up a control experiment in the same way but using a boiled yeast suspension or without yeast or without glucose.

Observation: Bubbles of a gas are seen in limewater and limewater turns milky.
Conclusion: Carbon dioxide is produced during anaerobic respiration.
Explanation:
Yeast breaks down glucose in absence of oxygen to produce ethanol, CO_2 and some heat.
The CO_2 produced turns lime water milky by reacting with calcium hydroxide to form a white precipitate.

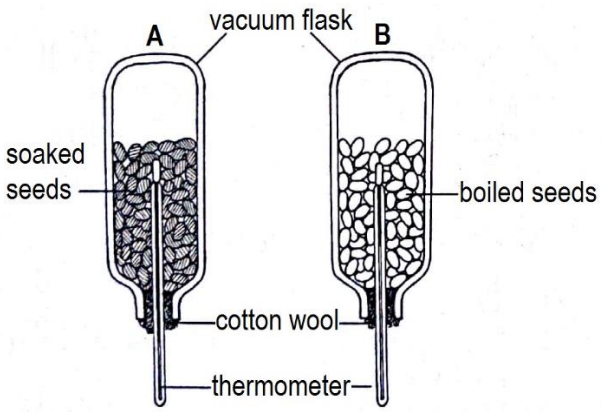
Experiment to show that heat is produced by germinating seeds during respiration

Materials: Two vacuum flasks, beans, cotton wool, two thermometers and sterilizer such as sodium hypochlorite or formalin.
Procedure:

- Sock bean seeds for 24 hours in water after which divide the seeds into two equal portions.
- Boil one portion for 10 minutes to kill the protoplasm in the seeds.
- Soak the boiled beans.
- Both sets of seeds are socked in formalin for 15 minutes in order to kill any bacterial and fungal spores.
- Place unboiled beans in vacuum flask ***A*** and the boiled beans in vacuum flask ***B***.

- Insert a thermometer in each of the flasks and plug their mouths with cotton wool. Make sure that the bulbs of the thermometer are dipped in the beans.
- Leave the experiment to stand for three days.

Setup:



Observation:

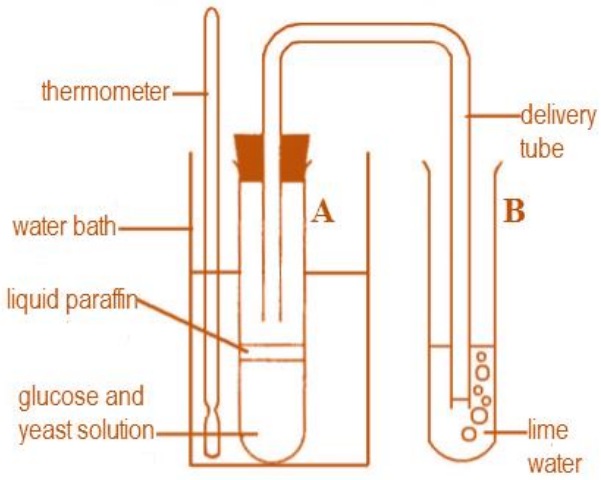
After three days the temperature in the germinating seeds (unboiled beans) is higher than that of the boiled seeds. That of the boiled seeds remains constant.

Conclusion: Germinating seeds give out heat.

Explanation: During germination oxygen is absorbed to carry out respiration, which gives out energy in form of heat.

Revision questions

The figure below illustrates an experiment to demonstrate a certain biological process in yeast cells. Before addition of yeast suspension, the glucose solution was first boiled and then cooled.



*The gas produced in tube **A** passed through the delivery tube and formed bubbles in lime water in **B**.*

The number of bubbles produced during the period of 5 minutes intervals, at each temperature starting at 15^0C. At each temperature, tube A was immersed in a water bath for two minutes before counting the bubbles began.

Temp. in ^0C	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*50*	*55*	*60*	*65*
No. of bubbles	*0*	*1*	*4*	*9*	*14*	*21*	*28*	*35*	*38*	*38*	*38*

a) Plot a graph of changes in the number of bubbles released by yeast with temperature.
b) From the graph, explain the changes in the number of bubbles produced with temperature
c) Determine the rate of bubbling at 27^0C.
d) What process was investigated in the experiment above?
e) What observations would you make in lime water a few minutes after the experiment has begun? Explain your answer.
f) Explain why:
i) Glucose was boiled.
ii) Glucose was cooled before adding yeast

iii) A liquid paraffin seal was placed over the reaction mixture in the tube.

g) List any two industrial uses of the process that is being demonstrated by the experiment.

Differences between aerobic and anaerobic respiration

Aerobic respiration	Anaerobic respiration
More energy is released from one glucose molecule.	Less energy is released from one glucose molecule.
Products are water, carbon dioxide and energy.	Products are carbon dioxide, energy and alcohol or lactic acid.
There is complete breakdown of glucose.	Incomplete breakdown of glucose.
Oxygen is used	Oxygen is not used.
Occurs in the cytoplasm and mitochondria	Occurs in the cytoplasm.

Similarities between aerobic and anaerobic respiration

- Both require glucose as a raw material.
- Both produce energy.
- Both produce Carbon dioxide.
- Both take place in living cells.

Importance of respiration

- Respiration produces energy that is used to run the various activities in the body.
- It is exploited commercially in baking, brewing and making of dairy products such as cheese, yoghurt and butter.

Differences between respiration and photosynthesis

Respiration	Photosynthesis
Oxygen is used	Oxygen is released.
Carbon dioxide is released	Carbon dioxide is used.
Takes place in light and darkness	Needs light to take place.
Energy is released	Uses energy.
Does not require chlorophyll	It requires chlorophyll.
Take place in plants and animals	Takes place in plants only.

EXCRETION AND HOMEOSTASIS

Excretion is the removal of waste products of metabolism from the body. These waste products are toxic when allowed to accumulate in the body.

Homeostasis is the control and maintenance of a constant internal environment around the cells in the body despite fluctuations in the external environment.

The processes that contribute to excretion and homeostasis are egestion and secretion. **Egestion** is the removal of indigestible and undigested food substances that have not participated in the metabolic activities from the body. **Secretion** is the release of *useful substances* from cells into body fluids such as blood and tissue fluids, or to the outside of the body. Examples of secretions are hormones, enzymes, mucus, milk and wax.

Importance of excretion and homeostasis

- Excretion removes toxic waste products whose accumulation in the body poisons/harms the organism.
- Excretion removes excess materials in the body which when left to accumulate affects the body metabolism.
- Homeostasis maintains the internal environment within normal range whose deviation would affect body's metabolic reactions.

Examples of excretory products

1. Nitrogenous excretory products.

These are excretory products, which contain the element ***nitrogen***. They include ammonia, urea and uric acid.

Ammonia:

This is a ***highly toxic*** nitrogenous waste and it ***requires a lot of water for its elimination***. It is very soluble in water and due to this it requires less energy to be excreted. Ammonia is excreted by organisms which live in fresh water and therefore have a lot of water in their bodies. Such organisms include bony fish, protozoans and amphibians when in water.

Urea:

This is a ***less toxic*** nitrogenous waste. It ***requires less water for its excretion***. It however requires a lot of energy for its excretion because of its low solubility in water compared to ammonia. Urea is excreted by terrestrial organisms which have easy access to water and marine organisms. Such organisms include terrestrial mammals, amphibians when on land and cartilaginous fish.

Uric acid:

This is ***less toxic*** than urea and ***requires no water for its elimination*** from the body. It is ***insoluble in water***. The disadvantage of excreting uric acid is that it requires a lot of energy for its excretion. Uric acid is excreted by birds, reptiles and insects and also common in desert animals.

2. Non nitrogenous excretory products.

These are excretory substances that do not contain the element nitrogen. Such products include carbon dioxide, water, excess salts and excess water.

Excretion in Amoeba

Amoeba is a protozoan. They live in fresh water and therefore their body fluids are hypertonic to the surrounding medium. Water moves by osmosis through the cell membrane into the body of the amoeba. This leads to accumulation of excess water in the cytoplasm which is removed by the ***contractile vacuole***. Water containing dissolved ammonia, excess mineral salts and carbon dioxide is drawn into the contractile vacuole. The vacuole fills up and then moves towards the cell membrane which bursts to release its contents into the surrounding. Most of the carbon dioxide is excreted by simple diffusion.

Excretion in plants

Plants carry out metabolic processes such as photosynthesis and respiration. Carbon dioxide from respiration is used in photosynthesis, while oxygen from photosynthesis is used in respiration. Any waste products from metabolic processes that are not used need to be excreted. Metabolic processes in plants occur at a slower rate than in animals and hence plants do not need special excretory organs because:

- Some waste products produced in one process are used in another process yet animals rarely reuse their waste products.
- Most of the substances broken down in plants are carbohydrates in nature which are not harmful to plants.
- Animals are more active than plants because they move about in search for food, shelter and mates.
- Animals produce a variety of waste products in larger quantities than plants.
- Plants can store excess proteins unlike in mammals.
- Plants do not produce nitrogenous waste products. They produce non-nitrogenous wastes which are less toxic to their bodies.
- Some wastes accumulate in particular parts of the plant and they are eliminated when this part of the plant falls off.
- Plants do not locomote and they are less metabolically active than animals.

Plant waste products

Most of the excretory products of plants are useful to humans. These include:

i) **Carbon dioxide:** this is produced during respiration. It is released out of the plant at night. However, during day it is reused for photosynthesis.
ii) **Oxygen:** it is produced during photosynthesis. It is reused during respiration.
iii) **Resins:** It is a transparent hard or sometimes soft substance exuded by some trees and plants such as fir and pine. It is secreted by plants for protection in response to injury against insects and pathogens. They are used to make varnish and adhesives.
iv) **Tannins:** they are deposited in dead tissues of trees such as bark and wood. They are common in acacia, conifers and mangroves. Tannins are used in the treatment of leather and in the manufacture of ink. They are also used in cosmetics like *henna* used to colour the nails, feet and hair.
v) **Latex:** is a milky substance produced by some plants. Latex from the *rubber tree is used to make rubber.*
vi) **Anthocyanin:** these produce the red, purple and blue colours of petals. They are extracted to make dyes.
vii) **Alkaloids:** these are very poisonous nitrogenous compounds, some of which are used in small dozes as medicines such as quinine, cannabis, cocaine, caffeine and morphine.

Methods of excretion in plants

i) Diffusion: Waste products that are in gaseous form like carbon dioxide and oxygen are excreted through stomata and lenticels by diffusion.
ii) Transpiration: Water containing dissolved carbon dioxide and oxygen are excreted through transpiration.
iii) Guttation: This is the secretion of droplets of water from the pores of plants. Water and dissolved mineral salts are excreted through guttation.
iv) Deposition: Resins, tannins, caffeine, nicotine, etc. are deposited in the xylem, bark, seeds, fruits, flowers and leaves of plants so that the plant is able to carry out metabolic activities without the influence of the deposited substances. When these structures fall off or drop, any waste products they contain are got rid of incidentally.
v) Exudation: This is the release of a fluid from a plant at a slow rate. Such wastes include gums, resins, latex and rubber.

EXCRETION IN ANIMALS

Animals like human beings have specialized organs such as the kidneys, lungs, liver and skin for excretion. Waste products include carbon dioxide, water, mineral salts and

nitrogenous wastes. These excretory organs ensure that ions, water and temperature are regulated in the body.

A table showing organisms and their excretory organs, products and habitat

Example of organism	Excretory product	Excretory organ	Habitat
Bony fish	Ammonia	Kidney	Fresh water
Cartilaginous fish	Urea	Kidney	Marine water
Reptiles	Uric acid	Kidney	Terrestrial
Birds	Uric acid	Kidney	Terrestrial
Tadpoles	Ammonia	Gills	Fresh water
Adult amphibians	Ammonia	Kidney	Fresh water
	Urea		Terrestrial
Mammals	Urea	Kidney	Terrestrial
Insects	Uric acid	Malphigian tubules	Terrestrial

In mammals the excretory organs are the kidneys, skin, liver and lungs. Their excretory waste products are as shown in the table below.

Organ	Excretory products
Skin	Urea, ammonia, carbon dioxide, lactic acid, excess mineral salts and excess water
Lungs	Carbon dioxide and excess water
Kidney	Urea, ammonia, uric acid, excess salts and excess water.
Liver	Bile, excess cholesterol, urea

Revision questions

The table below shows changes in the amount of ammonia excreted by a tadpole during development.

Age of tadpole or frog(days)	*50*	*55*	*65*	*75*	*90*	*95*	*100*	*110*
Ammonia as % of total excretory material	*92*	*88*	*84*	*83*	*68*	*20*	*13*	*12*

a) Plot a graph of the data above.
b) Describe the changes in percentage of ammonia excreted with time.
c) With a reason, identify the period when the animal leaves water.
d) Explain the importance of excretion by animals.
e) State two structural changes that accompany the change in excretory product.
f) From the data what is the importance of metamorphosis in the animal?

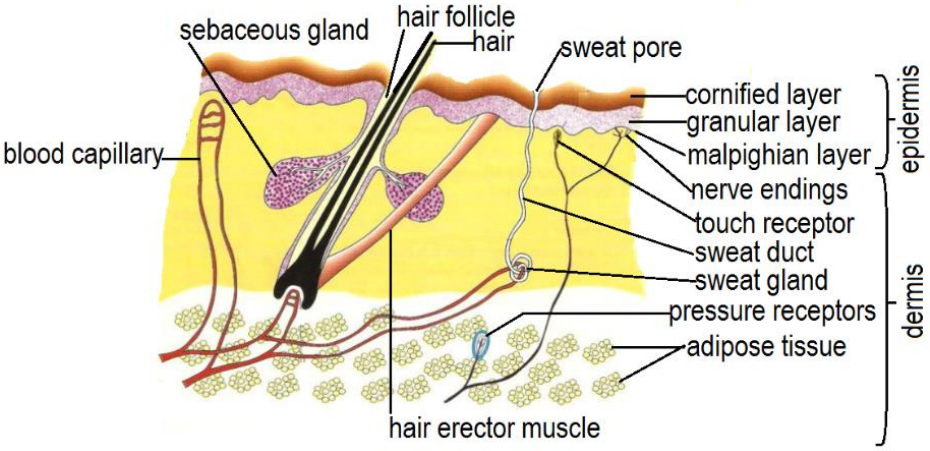
The skin

The skin is a continuous protective layer over the body. It is the largest organ of the body.

Functions of the skin

- Protection of the body from physical damage.
- Protection against entry of microorganisms such as bacterial and viral infections.
- Prevents loss of water from the body.
- It acts as a sense organ sensitive to pain, touch and heat. This helps the organism to be aware of its environment.
- Regulates body temperature.
- It synthesizes vitamin D in presence of sunlight.
- It excretes salts, excess water, lactic acid, carbon dioxide and traces of urea.
- Stores fats in the adipose tissue.
- Melanin pigment blocks ultraviolet rays from penetrating into the body tissues.

Structure of the skin



The epidermis:

This is made up of three sub layers.

i) The Malpighian layer

This is the inner most sub layer in the epidermis. It consists of dividing cells which give rise to cells of the granular layer. It secretes a pigment called melanin, which gives the skin its colour and protects the skin from ultraviolent rays. Albinos do not produce melanin in their skins.

ii) The granular layer

This contains living cells arising from the malphigian layer. It is the biggest layer of the epidermis. It gives rise to cells of the cornified layer.

iii) The cornified layer.

This is the outermost layer of the skin. It is made up of dead cells, which are keratinized. Cells of this layer continuously ware away and are replaced by cells from the granular layer. Its function is to protect the inner parts of the body from mechanical injury and entry of bacteria and other germs.

The dermis:

This is the inner layer of the skin. It is below the Malpighian layer. It is thicker than the epidermis.

It contains the sweat glands, nerve fibers, fat cells and blood capillaries.

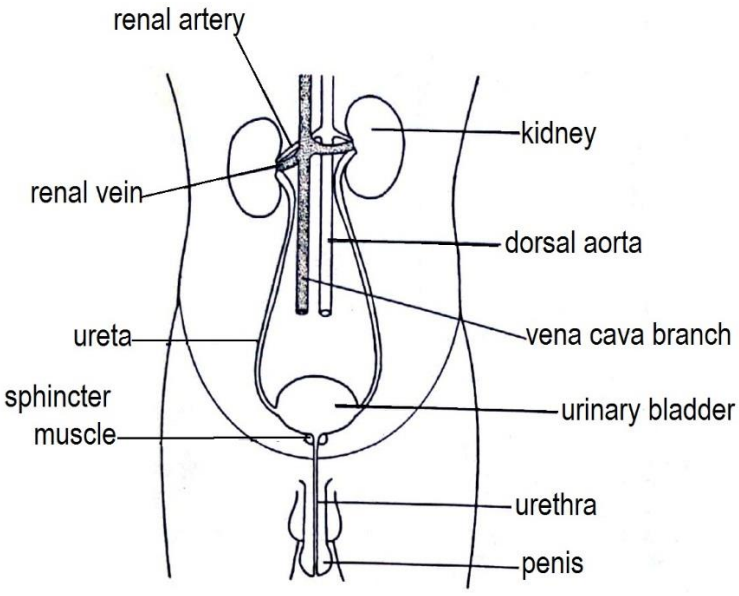
Functions of other parts of the skin

i) **Hairs:** They protect the body and trap a layer of air on the skin which insulates the body against heat loss.
ii) **Sebaceous gland:** This secretes an oily substance called sebum. This oil softens the cornified layer and prevents it from cracking. The oil also provides water proofing to the skin.
iii) **Nerve endings:** These perceive external stimuli and transfer impulses to the central nervous system.
iv) **Sweat glands**: They excrete sweat, which is released out of the skin through the sweat duct.

The human urinary system

This is a collection of organs and tissues involved in the formation and removal of urine out of the body.

Diagram showing the human urinary system



Functions of parts of the urinary system

Aorta:

Supplies blood to renal artery.

Renal artery:

It brings blood containing excretory products to the kidney.

Renal vein:

It carries filtered blood from the kidney to the posterior vena cava.

Ureter:

Carries urine from the kidneys to the urinary bladder.

Urinary bladder:

It is a thick walled elastic sac-like structure which stores urine before it is removed from the body.

Sphincter muscles:

They relax to let urine out of the bladder into the urethra.

Urethra:

It's a passage for urine out of the body from the urinary bladder.

The human kidney

The kidneys are solid bean-shaped structures and they occur in pairs in mammals. They are reddish-brown in colour enclosed in a transparent membrane and attached to the back of the abdominal cavity. It plays a role in excretion, homeostasis and osmoregulation.

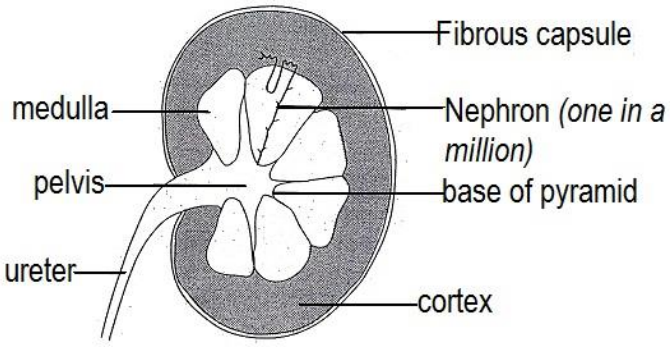
The kidney has two major parts:

1. The **cortex** which is a dark outer part. It consists of the Bowman's capsule which is responsible for ultra-filtration of blood passing across it.
2. The **medulla**, which is a lighter inner part. It is made up of many cone-shaped portions called pyramids.

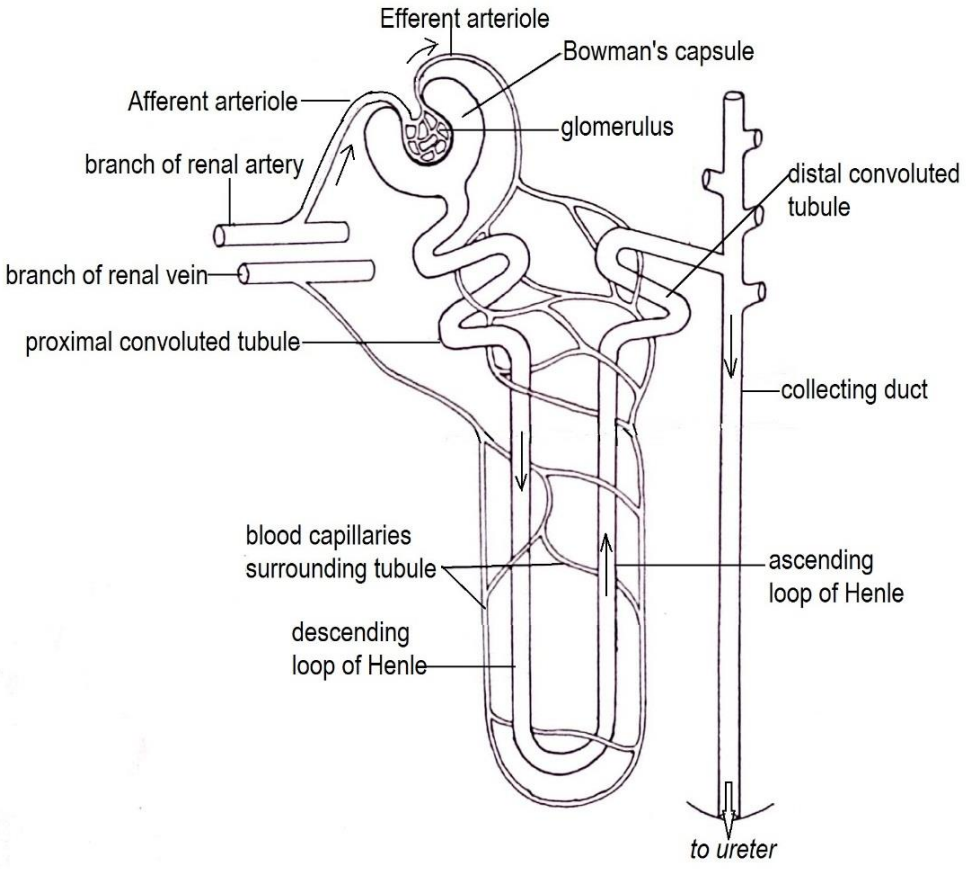
The pelvis is the area where the ureter leaves the kidney.

The kidney is made up of several microscopic structures (functional units) called **nephrons** where the actual excretion and osmoregulation takes place. The nephrons run from the cortex, thorough the medulla and back to the cortex.

Structure of the kidney



Structure of the nephron



Parts of the nephron and their functions

1. Bowman's capsule:

Contains a dense-network of capillaries called ***glomerulus*** formed from a wider afferent arteriole.

The Bowman's capsule filters small molecules from blood into the capsular space such as urea, glucose, etc. which forms the glomerular filtrate through a process called *ultra-filtration*.

Adaptations of the glomerulus to ultra-filtration

- The afferent arteriole is wider than the efferent arteriole which generates high blood pressure in the glomerulus that forces small molecules out of the glomerulus.
- Has many capillaries in the glomerulus that give it a large surface area for ultra-filtration.
- Has a semi permeable membrane that allow any small molecule to pass through.

2. Proximal convoluted tubule:

This is a site where re-absorption of useful materials such as glucose and some small amino acids and water from glomerular filtrate back to blood takes place.

3. Loop of Henle:

It's made up of a descending (going down) limb and an ascending (going up) limb. The *main function of the loop of Henle is to make the tissue fluid in the medulla more concentrated than the glomerular filtrate in the nephron so that water needed in the body is reabsorbed****. It's known to cause water retention in the body****.** *This is one way of conserving water in camel because of its extremely long loop of Henle.*

4. Distal convoluted tubule:

It mainly re-absorbs salts like chloride ions together with water, leaving a concentrated liquid now called urine which passes down to collecting ducts.

5. Collecting duct: This duct carries urine from the distal tubule to the pelvis. It is also permeable to water thus allows reabsorption of water back into blood.

Functions of the kidneys

- It contains endocrine glands, which secrete hormones.
- Excretion of metabolic waste products such as urea, excess water, uric acid, ammonia, etc.
- Regulation of water and solute content of blood (osmoregulation)
- Maintenance of PH of body fluids at 7.4.
- Regulation of blood levels of ions such as Na^+, K^+, Cl^-, Ca^{2+}
- Retention of important nutrients such as glucose and amino acids through reabsorption from glomerular filtrate into blood.

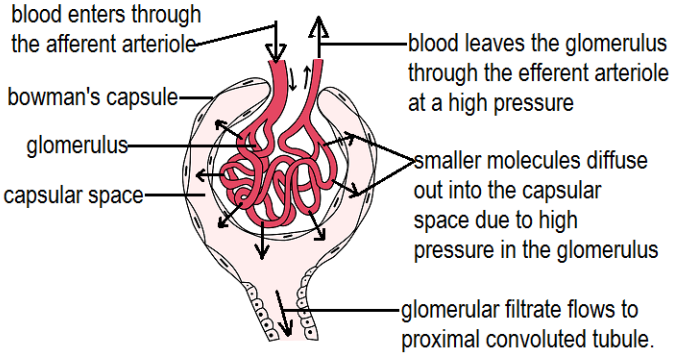
Urine formation

The process of urine formation takes place in the nephron. It occurs in two phases i.e. ***Ultra-filtration*** and ***Selective re-absorption***.

Much blood comes from the afferent vessel into the glomerulus than that which leaves through efferent because the afferent vessel is wider than the efferent vessel. This creates high pressure in the glomeruli that leads to **ultrafiltration.**

The walls of the blood capillaries have very small pores which only allow small molecules to pass through into the Bowman's capsule to form the glomerular filtrate. *This filtrate contains glucose, amino acids, hormones, uric acid, urea, water, salts and vitamins.*

Diagrammatic illustration of ultrafiltration



Plasma proteins and blood cells are retained in the blood capillaries because they are made up of large molecules which cannot pass through the capillary walls.

The glomerular filtrate flows into *proximal convoluted tubule* where useful substances are selectively reabsorbed back into the blood capillaries.

Substances useful to the body are reabsorbed. This is referred to as **selective reabsorption**

In the proximal convoluted tubule:

All the glucose, amino acids, vitamins, hormones and a big percentage of sodium chloride and water are reabsorbed into the blood capillaries. The blood capillaries join and drain the substances into the renal vein and eventually into the general blood circulation. The glomerular filtrate flows into loop of Henle.

In the loop of Henle:

The loop of Henle is U-shaped with a descending and ascending limb. As the filtrate flows down the descending limb, water is re absorbed back into the capillaries by osmosis leading to increased concentration of the filtrate down the descending limb.

As the filtrate ascends the thick ascending limb, sodium chloride is reabsorbed by active transport. The glomerular filtrate flows to the distal convoluted tubule.

In the distal convoluted tubule:

Selective reabsorption of salts occurs. Also water is reabsorbed depending on the permeability of the tubules which is affected by hormones. The glomerular filtrate flows to the collecting ducts.

In the collecting duct:

More water is reabsorbed and the remaining highly concentrated filtrate is ***urine***. The urine drains into the pelvis. It then flows to the urinary bladder through the ureter.

Note: *Because of the high concentration, when urine is poured on grass or any plant, they get scotched because the cells lose water to the surrounding concentrated urine and the plant cells become flaccid. This brings about wilting and drying of the plant.*

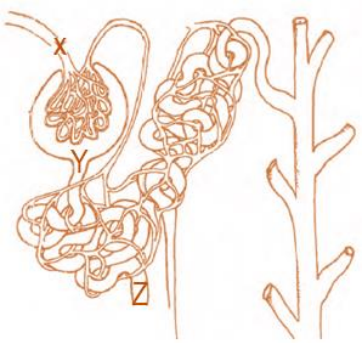
Comparison of substances in blood and urine

Nitrogenous waste	In blood	In urine
Urea	0.03	2.0
Proteins	7-9	0
Glucose	0.1	0
Chloride ions	0.37	0.6
Sodium ions	0.32	0.35
Water	93	95

- ✓ There are proteins in blood and there is none in urine because proteins are not filtered out of the blood vessels into the glomerulus due to the large size of their molecules.
- ✓ Urea is more in urine than in blood because it is filtered out of blood and it is not reabsorbed back in the blood.
- ✓ Water is more in urine than in blood because it is used to dissolve urea.
- ✓ However the relative amounts of water in urine and in blood varies depending on the amount of water in the body, amount of solutes in the body, temperature and body activity.
- ✓ There is glucose in blood and no glucose in urine because glucose is reabsorbed from the glomerular filtrate back into the blood.
- ✓ Salts like chlorides and sodium ions are more in urine than in blood. This is because they are in excess and they are not reabsorbed back into the blood. Because of this they tend to concentrate in urine.

Revision questions

1. *Distinguish between **excretion** and **osmoregulation**.*
2. *Describe the contribution of the following parts to urine formation in mammals:*
   - *i) Bowman's capsule*
   - *ii) Proximal convoluted tubule*
   - *iii) Loop of Henle*
   - *iv) Collecting duct*
3. *The diagram below represents a single kidney nephron:*



Two experiments were carried out to analyze fluid from different regions of the kidney.
*In experiment one, samples were taken using a micropipette from the three regions, **X, Y** and **Z**.*
These were then tested using Benedict's (for reducing sugars) and Biuret reagents (for protein).

The results are shown in the table below:

Sample	***Benedict's***	***Biuret***
Experiment one		
X (blood plasma)	*Brown ppt*	*Intense purple*
Y (glomerular filtrate)	*Brown ppt*	*Pale purple*
Z (start of loop of Henle)	*Blue solution*	*Blue (unchanged)*
Experiment two – chilled kidney		
Z	*Green solution*	*Very pale purple*

a) Explain the difference in the Biuret result between samples X and Y (in experiment one).

b) Account for the difference between the Benedict's result between samples Y and Z (in experiment one).

*c) In experiment two, the kidney was **chilled (placed in freezing temperature)** and a sample was taken from region Z using a micropipette. Explain the results of the Benedict's and Biuret tests shown above.*

The lungs as an excretory organ

Lungs play a role in excretion of heat, water and carbon dioxide in the following ways:

1) **Heat:** when the liver carries out metabolic reactions, a lot of heat is generated which leaves the liver by blood. When the blood reaches the lungs, the heat leaves the blood and dissolves into the moisture in the alveoli and warms up the air in the alveoli. The warm air is then removed out of the lungs into the atmosphere.
2) **Water:** some water is lost through exhalation of moist air from the lungs.
3) **Carbon dioxide:** carbon dioxide from respiration in tissues is brought by blood to the lungs where it diffuses into the alveoli and then removed from the body through exhalation.

HOMEOSTASIS

Homeostasis is the maintenance of a constant internal environment of the body. The internal environment of the body is composed of tissue fluids which surround cells. Homeostasis therefore involves maintenance and control of blood sugar level, blood salt level, blood water level, body temperature and carbon dioxide concentration in tissues. This is done by the kidney, liver, skin and lungs.

Role of the kidney in homeostasis

The kidney is involved in water and salt balance regulation. These two influence the concentration of blood.

1) Role of the kidney in osmoregulation:

Osmoregulation is the control of the amount of water in the body.

The water level is kept neither high nor low but within a limit according to the demands of the body. The level is maintained by loss of excess and gain if more is required.

Water is lost from the body through urine, sweat, expiration, and faeces during egestion and it can be gained through; drinking, eating and water from metabolism.

The loss and gain of water brings about changes in blood concentration. These changes are detected in the brain by the hypothalamus.

If the blood passing through the brain is too concentrated, the hypothalamus stimulates the posterior lobe of the pituitary gland to secrete a hormone called ***antidiuretic***

hormone (ADH) into the blood stream. When the hormone reaches the kidneys, it increases the permeability of the nephron tubules (distal convoluted tubules and collecting ducts) to water. More water is reabsorbed from the glomerular filtrate back into the blood. Less urine that is concentrated and yellowish in colour is produced. This restores the optimum concentration of the blood.

If blood passing through the hypothalamus is too dilute, the hypothalamus signals the posterior pituitary gland to reduce the production of ADH. Less ADH decreases the permeability of the nephrons to water. Less water is therefore reabsorbed from the glomerular filtrate resulting into production of colourless urine in big volumes. This mostly happens during cold conditions where water loss through sweating is minimal.

When conditions are hot, sweating increases lowering the water level in blood. This causes more re-absorption of water in the nephrons resulting in production of concentrated pale yellow urine.

When the level of water in blood is too low, the hormone causes a feeling of thirst which makes one to drink water in order to bring back the normal water level in blood.

Failure of the kidney to regulate the volume of water in urine due to inefficient production of ADH leads to frequent urination of large amounts of dilute urine thus increases the blood concentration. This condition is known as ***diabetes insipidus.*** *Diabetes insipidus is treated by administering natural or synthetic ADH.*

2) Role of the kidney in ionic/salt balance (control of salt levels) in blood:

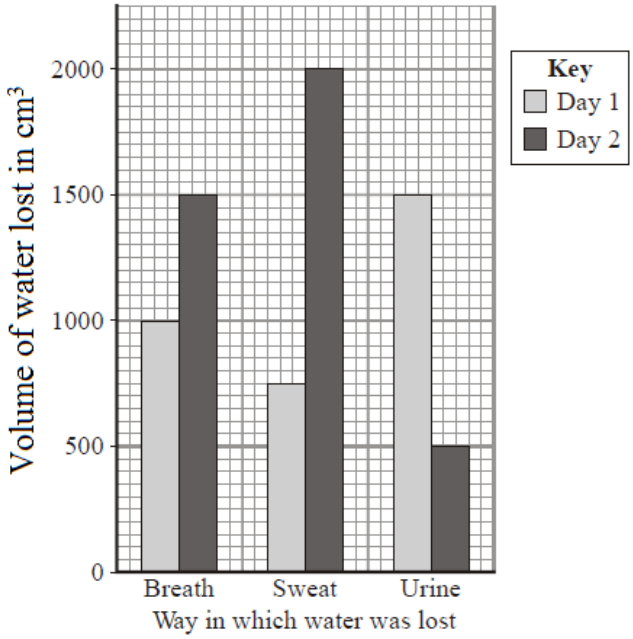
The ions/salts involved are the sodium, potassium and chloride ions. The hormone involved is ***aldosterone.*** Aldosterone is secreted by the adrenal gland found close to the kidney.

Aldosterone stimulates reabsorption of sodium ions into the blood from the glomerular filtrate along with chloride ions.

When the concentration of sodium ions in the blood is very high, aldosterone secretion is inhibited. This causes more ions to be lost through urine.

Revision question

The bar chart shows the amount of water lost from the body of a student on two different days. The student ate the same amount of food and drank the same amount of liquid on the two days. The temperature of the surroundings was similar on the two days.



a) The total volume of water lost on day 1 was 3250 cm³. How much water was lost on day 2? Show your working.

*b) The student did much more exercise on one of the days than on the other. On which day did he do more exercise? Give **two** reasons for your answer.*

*c) State **one** chemical reaction that produces water in the body.*

d) Briefly explain how sweating is important to the body

e) If the body loses more water than it gains, it becomes dehydrated and the concentration of the solution surrounding the body cells increases.

f) Briefly explain how this affects body cells.

g) Describe the effect of ADH on the functioning of the kidney nephron.

Role of the liver in homeostasis

The liver regulates blood sugar levels. Blood sugar is called glucose. The regulation is done by the hormones secreted by the islets of Langerhans in the pancreas.

Importance of blood sugar regulation

- It prevents cells running short of glucose in case its level drops. Blood sugar (glucose) is the main source of energy.
- Any slight increase in glucose level alters the concentration of blood's concentration which results in alteration of the rate at which water moves in and out of the body cells by osmosis.

Regulation of blood glucose

The normal amount of glucose in blood is about 90 mg per 100 cm^3. After a meal, carbohydrates are digested in the alimentary canal to glucose and absorbed from the gut into the blood stream and taken to the liver through the ***hepatic portal vein.*** Any increase in blood glucose level above the normal level is detected by the brain which sends impulses to the pancreas to secrete insulin. Insulin moves to the liver and sets up mechanisms that reduce the amount of glucose back to the normal range.

Insulin causes glucose;

- To be converted into glycogen and stored in the liver and muscles.
- To be converted into fats and later stored under the skin and around internal organs.
- To be broken down faster into carbon dioxide, water and energy. This energy is stored in form of ATP.

When there is decreased glucose concentration in the blood, for example during fasting or starvation, the pancreas is stimulated to release glucagon hormone. Glucagon is transported to the liver where it raises and restores glucose concentration in the blood back to the normal range.

Glucagon causes;

- Conversion of stored glycogen to glucose.
- Conversion of fats to glucose.
- A reduction in the rate of respiration to reduce the rate at which glucose is broken down.

Failure to produce insulin causes the presence of much glucose in urine a condition known as ***diabetes mellitus.***

Other functions of the liver

1) ***Deamination.*** Excess amino acids are not stored in the body but are deaminated. Deamination is the removal of the amino group from an amino acid. The amino group undergoes some reactions to from urea which is excreted through the kidney.
2) ***Production of heat.*** Many metabolic reactions occur in the liver leading to heat generation. This heat is distributed by the blood to other body parts.
3) ***Production of bile.*** The liver produces bile which is important in the process of digestion i.e. in the emulsification of lipids.
4) ***Storage of minerals.*** The liver stores iron, potassium, copper and zinc.
5) ***Storage of vitamins*** A, B, D, E and K which can later be released if deficient.
6) ***Formation and breakdown of red blood cells***. Red blood cells in the fetus are produced by the liver but in adults, they are made in the bone marrow. The adult liver however continuous to break down the expired red blood cells at the end of their 120-day life span.
7) ***Storage of blood.*** Blood vessels in the liver can expand and contract such that the amount of blood in the liver can vary from $300cm^3$ – $1500cm^3$, an increase of five times thus the liver can be a blood reservoir.
8) ***Detoxification.*** The liver converts toxic substances to harmless substances by altering their chemical structure and later sends them to the excretory organs for

expulsion e.g. it converts Ammonia to urea which is then expelled by the kidneys. It also contains ***catalase enzyme*** which catalyzes the breakdown of hydrogen peroxide to water and oxygen. Hydrogen peroxide is a toxic waste product produced when the water from metabolism combines with oxygen.

9) ***Breakdown of hormones.*** The liver breaks down all hormones like testosterone and insulin.

Revision questions

The table below shows the effect of exercise on the secretion of insulin and glucagon hormones in a human being. The exercise lasted 6 minutes.

Time (Minutes)		*0*	*1*	*2*	*3*	*4*	*5*	*6*
Concentration of hormone in blood in arbitrary units	*Glucagon*	*3*	*4*	*6*	*9*	*15*	*20*	*26*
	Insulin	*18*	*14*	*11*	*10*	*9*	*8*	*7*

a) Draw an appropriate graph to represent the information in the table.

b) Explain the variations in insulin and glucagon during the exercise.

c) Explain how the concentration of the two hormones would vary if the individual swallowed much glucose after the exercise.

CO-ORDINATION IN PLANTS AND ANIMALS

All living organisms detect changes in their environment and respond appropriately.
Irritability is the ability of an organism to detect, interpret and respond to changes in the environment.
A stimulus is a change in the external or internal environment to which an organism responds to.
A response is a physiological, muscular or behavioral activity that is initiated by a stimulus.

COORDINATION AND IRRITABILITY IN PLANTS

Plant responses involve growth movements of part of the plant, turgor changes within cells and very limited movements. They respond to light, water, gravity, chemicals, obstacles and touch. The stimulus causes parts of the plant move towards or away from a stimulus. Plant responses are divided into two categories i.e., nastic responses and tropic responses.

Nastic response

This is the movement of part of the plant in response to a non-directional stimulus. Nastic responses involve changes in turgidity and growth to some extent. This can be observed in the folding of the leaves of the sensitive plant (*Mimosa pudica)* when touched (thigmonasty). The touching of the plant causes water to be quickly withdrawn from the leaf cells into the pulvinus cells which have large air spaces, therefore causing the leaf or petiole to collapse due to change in turgidity.

Nastic responses are named depending on the type of stimulus i.e. Photonastic if the stimulus is light.
Hydronasty if the stimulus is water.
Thigmonastic if the stimulus is touch.

Characteristics of a nastic response

- It involves changes of turgidity of plant cells.
- It is a rapid response.
- It occurs in any part of a plant.
- The response is not related to the direction of the stimulus.
- It is induced by non-directional stimulus.

Examples of nastic responses

- Opening and closing of flowers in response to light e.g. morning glory.
- Sudden folding of the sensitive plant's (*Mimosa pudica*) leaves in response to touch.
- Closure of leaves of insectivorous plants e.g. butter walt and pitcher plant when the insect lands on the leaf. Such plants are found in nitrogen deficient soils.

Tropic response (tropism)

Tropism is a growth movement of part of the plant organ in response to an external unidirectional stimulus. Growth movement towards a stimulus is referred to as ***positive tropism*** while growth movement away from a stimulus is referred to as ***negative tropism***.

Examples of tropisms

Example of tropism (response)	Stimulus
1. Hydrotropism	Water
2. Thigmotropism / haptotropism	Touch
3. Chemotropism	Chemicals
4. Geotropism	Gravity
5. Phototropism	Light

Characteristics of a tropic response

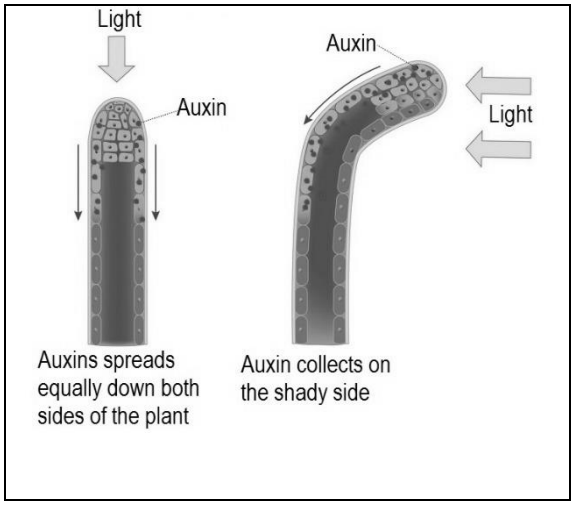
- It involves growth.
- It is a slow response.
- It occurs at the shoots and root tips.
- It is related to the direction of stimulus.
- It is induced by directional stimulus.

Phototropism

This is the growth movement of part of the plant in response to unidirectional light. Plant shoots are positively phototropic that is, they grow towards the direction of light while the roots are negatively phototropic (they grow away from the direction of light).

The shoot apex detects a light stimulus. When a shoot apex is exposed to a unilateral source of light causes ***auxins***, which are plant growth hormones produced at the shoot apex to migrate to the shaded side. The higher concentration of auxins on the shaded side causes faster growth than on the illuminated side, hence the shoot curves towards the source of light.

However, high auxins concentration limits growth in plant roots



Importance of phototropism

- The shoot grows towards light hence the leaves are able to carry out photosynthesis.
- Roots grow away from light into the ground from which water and mineral salts are absorbed and also provide support.

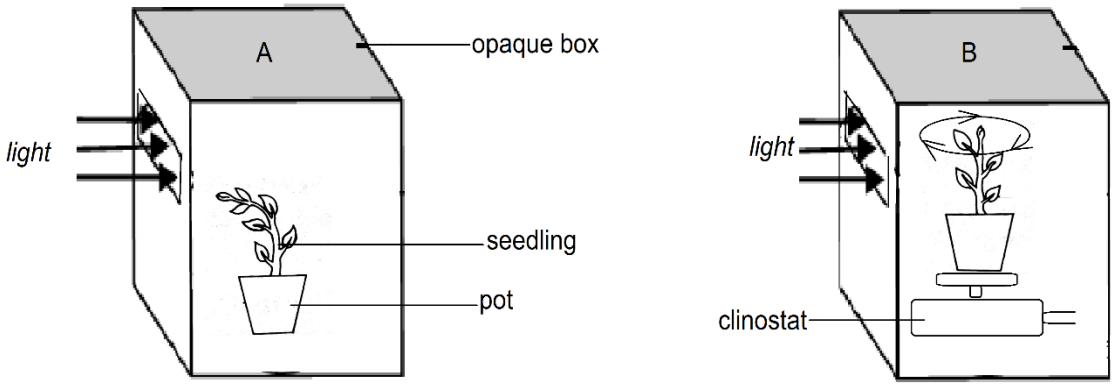
An experiment to show the effect of unidirectional light on growth of the plant shoot

Materials: Potted seedlings, 2 opaque boxes, clinostat and Razor blade

Procedure:

- Cut a small hole on one side of two opaque boxes using a razor blade.
- Place a potted seedling in box '***A***' and fix another potted seedling on a clinostat and put it in the second box '***B***'.
- Place both boxes in light and start the clinostat to rotate the plant in box ***B***.
- Leave the experiment for 3-4 days.

Observation: The seedling in box '***A***' bent towards the direction of light while that in box '***B***' continued to grow straight.



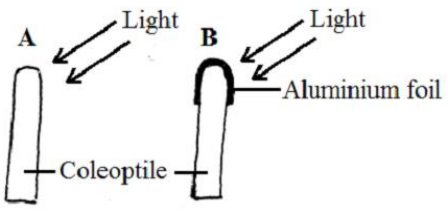
Conclusion: The shoot responds positively towards light.

Explanation: Light coming from one direction in box '***A***' made the stationary shoot to bend towards the direction of light.

The shoot in box '***B***' was rotating on a clinostat hence all of its sides received equal amounts of light and there was no effect on growth.

Revision question

1. *Distinguish between coordination and irritability.*
2. *An experiment was set up as shown in the figure on the right to investigate the effect of unidirectional light on the growth of a coleoptile.*



i) Explain the response of plant shoots A and B after exposure to unidirectional light for 6 hours.

ii) Explain how the response you have stated in (i) above can be important to plants.

Geotropism

This is the growth movement of part of the plant in response to gravity. Roots grow towards gravity and are said to be positively geotropic. Shoots of plants grow away from gravity and are said to be negatively geotropic.

When a seedling is placed in a horizontal position and left in place for about 3 days, the shoot curves and grows vertically upwards and the roots grow and curve downwards.

This is so because auxins move and accumulate on the lower side of the seedling due to the force of gravity. The upper part of the seedling gets less auxins. The higher auxin concentration causes more elongation on the lower side of the shoot and the shoot therefore bends upwards away from the force of gravity.

In the root, the higher auxin concentration causes less elongation on the lower side. The upper side with lower auxin concentration elongates more. The root, therefore bends vertically downwards towards the force of gravity.

Importance of geotropism

- Roots grow towards the soil so that the root hairs can obtain water and mineral salts for use during photosynthesis.
- Ensures that plants are anchored in the substratum.
- Negative geotropism ensures that shoots grow upwards towards the sunlight.

Experiment to demonstrate geotropism in plant roots (the effect of gravity on roots)

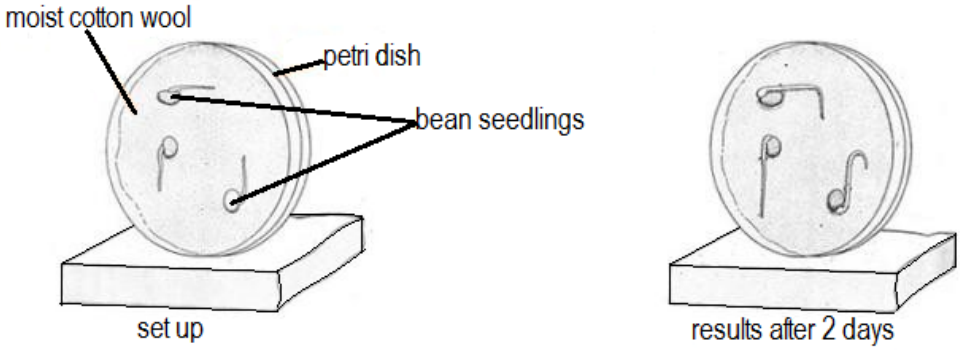
Apparatus: Petri dish**,** cotton wool and cupboard

Procedure:

- Bean seeds are allowed to germinate and three seeds with straight radicles are selected.
- The seedlings are placed on moist cotton wool in a petri dish
- They are arranged so that the radicle of one is horizontal, the second radicle points vertically upwards and the third radicle points vertically downwards. The whole set up is placed in a dark cupboard for two days.

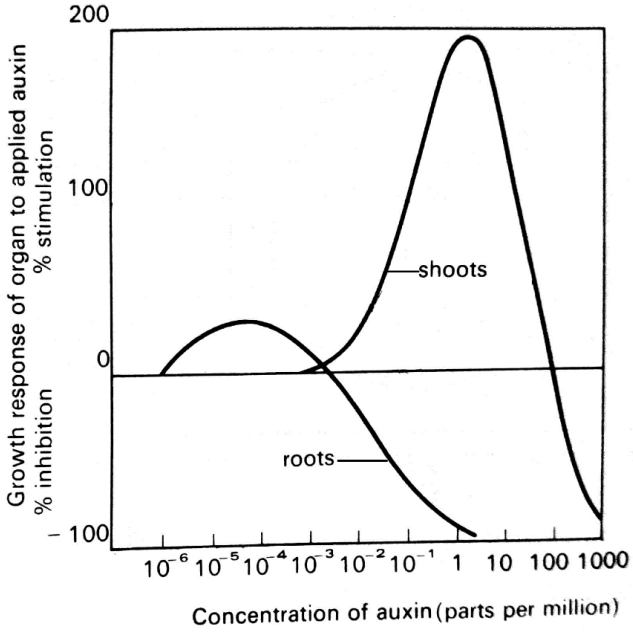
Observations:

- The horizontal radicle curves downwards towards the pull of gravity.
- The radicle that was pointing vertically upwards also curves downwards.
- The radicle that was pointing vertically downwards continues to grow downwards



Conclusion: Roots are positively geotropic.

Graph showing the effect of auxins concentration on the growth of roots and shoots.



Observations:

Very low concentrations of auxins do not stimulate shoot growth. However, an increase in the concentration of auxins brings about a rapid increase in the rate of growth of the shoot. If the amount of auxin in the shoot continues to increase, there comes a stage where the growth rate begins to slow down until at very high auxin concentration where growth is inhibited.

Roots are stimulated and inhibited by much lower concentrations of auxins than the shoots. Concentration of auxins which stimulate shoot growth inhibit root growth.

Very low concentrations of auxins stimulate root growth and high concentrations inhibit root growth.

Higher concentration of auxins stimulates growth of the shoot but inhibits growth of the root.

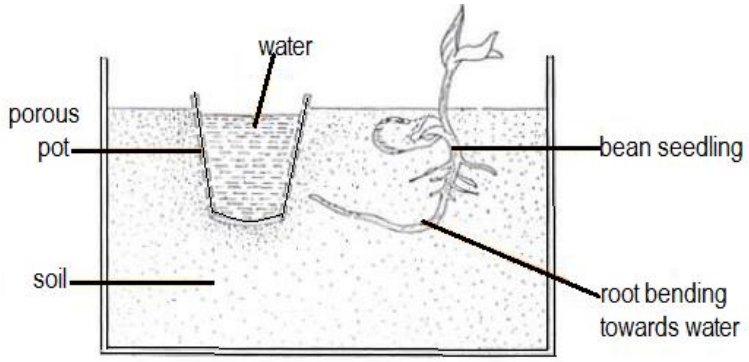
Hydrotropism

This is the growth movement of part of a plant in response to water. The roots of a plant grow towards water and are said to be positively hydrotropic.

When the root apex detects a unidirectional source of water, auxins move from the side without water to the side of water. Because growth in roots is favoured by a low auxin concentration, the side with a low auxin concentration grows faster than the side with high concentration hence causing the root to bend towards the source of water.

Roots enable a plant to absorb water and mineral salts through the root hairs. Water and mineral salts are used for processes like photosynthesis.

Experiment to show hydrotropism in roots



Revision question:

A biologist carried out an experiment to determine how auxins affect root and shoot growth. Different amounts of auxins in (ppm) were supplied to roots and shoots. The resulting growth responses of both shoots and roots are as follows in the table below. (Negative values are as a result of growth inhibition, while positive values are as result of growth stimulation).

Concentration of auxin /ppm	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	10^{0}	10^{1}	10^{2}	10^{3}
% growth response of shoots.	*0*	*0*	*0*	*0*	*20*	*100*	*200*	*100*	*0*	*-75*
% growth response of roots.	*0*	*25*	*30*	*10*	*-20*	*-60*	*-80*	*-100*	*-100*	*-100*

a) *Using an appropriate scale(s) and on the same graph, draw graphs to represent the percentage growth response of shoots and roots with varying auxin concentration.*
b) *From your graph, describe the growth response of shoots and roots at different concentrations of auxin.*
c) *How does light influence the distribution of auxins, and what effect does this induce in shoots and roots?*
d) *Give the significance of the plant responses you have stated in (c) above to plants.*

Plant growth substances

1. Indole Ascetic Acid (IAA)

Auxins are a group of plant growth hormones responsible for processes like growth, root formation and apical dominance. Auxins produced in plants include the ***Indoleacetic acid (IAA).***

Auxins are produced in small amounts in seeds, germinating embryos, buds, leaves and apices of roots, shoots and buds.

Effects of auxins on plant growth

- Promote elongation of young leaves.
- High auxin concentration stimulates the growth of the shoot but inhibits the growth of the root.
- They cause tropisms.
- They promote formation and growth of adventitious roots.
- They retard lateral buds in shoots.
- They promote apical dominance.

Commercial applications and uses of synthetic auxins

- Auxins are used to initiate rooting in stem cuttings.
- They are used to inhibit leaf fall when the leaf matures.
- They inhibit fruit fall.
- They inhibit the development of lateral buds hence reducing branching in plants. Removal of the apical buds therefore leads to branching.
- Synthetic auxins kill plants by disrupting growth hence used as selective weed-killers.
- Synthetic auxins stimulate fruit growth and parthenocarpic fruit development. Parthenocarpy is fruit development without fertilization.

2. Gibberellins

- They are produced by plants in varying amounts in seeds and young leaves and roots.
- They promote cell elongation.
- They promote germination in many seeds.
- Application of synthetic gibberellins to genetically dwarf plants causes bolting hence making dwarf plants grow taller.
- They also induce flowering in some plants.

Experiment to show that auxins are responsible for growth

Materials: Coleoptiles (plant seedling) and razor blade

Procedure: Using a razor blade cut off the tip of the coleoptile and leave it to stand for 3-6 days.

Observation: Growth stops taking place.

Explanation: The coleoptile tip produces new cells by cell division and it also produces a growth-promoting chemical, auxins. When the tip is cut off, the shoot no longer produces auxins hence growth stops.

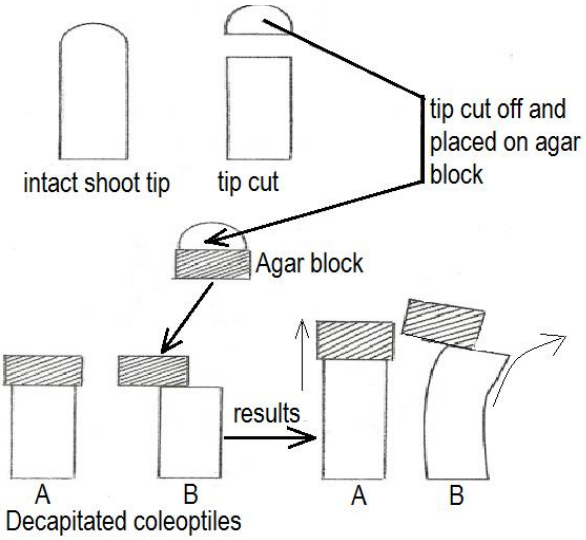
Experiment to show the effect of unequal distribution of auxins and to show that auxins are diffusible

Apparatus/Material: Maize seedlings with coleoptiles, agar block (gelatinous substance through which auxins diffuse) and razor blade.

Procedure:

- Two maize seedlings with coleoptiles at least 2cm long are exposed to light for at least 4 hours.

- Cut the coleoptiles tips and transfer each on to an agar block and leave them for 24 hours.
- Remove the coleoptile tips and place the agar blocks on fresh decapitated shoot tips as shown below.



Observation:
Shoot A grew straight upright while shoot B grew bending away from the side with agar block.

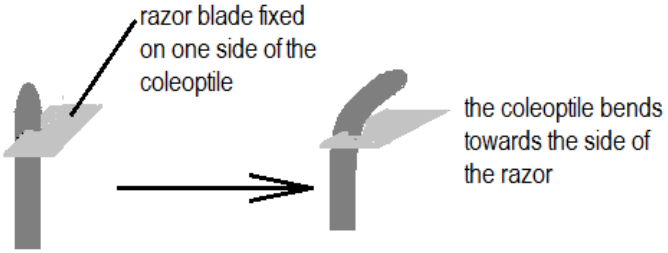
Explanation:
Auxins diffused from the coleoptile tips into the agar block. Thus auxins are evenly distributed on the agar block.
In shoot A- Auxins diffuse from the agar block into the decapitated shoot.
All sides receive same concentrations of auxins. Cell elongation occurred and growth took place evenly with the shoot growing up right.
In shoot B- Auxins diffused on one side of the shoot. i.e., the side covered with agar block. There was faster cell elongation and hence faster growth on the side compared to the uncovered side. This resulted to the growth curvature observed.

Experiment to investigate the effect of auxin distribution on plant growth

Materials: Seedling coleoptile and Razor blade.

Procedure: Insert a razor blade on one side of the coleoptile tip and leave it to grow for about 3 days.

Observation: The coleoptile continues to grow bending towards the side with the razor blade.



Conclusion: The side without a razor blade grows faster than the one with a razor blade causing the coleoptile to bend towards the side with a razor blade.

Explanation:
In equal illumination, auxins are equally distributed in the shoot. The insertion of a razor blade on one side prevents auxins from moving down on that side. Unequal distribution of auxins causes uneven growth of the shoot.

Other examples of Tropic responses

1) **Thigmotropism**: This is also called haptotropism. It is the growth movement of part of a plant in response to touch. It occurs in plants which wind their stems round a support. E.g. passion fruits. Most of these plants have tendrils by which they cling to a support. When the tendril touches an obstacle, it twins round it. The climbing roots of certain figs and vanilla also show haptotropism.
2) **Chemotropism**: This is the growth movement of part of the plant towards or away from a particular chemical e.g. pollen tube grows towards the embryo sac through the style during fertilization by responding to the source of chemicals produced by the embryo sac.

Importance of tropisms to plants

i) Phototropism enables plant leaves trap maximum sunlight by enabling plant shoots to grow towards light.
ii) Geotropism enables plants to become firmly anchored in the soil by the roots growing towards the ground.
iii) Hydrotropism enables plant roots to absorb or obtain water which is necessary for plant growth and photosynthesis.
iv) Chemotropism enhances fertilization in plants since the pollen tubes grow towards the chemicals of the embryo sac.
v) Thigmotropism enables climbing plants to gain support by twinning around the support.
vi) Tropisms allow plant parts to alter direction in response to changing conditions in the environment.

Similarities between nastic and tropic movements

- Both are brought about by external stimuli.
- Both occur in plants
- Both involve movement of plant parts.

Differences between tropisms and nastic responses

Nastic response	Tropism
• Does not depend on the direction of the stimulus.	• It depends on the direction of the stimulus
• It occurs in any part of the plant.	• It occurs in growing tips of plants
• It does not involve auxins	• It involves auxins
• Are usually faster	• Are usually slower
• It involves growth and turgor changes	• It involves growth only.

Revision questions

1. *Explain what you understand by the terms irritability, stimulus and response.*
2. *a) Distinguish between a tactic and a tropic response.*
   b) Explain the survival values of tactic and tropic responses.
   c) What type of response would you expect in roots of a plant that are subjected to dry conditions on one side of the soil while the other side is moist?
3. *a) Name three plant hormones.*
   b) In which parts of a seedling are hormones produced?

The length of lateral shoots were measured at intervals of two days. The table below shows data on the growth of the four lateral shoots.

Time from the start of experiment (days)	***Length of lateral shoot (mm)***			
	A	***B***	***C***	***D***
0	*1.8*	*1.8*	*1.8*	*1.8*
3	*1.8*	*5.8*	*2.0*	*4.0*
5	*1.85*	*6.2*	*2.0*	*15.0*
7	*1.85*	*8.0*	*2.0*	*32.0*
9	*1.85*	*10.0*	*2.5*	*66.0*
11	*1.90*	*40.0*	*2.5*	*110.0*

a) i) Plot the results on a graph.
ii) With reference to the graph, describe the effects of each treatment in A, B, C and D.
iii) Give reasons to support your observations above.

b) i) State two precautions which should be taken when carrying out this experiment.
ii) Suggest one practical application of the results obtained in this experiment.

CO-ORDINATION IN ANIMALS

Animals have the ability to sense their environment and respond appropriately. The stimuli in animals include touch, pressure, sound, etc. The response made to a stimulus is usually a movement. When the whole organism moves, the movement is called a tactic movement (taxis). Most plants are fixed, and in their case, only part of the organism responds to the stimulus. Taxes are therefore, characteristic of animals rather than plants.

Protozoans, worms, arthropods and euglena respond to a unidirectional stimulus by a positive or negative tactic movement. *(Stone and Cozens: New biology for tropical schools, third edition)*

Tactic response (taxis)

This is the movement of whole organism or cell from one place to another in response to a directional stimulus. It is a positive tactic response when the whole organism moves towards the stimulus and negative tactic when the organism moves away from the stimulus.

Types of tactic movements

i) Phototaxis is movement in response to light.
ii) Chemotaxis is movement in response to chemicals.
iii) Thigmotaxis is movement in response to touch.
iv) Geotaxis is movement in response to gravity.

Examples of tactic movements

i) Unicellular organisms e.g. Euglena moves to areas of optimum light intensity and carries out photosynthesis hence positively phototactic.
ii) Earth worms, wood lice and cockroaches move away from light hence negative phototactic.
iii) Sperms of ferns and mosses swim towards the chemical produced by the ova hence positively chemotactic. This increases the chances of fertilization raising the chances of survival of these plants.
iv) White blood cell moves towards harmful bacteria in the body hence positively chemotactic.
v) Aerotaxis is a response to air. The atmospheric oxygen acts as the stimulus where the motile bacteria move towards oxygen.
vi) When pollen grains germinate on the stigma, the pollen tube exhibits negative aerotaxis thus grows into the stigma.

Coordination Systems in Mammals

There are two main distinct coordination systems in mammals

1. **The nervous system**; which is a network of message conducting cells called neuron cells connected to all body parts.
2. **The endocrine system;** which is made up of a system of glands that produce chemical substances (hormones) for coordination.

Chemical coordination in vertebrates

This is the endocrine system of glands that secrete chemical substances called hormones.

*A hormone is a specific chemical substance produced by glands and is transported to a **target organ** to regulate physiological activities in the body.*

Characteristics of hormones

- They are protein in nature.
- They are produced and work best in small quantities.
- Their site of action is far from where they are produced.

- They are secreted by glands.
- Their effect on the target organ is either by stimulation or inhibition i.e. they regulate the activities of the target organs.

Hormones are secreted by endocrine glands and transported to the target organs by the blood.

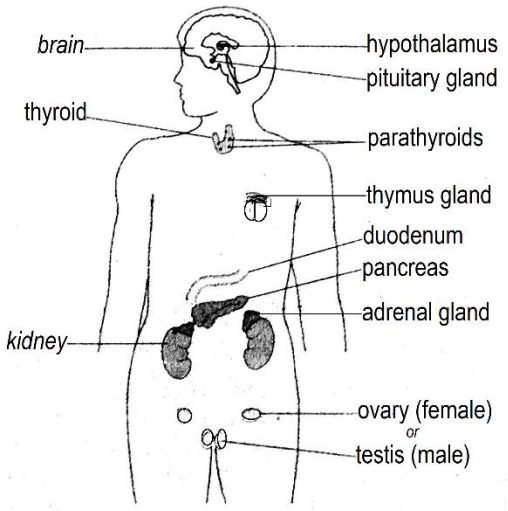
These are tissues or organs that produce and secrete chemical substances. There are 2 types of glands i.e. ***endocrine*** and ***exocrine.***

Exocrine glands secrete hormones into ducts that transport the hormones to their target organ hence they are called **duct glands.** Examples include the pancreas which secrets pancreatic juice, salivary glands secret through ducts into the mouth cavity, sweat glands and tear glands.

Endocrine glands are ductless glands that secret their hormones directly into the blood stream. The blood carries the hormones from the glands to their target organs hence endocrine glands are called ductless because they have no ducts e.g. pituitary gland, thyroid gland, pancreas, etc.

Endocrine glands are stimulated to secrete hormones either by impulses from the motor nerves or by hormones from other endocrine glands. The endocrine system is linked to the nervous system by the hypothalamus, which controls the activities of the pituitary gland.

Location of endocrine glands



Endocrine hormones and their functions

1. Pituitary gland

The pituitary gland releases several hormones most of which stimulate the production of other hormones from other endocrine glands. Because of this it controls other endocrine glands and it is referred to as the master gland.

The pituitary as a master gland:

The pituitary gland acts as a master gland because it produces several hormones most of which stimulate other endocrine glands to produce their hormones. Because of this, the pituitary controls other endocrine glands.

Hormones produced by the pituitary gland.

i) It produces antidiuretic hormone (ADH), which controls the amount of water and salts reabsorbed into the blood stream by the kidneys.

ii) It produces follicle-stimulating hormone (FSH), which causes the development of graafian follicles in the ovary.
iii) It produces thyroid-stimulating hormone (TSH), which stimulates the thyroid gland to secrete thyroxin.
iv) It produces adrenal cortical stimulating hormone (ACSH), which stimulates the adrenal gland to produce a hormone called cortisone.
v) It produces interstitial cell stimulating hormone (ICSH), which stimulates the testes to produce their hormone called testosterone.
vi) It produces a growth hormone, which controls the growth of bones and other tissues. Over secretion of growth hormone causes ***gigantism.*** Under secretion of growth hormone causes ***dwarfism.***
vii) It produces luteinizing hormone (LH), which causes ovulation.
viii) Prolactin which stimulates milk production in pregnant females.
ix) Oxytocin which causes the contraction of uterus thus inducing birth. It also stimulates milk flow from the mammary gland.

2. The thyroid gland.

This produces a hormone known as **thyroxin**, which in young organisms control growth and development for example in tadpoles it brings about metamorphosis.
In adults, thyroxin controls the rate of respiration.
In adults too little thyroxin leads to overweight and sluggishness and too much of it causes thinness and over activity.
Deficiency of thyroxin in infancy cause a type of mental deficiency known as **cretinism** which can be cured if identified early by administering thyroxin in the body.
Thyroxin is made up of an amino acid containing iodine. Lack of iodine causes the thyroid gland to increase in size as a way of producing more thyroxin. This leads to a disease known as **goiter.**

3. Adrenal gland.

There are two adrenal glands situated above each kidney. The gland is made up of two parts.

Cortex; this is the outer part of the adrenal gland.
Medulla; this is the inner part of the adrenal gland.

The adrenal medulla is stimulated by nervous impulses to produce a hormone known as **adrenaline**. Adrenaline is produced when the animal feels frightened or excited. Adrenaline brings about the following changes in the body:

- It increases the rate of heartbeat.
- It increases the breathing rate.

- It widens the pupils of the eyes.
- It brings about conversion of glycogen to glucose in the liver.
- It brings about the growth of goose pimples on the body.
- It increases the rate of respiration in order to ensure adequate supply of energy to body muscles.

Due to the abundance of energy, there is increased muscle contraction making the animal to feel stronger. This hormone prepares the animal to fly or run away or to fight with another. This hormone is therefore known as a **"flight or fight" hormone.**

4. The pancreas:

In addition to production of digestive enzymes, the pancreas produces two hormones known as ***insulin*** and ***glucagon***. These hormones are produced from groups of cells in the pancreas known as ***islets of Langerhans***.

Insulin is produced from the β- islets of Langerhans***. Insulin stimulates the liver to convert excess glucose into glycogen for storage***. If the pancreas produces little or no insulin, the amount of sugar increases in blood resulting into a disease called **diabetes mellitus**. The disease is controlled by continuous injection of insulin in the body.

Glucagon is produced from the α- islets of Langerhans in the pancreas. When released in blood, ***glucagon moves to the liver and stimulates the liver to convert glycogen to glucose.***

5. The duodenum.

The presence of food in the duodenum stimulates the lining to produce a hormone called **secretin**. Secretin moves in blood to the pancreas and stimulates it to produce pancreatic digestive enzymes. This ensures that the enzymes are produced when food is present.

6. The reproductive organs (testes and ovaries)

The ovary in females produces two major hormones. These are **estrogen** and **progesterone**.

Oestrogen controls secondary sexual characteristics in females such as;

- Development of breasts.
- Growth of pubic hairs.
- Widening of hips.
- Enlargement of reproductive organs.
- Softening of the voice.
- Oestrogen also causes repair of the uterine lining after menstruation.

Progesterone is responsible for maintaining the endometrium prior to implantation.

In males the testes produce a hormone known as **testosterone**. This hormone brings about male sex characteristics, which include;

- Deepening of the voice.
- Growth of beards.
- Toughening of muscles.
- Widening of the chest.
- Enlargement of reproductive organs.
- Growth of pubic hairs.
- Sperm production.

7. Parathyroid gland:

It secretes parathormone which has the following effects:

- Controls the distribution of calcium and phosphorus in the body.
- It affects development of bones.

8. Thymus gland:

This gland is close to the heart and well developed in young mammal but greatly reduced in adults.

It provides immunity in young mammals.

Revision questions

1. *What is meant by a hormone?*
2. *A student was frightened by a snake and immediately made an alarm.*
   i) *Giving a reason, suggest the hormone that is most likely to be found in the student's blood at a higher concentration.*
   ii) *State the effect of that hormone to the student's body.*
3. *Explain why*
   i) *The pituitary gland is referred to as the master gland.*
   ii) *The pancreas is both an exocrine and endocrine gland.*
4. *Draw a well labeled diagram showing the location of the glands in the endocrine system in man.*
5. State one function of at least one hormone secreted by each endocrine gland.
6. *A child sees a fierce lion and gets frightened, describe the events that occur in the child's body to escape this lion.*

NERVOUS COORDINATION IN MAMMALS

This is comprised of the nervous system which is a system of nerve cells and sensory organs that carry out co-ordination by transfer of impulses.

The nervous system consists of;

Receptors: These are organs detect ***stimuli*** to which the animals respond. E.g. sensory endings in the skin, nose, tongue, eyes and ears.

Stimuli create impulses which are relayed to the coordinating system.

Impulses: these are electrical transmissions or chemical stimuli sent from the receptors to the coordinating center. The coordinating center interprets the impulses before a response is made.

Effectors: These are organs that respond to the stimuli and carry out the response.

Functions of the nervous system

1. It receives impulses from all sensory organs of the body.
2. It stores information.
3. It correlates various stimuli from different sensory organs.
4. It sends messages to all parts of the body making them function accordingly.
5. It's involved in temperature regulation.

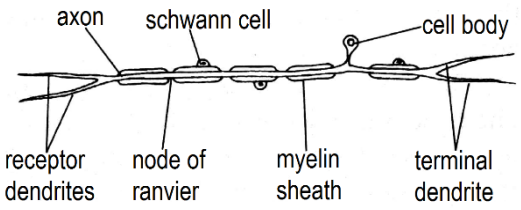
Structure and functions of the neurone

A neurone is made up of a small mass of cytoplasm, a nucleus in a structure called the cell body, branching cytoplasmic filaments called dendrites and a single long fiber called axon.

There are three types of neurones i.e. Sensory neurone, Motor neurone and Relay neurone

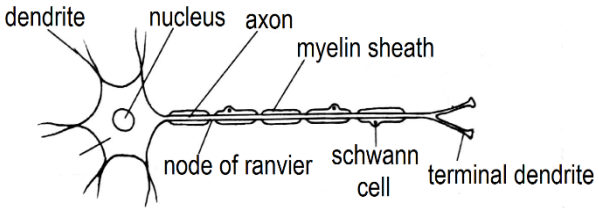
Sensory neurone

Sensory neurones are cells that transmit impulses from the receptor cells to the central nervous system.



Motor neurone

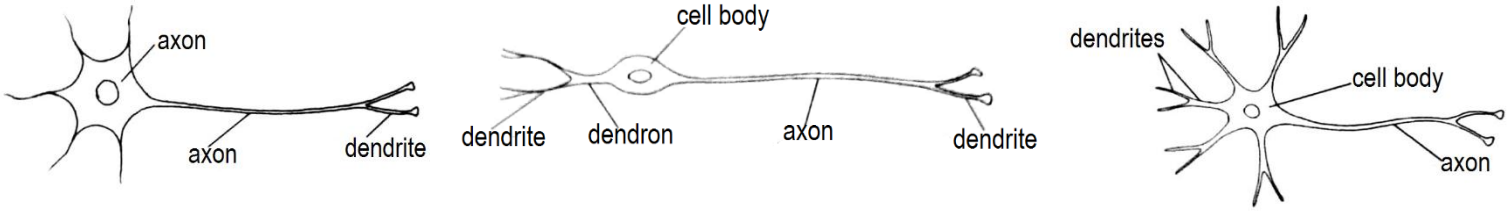
This is a neurone that transmits impulses from the central nervous system to the effector organs such as muscles and glands, where a response is made. The muscles respond by contracting while glands respond by secreting substances.



Relay neurone

This is a neuron located in the central nervous system and transmits impulses from the sensory neurone to the motor neurone. The axon extends towards the motor neurone. It is also referred to as an intermediate neurone. A relay neurone is either unipolar, bipolar or multipolar.

Unipolar neurone: **Bipolar neurone:** **Multipolar neurone:**



Functions of the parts of a neurone

Cell body: This consists of a nucleus surrounded by a mass of cytoplasm. The nucleus controls all activities of the neuron.

Axon: Transmits impulses over long distances in the body. Each axon is filled with cytoplasm called axoplasm.

Myelin sheath: This is a fatty material that covers the axon. The myelin sheath is secreted by cells called ***Schwann cells***. The myelin sheath insulates the axon and speeds up the transmission of impulses.

Dendrites: These are hair-like structures surrounding the cell body. They conduct incoming signals.

Node of Ranvier: This is the space on the axon between two adjacent myelin sheaths. It speeds up nervous transmission.

Dendron: It is a branch through which impulses are transmitted to the body.

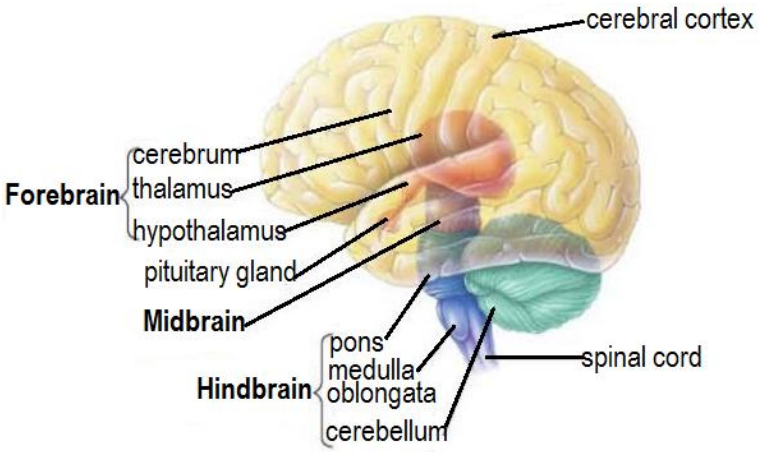
Differences between motor and sensory neurons

Motor neuron	Sensory neuron
Has a long axon.	Has a short axon.
It has a cell body at the terminal end of the axon.	Has a cell body located on the axon branch.
It has a short dendrons.	It has a long dendron.
It carries impulses from the central nervous system to the effector organ.	It carries impulses from the receptor cells to the central nervous system.
It has several dendrons.	It has one dendron.
Terminal dendrites connect with effector organ.	Terminal dendrites connect to relay neurones.

The central nervous system

This is made up of the brain and spinal cord and it coordinates all the neutral functions.

The brain



The brain is covered and protected externally by the skull (cranium) and internally by membranes called meninges. It is made up of three distinct areas namely the forebrain, midbrain and hindbrain.

Functions of the parts of the brain

1. The fore brain

It consists of:

i) The cerebrum (cerebral hemisphere):

It consists of right and left cerebral hemispheres which are interconnected by the corpus callosum. It is covered by a thin layer of cerebral cortex.

The right hemisphere sends and receives impulses from the left side of the body while the left hemisphere receives impulses from the right side of the body.

It coordinates learning, memory, reasoning, conscience and personality. It is responsible for intelligence. (Sensing, thinking and imagining).

ii) Thalamus: It transmits impulses of sensations received from sense organs to the cerebral cortex.

iii) Hypothalamus:

It controls activities of the pituitary gland

It also coordinates and controls the autonomous nervous system. The **autonomic nervous system** is a control system that acts largely unconsciously and regulates bodily functions, such as the heart rate, digestion, respiratory rate, pupillary response, urination, and sexual arousal. This system is the primary mechanism in control of the fight-or-flight response.

2. The mid brain

It relays audio and visual information.

It is also responsible for movement of the head and the trunk.

3. **Hind brain:** It is made up of:
   i) **Cerebellum:** It is responsible for balance, muscular coordination (motion). It is the one affected in drunkards.
   ii) Medulla oblongata: It controls automatic functions in the body like heartbeat, blood pressure, breathing rate, coughing and sneezing.

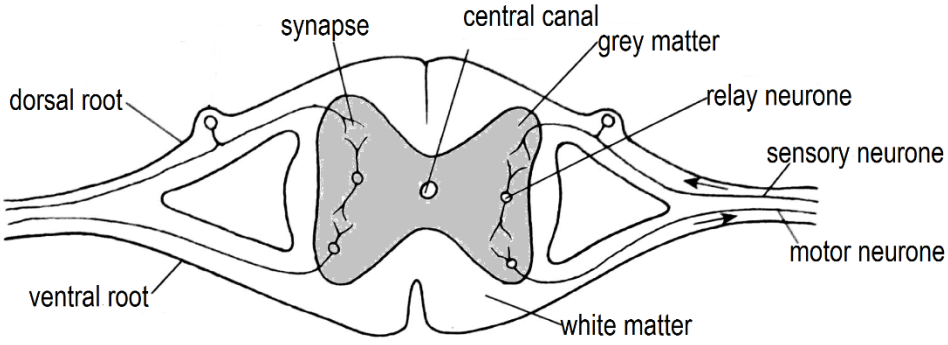
Functions of the brain

- It receives impulses from all receptors and sends back impulses to the effectors.
- It integrates and coordinates all activities in the body such that the body works efficiently.
- It stores information.
- It is involved in cranial reflex actions but it does not initiate them.

The spinal cord

This is part of the central nervous system that runs from the brain through to the tail and protected by the vertebral column.

Transverse section through the spinal cord



Functions of the spinal cord

- It connects the peripheral nervous system to the brain.
- It is a center for simple spinal reflex actions.
- Receives impulses from receptors.
- Interprets messages especially in reflex arc.
- Sends impulses to the effectors.

The peripheral nervous system

It is made up of neurones that link the brain and spinal cord to muscles and organs such as the eyes and ears.

It is divided into autonomic nervous system and somatic nervous system. The autonomic nervous system is responsible for the ***involuntary*** control of internal organs, blood vessels, smooth muscles and cardiac muscles.

The somatic nervous system is responsible for the ***voluntary*** control of skin, bones, joints and skeletal muscles.

Voluntary and involuntary actions

A voluntary action *is one initiated consciously under the direct control of the brain i.e. they are actions one does at will e.g. dancing, laughing, stealing, etc.* These actions are performed consciously by an animal. In such actions the animal chooses to do or not to do something.

Involuntary actions *are the ones that occur without conscious thoughts e.g. breathing, etc.*

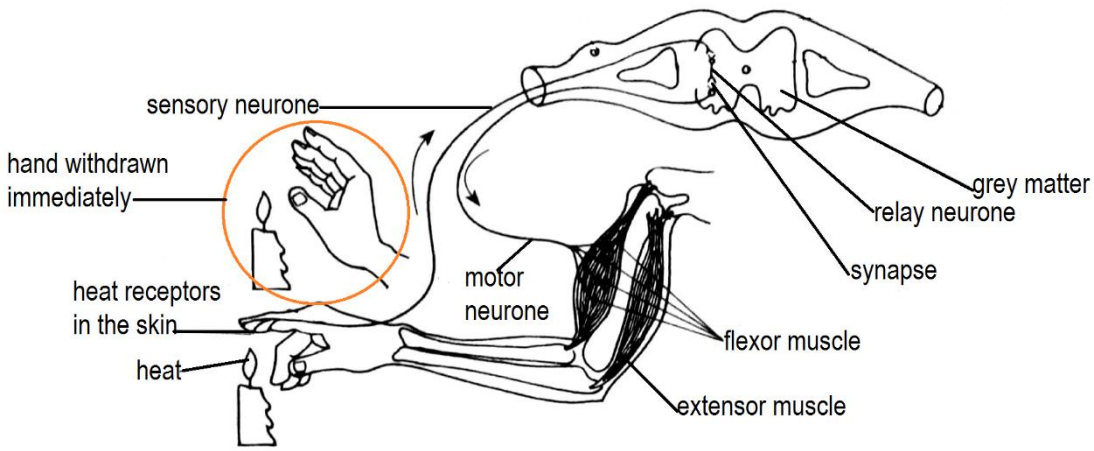
The reflex action

A reflex action is an automatic (involuntary) response to a particular stimulus. Reflex actions take place without the awareness of the individual. A reflex action occurs as a result of impulses travelling along neurons in a path called a ***reflex arc***. A reflex action can either be **simple** or **conditioned reflex**

Simple reflex action

This is an involuntary quick response to a stimulus without conscious thought. It is also known as an ***instinctive reflex*** which does not have to be learnt. They include sneezing, coughing, salivating, the knee jerk and removal of a hand from a hot flame. For instance, when one steps on a sharp object, the knee jerk enables the removal of the foot thus avoiding further injury.

Reflex arc of a hand being withdrawn from a hot flame



The stimulus is perceived by the receptors, which change it into nervous impulse (transduction). The impulse travels along the sensory neurone to the spinal cord. In the grey matter of the spinal cord, the sensory neurone makes synaptic connections to the relay neurone and impulses move from the sensory neurone to the relay neurone across synapses. The relay neurone in turn transmits the impulse to the motor neurone across a synapse. The impulse then moves from the spinal cord to the effector muscles through the motor neurone. The impulse causes the muscles to contract or relax depending on the stimulus.

Characteristics of a simple reflex action

- ✓ It occurs rapidly i.e. the action occurs very fast.
- ✓ It is inborn (innate) but not learnt.
- ✓ It is coordinated by either the brain or spinal cord but usually initiated by spinal cord.
- ✓ It occurs without one's will.
- ✓ It is a repeated response to a similar stimulus.
- ✓ Three neurons are involved.

Examples of simple reflex actions

1) Blinking when a foreign body falls on the eye
2) Withdraw of the arm when someone accidentally touches a hot body.
3) Sneezing
4) Knee jerk i.e. a relaxed leg gives a forward kick when tapped slightly below the patella.
5) With draw of the foot from a sharp object.

How a hand is withdrawn from a hot object (an example of a simple reflex action)

When one accidentally touches a hot body using a finger, the receptors in the finger receive the stimulus and change it into nervous impulses that travel along the sensory neurone to the spinal cord and then cross the synapse.

The impulse is then handed over to the relay neurone in the spinal cord (gray matter) and then cross another synapse.

The relay neurone in turn hands over the impulse to the motor neuron.

The motor neuron then carries the impulse from the spinal cord to the effector muscles of the hand. This causes the muscles to contract and the hand is removed from the hot body.

At the same time, the original message is sent to the brain which then interprets it as pain or heat.

Note; these processes occur rapidly in the body without the awareness of the individual

Importance of simple reflex actions to animals

- They help animals to avoid danger.
- They control activities in the body, which we do not have conscious control over.

Conditioned reflex action

Conditioned reflex actions are reactions that the organism has learned to associate with a meaningless stimulus because of prior experience. The classic example is the training Pavlov did with dogs. Producing saliva is response animals naturally have

when they smell or see food. Pavlov rang a bell first, then gave the dog food. The dog quickly learned that a bell sound was followed by food and produced saliva when the bell sounded even if no food was present. Other examples can include:

- Applying the brake while driving when a red or yellow traffic light appears; you do not have to think about pressing the brake.
- Feeling sick/upset near a location where a person was attacked in the past.
- Experiencing nausea when presented with an exam in a subject that is one in which multiple tests have been failed.
- The "Little Albert" experiment (see second link), an experiment in which a child was trained to fear animals/masks (which he had not been afraid of) because they were coupled with a loud noise--which he was afraid of.

This is the type of reflex action which involves learning. Organisms learn to respond to strange or meaningless stimuli by associating it with other meaningful/familiar stimuli, e.g. ***the Ivan Pavlov's experiment.***

A scientist called Ivan Pavlov performed an experiment to demonstrate a conditioned reflex action in a dog.

In his experiment he noticed that the sight or smell of food triggers off salivation reflex in a dog.

When Pavlov gave his dog food, the smell made the dog salivate. He later modified the experiment by ringing a bell each time he fed the dog. The two unrelated stimuli, that is sound and smell, were sensed simultaneously.

After several presentations of the two stimuli, he discovered that the dog salivated when the bell was rang even without the presentation of food. The dog had learned to associate the ringing of the bell to food, to a point whereby ringing the bell alone caused salivation.

Characteristics of a conditioned reflex action

- It is a temporary reflex
- It involves learning
- It takes a longer time to learn
- It is coordinated in the brain
- It involves more than one stimulus
- It involves association of stimuli
- It is reinforced by repetition
- Responses are involuntary

Similarities between simple and conditioned reflex actions

- They both involve the central nervous system particularly the brain.
- Both are autonomic responses
- Both are associated with a stimulus.
- Both involve neurons for the transmission of impulses

Differences between simple and conditioned reflexes

Conditioned reflex action	Simple reflex action
Stimulus and responses are not directly related	Stimulus and response are related
More than one stimulus is required to cause a response	Only one stimulus is needed to cause a response
It involves learning	No learning but in born
Takes time	Takes a very short time
It is coordinated in the brain only	Co-ordinated in either the brain or spinal cord
Responses occur as a result of repetition and practice.	Responses occur instantly after a stimulus.
Is an inborn, automatic response	Is a learned, automatic response
It is always constant	Can be reinforced through rewards or punishment.

Similarities between the nervous and endocrine system

- Both are affected by change in stimulus.
- Both cause a response.
- They provide a means of co-ordination in the body.
- Both systems transmit messages.

Differences:

Nervous system	Endocrine system
Nerve impulses are electrical	Impulses are chemical
Responses are fast as the impulses are carried fast.	Responses are slow but long lasting.
Impulses go along nerve fibres.	Hormones are carried in blood.
This effect is more localized (specific).	Effect is wide spread in the whole body.
Stimulus arises from any part of the body where sensory receptors are located.	Stimulus arises from specific places only e.g. endocrine glands.

Revision question:

a) *Explain three ways in which the body benefits from effects of adrenaline.*
b) *Compare nervous and hormonal control systems.*
c) *Describe an experiment which can be set up to investigate the response of plant shoots to light coming from one direction.*
d) *How do shoots benefit from responding to unidirectional light?*

RECEPTOR ORGANS IN MAMMALS

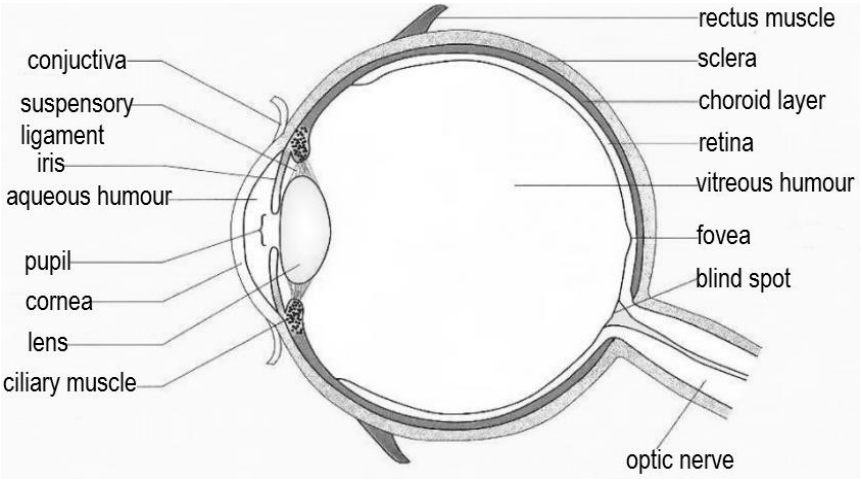
These are organs that perceive the stimulus and change it into nervous impulse (transduction).

Receptor organs are made up of cells called receptor cells. There are different types of receptor cells depending on the nature of the stimulus they perceive and the organ in which they are contained.

THE MAMMALIAN EYE

The mammalian eye is a receptor organ responsible for sight. It contains photoreceptor cells, which perceive the light stimulus and change it into nervous impulse.

Structure of the mammalian eye



Parts of the eye and their functions

The conjunctiva: This is a thin transparent layer lining the inside of the eyelid.

- It protects the eye and holds it in position.
- It enables the eye ball to move easily by secreting mucus.

The sclera: This is a tough inelastic layer that gives shape to the eye.

- It protects the inner most delicate parts.
- It provides attachment for the muscles of the eye.

The cornea: This is a transparent layer in front of the eye.

- It refracts (bends) light into the eye.

The choroid layer: It is pigmented and mainly contains black pigment.

- It prevents internal reflection of light.
- This contains a network of blood vessels supplying oxygen and nutrients to the eye.

The aqueous humour: It is a solution of sugar, salts and proteins.

- The aqueous humor is a watery fluid which maintains the shape of the eye.
- It also refracts light into the pupil and the lens.

The vitreous humour: It is a jelly-like substance that fills the inner cavity of the eye.

- It is transparent and maintains the shape of the eye.
- It refracts light to the retina.

The ciliary body: This contains ciliary muscles which control the size of the lens during viewing nearby or distant objects.

The lens: It refracts light to make an image on the retina.

The iris: It is responsible for controlling the amount of light entering the eye.

The retina: The retina is where the image is formed in the eye. This layer contains photoreceptor cells (light sensitive cells) the ***rods*** and the ***cones.***

The cones are sensitive to coloured light and are responsible for colour vision. They are stimulated by high intensity light are hence used during daytime.

Most cones on the retina are concentrated on the fovea or yellow spot.

The rods are incapable of perceiving coloured light and are sensitive to light of low intensity (dim light). They are mainly used during night vision. Rods view objects only in black, white and sheds of grey that's why objects in dim light like at night appear in black and white.

Pupil: This is a round black hole in the center of the eye lying behind the cornea. It allows light to pass into the eye to the lens.

Suspensory ligaments: These are inelastic fibers that hold the lens in position.

The blind spot: This is a region where the nerve fibers leave the eye to enter the optic nerve. It has no light sensitive cells. When an image falls on this point, it is not taken to the brain thus blind spot.

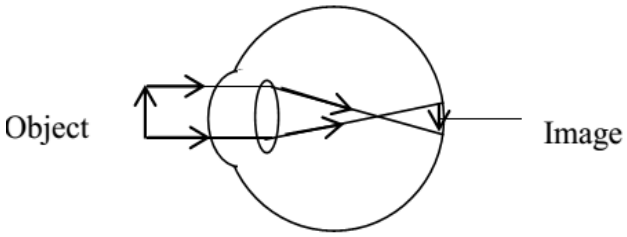
The fovea: This is a small depression in the center of the retina. It has only cones in a high concentration. It is therefore a region on the retina that contains the largest number of sensory cells. Due to this, it produces the most accurate images in the eye.

Eye lids: These protect the eye and remove any foreign bodies that enter it. Regular blinking enables the spread of the tears all over the exposed surface of the eye.

Eye lashes: They prevent dust particles and other objects from entering the eye.

Image formation and vision

Light from an external object enters the eye. It is refracted by the cornea into the aqueous humour. The aqueous humour then refracts it to the lens. The lens refracts it to the vitreous humour. The vitreous humour finally refracts light and focuses it to the retina making an image on the retina.



The photoreceptors in the retina change the light stimulus into a nervous impulse. The impulse travels along the optic nerve to the brain where interpretation of the image is made. The image formed on the retina is smaller to the real object and it is ***upside down.***

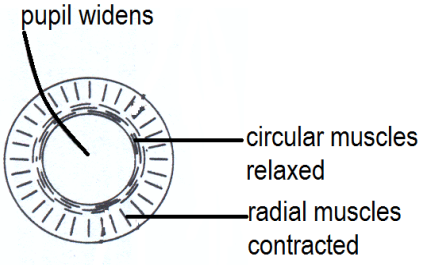
Control of light amount entering the eye

The iris controls the amount of light entering the eye. It is made up of circular and radial muscles.

This is done to protect the retina from damage by bright light and the wide size of the pupil during dim light allows in enough light of low intensity.

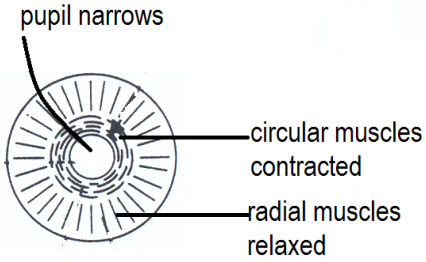
Control of the amount of light rays entering the eye in dim light

- In dim light, radial muscles contract,
- Circular muscles relax,
- Pupil widens and more light is admitted into the eye.



Control of amount of light rays entering the eye in bright light

- Circular muscles of the iris contract,
- Radial muscles relax,
- Pupil becomes smaller and narrower hence less light is admitted into the eye.

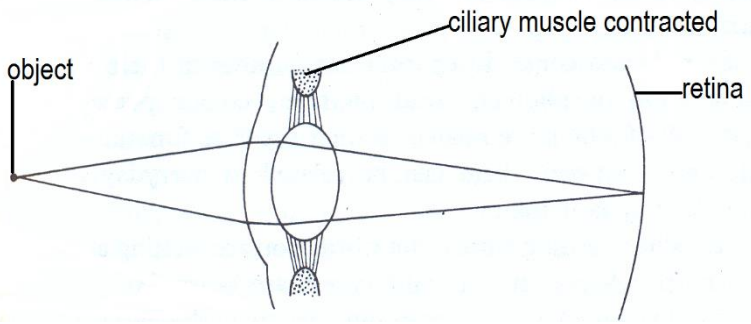


Accommodation of the eye

Accommodation is the ability of the eye to change the focal length of the lens when viewing distant or nearby objects.

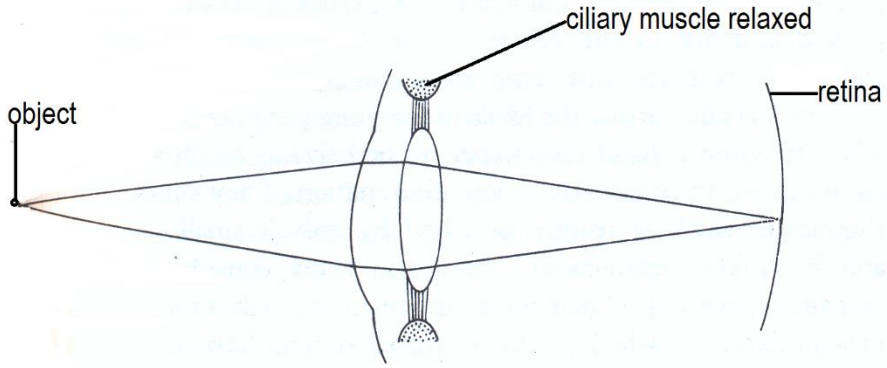
Accommodation for a nearby object:

When looking at a nearby object, the ciliary muscles in the ciliary body contract, the suspensory ligaments slacken. This makes the lens short and thick. This increases the ability of the lens to refract light and reduces the focal length of the lens for the nearby object to be seen clearly.



Accommodation for a distant object:

When viewing a distant object, the ciliary muscles in the ciliary body relax. This causes tension in the suspensory ligaments. The suspensory ligaments pull the lens apart making the lens thin and long. This makes the lens to refract less and increase the focal length of the lens.



Summary of accommodation

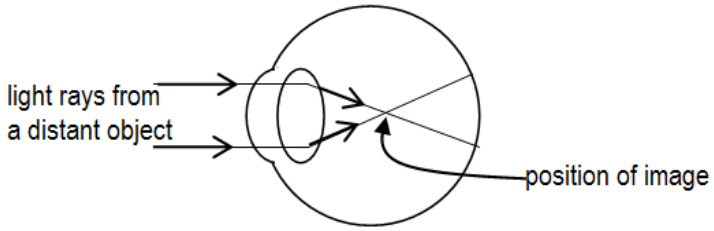
Nearby object	Distant object
Diverging light rays from a nearby object are refracted by cornea.	Parallel light rays from a distant object are refracted by the cornea.
Ciliary muscles in the ciliary body contract.	Ciliary muscles in the ciliary body relax.
Suspensory ligament slacken.	Suspensory ligaments develop tension.
The lens become short and thick.	The lens becomes thin and long.
The focal length of the lens decreases	The focal length of the lens increases.
Light rays are refracted to the retina.	Light rays are refracted to the retina.

Eye defects

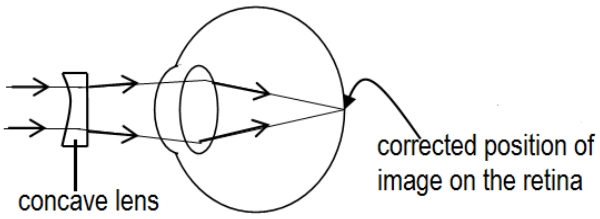
An eye defect is a condition where the eye fails to focus an object well unless aided by external lenses. The common eye defects include:

1. Short sightedness (myopia):

This is an eyesight abnormality whereby an individual focuses clearly on nearby objects. Distant objects are not clearly focused. It is usually caused by a large eyeball. Light rays from a distant object are brought to a focus before they reach the retina, and hence form a blurred image while the rays from very near objects are normally converged so as to produce a clear image.

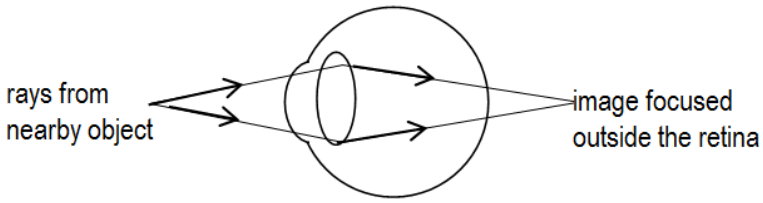


This can be corrected by putting on diverging (concave) lenses.

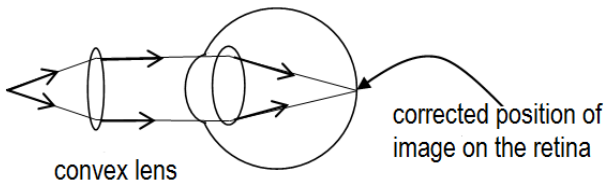


2. Long sightedness (Hypermetropia):

This is an abnormal condition in which vision for distant objects is better than for near objects. It is caused by a small or short eyeball or a very weak lens such that a close object is focused far behind the retina.



Long sightedness can be corrected by wearing converging (convex) lenses.



3. Astigmatism:

This is a defect in which light rays from a single point fail to converge in a single focal point. It is caused by unequal refraction of the cornea and lens due to uneven curving in them. It results into some parts of the object being well focused on the retina and some not to be focused. It is normally due to old age. This can be solved by wearing cylindrical lenses.

4. **Presbyopia:**

This is farsightedness/long sightedness resulting from reduced ability to focus caused by loss of elasticity of the crystalline lens with age. It is a defect of vision due to old age. It produces difficulty of accommodation and recession of the near point of vision so that objects very near the eyes cannot be seen clearly without the use of convex glasses.

Colour vision

The cones are photoreceptor cells on the retina, which are concerned with colour vision. There are three types of cones, which are sensitive to three primary colours i.e. the blue sensitive cone, green sensitive cone and red sensitive cone. When blue sensitive cones alone are stimulated, blue colour is perceived. Stimulation of green sensitive cones alone gives green colour. Stimulation of red sensitive cones produces red colour. Equal stimulation of both green and red sensitive cones gives yellow colour. Equal stimulation of the entire three cones gives white colour and when no cone is stimulated, no colour (black) is perceived. This is known as the **trichromatic theory.**

Revision question

1. *The table below shows the changes in the diameter of the pupil of the eye in different light intensities.*

Light intensity (a.u.)	*0*	*5*	*10*	*15*	*20*	*25*
Diameter of pupil (mm)	*8.0*	*8.0*	*7.1*	*6.3*	*5.4*	*4.5*

   a) Plot a graph to represent the information in the table.
   b) Describe the effect of increasing light intensity on the diameter of the pupil.
   c) Explain how increasing light intensity affects the diameter of the pupil.
   d) The changes in the diameter of the pupil are because of a nervous response.
      i) Name the type of nervous response to which the pupil responds.
      ii) Name two features of the nervous response to which the pupil responds.
      iii) Outline three benefits to the organism of eyes responding to light.
2. What is meant by accommodation?
3. Describe with the aid of a well labeled diagram events that occur in the eye to focus and see clearly;
   i) An aero plane in the sky.
   ii) An apple while seated on a dining table.
4. Explain how footballer during a match is able respond to the sound of a whistle made by the referee.
5. What is accommodation of the eye?
6. Explain how eyes adjust to see:
   i) Nearby objects
   ii) Far objects
7. State the causes of at least two eye defects among humans.

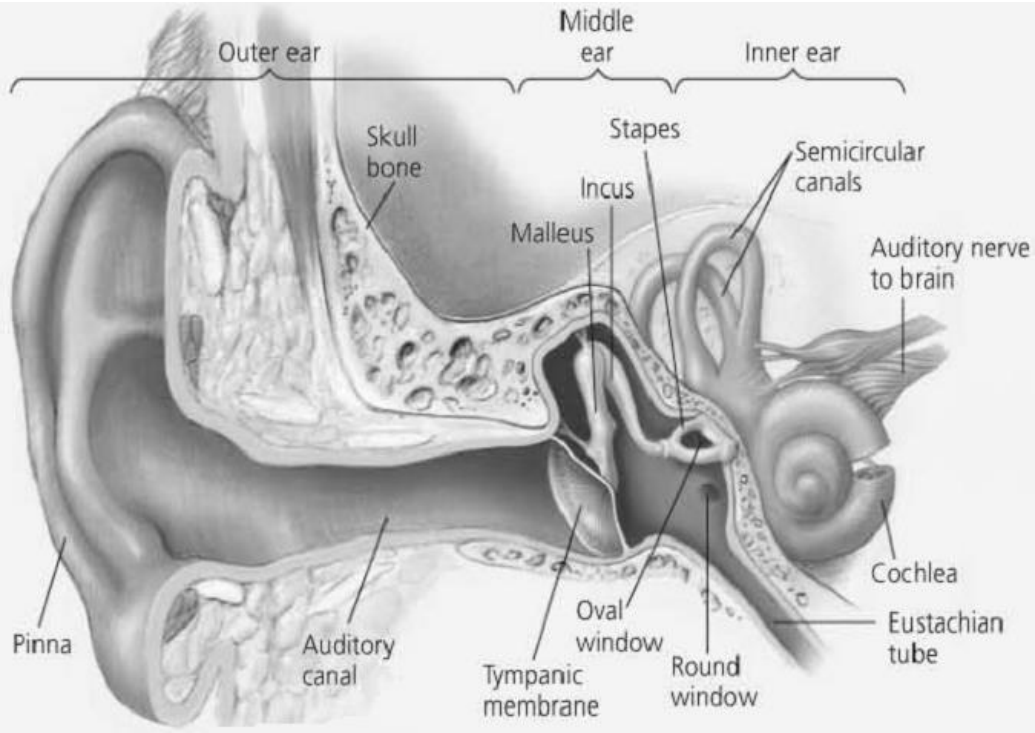
THE EAR

The ear has **mechanoreceptors** (receptors that detect physical transformation) associated with sound, gravity and displacement.

The ear performs three basic functions i.e. detection of:

- Sound (hearing)
- Head movements
- Changes in gravity (balance or posture)

Structure of the ear



The ear is made up of three areas i.e. the outer ear, middle ear and inner ear.

1. The outer ear:

It has an outer extension called the pinna. The pinna concentrates and directs the sound vibrations into the ear through the auditory canal which makes the ear drum vibrate.

2. The middle ear:

This is a cavity in the skull filled with air. It communicates with the mouth cavity through the Eustachian tube. There are three small bones called ossicles in the middle ear which link the eardrum and the opening of the skull called oval window that leads to the inner ear.

3. The inner ear:

The inner ear is filled with a fluid and consists of mainly a coiled tube known as the cochlea.

The cochlea has sensory nerve endings leading to the brain. These transmit nervous impulses from the ear to the brain.

Functions of the parts of the ear

- The outer projecting portion of the outer ear is known as the **pinna**. Its function is to receive and concentrate sound waves.
- The **auditory canal** has hairs and wax that trap foreign bodies. It transmits sound waves to the **eardrum** (**tympanum**).
- The ear drum is a thin membrane; the eardrum transmits sound waves to the middle ear.
- The three small bones i.e. **hammer** (**malleus**), **anvil** (**incus**) and **stapes** (**stirrup**) are known as **ear ossicles**. They transmit acoustic vibrations from the eardrum to the inner ear.
- The **Eustachian tube** is a slender canal that connects the middle ear to the pharynx. It equalizes the air pressure on the two sides of the eardrum.
- The **oval window** transmits sound vibrations to the inner ear.
- The **semi-circular canals**, **utriculus** and **sacculus** form the **vestibular apparatus**, which controls body balance and posture. The canals are filled with fluid which moves as the body moves or when the head changes position.
- The **cochlea** facilitates hearing.
- The **round window** equalizes pressure in the cochlea.
- The **auditory nerve** transmits impulses to the brain.

The process of hearing in mammals

The pinna receives and concentrates the sound waves.

They are transmitted to the eardrum, which vibrates.

The vibrations of the eardrum are transmitted to the ossicles that vibrate and transmit the vibrations to the oval window at the entrance of the **vestibular canal** of the cochlea.

The **perilymph** (fluid in the vestibular canal) vibrates and causes **Reissner's membrane** to be displaced.

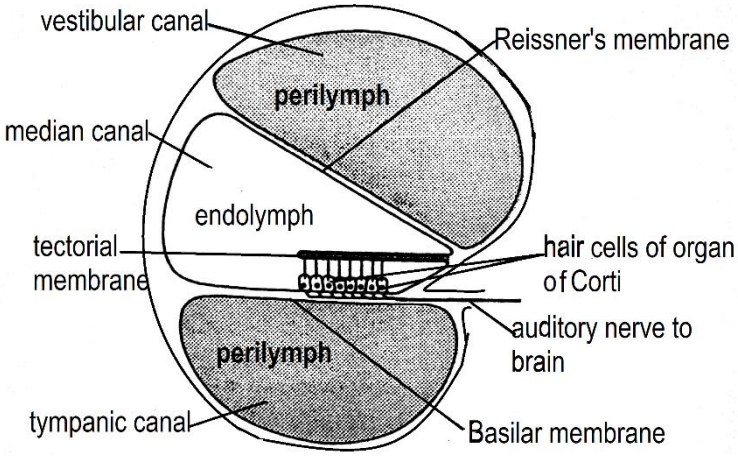
The displacement of Reissner's membrane causes the **endolymph** in the **median canal** to vibrate, which in turn causes the **basilar membrane** to vibrate.

The vibration of the basilar membrane stimulates sensory cells (in the **organ of Corti**), which generate impulses.

The impulses are transmitted by the auditory nerve to the brain, which interprets them into sounds.

The vibrations of the basilar membrane disturb the perilymph in the **tympanic canal**. The round window takes up these vibrations.

Transverse section of the cochlea



Deafness

Deafness is the inability to hear. It may be brought about by a defect in the nerves or the conduction of waves.

Causes of deafness

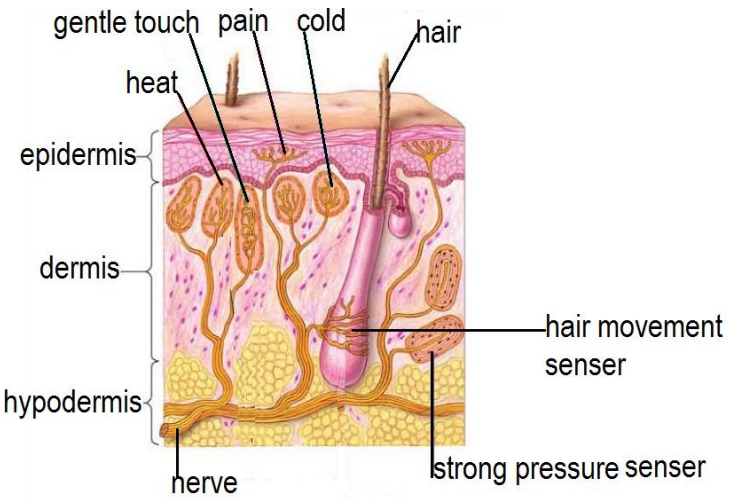
- ***Accumulation and hardening of wax in the outer auditory canal*** that presses against the eardrum. This can be controlled by use of cotton buds to remove excess wax after the wax has been softened using warm water.
- ***Blocking of the Eustachian tube*** as a result of accidents and certain infections such as the common cold, etc. This can be treated by use of antibiotics to kill the bacteria that caused the infection.
- Some individuals are born with ***thick eardrums*** that do not easily vibrate. This can be solved by use of hearing aids.
- ***Ruptured eardrum*** due to accidents and infections. Sometimes the eardrums heal on their own or a hearing aid can also be used.
- Damage to the cochlea as a result of ***exposure to loud noise over a long period of time***. This can be prevented by keeping sound volume low because once the cells of organ of Corti in the cochlea are damaged, they cannot be repaired.
- ***Fused ossicles*** due to infections that cause inflammation in the middle ear. Some individuals are born with fused ossicles. The ossicles do not hit each other when they vibrate. This can be treated by medication to kill the microorganisms that caused the infection or surgical operation to replace the ossicles.
- ***Damage to the hearing centre of the brain*** also causes deafness.

THE SKIN

The skin is a sense organ responsible for the senses of pain, touch, pressure and temperature. The skin has mechanoreceptors, pain receptors and thermo receptors.

Mechanoreceptors sense physical deformation caused by forms of mechanical energy such as pressure, touch, stretch and motion. The sense of touch relies on mechanoreceptors that are dendrites of sensory neurons. Touch receptors are often embedded in layers of the skin. Other receptors sense movement of hairs.

Structure of the skin as a sense organ showing the sense receptors



For example, cats and many rodents have extremely sensitive mechanoreceptors at the base of their whiskers which help them to detect the size of the tunnel and also get information about nearby objects.

Pain receptors detect stimuli that reflect harmful conditions like extreme pressure and temperature hence triggering defensive reactions such as withdrawal from danger.

Thermo receptors in the skin and hypothalamus detect heat and cold. *(**Note:** in essence, we describe spicy foods as 'hot' because they activate the same sensory receptors as do hot things).*

LOCOMOTION IN MAMMALS

Locomotion is the movement of the whole organism from one place to another.
Movement is the displacement of part of the body of an organism.

Forms or types of locomotion

- ✓ By crawling
- ✓ By walking
- ✓ By flying
- ✓ By creeping

Structures used in locomotion are referred to as limbs and they include; Wings, Fins, Legs, Arms, Cilia, Flagella and Pseudopodia

An animal locomotes in order to:

- ✓ Look for food
- ✓ Search for mates
- ✓ Avoid danger and catastrophes.
- ✓ Avoid competition with other animals
- ✓ Colonize new areas.

Requirements for locomotion

Locomotion requires the following:

- Energy. This is obtained from respiration.
- Skeleton. This is a rigid framework for support and attachment of muscles.
- Muscles. These contract and relax in order to move the skeleton during locomotion.
- Medium. This is the environment in which the organism moves. The medium can be water, land or air.

Skeleton

A skeleton is a frame work of muscles.

Types of skeleton

There are three types of skeletons, i.e. Endoskeleton, exoskeleton and hydrostatic skeleton.

1. **Hydrostatic skeleton**

This is a type of skeleton made up of a water filled cavity. The cavity is surrounded by a set of antagonistic muscles. Locomotion is caused by compression of the fluid under

high pressure by action of muscles on the fluid to form a rigid surface that offers support e.g. In earthworms.

2. Exoskeleton

This is a skeleton found outside the body of an organism. It is made up of a substance called chitin in insects and shells in mollusks. The exoskeleton is rigid and made up of nonliving material. It does not allow increase in size of an insect except for periods when it is shed during moulting.

3. Endoskeleton

This is a skeleton found inside the body of an organism. This is found in all vertebrates. Its made-up materials called bone and cartilages.

Cartilage is softer and elastic and it's the first part to form the skeleton in the embryos of all vertebrates and it's gradually replaced by bone as growth takes place

Bone is harder and inelastic and is made up of living cells and nonliving material of calcium phosphate and calcium carbonate.

Ossification is the process through which cartilage changes to bones.

Merits of endoskeleton

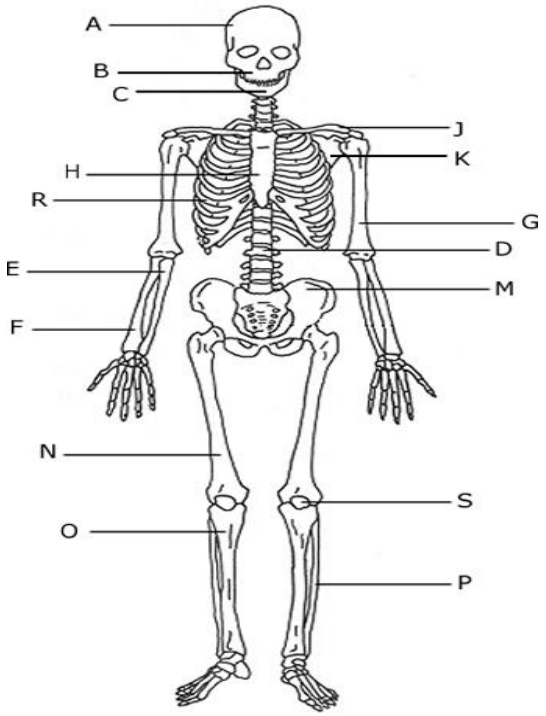
- The endoskeleton is more flexible hence it facilitates easier movement since it has movable joints.
- The endoskeleton is harder so it offers better protection and support to the internal organs compared to exoskeleton.
- It enables greater and continuous growth.
- An endoskeleton can manufacture red and white blood cells required for oxygen carriage and body defense against diseases respectively.

Merits of exoskeleton over endoskeleton

It can protect all the inner parts unlike the endoskeleton which can't protect the muscles and blood vessels.

It's lighter so it offers fewer burdens to the organism.

The human skeleton



Bones of the skeleton

A. Skull
B. Maxillae
C. Mandible
J. Clavicle
K. Scapula
H. Sternum
G. Humerus
D. Vertebra
R. Rib
E. Ulna
F. Radius
M. Pelvic bone
N. Femur
O. Tibia
P. Fibula
S. Patella

Functions of mammalian skeleton

Support: The skeleton forms a rigid framework over which body organs are suspended e.g. The lungs, heart, intestines, kidney, bladder or else these organs would crush into one another and hence make the body shapeless.

Locomotion: It provides surfaces for attachment of muscles to allow movement.

It is a site for manufacture of red blood cells and white blood cells: These cells are made in bone marrows.

Protects delicate organs of the body: Delicate parts of the body are protected by the skeleton. The skull protects the brain, inner ear and eyes. The vertebral column protects the spinal cord. The rib cage protects the heart, lungs and all organs in the thoracic cavity.

Stores calcium for usage in the body: Calcium is an element that is added to cartilage to form bone. All bones contain calcium, which makes them strong. When calcium is needed in other areas, it can be obtained from the bones.

It is used in breathing: The rib cage adjusts the volume of the thoracic cavity during breathing.

NOTE: REFER TO PRACTICAL WORK BOOKS FOR VERTEBRAE COLUMN

Joints

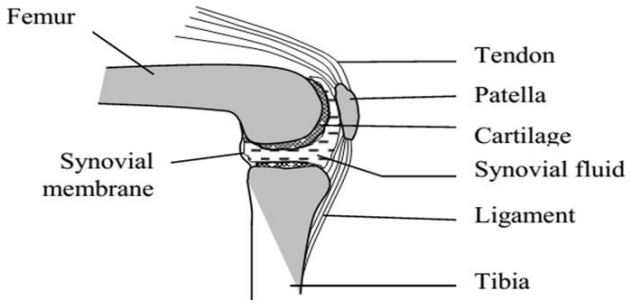
A joint is a place where two or more bones meet. The bones are connected together by ligaments to allow movement.

Types of joints

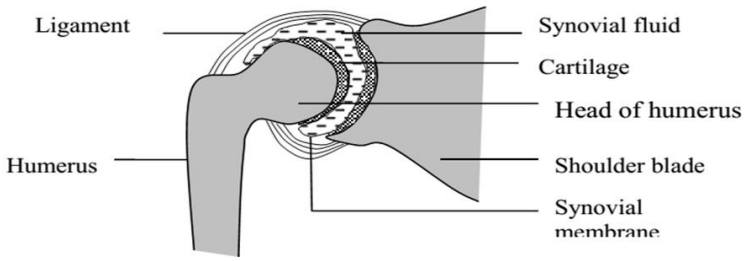
Joints are classified according to the degree of movement into the following categories;

1. **Immovable joints**: these are joints where no movement is possible for example the joints in the skull (sutures).
2. **Movable joints**: these are joints which allow some degree of movement. They are also called synovial joints. The movable joints are further divided into the following types;
   - **Sliding joints.** These are joints which allow bones to slide over one another for example in the wrist and ankle.
   - **Pivot joints.** These allow rotation of one bone over the other for example between the axis and atlas of the vertebral column.
   - **Hinge joint**. This allows movement in one plane for example in the elbow of the hand, in the knee, fingers and between the jaw and skull.
   - **Saddle joints:** it allows twisting movements i.e. Rotation of each bone between 2 axis e.g. The radius and ulna.
   - **Ball and socket joint:** this allows movement in all directions. The hip and shoulder joints are ball and socket joints.

Hinge joint at the knee



Ball and socket joint at the shoulder



Parts of the joint

Ligament. This is a tissue that connects a bone to another bone.

Tendon. This is a tissue that connects a muscle to a bone.

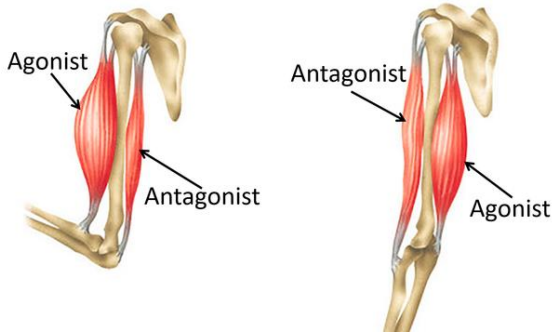
Cartilage. This is a tissue that encloses the ends of bones at the joints. It prevents articulating bones from wearing out due to friction. It also acts as a shock absorber.

Synovial cavity. This is located between two surfaces of articulating cartilage. It is surrounded by a synovial membrane that encloses the synovial fluid.

Synovial fluid. This is a lubricant during movement. Damage of a joint causes excess synovial fluid to be formed and the synovial cavity bulges causing a swelling in the joint.

Antagonistic muscles

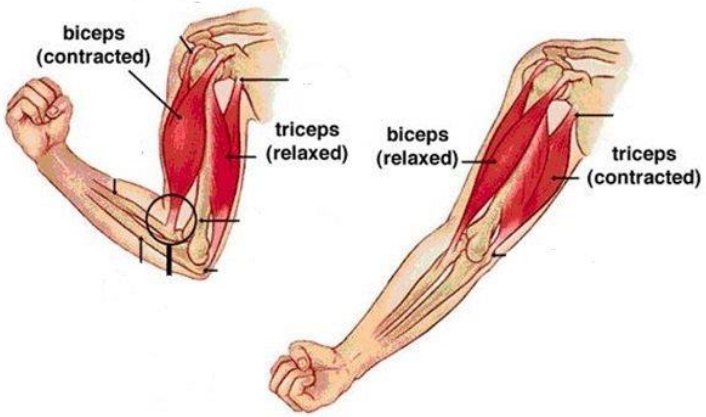
Antagonistic muscle is **a muscle that opposes the action of another**. For example, when the triceps oppose the contraction of the flexing biceps by relaxing, the triceps would be regarded as the antagonistic muscle to the biceps whereas the biceps, the agonist muscle.



An example of the antagonistic muscle functioning is the movement of the arm at the elbow.

The contraction of the biceps (flexor) muscle pulls the radius, which causes the arm to be raised. This causes the elbow to bend (flex) hence the bending of the whole arm.

When the triceps (extensor) muscle contract, it pulls the ulna thus straightening the arm.



Locomotion In Birds

Locomotion is brought about by contraction of muscles in most of the vertebrates.

The normal way of movement is walking but birds and bats are unique animals in that they have the ability to fly.

A few birds are completely unable to fly e.g., ostriches, emus, kiwis, etc.

Adaptations of birds for locomotion

- Fore limbs have been modified to form wings for flapping.

- Wings spread out to provide a large surface area for movement in air.
- Presence of large pectoral muscles the pectoralis major and pectoralis minor which flap the wings when they contract.
- A light and strong skeleton made up of hollow and small bones which can be easily moved in the air.
- A rigid skeleton made up of fused bones with a deep keel like extension of the sternum which provides a large surface area for the attachment of flight muscles.
- A stream lined shape to reduce air resistance and provide smooth movement in the air.
- Ability to fold the leg away during flight so as not to cause any unnecessary friction with the air.
- Feathers are light to reduce the body weight during flight.
- An efficient breathing system with air sacs attached to the lungs necessary to provide the necessary oxygen for respiration and to removing the resulting carbon dioxide.
- A high metabolic rate for providing the high amount of energy required for flight.
- An efficient circulatory system necessary for transporting both the nutrients and respiratory gases as fast as the body needs require.
- A high red blood cell count for efficient oxygen transport.
- A keen eyesight to enable them judge distances correctly especially on quick landing.

Structure and Functions of Feathers

There are four types of feathers:

1. Quill feathers
2. Covert feathers
3. Down feathers
4. Filoplumes.

NOTE: REFER TO PRACTICAL WORKBOOKS FOR DETAILS ON FEATHERS

Functions of feathers to birds

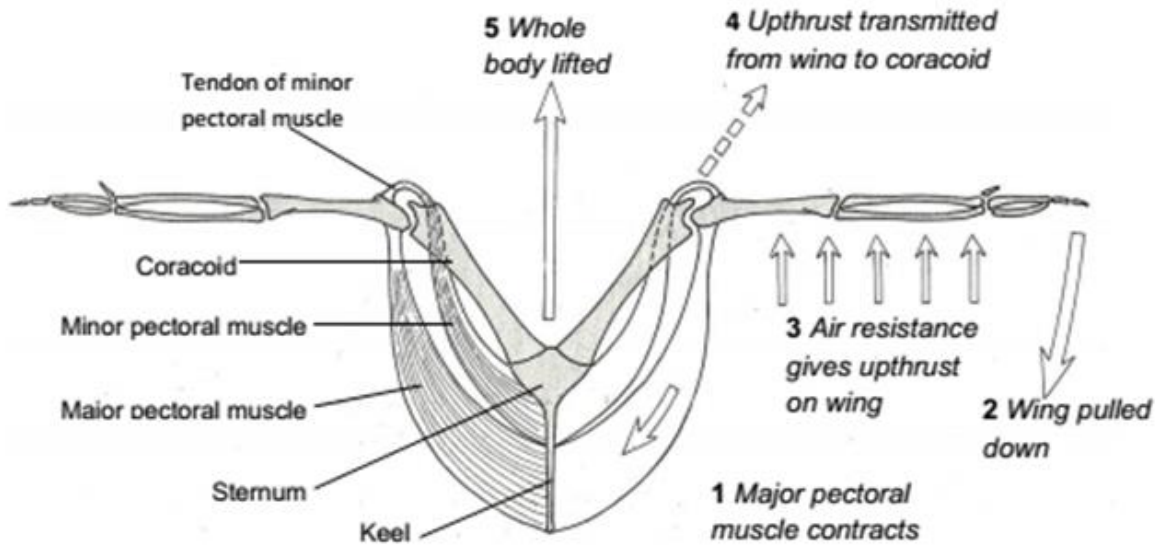
- They protect the skin from abrasion, rain and direct sunrays.
- They assist in maintenance of body temperature or regulating body temperature by insulating against heat loss.
- They are used in flight
- They are for camouflage to avoid predators.
- They are for courtship. Feathers are used to attract the opposite sex in birds.
- They are for sensation, i.e. They collect sound waves

Flight in birds

Mechanism of active flight/flapping in birds

Active flight occurs with the help of flight muscles. These muscles are pectoralis minor and pectoralis major. The muscles are antagonistic.

Active flight involves two strokes; the downward stroke and upward stroke.



During the down stroke:

- The pectoralis major contracts and the pectoralis minor relax.
- The wing moves down and backwards. The air offers resistance to the wing, which gives the bird an upward and forward thrust.
- The flight feathers overlap and become air-tight in order to prevent air moving through them.
- The bird is then able to move upwards and forward.

Note: *forward movement is provided by the stream of air directed backwards because the wing is flapped with the leading edge below the trailing edge. In this way the wing acts as an aero foil.*

Upstroke:

- This is also called the recovery stroke. It is brought about by the contraction of the pectoralis minor and relaxation of the pectoralis major which raises the wings.
- The pectoralis minor contracts and the flight feathers open to allow air through them such that less resistance is felt.
- The reduction in air resistance causes the wing to be raised.
- When the wing reaches maximum point, the pectoralis major resumes its contractions, starting the downward stroke again.

Locomotion In Insects (Grasshopper)

Questions:

1. Name the parts of a grasshopper that enable it to move.
2. Draw and label the hind legs of a grasshopper.
3. Mention the importance of the hind legs of a grasshopper?
4. How are the hind legs adapted to their functions?
5. State differences in structure between inner and outer wings of a grasshopper.
6. State the importance of each: Inner wings and Outer wings.

Flight in insects

Flight is brought about by the action of flight muscles attached to the exoskeleton and wing.

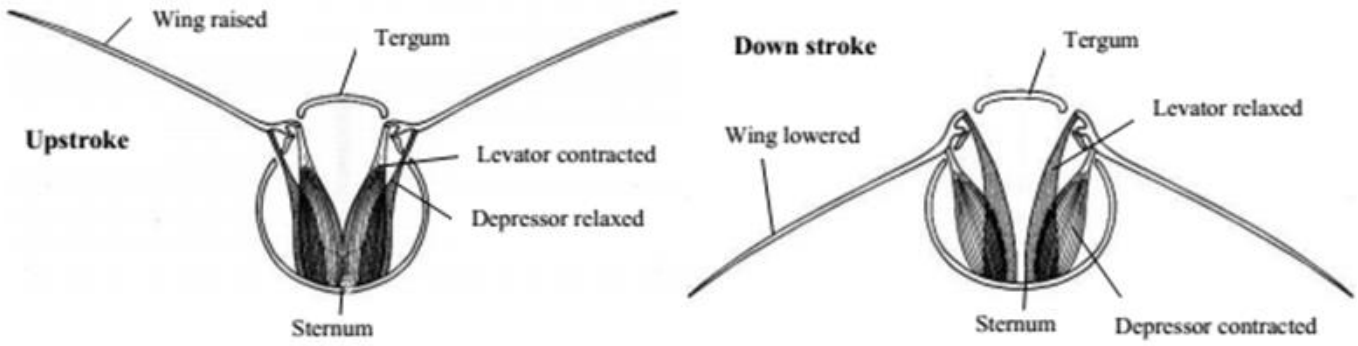
Flight using direct flight muscles like in a grasshopper

During the upward stroke:

The elevator muscles contract while the depressor muscles relax. This leads to upward movement of the wing.

During the down ward stroke:

The depressor muscles contract while the elevator muscles relax. This leads to down ward movement of the wing



Locomotion in fish

Fish live and move in water

For external parts of a fish (Refer to the Practical workbooks)

Adaptations for living in water

- All fish have a streamlined body which reduces water resistance as the fish moves.
- They possess gills which enable them carry out gaseous exchange.
- Their body surfaces are smooth, covered with slime, which enables the fish to escape from the enemy in the water easily.

- Most fish have scales which protect the fish from external abrasion by moving sticks in the water. Those without scales have tough leathery skins for the purpose of protection.
- Fish possess fins which are for balancing and motion in the water.
- Many fish possess a swim bladder, which is a gas filled structure that enables them to alter their densities according to the depth of the water where they are. Hence, the swim bladder enables the fish to gain buoyancy at any depth.
- Fish have large eyes, which give them a wide field of view to detect and avoid obstacles and danger in water.
- They have a lateral line, which enable the fish to detect vibrations and pressure changes in water.
- They have fins for propulsion and stability while in water.
- They have a swim bladder, which makes them buoyant. They can float in water and sink to the bottom by inflating and deflating their swim bladders.
- They have streamlined bodies to reduce on water resistance.
- They have gills, which help them to exchange gases while in water. The gills are adapted to obtain oxygen dissolved in water and to release carbon dioxide into the water.
- They have a slivery appearance on the ventral side and a dark colour on sides, which help it to camouflage in water to escape from predators.
- Scales are arranged in a backward overlapping way that offers little resistance to water.
- The vertebral column is considerably flexible to allow sideways movement.

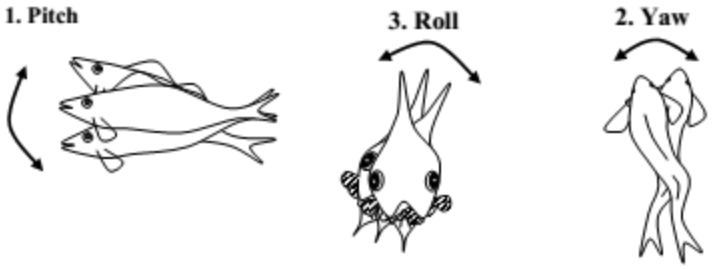
Action of fins

Fins control direction and stability in water.

Instabilities during fish locomotion

1. **Yawing**; this is the deflection of the head resulting from the propulsive action of the tail. It is prevented by dorsal and ventral fins
2. **Pitching**; this is the tendency of the head to plunge vertically downwards as the fish moves. This is prevented by pectoral and pelvic fins.
3. **Rolling**. This is the rotation of the fish about its longitudinal axis. It is controlled by median fins.

Illustrations of instabilities



There are two categories of fins.

1. **The paired fins**; these include pectoral and pelvic fins which are used for steering and balancing to control pitching
2. **The median fins**; these are unpaired fins. They include dorsal and ventral fins. This control rolling and yawing by increasing vertical surface.

Revision questions:

1. Name the external features of a bony fish.
2. Explain the function of each feature.
3. List the various adaptations that enable a bony fish to move.
4. Explain how movement is brought about in bony fish.

GROWTH AND DEVELOPMENT

Growth is defined as an irreversible or permanent increase in the size and dry weight of an organism. Growth in multicellular organisms is brought about by 3 processes.

(i) Cell division: This involves increase in the number of cells mainly as a result of mitosis.
(ii) Cell expansion: This is the permanent increase in the cell size as a result of uptake of water or synthesis of living materials.
(iii) Cell differentiation: This is the change in the form and activity of a cell to enable it perform a certain activity more efficiently.

Growth is usually accompanied by an increase in the complexity of an organism which is also called **development. Development** is the permanent change in form and complexity of an organism.

Growth and development in plants

Growth is a continuous process in plants which occurs mainly at the tips of the root and shoot systems. These regions are called **meristems. A meristem** is a group of undifferentiated plant cells which are capable of dividing repeatedly by mitosis.

Two types of meristems i.e. apical meristems and lateral meristems

i) Apical meristems

They are located at the tip of roots and shoot. They bring about increase in length or height of the plant. This type of growth which involves increase in length or height of a plant is known as **primary growth.** The meristematic region is just behind the tip of the shoot and root.

Diagram showing regions of cell growth in a root

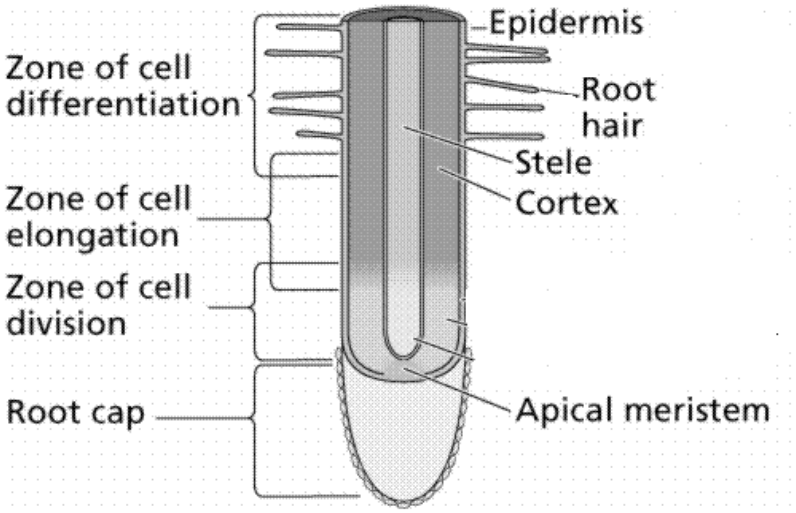


Diagram showing apical meristems in a shoot

ii) Lateral meristems

These are laterally situated in the stems and roots of the dicot plants. It brings about **secondary growth.** Secondary growth takes place after primary growth. Secondary growth (secondary thickening) involves increase in thickness/ width of a plant. It takes place in stems, branches and roots of dicot trees and shrubs each year.

Lateral meristems are of 2 types namely:

a) Cork cambium; which forms the secondary cortex
b) Vascular cambium; which gives rise to the secondary phloem and xylem tissues.

Experiment to identify the region of growth in a root of a bean seedling

Requirements; A bean seedling. a marker pen, pins, petri dish, ruler and cotton wool

Procedure;

- **Germinate bean seeds in damp sawdust to enable the roots to grow straight.**
- Select a seedling whose root is straight and wash off the sawdust. Wipe it dry.
- Staring from the tip of the root, mark out equal spaces of 1 mm each using a marker pen.
- Pin the seedling firmly onto a petri dish lined with wet cotton wool and place it in such a way that the seedling is vertically upright
- Leave the set up for about three days then observe and measure the marked spaces on the root.

Observation: The spaces marked closely behind the tip become wider while those furthest away from the tip remain the same.

Conclusion: Growth takes place at the region just behind the root tip.

NB; The same experiment can be repeated using the shoot of the seedling instead of the root

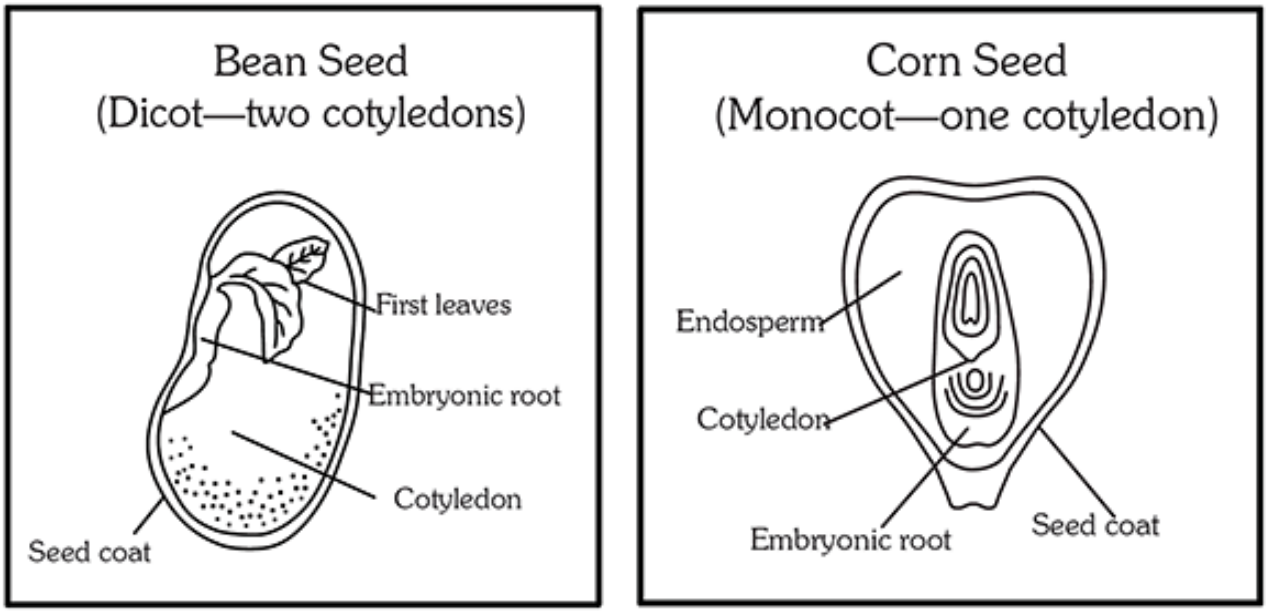
Revision Questions

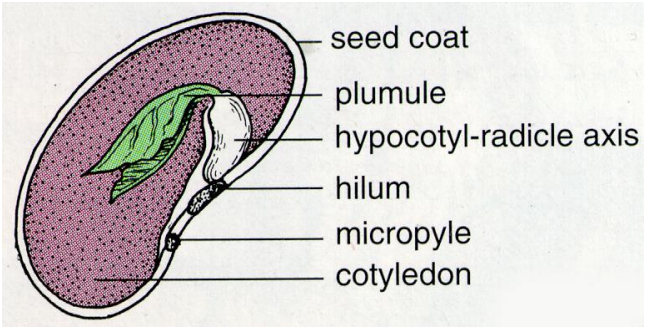
- *Explain the importance of meristems in plants*
- *Identify regions of greatest cell elongation in roots and shoots.*

Germination

This is the emergence and development of an embryo in a seed into a seedling capable of existing as a new and independent plant under favorable conditions.

Diagrams showing parts of a seed





Non-endospermic seeds do not have an endosperm in the mature **seed**. The cotyledons are thick and fleshy, and function as the sole food storage organs. Dicotyledonous plants have non-endospermic seeds.

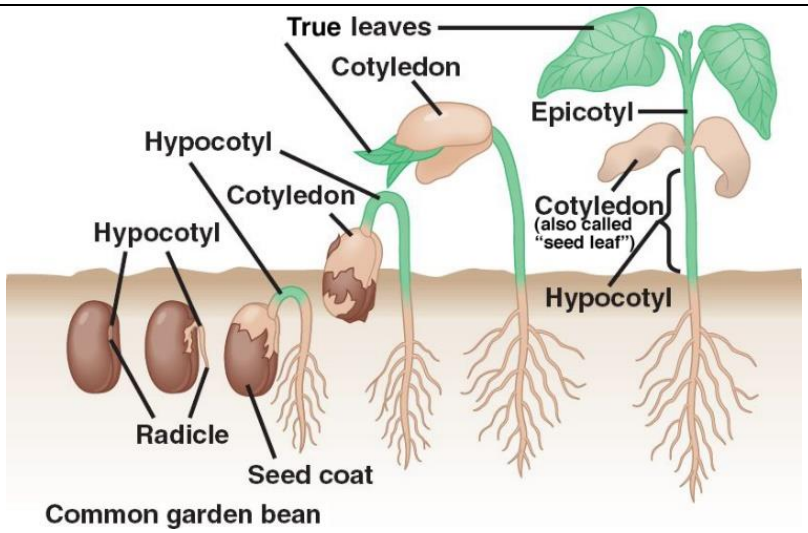
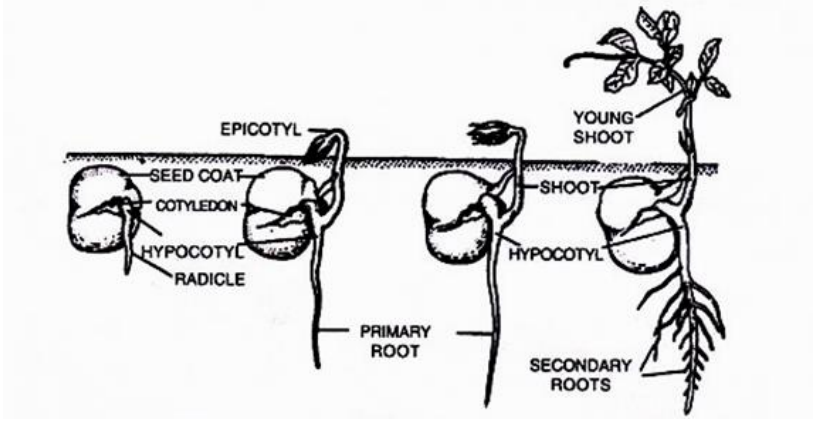
Monocotyledonous plants like maize have **endoplasmic seeds**

Exercise

1. Define growth and cell division.
2. Draw and label the internal and external parts of a seed

Types of germination

There are two types of germination;

i) Epigeal germination This is where the cotyledons appear above the ground due to rapid elongation of the **<u>hypocotyl</u>**. E.g. beans, tomato, cotton, mangoes, etc. The cotyledons on exposure to sun light turn green and become photosynthetic. This is because they contain chlorophyll. This is when they assume the function of making food.	
ii) Hypogeal germination The cotyledons remain underground due to the **<u>epicotyls</u>** growing faster than hypocotyls. Seeds showing hypogeal germination are endospermic. Examples include maize and G nuts.	

Revision Questions

- Explain the development of a simple seed into a huge plant
- List the differences between endospermic seeds and non-endospermic seeds
- Describe epigeal and hypogeal germination

Conditions necessary for seed germination

Condition	Required for
Water	• It activates the enzymes within the seed to hydrolyze the stored food. • It makes the seed swell, soft and the testa to burst. • It dissolves the stored food. • It is a medium in which all the chemical and enzymatic reactions proceed.

	• It is a medium of transport of the dissolved food substances to the developing shoot and root of the new plant. • Water is needed for the development of cell vacuoles. Large cell vacuoles contribute to increase in size of cells.
Oxygen	**Oxygen** is used in aerobic respiration; the main source of the seedling's energy until it grows leaves.
Warmth	Suitable temperature is important for enzyme-controlled reactions in the cotyledon of the germinating seed. At low temperatures, the enzymes are inactive and at very high temperatures, they are denatured hence no germination. Germination will require an optimum temperature which varies from 10^0C-50^0C for most tropical seeds.

The process of germination

During germination, a seed takes in water from the soil by imbibition through the micropyle. This makes the cotyledons swell and the testa to split.

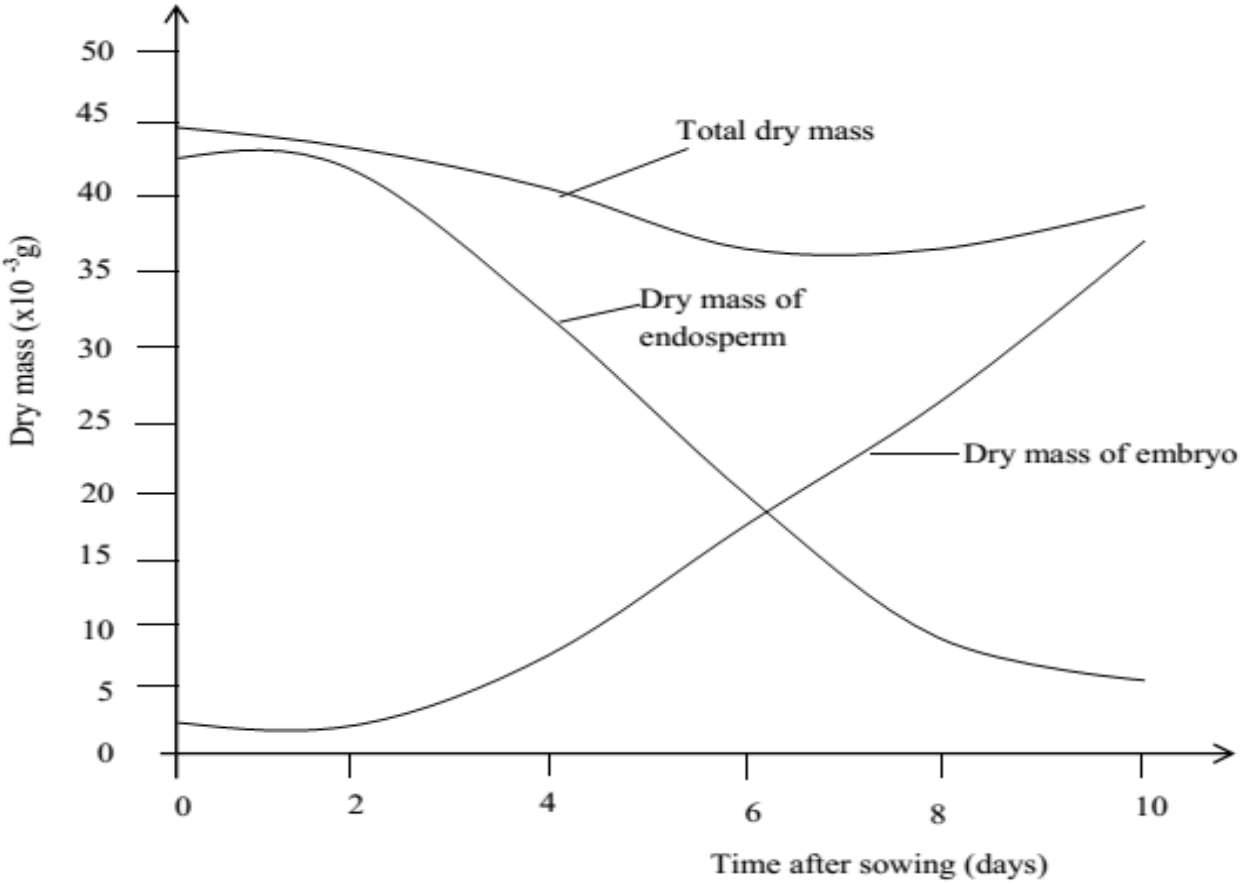
The absorbed water activates enzymes, thus leads to breaking of food materials e.g., starch and protein which are stored in the cotyledons or endosperm.

The soluble food materials are trapped to the growing points of the embryo where they are used to provide energy and making of new cells.

The radical is the first to emerge, it grows down wards between soil particles, and root hairs develop a short distance from the root cap and start absorbing water and mineral salts.

Absorption of water from the soil results into increase in the size of the seed and growth of the radicles and plumule which brings about rapturing of the seed coat and an embryo emerges.

Relative changes in dry mass of endosperm and embryo during germination of barley



Task: explain the variations of the dry mass in the graph.

Question: the table below shows the changes observed in dry weight in mg of a barley seedling, its embryo and endosperm during the first ten days after onset of germination.

Time/days	Embryo	Endosperm	Whole seedling
0	2	41	45
2	2	39	43
4	7	32	41
6	15	21	38
8	22	11	35
10	35	6	43

a) Suggest how the experiment was carried out

b) Using a suitable scale and on the same set of axes plot graphs of dry weight of embryo, endosperm and whole seedling against time.

c) Describe and account for the changes in weight shown by:
   i) The embryo
   ii) The endosperm
   iii) Whole seedling during the period of the experiment.

d) Explain how you would expect the weight of the whole seedling to change if the experiment was carried out in the dark.

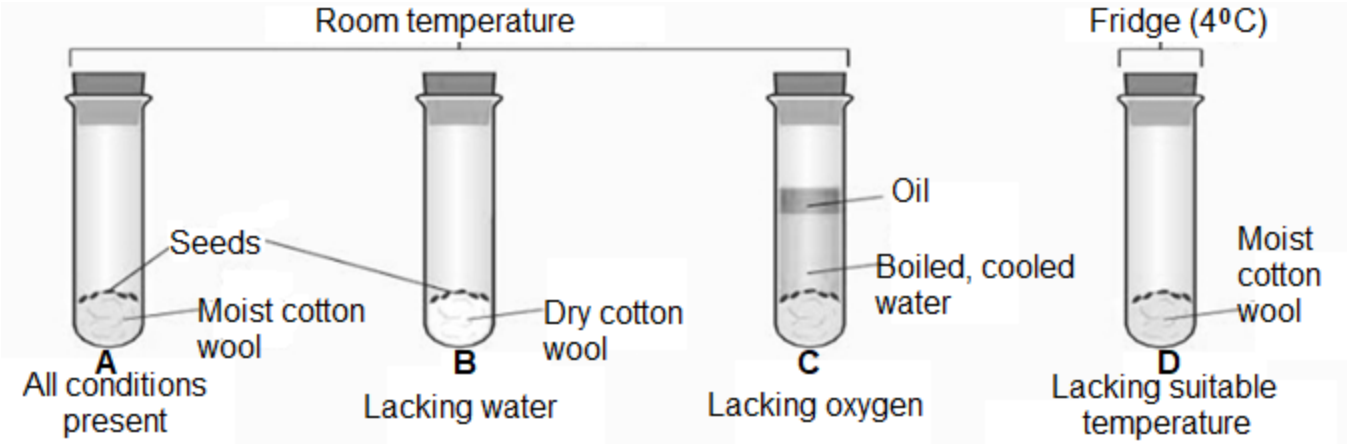
An experiment to demonstrate the conditions necessary for germination

Materials: refrigerator, 4 test tubes, Cotton wool, Seeds, Oil and Water.

Procedure:

- Arrange four test tubes labeled A-D
- To test tube A, add moist/wet cotton wool and seeds.
- To test tube B, add dry cotton wool and seeds.
- To test tube C, add seeds, boiled cooled water and a layer of oil.
- To D, add seeds, moist/wet cotton wool and keep in a refrigerator under non-freeze cold temperatures (about 4^0C).
- Cork all the test tubes and leave them for 3 days.

Setup:



Observations: Seeds germinated in only test tube A. Those in B, C and D did not germinate.

Conclusion: Air, water and warmth are necessary for germination.

Experiment to show that oxygen is necessary for germination

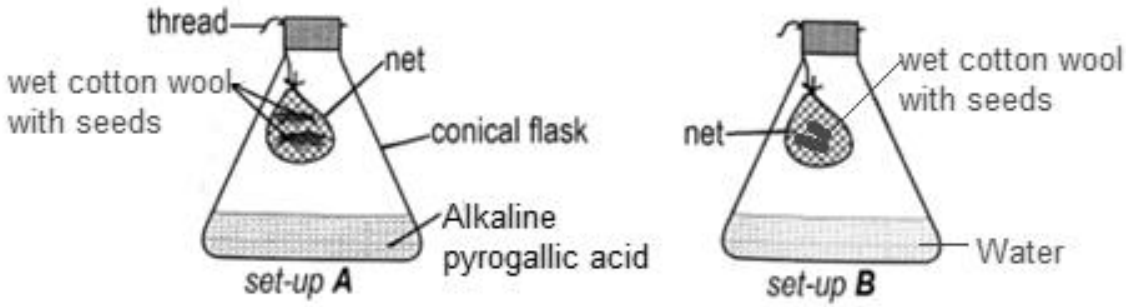
Apparatus: 2 conical flasks, 2 corks, Water, Cotton wool, Seeds and Alkaline pyrogallic acid.

Procedure:

- Pour some water in one conical flask and some pyrogallic acid in another conical flask.

- Tie some seeds in wet cotton wool and suspend the cotton wool in the flasks using a thread.
- Fix the threads using a cork.
- Leave the set up for three days.

Set up:



Observation: After a few days the seeds in B germinated while those in A did not germinate.

Conclusion: Oxygen is necessary for germination.

Explanation: Alkaline pyrogallic acid absorbs oxygen from air in flask A thereby preventing germination.

Revision questions

1. List the factors /conditions necessary for seed germination
2. Describe experiments on conditions necessary for seed germination
3. Name the types of seed germination in monocots and dicots

Seed dormancy

This is a state in which a viable seed will not germinate under favorable conditions. Dormant seeds usually have low metabolic activity, they have low water content and 'Zero' growth rate i.e. the embryos do not grow in any way.

Importance of seed dormancy

- It promotes germination of seeds during favourable conditions e.g. seeds dispersed in winter remain dormant in summer.
- It improves the chances of seedling to grow to maturity during favourable conditions.
- Dormant seeds can be stored for a long time and the seed dormancy can be broken by giving artificial conditions. This helps in their transportation.
- It reduces the risk of seeds being frozen to death during unfavorable conditions.

Causes of seed dormancy

1. **Immature embryo of the seed**

This may cause dormancy in seed germination since the embryo may undergo development before germination occurs.

2. **Presence of germination inhibitors:** Some chemical substances like acids do not promote germination of seeds when present. They destroy the enzymes.
3. **Extreme temperatures:** These greatly affect the working of enzymes in the seed. High temperatures denature enzymes while low temperatures inactivate them.
4. **Presence of hard impermeable seed coat:** Some seeds have a strong seed coat that does not allow water and gases to enter the seeds. Without water and gases, germination will not take place.
5. **Dryness of soil and lack of sufficient oxygen enough for seeds:** If oxygen is absent, seed respire anaerobically and obtain less energy. This will not allow seeds to germinate.

Ways of breaking seed dormancy

1. Harvesting mature seeds. This involves allowing embryos in seeds to develop up to maturity for certain period called ***after-ripening period.*** This allows the seed to develop fully.
2. By providing growth promoters which deactivate germination inhibitors. These are chemical substances that can make inhibitors less active. They contain nutrients or hormones for proper growth.
3. By exposing seeds to a cool period or chilling to initiate germination. This is common method of breaking seed dormancy in cereals.
4. By providing suitable conditions of oxygen, temperature and moisture which favour germination.
5. Removing the hard seed coat by:
    - Soaking seeds in water to soften it.
    - Action of fire to burn away the seed coat.
    - Passing seeds through animal gut.
    - Churning seed coat in concentrated acids.
    - Physical removal of the seed coat by using the hand or pricking or by action of bacteria in the soil.

Revision questions

- Explain seed dormancy
- List the causes of seed dormancy
- Explain how seed dormancy can be broken
- Explain the importance of seed dormancy

Measurements of growth

Measurement of growth involves the use of fresh weight and dry weight of a seedling.

1. Fresh weight/mass:

This is the total amount of organic matter and water in an organism.

Advantages of measuring growth by using the fresh weight

- It does not involve the killing of the organism.
- It is a very method of determining growth.
- It is the most suitable method of determining growth of seedlings.

Disadvantages of measuring growth by measuring the fresh weight

- It is less accurate since the biggest part of an organism is water.
- It is not reliable because the mass keeps on fluctuating due to water loss by transpiration and evaporation.

2. Dry weight/mass

This is the total amount of organic matter making up the body of an organism after removing water. It involves heating of an organism in an oven to a constant weight.

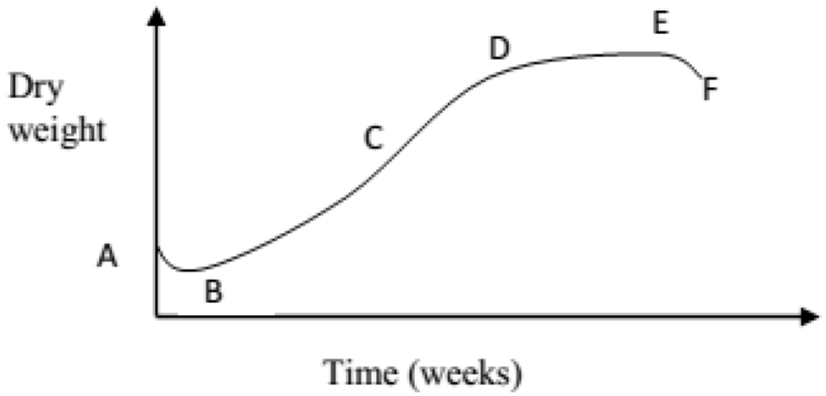
Advantages:

- It is a more accurate method of determining growth.
- It is reliable because constant results are obtained.

Disadvantages:

- It involves killing of an organism.
- The volatile tissues may decompose before removing all the water.

Changes in dry weight of a germinating seed



Description and explanation of the graph:

From point **A-B**, the dry weight of the seed decreases. This is because the stored food in food reserves is hydrolyzed (broken down) to produce energy for germination.

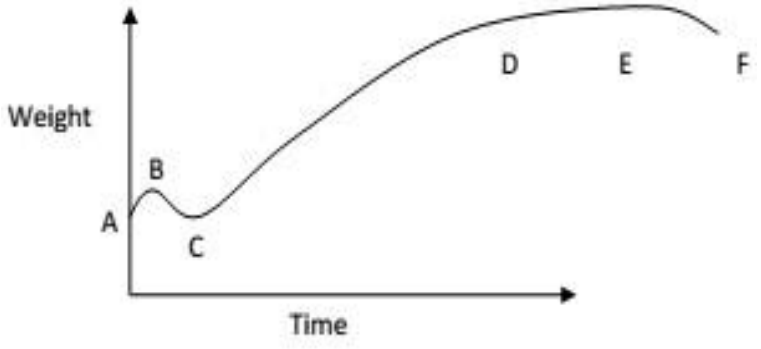
From point **B-C**, the dry weight increases rapidly. This is because the seed has produced leaves, which are carrying out photosynthesis. It makes food, which causes its dry weight to increase.

From points **C-D**, the growth rate decreases. This is because the plant has matured and preparing for flowering and fruiting.

From points **D-E**, the dry weight remains constant. The plant has produced fruits and no more growth takes place.

From point **E-F**, weight drops because the seed are dispersed, the plant leaves dry and fall off. This causes a reduction in dry weight.

Change in total weight of a germinating seed.



Explanation of the graph:

Most of the changes are similar to those in the graph showing changes of dry weight with time in a germinating seed except that for dry weight, the weight of water in the seed is not considered. For the total weight of the seed during germination, water is put into consideration.

The initial slight increase in weight from point A-B is due to imbibition (absorption) of water into the seed. The other changes that follow in the subsequent points on the curve are similar to those in the change of dry weight with time.

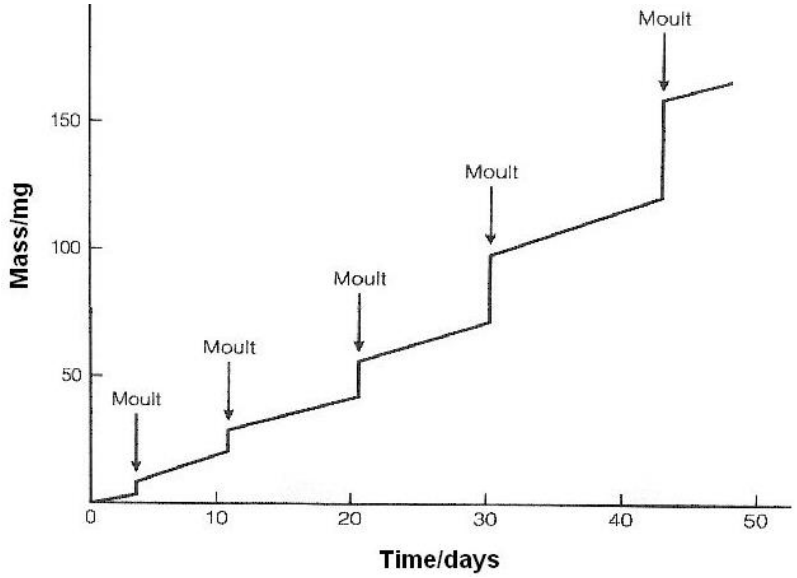
Growth and development in selected animals

In animals, growth occurs throughout the body of the organism unlike in plants where growth is localized in specific areas called meristems. Most animals grow continuously until they reach maturity. This is called **continuous growth.** However, arthropods like insects undergo **discontinuous growth**, i.e. there are periods of growth and no growth.

Growth and development in insects

Insects have an exoskeleton which is rigid and prevents expansion of the insect during growth. Before the insect grows, it sheds the exoskeleton in a process called moulting (ecdysis). Without the exoskeleton, the insect expands and grows. A new exoskeleton then forms and growth ceases. This kind of growth is referred to as **intermittent growth** or **discontinuous growth**. Successive moults result into formation of a new form of the insect. This is called metamorphosis.

A graph showing intermittent growth in insects



Metamorphosis is the change from one body form to two or more distinct stages until maturity. Metamorphosis is common in arthropods and amphibians.

Importance of metamorphosis

- Metamorphosis enables the larva and the adult to live in different habitats and even occupy different ecological niches. This reduces competition for resources.
- It also synchronises each stage with suitable climatic conditions ensuring survival of the species.

During **complete metamorphosis** the egg hatches into a larva that is different from the adult, the larva moults to produce a pupa before moulting to produce the adult. E.g. butterfly; An adult butterfly has six jointed legs for walking and two pairs of wings for flight. On the other hand, the larva has three pairs of jointed legs on the thorax, and projections called pro-legs on the ten abdominal segments for walking. The adult sucks nectar from flowers by use of a long flexible proboscis, while the larva has mouth parts for chewing and feeds on foliage.

During **incomplete metamorphosis** the egg hatches into stages of nymphs that resemble the adult. E.g. cockroach. The nymph is the active growth stage. A nymph resembles the adult insect except it is smaller, sexually undeveloped and has no wings,

Growth and development in vertebrates

After fertilization, the zygote undergoes three changes during its growth and development. These changes are;

(i) Cleavage:

This is the mitotic division of the zygote to form a mass of cells. The zygote at this stage is called a **blastocyst**.

(ii) Gastrulation:

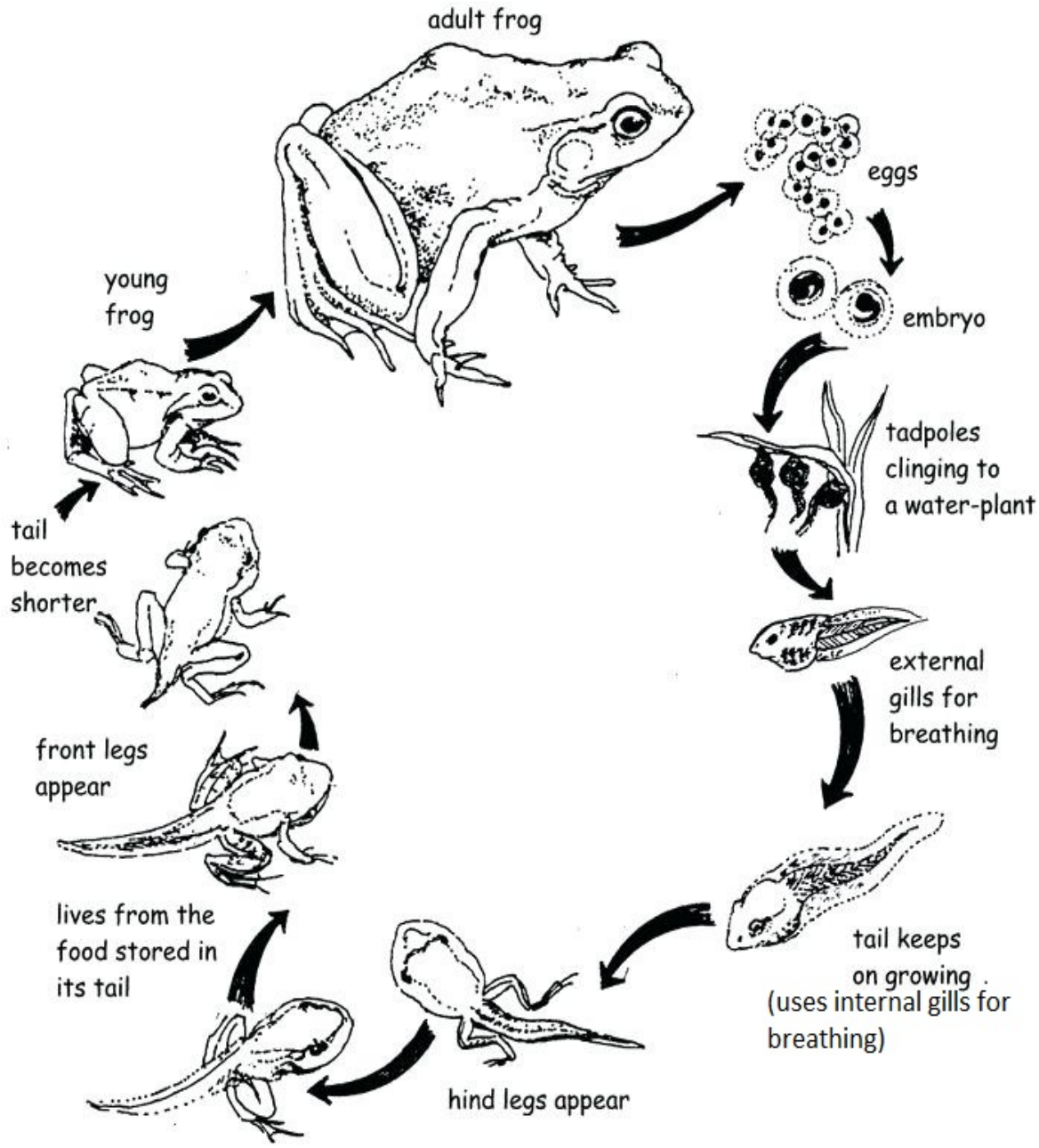
This is the rearrangement of the cells into distinct layers. The outer cells make up a layer called ectoderm. The cells in the middle make up a layer called mesoderm and the inner cells make up the endoderm. From these layers the various organs and systems are formed.

(iii) Organogenesis:

This is the formation of organs and organ systems.

Growth in amphibians

They develop in both land and water.



Revision questions

1. Define the term metamorphosis
2. Explain the difference between complete and incomplete metamorphosis
3. Describe the stages of development in an amphibian and a mammal
4. Explain metamorphosis in a frog.
5. Record observations of human baby by weight for a period of 4 month using a health card
6. Explain the growth patterns in insects, amphibians, and mammals

CELL DIVISION

Cell division is a process by which a parent cell divides to give rise to two or more daughter cells.

In single celled organisms like amoeba, this process results into increase in number of organisms while in multicellular organisms; cell division brings about growth, repair of worn-out tissues and formation of reproductive cells (gametes i.e. Sperms, ova, and pollen grains).

During cell division, the nucleus divides into two followed by the division of the cytoplasm. The cell membrane constricts to surround the formed cells each containing a nucleus.

The nucleus contains ***chromosomes***. The chromosomes contain the material responsible for inheritance, the ***genes***.

Chromosomes are thread-like structures found within the nucleus of cells of both plants and animals.

The chromosomes become visible when a cell is dividing. Chromosomes are composed of ***chromatin threads*** spread out within the nucleus of the cell.

During cell division, the chromosomes shorten and thicken, forming two parallel ***chromatids*** joined at the ***centromere***. At this stage, the chromosomes are visible under a light microscope.

The number of chromosomes in a body cell is known as the ***diploid*** number (2n). Body cells are also known as somatic cells.

The diploid number is obtained from two sets of chromosomes. A human being has 46 chromosomes. Homologous chromosomes have the same structural features. Chromosomes have genes located along their length. These genes interact to determine the inherited characteristics of an individual.

A gene is made up nucleic acids Deoxyribonucleic Acid (DNA) or Ribonucleic Acid (RNA). DNA is the major hereditary material of most organisms.

There are two types of cell division; mitosis and meiosis. Cell division is controlled by nucleus of the cell.

Mitosis

This is a type of cell division where a cell divides to give rise to two daughter cells each having the same number of chromosomes as the parent cell.

The daughter cells are diploid (2n) i.e. They have 2 sets of chromosomes.

In man, mitosis occurs in;

- The bone marrow.
- The epidermal cells of the gut.

- The malpighian cells of the skin epidermis, etc.

In plants, it occurs in the apical meristems of the stem, root tip and the cambium. Mitosis occurs in the somatic cells. It takes place in four phases in between the resting phase (interphase) and the final separation phase (cytokinesis). They are:

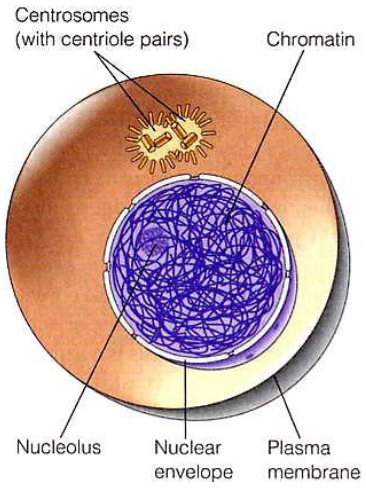
1. Interphase
2. Prophase
3. Metaphase
4. Anaphase
5. Telophase

Interphase:

This is the resting stage in between one cell division and the next. During this phase:

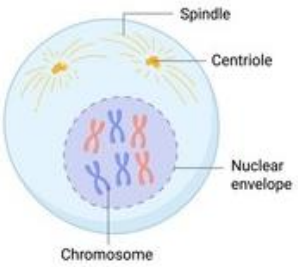
- Chromosomes appear as thin chromatin threads.
- The chromosomes, centrioles and mitochondria replicate.
- The cell manufactures and stores energy through respiration in preparation for cell division.

Interphase is followed by prophase.



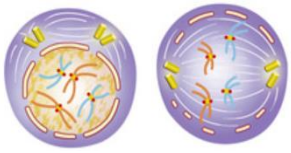
Prophase:

- The chromosomes thicken and shorten and thus become visible.
- Each chromosome appears to consist of two chromatids lying parallel to each other and attached at a point called the centromere.



- The centrioles migrate to opposite ends or poles of the cell. (Plant cells do not have centrioles).
- From each centriole, microtubules develop and form star-shaped asters. Some microtubules called spindle fibres also develop and originate from centrioles towards the center of the cell.

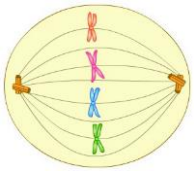
- The nucleolus disappears.
- The nuclear membrane dissolves and disappears towards the end of prophase, leaving the chromosomes within the cytoplasm of the cell.



Prophase is followed by metaphase.

Metaphase:

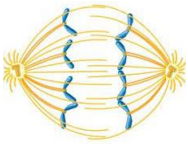
- Chromosomes move to the center of the cell and arrange themselves at the centre or spindle equator.
- Chromosomes become attached to the spindle fibers at the centromeres.



Metaphase is followed by anaphase.

Anaphase:

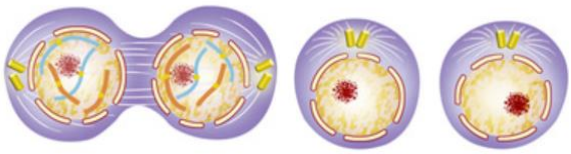
- Centromeres divide and the sister chromatids separate from each other.
- The spindle fibres shorten, pulling each sister chromatid to the opposite pole.



Anaphase is followed by telophase.

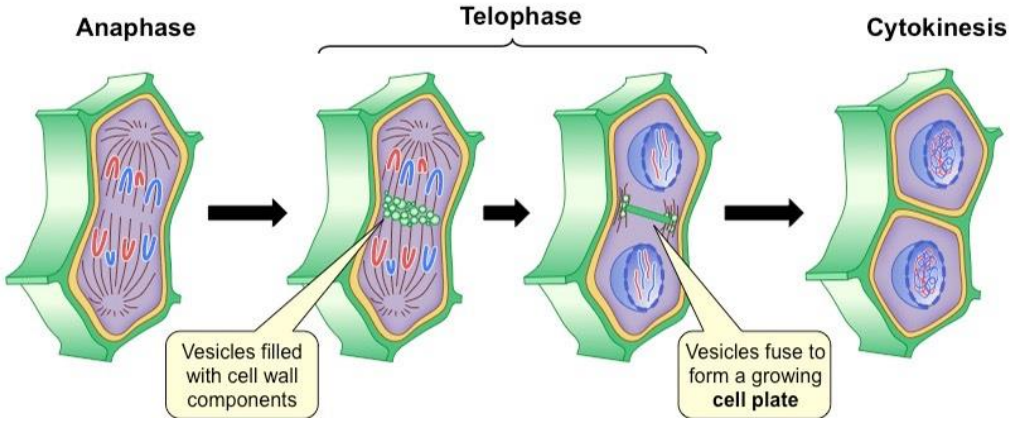
Telophase:

- The chromatids reach their respective poles and a nuclear envelope form around each group.
- The chromatids uncoil and lengthen, thus becoming invisible again.
- Spindle fibres disintegrate (break down) and the nucleolus reforms in each new nucleus.



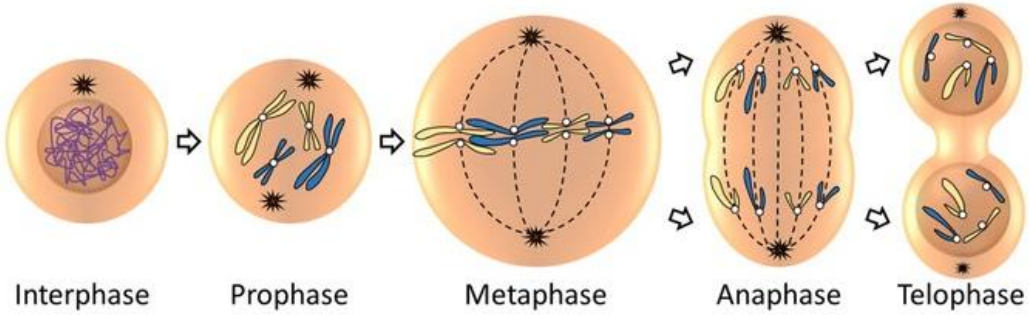
- **In the animal cell**, the cytoplasm constricts and finally divides the parent cell into two daughter cells. Each of the daughter cells has the same number of chromosomes as the parent.

- ***In a plant cell***, a cell plate is formed separating the cytoplasm of the two daughter cells along the equator of the spindle. The cell eventually fuses with the cell wall of the parent cell, dividing it into two daughter cells.



A summary of major events during mitosis

- Replication of DNA and cell organelles during interphase.
- Thickening of the chromosomes during prophase.
- Formation of the spindle fibres and disappearance of the nuclear membrane during prophase.
- Chromosomes align at the cell equator during metaphase.
- Sister chromatids are pulled to opposite poles and they become chromosomes during anaphase.
- Cells divide into two daughter cells during telophase.



Significance/importance of mitosis

- Growth due to an increase in the number of cells within an organism.
- Regeneration of body parts which have been cut off, for example the tail of a lizard regenerates when cut off by new tails cells being formed by mitosis, finger nails, and hair also regenerates by mitosis.
- Repair of worn out or damaged cells which must be replaced by the exact copies of the original cell.
- It is important in asexual reproduction where cells divide by mitosis to form spores or tissues that develop into a new individual.

- It maintains the genetic composition of the organism resulting from retention of the chromosomes similar to those of the parents.

Meiosis

Meiosis is **a type of cell division that reduces the number of chromosomes in the parent cell by half** and produces four gamete cells. This process is required to produce egg and sperm cells for sexual reproduction.

A cell divides into four haploid reproductive cells or gametes each with half the number of chromosomes as the parent cell.

Meiosis takes place in the ***testes*** and the ***ovaries*** of animals. In plants, it occurs in the ***anthers*** and ***ovaries***.

Meiosis occurs in two major phases, i.e.

Meiosis I (first meiotic division)

Meiosis II (second meiotic division)

Meiosis I

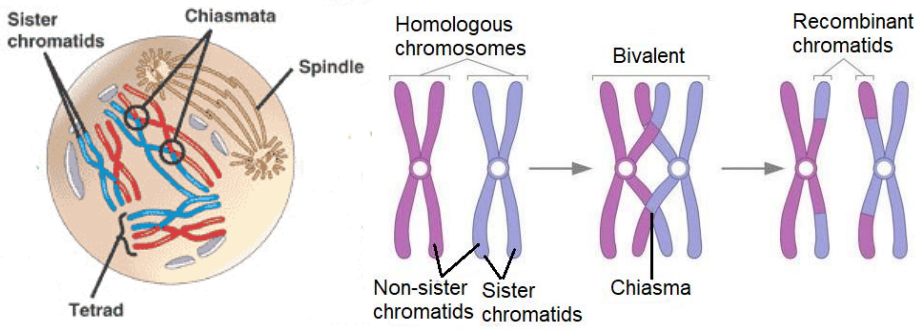
Meiosis I begin with interphase where the cell carries out several activities to prepare for division. These include;

- Replication of the genetic material.
- Replication of the centrioles and mitochondria.
- Large stores of energy built up.

Prophase I:

This is the longest stage in meiosis. During this stage;

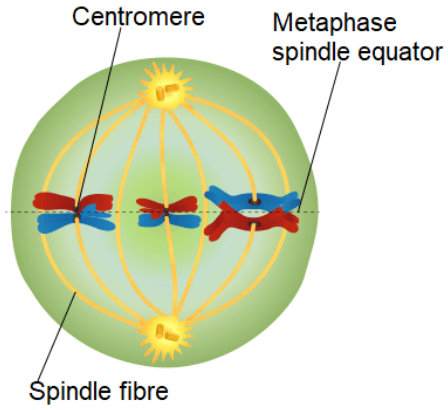
- Chromosomes become thicker and shorter, hence they become more visible.
- Where present, the centrioles migrate to opposite poles.
- Spindle formation starts.
- Homologous chromosomes lie side by side and pair up in a process called ***synapsis***.
- Non-sister chromatids of homologous chromosomes join at certain points called ***chiasmata*** (*singular*-***chiasma***) to form a ***bivalent*** and exchange portions in a process called ***crossing over***. Several chiasmata may be formed.



- The nucleolus disappears and the nuclear membrane breaks down.

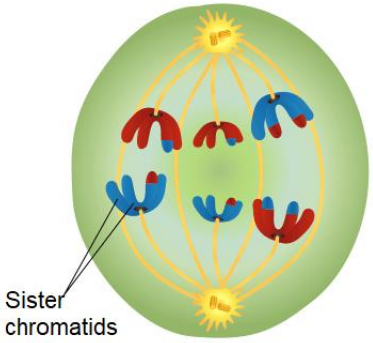
Metaphase I:

Spindle fibers attach at the centromere of each chromosome and align the bivalents to the spindle equator.



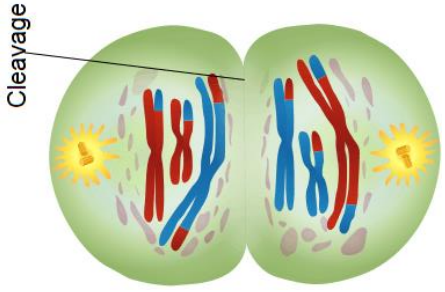
Anaphase I:

Spindle fibres contract and pull the homologous chromosomes apart. One of each pair is pulled to one pole, and its sister chromosome to the opposite pole.



Telophase I:

- Chromosomes arrive at the poles.
- The nuclear membrane forms around each group and the nucleolus reappears.
- The spindle fibres disappear and the chromatids uncoil.
- The cell may divide into two.



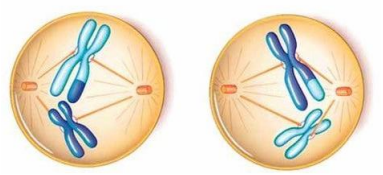
Note: *the first meiotic division results into separation of homologous chromosomes.*

Meiosis II

After meiosis I, in some organisms, telophase I is followed by interphase II although no replication of the DNA takes place, while in others telophase I and interphase II do not occur and anaphase I is followed by prophase II.

Prophase II

- The nucleoli and nuclear membrane disappear.
- New spindle fibres form.
- The chromatids condense and centrioles, if present, migrate to opposite poles.

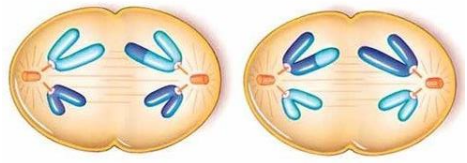


Metaphase II

Chromosomes arrange themselves on the equator of the new spindle with centromeres facing opposite poles and attach to the spindle fibres by their centromeres.

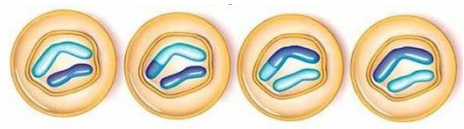
Anaphase II

Sister chromatids of every chromosome separate and begin to move towards the opposite ends of the cell.



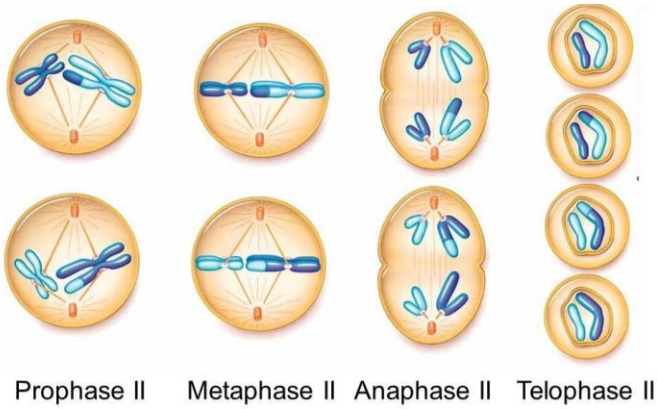
Telophase II

- The nuclear membrane and the nucleolus reform.
- The spindle disappears
- This is followed by cytokinesis, wherein each of the two cells produced from meiosis I will give rise to two daughter cells, resulting in a total of four genetically different *haploid cells*. The chromosomes de-condense and lengthen.
- Each haploid cell has half the number of chromosomes as the parent cell.

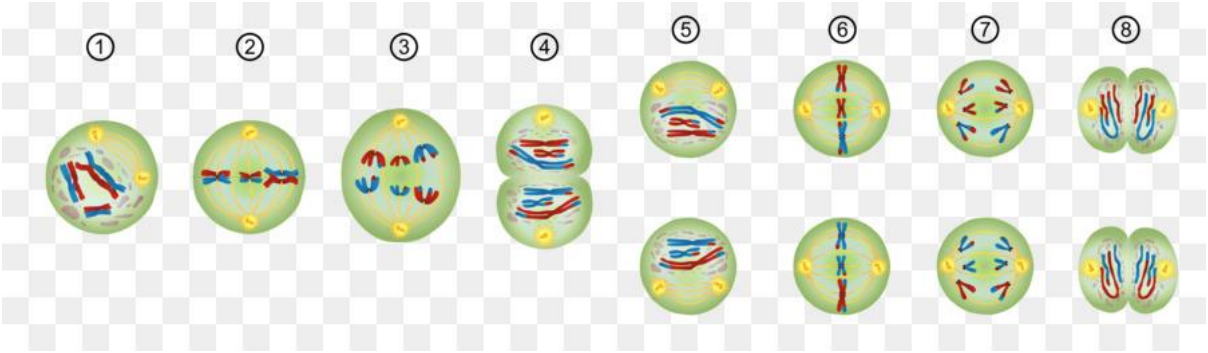


NOTE: The second meiotic division results into separation of sister chromatids

Meiosis II summary



Meiosis summary



Significance of meiosis

- Gamete formation.
- It halves the chromosome number to ensure that the total number is restored during fertilization.
- It introduces variations within cells through crossing over during prophase I.
- It results into rapid multiplication of cells since four are produced in a single division.
- Since it occurs in reproductive cells, it results into varied offspring during sexual reproduction. This provides a basis for natural selection, which ensures evolution of the species.

Comparison between mitosis and meiosis

Similarities

- Both result into formation of new cells from a parent cell.
- They both involve replication of chromosomes.
- They both involve similar stages e.g., Prophase, metaphase, anaphase, telophase and interphase.
- In both chromosomes arrange themselves at the spindle equator.
- In both spindle fibres are formed.
- Both begin with a diploid parent cell.

Differences

Mitosis	Meiosis
Occurs in somatic cells.	Occurs in reproductive cells.
Involves a single division of chromosomes and cytoplasm	Involves two divisions of chromosomes and cytoplasm.
Does not involve the process of synapsis	It involves synapsis
Crossing over does not occur	It involves crossing over between homologous chromatids.
Formation of bivalents does not occur.	There is formation of bivalents.
Two daughter cells are produced.	Four daughter cells are formed.
Diploid cells are formed.	Haploid cells are formed.
Daughter cells formed have the same number of chromosomes as the parent cell	Daughter cells formed have half the number of chromosomes compared to the parent cell
Does not involve formation of chiasmata.	It involves formation of chiasmata

Summary of terms used

Chromosome; this is a thread-like structure in the nucleus that carries the genes of an organism.

Chromatid; this is one half of a chromosome.

Sister chromatids; these are chromatids of the same chromosome.

Homologous chromatids; these are chromatids of different chromosomes in a bivalent.

Bivalent; this is a pair of homologous chromosomes.

Centromere; this is a structure of chromatid attachment and separation on a chromosome.

Chiasmata; this is a crossing over point between two homologous chromatids.

Haploid; this is where a cell has half the number of chromosomes compared to the parent cell.

Diploid; this is where a cell has a whole set of chromosomes.

Replication; this is where a structure/organelle produces an exact copy of itself.

GENETICS

Genetics is the scientific study of heredity and variations between organisms while inheritance describes how the similarities are transferred from the parent to the offspring. The similarities are in form of characteristics such as skin colour, intelligence, height and many others. Mendel was the first scientist to study genetics and inheritance.

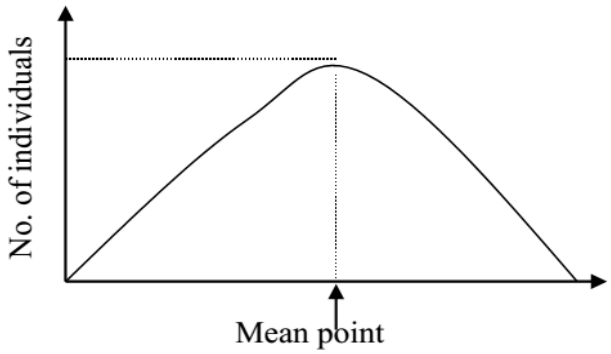
Categories of variation

There are two types of genetic variations.

1. Continuous variations.

These are variations that show a gradual change in individuals without a clear-cut division between the two extremes. It results into formation of intermediates. Such variations include height, intelligence, skin colour, yield in plants, etc. In such variations, organisms are usually very many around the mean/average point.

Graphic illustration of continuous variation



2. Discontinuous variation.

This is a variation, which shows a clear-cut difference between the two extremes without intermediates. This results into expression of only two phenotypes. Examples of discontinuous variations include, tongue rolling, blood groups, sex, etc.

Causes of variation

Some variations are inherited and are called inherited variations while others are occupied as a result of the environment hence called environmental variations.

Examples of inherited variations are blood groups, eye colour, albinism, hair, etc.

Examples of environmental variations are knowledge, etc.

Environmental factors that cause variations

- ✓ Diet
- ✓ Pathogens
- ✓ Altitude
- ✓ Light

Factors that cause inherited variations

- ✓ Mutation
- ✓ Crossing over
- ✓ Fertilization

Terms used in genetics.

Chromosome: These are thread-like structures bearing genes and located in the nucleus.

Chromatid: This is half of a chromosome split longitudinally.

Bivalent: This is a pair of homologous chromosomes.

Gene: This is a unit of the hereditable material found on the chromosome and responsible for controlling a particular trait/character.

Allele: This is the alternative form of the same gene. Most genes are made up of two alleles. Alleles of the same gene are represented by the same letter but the dominant allele is represented by a capital letter and the recessive allele by a small letter in the case of dominant-recessive characters.

Diploid: This is a description of a cell, which has a whole set of chromosomes.

Haploid: This refers to a cell with half the set of chromosomes.

Genotype: This refers to the genetic composition of an organism.

Phenotype: This is the physical appearance or the outward expression of an individual.

Dominant gene/dominant allele: This is a description of a gene /allele whose effect is seen in the phenotype of the heterozygous individual. The effect of the dominant gene/allele is seen in the phenotype even in the presence of another gene/allele.

Recessive: This is a description of a gene whose effect is not phenotypically expressed in the heterozygous state. The effect of a recessive gene/allele is not seen in the presence of another (dominant) gene/allele.

Homozygous: This refers to a gene with two identical alleles for example if T represents the gene for height where tallness is dominant to shortness then the allele for tallness is T and that for shortness is t. an individual with TT is said to be homozygous tall and tt is said to be homozygous short.

Homozygous dominant: This is where both alleles of a gene determine a dominant character.

Homozygous recessive: This is where both alleles of a gene determine a recessive character.

Heterozygous: This refers to a gene with two different alleles for example if T represents the allele for tallness and t for shortness then Tt is the heterozygous state of this gene.

Hybrid: This is an offspring produced by parents of two different pure lines.

Incomplete dominance: This is a condition where neither of the genes is dominant over the other.

Gametes: These are reproductive cells.

Fertilization: This is the fusion of the male and female gametes to form a zygote.

Monohybrid inheritance: This is a type of inheritance, which involves studying a single pair of contrasting characteristics.

Dihybrid inheritance: This is a type of inheritance, which involves studying two pairs of contrasting characteristics at ago.

Test cross: This is a type of back cross which involves crossing an offspring having a dominant character with its recessive parent in order to determine the test of that offspring.

Back cross: This is the mating of an offspring with one of its parents.

Mendel's experiment

For his experiment he collected one of the varieties of garden peas (*Pisum sativum*) with contrasting features such as one variety was producing tall plants when stems are about 200cm and another short plant with stems of 25cm. He crossed these plants for his experiments.

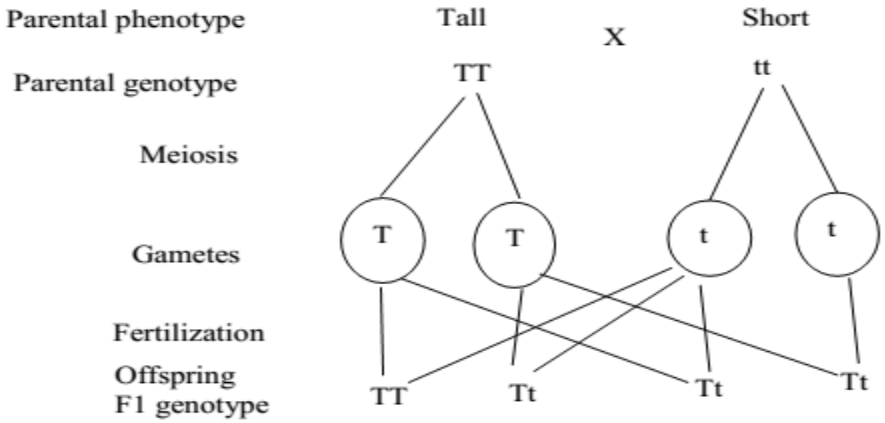
He crossed pure tall pea plants with pure short pea plants and all the off springs were tall (F1 generation)

Tallness was the dominant character and shortness the recessive character.

The dominant character is represented using a capital letter while the recessive character is represented using a small letter.

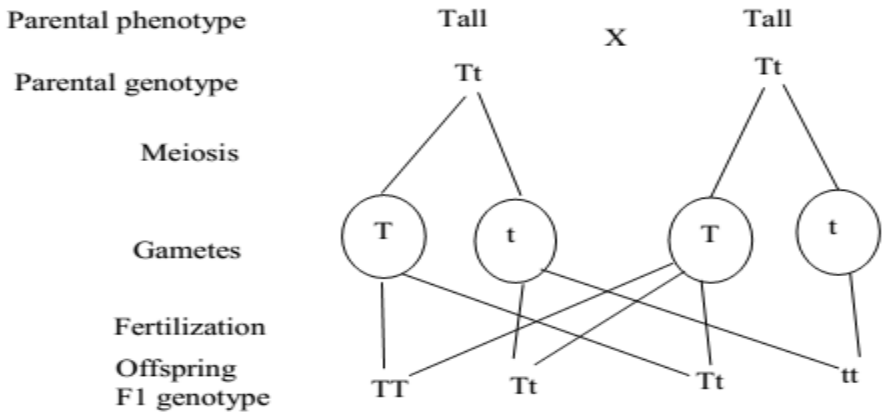
Let T represent the gene for tallness

Let t represent the gene for shortness



Offspring phenotype: All tall

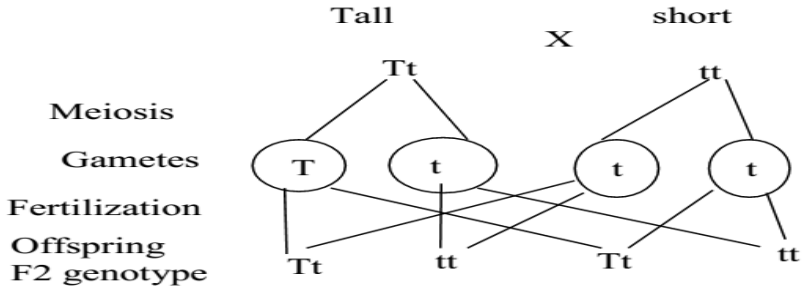
Mendel then selfed the plants of the F1 generation and obtained an F2 generation with tall and short plants in a ratio of 3:1



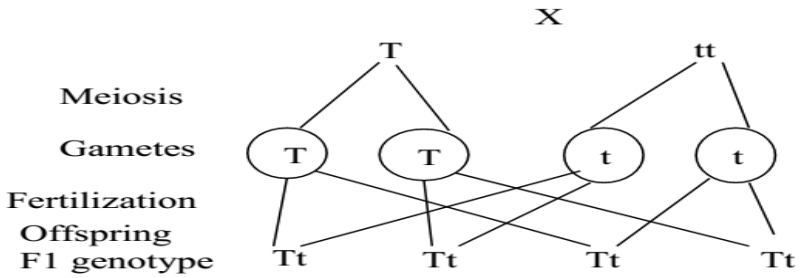
Genotypic ratio; TT: Tt: tt = 1:2:1
Phenotypic ratio; 3 tall: 1 short

Test cross

A test cross is used to distinguish between homozygous and heterozygous dominant forms. This is when an F1 individual with the phenotype of the dominant parent is crossed with the recessive parent to determine the phenotype of the parent. If the F1 is homozygous dominant, all the off springs will show the dominant character.
If the F1 individuals are heterozygous, a 1:1 ratio of dominant or recessive characters is obtained. E.g.
Let T represent the allele for tallness
Let t represent the allele for shortness



Two off springs will be heterozygous tall and 2 will be homozygous short.



All are heterozygous tall

Mendel's conclusions

1. Gametes like pollen grains and ovules of garden peas carry characters determining factors through which resemblance is passed on from one generation to the next.

2. A character like height of the garden pea is controlled by a pair of genes. These separate during formation of gametes and only one goes into each gamete. This means that only half of the usual number of genes is present in the gametes. However, the normal number is restored at fertilization by the fusion of the two gametes
3. He named a gene determining a dominant character as a dominant gene and one determining a recessive character as a recessive gene. In his representation dominant genes were given capital letters and recessive genes were given small letters.

Mendel's laws of inheritance

From his observations, Mendel put up two laws of inheritance.

First law: The law of segregation.

This law states that the character of an organism is determined by a pair of alleles. Only one allele of such a pair is carried in a gamete.

Second law: The law of independent assortment.

This states that each of the alleles in a pair may combine with another allele from another pair randomly.

Conclusions from Mendel's' crosses.

1. A character can be transmitted from parent to offspring independent of other characters.
2. Genes occur as a pair of alleles.
3. Only one allele of the same gene is carried in a single gamete.

Monohybrid inheritance

Inheritance is the passing over of characteristics of the parents to their off springs. Monohybrid inheritance involves the study of how one character is inherited from the parents to the off springs. Mendel carried out several experiments on peas to study monohybrid inheritance.

Mendel chose garden peas for his experiments because of the following reasons:

1. They grow very fast and produce results in a very short period of time.
2. They are relatively small and can be grown on a small plot for study purposes.
3. Some of their characters are controlled by single genes, which make it easy to study them.
4. They have characteristics, which show clear-cut differences without intermediates like tall and short, green and yellow cotyledons, etc.

He therefore concluded that their reproduction can be manipulated by pollination.

Examples:

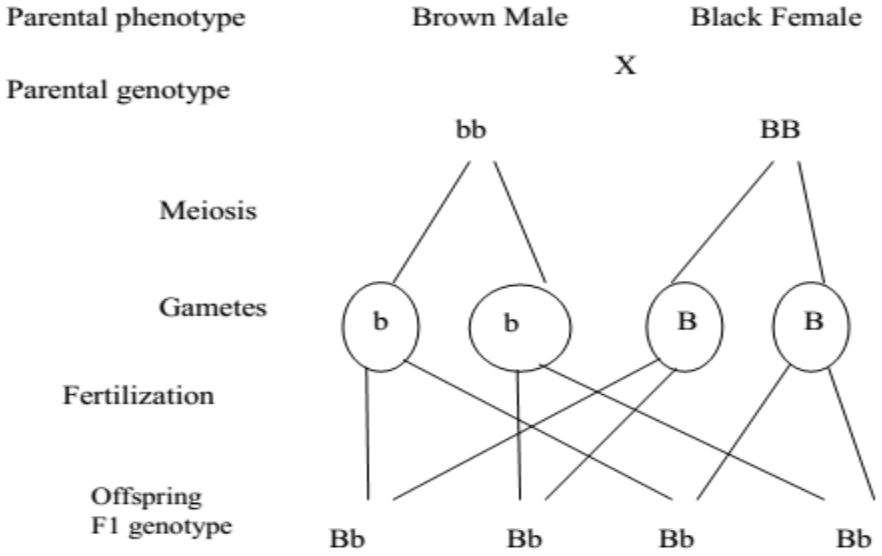
1. What would be the offsprings for a cross between homozygous black and homozygous brown. Take B for black and b for brown.

Let B represent the allele for black fur.

Let b represent the allele for black fur.

Note.

1. It is one gene controlling a character, which is fur colour. For this reason, we use the same letter
2. Black colour is dominant that is why we use (B) and brown is recessive (b)
3. The term pure-breeding is used to mean homozygous for that particular gene.

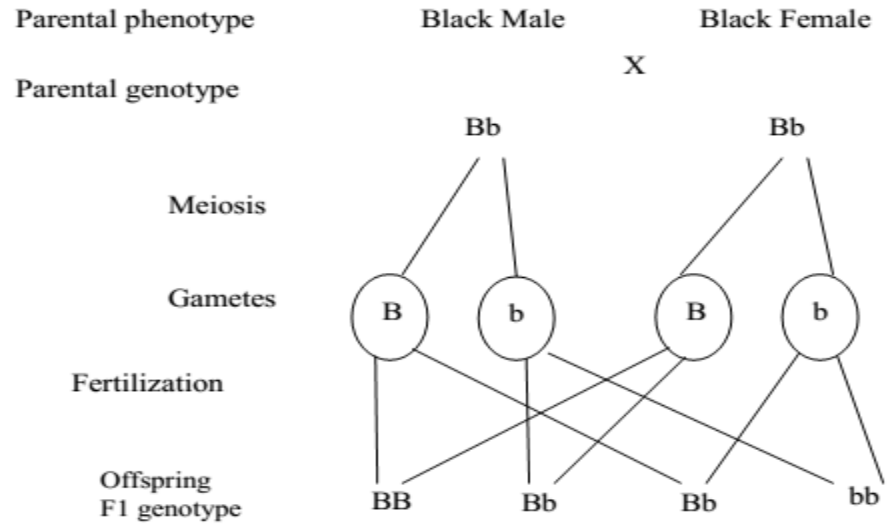


Offspring genotype: all Bb (heterozygous)

Offspring phenotype: all black.

They are all black because black is dominant to brown and it shows up in the heterozygous state.

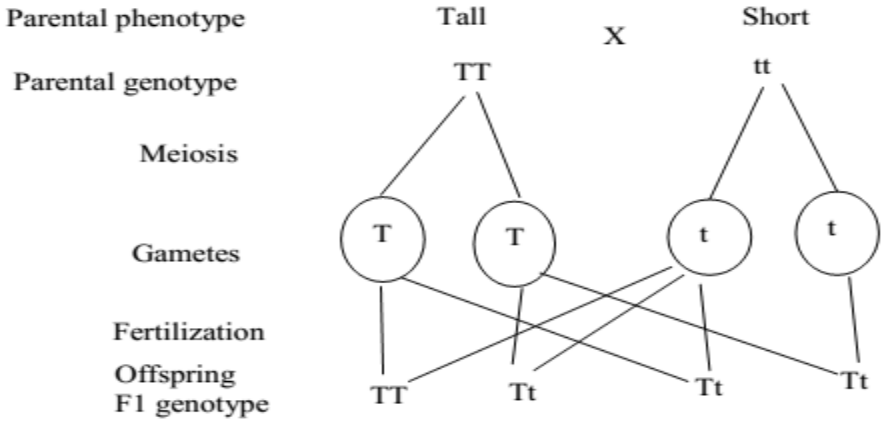
Consider Selfing of F1 (crossing two offsprings of F1 above).



F2 phenotypic ratio. 3 black: 1 brown

3:1

2. Consider a gene for height in garden peas. Tallness is dominant over shortness. *Let the gene for tallness be represented by T and that for shortness t*. Show the cross between pure-breeding tall pea and a pure-breeding short pea.



F1 phenotype: All offsprings are tall.

Selfing of F1 produces F2 with a phenotypic ratio of 3 tall to 1 brown. (3:1)

3. The fruit fly (drosophila melangaster) usually has wings twice as long as its abdomen but some drosophilae have very short or vestigial wings. A long-winged drosophila (male) was crossed with a vestigial winged female drosophila and all the F1 off springs were long winged. The long winged F1 generation were then mated.
   i) How can the cross be represented diagrammatically
   ii) State the phenotypes of the off springs in the F2 generation and state their genotypic ratio.

iii) What is the percentage of the vestigial winged drosophila flies in the F2 generation?

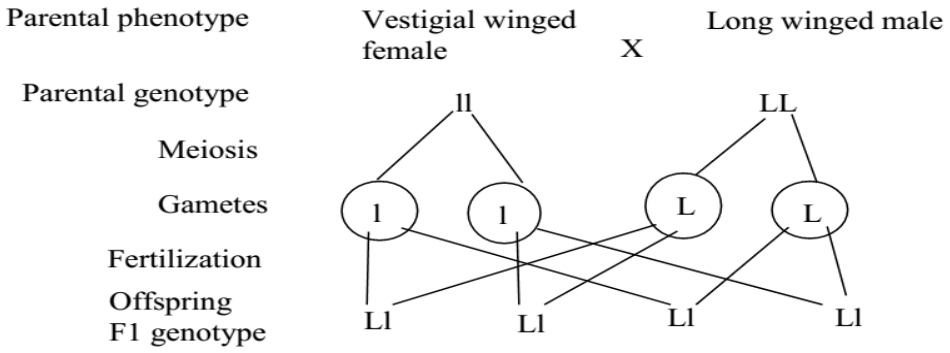
iv) A drosophila is normally used in experiments on heredity, why do you think it is suitable for such experiments.

Solution:

Let L represent the allele for long wing and l represent the allele for vestigial wing l

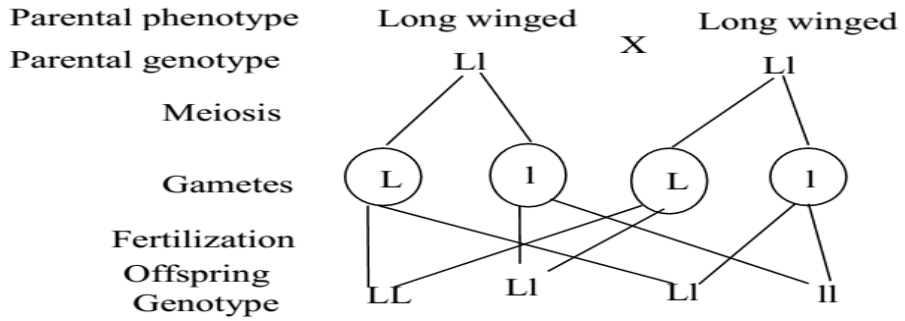
The long winged female can be LL or Ll because long winged is dominant to short winged.

i)



F1 phenotype. All long winged.

ii)



One of the off springs will be homozygous long winged

Two of them will be heterozygous long winged

One of them will be homozygous short winged or vestigial winged

Genotypic ratio; 1:2:1

iii) ¼ x100=25%

iv) It's because they:

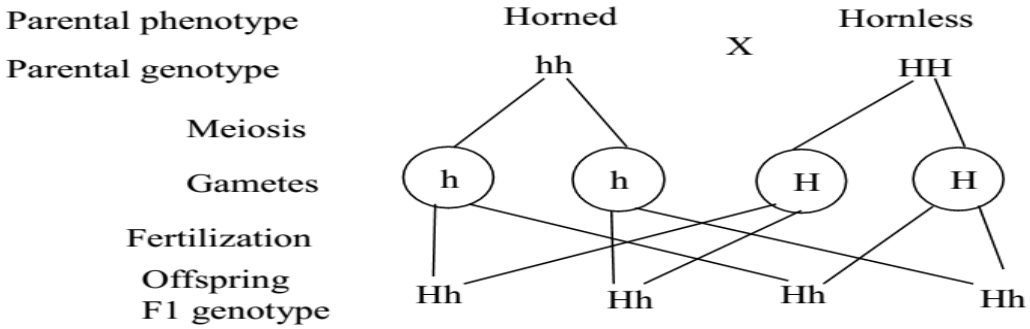
- Have contrasting characters
- Have short life span
- Show clear cut differences.

4. In cattle, the gene for hornless condition is dominant over one for horns. A pure hornless cow was mated with a horned bull. Using genetic symbols, show the possible phenotype and genotype of the F1 offspring.

Solution:

Let h represent the allele for horned condition.

Let H represent the allele for hornless condition



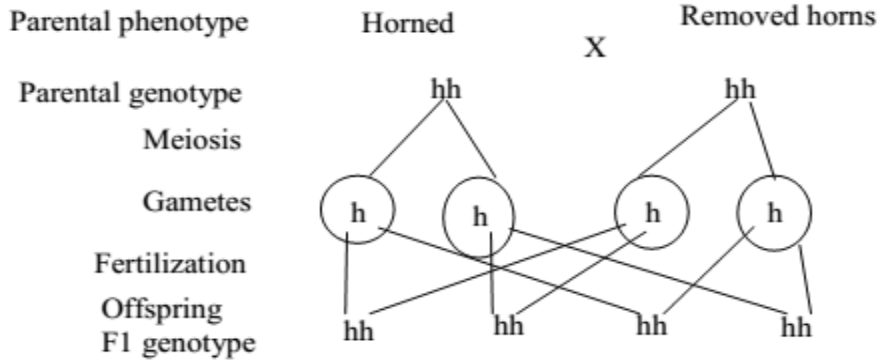
All were horned cows.

5. A bull whose horns were removed was mated to a horned cow. Show the possible genotypes and phenotypes of the F1 off springs. Give a reason for your answer.

Solution:

Let h represent the allele for horned condition.

Let H represent the allele for hornless condition



All are horned

Note: cutting the horns doesn't change the genetic make-up (genotype) of the horned bull. Genetic composition of an organism is permanent and can't be manipulated.

Assignment:

In peas, yellow seed colour is dominant over green seed color. What would be the phenotype of the offspring if a true breeding yellow-seeded plant is crossed with a green-seeded plant?

Monohybrid inheritance in human beings

1. Albinism

This is a condition in human beings where the individual fail to produce skin pigments called melanin.

Albinos have;

- ✓ Light skin
- ✓ White hair
- ✓ Pink eyes
- ✓ They are sensitive to bright light

Albinism is caused by a recessive gene.

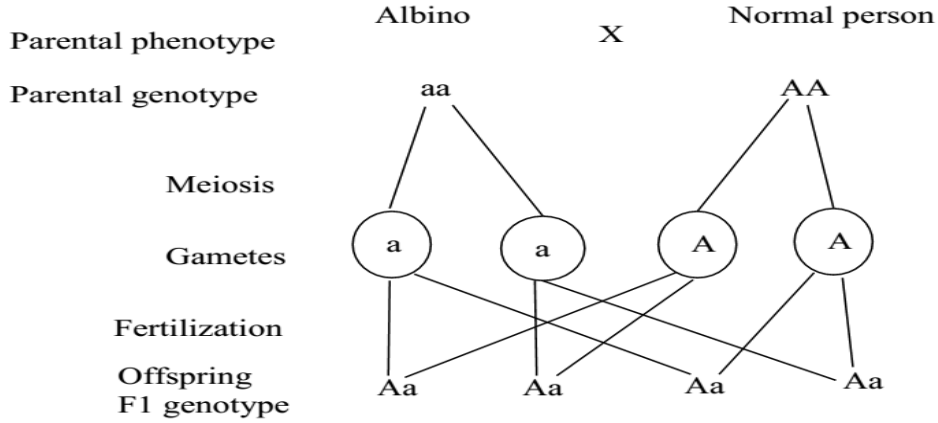
Examples

1. What would be the off springs if an albino marries a normal person?

Let A represent the allele for normal skin colour

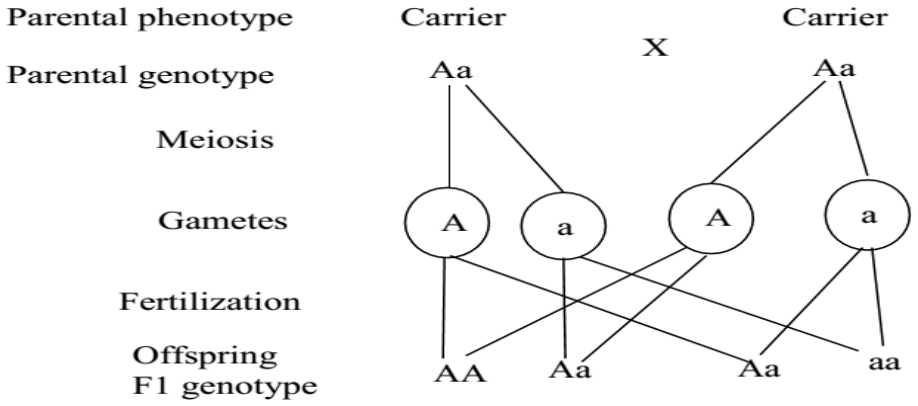
Let a represent the allele for no skin colour.

Genotype	Phenotype
AA	Normal skin colour
Aa	Carrier for albinism
aa	albino



All the off springs will be carriers of albinism

2. What would be the off springs when 2 individuals who are carriers of albinism get married?



Genotypic ratio; 1 normal: 2 carrier: 1 albino

1:2:1

Phenotypic ratio; 3:1

2. Sickle cell anaemia

It is due to a mutation of a gene. A person suffering from sickle cell anaemia has a defective type of haemoglobin. ***It is caused by a recessive gene.***

When the concentration of oxygen is low in blood, the red blood cells assume the shape of a sickle. Because of this, the red blood cells cannot absorb oxygen properly.

This is a hereditary disease and can be passed on to the children by the parents in their gametes. Sickle cell anaemia has a fatal effect on people who are homozygous for this mutated gene.

People who are heterozygous i.e. they have mutated and non-mutated genes have normal red blood cells.

Example:

Let B represent the allele for normal RBC

Let b represent the allele for sickle shaped RBC

Genotype	Phenotype
BB	Normal RBC
Bb	Normal but carrier
bb	Sickle shaped RBC

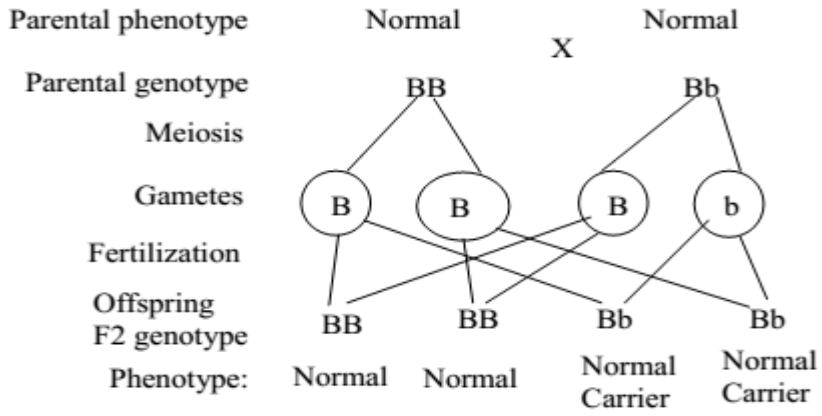
Question:

A normal male married a carrier female for sickle cell anaemia. Determine the phenotype and genotype of the children.

Solution:

Let B represent the allele for normal RBC

Let b represent the allele for sickle cell



Assignment:

A normal male whose mother had sickle cell anaemia married a carrier female. What percentage of their children had sickle cell anaemia?

Sex determination in human beings

There are 23 pairs of chromosomes in each cell of the human body. One pair determines the sex of the individual and they are called sex chromosomes.

There are two sexes, i.e. male and female. The gene controlling sex is carried in the reproductive cells on the sex chromosomes. There are two sex chromosomes the X chromosome and the Y chromosome. These chromosomes occur in a pair to determine the sex of an individual. Each gamete carries one of the sex chromosomes.

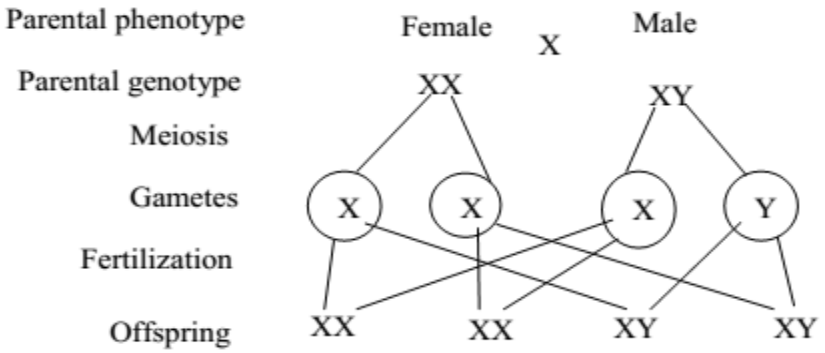
In males some of the sperms contain the X chromosome while some contain the Y chromosome. Y only occurs in males.

In females all the eggs contain the X chromosome.

At fertilization, a sperm fuses with the egg. If the X sperm fuses with an egg (X), the resulting offspring is XX and is a female. If a Y sperm fuses with an egg (X), the resulting individual is XY and is a male. Therefore, the male determines the sex of the offspring. This is because the male produces two different sperms (X and Y) while the female produces only eggs with X chromosomes.

Note: The Y sperms are more active and persistent than the X sperms. This increases the chances of an ovum to be fertilized by a Y sperm. So, to every 100 girls, 120 boys are born but more boys than girls die at the time of birth.

Illustration:



Phenotypic ratio; 2 boys: 2 girls

Sex linked traits/characters

These are traits or genes associated with the sex of the individual. These characters are carried on the sex chromosomes and are controlled or determined by the genes on those chromosomes. Such characters appear in a recessive form hence are very common in males than in females. Such characters include;

- ✓ Colour blindness
- ✓ Haemophilia (bleeder disease)
- ✓ Etc.

Inheritance of colour blindness

Colour blindness is a defect of the eyes caused by a recessive gene on the X chromosome.

Example

Let B represent the allele for normal colour vision

Let b represent the allele for colour blindness

Genotype	Phenotype
X^BX^B	Normal female
X^BX^b	Carrier female
X^bX^b	Colour blind female
X^BY	Normal male
X^bY	Colour blind male

***Question*:**

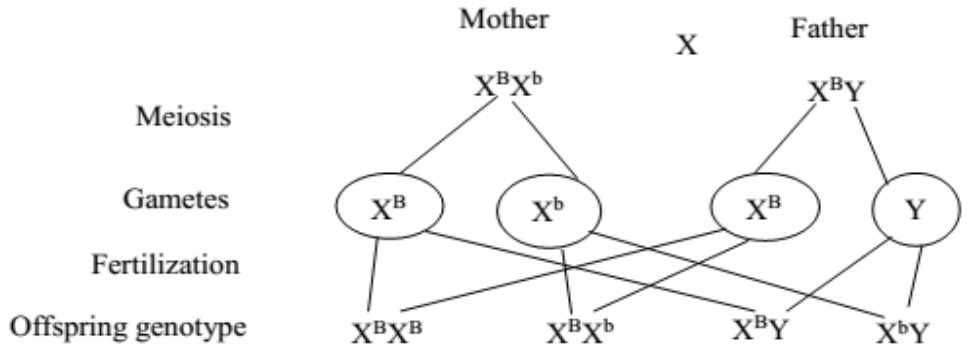
i) What would be the off springs when a carrier female for colour blindness marries a male with normal colour vision?

ii) Write the genotypic ratio of the off springs and make a comment of their condition.

Solution:

Let B represent the allele for normal colour vision

Let b represent the allele for colour blindness.



Genotypic ratio 2:1:1

2 will be normal girls (females)

1 will be normal boy (male)

1 will be carrier girl (female)

1 will be colour blind boy (male)

Assignment:

What would be the offspring if a colour blind woman marries a normal man?

Inheritance of haemophilia (bleeder disease)

It is a disease in which blood takes a long time to clot at a wound. It is also known as the bleeder's disease. This disease is caused by a recessive gene which is carried on the X chromosome.

Let H represent the allele for normal blood clotting

Let b represent the allele for haemophilia

Genotype	Phenotype
X^HX^H	Normal female
X^HX^h	Carrier female
X^hX^h	Haemophiliac female
X^HY	Normal male
X^hY	Haemophiliac male

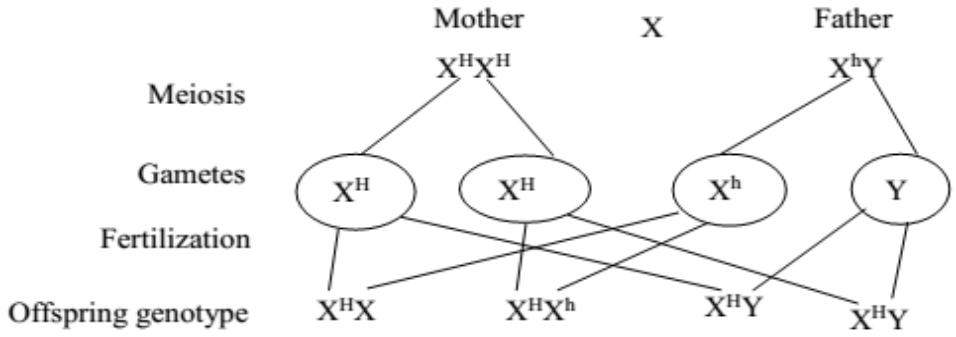
Question:

What would be the off springs if a normal woman marries a haemophiliac man?

Solution:

Let H represent the allele for normal blood clotting

Let h represent the allele for haemophilia



2 carrier females: 2 normal males

Sex limited traits

These are characteristics that only show in one sex e.g. secondary sexual characteristics, hairy pinna, etc.

Exceptions to mendelian inheritance

The following do not conform to the process of inheritance as illustrated by Mendel.

1. Linkage
2. Incomplete dominance.
3. Co-dominance
4. Multiple alleles.

Co-dominance

This is a condition where genes determining a particular character all show up such that the phenotype of the offspring is a mixture of that of the parents. All the characters of either parent appear in the offspring, e.g. black and white gives white and black spots in the offspring***. It mainly occurs in animals.***

Co-dominance is where in the heterozygous state neither allele is completely dominant over the other i.e. the 2 alleles are co-dominant. This results in the phenotype intermediate between the parent's appearances. The alleles for each trait are represented with different capital letters.

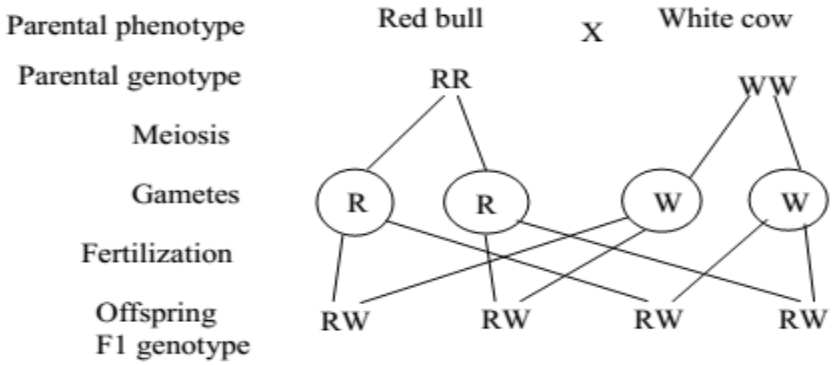
Examples*:*

1) In animals, the genes for fur colour are co-dominant. What will be the offsprings when a red bull is crossed with a white cow?

Solution:

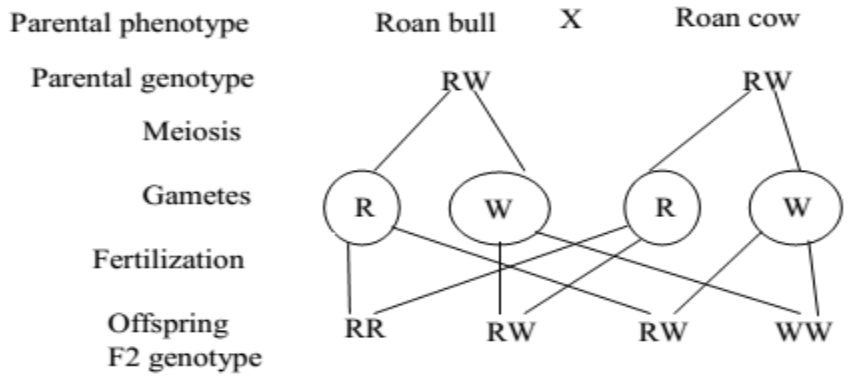
Let R represent the allele for red bull

Let W represent the allele for white cow



F1 phenotype: all the off springs will be roan.

2) What would be the off springs in the 2nd generation?



F2 phenotype: 1 red, 2 roan and 1 white.

Incomplete dominance

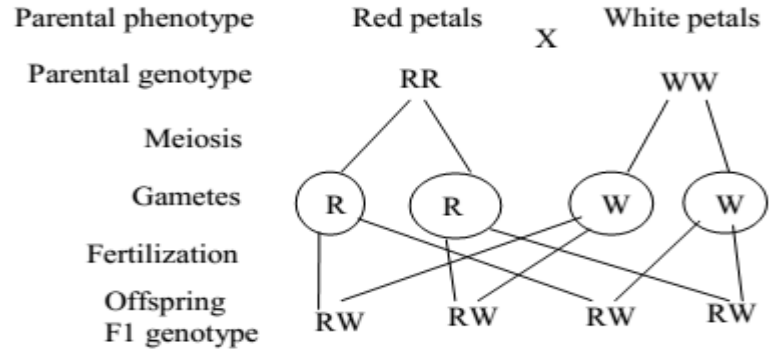
This is a condition in the heterozygous where neither of the alleles is dominant over the other and the phenotype of the offspring is an intermediate between that of the parents. An intermediate of the parents' phenotype results, e.g. black and white gives grey. ***It mainly occurs in plants.***

For example, consider petal colour in flowers: when a red flowered plant is crossed with a white flowered plant, the offsprings produced are all pink coloured petal flowers.

Example:

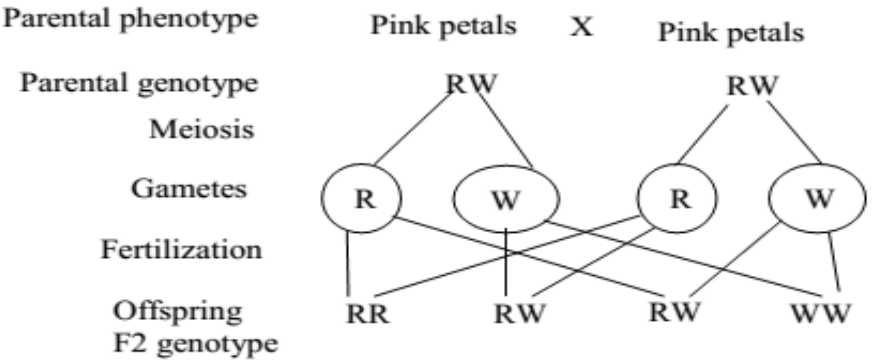
Let R represent the allele for red petal colour.

Let W represent the allele for white flowers



F1 phenotype: all pink petals.

Then Selfing F1. (Cross between offspring in F1)



F2 phenotype: 1 red, 2 pink and 1 white.
F2 Phenotypic ratio: 1 red: 2 pink: 1 white. (1:2:1)

Multiple alleles

This is where one character is determined by more than two alleles. This implies that a single gene contains more than two alleles. An example is blood group inheritance. The gene controlling blood groups is made up of three different alleles (multiple alleles). These alleles are A, B and O. The inheritance of blood groups is also an example of co-dominance. There are 4 blood groups that is group A, B, AB and O. An individual inherits two of these alleles one from each parent. The table below shows the possible blood groups that can arise from the different genotypes.

Genotype (alleles)	Blood group (phenotype)
AA	A
OA	A
BB	B
OB	B
AB	AB
OO	O

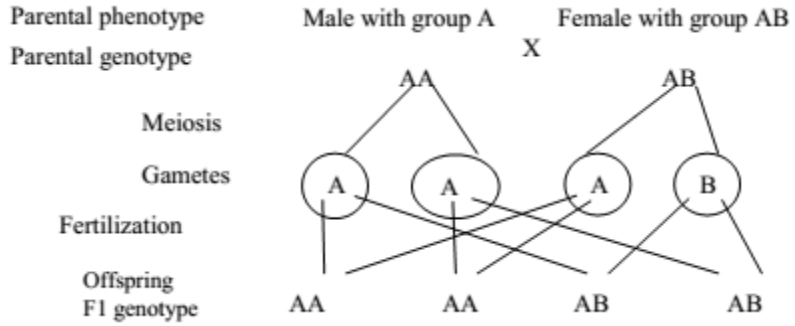
Example:

Work out the possible blood groups of the off springs produced if a man of blood group A marries a woman of blood group AB

Solution*:*

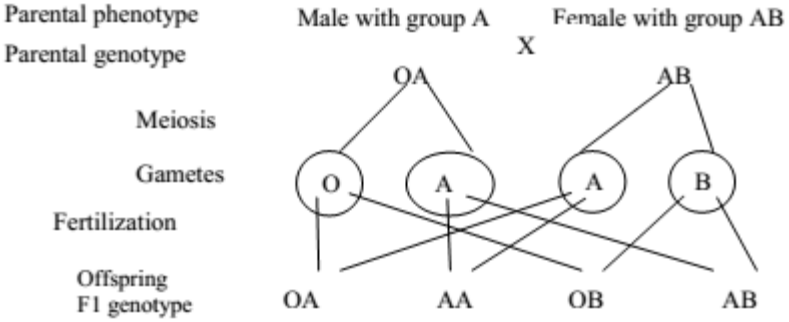
The man can have two possible genotypes, i.e. OA and AA. This is because allele A is dominant to allele O.

Considering the case where the man is AA



Offspring phenotype: 2 blood group A and 2 blood group AB

Considering the case where the man is OA



Offspring phenotype. 2 have blood group A, 1 has blood group AB and 1 has blood group B

Assignment one:

a) What is meant by genotype? (01 mark)

b) A man of blood group A, married a woman homozygous for blood group B and they produced a son of blood group B.

   i) Work out the genotypes of the father and of the son. (04 marks)

   ii) The son married a wife of blood group O. Show your working and give the percentages of the possible phenotypes of their offspring. (03 marks)

c) Blood groups in humans show discontinuous variation. Explain what you understand by this statement. (02 marks)

Assignment two:

a) i) Give any four differences between mitosis and meiosis. (4 marks)
   ii) Give the parts where meiosis occurs in plants and animals respectively. (2 marks)
b) What is the relevance of meiosis? (2 marks)
c) When a white-haired male fox was mated with a black-haired female fox, both pure breeding, all off springs were grey.
   i) Explain why the offsprings were grey in colour? (1 mark)
   ii) Using genetic diagrams, show how the F1 offsprings were produced; and F2 offsprings if two of the F1 foxes were allowed to interbreed. (6 marks)

Application of genetics

- The study of genetics encourages breeding of animals with good characteristics to improve livestock.
- It helps to eliminate or reduce harmful characteristics through the study of genetics.
- Through genetic counseling and advice individuals may be advised on the possibility of their off springs.
- It helps in prediction of offspring from two mating individuals and solves problems like fraternal uncertainty.

Mutation

This is a sudden/spontaneous change in the structure and composition of a gene or chromosome.

Types of mutation

i) Chromosome mutation: this is a sudden change in the number or structure of a chromosome.
ii) Gene mutation: This is a sudden change in the chemical nature of a gene. Examples of gene mutation are albinism and sickle cell anemia.

Types of chromosome mutation

i) Deletion: This is when a piece of chromosome is broken off and lost therefore the chromosome becomes shorter than the original one.
ii) Inversion: A piece of the chromosome breaks and joins on a different side of the same chromosome.
iii) Duplication: A chromosome gains a piece from another chromosome of the same type and becomes longer.
iv) Translocation: A piece of chromosome breaks and joins to another chromosome of different type.

Examples of chromosome mutation in man

i) **Turner's syndrome:** the individual has one X chromosome. This gives rise to a sterile abnormal short female and it is due to loss of one sex chromosome.
ii) **Down's syndrome (mongolism):** this is due to the increase in the number of chromosomes. The individual is mentally retarded with weak muscles, a big or large head, a broad chest, stunted growth and dropped eyes.
iii) **Clinefelter's syndrome:** this is due to an additional X chromosome in an individual. This results in a sterile male who may be mentally retarded.

Causes of mutations.

Mutations are caused by substances generally referred to as **mutagens**. These include;

i) High temperatures.
ii) Chemicals such as mustard gas, colchine and caffeine.
iii) High-energy particles such as alpha and beta particles.
iv) High-energy radiations such as x-rays, gamma rays and ultra violet radiations.

Note; most mutations are disadvantageous and recessive. They are rare but persistent in the population.

Evolution

Evolution is the process by which more complex forms of organisms arise from simpler forms over a long period of time.

This is a gradual process by which organisms change from simple to complex forms over a period of time.

But how then did the first primitive organisms arise and from where? To answer the question, many biologists have tried to put up theories to explain the origin of life.

Theories of origin of life

The origin of life is not exactly known. However, some theories have been put forward to explain the origin of life. These are:

1. **Special creation theory:** All living things were created by God.
2. **Steady state theory:** It suggests that life has no origin and it has been in existence.
3. **Spontaneous generation theory:** It suggests that life arose from non-living matter.
4. **Cosmozoan theory:** It suggests that life arose from another planet of the universe and arrived on earth by some means.
5. **Biochemical evolution theory:**

It suggests that inorganic molecules i.e. DNA and chromosomes and other protein molecules were organized into a basic unit of life called a cell.

It is the most accepted theory of the origin of life. The simple life (cell) gradually underwent numerous changes along different lines to form the present diversity of complex organisms.
This confirms that all the present organisms despite of their differences arose from the same ancestors, a process called ***evolution.***

Natural selection

This is the process by which organisms that are better adapted to the environment survive to reproduce while those less adapted fail to do so and become extinct.
This is a process by which nature selects for the best adapted organisms and selects against the less adapted ones.
When the environment changes, it affects organisms and those, which possess characters that enable them to survive in the changing environment survive while those less adapted, die over a long period of time. This occurs because organisms possess variations (differences between them).
The survival of the best adapted and removal of the less adapted is known as ***survival for the fittest.***
This theory was stated by Charles Darwin.
Darwin suggested that there must be a struggle for existence where by the fit individuals (better adapted) survive and the unfit ones die (survival for the fittest). Over a very long period of time these organisms can change into a different species.

Evidence of evolution

There are several evidences put forward to support the theory of evolution. These include;

- Comparative anatomy
- Comparative embryology
- Paleontology
- Taxonomy
- Comparative biochemistry
- Geographical distribution of organisms

1. Paleontology

This is the study of fossils. Fossils are remains of organisms that lived in the past and were preserved in rocks. Fossil studies show that organisms that lived in the past had some resemblance to the present-day organisms. This shows that they had a common ancestry. The differences between them shows that evolution has occurred in the present-day organisms.

2. Comparative embryology.

The study of the development of the zygote shows that organisms had a common ancestor. In all vertebrates for example the zygote develops a tail in the early stages and it is surrounded by membranes (amnion and allantois).

3. Cell biology.

The study of cells shows similarities between organisms. For example, all cells of multicellular organisms have a nucleus, mitochondria and other organelles. This shows that the organisms had a common ancestry. The differences e.g. chloroplasts in plant cells shows that evolution took place

4. Comparative anatomy.

When anatomical structures of organisms are studied, they show similarities and differences. Similarities indicate that the organisms had a common ancestor while the differences show that they have evolved. For example, all vertebrates have a pentadactyl limb but the limb has been modified in the different vertebrates and it performs different functions.

Homologous structures: These are structures from the common ancestral origin that serve different functions e.g. the pentadactyl limb composed of five digits like in the horse for running, monkeys for grasping, human beings for handling and bats for flying. This type of evolution is called ***divergent evolution*** which is the type of evolution where by organisms with common ancestors have developed structures that perform different functions because of change in the environment they live in.

When structures are further compared, it is observed that some of them differ but serve the same functions. Such structures are known as ***analogous structures.***

Thus, ***analogous structures are structures from different ancestral origin but serve the same functions***. Such evolution is called convergent evolution which is a type of evolution where by different organs with different ancestral origins perform the same function. This is because of the similar environments they live in e.g. wings of birds and wings of insects.

5. Comparative biochemistry.

The study of chemical composition and functioning between living organisms shows that they have a common ancestor for example all organisms have DNA, they have enzymes made out of protein, etc.

6. Geographical distribution:

Distribution of plants and animals in different parts of the world indicates evolution. i.e. different environment look different. However, some organisms in different geographical location are similar meaning that they had a common ancestor.

REPRODUCTION

Reproduction is the process by which organisms multiply to increase in number. This is important in maintaining the life of organisms from one generation to another.

Types of reproduction

There are two types of reproduction i.e., asexual reproduction and sexual reproduction.

Asexual reproduction

This is a type of reproduction, which does not involve fusion of gametes, and therefore only one individual is involved. This type of reproduction takes several forms, which include the following.

a) Budding.

This is a mode of asexual reproduction in which an organism develops an outgrowth (bud), which detaches its self from the parent organism and starts to grow as a self-reliant organism. It is common in yeast and hydra.

b) Spore formation

This is a mode of asexual reproduction, which involves production of spores. Spores are microscopic structures, which can be dispersed and have the ability to germinate into a new organism under favorable conditions. This mode of reproduction is common in fungi and some bacteria.

c) Fragmentation

This is a mode of asexual reproduction where an organism breaks into many small parts (fragments) and each is able to grow into a new individual. It is common in tapeworms and spirogyra.

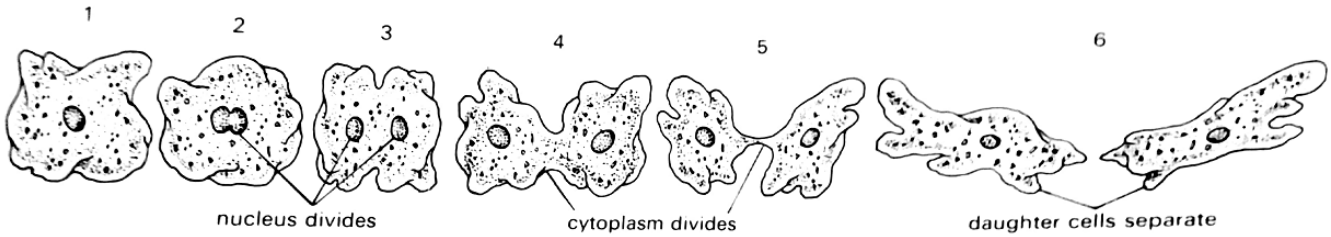
d) Binary fission

A single celled organism divides up into two parts, which start to grow as separate individuals. It is common in amoeba and other protozoans.

Reproduction in amoeba

- Amoeba reproduces by ***binary fission.***
- An amoeba ready to reproduce stops moving and rounds off.
- The nucleus then constricts and divides into two identical parts.
- The cytoplasm begins to constrict so that the separation of the remaining parts into 2 can occur.

- Two identical amoebae forms and move apart to feed and grow into mature amoebae before they divide again.



Question: *Describe the process of asexual reproduction in; Amoeba, Rhizopus, Yeast and Spirogyra*

e) Multiple fission

This is a mode of asexual reproduction where a single celled organism divides into many parts, which grow into separate individuals. This occurs in plasmodium.

f) Vegetative reproduction

This is a mode of reproduction in plants where part of the plant other than the seeds develops into a new individual.

This normally takes place in rhizomes, bulbs, corms, suckers, stolons, runners etc

Parts used for vegetative propagation (asexual reproduction) in plants

Name of plant part	Characteristics	Examples
Rhizome	Underground stem, swollen with food, has lateral buds, has scale leaves, and has nodes and internodes.	Ginger, Cana lily
Stolon	Underground stem, not swollen with food, has lateral buds, has scale leaves.	Couch grass, spear grass
Runners	Grows on the surface, has fibrous roots, has lateral buds, has scale leaves, has nodes and internodes.	Star grass
Bulbs	Leaves swollen with food, has a short stem, has adventitious roots, has scale leaves, has thick foliage leaves, has lateral buds.	Onions, garlic
Corms	Vertical stem swollen with food, has adventitious roots, has lateral buds, and has scale leaves.	Yams
Suckers	New individual plant produced alongside the parent plant	Pineapple, banana

Advantages of vegetative reproduction

- New plants resemble the parent plant and any good quality in the parent is retained.
- The growth of the new plant is rapid.
- The reproductive organ stores plenty of food which the new plant uses.
- It does not involve processes like pollination, fertilization and dispersal agents are not required.
- Large areas can be covered in relatively little time.
- It involved only one individual.

Disadvantages

- Since new plant grows on its parent, it can lead to crowding.
- Shortage of water and mineral salts is likely to occur due to competition.
- Diseases of the parent plant can be transmitted to the young ones.
- If the parent plant has poor characters, they can be maintained by the young ones.

Artificial vegetative propagation

This is a mode of reproduction where man is involved in the propagation process. It is done in several ways, which include, budding, grafting, layering, cuttings, etc.

1. Budding

This is the process where a bud is detached from a plant and grown in suitable conditions into a new plant.

2. Grafting

This is the insertion of part of one plant onto another plant so as to come into organic union and to grow as one plant. The part inserted can be a bud or a shoot of a plant and it is called a **scion**. The part in the ground on which the scion is inserted is called a **stork**. The scion and stock should be of different varieties but same species.

3. Layering

This is where a branch of a plant is bent to touch the ground and allowed to develop roots. When the roots are developed, it is cut from the plant and it starts to grow as a separate self-supporting plant.

Advantages of asexual reproduction

1. It is reliable because it is less likely to be affected by adverse environmental factors like for the case of seeds.
2. It leads to genetic consistence since there is no mixing of genes during reproduction.

3. It results into early maturity because the organisms produced have enough food reserve from the parent.
4. It is self-sufficient because it does not rely on external processes like pollination, fertilization and dispersal.
5. It does not result in indiscriminate and wide spread distribution like in the case of seeds, which leads to wastage.
6. It does not require formation of sex organs.
7. It is the only means of reproduction in some organisms.

Disadvantages of asexual reproduction

1. It leads to maintenance of bad characters.
2. It does not introduce variations in the offspring since there is no gene mixing.
3. It easily results into competition between offspring due to overcrowding.
4. It gradually results into reduction of the strength and vigor of the succeeding generations.
5. There is a high chance of disease transmission from parent to offspring.

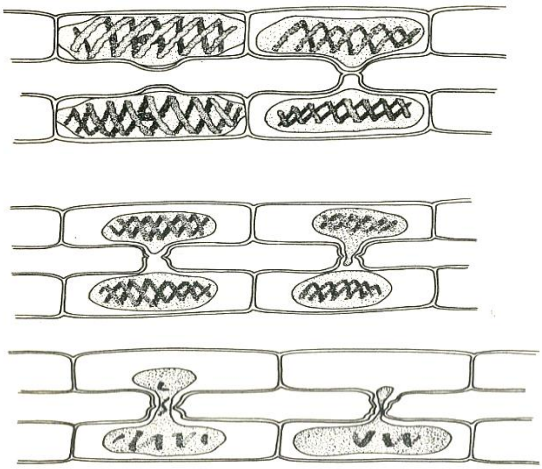
Sexual reproduction

This is a type of reproduction which involves the fusion of male and female gametes to form a zygote.

Reproduction in spirogyra

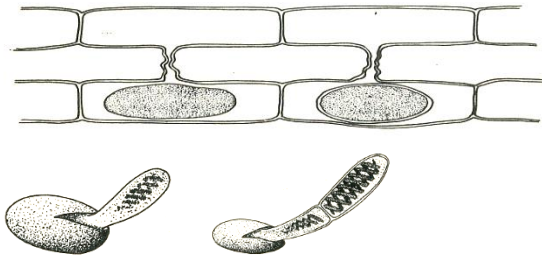
Spirogyra is a green non flowering plant belonging to a group of plants known as algae.
The main type of sexual reproduction in spirogyra is conjugation.
Spirogyra reproduces by conjugation between filaments lying side by side as follows;

i) The opposite cells of the two different filaments lying side by side develop a swelling or an out-growth which begins to grow towards each other.
ii) On touching they dissolve to form a conjugation tube and at the same time the contents change into gametes.
iii) The gametes from one cell (male gamete) migrate through the conjugation tube to another cell (female) gamete.



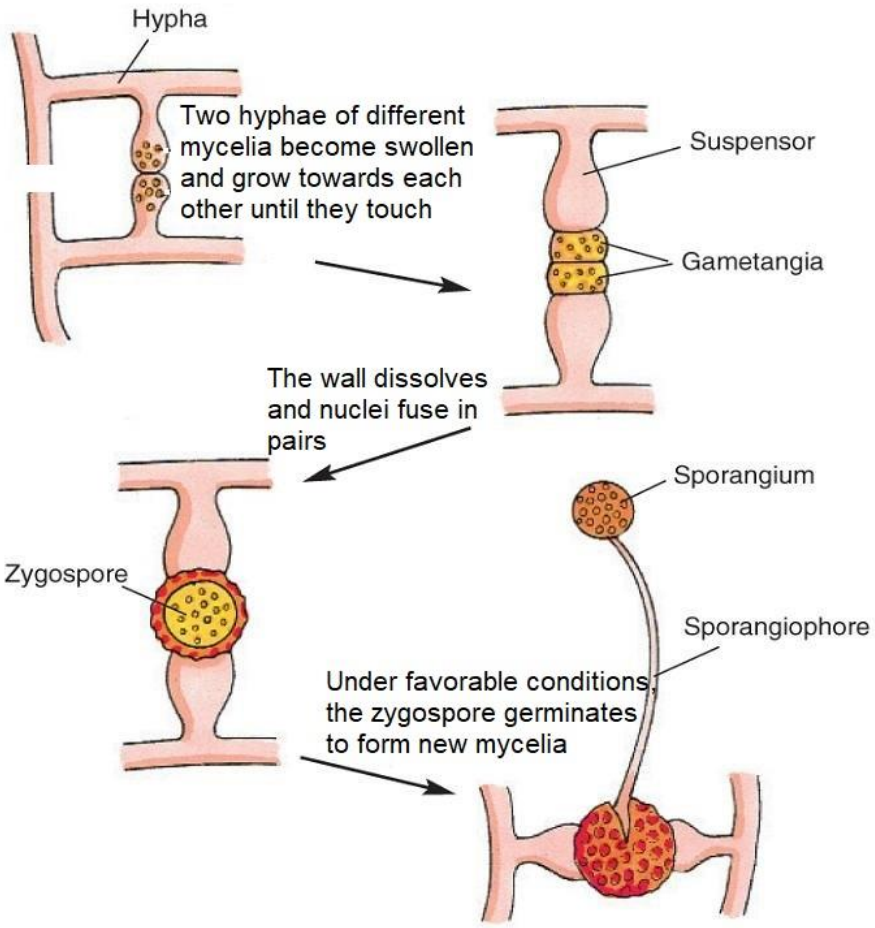
iv) The two gametes fuse to form a zygote which develops a thick resistant wall and becomes a zygospore.

v) When the conditions are favorable, the zygospore germinates and grows into another filament.



Sexual reproduction in fungi (Rhizopus) E.g., mucor

- The tips of the two hyphae of different mycelia become swollen and grow towards each other until they touch.
- The swellings are cut off from the rest of the mycelia by a cross wall.
- Nuclear division takes place and each swelling contains several nuclei.
- When they touch, the wall dissolves and nuclei fuse in pairs.
- The thick outer cover forms around them to form a zygospore.
- Under favorable conditions, the zygospore germinates into new mycelia.



Sexual reproduction in flowering plants

In flowering plants, the flower is the reproductive organ.

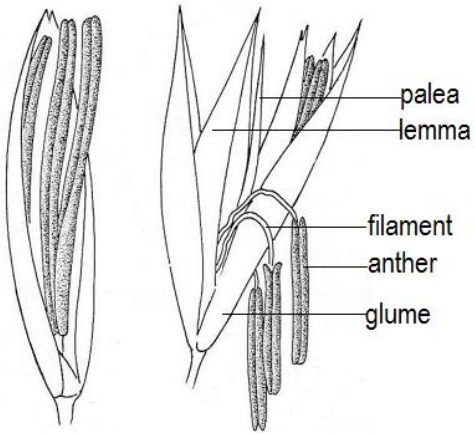
The male gametes are the male nuclei found in the pollen grains produced by the anthers.

The female gametes are the egg nucleus and polar nuclei found inside the ovules located in the ovary. These two are brought together shortly after pollination.

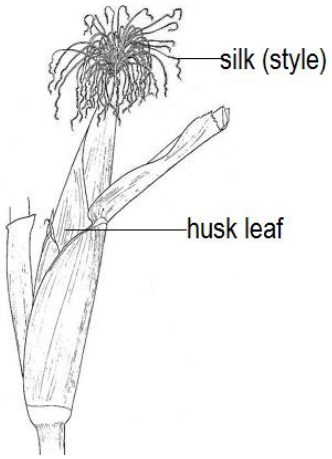
Parts of an inflorescence

Male inflorescence

A single floret (spikelet) from a maize male inflorescence



A maize female inflorescence



A single unit of an inflorescence is a **spikelet**. It has two ***glumes*** (outer bracts) at the base of one or more florets above. A glume is a bract (leaf-like structure) below a spikelet in the inflorescence.

In place of sepals, inflorescences have evolved the external ***lemma*** and the internal ***palea***; two bract-like structures that partially or fully enclose the inner reproductive organs.

Note: refer to practical work book for practicals on flowers

Pollination

Pollination is the transfer of pollen grains from the anther of a flower to the stigma of the same flower or different flowers of the same species.

Pollination is of two types; Self-pollination and Cross pollination.

Self-pollination; is the transfer of pollen grain from anther of a flower to the stigma of the same flower.

Cross pollination; is the transfer of pollen grain from anther of a flower to the stigma of another flower of the same species. Flower may or may not be from the same plant.

Features that promote cross pollination

- Brightly colored petals.
- They have a nice scent to attract insects.
- Produce nectar which is food source for the insects.
- Stamen produces sticky pollen grains which adhere firmly to the bodies of visiting insects.

- The stigma is flat, lobbed and has sticky surface to which pollen grain can easily adhere.
- Presence of landing plat form and pollen guide which ensures that insects visit the flower.
- Stamen hanging outside the corolla to ensure that pollen grains are blown away by wind to another flower.

Characteristics of wind pollinated flowers

- Usually not brightly colored
- Not scented and lack nectar.
- Stamen of wind pollinated flowers produce large quantity of light powdery pollen grains.
- Usually small and inconspicuous but are borne in large inflorescences.
- The stigma is large often feathery and hang outside the flower by long styles. This provides a large surface area on which pollen grains floating in the air may be trapped.

Arrangements that promote self-fertilization (arrangements preventing cross pollination):

- Maturation of both male and female parts of the flower at the same time.
- Flowers borne underground.
- Flowers being bi-sexual.
- Flowers remaining closed.

Arrangements that promote cross pollination (arrangements preventing self-pollination):

- Possession of unisexual flowers such that both sexes appear on different plants (dioecious). e.g. in pawpaw
- Self-sterility in monoecious plants like maize.
- **Dichogamy,** a condition in which the stamens and pistils do not ripen at the same time. This results in failure of cross fertilization. If the stamens ripen before the pistil the condition is referred to as **protandry** while if the pistil ripens before the stamens, it is called **protogyny.**
- Stigmas being higher than anthers.

Differences between wind pollinated and insect pollinated flowers.

Wind pollinated	Insect pollinated
Produce light pollen grains	Produce relatively large and heavier pollen grains.
They produce large quantities of pollen grains	Produce small quantities of pollen grains.
They are usually not scented	They are scented.
Petals are dull colored.	Petals are brightly colored.

N.B:

Self-pollination has the disadvantage of failing to introduce variation in the new generation. This results into maintenance of poor characters from one generation to the next.

Cross pollination results into mixing of genetic material which leads to variation. This results into introduction of new character from one generation to the next.

Fertilization in plants

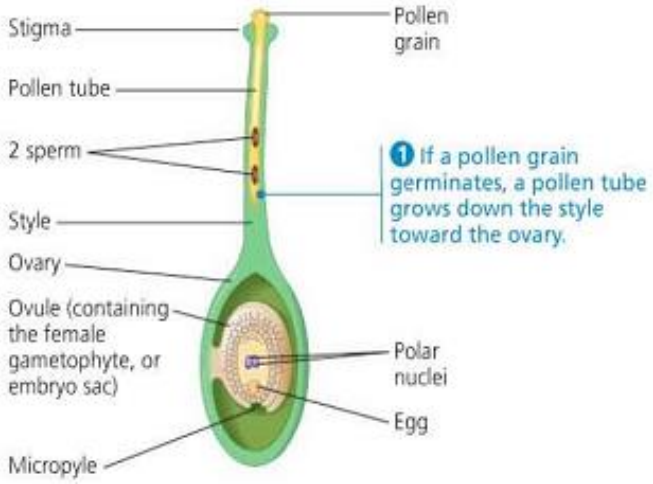
This is the fusion of male and female gamete to form a zygote. Fertilization in plants is internal taking place inside the ovary in the structure called embryo sac.

The process of fertilization in plants:

Pollen grain lands on the stigma of a flower of the same species.

On the stigma, pollen grain absorbs water, nutrients and then germinates to form a pollen tube which grows through the style under the control of the tube nucleus at the tip.

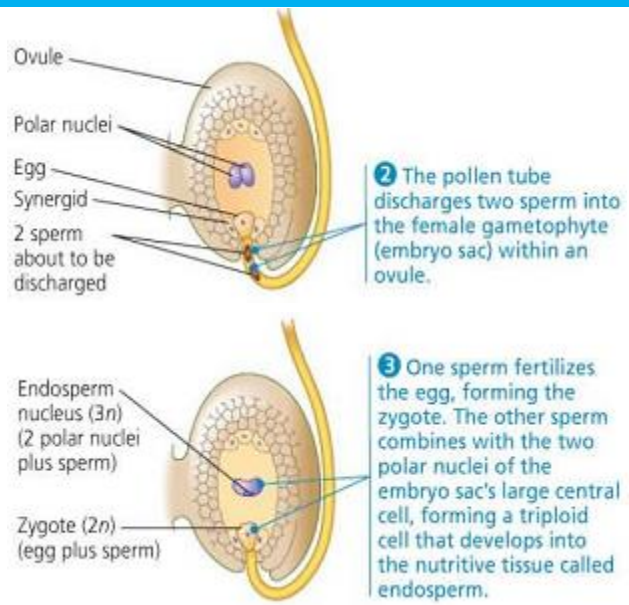
Pollen grain has two nuclei i.e. generative nucleus and pollen tube nucleus. The generative nucleus divides mitotically to form two male nuclei which lie behind the pollen tube nucleus.



The pollen tube enters the ovary and the tip of the pollen tube breaks. The pollen tube nucleus disappears.

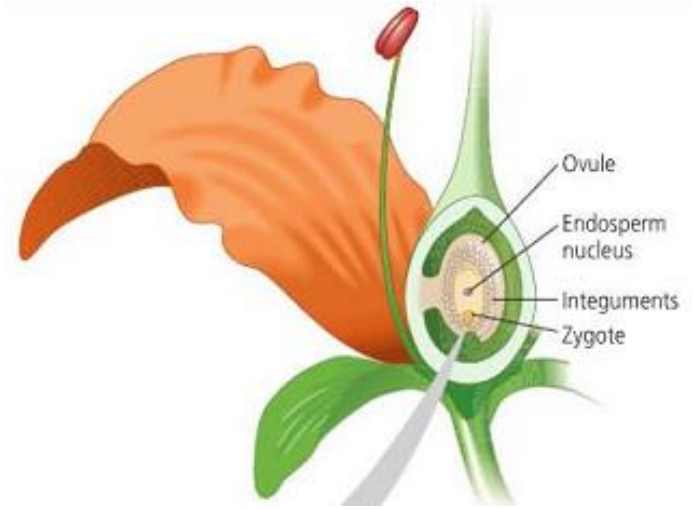
One of the male nucleus fuses with the egg nucleus to form a zygote which divides mitotically to form embryo.

The other male nucleus fuses with two polar nuclei to form a triploid endosperm which develops into endosperm. This is called double fertilization.



Events after fertilization

1. The zygote divides mitotically followed by growth and development resulting into an embryo.
2. The triploid endosperm divides mitotically to form good solid organs called endosperm.
3. The ovules develop into seeds.
4. The integuments become the seed coat.
5. The ovary develops into a fruit and ovary wall develops into a fruit wall which protects the seeds.



6. Petals, stigma, style and stamen wither and fall off while the calyx may wither and fall off or may remain in shriveled form.

Reproduction in animals

Sexual reproduction is the only form of reproduction in vertebrates and few invertebrates. e.g. Arthropods.

For this reason, most of animals have reproductive organs in which the gametes are produced. To adopt various conditions in the habitat in which they live different animals show different forms of fertilization and development.

Reproduction in insects

Insects show internal fertilization and external development with complete and incomplete metamorphosis.

Metamorphosis:

This is the developmental change from the eggs to the adult stage in the life cycle of an organism. It is divided into two, i.e. complete and incomplete metamorphosis.

i) Complete metamorphosis

This is the type of metamorphosis where eggs hatch into larvae, pupa then to adult.
It occurs in houseflies, butterflies and moths. Insects which show complete metamorphosis are called holometabolous insects.

ii) Incomplete metamorphosis

This is the type of metamorphosis where eggs hatch into nymph that resembles the adult except that it lacks wings, smaller than the adult and sexually immature. It occurs in insects such as cockroaches, grass hoppers and locusts. Insects which show incomplete metamorphosis are known as hemimetabolous insects.

Sexual reproduction in Bony fish

Like Tilapia, show external fertilization and external development beginning with laying of large quantities of eggs. Mating may follow courtship in some species and the eggs after hatching may get minimum parental care in form of protection from enemies.

Sexual reproduction in amphibians

They show external fertilization and external development. There is some protection offered to the eggs by a jelly but there is lack of parental care to the tad poles.

Sexual reproduction in birds

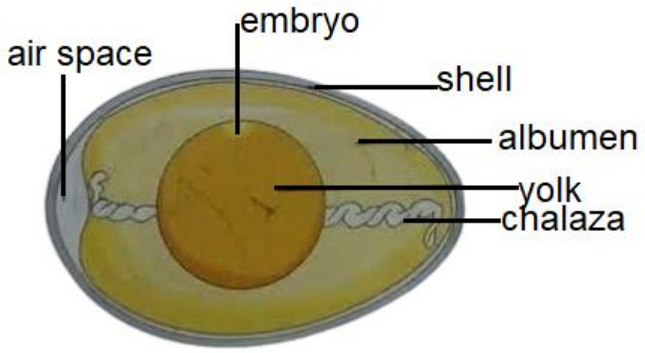
Birds show internal fertilization and external development. Prior or before fertilization most birds show courtship behavior, nest building and development begins with laying of eggs which hatches into young ones.

Courtship stimulates the female sexually to a point (nest) where the male bird is;

- ✓ On mating, the male presses his cloaca directly against the female's cloaca and sperms are released directly into the oviduct through the cloaca.

- ✓ The sperms swim up to the oviduct until they come into contact with the eggs without shell. Here internal fertilization takes place.
- ✓ The fertilized eggs pass to the oviduct where they release albumen and a hard protective shell.
- ✓ The eggs are laid in the nest and incubation starts after all the eggs are laid.

Structure of the egg.



Parts of the egg

Shell; this protects the egg and prevents it from desiccation.
Airspace; this stores air for gaseous exchange of the embryo.
Chalaza; this holds the yolk in position.
Albumen; this is a source of proteins and fats to the embryo.
Germinal disc; this develops into an embryo.
Yolk; this stores food for and surrounds the embryo.

Development:

The living cells in the egg divide to make the tissues and organs of the young birds. The yolk provides the food for this development. The albumen is the source of proteins and water. The shell and shell membrane are permeable to air. Oxygen diffuses into the airspaces and is absorbed through the blood capillaries of the embryo. The blood carries oxygen to embryo and Carbon dioxide is eliminated through the egg shell by the reverse process. When the chick is fully developed, it breaks out of the shell by help of its beak during hatching.

Incubation:

The female bird is responsible for incubation of the eggs. The function of incubation is to provide the optimum temperature for the embryo's development in the egg. The incubation period differs from one species of birds to another.

Differences between internal fertilization and external fertilization

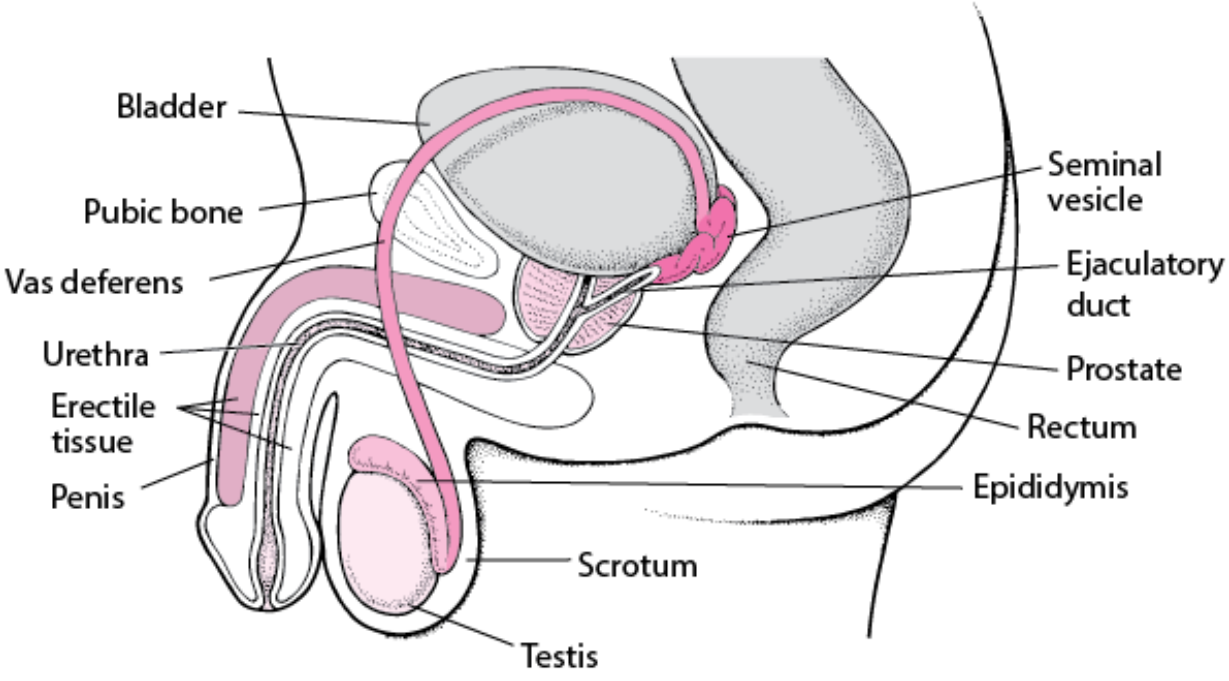
External fertilization	Internal fertilization
Water as an external factor is necessary	Water as an external factor is not necessary
A lot of gametes are produced and necessary	Less gametes are involved in the process
Embryos develop not well protected and mostly helpless after birth	Embryos develop well protected and normally offered help after birth
A lot of energy is involved since more gametes are produced.	Less energy is involved since fewer gametes are produced
Chances of fertilization occurring are fewer	Chances of fertilization are higher

N: B the above points can serve as advantages of internal over external fertilization.

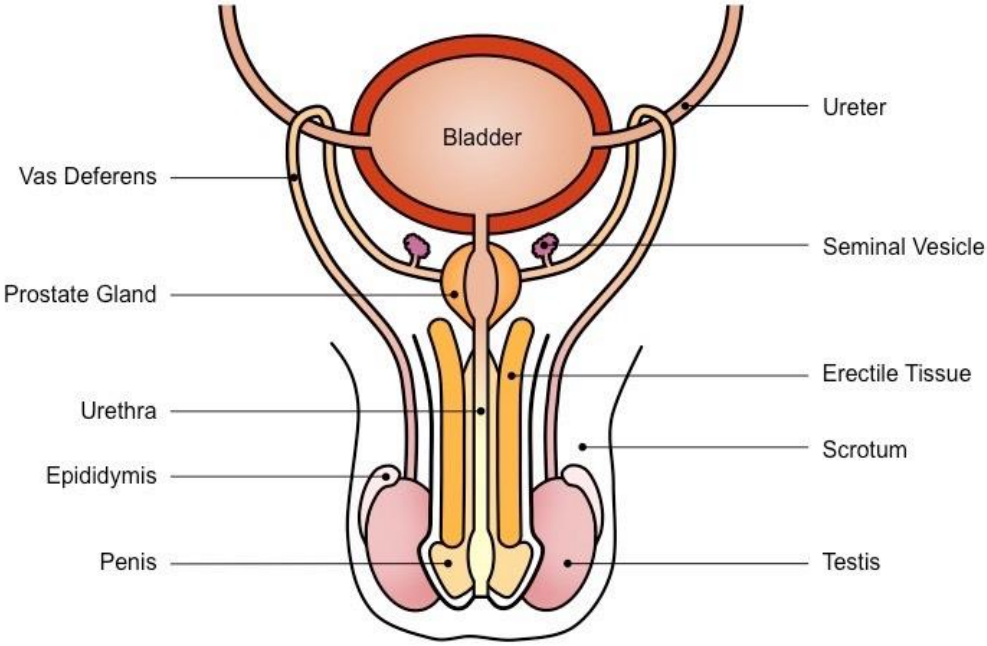
Sexual reproduction in mammals

Mammals reproduce sexually. They have special reproductive organs that produce the gametes i.e. sperms and ovum.

The male reproductive system (side view)



The male reproductive system (anterior view)



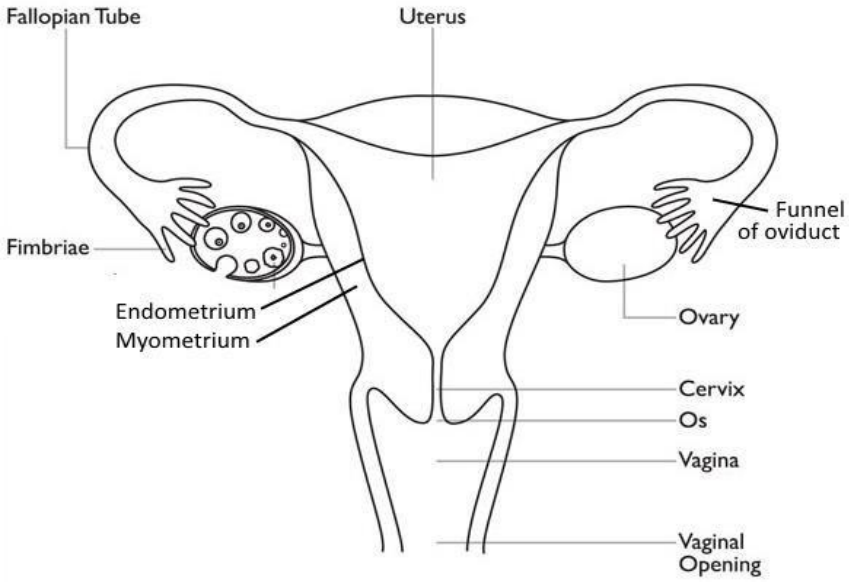
Functions of the parts:

1. **Seminal vesicle;** secrets viscous fluid-containing fructose which acts as a nutrient for sperm cells.
2. **Prostate gland;** this gland secretes an alkaline, milky-white fluid that neutralizes the acidity of the Vagina.
3. **Penis;** delivers sperms into the female reproductive organ.
4. **Testis;** manufactures and store sperms.
5. **Scrotal sac;** protects the testis.
6. **Vas deferens;** conducts sperms from the testis to urethra during ejaculation.
7. **Urethra;** passage of sperms and semen during ejaculation.
8. **Cowper's gland;** produces mucus for lubrication of both the male and female urethra to ease copulation.

Functions of the male reproductive system

- Used in the delivery of sperms into the female reproductive organ.
- Production and storage of sperms.
- Secrets male sex hormones e.g. testosterone hormone.

Female reproductive system (anterior view)



Function of parts:

1. **Uterus;** provides suitable environment for growth and development of the fetus. It is also an area for implantation.
2. **Vagina;** it provides the following functions;
   - Passage of sperms to the uterus.
   - Passage of blood during menstruation.
   - Allows passage of the fetus at birth.
3. **Oviduct (fallopian tube);**
   - It allows movement of fertilized egg towards the uterus for implantation.
   - It provides suitable place for fertilization.
4. **Cervix**; contains elastic muscles which allows its expansion during birth and it is the gate way to the uterus.
5. **Vulva**; This is a collective term for the external genetalia. It is made up of two skin folds that is the inner fold (**labia minora**) and the outer fleshy fold **(labia majora**). Labia minora contains mucus secreting glands which lubricates the vagina during sexual intercourse (copulation).
   Labia majora cushion the vagina and helps in sexual arousal. In the place where labia majora and **labia minora** meet is a bean-like structure called **clitoris**. This is the most sensitive part, which brings about sexual excitement in females.
6. **Vagina**; This is a muscular tube, which connects the vulva to the uterus. It has an average length of 10cm. It secretes acidic mucus, which prevents growth of bacteria and fungi. The mucus also lubricates the vagina. The vagina plays the following roles:

- ✓ It is a passage for menstrual flow.
- ✓ It is a birth canal.
- ✓ It is where the male inserts his erect penis during sexual intercourse.

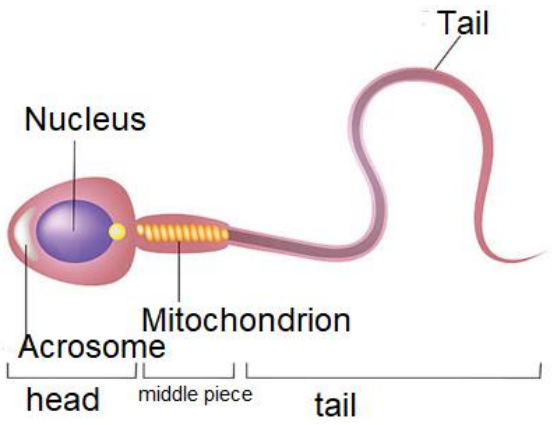
General function of the female urino-genital system

- Production of the female gametes i.e. the ovum
- Reception of the male gametes i.e. the sperm
- Provision of a suitable environment for fertilization
- Provision of a suitable environment for the fetus development.
- Provision of a means for the expulsion of the developed fetus during birth.
- Secretion of hormones like oestrogen

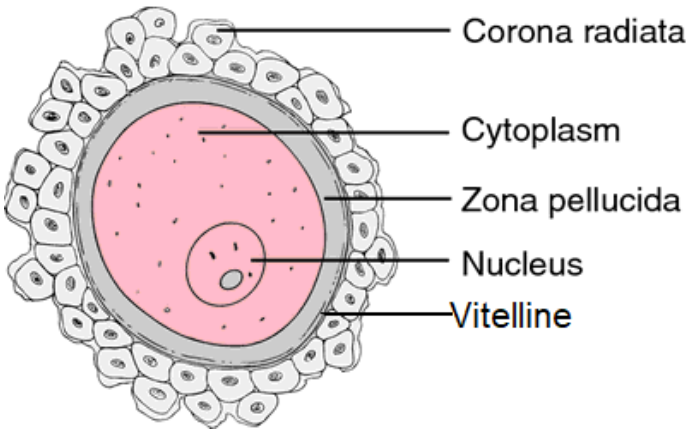
Gametes

These cannot develop any further until fertilization occurs. There are two types of gametes namely; male and female gametes also known as sperm cells and ova (singular; ovum or egg cell) respectively. Both male and female gametes are haploid.

Structure of a sperm cell (male gamete)



The structure of the ovum



Functions of the parts

Acrosome; contains enzymes which dissolve the egg membrane (Vitelline) for penetration of the sperm nucleus into the egg for fertilization to occur.
Nucleus; contains genetic material responsible for transmission of characters from the parent to the off spring.
Middle piece; contains mitochondria which provides energy sperm movement.
Tail; propels the sperm forward as it swims towards the ovum.
Cytoplasm; it acts as a food store for the embryo.
Vitelline; It provides protection to the inner part of the egg.
Allows exchange of materials around the egg and its surrounding.

Zona pellucida;

- Responsible for species-restricted binding of sperm to unfertilized eggs.
- Prevents sperm from binding to already fertilized eggs.

Differences between sperm and ovum

Sperm cell	ovum
Has a tail	It is spherical and has no tail
It is very small	It is big
Has less food store	It has more food store
It is mobile	It is immobile
It has either *X* and *Y* chromosomes *(XY)*	It has only *X* chromosomes *(XX)*

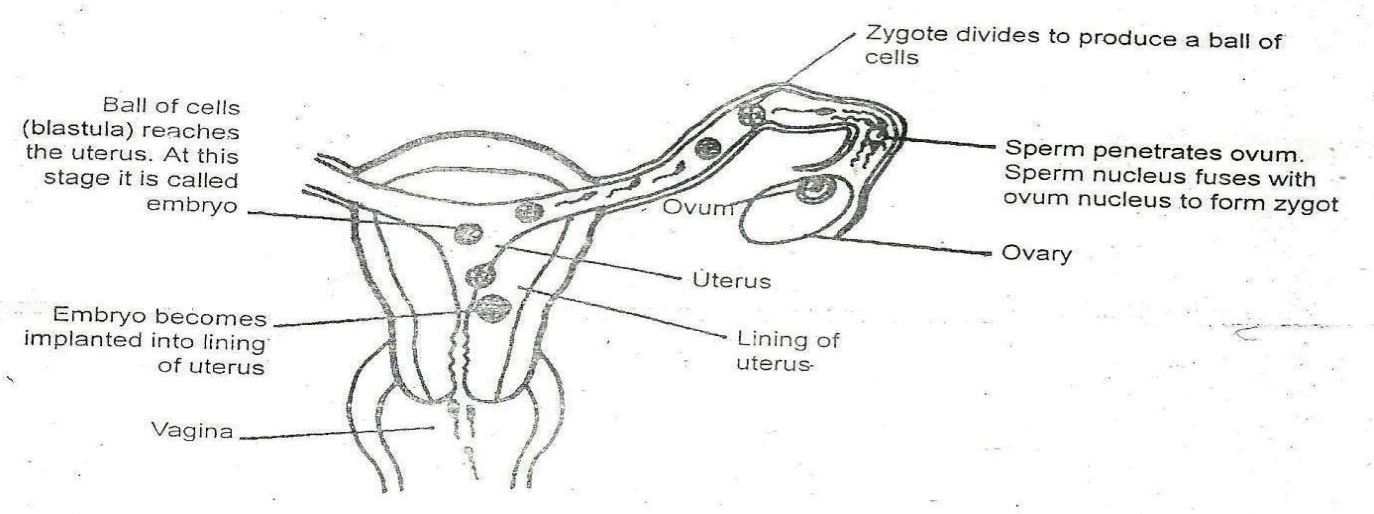
Fertilization in man

Fertilization in man occurs after copulation where erect penis is inserted into the vagina. At orgasm, the penis releases large number of sperms (200-300 million) near the cervix. The cervix relaxes and opens as sperms swim through its opening to the uterus then to the oviduct where fertilization takes place.

When a sperm gets into contact with the egg membrane, it releases enzymes from acrosome which breaks the egg membrane and enable the sperm cell penetrate into the cytoplasm of the ovum.

When the sperm cell enters, the egg membrane becomes thickened to form the fertilization membrane which serves as a barrier preventing the entry of other sperm cells.

The nuclear membrane of the two gametes breaks down and male nucleus fuse with a female nucleus to form a fertilized egg. This process is known as fertilization and the female is said to have conceived.

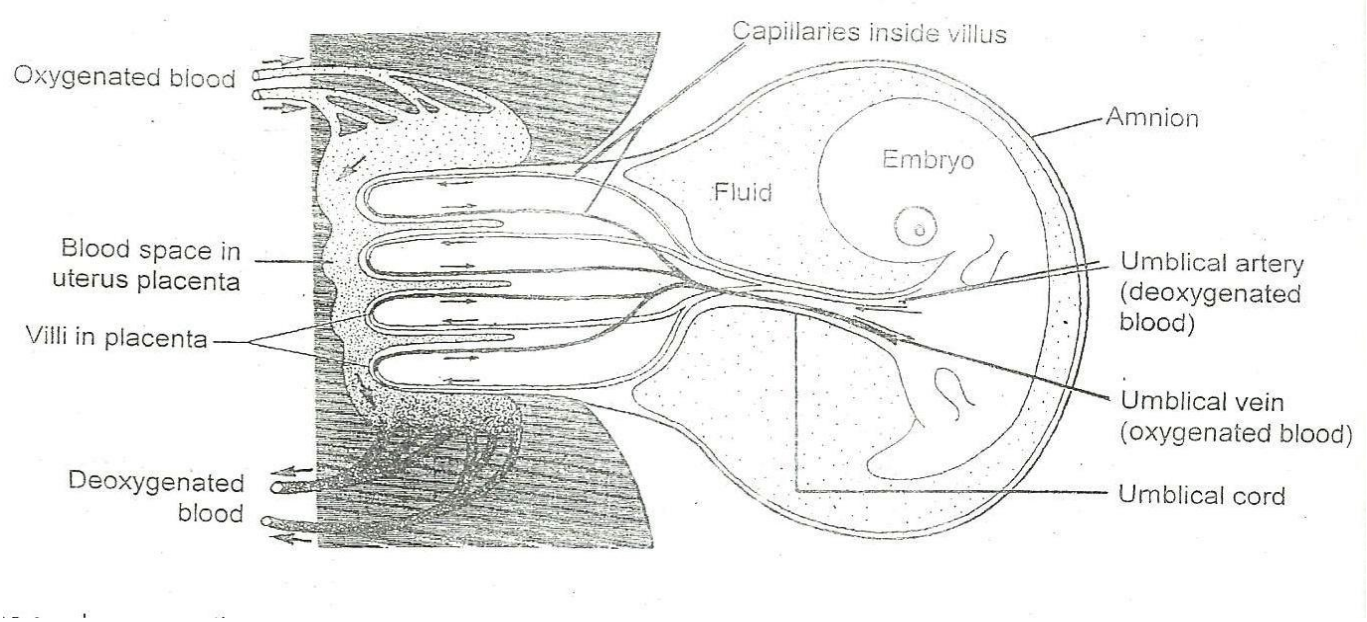


Pregnancy

Gestation is the period from fertilization of an ovum to birth. After fertilization, the under goes cell division by mitosis and move down to the uterus. Its movement is aided by constriction of the oviduct and it takes about one week. Finally, the fertilized egg (zygote) is embedded in the lining of the uterus a process known as implantation and it continues with its development.

The fertilized egg now becomes known as the fetus. Later, finger like connections develop between the fetus and the mother's blood system. This later unites to form placenta connected to the fetus by umbilical cord.

Diagram showing blood circulation to and from the fetus



Major nutrients needed by a pregnant mother

i) Calcium and Phosphates. These are needed for the development of bones and cartilage of foetus.
ii) Iron needed for the formation of foetal red blood cells
iii) Proteins needed for the formation of new tissue.
iv) Vitamins needed for proper growth.

Functions of the placenta

i) It allows exchange of materials without the mother's blood mixing with that of the fetus.
ii) It allows transfer of oxygen, water, glucose, amino acids and other substances into the fetus which are used as nutrients.

iii) Carbon dioxide, urea and other wastes are transferred from blood circulatory system of the fetus to the mother's blood across the placenta.
iv) It protects the fetus by preventing certain toxins and foreign materials from crossing to the fetus.
v) It acts as a barrier to mother's hormones and some other chemicals which may affect the fetus.
vi) It allows anti bodies to pass onto the fetus there by providing immunity against diseases.

Nutrition of the fetus

Soluble food substances, oxygen, water and mineral salt passes across the placenta by either diffusion or active transport from the mother's blood to the fetal blood through the umbilical vein. Waste products such as carbon dioxide and nitrogenous wastes are brought in to the placenta by umbilical artery where they are passed into mother's blood. The placenta is therefore the excretory organ of the fetus as well as respiratory surface and source of nourishment.

Protection of the fetus

The fetus is contained in a sac called the amnion which is filled with amniotic fluid. The amniotic fluid protects the fetus from mechanical shock and drying.
The fetus is warmed by blood temperature all the time and regulated by mother's blood.
The placenta prevents passage of bacteria, other foreign materials, nervous transmissions and maternal blood pressure from affecting fetal circulation and also it keeps out toxins from the fetus.

Birth (parturition)

The embryo turns head down wards in the uterus a few days before birth which occurs at approximately 9 months after fertilization. At time of birth, the uterus contracts rhythmically.
The opening of the cervix dilates (relax) to allow the young's head to pass through. The amniotic fluid passes out through the vagina.
The contraction of the uterus pushes the young one through the vagina to the exterior. It takes the 1st breathe of life and usually cries, a sign of changed conditions in its environment. After some time, the placenta separates from the uterus and finally expelled as after-birth.

Differences between sexual and asexual reproduction

Sexual reproduction	Asexual reproduction
Two parents are involved	Only one parent is involved
Needs males and female gametes	Does not need gametes

Off springs are not identical	Off springs produced are identical
Rate of reproduction is slow	Rate of production is fast
Fertilization usually occurs	Fertilization does not occur
Usually few off springs are produced	Usually very many off springs are produced

Male hormones

At puberty, the hypothalamus stimulates the anterior part of the pituitary to release two hormones.

The **follicle stimulating hormone (F.S.H)** which stimulates sperm production.

The **Luteinizing hormone (LH)** also known as the interstitial cell stimulating hormone (ICSH) which stimulates the interstitial cells of the testis to release another hormone **testosterone** which stimulates the development of the male secondary sexual characters.

Secondary sexual characteristics of Males and Females

Secondary characteristics in man	Secondary characteristics in females
• Deepening of the voice • Growth of pubic hair • Enlargement of the penis • Onset of wet dreams • Growth of beards • Growth of hair in the arm pits	• Softening of the voice • Enlargement of breasts • Enlargement of hips • Onset of menstruation • Enlargement of reproductive organs • Growth of pubic hair • Growth of hair in arm pits

Female hormones and the menstrual cycle

When the ovum is released by the ovary, the uterus wall thickens with addition of new layer of cells for the ovum to sink if fertilized. The blood supply also increases at the same time. If the ovum is not fertilized, the new layer of cells breaks down and the unwanted cells, mucus and some blood pass out through the cervix and vagina. This is called menstruation. It takes place once about 28 days, 12-14 days after the release of the ovum.

The menstrual cycle

The menstrual cycle is controlled by four hormones of which two are secreted from **the interior lobe of pituitary gland and the other two from the ovaries.** The pituitary gland secretes **Follicle stimulating hormone (FSH) and Luteinizing hormone (LH)**

and the ovary secretes **progesterone and oestrogen**. The four hormones are secreted in the following sequences.

FSH ⟶ Oestrogen ⟶ LH ⟶ Progesterone

It is a reproduction cycle occurring in sexually a mature female in absence of pregnancy and involves series of changes in the female reproductive system which is controlled by hormones.

Role of hormones in regulating the menstrual cycle

1. **Follicle stimulating hormone (FSH):**
   - Causes the development of the graafian follicles in the ovaries.
   - It stimulates the ovary to produce oestrogen.

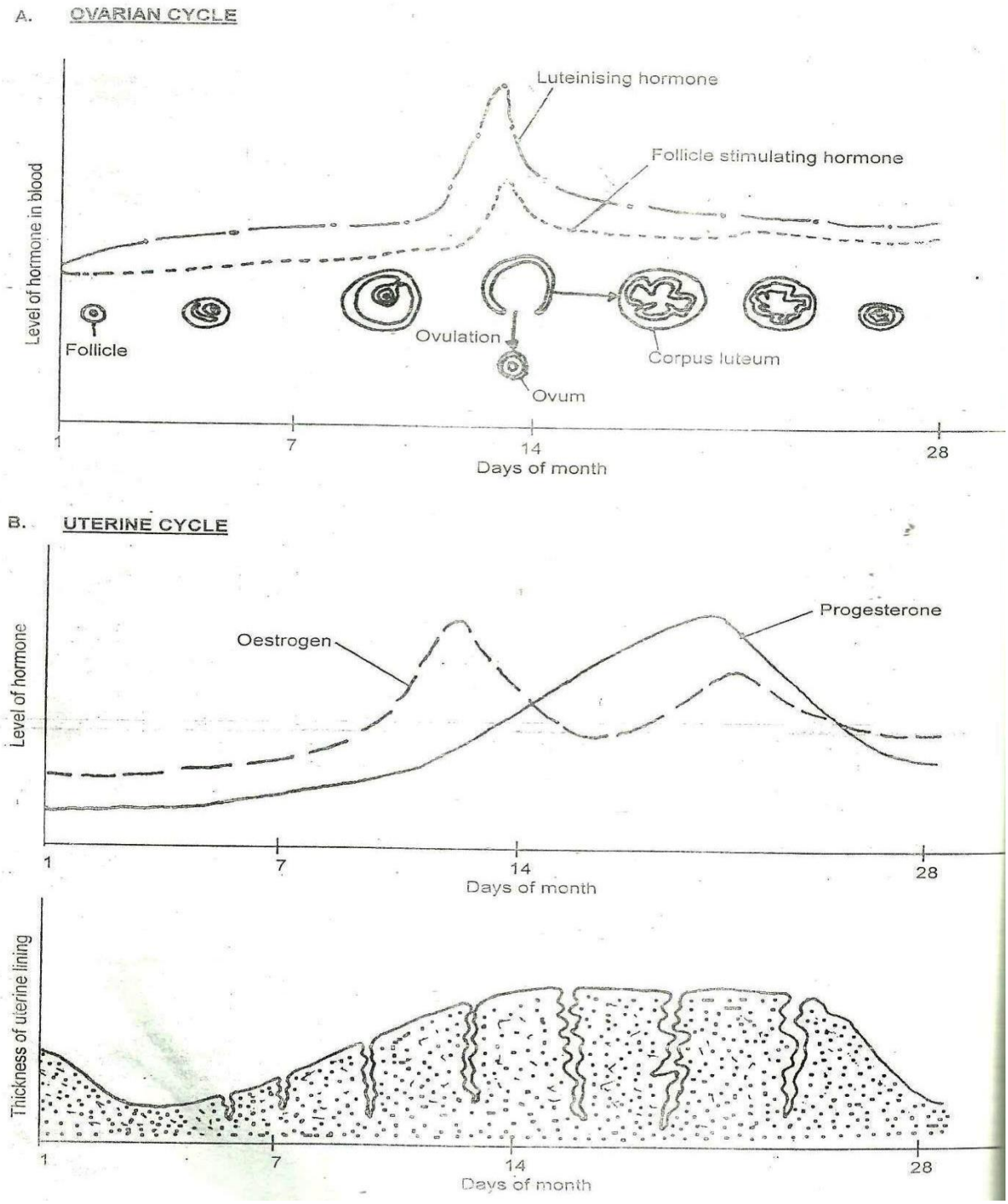
2. **Oestrogen:**
   - This stimulates the repair of the uterine wall after menstruation.
   - When in high levels, it stimulates the pituitary gland to produce LH
   - It inhibits the production of FSH from the pituitary gland.

3. **Luteinizing hormone (LH):**
   - This cause ovulation in the middle of the cycle.
   - It also stimulates the ovary to produce progesterone from the corpus luteum.

4. **Progesterone**:
   - This maintains the uterine lining in preparation for implantation.
   - It inhibits production of FSH and LH if its level is high.
   - High levels of progesterone lead to the breakdown of the corpus luteum within 14 days after ovulation and hence stops further production of progesterone.
   - If the ovum is not fertilized, the production of progesterone stops and the endometrium breaks down leading to menstruation (flow of blood).
   - If fertilization occurs, the placenta produces the progesterone which prevents the breakdown of the uterine endometrium to maintain the pregnancy.

Menstruation stops at around the age of 45 years on average and one is said to have reached menopause. At this stage no more pregnancy is possible.

Graph illustrating the hormonal changes in blood during a menstrual cycle.

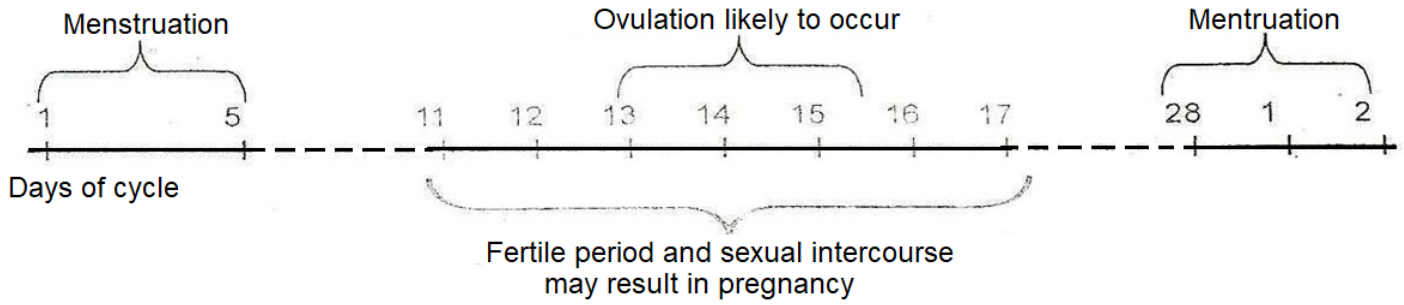


Safe days

It refers to the days within the menstrual cycle when there is no mature ovum in the reproductive system so a female can have sexual intercourse without getting pregnant. During the first safe period, there is development of a graafian follicle and takes about 10 days from the end of menstruation.

A female should abstain for the first 3 days before ovulation and 3 days after ovulation because the sperm cannot survive for more than 3 days. It will die after waiting for more than 72 hours.

The 2nd safe period starts from around the 18th day up to the 28th day when the egg is in the uterus. Fertilization can only take place when the egg is in the oviducts; in the uterus it can't be fertilized.



TWINS

These are two babies produced with in the same time to the same mother as a result of the same pregnancy.

Types of twins

1. **Fraternal twins**. These are twins who arise from the fertilization of two ova produced at the same time and fertilized by two different sperms. The babies are not identical but resembles as normal babies in the family. They may or may not be of the same sex.
2. **Identical twins**. These are two babies, who develop from one fertilized ovum that latter divides into two and the two develop as separate individuals. Such babies look alike and are of the same sex

Multiple births

These are more than two babies produced to the same mother with in the same time as a result of the same pregnancy.

Methods of birth control

1. Coitus interruptus where the penis is withdrawn from the vagina before ejaculation.
2. Rhythmical method where sexual intercourse is avoided at times when ovulation is likely to occur.
3. Use of condoms and diaphragms which prevents sperm from reaching the eggs.
4. Vasectomy where vas deferens are cut by surgical means there by preventing the passage of sperms.

5. Tubal ligation where the fallopian tubes are cut by surgical means there by blocking the passage of the egg.
6. Use of oral contraceptives known as pills; these prevent development of the egg.
7. Use of injectable contraceptives. This is taken every 3 months to prevent ovulation.
8. Intra uterine devices. This prevents fertilized egg from implanting into the uterus.
9. Use of intra-vaginal rings. This ring secretes progesterone like substance which inhibits development of the egg.
10. Use of morning pills which are taken 3 days after sexual intercourse.
11. Abortion which involves termination of viable pregnancies.

Questions:

What is vegetative reproduction in flowering plants?
Define the term menstruation.
Describe the menstrual cycle in females
What are the causes of infertility in males?
Describe the process of fertilization in man
Describe the different forms of asexual reproduction in flowering plants.

ECOLOGY

Ecology is a branch of biology that deals with the study of organisms in relation to their natural environment. The natural environment comprises of the living things and the non-living things.

Definitions of terms used in ecology

Environment:

This refers to everything in the surrounding of an organism that influences its life. The environment of a tadpole for example is everything in the water where it lives.

Biosphere:

This is the part of the earth and its atmosphere that is occupied by living things or where life exists. It's the largest habitat.

Habitat:

This is a place where an organism lives. In the habitat, the organism obtains water, shelter and it is able to reproduce there.

Population:

This is the total number of organisms of the same species living in a particular place at a given time.

Ecological niche:

This refers to a particular place an organism occupies within a habitat and the role it plays there. A niche is like the 'profession' of an organism.

Community:

This is a collection of populations living and interacting with non-living components. It is therefore the total of all organisms in an area.

Ecosystem:

This is a unit of the environment consisting of both living (biotic) and nonliving (abiotic) components interacting to form a self-sustaining unit. E.g. living things may include fish, cockroaches, and nonliving things may include lake, pond, forest, etc.

The two major factors within an ecosystem include:

- ✓ The flow of energy through an ecosystem.
- ✓ Cycling of matter within an ecosystem.

COMPONENTS OF AN ECOSYSTEM

The ecosystem is made up of two components;

1. The abiotic component (nonliving component)
2. The biotic component (living component)

The abiotic component of the ecosystem

This is the non-living component of the ecosystem. Living organisms interact with the non-living components in their community to form a self-sustaining unit called an ecosystem.

The abiotic components in the ecosystem include the ***soil factors (edaphic factors).*** Edaphic factors are physical and chemical factors in soil and atmosphere that influence the life and activities of living organisms. These factors affect different organisms differently. Such factors include:

i) **Light intensity**. Light intensity affects the process of photosynthesis in plants, visibility in some animals and causes responses such as phototropism in plants.
ii) **Temperature**. This affects the activity of enzymes in the body of organisms and therefore determines the overall activity of an organism. Temperature also affects germination of seeds.
iii) **Water**. This is a very important edaphic factor. Water is a component of the bodies of living organisms. It is a raw material for photosynthesis, it aids dispersal of seeds, it is an agent of pollination, it is a habitat for some organisms, it is a condition for germination, etc.
iv) **Humidity**. This is the amount of water vapour in the atmosphere. Humidity affects the rate of transpiration in plants; it also affects the rate at which water is lost from the bodies of animals through evaporation.
v) **PH**. This is the alkalinity or acidity of soil. PH affects the dissolution of mineral elements in water; it affects growth of plants and microbes in an area, etc.
vi) **Nutrients**: Presence or absence of a particular nutrient in soil determines the organisms, which can grow in that soil. Nutrients are required for proper growth of all organisms in the ecosystem.
vii) **Oxygen concentration**. Most of the organisms are aerobic, i.e. they require oxygen for their respiration. Oxygen is abundant in air (21% by volume) however in water the concentration of oxygen varies due to factors that affect its dissolution in water and over exploitation by organisms. This affects the growth of organisms in water. In such a case anaerobic organisms can thrive and aerobic ones die.

Biotic components

This is made up of living organisms in the ecosystem. They are categorized into the following.

1) **Producers:**

These are green plants and some bacteria that make organic food by photosynthesis or chemosynthesis. They are nutritionally referred to as autotrophs.

2) Consumers:

These are organisms which eat other organisms.

Consumers are classified into feeding levels called trophic levels. The classification is based on the type of food they feed on. The feeding levels/trophic levels of consumers are:

- ✓ Primary consumer
- ✓ Secondary consumer
- ✓ Tertiary consumer

The primary consumers (1st order consumers):

These are organisms that feed directly on plants (producers). They are called herbivores. Examples are cattle, grasshoppers, goats, sheep, etc.

The secondary consumers (2nd order consumers):

These are organisms that obtain their food by feeding on primary consumers. They are also referred to as carnivorous organisms since they feed on flesh. Examples include cats and reptiles.

The tertiary consumers (3rd order consumers):

These are organisms that obtain their food by feeding on the flesh of secondary consumers. These are usually big carnivorous animals like lions, crocodiles, vultures and tigers.

3) The decomposers:

These are organisms that feed on dead decaying organic matter. They are commonly called saprophytes. The major examples are bacteria and fungi. Decomposers are important because they bring about decay of plant and animal tissues. This helps in the recycling of nutrients in the soil.

They also reduce the number of wastes and litter in the environment.

Types of food relationships

Food chain

A food chain is a linear sequence of energy flow among organisms starting with the producers (plants). One of the ways in which the organisms of a community interact is by feeding on and providing food for each other. For example, on one abandoned school farm, hawks were found to feed on small snakes, the snakes on the lizards, the lizards on grasshoppers, and the grasshoppers on grasses. These relationships may be set out in the form of a food chain shown below:

Grass → grasshoppers → lizards → snakes → hawks

Energy from the sun is fixed by producers (plants), the herbivores eat the plants and obtain this energy and also the carnivores feed on herbivores to obtain this energy. At each successive trophic level, some energy is lost.

In a community of grasshoppers, dove and cat, the food chain would be as follows:

Grass ⟶ grasshopper ⟶ dove ⟶ cat

In the food chain above, the grass is the primary producer, the grasshopper is the primary consumer, the dove is a secondary consumer and the cat is a tertiary consumer.

Arrows are used to show the movement of energy from one organism to another. Energy moves from the producers to tertiary consumers through the food chain.

Exercise:

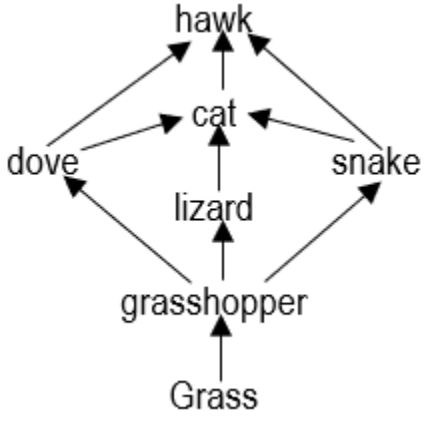
Draw a food chain for the following organisms;

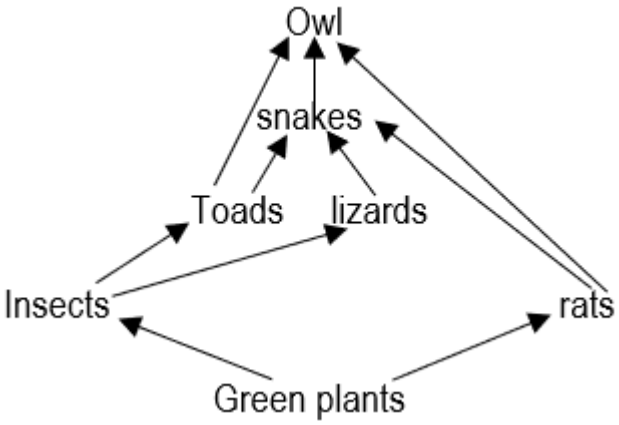
1. Vegetation, beetle, owl and fox.
2. Cow, man, lion and grass.
3. Nile perch, algae, water flea and tilapia.

Food web

A food web is a feeding inter-relationship of interlinked food chains whereby most animals have alternative sources of food.

Examples of food webs:





Note: When drawing the food web, the organisms should be arranged in trophic levels. The produces should be at the bottom followed by primary consumers and tertiary consumers at the top of the food web.

Elimination of one organism from the food web disrupts the food chain. For example in the above food web, when the grasshoppers are eliminated from the ecosystem, the following occur:

- The grass grows and increases in number because the grasshopper that used to feed on it has been removed.
- The doves, lizards and snakes lack food because they feed on grasshoppers, which have been removed. This causes their numbers to drop.
- The cats also reduce in number because of the reduction of its source of food (doves, lizards and snakes).

Exercise: Construct a food web using the following organisms: phytoplanktons, mosquito larvae, small fish, large fish, and crocodiles.

Ecological pyramids

These are used to show either the number of organisms or energy present at each level in the food chain and food web. There are three types of pyramids namely;

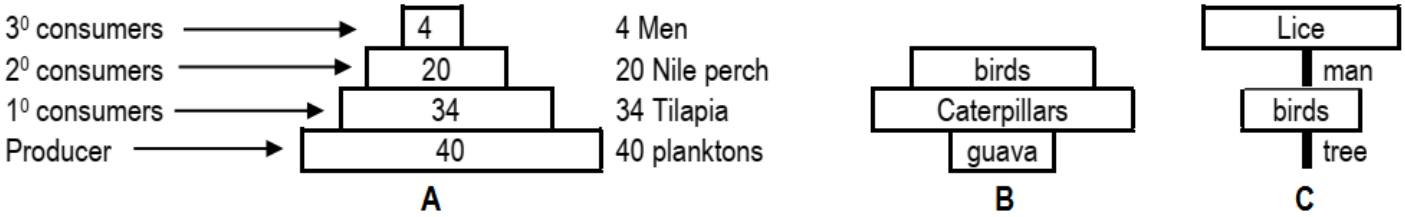
1) Pyramid of numbers
2) Pyramid of biomass
3) Pyramid of energy

Pyramid of numbers

This is used to represent the number of individuals at each trophic level.

The number of organisms at each trophic level is counted and a pyramid is drawn with the primary producers at the base. The width of each rectangle represents the number of organisms at each trophic level.

Examples of pyramid of numbers:



Pyramid ***A*** represents 20 nile perch, 40 planktons, 34 tilapia and 4 men

Pyramid ***B*** represents few birds feeding on the many caterpillars eating fruits on a single guava tree.

Pyramid ***C*** represents a big fruit tree having several birds feeding on a fruit, man being an immediate consumer of the birds while at the same time, several lice being parasites to man.

The problem with the pyramid of numbers is that it does not account for size of the organism at each trophic level. For this reason, the pyramid of biomass is used.

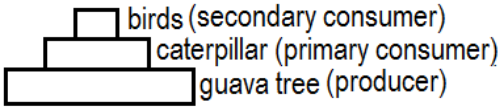
Exercise:

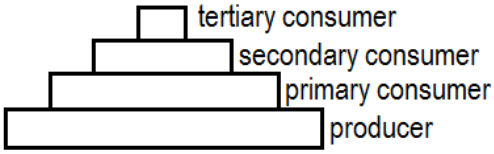
Husnah carried out an ecological study in Kabowa. In one of the sections, she found 15 toads, 180 plants, 4 snakes and 120 grass hoppers. Use the information to answer the questions.

a) Construct a possible food chain for the above information.
b) State the trophic levels occupied by each of the organisms in the community.
c) Draw the pyramid of number for the community.
d) Explain what would happen to the rest of the organisms if all toads were destroyed.

Pyramid of biomass

This represents of the mass of the organism at each trophic level. Biomass refers to the mass of a living organism. Biomass decreases from producers to tertiary consumers. Producers have a higher biomass than all other trophic levels. Considering the pyramid of numbers ***B*** above, the pyramid of biomass would be.





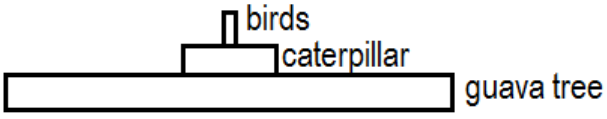
Even if the guava is one, it has a bigger biomass than caterpillars and caterpillars have a larger biomass than birds.

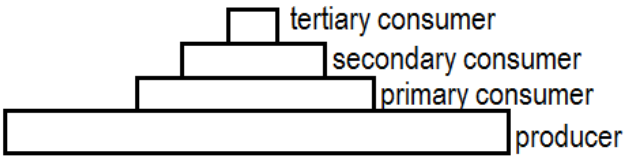
In most cases the pyramid of bio mass is constructed using dry weight of organisms. This is because the fresh mass of an organism varies so much with water content. Dry weight is the mass of an organism without water.

The problem with biomass is that it varies greatly as the organism grows. Using a pyramid of energy can solve this problem.

Pyramid of energy

This shows the amount of energy at each trophic level. Energy decreases with succeeding trophic levels. Producers contain more energy than tertiary consumers. The pyramid of energy gives the most accurate representation.





Energy flow in an ecosystem

Energy flows through food chains and food webs. Energy is obtained from the sun by green plants.

The plants trap light energy and use it to carry out photosynthesis. During photosynthesis, light energy is converted into chemical energy. When primary consumers eat the plants, they obtain this energy. The energy is then passed on to other organisms through their feeding relationships.

At each trophic (feeding) level there is loss of energy because;

- Some energy is used up during respiration.
- Some energy is lost from herbivores in form of indigestible plant material i.e. the parts that can't be digested.
- Some parts are not eaten by the consumers.
- Some organisms die before they are eaten.
- Some plants are not edible.
- Some of the chemical energy is converted into other forms such as sound, light energy, heat energy, which easily escapes from the organisms.

At each trophic level, decomposers (saprophytes) such as bacteria and fungi break down dead organic matter to release some of the energy locked in it.

Changes in populations

Population is a group of organisms of same species living in a particular area at a given time.

Organisms live in a population in order to:

- ✓ Gain more protection as the population
- ✓ Have increased chances of gathering mates and breeding.
- ✓ Ability to get shelter

However, organisms in a population face:

- ✓ High chances of overcrowding
- ✓ High competition among themselves for food, shelter, etc.
- ✓ Increased chances of predation.

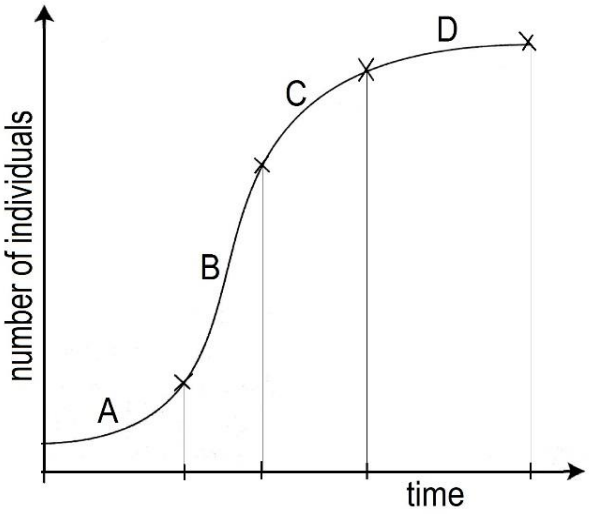
Each population has specific characteristics which distinguish it from others. The characteristics are density, dispersion, age, sex ratio, birth rate and death rate (mortality) and population growth.

Population growth

This refers to the increase in number of organisms of the same species. When organisms like bacteria, houseflies or cockroaches have a suitable environment, their population increases. Data on the growth rate can be obtained by counting the number

of organisms per given time. When such data is plotted against time, an ***S***- shaped or ***sigmoid*** growth curve is obtained.

The population growth curve



The growth curve is S-shaped and it is referred to as a sigmoid curve. It is divided into five phases.

A. Lag phase: During the lag phase, the population grows at a slow rate because the reproducing individuals/organisms are few and are also still adjusting to the environment. During this early period of growth, there is adequate supply of nutrients, oxygen and shelter/space.

B. Exponential phase: this is also referred to as the log phase. During this phase, there is rapid increase in the population size. This is because the organisms have adjusted to the environment, the number of reproducing organisms has increased and the supply of oxygen and nutrients is plentiful. The rate of birth is high and death rate is low.

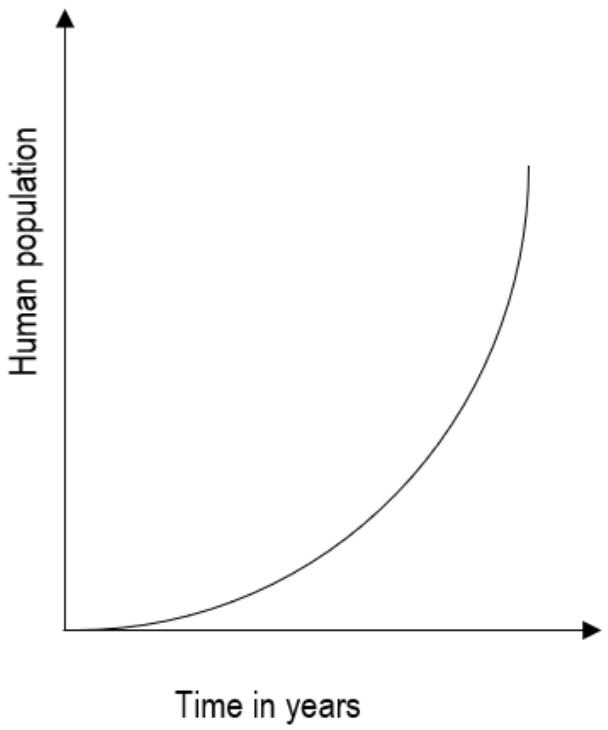
C. Decelerating phase: The rate of growth starts to slow down as the organisms start to die. This is mainly due to overcrowding, accumulation of toxic waste products and shortage of food. Their number has become big and have started to compete for resources like food, shelter, mates and space. This therefore creates shortage of resources. The available resources cannot support a big number of organisms.

D. Stationary phase: In this phase, there is no further increase in the population. Most organisms are old are not capable of reproducing. The rate of birth is equal to the rate of death hence the rate of population growth remains constant.

At the stationery phase, the population is referred to as the carrying capacity. Carrying capacity is the maximum population the environment can support at a particular time without exhausting the resources.

Growth of the human population

The population is presently growing exponentially (rapidly). This is shown in the human population growth curve below:



The exponential human growth is usually due to:

- ✓ Advancement in science and technology leading to prevention of infectious diseases.
- ✓ Early warning on natural catastrophes.
- ✓ Proper nutrition.
- ✓ Decrease in infant mortality.
- ✓ Increase in life expectancy in developing countries.
- ✓ Increasing agriculture hence leading to more food.

Factors affecting population growth

These factors are grouped into two categories.

1. **Density dependent factors**; these are factors whose effect depend on the size of the population, e.g. food, diseases, space, pollution, predation, competition, light, etc.
2. **Density independent factors**; these are factors which affect the population regardless of the population size e.g. earth quakes, floods, droughts, thunderstorm, lightening, fire strong winds, etc.

Population size

This refers to the number of organisms of the same species in a particular area at a particular time.

Factors that determine the population size

- **Natality** (birth rate). This is the frequency of birth. Increase in natality results into increase in population size.
- **Mortality** (death rate). This is the frequency of deaths. When the death rate increases, the population size decreases.

- **Emigration**. This is the movement of individuals out of the population. It results into a decrease in population size.
- **Immigration**. This is the movement of individuals into the population. It causes the population to increase.

Methods of estimating population size

1. Direct count

This is suitable for large organisms living in an open habitat, e.g. elephants, lions and buffaloes. In this method, one moves through the area along predetermined paths and counts the organisms in question. When counting aggressive animals, a low flying aircraft is used. Several counts are made and an average is taken to get an estimate of a particular area.

2. Aerial photography

This is suitable for large organisms living in an open area. Photographs are taken from a low flying aircraft over the study area. When the photographs are developed the number of organisms in the photographs is determined. The photographs are taken several times and the average number is taken for the population of that particular organism in the area.

3. The quadrat

This is a method used for small static organisms like plants or slow-moving animals. A quadrat is a square metal or wooden flame of 1-meter-long sides. It therefore encloses an area of $1m^2$. The quadrat is thrown at random in the study area and the individuals covered counted. Several quadrats are thrown at random and the average number of organisms is taken.

The average number is then multiplied by the total area of the study to get the estimated population.

4. Line transect method:

This method involves lying along measuring tapes along a selected strip within the habitat. A record is made of the organisms touching or covered by a line at all points at regular intervals.

5. Capture mark recapture method:

This is suitable for animals, which are fast moving. E.g. rats and grasshoppers.

In this method animals in an environment are captured and counted (n_1). They are then marked and released back into the environment.

The traps are then laid after a given period of time.

The organisms captured are counted (n_2).

The organisms that were marked and recaptured are also counted (n_3). The population is then calculated from:

Total population $= \frac{number\ of\ individuals\ in\ 1st\ capture \times number\ of\ individuals\ in\ 2nd\ capture}{number\ of\ individuals\ in\ 2nd\ capture\ with\ a\ mark}$

$P = \frac{n1 \times n2}{n3}$

Where;

P = population

n_1 = number in the first capture

n_2 = number in the second capture

n_3 = number in the second capture which are marked.

Examples

1. 30 rats were caught in the bush around the school. They were all marked with ink on the tails and released. After 3 days 20 rats were caught from the same area. 6 out of the 20 rats had a mark. Estimate the population of rats in this bush.

Solution.

Using $P = \frac{n1 \times n2}{n3}$

P = population.

n_1 = 30

n_2 = 20

n_3 = 6

$P = \frac{30 \times 20}{6}$

= 100 rats.

Assignment:

Arthur captured and marked and replaced 45 cockroaches on the first day. He captured 26 cockroaches from the same area 17 of which were not marked. Estimate the population in the area.

Interactions between populations

Individual organisms in the population do not live in isolation in a community. They are continuously interacting with each other in the following ways:

- ✓ Competition
- ✓ Predation
- ✓ Symbiosis

Competition

As the population of the individuals increase, the resources become limited and the organisms compete for them.

Examples of resources competed for include, food, space, mates, etc. Competition is of two types;

1. **Interspecific competition**; this is the competition between organisms of different species, e.g. the competition between goats and cattle for pastures.
2. **Intraspecific competition**; this is the competition between organisms of the same species, e.g. the competition between goats for grass.

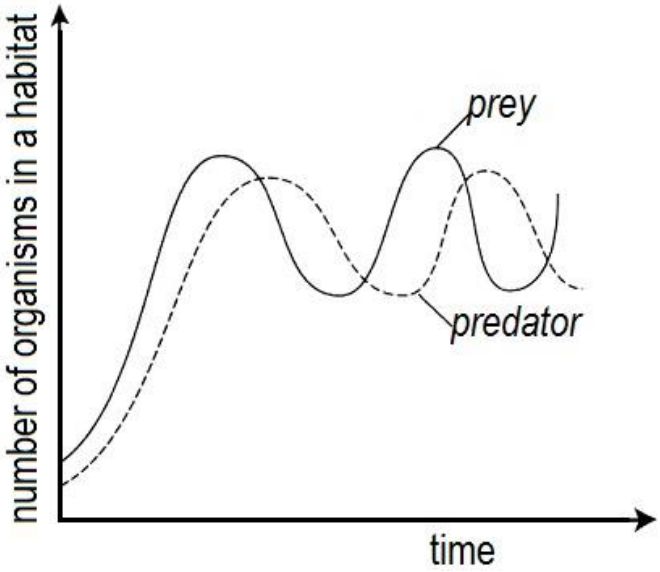
Predation

This is the relationship between a predator and the prey.

A predator is an organism that hunts and kills another organism (prey) for food.

A prey is an organism that is hunted and killed for food.

The graph showing the predator-prey relationship



Description and explanation of the graph:

The population of the prey is higher than that of the predator at the start. This leads to an increase in the number of predators.

The prey reaches a peak earlier than the predators. Further increase in the predator population leads to a decrease in the prey population due to the fact that they are being fed on by the predators. When the number of preys goes down, the predators starve and this makes their population to go down. When the predator number decreases below that of the prey, the population of the prey increases again due to the fact that the predators are few which would feed on them.

Note: Both the predator and prey control the population of each other.

Adaptations of predators that enable them to feed on prey

i) They have keen eyesight to see their prey.

ii) They have strong jaw muscles to tear flesh of the prey.

iii) They have sharp claws to hold and kill their prey.
iv) They move very fast to enable them chase the prey.
v) They have streamlined bodies to cut through air during movement.
vi) Some have very sharp canines to tear flesh of their prey.
vii) They have colours, which help them to camouflage.

Adaptations of the prey to avoid being eaten by predators

i) They perceive sound with high accuracy and are able to sense their predators at a distance.
ii) They are very fast in movement to escape from their predators.
iii) They have developed structures for defense such as horns.
iv) They normally move in groups to scare their predators.
v) They prefer to stay in areas, which give them good visibility such as grasslands.
vi) They have colours, which help them to camouflage.
vii) Mimicry; this is where a palatable harmless organism attains colours of an unpalatable harmful organism and it is confused for a harmful organism.

Symbiotic feeding relationships among organisms

1. Mutualism:

This is the relationship between two organisms of different species in which both organisms derive benefits from the association.

Examples

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

2. Commensalism:

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

Examples:

i) The cattle/buffalos and the egret. The egret gets food in form of insects forced to fly by grazing animals. The cattle do not gain and do not lose

ii) The shark and the ramora. The ramora is a small fish that lives as a commensal attached to the shark by its sucker. When the shark feeds, the ramora feeds on left overs of the shark. The shark neither benefits nor loses.

3. Parasitism:

This is the association between two organisms in which one (the parasite) is nutritionally dependent on the other (host). The host is harmed in the process.

Parasites are divided into two categories:

i) **Endo-parasites;** these are parasites that live inside the body of the host, e.g. plasmodium and HIV

ii) **Ecto-parasites;** these are parasites which live outside the body of the host, e.g. ticks, lice and flea.

Parasites can also be described as:

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

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

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

Problems faced by parasites

i) Finding the host may be difficult since most hosts keep on moving from one place to another.

ii) Deficiency of food in case the host has similar deficiency.

iii) They may be killed by the hosts' immune reactions.

iv) Death of parasites incase the host dies due to starvation.

v) Inabilities to live in a wide range of environment since most of them have low power of locomotion i.e. they are not able to live freely.

To overcome some of these problems, the parasites have a number of adaptations so as to cope up with their mode of life.

General adaptations of parasites

i) They have means of attachment to the host.

ii) They have penetrative devices for entering and feeding on the host

iii) They show degeneration of unnecessary organs and systems to reduce on their body size in order to fit in the host. e.g. eyes

iv) They produce many eggs, seeds or spores to enhance their survival.

v) They have vector intermediate hosts

vi) They produce resistant stages to survive in periods when they are outside the host

Types of hosts

1. **Intermediate host:** This is the host in which the larvae stage of parasites develops from secondary host.
2. **Primary host (infinite host):** This is the host in which sexual reproduction of a parasite occurs from.

Examples of parasites

1. Plasmodium

This is a protozoan parasite that causes malaria. It is transmitted from one person to another by the female anopheles mosquito. The mosquito acts as the vector.

Life cycle of plasmodium

- Mosquitoes bite a human and inject saliva to stop blood from clotting in its alimentally canal.
- In the process hundreds of parasites are moved from the mosquito into the person.
- The parasites move to the liver through the circulatory system.
- They burrow in the liver cells and reproduce very fast.
- Within one to two weeks, the daughter cells break out of the liver and move to invade the red blood cells.
- In the red blood cells, they reproduce rapidly causing the cells to rapture and invade other red blood cells.
- They then attack new red blood cells causing them to rapture also.
- If a mosquito sucks blood from an infected person, it will take up these parasites in the red blood cells.
- The parasites reproduce in the mosquito and migrate to the salivary glands ready to infect the next person when that mosquito bites.

Note.

Each time the daughter cells of plasmodia are released, thousands of red blood cells rapture and the patient experiences chills accompanied by shivering and sweating. The patient may also become anemic due to loss of red blood cells.

2. Tapeworm

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

i) Taenia sagnata (beef tape worm)
ii) Taenia solium (pork tape worm)

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

Life cycle of a tapeworm

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

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

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

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

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

Within the muscles they develop into bladder worms.

Control

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

Adaptations of tapeworms to parasitic life

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

3. Schistosomes

These are flat worms known as flukes. They are parasites that cause bilharzia (schistosomiasis)

Control

i) Boil all the water for drinking and bathing
ii) Proper disposal of faeces and all wastes
iii) Kill snails using chemicals
iv) Treatment of water in swimming pools
v) Drain water around homes.

Ecological succession

This is the successive replacement of organisms in a community from simple one to the most complex ones gradually. This is a gradual change in the composition of organisms in the area. There are two types of succession i.e. Primary succession and Secondary succession

Primary succession

This is a type of succession where life begins from a bare rock or new pond, which has never been occupied by living organisms before. The pioneer plants in such areas are those, which can with stand dry conditions with low water content and high temperatures. The first organisms to inhabit such an area are called pioneer organisms.

Stages of succession on a bare rock

Stage 1: The lichens grow on bare rock. When they die, they decompose to form a thin layer of soil, which traps some moisture.

Stage 2: Mosses start growing on the soil formed by the decayed lichens. When the mosses die, they decay to form more soil.

Stage 3: The soil formed favours the growth of ferns.

Stage 4: Grasses start to grow due to coming in of favourable conditions such as moisture, enough soil for anchorage of the plants. During this stage some rodents may start coming in.

Stage 5: Shrubs are formed and they finally develop into trees. The trees form the climax community after which no other changes take place.

Lichens. Pioneer → Mosses → Ferns → Grasses → Shrubs → Trees. Climax community

Succession in a new water pond

Floating plants → Papyrus → Trees (forest)

It takes several years for a climax community to be established. Any disturbance at any one level causes the process of succession to go back to the initial stages and it later

on re -establishes. The ability of the community to re-establish after a disturbance is known as **resilience**.

A **climax community** is the final steady community that develops at the end of the succession process.

Characteristics of primary succession

- ✓ A pioneer community has very few species of plants and animals.
- ✓ The pioneer vegetation is shallow rooted
- ✓ The pioneer community colonizes a bare rock.
- ✓ It takes a long time to reach the climax community.

Secondary succession

This is a type of succession, which takes place in an area, which has ever been occupied by organisms and destroyed by disasters like fire, floods and human activities. This type of succession is faster than primary succession.

Characteristics of secondary succession

- ✓ The pioneer community has a variety of plant and animal species.
- ✓ It takes a short time to reach the climax community
- ✓ The pioneer vegetation is of higher plants which are deep rooted.

Forests are renewed by afforestation and avoiding deforestation.

Ecological importance of forests

- ✓ They act as habitats of organisms.
- ✓ Source of food to organisms.
- ✓ Used in rain fall formation, this improves on the climate of an ecosystem.
- ✓ It forms soil by dropping litter which helps in decomposition into humus.
- ✓ Maintains plants and animal diversity.

Ecological effects of deforestation

- ✓ Destruction of habitats of animals.
- ✓ It leads to soil erosion
- ✓ It leads to desertification.
- ✓ It increases CO_2 content in the atmosphere.
- ✓ Increases predation due to removal of vegetation cover.

Importance of forests to wild life conservation

- ✓ They are sources of food to animals
- ✓ They are habitats to animals.
- ✓ Formation of rain falls to prevent drought.
- ✓ Reduces soil erosion thereby conserving soil fertility.
- ✓ Maintains the bio diversity for a variety of plant and animal species.
- ✓ Purifies the environment by removing CO_2 and adding oxygen.

- ✓ Provides a variety of litter that decomposes to form humus.
- ✓ Reduces predation of some wild animals.

Pollution

This is the addition of substances to the environment to levels that harm or destroy living components of the environment (ecosystem). Substances that can cause pollution to the environment are called **pollutants**. E.g. sewerage, fertilizers, oil links, etc.

Types of pollution

1. Water pollution
2. Air pollution
3. Noise pollution
4. Radioactive pollution
5. Sound pollution

Air pollution

The main pollutants of air or atmosphere are poisonous gases e.g. SO_2, CO_2, NO_2, and CO.

Some of these gases e.g. SO_2, CO_2, and CO form acidic components that destroy vegetation. Another air pollutant is smoke that causes poor vision, reduced light penetration, and reduction of photosynthesis by coating on plant leaves. Excess gases in the atmosphere e.g. CO_2 and CFC^s (Chloro Floro Carbon) used in fridges cause global warming.

Water pollution

This is as a result of addition of excess nutrients e.g. nitrates, phosphates, potassium to water bodies making them too nutritive leading to increased productivity of water. The highly productive lake is called eutrophic lake and the process of polluting water bodies by adding excess nutrients is called eutrophication. The main pollutants that cause eutrophication are fertilizers.

Domestic wastes drained in water bodies, industrial wastes e.g. detergents which contain a lot of phosphates and nitrates also cause eutrophication in the lake.

Eutrophication:

This is the accumulation of nutrients (nitrates and phosphates) in a water body leading to increased growth of aquatic plants e.g. algae which decompose after death leading to a decrease of oxygen contents as a result of being utilized by decomposers of dead plants. Due to the decrease of oxygen content, in water, aquatic animals that need oxygen for respiration e.g. fish suffocate and die.

Soil pollution

Use of excess fertilizers, herbicides, insecticides pollutes the soil. Excess herbicides and insecticides lead to death of living organisms in the soil there by reducing the rate of decomposition of dead matter. Non degradable insecticides do not break down but accumulate in animals along the food chain to poisonous levels that can kill.

Activities of man that have led to the degradation of soil

i) Over stocking leading to over grazing that reduces the amount of vegetation cover to expose the soil there by encouraging soil erosion.
ii) Deforestation exposing soil to agents of soil erosion.
iii) Use of insecticides, pesticides and herbicides which cause the death of soil organisms hence affecting the rate of decomposition.
iv) Burning of vegetation that removes the vegetation cover which encourages surface run off hence leading to soil erosion.
v) Mining, construction, quarrying leads to the destruction of soil structure which encourages soil erosion.
vi) Digging or cultivating down slope also encourages soil erosion.

Radioactive pollution

This is the release of radioactive chemicals into the environment in large amounts e.g atomic substances are from atomic bombs.

Human activities that lead to environmental pollution

i) Drainage of excess untreated sewage into the water bodies causing eutrophication.
ii) Application of excess fertilizers that are later eroded in water bodies.
iii) Burning of vegetation that exposes the soil to erosion agent and it also leads to the emission of smoke which causes air pollution.
iv) Emission of excess poisonous gases in the atmosphere e.g. SO_2, CO_2 and CO form industries and automobiles which cause acidic rains.
v) Use of excess herbicides and insecticides which kill the soil organisms leading to decreased rate of decomposition.
vi) Spilling of oil onto water bodies which leads to suffocation of aquatic animals.
vii) Construction of noisy industries in town which cause sound pollution that can damage the hearing process of man.
viii) Decomposition of non-biodegradable materials into the soil e.g. plastics, glass, etc. which destroy the soil structure.
ix) Deforestation
x) Monoculture
xi) Over stocking

Uganda's water bodies

The major water bodies in Uganda are lakes and rivers. They are pollution by sewage from industries; fertilizers used by man, oil from machines e.g. boat engines.
Water bodies are also invaded by water weeds especially water hyacinth which is a flowering plant which can also reproduce asexually and with a high rate of reproduction.

Effects of water hyacinth on water bodies

- ✓ They hinder navigation
- ✓ They habour dangerous animals e.g. snakes
- ✓ Reduction in the amount of fish in water bodies as some dies due to starvation.
- ✓ They reduce on the amount of light penetration in water column.
- ✓ Siltation of water bodies i.e. they become shallow as a result of death and decomposition of water hyacinth.
- ✓ Reduction in the amount of water in lakes as a result of increased rate of transpiration.
- ✓ They hinder smooth flow of water in lakes since they block the drainage channels.
- ✓ It has caused economic injuries to the country especially when trying to eradicate it.

Uses of water hyacinths

- ✓ Production of biogas
- ✓ Feeds for cattle and pigs.
- ✓ A good fertilizer when used as mulches.
- ✓ A good raw material for art and craft.
- ✓ Raw material for making manure.

Methods of controlling the water hyacinth

i) Physically or removing it manually by hand picking however it is not effective.
ii) By use of machines (mechanical control) however the method is effective but expensive.
iii) By using biological control methods e.g. use of bottles.
iv) Use of herbicides (chemical control) and it involves the spraying of herbicides directly onto the weed. The method is quick but has the following demerits:

- ✓ It contaminates water
- ✓ Destruction of aquatic life especially fish
- ✓ Pollution of water since the weed is not completely removed but decomposes in water.
- ✓ It is expensive since it involves the use of space air crafts to apply it.

Congratulations for completing the syllabus