TRANSPORTATION

TRANSPORTATION OF MATERIALS IN LIVING ORGANISM

Why is there a need of special transport system?

Answers:

Over short distances, means of transport are rapid and efficient ie: osmosis, diffusion, endocytosis etc. But in multicellular organisms which have a large surface area to volume ratio; these means are sufficient as cells may be too widely separated from each other. Therefore for these practices to be adequate, specialised long distance transport systems are necessary.

Materials are generally moved by a mass flow system, being the bulk transport of materials from one point to another as a result of pressure difference between the two points.

Example of flow systems in plants and animals are;-

- In plants- Vascular system.
- In animals – Alimentary canal, respiratory system, etc.

Definition:

A vascular system is one which has tubes which are full of fluid being transported from one place to another.

In animals the blood system is a vascular system.

In plants the xylem and phloem form vascular systems.

Definitions:

1. **Osmosis:** This is a movement of water molecules from a region of higher water potential or lower solute potential to a region of lower water potential or higher solute potential through a deferentially permeable membrane.
2. **Diffusion:** This is a movement of materials from a region of higher concentration to a region of lower concentration.
3. **Active transport:** This is a transportation of materials against concentration gradient. Due to this, the process involves the consumption of energy. Any part of the body where active transport occurs is characterized by;

   a) Presence of numerous mitochondria.

   b) High rate of metabolism.

c) High concentration of ATP.

- Since active transport involves the use of energy, the materials transported actively move faster than those transported passively.

Significance of transportation system

The system of transportation of materials is important for:-

1. Distribution of food materials in the body.
2. Carriage of excretory wastes from their sites of synthesis.
3. Carriage of hormones from their respective glands to their target organs.
4. Distribution of antibodies.
5. Carriage of respiratory gases.

(I) TRANSPORT IN PLANTS

- The movement of substances through the conducting or vascular tissues of plants is called Translocation.

Important application of the study of Translocation:

- It is useful to know how herbicides, fungicides, growth regulators and nutrients enter plants and the routes that they take through plants, in order to know how best to apply them and to judge possible effects that they might have.
- Plant pathogens are sometimes translocated, and such knowledge could influence treatment or preventive measures.

Terms used:

(i) Water potential, symbol Ψ, Greek latter psi.

- The term is used to describe water movement through membranes. It can be described as the tendency of water molecules to move from one place to another. The higher (less negative) the water potential, the greater tendency to leave a system.

  Factors affecting water potential of plant cells are:-

1. Solute concentration and
2. Pressure generated when water enters and inflates plant cells.

They are expressed in terms of Solute and Pressure Potentials respectively.

NOTE

- Pure water has maximum water potential (zero).

- Water always moves from a region of higher Ψ to a region of lower Ψ.
- All solutions have lower Ψ than pure water, therefore negative values of Ψ

(ii) Solute potential, Ψs

- The effect of dissolving solute molecules in pure water is to reduce the concentration of water molecules and hence to lower the water potential.
- Solute potential is a measure of the change in water potential of a system due to the presence of solute molecules.

(iii) Pressure potential, Ψp

If pressure is applied to pure water or a solution, its water potential increases. This is because the pressure tends to force water from one place to another.

$$\Psi = \Psi_s + \Psi_p$$

(iv) Plasmolysis and Turgidity

If a plant cell is in contact with a solution of lower water potential than its own contents, then water leaves the cell by osmosis through the cell surface membrane. Consequently, the protoplast shrinks and eventually pulls away from the cell wall. The process is called plasmolysis and the cell is said to be plasmolysed.

The point at which plasmolysis is just to happen is called Incipient plasmolysis. At this point, the protoplast has just ceased to exert any pressure against the cell wall, so the cell is Flaccid. Water will continue to leave the protoplast until its contents have the same Ψ as the external solution. No further shrinkage then occurs.

If a plasmolysed cell is placed in pure water or a solution of lower solute potential or higher water potential than the contents of the cell, water enters the cell by osmosis. As the volume of protoplast increases, it begins to exert pressure against the cell wall and stretches it.

The pressure inside the cell rises rapidly, the pressure is called the Ψ_p. As the Ψ_p of the cell increases due to water entering by osmosis, the cell becomes turgid.

Animal cells have no cell wall and the cell surface membrane is too delicate to prevent the cell expanding and bursting in a solution of higher Ψ. They are therefore protected by Osmoregulation.

Question.

1. What occupies a space between the cell wall and the shrunken protoplasts in plasmolysed cells?

2. What is the Ψ_p of a flaccid cell?

Answer;

1. The external solution, since the cell wall is freely permeable to solutions.
2. Zero. The protoplast is not exerting pressure against the cell wall.

- In higher plants, the materials are transported by the vascular tissues. Which are of two types:-

1. The xylem and
2. The phloem.

(i) The xylem tissue

This is a plant vascular tissue which is mainly concerned with transportation of water and dissolved mineral salts through the plant.

Structure of the xylem

The histology of the xylem tissue reveals the presence of four types of cells.

Note: The only conducting cells are the vessels and tracheids.

1. TRACHEIDS

Structural features:

-They are more or less elongated cells with tapering ends.

-They have secondary thickened or lignified walls with a variety of pits (simple or bordered).

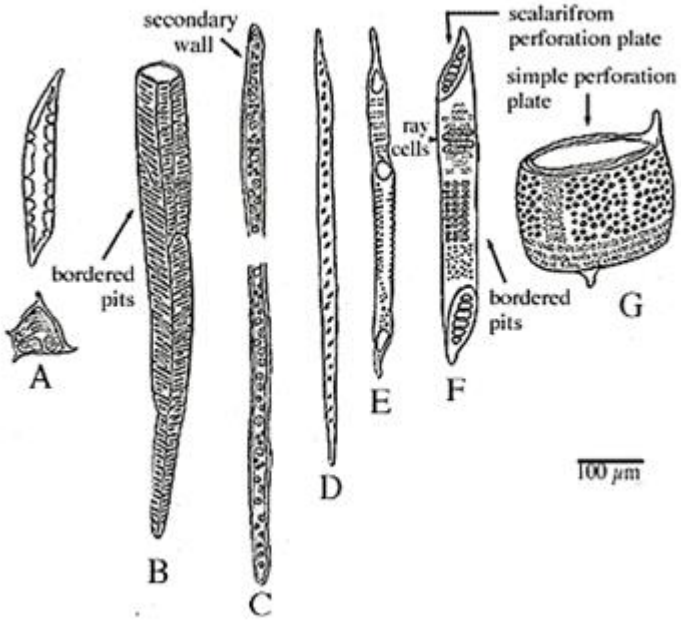
-They are not perforated.

-They are dead at maturity ie: they lose all the protoplasmic contents leaving an empty lumen.

NOTE:

Tracheids are present in all vascular plants, but in the coniferophytes they are only xylem conducting cells

Diagram



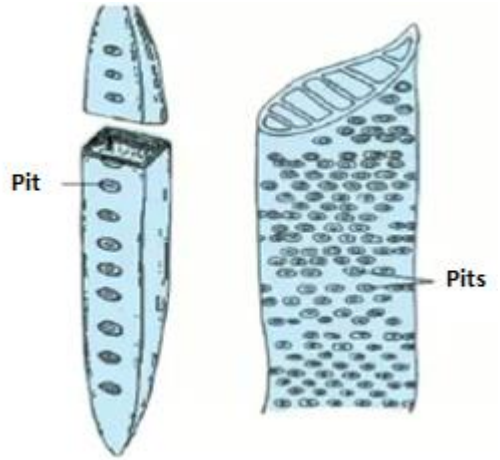
2. VESSEL MEMBERS

- These are perforated elements that aggregate into files of cells connected to one another by means of perforations.

-The vessel members are more specialised than the tracheids and they are characterized by the following features:-

- They have secondary thickened wall.
- They are dead at maturity.
- They are shorter and wider.
- They have bordered pits along their sides.
- They have perforated plates.

Diagram:



Role of vessels and tracheids

- The vessels and tracheids conduct water and dissolved mineral salts through the plant ie: from the roots to the shoots.

Adaptations of the Xylem (vessels and tracheids) to transport

1. Both have long cells joined end to end. This allows the flow of water and dissolved mineral salts in a continuous column.
2. The end walls of the xylem vessels have been broken down forming uninterrupted flow of water from the roots to the leaves. Even in the tracheids where the end walls are present, larger bordered pits reduce the resistance of flow due to the presence of end walls. Absence of end walls in the vessels and presence of bordered pits in tracheids facilitate easy flow of water as resistance to flow is reduced.
3. There are pits at particular parts in the lignified walls. These allow lateral movement of water and mineral salts where this is necessary.
4. Narrowness of the lumen of vessels and tracheids increases the capillarity force.
5. The walls are lignified (for strength) making them especially rigid to prevent them from collapsing due to large tension force set up by the transpiration pull.
6. Impregnation of the walls with lignin material increases the adhesion of water molecules which helps the water to rise up the plant by capillarity.
7. Loss of protoplast in the vessels and tracheids leaves an empty lumen which forms a continuous tube as one cell rests on top of the other.
8. Since the conducting cells of the xylem tissues are dead, their materials are transported through them passively and this minimizes energy consumption.

Question: Describe the histology of the xylem conducting cells and show how they structurally relate to their function.

3. THE XYLEM FIBRES

-These are elongated, slender, thick walled and non conducting cells.

-They are thought to have been evolved together with the tracheids and they function as supporting elements.

-They also facilitate lateral movement of materials and they sometimes store food.

4. THE XYLEM PARENCHYMA

-These consist of simple undifferentiated living cells.

-They have lignified pitted walls and they are frequently arranged in radial sheets to form rays.

-They function as pathways for lateral movement of materials and they sometime store food.

(ii) The phloem tissue

- It is chiefly concerned with translocation of photosynthetically manufactured food from the autotropic parts (sources) to the heterotropic parts (sinks) of the plant.

Structure of phloem

The histology of the phloem tissue reveals the presence of the following structural cells:-

1. Sieve element.
2. Companion cells.
3. Phloem parenchyma.
4. Phloem fibres and sclereids

1. **SIEVE ELEMENTS**

   -These include the sieve cells and sieve tube members.

2. **COMPANION CELLS**

- These are associated with the sieve tube members only in the Angiospermophytes. They are highly specialized parenchyma cells.
- They arise from the same meristematic initial with the sieve tube cells.
- They contain nucleated dense cytoplasm in communication with the cytoplasm of sieve tube member by means of plasmodesmata in the pitted areas of the thin dividing walls.

3 .PHLOEM PARENCYMA

- These contain stored carbohydrates and accumulation of tannins and resins.
- The phloem parenchyma is always in communication with the sieve elements and companion cells by the adjacent sieve areas.

4. PHLOEM FIBRES AND SCLEREIDS

- These occur in both primary and secondary phloems.
- The walls may be lignified or not but generally pitted with simple or bordered pits thus facilitating lateral movements of food substances.

Phloem:

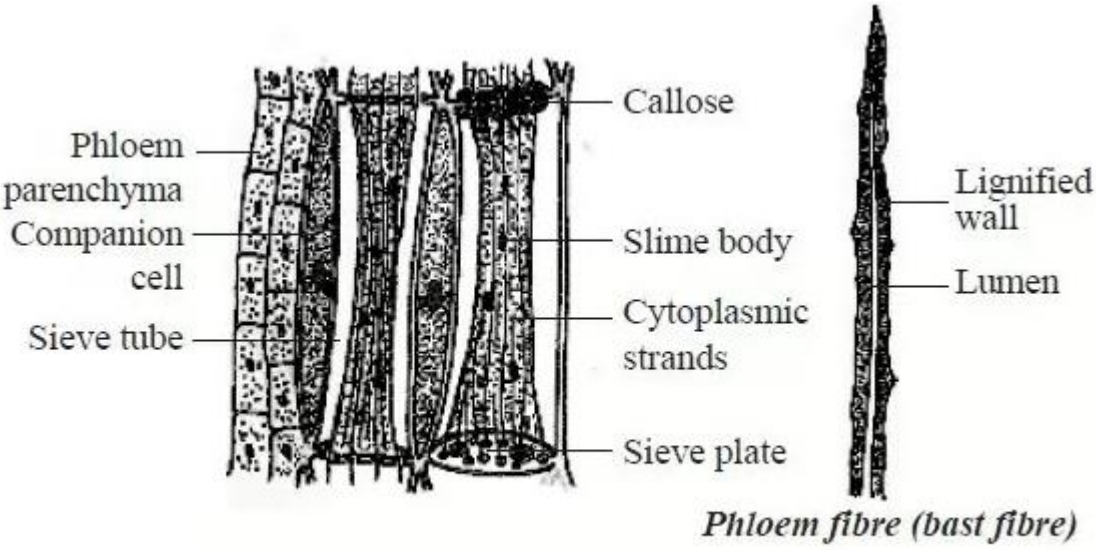


Fig. 2.7. Phloem tissue

Summary:
1. The sieve tube elements when mature do not have the nucleus, no ribosomes, no golgi bodies, no tonoplast. There are no mitochondria and there is a very little peripheral cytoplasm. However, the cells remain living since they

are connected to the companion cells

2. The companion cells have a dense cytoplasm with a nucleus, mitochondria and ribosome. The cells are very metabolically active.

3. The sieve tube members and the companion cells are in communication with one another by means of a large plasmodesmata.

Function of the phloem tissue:

- The role of the phloem (sieve tube) is to carry food substances from the leaves to the other parts of the plant.

Adaptations of the phloem:

1. The sieve elements are tubular to allow the passage of food substances.
2. There are sieve plates with various pits to facilitate the passage of food from one cell to another.

3. The pits in the sides together with plasmodesmata facilitate lateral movements of food.
4. The mitochondria in the companion cells provide energy necessary for active transport of food.
5. The tubes in the sieve elements are very narrow. This increases the pressure which in turn facilitates rapid transportation of food.

Questions:

1. Describe the structure of the phloem tissue and show how its structure relates to its function.
2. Describe the histology of the plant vascular tissue.

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(b) How is the structure of xylem tissue suited to its function of transporting water.

Movement of materials across the root

- Water and dissolved mineral salts from the soil, enter the root by osmosis across the epidermis of the root hair cells.
- In the root, these materials move through three different routes/pathway namely:-

1. Apoplastic pathway.
2. Symplastic pathway.
3. Vacular pathway.

I. Apoplastic pathway

Definition:

- The apoplastic pathway is found throughout the plant. However, in the root endodermis, it is prevented by the water proof substances called Suberin or Casparian strips.
- Due to the presence of casparian strips, the moving water and dissolved mineral salts are forced into the living protoplast of the endodermis as the only available route to the xylem. This in turn, causes active secretion of salts into the vascular tissues from the endodermal cells. This makes water potential in the xylem lower (more negative) thereby increasing more chances for water to move into the xylem.

Significance of the casparian strips:

1. They increase the chances of water moving into the xylem. This is because as they force water into the living protoplast of the endodermal cells, they cause salts to be actively secreted into the vascular tissue (xylem)from the endodermal cells. This makes water potential in the xylem lower (more negative), the result of which water moves into the xylem following a water potential gradient.

2. They prevent an apoplast movement of water and dissolved mineral salts and therefore water and salts must pass through the cell membrane under the cytoplasmic control of the endodermal cells i.e They ensure the control of moving water by the living cells.
3. They regulate salts movement and may be protective measures against entry of toxic substances example; Fungal pathogens.
4. They serve the life of the cell when it plasmolyses as the cell surface membrane remains held in position at the strips although other parts detach.
5. Since they are water proof bands, they normally regulate the amount of water to be admitted into the root.
6. They are connected for maintenance of root pressure since they cause active secretion of ions/salts into the xylem vessel.
7. It acts as an air tight dam in that it prevents water from being clogged with air.

1. **Symplastic pathway**

   Definition:

1. **Symplast:-**Is a system of interconnected protoplasts in the plant in which the cytoplasm are connected by the plasmodesmata, the cytoplasmic strands that extend from one cell to another through the pores in the cell wall.

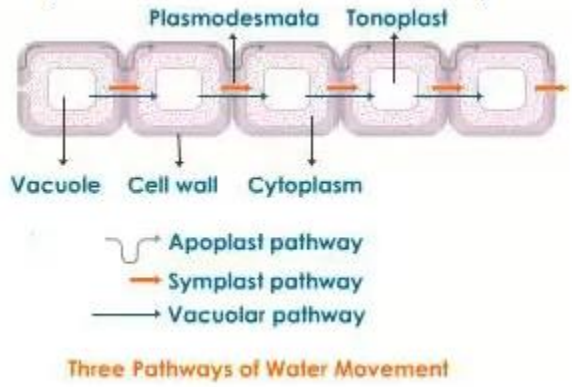
- The system in which the plasmodesmata link to ensure a living connection between the two neighbouring cells is called a **Symplasm.**

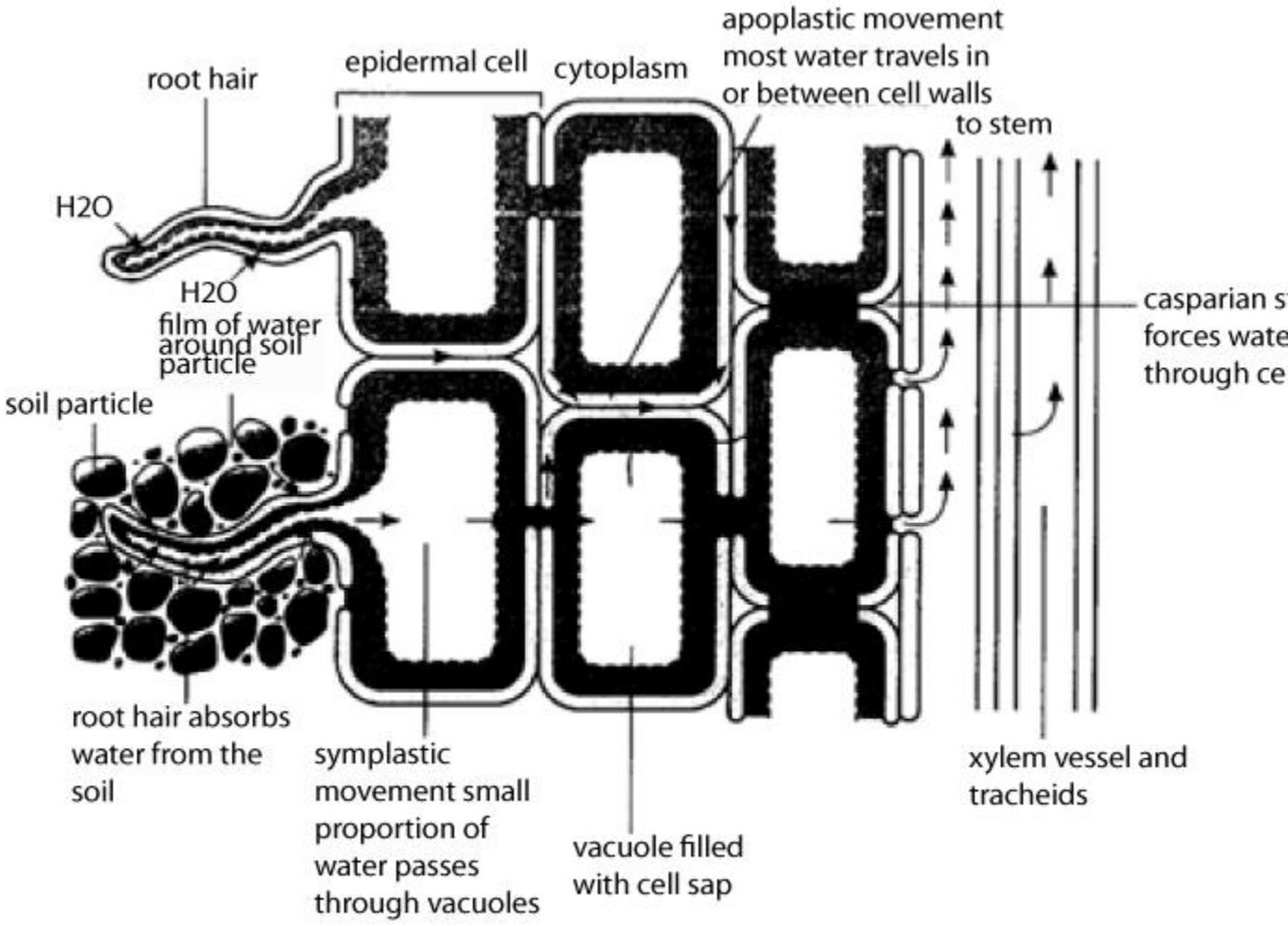
(ii) Symplastic pathway:- It is a pathway in which water moves from the cytoplasm of one cell to that of another through the pits by the aid of the plasmodesmata.

1. **Vacuolar pathway**

   In the vascular pathway, water moves from vacuole to vacuole. In this process, water moves across the cell surface membrane and tonoplast by the process of osmosis.

Diagram: **Routes for water transport across cells**





Questions:

1. Give an illustrated description of the pathway through which water and mineral salts pass from the root hair to the xylem vessel.

1. Describe the significance of the casparian strips in the root endodermal cells.

Uptake of mineral salts and their transport across the root and through the plant

- The plants take in the necessary mineral salts from the soil and their absorption is greatest in the region of root hairs. These are taken in either solution form or ions.

To explain the absorption of mineral salts, the following facts should be adhered to;

- The cell membranes including the cell surface membrane and the tonoplast are not true semi permeable, but rather are differentially (selectively) permeable allowing some minerals to pass.
- Minerals may be absorbed either passively or actively.

I.Passive absorption

If the concentration of a mineral in the soil solution is greater than its concentration in a root hair cell, the mineral may enter the root hair by **diffusion**.

II.Active absorption

If the concentration of a mineral in a soil solution is less than that in a root hair cell, it may be absorbed by active transport. Most minerals are absorbed in this way. The process is selective because active absorption requires energy; the rate of absorption is dependent upon respiration.

- There is a continuous system of interconnected cell walls, the apoplast in which water and any solute it contains enters by **Mass flow** and to a lesser extent by **diffusion**.
- Although leaves can also absorb them if sprayed with a suitable solution, such sprays are called **foliar feeds.**
- Water moves through the apoplast as a part transpiration stream. Transpiration stream is a movement (flow) of water from a root to the stomata.

Question:

Concisely but precisely, describe the process of uptake of mineral salts by the root.

Ans:

- Generally the concentration of mineral salts in the root hair cells is greater than that in the surrounding environment. This implies that the mineral salt enter the plants against the concentration gradient.
- However, some ions are more concentrated than others. This suggests that ions are selectively absorbed by active transport involving the expenditure of energy from ATP.
- Basically, ions (minerals salts) are absorbed from the soil by the root hair cells, where prime role is to increase the surface area for absorption. They are taken in together with water in order to form solutions after dissolving.
- After absorption, they move to the xylem tissue through the apoplast pathway.
- In the endodermis, there are water proof bands called casparian strips which concentrate the ions before passing to the xylem vessels.
- In the xylem tissue, the ions together with water are carried upwards to the upper parts of the plant.

Upward movement of water and mineral salts

Once the mineral salts have been taken up from the soil, they enter the xylem together with water for their further transportation through the entire plant. This upward movement of water and mineral salts take place in the xylem vessels.

Forces governing upward movement of water and mineral salts

The forces that govern the upward movement of water and mineral salts through the plant include the following:-

1. Capillarity.
2. Root pressure.
3. Transpiration pull.

1. **Capillarity**

- Capillarity (capillary forces) is the upward force that draws water up the plant against gravitational pull.
- By this force, water moves up the plant through the narrow tubes of the xylem under the influence of pressure. The latter is due to narrowness of the xylem vessel tubes.
- Capillarity is an important force as it causes water to rise high up in the tall trees.

The cohesion – Tension theory:

- The cohesion theory describes the upward movement of water by capillarity through the plant.
- According to this theory, the rising of water from the root is caused by evaporation of water from the lenticels.
- Evaporation results in reduced water potential in the cells next to the xylem. Water therefore enters the cell from the xylem sap where it has a higher potential.
- The xylem vessels are full of water and as water leaves the xylem, a tension is set up in the column of water.
- This is transmitted back down the roots by cohesion of water molecule.
- The latter have high cohesion due to their polarity and therefore tend to stick together being held by the hydrogen bonds.
- Water molecules also tend to stick to the vessel walls by a force called adhesion. Thus, the tension in the xylem vessels builds up a force capable of pulling the whole column of water upwards by mass flow.
- Water thus, rises in the fine capillary tubes due to high surface tension.

2. Root pressure

- Water initially enters the root cells by osmosis from the soil solution and in that way it lowers the solute potential of root epidermal cells.
- An active secretion of salts and other solutes into the xylem sap, tends to lower its water potential and for this reason water moves from one root cell by osmosis and then into the xylem.

- The overall result is the creation of the root pressure which generates a hydrostatic pressure which causes a continuous upward movement of water.
- However, this force alone is not sufficient to draw up water except in the slowly transpiring herbaceous plants where it causes guttation.

3. Transpiration pull

During transpiration; water is lost from the epidermal cells, as a result the water potential is lowered in the respective cells. Consequently, water is drawn from the xylem vessels whose sap has a higher water potential into the epidermal cells of the leaf.

- This creates a continuous stream of water flow called a TRANSPIRATION STREAM which is a main route of upward movement of water and dissolved mineral salts. The force that pulls water upwards in favour of transpiration is called TRANSPIRATION PULL.

TRANSPIRATION

Definition:

Transpiration is a process whereby a plant loses water from the epidermal cells of the leaves in the vapour form.

TYPES OF TRANSPIRATION

- There are three types of transpiration:-

(a) Stomatal transpiration

- This is a major way by which water evaporates from the plant leaves. It is a type of transpiration where by the plant loses water through the stomatal pores.

(b)Cuticular transpiration

- This involves loss of water through the cuticle. In this way a very little amount of water is lost from the plant because the cuticle among other functions restricts water loss from the plant.

(c)Lenticular transpiration

- This involves loss of water by the lenticels.
- The latter are small slits in the stems and bark of trees for gas exchange.

Significance of transpiration in plants:

Transpiration is considered to be "Necessary evil". This is because it is an inevitable but potentially harzadous process. It thus, has beneficial and harzadous effects.

1. **Beneficial effects**

Transpiration is necessary in that;

1. It is a means of transportation of water and dissolved mineral salts through a plant.
2. It is a means of cooling the plant ie: evaporation of water from the surface of the plant eg: leaves has a cooling effect.
3. It is a means of removal of excess water as waste product.
4. Aids uptake of water and mineral ions.

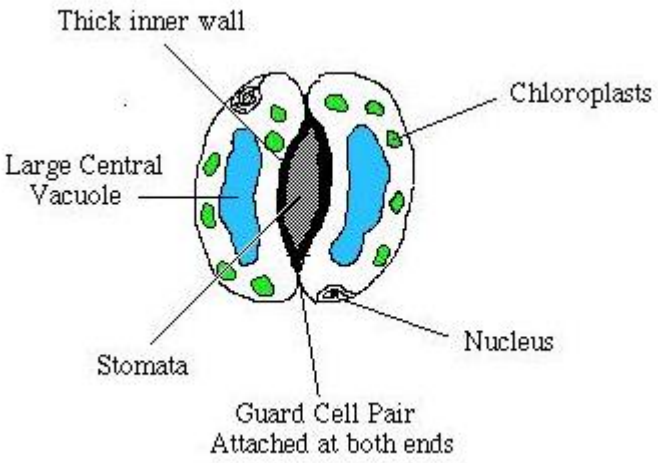
1. **Hazardous effects**

- Transpiration is an "evil" process because excessive transpiration (loss of water) leads to dehydration of cells.
- It also interferes with the process of photosynthesis, excretion, respiration etc. all of which require water.
- As a consequence of excessive water loss the plant wilts and finally dies.

STRUCTURE OF A STOMATA

- Structurally, the stomata pore is bordered by two sausage shaped guard cells. The latter have their inner walls being thick and less elastic whereas, the outer wall is thin and elastic (extensible).
- The guard cells have chloroplast capable of photosynthesis. Around the guard cells are the epidermal and subsidiary cells.

Diagram:



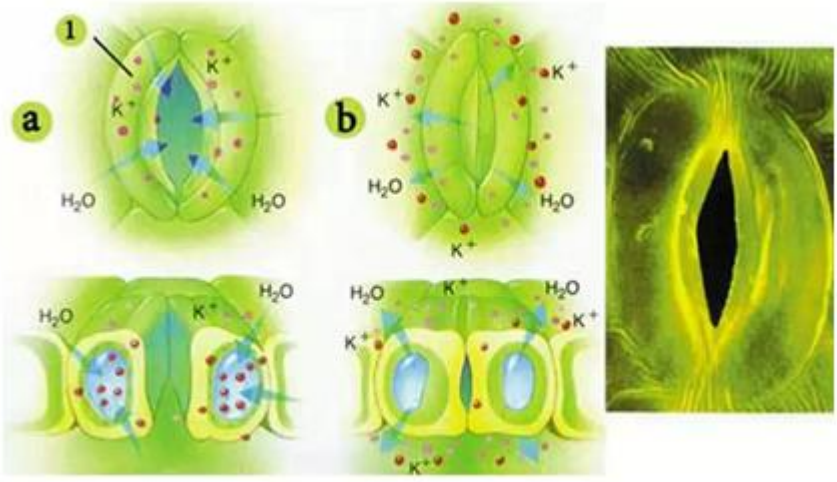
Mechanism of stomata closure and opening:

The closure and opening of the stomatal pore is caused by change in turgor pressure of the guard cells. If water is drawn into catalyses the hydrolysis of ATP into ADP and Pi and energy is released.

- The released energy used to pump K^+ ions into the guard cell and H^+ ions out of the guard cells. This also causes the inside of the guard cell to be alkaline.

- The accumulation of K^+ ion and glucose into the guard cells results into increased osmotic pressure in there.
- The result of this increased osmotic pressure is the osmotic movement of water in to the guard cells from the epidermal cells.
- Turgidity of the guard cells result into opening of the stomata aperture.
- On contrary during the night, K^+ ions are pumped out of the guard cells and H^+ ions are pumped in. There is also an accumulation of CO_2 in the intercellular spaces.
- This result into increased acidity of the guard cells ie: Fall in the pH value. This fall in pH value favours the association of glucose forming starch in the guard cells while in the surrounding epidermal cell K^+ ions (allophone) causes the accumulation of glucose.
- The net effect is the osmotic movement of water from the guard cells to the epidermal cells. Thus loss of water from the guard cells causes them flaccid and hence closure of the stomatal pore.

Illustration:



- Stoma is closed in the dark, but in the presence of light ATPase is stimulated to convert ATP to ADP and so provide the energy to pump out H^+ from the guard cells. These protons return on a carrier, which also bring Cl^- with it. At the same time K^+ enter guard cells.

- As a result of this influx of ions, the water potential of the guard cells becomes more negative (lower) causing H_2O to pass in by osmosis. The resultant increase in pressure potential causes the stoma to open.
- In the dark, the movement of ions and H_2O is reserved.

Question:

Describe the mechanism of stomatal closures and stomatal opening based on the osmotic pressure (Pressure flow) hypothesis.

- The guard cells, the latter become turgid and stomatal pore opens. And when the cells are flaccid, the stomatal pore closes. The guard cells, the latter become turgid and stomatal pore opens. And when the cells are flaccid, the stomatal pore closes.
- The guard cells have thicker inner inelastic walls and thinner elastic outer walls. During expansion they do not expand uniformly in all directions.
- The thick and less elastic inner walls are less pulled out wards leaving an open between them.

How is the mechanism explained?

1. A traditional hypothesis; the starch-sugar hypothesis suggested that an increase in sugar concentration in guard cells during the day led to their solute potential becoming more negative, resulting in entry of water by osmosis.

However, sugar has never been shown to build up in guard cells to the extent necessary to cause the observed changes in solute potential.

K^+ ion and osmotic pressure theories:-

It has now been shown that potassium ions and associated negative ions accumulate in the guard cell during the day in response to light and are sufficient to account for the observed changes.

In darkness, potassium (K^+) ions move out of the guard cell into surrounding epidermal cells. The water potential of the guard cells increases as a result and water moves out of the cells. The loss of pressure makes the guard cells change shape and stoma closes.

What causes Kâ• º to enter the guard cells in the light?

Ans: K^+ may enter in response to the switching on of an ATPase which is located into the cell surface membrane which pumps out H^+ and K^+ may then enter to balance the charge.

More explanations:-

- During the day, the plant photosynthesizes by consuming CO_2.

- This reduces the concentration of CO_2 in the intercellular spaces of the leaf.
- This lowers the level of Carbonic acid and hence a rise in pH value ie: The cells become more alkaline.
- This favours the conversion of starch into glucose which accumulates in the guard cells. At the same time the enzyme ATPase.

2. Using carbon – 14 isotope

- If a plant with a ringed stem is supplied with CO_2 containing C-14 isotope ie: $^{14}CO_2$, the food substances accumulated above the ring appear to contain C-14. This suggested that the synthesized food is translocated through the phloem.

3. Using mouth parts of a feeding aphid

- An aphid is an insect that uses its tubular needle – like mouth part to feed on the sugary solutions from the phloem sieve tubes.
- If the feeding insect is anaesthesized with CO_2 and the mouth parts are carefully cut so that the tube remains inserted into the phloem vessel, the food substances continue to move through the tubular needle of aphid.
- Analysis of this solution reveals the presence of sugary substances and amino acids all of which are the products of photosynthesis.

4. There are diunal variations in the concentrations of the glucose which are in turn reflected in the phloem sieve tubes.

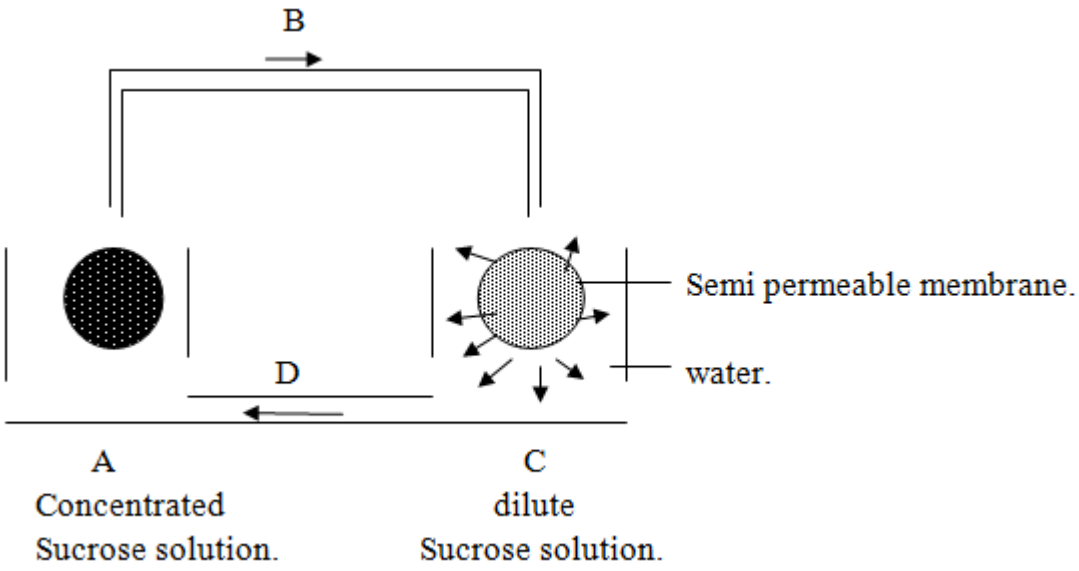
Mechanism of Translocation by the phloem:

There is no one agreed mechanism by which food substances are translocated through the phloem. However there are various hypotheses that try to describe the mechanism of phloem translocation. They include:

A. Mass flow hypothesis (Münch 1930)

This is also called Münch's hypothesis or pressure flow hypothesis. According to this hypothesis, food substances are translocated through the phloem in a mass flow mechanism.

Consider the munch model bellow:



- Could the ions reach the xylem entirely by means of the apoplast pathway?

Ans: No, the endodermis is a barrier to the movement of water and solutes through the apoplast pathway. This is due to the presence of casparian strips which prevents further progress

- To cross the endodermis, ions must pass by diffusion or active transport through the cell surface membranes of endodermal cells, entering their cytoplasm and possibly there vacuoles. Thus the plant monitors and controls which type of ions eventually reach the xylem.

Ions can also move through the symplast pathway. The final stage in the movement of mineral salts across the root is the release of ions into the xylem.

Once in the xylem, they move by mass flow throughout the plant in the transpiration stream.

The chief sinks, ie: Regions of use, for mineral elements are the growing regions of the plant, such as the apical and lateral meristerms, young leaves, developing fruits and flowers and storage organs.

Translocation of the manufactured food:

- In higher vascular plants, food substances are translocated through the phloem.

Evidence to show that phloem translocates food:

(i) Ringing experiment.

A ring of tissue containing phloem was removed from the outer region of the stem, leaving the xylem intact. It was found that the leaves did not wilt, but growth below the ring was greatly reduced. This is because, movement of sugars down the plant were stopped without affecting passage of water upwards.

Description of the model

- In the model, there is an initial tendency of water passing by osmosis into A and C. However, the tendency is greater for A than for C because the solution in A is more concentrated than that in C.
- As water passes into A, a pressure potential (hydrostatic pressure) builds up in the closed system A-B-C forcing water out of C.
- Mass flow of solution occurs through B along the hydrostatic pressure so generated.
- There is also an osmotic gradient from A to C and eventually the system comes into equilibrium as water dilutes the contents of A and solutes accumulate at C.

Application of the model to the living plant

- The leaves which make sugars during photosynthesis are represented by A. The synthesized sugars, lower the water potential of the leaf cells and consequently this fuses the flow of water into the leaves by osmosis through the xylem (D).

- Due to hydrostatic pressure generated into the phloem (B), food from the source (A) to the sinks such as roots and storage organs (C) are transported in a mass flow system.

- In the plants, equilibrium is not reached because sugars are constantly being made at sources (A) and constantly being used at sinks (C).

Critique (weakness) to the hypothesis

1. It is purely physical explanation and so does not explain why sieve tubes must be living and metabolically active.
2. It does not explain the observation that the leaf cells are capable of loading sieve tube against the concentration gradient. ie: The fact that the Ψ_s of sieve tubes is more negative than that of the leaf cells. The hypothesis

   has therefore been modified to include an active loading mechanism of solutes into the sieve tubes. The osmotic and hydrostatic pressure gradient therefore starts in the tubes rather than in the photosynthetic cells. It is

   also believed that unloading at the sinks is an active process.

3. It ignores the membrane barriers between the sieve tubes and the plastids.
4. It assumes an empty sieve lumen and fully open sieve plate pores.

(B) Transcellular strands hypothesis (THAINE).

- The hypothesis was described by Thaine. It explains the role of phloem proteins in the translocation of food.
- According to Thaine, the protein fibrils that run from one end of the sieve tube to the other are the ones that carry food substances.
- The food substances pass along these fibrils due to the peristatic action of the protein sheath in a manner resembling cytoplasmic streaming.
- This is an active transport and it accounts for transportation of materials in both directions in the same sieve tube.

Ideas of the hypothesis are summarized as;

(i) Food is transported by phloem protein, due to peristatytic action the food flows along the fibres.

(ii) Food is transported in both directions.

(iii) Food is transported actively.

(C) ELECTRO – OSMOSIS HYPOTHEIS (SPANNER)

- According to Spanner, the flow of food is produced and maintained by electro-osmotic force set up across the sieve plates.
- According to this hypothesis, K^+ ions are actively transported across the sieve plates, carrying with them water and dissolved mineral salts.
- This means that K^+ ions create an electric potential gradient as a result of which water molecules flow through the sieve plates carrying the sucrose molecules with them.

(D) SURFACE SPREADING HYPOTHESIS

In this hypothesis, the idea is that the solute molecules might spread over the interface between two cytoplasmic materials as oil spreads over an air-water interface the form of bands called Casparian strips. Therefore water and solutes particularly salts in the form of ions, must pass through the cell surface membrane and into the living part (cytoplasm) of the cells of endodermis. In this way the cells of the endodermis can control and regulate the movement of solutes through the xylem. Such control is necessary as a protective measure against the entry of toxic substances, harmful disease-causing bacteria, fungi etc.

As roots get older, the extent of suberin in the endodermis often increases. This blocks the normal exit of water and mineral salts from the cell

Uptake of mineral salts and their transport across roots.

In plants, minerals are taken up from the soil or surrounding water by roots. Uptake is greatest in the region of the root hairs.

Note:

- Mineral elements exist in the form of salts which are made up of ions, and in solution the ions can separate (dissociate) and move freely.
- Ions can cross membranes in a number of ways, including:-

1. **Active uptake** (transport)- In which ions are taken up into cells against a concentration gradient using energy from respiration.
2. **Passive uptake**- Where ions move by mass flow and diffusion through the apoplast.

The figure below shows the uptake of K^+ ions by young cereal roots which had previously been thoroughly washed in pure water. After 90 minutes respiratory inhibitor potassium cyanide was added to the solutions.

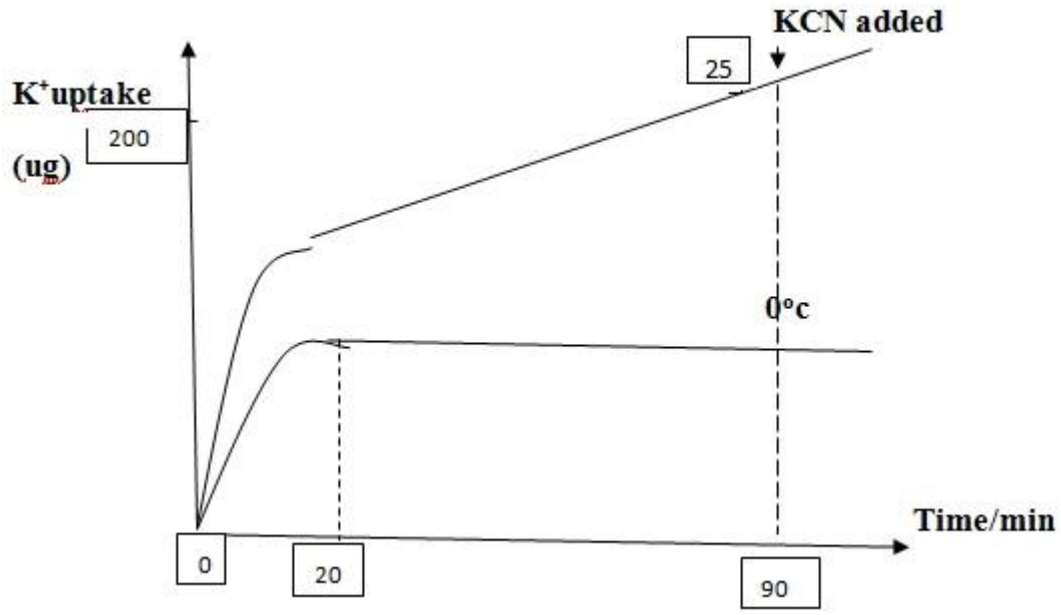


Figure above shows that two distinct phases of uptake. The 1st phase lasts for about 10 -20 minutes. Uptake during this phase is relatively rapid. K^+ ions come into contact with the epidermis of the root and start to move through the cell walls of the apoplast pathway, it is shown that this phase is more or less independent of temperature since it occurs just rapidly at 0^oC. It is passive process.

- The 2nd phase is temperature dependent and does not occur at 0°C when the rate of metabolism and respiration is very low. Its inhibition by KCN shows that it is dependent on respiration and the uptake at this time

  probably by active transport across all membrane into cells.

- Why the roots were thoroughly washed before placing them in a solution containing K^+ ions?

Answer:

To flush out any existing K^+ ions from the root

- It is shown that if the carrot discs are transferred from pure water to KCl solution, the rate of respiration increases. Why?

Answer:

Rise in respiratory rate is accompanied by a rise in KCl uptake. Once KCl is available, it is therefore apparently taken up by active transport, the energy being supplied by an increased respiratory rate.

- If KCN is added, the rise in KCl stops, this is because KCN inhibits respiration and therefore inhibits active transport of KCl into the carrot discs.

GUTTATION

- Guttation is a physiological process of the plants in which water is lost in form of liquid / droplets.
- The process occurs in members of the grass family, and in species found at the leaf margin and apex.
- Guttation is favoured by those factors that favour low rate of transpiration eg: High humidity, low temperature, absence of light etc.

Question. Summarize differences between guttation and transipiration.

Ans:

Transipiration	Guttation
(1) Water is lost in form of vapour	-Water is lost in form of liquid.
(2) It occurs all the time	-It occurs only at night.
(3) It occurs in stomata, cuticle and lenticels	-It occurs in the hydathodes.
(4) It is favoured by high temperature, low humidity and light	-Favoured by high humidity, low temperature and darkness.

(5) Occurs in all plants	-Occurs only in members of the grass family.

Evidence to show that xylem transports water

The evidence for water transportation in the xylem comes from the following observations:-

1. If a red dye such as cosin is dissolved in water and a cut end of the stem is immersed in that water, the plant takes water. After a time lag, the red dye is traced in the xylem vessels. That shows that xylem transports water.

2. If molten fats are added into water having a plant example; Potted plant, as the plant absorbs water, it takes some fats too. The latter block the xylem vessels resulting into wilting of the plant.

3. Ringing experiment

If a part of stem is ringed to remove the phloem, the plant does not wilt. However, if the tissues beneath the phloem are removed, the plant wilts showing that the removed tissues are xylem.

Question. Summarize the properties of xylem which make it suitable for the long distance transport of water and solutes.

Answer

1. Long tubes formed by fusion of neighboring cells, with breakdown of cross walls between them.
2. No living contents, so less sensitive to flow.
3. Tubes are rigid, so do not collapse.
4. Fine tubes are necessary to prevent water columns from collapsing.

Uptake of water by roots

Water moves across the root by pathways similar to those in the leaf namely apoplast, symplast and vacuolar pathways.

Symplast and vacuolar pathways

As water moves up the xylem in the root, it is replaced by water from neighboring parenchyma cells. As water leaves cell A, the water potential of cell A decreases and water enter it from cell B by osmosis or through the symplast. Similarly, the water potential of cell B then decreases and water enters it from cell C and so on across the root to the epidermis.

The soil solution has a higher water potential than cells of the epidermis including the root hairs. Water therefore enters the root from the soil by osmosis.

Apoplast pathway

The apoplast pathway operates in much the same way as in the leaf. However, there is one important difference. When water moving through spaces in the cell walls reaches the endodermis, its progress is stopped by a water

proof substance called **Suberin** which is deposited in.

Question. Why does transpiration occur mainly through leaves and not so much through the cuticle and lenticels?

Answer:

- Leaves contain a very large number of stomata for gaseous exchange and there is little resistance to movement of water vapour through these pores.
- Leaves have a large surface area (for trapping sunlight and exchanging gases). The greater the surface area, the greater will be the loss of water by transpiration.

FACTORS AFFECTING THE RATE OF TRANSPIRATION

- The factors that affect the rate of transpiration are of two main categories;

1. External (Environmental) factors.
2. Internal (plant) factors.

A: External factors

(i) Light

The rate of transpiration is high during the day. This is because the stomata pores get open due to turgidity of the guard cells. Thus, to night when the stomatal pores are closed, only lenticular and cuticular transpiration occur.

(ii) Temperature

High temperature favours the rate of water loss from the mesophyll cells. High temperatures do also lower humidity of air around the leaf. All these favour loss of water from the leaf to the surrounding area.

(iii) Humidity and vapour pressure

Low humidity around the leaf favours transpiration, because it results into a steeper diffusion gradient of water from the leaf atmospherer to external atmosphere.

(iv) Wind (Air currents)

If the air is still, the rate of transpiration becomes low. This is because the humidity of the atmosphere is high. If air is in motion (in windy situation) the rate of transpiration is high. This is because the blowing wind sweeps away the water vapour concentrated around the leaf surface thereby lowering the humidity and hence favoring high rate of transpiration.

(v) Availability of soil water

The rate at which the plant loses water by transpiration depends in the amount of water available in the soil. If the soil has insufficient amount of water, the rate of transpiration gets reduced as in decidious trees that shed their leaves in the dry season.

B: Internal factors

The plant factors include the following;

1. **Surface areas to volume ratio** – The greater the surface area to volume ratio, the greater is the rate of transpiration, since broad leaves have high transpiration rate than narrow leaves.
2. **Cuticle** (water proof material)-The thinner the cuticle, the higher the rate of transpiration and vice versa.
3. **Stomata**

(a) Size of the stomatal pore – The larger the size of the stomatal pore, the higher the rate of transpiration and vice versa.

(b) Number of the stomatal pore – The greater the number of stomata, the higher the rate of transpiration.

(c) Density of stomata

- The higher rate of transpiration occurs at the upper side of the leaf because it is at this side where stomata are directly exposed to light energy.

  Question: Describe the factors that affect the rate of transpiration.

  The molecular film so formed could be kept moving by molecules being added at one end removed at the other.

(E) ACTIVE TRANSPORT HYPOTHESIS

- This suggests that, the translocation of food through the phloem involves some sort of active mechanisms. This is supported by the facts that;

1. The phloem tissue has a high rate of respiration and there is a close correlation between the speed of transduction and metabolic rate.

2. Lowering temperature and treating the phloem with metabolic poisons, also lower the rate of translocation. This means that the enzymes involved in the production of energy are affected.

Question:Describe the various hypotheses of the phloem translocation.

Xerophytic adaptations

- **Xerophytes** are plants which have adapted to conditions of unfavourable water balance. This is the condition where the rate of loss is potentially greater than the availability of water.

- **Mesophytes** are plants which have adapted to conditions where water is available.

- **Halophytes** are plants that live in salt marshes where the concentration of salts in the soil makes it difficult to obtain water. Halophytes also exhibit Xeromophic features.
- **Xerophytes** plants have evolved a wide range of features designed to reduce the rate of transpiration. These are known as Xeromophic features.

Xeromophic adaptations take three general forms:

1. Reduction in the transpiration rate – clearly anything which lowers the rate of transpiration helps to conserve water when in short supply.

2. Storage of water – Plants living in areas where water supply is intermitted, store water for use during periods of drought. Plants which store water are termed Succulents.

3. Resistance to desiccation – Some species exhibit a remarkable tolerance to water loss and resistance to wilting.

Xeromophic adaptations of plants

1. Features for reduction of the transpiration rate:-

1. **Thick cuticle** – Reduces cuticular transpiration by forming a waxy barrier preventing water loss.
2. **Rolling of leaves** – Preventing water diffusing out through stomata which are confined to the inner surface.
3. **Layer of protective hairs on leaf** - Moist air is trapped in the hair layer, so reduce transpiration rate.

4. **Absence of leaves -** Reduces the rate of transpiration.
5. **Orientation of leaves** – The positions of leaves are constantly changed so that the sun strikes them obliquely. This reduce their temperature hence rate of transpiration.
6. **More negative water** – This makes it more difficult for water to potential of the cell sap, be drawn from them.

2. Futures for succulence (water storage)

1. They have succulent leaves which stores water.
2. They have succulent stems which stores water.
3. Closing of stomata during day light, so reducing transpiration rate.
4. Shallow but extensive root systems – This allows efficient absorption of water over a wide area.

3. Features for resistance to desication

(a) Reduction of transpiration surface through loss or adaption of leaves.

(b) Lignification of leaves – Preventing it from wilting in times of drought.

(c) Reduction in cell size – Making the plants less liable to wilt.

Hydrophytes adaptations

- Plants living in wholly or partly submerged in water are called hydrophytes.
- The greatest problem for hydrophytes is to obtain oxygen for respiration.

Adaptations

(i)Plants have aeration tissue (Aerenchyma) which comprises large air spaces called Lucunae between the cells of the stem and leaves. These stores oxygen produced by photosynthesis which can be used for respiration.

(ii) Plants can tolerate high level of ethanol which is a product of anaerobic respiration.

(iii) Aerating tissue confers buoyancy, raising leaves to the surface where they can take maximum advantage of the light.

(iv) They lack supporting tissue (water provides support) which would make the plant more rigid, rendering it liable to breakage by water currents.

Evidence supporting the role of xylem in transporting minerals

1. The presence of mineral ions in xylem sap.
2. A similarity between the rate of mineral transport and the rate of transpiration.

3. Experiments using radioactive tracers show that where lateral transfer of minerals can take place, minerals pass from the xylem to the phloem.

NOTE:

- The xylem transports water and dissolved mineral salts from the roots to the leaves, and phloem transports sugars and other products of photosynthesis from leaves to other parts of the plants.
- The fascinating thing is that two systems employ quite different principle. Xylem transport is essentially a passive process, depending mainly on water potential gradients within the plant. Indeed, the xylem tissue in which it takes place is composed of dead cells. Phloem transport on the other hand is an active energy requiring process which takes place in living tissue.

Factors affecting the rate of translocation

1. **Temperature** - Increase in temperature up to a maximum of about 35^{o} C, increases the rate of translocation probably by affecting the enzymes involved in the secretion and removal of sucrose from the tubes.
2. **Light**– Translocation to the roots is greatly enhanced in the dark.
3. **Metabolic inhibitors**– Hydrogen cyanide and dimtrophenol inhibit carbohydrate translocation.
4. **Concentration gradients** - Carbohydrate seems to move from regions of higher concentration to regions of lower concentration.
5. **Mineral deficiencies**- Boron seems to be important in forming an ionisable complex with sucrose which then passes more easily through the cell membranes. It also appears to slow down the enzymic conversion of glucose-1-phosphate to starch thus keeping more sugar available for translocation.
6. **Hormones** – Cytokinins, IAA and gibberellins appear to at best control translocation, probably by their effects on metabolic rates at the source and sink.

(II) TRANSPORT IN ANIMALS

As organisms increase in size and complexity so the quantity of materials moving in and out of the body increases. The distance that materials have to travel within the body also increases, so that diffusion becomes inadequate as a means for their distribution.

There are two circulatory systems which rely on mass flow in animals, names:-

- Vascular system and

- Lymphatic system.

In animals, materials are transported through blood vascular system which is characterized by the following features;

1. Presence of the circulatory fluid eg: blood.
2. Presence of the tubes in which the blood flows eg: blood vessels.
3. Presence of a pumping device such as heart or modified blood vessels.

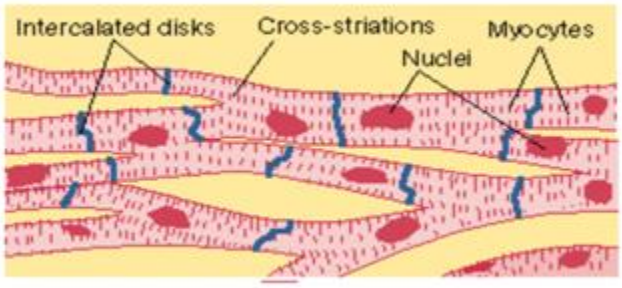
The cardiac muscle

The cardiac muscle is that muscle that forms the walls of the heart.

Structure of the cardiac muscle:

- Structurally, the cardiac muscle has fibers, each of which consists of cylindrical short cells arranged in columns. Each cell has a central nucleus, myofibrils and faint transverse striations.
- Adjacent columns are joined by oblique cross connections.
- The cells have abundant sarcoplasm and they are well supplied with blood and mitochondria.

Diagram:



Adaptations of the cardiac muscle

1. It is **striated** to confer strength so that it withstands the pumping pressure of the blood.
2. It is **highly vascularized** to ensure adequate supply of food and oxygen.
3. The **numerous mitochondria** supply the necessary energy required to pump the blood.
4. It is **myogenic** ie: Contraction and relaxation are initiated within itself.
5. It is **capable of contracting and relaxing throughout its life without any fatigue**.
6. **Cells can tolerate high levels of lactate** (a product of anaerobic respiration).

Composition of blood

(i) Plasma:- It consists of 90% water and 10% of a variety of substances in solution and suspension. ie: proteins, hormones, mineral salts, gases, wastes, water soluble vitamins B and C.

(ii) Blood cells:- They include;

(a) Red bood cells (RBC)- Which are packed with haemoglobin, the oxygen carrying compound which gives blood its red colour. They lack nucleus therefore makes more room for haemoglobin. RBC (erythrocytes) also lacks mitochondria which means they have to respire anaerobically. Therefore they do not use up any of the oxygen they carry.

RBCs also contain the enzyme carbonic anhydrase which plays an important role in carbondioxide transport.

(b) White blood cells (leucocytes)- They play an important role in the body's defence mechanisms against diseases.

(c) Platelets (Thrombocytes) – They are responsible for starting the process of blood clotting.

Types of circulatory systems in animals

Two distinct types of blood systems are found in animals;

1. Open blood system and
2. Closed blood system.

1. The open blood system

- This is a type of blood vascular system in which blood mixes with the body tissues.
- In this case, blood is pumped by the heart into an aorta which branches into a number of arteries.
- These open into a series of blood species collectively called **Haemocoel.**
- The blood then goes back through the open ended vein. In this system, the flow of blood cannot be adjusted and, the blood flows at a low pressure.
- This system is found in arthropods and molluscs.

2. Closed circulatory system

- This is a type of circulatory system in which the blood is confined to vessels.
- Blood never mixes up with the body tissues nor does it bath the organs directly.
- In this case, the speed of the blood can be adjucted, the blood is at high pressure and therefore goes around the body very quickly.
- This system is found in Annelids and vertebrates.

Question: Summarize the differences between open and closed circulatory systems.

Subdivisions of closed circulatory system

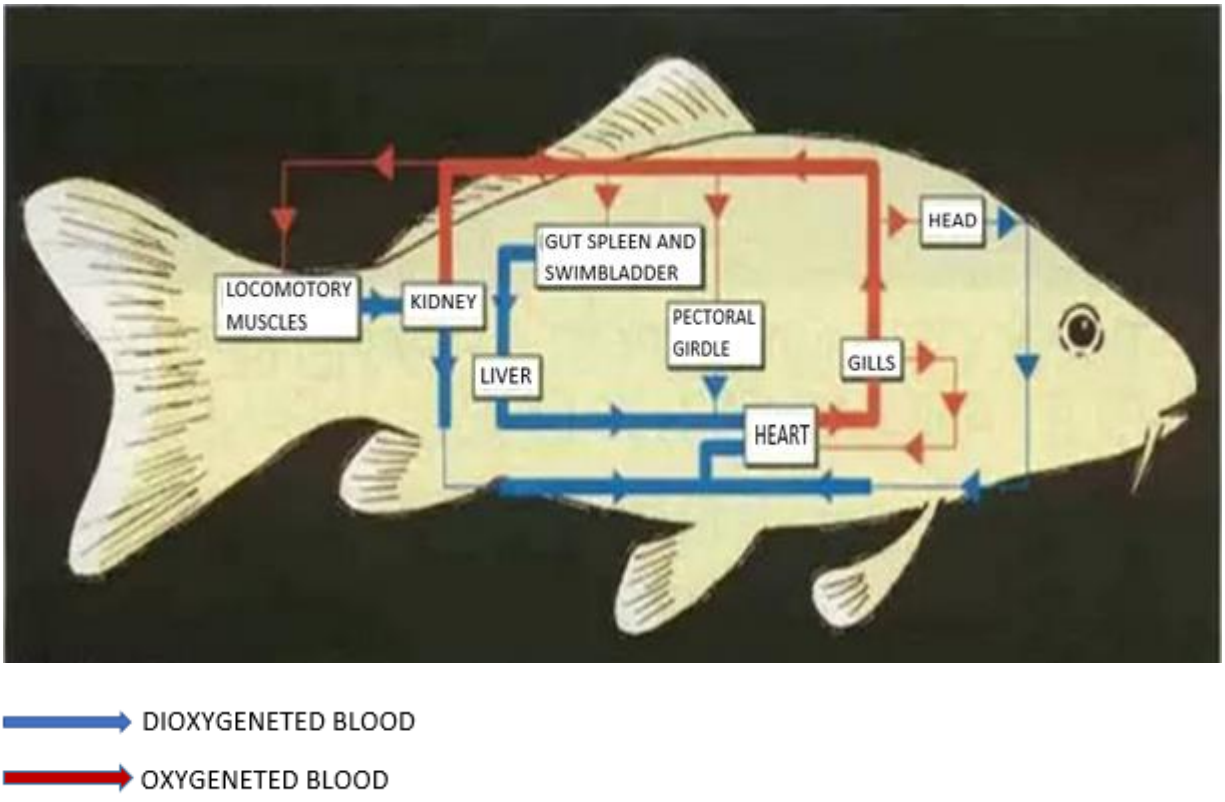
- The closed circulatory system is subdivided into:

(a) Single circulatory system

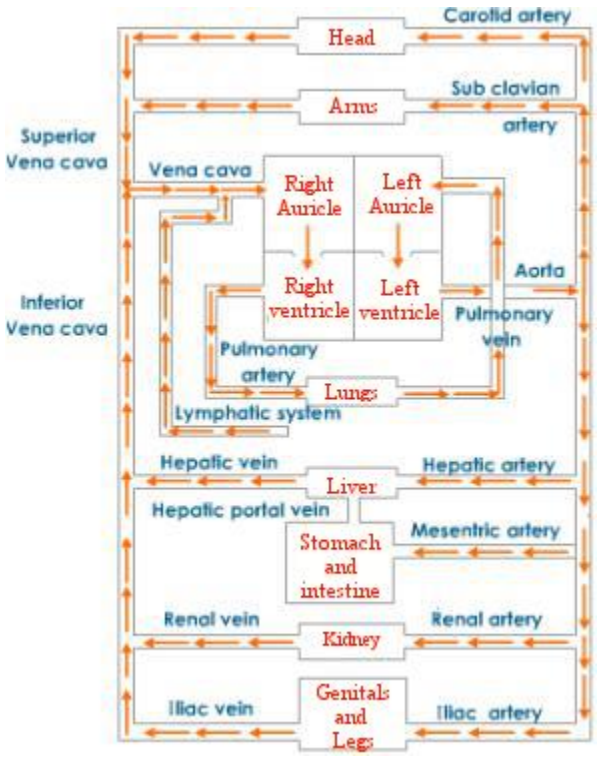
- This is a type of circulatory system in which blood passes the heart only once in a single complete circulatory turn.
- In fish for example blood from the heart first goes to the gills to collect oxygen, but then continues round the whole body before returning to the heart.

The deoxygeneted blood from various parts of the body passes direct to the heart which pumps it to the gills for being oxygenated for the circulation to begin once more.

(a) Diagram: Single circulation of blood in fish



(b) General plan of the mammalian circulatory system (Double circulatory system)



(b) Double circulatory system

- In this type of circulation, blood passed the heart twice in a single complete circulatory turn.

- Only birds and mammals have true double circulations. It is probably no coincidence that only birds and mammals are warm blooded.
- Warm-bloodedness requires a high metabollic rate and this is only possible if a good supply of oxygen is available for high levels of aerobic respiration. Animals with a high metabollic rate can maintain higher levels of activity than other animals.

Advantage of double circulation system

- Blood can be sent to the lungs to pick up oxygen and then be returned to the heart to be pumped again before travelling around the body.

Double circulatory system has;

(i) Pulmonary circulation and

(ii) Systemic circulation.

(iii) Coronary blood circulation.

(i) Pulmonary circulation

- This is a circulation between the heart and the lungs. Deoxygeneted blood from the heart is carried by the pulmonary artery to the lungs where as oxygenated blood from the lungs to the heart is carried by pulmonary vein.

(ii) Systematic circulation

The circulation between the heart and all other body parts except the lungs. Deoxygenated blood from various parts of the body is brought to the heart by the vena cava where as oxygenated blood from the heart is pumped to various body parts through the aorta.

(iii) Coronary circulation:- This is the circulation within the walls of the heart.

Features of a human circulation

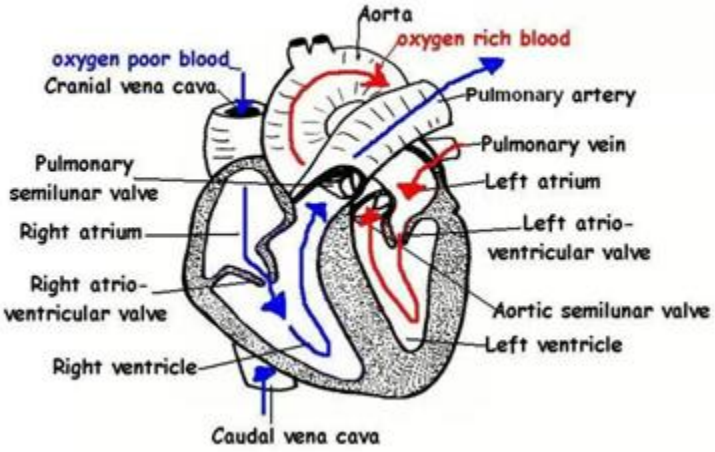
1. It is a double circulation.
2. The organs are arranged in parallel rather than in series. If they were arranged in series, blood would pass from organ. A to B to C and so on, losing pressure, oxygen and nutrients in each stage. This would be extremely inefficient. Also, any damage done to a blood vessel linking two organs would interrupt the whole circulation.
3. A portal vessel (vessel linking two organs neither of which is the heart) links the gut to the liver ie: Gut and liver are linked in series not in parallel.

Advantage of this series linkage is that blood from the gut is variable in composition and it contains other substances such as alcohol. Liver monitors blood passing through it and maintains a constant composition. Eg: Liver removes excess glucose from the blood and stores it as glycogen.

NOTE:

Vessels conveying blood away from the heart are called Arteries. These divide into smaller arteries called arterioles. The arterioles divide many times into capillaries where exchange of materials between blood and tissue takes place. Within the organ or tissue the capillaries reunite to form Venules which begin the process of returning blood to the heart. The venules join to from Veins. Veins carry blood back to the heart.

Section through heart, simplified diagram:



The cardiac cycle

- Refers to the sequence of events which takes place during the completion of one heart beat. It involves repeated contraction and relaxation of the heart muscle.

Contraction is called **Systole** and relaxation is called **Diastole.**

It occurs is follows;

1. **Atrial diastole** – During the time when the atria and the ventricles are both relaxed, blood returning to the heart enters the two atria. Oxygenated blood enters the left atrium and deoxygenated blood enters the right atrium. At first the bicuspid and tricuspid valve are closed but as the atria are filled with blood the valve are pushed open.

2. **Atrial systole** – When the atriole distole ends, the two atria contract simultaneously. This is termed as atrial systole and results in blood being pumped into the ventricles.

3. **Ventricular systole**. The ventricles contract and pressure rises in them and forces open the semi-lunar valve of the aorta and pulmonary artery and blood enters these vessels. During ventricular systole the first heart sound described as “Lub” is produced.

4. **Ventricular diastole** – Ventricular systole end and is followed by ventricular diastole. The higher pressure developed in the aorta and pulmonary artery tends to force some blood back towards the ventricles and this closes the semi-lunar valves of the aorta and pulmonary artery. Hence back flow into the heart is prevented. The closing of the valves causes the second heart sound “dub.” The two heart sounds are therefore:

   Ventricular systole = lub.

   Ventricular diastole = dub.

Myogenic contraction of heart rate

When a heart is removed from a mammal and placed in a well oxygenated salts solution at 37^{o}Cit will continue to beat rhythmically for a considerable time without stimuli from the nervous system or hormones. This demonstrates the **myogenic** nature of the stimulation of the heart, ie heart muscle has its own ‘build in’ mechanism for bringing about its contraction.

The stimulus for contraction of the heart originates in a specific region of the right atrium called the **SINO-atrial node (SAN).** This is located near the opening of the vena cavae. It consists of a small number of cardiac muscle fibers and a nerve ending from the automatic nervous system. The SAN can stimulate the heart beat on its own but the rate at which it beats can be varied by stimulation from the automatic nervous system.

The cells of the SAN slowly become depolarized during atrial diastole. This means that the charge across the membrane is gradually reduced. At a certain point an action potential is set up in the cell. A wave of excitation similar to a nerve impulse passes across muscle fibres of the heart as the action potential spreads from the SAN. It causes the muscle fibres to contract. The SAN is the PACEMAKER because each wave of excitation begins here and acts as the stimulus for the next wave of excitation.

Once contraction has begun, it spreads through the walls of atria through the network of cardiac muscle fibres and both atria contract more or less simultaneously.

The atrial musle fibres are completely separated from those of the ventricles except for a region in the right atrium called the **atrio-ventricular node** (AVN)

The structure of the AVN is similar to that of the SAN and is connected to a bundle of specialized muscle fibres, the AV bundle which provides the only route for the transmission of

the wave of excitation from the atria to the ventricles. There is a delay of approximately 0.15s in conduction from the SAN to AVN, which means that atrial systol is completed before ventricular systole begins.

The AV bundle is connected to the bundle of His (strand of modified cardiac fibres) which gives rise to finer branches known as Purkyne.

Impulses are conducted rapidly along the bundle and spread out from there to all parts of the ventricles. Both ventricles are stimulated to contract simultaneously. The wave of ventricular contraction begins at the bottom of the heart and spread upwards squeezing blood out of the ventricles towards the arteries which pass vertically upwards out of the heart.

NOTE: The period during which cardiac fibres do not respond is called **Absolute refractory period**. This period is longer in cardiac muscle than in other types of muscles and enables it to recover fully with becoming fatigued, even when contracting vigorously and rapidly. As muscle recover it passes through a relative refractory period when it will respond only to a strong stimulus.

Functions of mammalian Blood

1. Transport of digested food from the small intestine to various parts of the body where they are stored or assimilated and transport from storage areas to places where they are used.
2. Transport of soluble excretory materials to organs of excretion.
3. Transport of hormones from the glands where they are produced to target organs. This allows communication within the body.
4. Distribution of excess heat from the deeply seated organs. This helps to maintain a constant body temperature.
5. Transport of respiratory gases (ie: oxygen and CO_2).
6. Defence against diseases. This is achieved in three ways:-.

    i. Clotting of blood which prevents excessive blood loss and entry of pathogens
    ii. Phagocytosis which engulf and digest bacteria.
    iii. Immunity achieved by antibodies and lymphocytes

7. Maintenance of constant blood solute potential and pH as a result of plasma protein Activity

Transplantation

- Refers to the replacement of diseased tissue or organs by healthy ones.
- A technique is used increasingly in surgery today.
- However, when foreign tissue is inserted into another individual it is usually rejected by the recipient because it acts as an antigen, stimulating the immune response in the recipient.

Types of transplant:-

- **Isograft** - Grafting within the same individual.
- **Autograft** - Grafting between two individuals who are genetically identical.
- **Allograft** - Two individuals of the same species.
- **Xenographt** - Two individuals of different species.

- The details of these are beyond the scope of your level

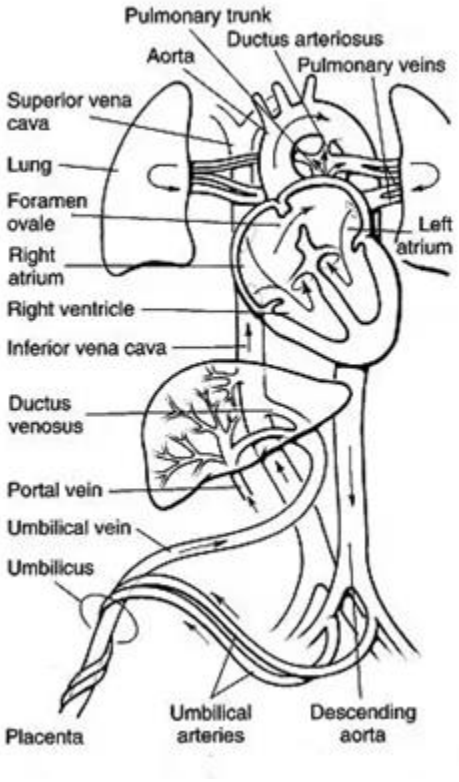
Comparison of the structure and function of:-

Artery	Vein	Capillary
- Transports blood away from the heart.	- Transport blood towards the heart.	- Link arteries to vein. Site of exchange of materials.
- Tunica media thick and composed of elastic & smooth tissues.	- Tunica media relatively thin and only slightly muscular. Few elastic fibres.	- No tunica media. - No elastic fibres.
- No semilunar valves (except where leaves heart).	- Semilunar valves present so as to prevent back flow of blood.	- No semilunar valves.
- Blood plow rapid.	- Blood flow slow.	- Blood flow slowing.
- Low blood volume.	- Much higher blood volume than capillaries or arteries.	- High blood volume.
- Blood oxygenated except in pulmonary artery.	- Blood deoxygenated except in pulmonary vein.	- Mixed oxygenated and deoxygenated blood.

Changes in fetal circulation at birth (The foetal circulation)

- Throughout the development in the uterus the fetal lungs do not function since gaseous exchange and nutrition are provided by the mother via the placenta.

- Most of the oxygenated blood returning to the fetus via the umbilical vein by-passes its liver in a vessel, the ductus venosus which shunts blood into the inferior vena cava and passes it to the right atrium.
- Some blood from the umbilical vein flows directly to the liver, blood entering the right atrium therefore contains a mixture of oxygenated and deoxygenated blood. From here most of the blood passes through an opening. Some blood passes from the right atrium into the right ventrical and into the pulmonary artery but does not pass to the lungs. Instead it pass through the ductus arteriosus directly to the aorta, so by-passing the lungs, pulmonary vein and the atrium and ventricle of the left side of the heart. Blood from the left atrium passes into the left ventricle and into the aorta which supplies blood to the body and the umbilical artery.
- Pressure into the fetal circulatory system is greatest in the pulmonary artery and this determines the fetus and placenta.



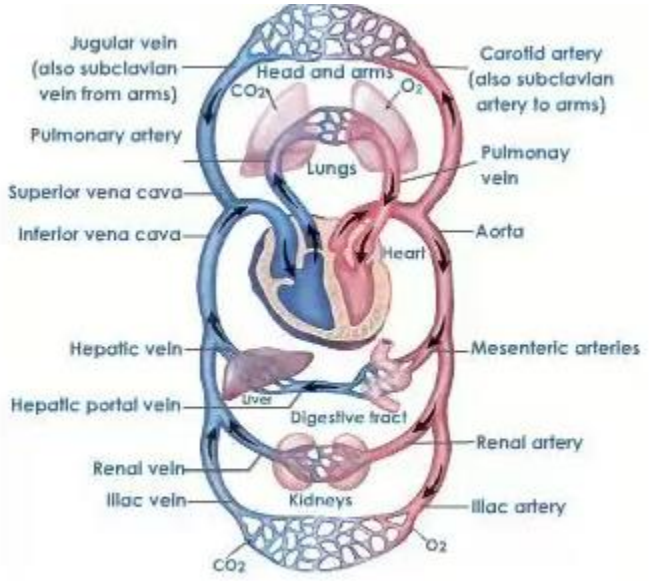
- The baby finally acquires an adult's circulatory system and independent physiology

Changes at birth

- At birth the sudden inflation of the lungs reduce the resistance to blood flow through the pulmonary capillaries and blood flows through them in preference to the ductus arteriosus; this reduces the pressure in the pulmonary artery. At the same time the typing of the umbilical cord prevents blood from flowing through the placenta, and this increases the volume of blood flowing through the body of the baby and leads to a sudden

increase in blood pressure in the aorta, left ventricle and left atrium. This pressure change causes the small valves guarding the foramen ovale which open to the left atrium to close, preventing the short circuiting of blood from right to left atrium. Within a few months these valves fuse to the wall between the atria and close the foramen ovale completely. If this does not occur, the baby is left with a "hole in the heart" and will require surgery to correct the defect.

The increased pressure in the aorta and decreased pressure in the pulmonary artery force blood backwards along the ductus arteriosus into the pulmonary artery and hence to the lungs, thereby boosting its supply. After a few hours, muscles in the walls of the ductus arteriosus constrincts under the influence of the rising of oxygen in the blood and close off this blood vessel. A similar mechanism of muscular contraction closes of the ductus venosus and increasing blood flow through the liver. The mechanism of closing down the ductus venosus is not known but is essential in transporting the ante-natal (before birth) circulation into the post-natal (after birth) condition.



Note:

Failure of the foramen ovule to close up, results into continued mixing up of the oxygenated and deoxygenated blood. Due to high concentration of CO_2 in the blood, the baby develops the blue tinks on its skin and it is described as a "Blues baby".

ROWTH AND DEVELOPMENT

Growth is a fundamental characteristic of living organisms.

OR

Growth – is defined as an irreversible increase in dry mass of living material.

OR

Growth is a permanent or irreversible increase in dry mass of protoplasm due to synthesis of proteins.

Dry mass is mass without water.

Why dry mass?

By specfifying dry mass we can ignore the short term fluctuation in the water content of the cells for instance when the plant cells take in water by osmosis. The reverse process can take place when cell lose water.

Other definitions of growth.

1. **Growth as increase in size**. This definition is inadequate some organisms e.g. plants can increase in size as they take in water by osmosis, but this process may be reversible when they lose water.
2. **Growth as increase in cells number**

   This definition is inadequate when the zygote divides repeatedly to form a ball of cells, they early embryo, there is an increase in cells number without increase in size of daughter cells.

   In some cases you can increase in size without increase in cells number e.g.: in the region of elongation behind the root and shoot tips.

3. **Growth as increase in number of individuals** (population of the single- celled organisms e.g. Micro – organisms such as bacteria)

Development: The process of development is so closely linked with growth that the phase "growth and development" is common used to the process which are normally thought of as growth. **Development** refers to an increase in complexity due to differentiation of tissues and organs (improvement in the functions of the body)

Growth can be regarded as change in the **quantity** as development is the change in **quality.**

Factors that affect growth

There are both external and internal factors that control growth.

External factors	Internal factors
1. Food/ nutrients	1.Genes
2. Diseases	2.Hormones
3. Temperature	3.Enzymes
4. Oxygen	
5. Light	
6. Space	
7. Toxins	
8. Soil	
9. Carbon dioxide(CO_2)	

Patterns of growth

1. **Positive and negative growth**

   Positive growth – it occurs when synthesis of materials (anabolism) increase break down of materials (catabolism)

   Example of positive growth in plants, the production of seedling which involve increase in cells number, cells size, fresh mass, length, volume and complexity of form as the seedling starts to photosynthesize and make up its own food.

Negative growth – occurs, when catabolism exceeds anabolism. Example increase in dry mass of germinating seeds

2. **Allometric and isometric growth**

Allometric growth occurs when organs grow at different rate. This produces a change in size of the organism which is accompanied by a change in shape of organism.

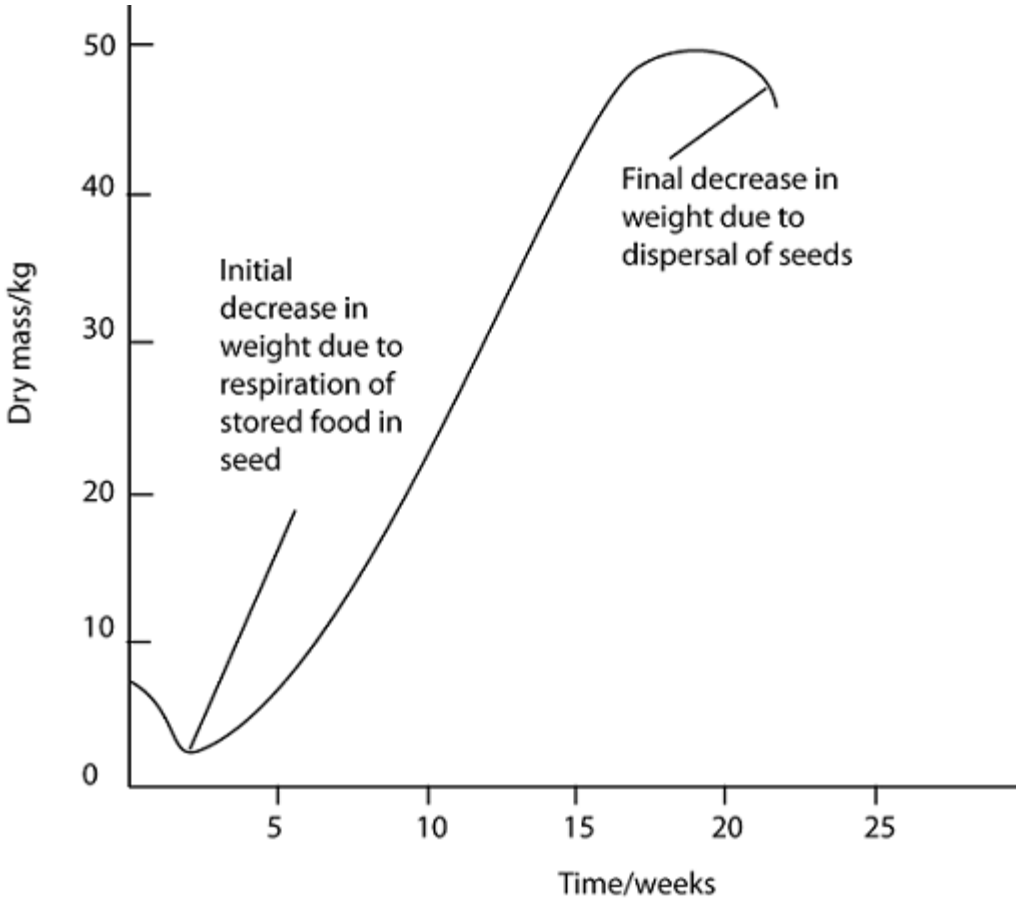
The pattern of growth is characteristic of animals. In almost all animals last organs to develop and differentiate are the reproductive organs. In man, the heart, brain and gonads all have different growth rate.

Isometric growth this occurs when organs grow at the same rate. In this situation, change in size of the organism is not accompanied by a change in shape, or external form of an organism.

This type of growth pattern is seen in fish and certain insects such as locusts

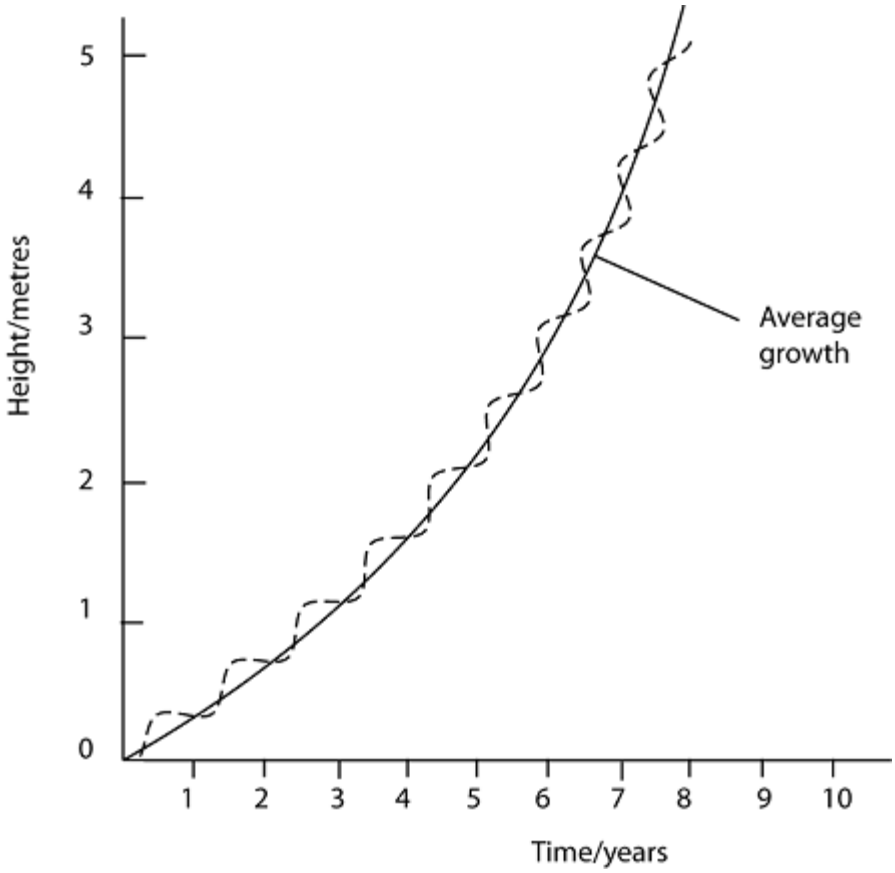
3. **Limited and unlimited growth**

Limited growth(**definite/ determinate**) - is the type of growth which shows a seization in growth when an organism matures and reaches a reproductive age. For example growth in annual plants.



The graph of Annual plants

Unlimited growth is a type of growth which occurs throughout the life of an organism. This growth occurs mostly in perennial plants. It is characterized by a series of sigmoid curves.



The graph of perennial plants

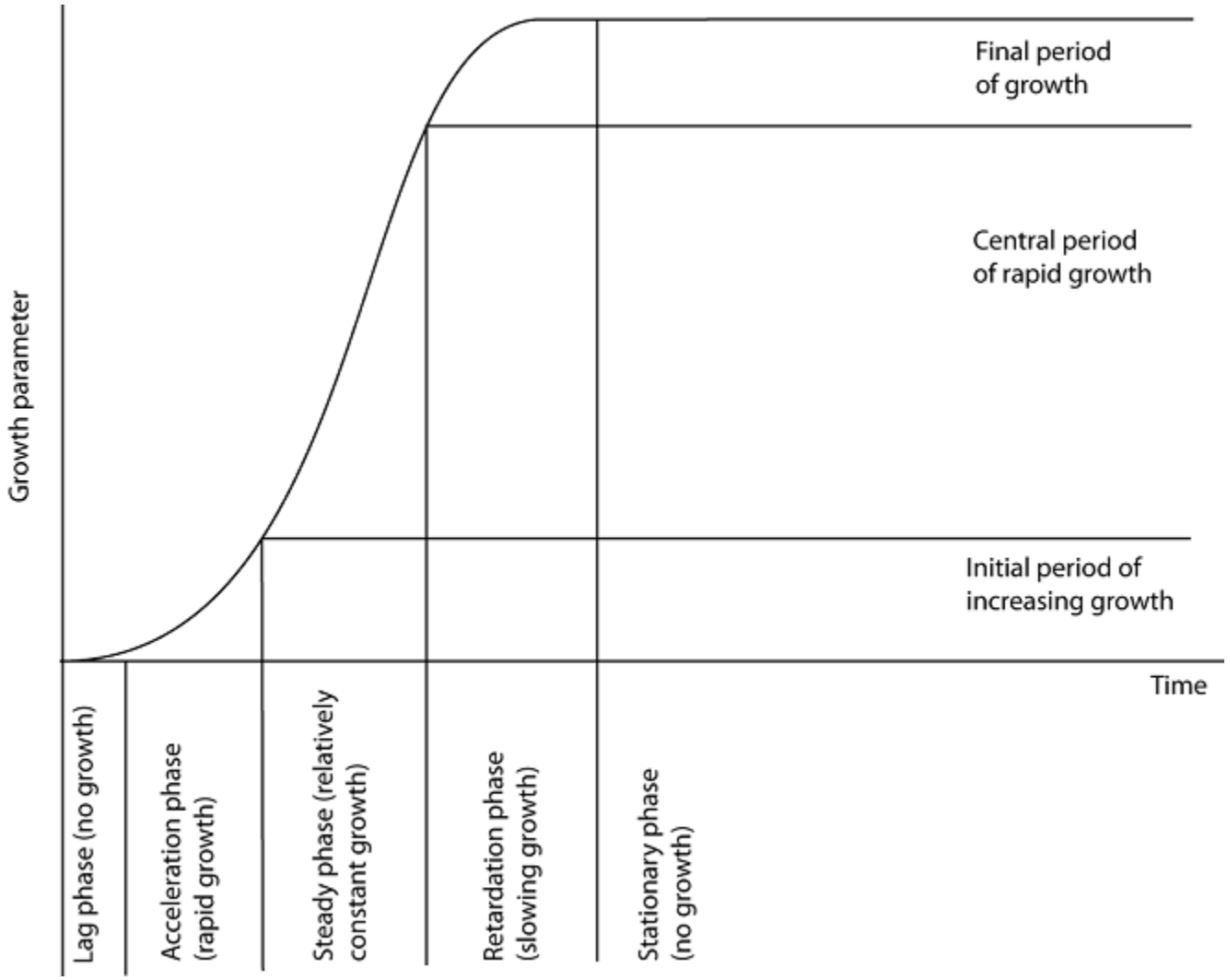
Measuring growth.

Growth can be measured using different parameters e.g. Length/ height, mass (dry/ fresh), weight, volume, area.

Growth curves

These are graphs obtained when data obtained from different parameters of measuring growth are plotted against time.

The curves show the overall growth pattern and extent of growth. It has found that growth pattern in many organism tend to be the same regardless the parameter used in measuring growth. In many cases if there is increase in measurable parameter is plotted against time a S- shaped growth curve is obtained. The shape of these curves is described as sigmoid, meaning S- shaped. The term sigmoid is derived from the Greek word sigma meaning letter S. A sigmoid curve is divided into four (4) parts or phases.



The sigmoid growth curve.

1. **Lag phase**

   This is the initial phase during which little growth occurs (slightly decrease in growth).In flowering plants this phase show a slight decrease in growth. This is the result of loss of dry mass during seed germination.

   In microorganism a few may die at the time of innoculation to the culture medium therefore showing decrease in number. Due to this phase the population of micro organism can grow rather slowly because they may have been in dormant state and time is required before their metabolism begin to work efficiently. Other reason for little growth for micro organism may be adjustment to the new diet.

2. **The log phase or exponential phase.**

This refers to the grand period of growth during which growth proceeds exponentially. During this phase the rate of growth is at maximum. The rate of growth is proportional to the amount material or number of cells or organism already present. In microscopic organisms this phase occurs when there is no limiting growth. Nutrients and oxygen are in plentiful supply umple space is available. In flowering plants is the period when green follicles increase in amount.

3. **Stationary phase**

   This marks the period where the overall growth has ceased .The parameters under consideration remain constant In micro organisms it is the phase when the number in the culture stabilize besides they neither decrease nor increase i.e. the number of individual dying are approximately equal to the number of new individual formed.

4. **Decelerating phase (decline phase)**

   This is the period in which growth become limited as the result of the effect of some internal and external factors, or the interaction of both. In many mammals including humans, this marks the period of negative growth. It is a period of senescence associated with increasing age.

   In micro organisms which are grown in a confined environment, this is the period where the carrying capacity of the environment declines and it is unable to support the high density of organisms. Nutrients are decreasing and excretory products are increased in the medium. The rate of growth keeps on decreasing until all organisms die as a result of starvation, shortage of oxygen or presence of waste products in toxic amount.

   Diagram showing a sigmoid curve

1. **Growth in arthropods**

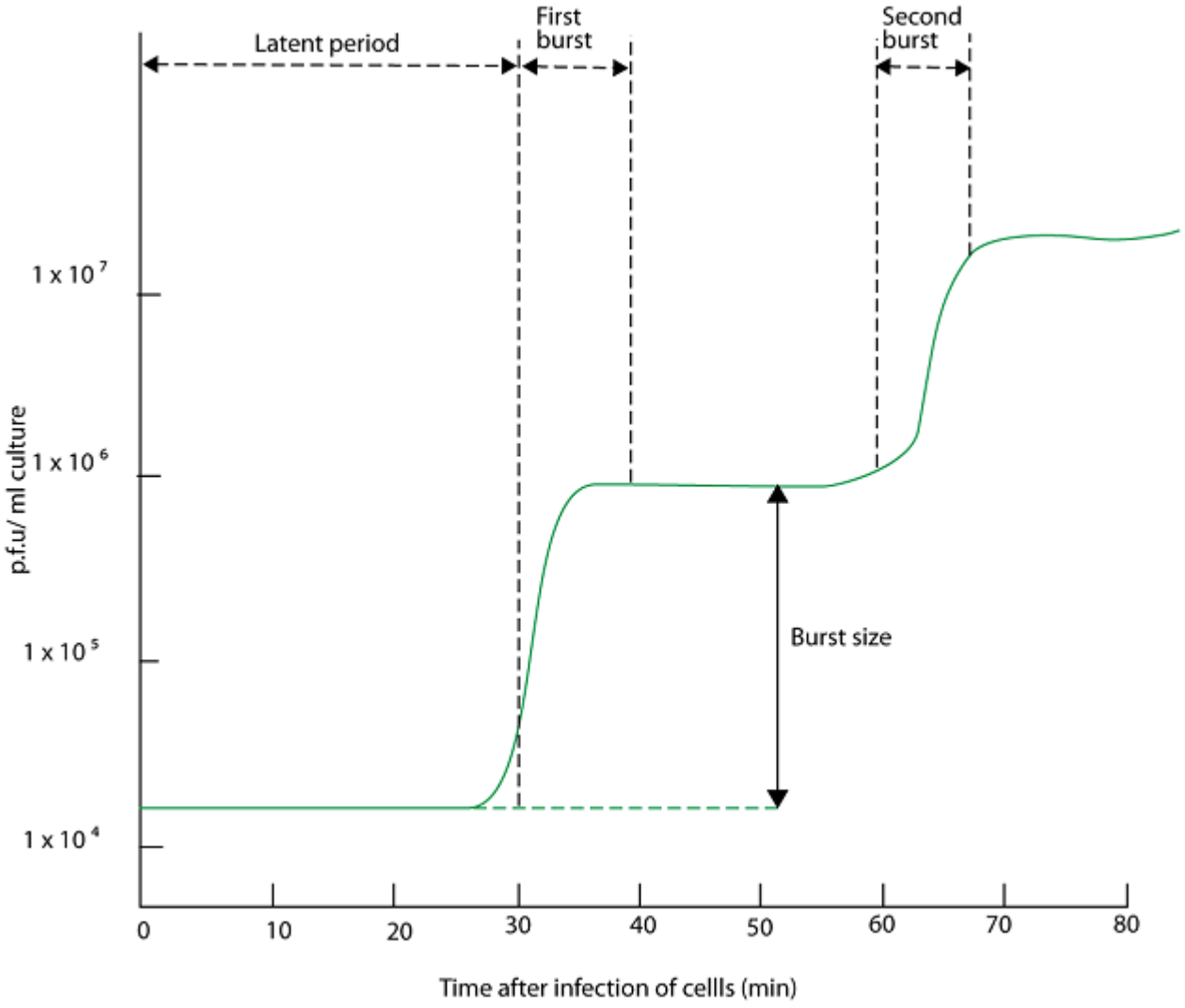
   Growth in arthropods occurs in a series of stages (instars). These series of stage show sudden changes in weight or length. This pattern of growth is known as intermittent growth, or discontinuous growth. Each growth stage is called an instar.

Reasons for intermittent growth.

All arthropods have an exoskeleton made up of hard chitinous cuticle, which prevents overall growth of the whole body. The exoskeleton is shade periodically in the process called moulting or ecdysis to allow growth.

The new cuticle underneath in soft enough to allow growth to take place. The cuticle later hardens making growth impossible until cuticle is shed again. It is for this reason; growth occurs in spurts interrupted by series of moults.

Diagram showing growth in arthropods

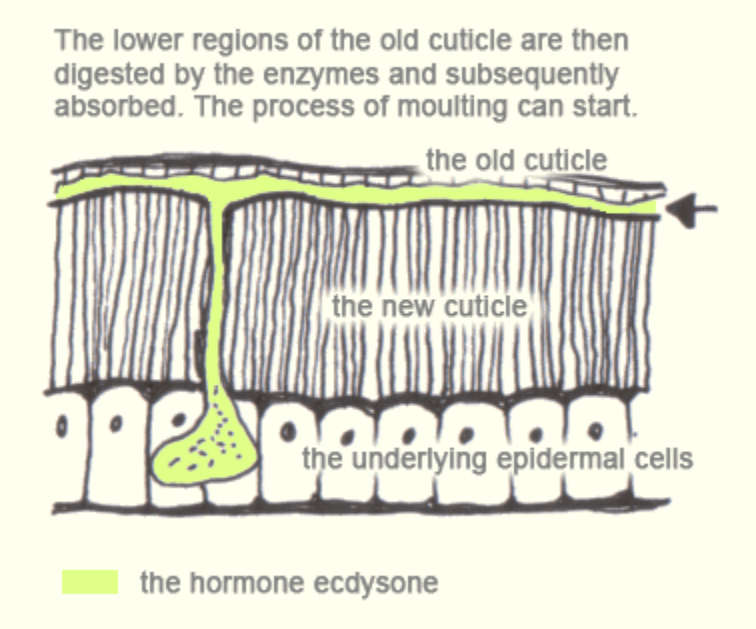


Hormonal control of ecdysis or moulting in insects

Moulting or ecdysis is controlled by a moulting hormone (mH) or ecdysone which is released in response to a specific stimulus. The moulting hormone is secreted by the thoracic gland. The production of ecdysone by thoracic gland is stimulated by certain hormone produced by neurosecretory cells in the brain.

Moulting hormone is a steroid. It brings about shedding of the cuticle and growth of an insect. Growth of insects is accompanied by series of mouths. Moulting hormone cause the secretion of moulting fluid immediately beneath the cuticle.

This dissolves the soft inner part, mean while the new cuticle soft first in secreted by epidermis.



Growth in insects.

The process of growth in insects involves changes in body for involving number of stages in their life cycle i.e. from the young to the adult form. The changes of forms from the young to the adults are referred to as **metamorphosis.**

Metamorphosis is found also in other groups of organisms such as amphibians, molluses, crustaceans, termatodes, cestodes and echinoderms to mention a few. In these organisms the term metamorphosis applies to those rapid changes which occur during the transition from larva to adult form.

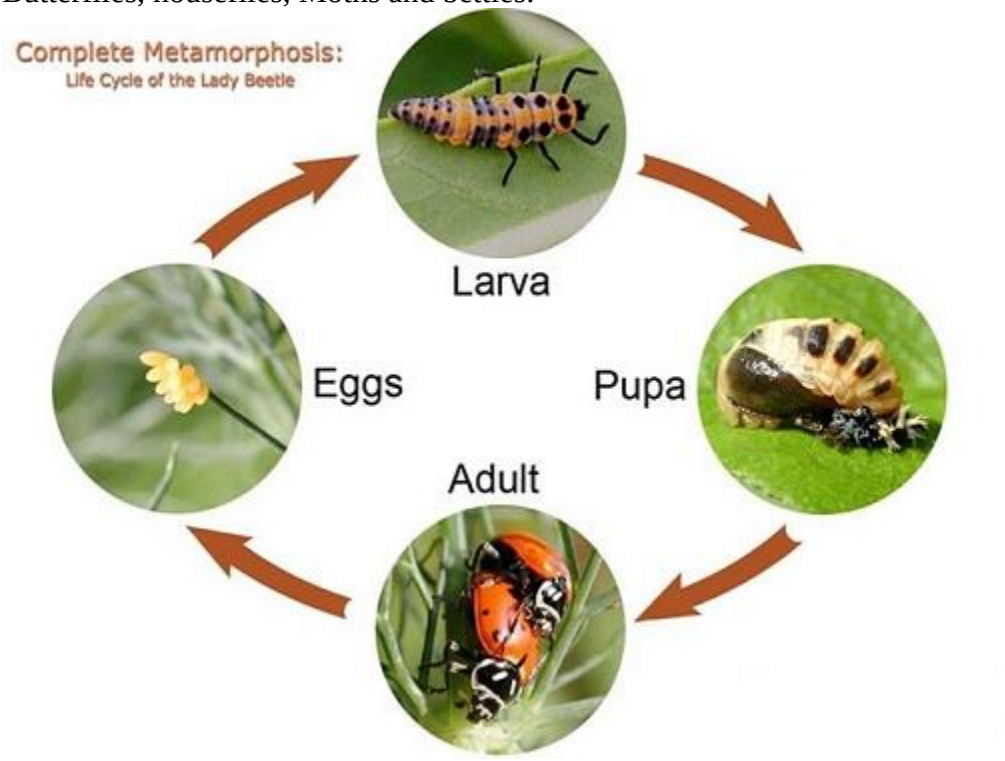
Metamorphosis in insects.

These are two (2) types of metamorphosis

1. **Complete metamorphosis**

   In this type, the life cycle of an insect passes through a series of four (4) stages i.e. Egg, larva, pupa and adult form.

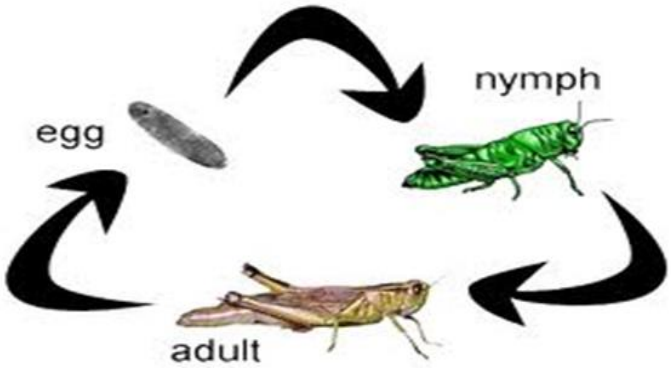
Insects that exhibit this type of metamorphosis are referred to as holometabolous insects. E.g. Butterflies, houseflies, Moths and bettles.



2.Incomplete metamorphosis (hemimetabolous)

In this type of metamorphosis, an insect pass through series of three (3) stages where the young resembles the adult. The insect passes into three (3) life stages i.e. the egg, nymph and adult.

Insects which exhibit this type of metamorphosis are known as hemimetabolous insects e.g. Cockroaches. Grasshoppers and mosquitoes.



Hormonal control of metamorphosis in insects

In insects, a successive moults lead to an insect to acquire either suddenly, or gradually, the features, characteristic of adults .The process of metamorphosis in controlled by two hormones .

- The moulting hormone.
- Juvenile hormone.

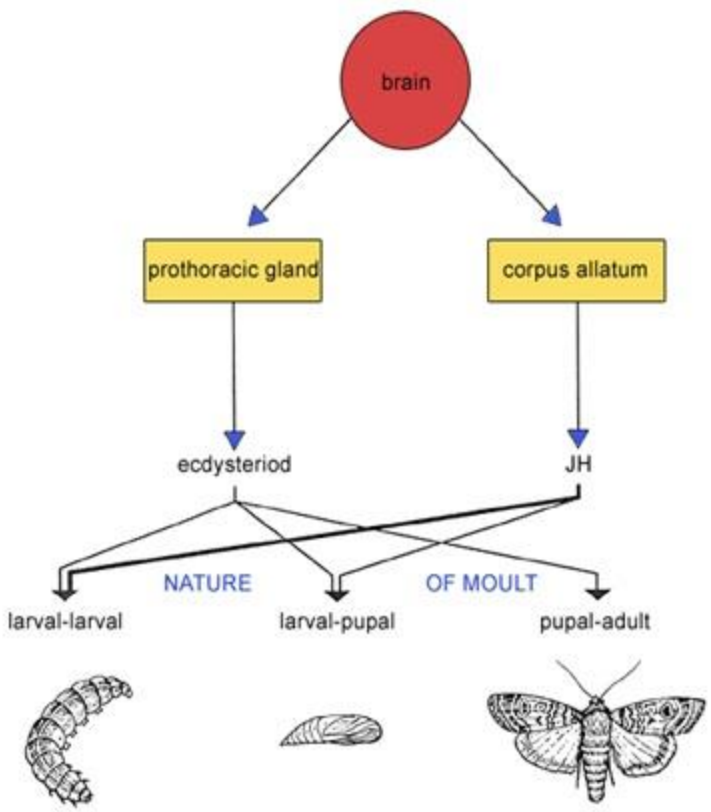
Metamorphosis is suppressed by the, juvenile hormone secreted by the gland called corpus allatum in the brain.

In the presence of juvenile hormone in the blood, epidermal cells under the influence of moulting hormone produce cuticle characteristic of juvenile stage. These are the nymph or larva as the case may be in order words, juvenile hormones inhibit metamorphosis and especially causes, the retention of larval characters in the suppress gene responsible for producing adult structure.

At metamorphosis the corpus allatum stop secreting its juvenile hormone and the moulting hormone in the absence of the juvenile hormone cause of epidermal cells to lay down the adult type of cuticle.

Summary

- For shedding of the cuticle the moulting hormone is required.
- Moulting hormone accompanied by juvenile hormone Cause epidermal cells to produce a larval cuticle.
- Moulting hormone alone without the juvenile hormone cause it to produce adult cuticle.



The process of growth

The growth of a multicellular organism can be divided into three (3) phases.

1. **Cells division** – an increase in cell number as a result of mitotic division and cell division.
2. **Cell expansion**- is the irreversible increase in the cell size as a result of the uptake of water in the synthesis of living materials.
3. **Cell differentiation** – the specialization of cells.

a) Cell Division

Cells are formed from pre – existing cells by the process of cell division. Cell division strictly is the process of division of the cell cytoplasm into two (2) daughter cells. The two (2) daughter cells share the same structures (organelles) which are duplicated before the cytoplasm start dividing.

The two (2) major events in the information of new cells include.

- Division of the nucleus (nuclear division)

- Separation or distribution of the cytoplasm between the daughter cells. The division of the nucleus is known as karyokinesis and the separation of the cytoplasm is known as cytokinesis.

  Nuclear division

  There are (2) two types of nuclear division

  1. Mitosis – is the process by which the cell nucleus divides to produce the two daughter nuclei containing identical sets of chromosomes to the parent cells.

  OR

  Mitosis is the type of nuclear division that maintains a diploid number of chromosomes in the daughter cells.

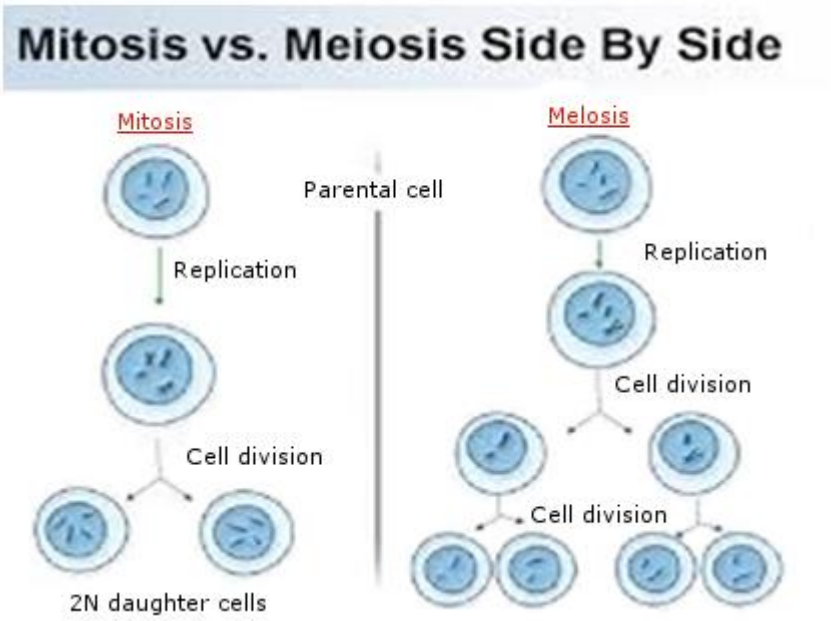
  Mitosis occurs in somatic (body) cells. It leads to the formation of body cells.

  2. Meiosis – is the process by which nucleus divided to produce four (4) daughter nuclei each containing half number of chromosome of the original nucleus.

  Meiosis is alternatively known as reduction division since it reduces the number of chromosomes in the cells from the diploid number (2n) to haploid number (n)

  Meiosis occurs in gonads. It leads to the formation of sex cells.

  NB: nucleus division principally involves the distribution of chromosomes in the daughter cells. Chromosomes are the most significant structures in the cells during cells division since they are responsible for the transmission of the hereditary information from generation to generation.



The cell cycle

Refers to the sequence of events which occur between the formation of a cell and its division into daughter cells. The cell cycle has three (3) main stages.

1. **Interphase**

Interphase is the period of intense synthesis and growth. The cells produce materials required for its own growth and carrying out other functions. Interphase is further divided into:

i.G1 (Gap one) or first growth phase

G1 is a phase which characterized with:

- Production of mitochondria, chloroplasts (in plant),lysosomes, ER, Golgi complex, vacuoles etc
- Formation of structural and functional; proteins.
- Production of RNAs
- Ribosomes are synthesized
- Metabolic rate of the cells becomes very high.

ii.S (synthetic phase)

- DNA synthesis takes place
- Production of histones that cover each DNA strand
- Chromosomes become as two(2) chromatids

iii. G2 (Gap two)second growth phase

- Centriole replicates
- Mitotic spindle start to form
- Energy store increases
- Intensive cellular synthesis (synthesis of RNA and protein)

1. **Mitosis (M)** -is the process of nuclear division involving the separation of chromatids and their redistribution as chromosomes into daughter cells.
2. **Cell division** – is the process of division of the cytoplasm into two (2) daughter cells.

1. **Process of mitosis**

Mitosis is a continuous process which occurs in four (4) active stages. These stages are the prophase, metaphase and telophase. An intermediate stage the interphase occurs between one cell division and another. The following are mitosis stage in animals

1. Prophase

This is the longest phase of mitosis division. Behavior of the chromosome is as follows;

- Chromosome appears as pair of chromatids joined by centromere.
- Nuclear membrane tends to disintegrate.
- Nucleoli start to disappearing
- Centrioles move to the opposite pole
- Microtubules radiate from centrioles called astars.

2. metaphase

- formation of spindle fibres (asters)
- Pairs of chromatids attached to spindle at the centromere.
- Nuclear membrane and nucleoli disappear
- Chromosomes line up at the equator of the spindle.

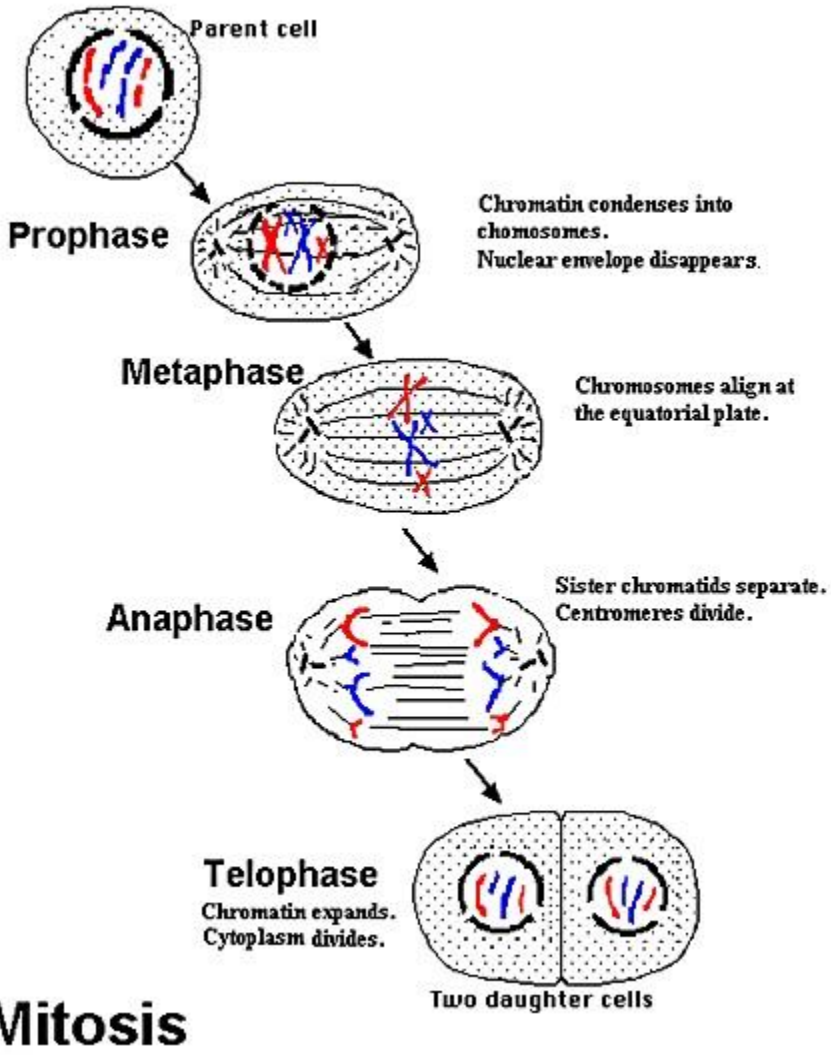
3. Anaphase – is a very rapid stage.

- The centromere splits into two (2)
- Daughter centromeres are pulled to the opposite sides by spindle fibre.
- Separated chromatids are now called Chromosomes, are pulled a long behind the centromeres.

4. Telophase

- Chromosomes reach the poles of the cell.
- Chromosomes uncoil, lengthen and form chromatin network.
- Spindle fibres disintegrate. Each centriole then replicates

- Nuclear membrane reappears and nucleoli reappear
- Leads to cytokitnesis.



1. **Cell division (cytokinesis.)**

   Cell division is a process of division of the cytoplasm into two (2) daughter cells. In preparation for division the cells organelles become distributed into the two (2) cells. After the nuclear division (karyokinesis.) the cytoplasm is divided into two (2) (more or less) equal parts. The cytoplasmic division differs in animal and plants cells.

   Cytokinesis in animals.

   The cells membrane begins to invaginate where spindle equal was present earlier. The cell membranes of opposite ends meet at the centre and cell divides into two (2) daughter cells.

Cytokinesis in plants

In plant cells the spindle fibres do not disappear at the region of equatorial plane, they increase in number and form cell plate across the equatorial plane. As the plate gradually become more distinct and develops into the new cell, it divides the cell in two (2).

Difference between mitosis in plant and animals

	plants	Animals
1	No centriole present.	Centrioles present.
2	No aster forms.	Aster forms.
3	Cells plate forms.	No cell plate forms.
4	No furrowing of cytoplasm at cytokinesis	Furrowing of cytoplasm at cytokines.
5	Occurs mainly at meristems	Occur in tissues throughout the body.

. **Significance of mitosis**.

1. **Growth and development**

Mitosis is a basic component of growth as its leads to increase in number of the body cells.

Body repair -the worn-out cells are replaced by the formation of new cells by mitosis.

The newly formed cells by mitosis have opportunity of differentiation forming of complex body.

2. **Genetic stability**

Mitosis produce the nuclei which have the same number of chromosome as the parent cells more over since these chromosomes were derived from parental chromosomes by exact replication of their DNA,they will carry the same hereditary information in their genes.

In other words , the daughter cells are genetically identical to their parent cells and no variation in genetic information is introduced during mitosis .

3. **Asexual reproduction**

Many animals and plant species are propagated by asexual method involving the mitotic division of cells alone .

4. Regeneration

The ability of some organism to replace the lost parts of the body such as legs in crustacean is brought about by the action of mitosis.

Seed germination

Germination – is defined as the onset of growth of the embryo in seeds.

Or Germination is the transformation of seed in to a seedling

Environmental conditions needed for germination.

1. Water

Water is required to activate the biochemical reactions associated with germination. Many biochemical reactions in the germinating seed take place in aqueous solution.

Water is also an important reagent in hydrolyzing the store food. Water enters the seed through the micropyle and the seed coat or testa by process called imbibition.

2. Temperature

For the seed to geminate there are minimum or optimum temperatures required. The temperature for seed germination range from 5 to 40'c. The temperature influences the rate of enzyme controlled reactions.

3. Oxygen

Oxygen is the required for aerobic respiration , the process where food material are oxidized to release energy in the cells .

In cases aerobic respiration can be supplemented with anaerobic respiration.

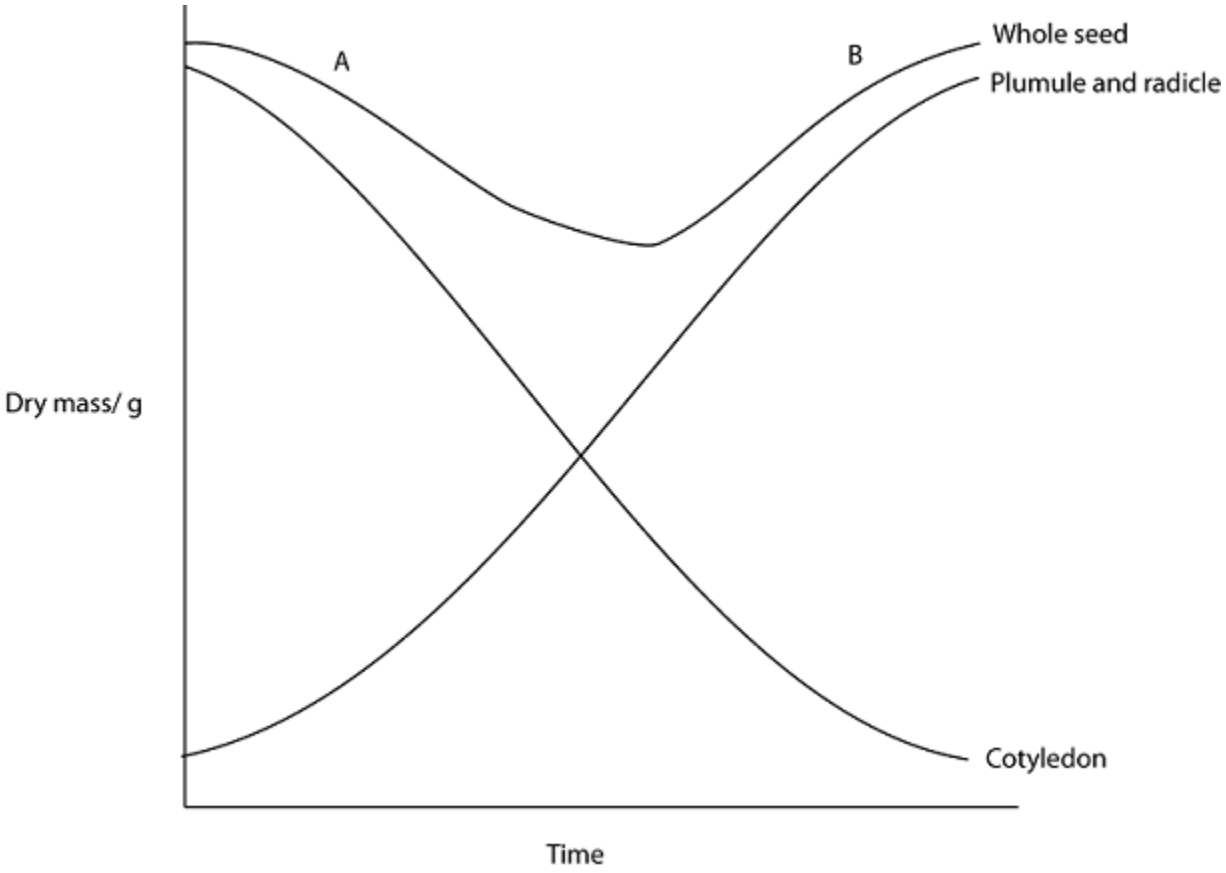
Physiology of seed germination

Seeds store food materials such as carbohydrates, lipids, proteins, mineral salts and vitamins. The large food reserves in seeds are the lipids and carbohydrates. Starch is the major food reserves of grasses and cereals. Legumes are very rich in proteins.

The food materials are stored in the endosperm in absence of the endosperm food in seeds is stored in the cotyledons of the embryo for this reasons we have endospermic seed and non – endospermic seed

In bean seeds, the cotyledons have been modified for food the storage of food. The stored food is used to provide energy and raw materials for building the tissue before the new seedling is able to photosynthesize.

The events leading to food germination can be summarized as follows



1. The water taken in by imbibitions and osmosis hydrates the food reserves which results into activation of enzymes of respiration. Other enzymes are synthesized possibly using amino acids provided by the digestion of stored proteins.

2. Digestion of food reserves hydrolysis .The soluble products of digestion are then translocated to the growth regions of the embryo.
3. Break down of food substrates (food reserves and the products of digestion) to release energy used in both storage tissue

and growing embryo . This involves oxidation of substrate usually sugar to carbon dioxide and water.

Respiration account for loss of dry mass in seeds due to the loss of sugars. Water is not counted in the loss of dry mass as water is excluded in accounting the dry mass. The respiration rates in both endosperms or other storage tissue and embryo are high owing to the intense metabolic activity in these regions . The loss in dry mass continues until the seedling produces green leaves and starts to make its own food.

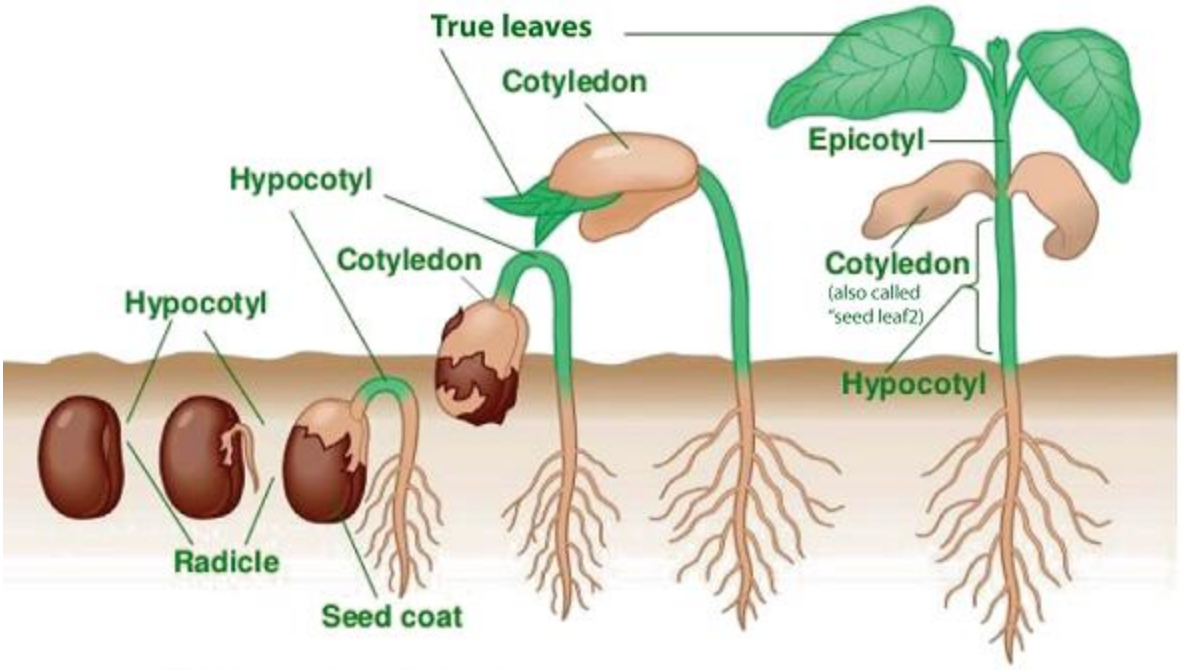
2. The graph below summarize the changes in dry mass of the endosperm and embryo during germination ,

Types of germination.

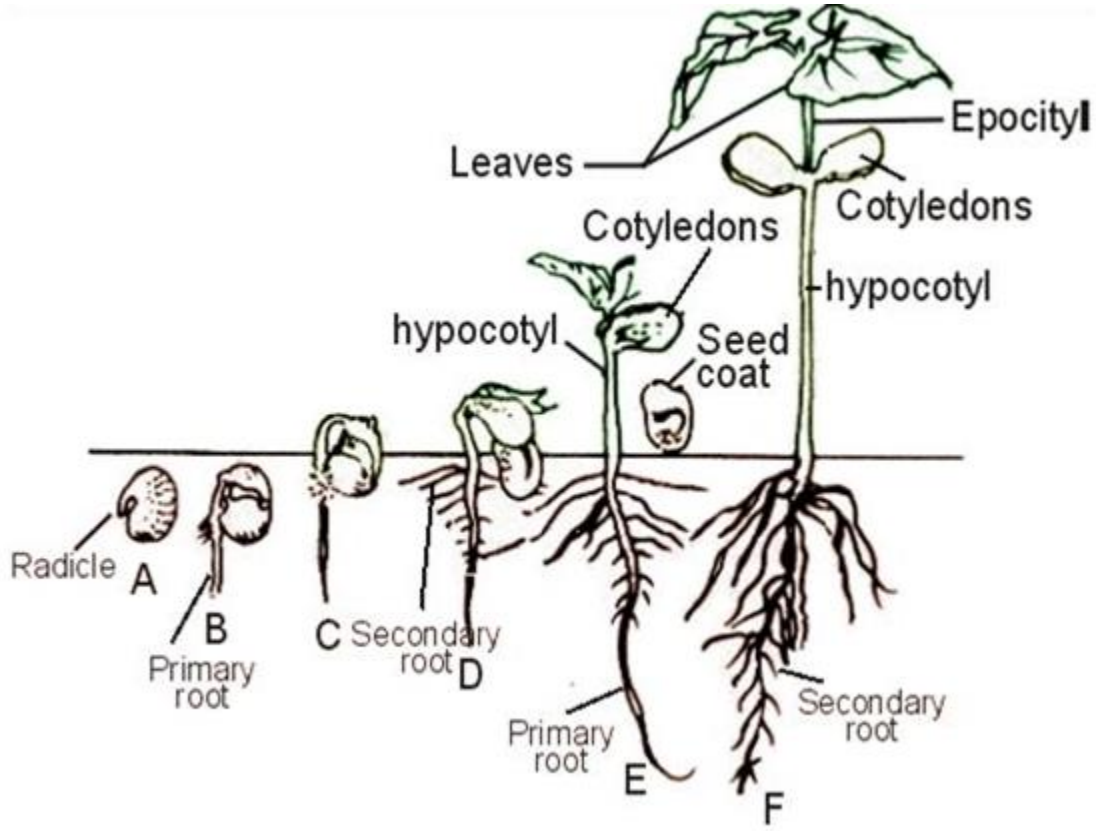
There are two types of germination according to whether or not the cotyledons grow above or remain below it.

1. **Epigeal germination**

   This is the type of germination when the cotyledons are carried above the ground. In dicotyledons, the part of the shoot axis or internode just below the cotyledon the (hypocotyl) elongates carrying the cotyledon above the soil, in epigeal germination the hypocotyle remains hooked as it grows through the soil , meeting the resistance of soil rather than the delicate plumule tip which is further enclosed and protected by cotyledon. The hypocotyl strengthens immediately on exposure to sunlight.



Common garden bean



1. **Hypogeal germination**

This is the type of germination where cotyledons remain below the ground. The internode just above the cotyledons (the epicotyl) elongates and therefore the cotyledons remain below the ground. In hypogeal germination of

dicotyledons the epicotyledons is hooked to protect the plumule tip .it immediately straightens on exposure to sunlight. In grasses which are monocotyledons, the plumule is protected by a sheath called coleptile. The first leaf

grow out through coleptile and unrolls response to light.

GROWTH OF THE EMBRYO

The first sign of the embryo growth is the emergence of the embryonic root, (the radical).This grows down and anchors the seed. The radical is positively geotropic.

Then it follows the emergence of the plumule which grows upward and it is positively phototrophic.

Primary and secondary growth in flowering plants.

With exception of the young embryo, growth in plants is confined to certain regions known as meristems .

Growth in plants is said to be localized i.e. confined to specific regions such as root and shoot tips.

Meristems

A meristem is a group of cells which retain the ability to divide by mitosis, producing the daughter cells which grow and form the rest of the plant body. The cells that have lost the ability to divide form the permanent tissue.

Meristems are also known as initials. There are three types (3) of initials. The classification is based on their location. These include:

1. **Apical meristems**

   This is a type of meristem located in the root and shoot apex. They are responsible for primary growth, giving rise to primary plant body. The effect of apical meristem is to cause increase in length.

2. **Lateral meristems (the cambium.)**

These are laterally situated in older parts of plants parallel with long axis of organs E.g. cork cambium (phellogen) and vascular cambium. They are responsible for secondary growth. Vascular cambium gives rise to

secondary vascular tissues, phellogen gives rise to the periderm which replaces the epidermis and includes cork. The Effect of lateral meristem is to cause increase in girth.

3. **Intercalary meristems.**

   These are found between regions of permanent tissues E.g. at nodes of many monocotyledonous plants in the bases of grass leaves. Intercalary meristems allow growth in length to occur in regions other than tips. This is

   very useful if the tips are susceptible to damage or destruction. E.g. being eaten by herbivores. Branching from the main axis is not then necessary.

Types of growth in plants.

1. **Primary growth** - This is the first form of growth which results into the plant increasing in length. This is the only type of growth occurring in most monocotyledonous plants and herbaceous dicotyledonous. Primary growth is a result of the activity of the apical and sometimes intercalary meristems.
2. **Secondary growth**

   This is the growth which occurs after primary growth as a result of lateral meristems characterized by deposition of new phloem and large amount of secondary xylem called wood. Secondary growth results into increase in girth. Secondary growth is a characteristic feature of trees and shrubs. A few herbaceous plants show restricted amount of secondary thickening.

1. **Primary growth**

   Primary growth in shoots. The shoots apex can be distinguished into four (4) regions. These are the regions of cells division, region of cell elongation, region of cell differentiation and region of permanent tissue. The cells become progressively older as you move from the apical meristems.

The region of cell division.

The apical meristem is dome shaped. The meristems cells are distinguished into the protoderm, which give rise to the epidermis, the ground meristems which produce parenchyma ground tissues which form the cortex and pith in dicotyledons, and the procambium which gives rise to the vascular tissues, including pericycle, phloem, vascular cambium and xylem.

Characteristics of Apical meristems

- The cells are relatively small, cuboids with thin cellulose wall and dense cytoplasm content.
- They have few small vacuoles.
- They are packed tightly together with no obvious air space between cells.
- They lack chloroplasts'.
- When they divided by mitosis, one daughter cell remains in the meristem while others increase in size and differentiate to become part of permanent plant body.

Zone of expansion or cells elongation.

The daughter cells produced by initials increase in size mainly by osmotic uptake of water into these cells. Increase length of stems and root is mainly brought about by elongation of cells during this stage.

The expansion of cells in addition is due to thickening of the cell wall either by cellulose or lignin depending on the type of cell being formed.

Zone of cells differentiation

The process of differentiation is initiated from the procambium. This gives rise to the protoxylem in the inside and protophloem on the outside which are part of the primary xylem and primary phloem respectively. Between the xylem and phloem, there are cells that retain the ability to divide. They form the vascular cambium.

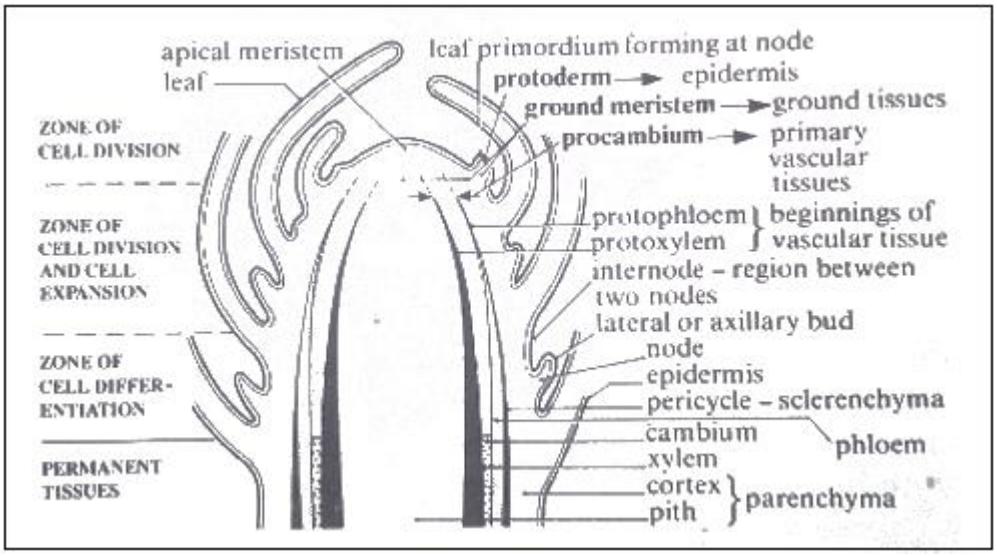


Diagram of shoot tip showing apical meristem

Formation of leaves and Lateral buds.

Growth and development of the shoot also includes growth of leaves and lateral buds. Leaves arise from small swellings or ridges containing groups of meristematic cells.

These swellings or ridges are called primordial. The primordial appear at regular interval, the side of origin being called nodes and the region between the internodes.

The nodes can be arranged in specific pattern or arrangement on the stem. E.g. As whort, singly or spirally. The primordial elongates rapidly, as a result, it soon encloses and protects the apical meristems both physically and by

heat they generate in respiration. They later grow and increase in area to form the leaf blade.

The Lateral bud (auxiliary bud)

These are small groups of meristematic cells which normally remain dormant but retain the capacity to divide and grow at later stage. They form branches or specialized structures such as flowers. Lateral buds also form

underground structure such as Rhizomes and tubers.

They are under control of apical meristems. The lateral buds develop in the axis of the leaves and stem.

Primary growth in roots.

The growth region of the root is distinguished into:

1. **The root cap.**

   The root cap forms the outside of the apical meristems. It is made up of the parenchyma cells. It protects the apical meristems as the roots grow through the soil. The cells of the root cap are constantly being worn away and replaced. The outer layer of the root cap has mucilage which makes it slimy in order to reduce friction. The root cap also has the important additional function of acting as gravity sensors.

2. **The zone of cells division**.

   The zone of cells division is distinguished into the following:

3. **The quiescent centre**

This forms the very tip of the apical meristems. The quiescent centre is composed of group of initials (meristematic cells) from which all other cells in the root originate. The cells in the quiescent centre has lower rate of cells division in comparison with the surrounding daughter cells.

b) The protoderm ground meristems and procambium.

These are different types of the apical meristems which follow below the quiescent centre. The functions of these cells are the same as the in shoots.

The protoderm form the epidermis, the ground meristems form the cortex, including endoderm and the procambium which form primary phloem, vascular, primary xylem, pith and the pericycle if present. The procambium in roots is used to describe the central cylinder in roots.

1. **The zone of cells Elongation.**

   As in shoot the zone of cell division is followed by a zone of cell elongation. Growth in this region is brought by cell elongation due to osmotic uptake of water in the cytoplasm and then into the vacuole. The zone of elongation cells extends to about 10mm behind the root tip. The increase in length of these cells forces the root tip down through the soil.

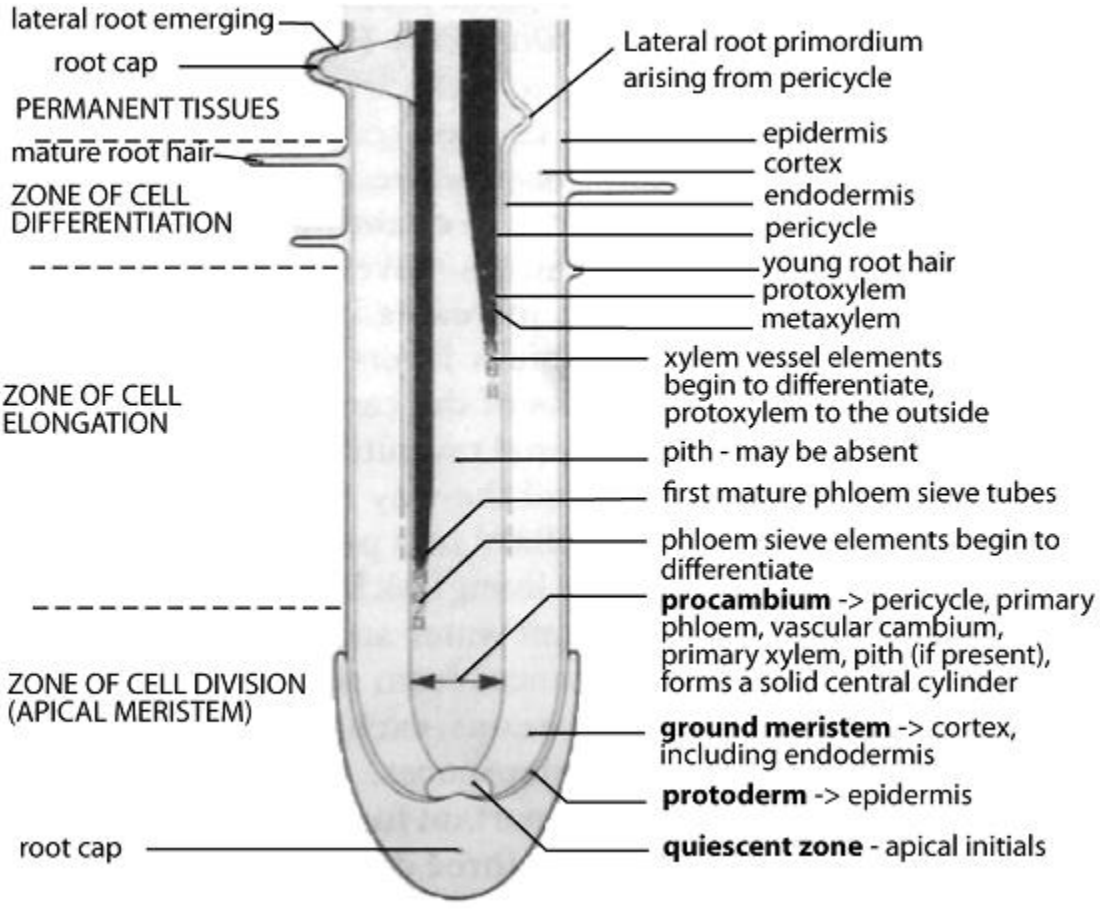


Diagram of Root tip showing apical meristem

1. **The zone of cells differentiation**

   This is a zone where each cells became fully specialized for its own particular function. In this region the phloem sieve element begin to differentiate. The development of phloem is from outside inward and become progressively more mature further back from the root tip.Xylem starts differentiating further back in the same manner as phloem that is from outside inwards (exarch xylem). The first to differentiate are the xylem

   vessels, starting with the protoxylem vessels which transform into the metaxylem and later into mature xylem. The xylem in roots spreads to the centre of the root in which case no pith develops. Further differentiation in this region includes the development of the root hairs from the epidermis .

   Formation of lateral root of adventitious root and adventitious buds.

   Lateral roots : These are roots that arise from the main root formed by the resuming of the meristematic activity of the pericycle cells . This is in contrast to the formation of the buds in the shoot.

   In the root a small group of the pericycle cells in the zone of differentiation resume meristematic activity and forms a new root epical meristem which grows forcing its way out through the endodermis , cortex and epidermis.

   Adventitious roots and buds - Adventitious are those growing in uncharacteristic position formed by a certain cells resuming meristematic activity . Examples are the adventitious buds and roots.

- **Adventitious roots** – they develop independently of the original primary root and form the main rooting system of monocotyledons arising from the nodes on stem.

- **Adventitious roots** are important in the propagation of plants by stem cutting. Some plants like Ivy use adventitious root to cling.
- **Adventitious buds** –adventitious buds may develop on roots, steam or leaves. In trees can develop new branches adventitiously from buds arise in the trunk.

2) **Secondary growth**

This is the growth which occurs after primary growth as a result of the activity of lateral meristems .Secondary growth results in an increase in girth. It is associated with deposition of large amount of xylem called wood. The wood gives charactestic feature of trees and shrubs. Secondary growth is brought about by two (2) types of lateral meristems **the vascular cambium** which give rise to new vascular tissue **cork cambium or phellogen** which arises later to replace the ruptured epidermis of expanding plant body .

The activity of the vascular cambium.

There are two types of cells in the vascular cambium these are;

a) **The fusiform initials**. These are narrow , elongated cells which divide by mitosis to form secondary phloem to the outside or secondary xylem to the inside . The xylem material produced exceeds the amount of phloem.

b) Ray initials

These are almost spherical in shape and divide mitotically to form parenchyma cells. Parenchyma accumulates to form rays between neighboring xylem and phloem.

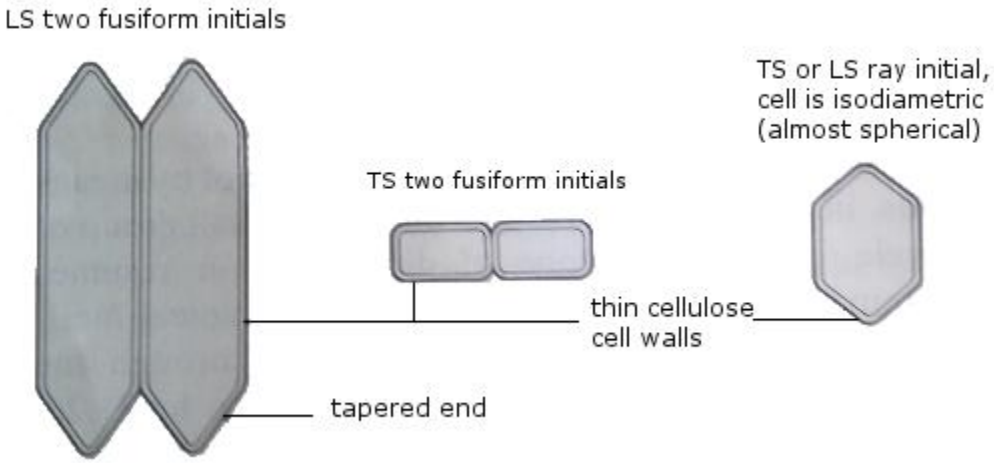


Diagram of Fusiform and Ray initials

Secondary growth in woody dicotyledonous stem

Secondary growth or thickening in stem is brought about by deposition of large quantity of secondary xylem and lesser quantities of secondary phloem by fusiform initials of the vascular cambium.

The vascular cambium is originally located between the primary xylem and primary phloem of the vascular bundles. This is called **lutoa fascular cambium**. The vascular bundles of dicotyledonous stems are arranged in form of a ring. When the primary xylem and primary phloem are first differentiated, there is no cambium across the pith or a medullary ray which lies in between the edges of the cambium within the bundles divide accordingly and form a layer of cambium across the medullary rays.The newly formed cambial strip which occurs between the gaps in the bundles is called interfaxular cambium. I.e. the cambium in between the two (2) vascular bundles. The complete cambium ring is formed.

The formation of secondary xylem and secondary phloem.

The cambial layer consists of essentially one layer of cells. These cells divide in a direction parallel with epidermis.

Each time a cambial cell divides into two, one of the daughter cells remains merstematic, while the other is differentiated into permanent tissues. If the cell that is differentiated is next to the xylem, it forms xylem while if it next to the phloem it becomes phloem.

The xylem is formed towards the inner side while the phloem towards the outside of the cambium. The cambium cells divide continuously in this manner producing secondary tissues on both sides of it. In this way, new cells are added to the xylem and phloem, and the vascular bundles increase in size.As the stem increase in thickness the circumference of the vascular cambium layer need to increase. This is achieved by radial division of the cambial cells.

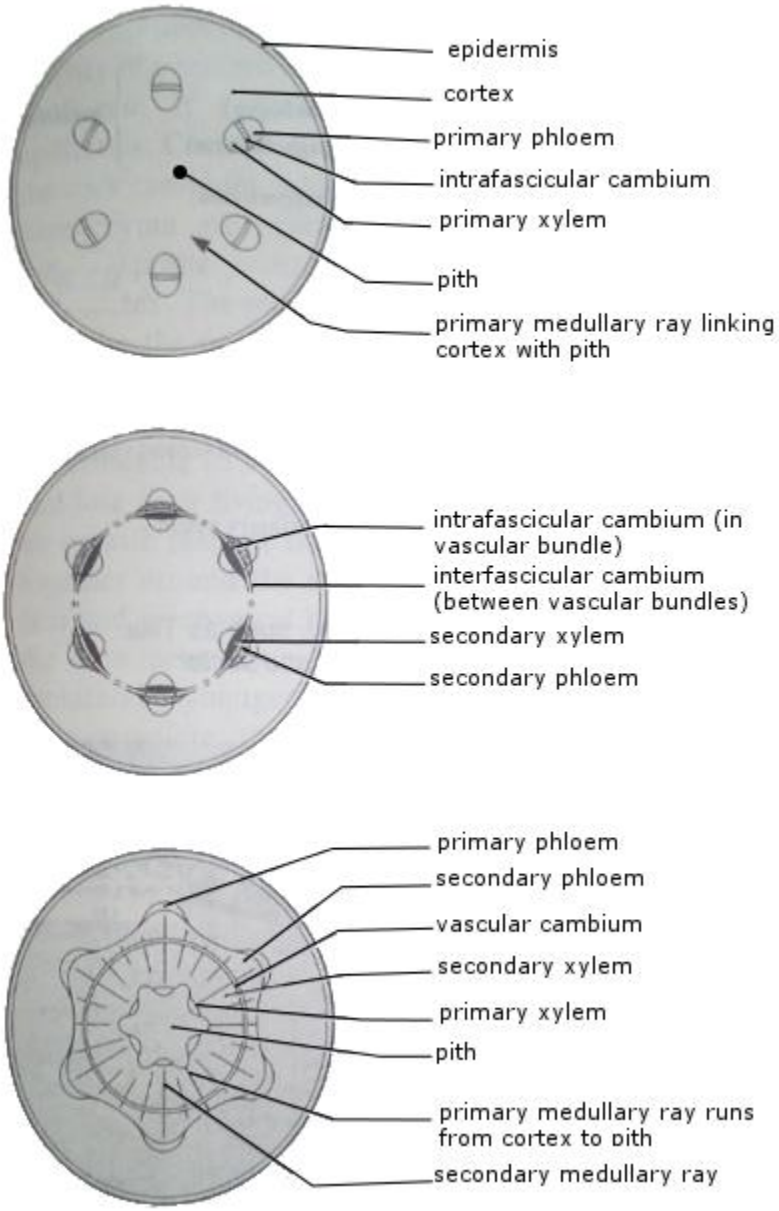


Diagram of Early stages in secondary thickening of typical woody dicotyledon stem.
a. Primary structure of stem.
b. Cambium forms a complete cylinder.
c. a complete ring of a secondary thickening has developed.

Formation of medullary rays.

Medullary rays are formed by ray initials. These are parenchyma four cells that run all the way from the pith or medulla to the cortex.

The pith or medulla forms the central region of the stem of the dicot plant and roots of monocots. The extension of the pith in form of narrow parenchymarous strips are called medullary or pith rays. In some stem the pith is obliterated to form hollow. The medullary rays extend between thee vascular bundles. These are primary and secondary Medullar rays. The primary medullary rays are produced by original ray initials and secondary Medullary rays which are produced by later ray initials.

Function of Medullar rays.

The rays maintain a living link between the pith and cortex. They help to transmit water and mineral salts from xylem and food substance from the phloem rapidly across the stem.

Annual rings.

Annual rings or growth rings refers to the concentric layers of secondary xylem in the stem of the perennial plants each one of which represents a seasonal increment or different phase in deposition of new xylem tissues.

In transverse section of the axis these layers appear as rings and are called annual rings or growth rings. They are commonly termed as annual rings because in woody plants of temperate regions and those of tropical regions, where there is annual alternation of growing and dormant periods each layer represents the growth of one year.

By observing the pattern of annual ring one can pin point the time during which the wood was growing. Dendrochronology is the dating of wood by recognition of pattern of annual rings.

Heart wood and sap wood

The heart wood

This refers to the central region of the old tree where the xylem tissue have ceased to serve as conducting function and become blocked with darkly staining deposits such as tannins, gums, resins and other substance which make it hard and durable. It looks black due to the presence of various substances in it.

Sap wood.

This refers to the outer region of the old trees consisting of recently formed xylem element. This is of light color and some living cells. This part of the stem performs the physiological activities such as conduction of water and nutrients, storage of food.

Cork and lenticels.

Cork (phellogen)

This refers to the tissue formed by activities of a secondary lateral cambium or the Cork

cambium to replace the ruptured epidermal cells. It is immediately below the epidermis. The rupturing of the epidermis is a result of increasing circumference of the stem due to outward growth of the secondary xylem.

As the cork cells mature, their walls become impregnated with fatty substance called suberin which is impermeable to water and gases. The cells gradually die and lose their living contents which become filled with either resins or tannins.The cork cells fit together around the stem to prevent dessical infection and mechanical injury.

These are slit- like openings containing mass of loosely packed walled dead cells lacking suberin found at random intervals in the cork. The lenticels are produced by the cork cambium and have large intercellular air space allowing gaseous exchange between the stem and the environment.In the absence of lenticels it would be difficult for gaseous to take place in the stem as the cork which surrounds the stem do not allow air to pass.

Other tissues formed from cork cambium.While the cork (phellem) is produced to the outside of the cork cambium, in the inside one or two (2) layers of parenchyma are produced. These are indistinguishable from the primary cortex and form, the phelloderm or secondary cortex. The phellogen (cork) and phelloderm together comprise the periderm.

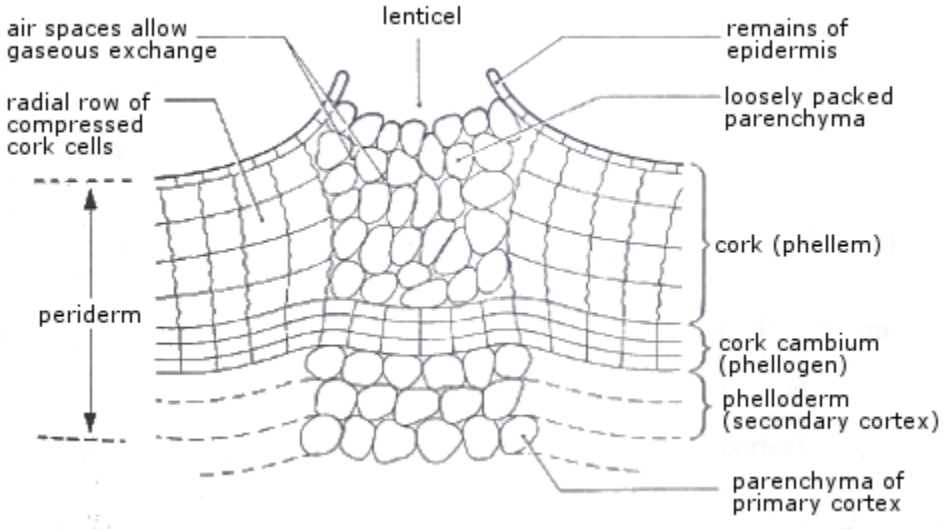


Diagram of lenticel.

The Bark.

The term bark is used to refer either to all the tissue outside the vascular system or strictly to those tissues outside the cork cambium, in either primary or secondary state of growth.

The bark cover the woody stem, peeling bark from a tree generally strips tissue down to the vascular cambium. The bark is composed of dead cells together with the cork layers.

SEED DORMANCY

Refers to a condition where seed will not germinate despite the presence of those environmental conditions for germination.

Causes of seed dormancy

1. Immaturity of the embryo

Newly harvested seed need some period of time for the embryo to become mature .The seed undergo some internal transformation before it can be able to germinate .This period where the seed undergo internal changes for maturation is called the **after ripening**. To terminate this type of seed dormancy allow the seeds to have enough period of time before they can be sown again .

2. **Hardness of the testa**

Hard seed coat or testa makes it impermeable to water and oxygen or being physically strong enough to prevent embryo growing.

How to break this type of dormancy.

- physical damage or scarification to the seed coat
- By action of micro organism such bacteria.

-soaking for a long period of time and by chemical action in the soil.

BREAKING OF SEED DORMANCY

The mechanism of breaking seed dormancy depends on the type of dormancy under consideration.

For primary Dormancy.

1. The seed need to be stored for long periods until the embryo matures
2. Wetting of seeds with appropriate solvents such as water and gibberellins so as to remove growth inhibitors.
3. Removal of the testa by mechanical secretion or by weakening chemicals such as enzymes so as to enable the emergence of the radical and plumule.
4. Using organic solvents to dissolve the waxy coating over the testa rendering it permeable to gases and water.
5. Soaking the seeds in water for sometime soften the testa and therefore makes it permeable to water and oxygen

For Secondary dormancy.

1. The seeds have to be supplied with appropriate temperature. This may be by chilling in deep freezers / refrigerators or by temperature shocking in which the seed are either boiled for a while or washed in hot water.
2. The seeds have to be provided with specific light intensity so as to rise the levels of gibberellins to work (activated)
3. They have to be provided with enough moisture and oxygen.

SEED VIABILITY AND GERMINATION

a). SEED VIABILITY

1. Viability is the capacity of the seed to remain capable of germination when conditions are not favorable.

- A viable seed is that which is capable of germinating when all causes of dormancy are broken.
- Seed viability ensures that the seed will germinate once supplied with all conditions necessary for germination and all causes of seed dormancy are broken.

Factors governing seed viability:-

1. **Seed maturity**

Immature seeds die, thus when sown they never germinate since they are inviable due to the fact that their embryos are not completely formed after seed formation, seeds need time to completely form their embryo so as to be able to carry active growth.

2. **Activity of enzymes**

- Since germination is an enzyme controlled process, depends on enzymes for its take off.
- In the seeds where enzymes are inactive, they cannot be activated, germination is impossible and the seeds are therefore inviable

3.**Storage condition of**

4.State of health of the seed

1. **Temperature:** Optimum temperature is acquired for the seed in the store for them to remain viable. Extremely high temperature denatures the enzymes in the seeds. This results into failure of seeds to germinate
2. **Moisture:** high moisture content of storage site can cause seed to hence lose their viability. Dry atmosphere is the preferred one.

3. **Aeration:** Enough supply of oxygen is required to cater for the minimum metabolism in seeds. Lack of aeration will hinder metabolic reactions in the seed and seeds may lose their viability

- This diseased seed may lose its viability as its embryo may be infected by fungi or bacteria.

5.Time of storage of seeds.

This varies from seed to seed and from species. Most of the annual plant seeds lose their viability in a period of one year.

However there are other seeds e.g. those of cassia bicaspsularis and cassia maltijuge retain their viability for about 115 and 158 years respectively.

- Also long storage may result into seeds being destroyed by insects.

GENETICS

Genetics is the study of heredity and variation
Heredity- is the passage of character from one generation to another.
Variation - these are differences among individuals of the same species.

GENETICS & VARIATION

HEREDITARY MATERIALS:-

Hereditary or genetic materials are chemical substances or units on the chromosome that are responsible for the passage of genetic information from one generation to another.

Characteristics of hereditary materials:-

The features that characterize hereditary materials include the following:-

1. Metabolic stability. Hereditary materials are metabolically very stable or chemically inert. If it were altered to any extent, impercfect copies would be made.

2. Mutation: There is a close correlation between hereditary materials and mutation agents that is, when the hereditary materials are exposed to mutagens undergo mutations.

3. Self replication – Hereditary materials are capable of reproducing themselves.

4. Constancy within the cell – The amount of hereditary materials remains constant within a cell or in the cells of organisms of the same species.

5. Carriage of information – The hereditary materials are capable of carrying genetic information from one generation to another.

6. Linearity – The information or the genetic materials if always arranged in a linear array.They are macromolecules

SPECIES CONCEPT:

There are several ways if defining what a species is:-

(a) According to genetics: A species is defined as a group of organisms that share a common gene pool and have the same number of chromosomes. Gene pool is the total of all genetical make up in a given population.

(b) According to ecology: A species is defined as a group of organisms that share a common ecological niche no two species can share the same genetic niche.

(c) According to plant and animal breeding: A species is a group of organisms as that can freely interbreed and produce fertile offspring.

Qn;-How does a breeder define a species?

By the above definition is a horse and donkey of the same species? Give reasons.

SOLN:-

According to definition of species given by a breeder as horse and a donkey are of different species. This is because although they interbreed freely producing a mule but a mule is non – fertile and therefore it cannot produce another mule.

Qn:-In a certain research programme at Kwamsisi Rodent research centre, cage of 159 rats from Usambara mountains and a cage of 162 rats from Pugu forest; reserve were researched. If you were one of the researchers how would you identify those rats of the same species?

SOLN:-

To identify those of same species the following should be done:-

(a) To allow interbreeding:

- Those rats of the same species will interbreed freely and produce fertile offspring.
- Those rats of different species will either fail to interbreed or if the will inter breed the product so produced will be non – fertile.

(b) Chromosomes analysis:

- Those rats of the same species will have the same number of chromosome.

EXTRA OF HEREDITARY MATERIALS

Macromolecules

- They are universal but restricted within species.
- All are made due to phosphoric acid.
- All are comprised of pentose sugar, nitrogen base and phosphate.

CHROMOSOMES AND THEIR STRUCTURE

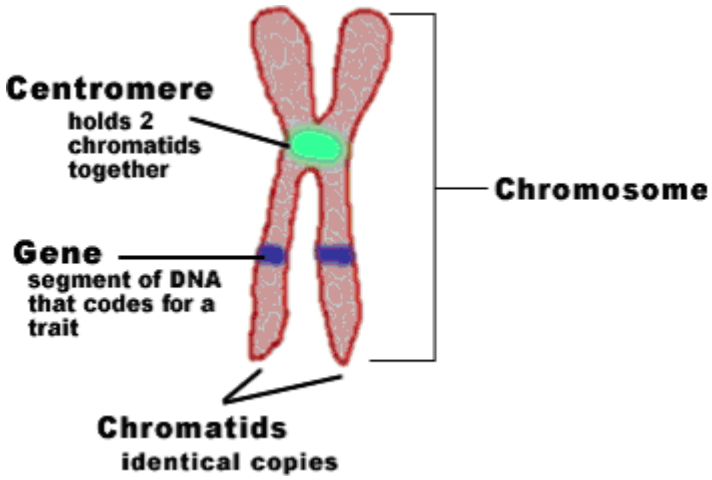
Chromosomes carry the hereditary – material DNA. In addition they are made up of protein and RNA. Individual chromosomes are not visible in a non – dividing (resting) but the chromosomal material can be seen especially if stained. This material called Chromosomes become visible only during onset of cell division.

Each chromosome is seen to consist of two threads called chromatids joined to point called centromere. Chromosomes vary in shape and size both with and between species.

Homologous chromosomes are similar in structure.

Arrangement of homologous chromosomes in pair is known as Karyograi and the set of chromosomes is known as Karyotype.

Structure of chromosome:-



THE NUCLEIC AIDS, TYPES OF HEREDITARY MATERIALS

There are two types of nucleic acids:-

(a) Ribonucleic acid, RNA.

(b) Deoxyribonucleic acid, DNA.

Chemical nature of nucleic acids:-

Chemically nucleic acids are composed of the following:-

1. Pentose sugar – This is a five carbon sugar.

In RNA, there is ribose sugar where as in DNA, there is deoxyribose sugar.

2.Nitrogenous (organic) base

There are two groups of organic bases:

(a)Purine bases-

These include: (i) adenine (A)

(ii) guanine (G)

(b)Pyrimidine bases-

These include (i) Thymine(T)

(ii) Cytosine (C)

(iii) Uracil (U)

Note that;

Thymine is a DNA pyrimidine while Uracil is an RNA pyrimidine. No uracil in DNA nor is there thymine in RNA

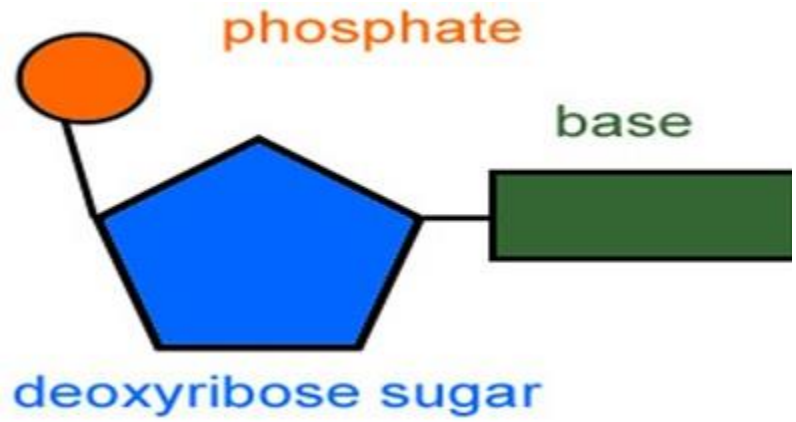
3. Phosphate group:-

This is derived from phosphoric acid and it is this group that makes compounds (DNA and RNA) acidic in nature.

The three components are combined by condensation reactions to give a nucleotide. By a similar condensation reaction a dinucleotide is formed and continued condensation reaction leads to the

formation of a polypeptide.The main function of nucleotides is the formation of nucleic materials RNA and DNA which have vital roles in protein synthesis and heredity.

Structure of a typical nucleotide:-



4. **Chemical bonds:-**

There are two types of chemical bonds:-

Phosphodiester bonds – These hold the nucleotides together.

Hydrogen bonds – These hold together the complementary base pair in DNA as well as RNA.

5. **Protein cost**:-

The DNA of the eukaryotes has a history protein coat over its surface.

(A) RIBONUCLEIC ACID (RNA)

Chemical nature:-

Ribonucleic acid is chemically composed of the following substances:-

(a) Pentose sugar – This is a 5 carbon sugar called ribose.

(b) Phosphate group- derived from phosphoric acid.

(c) Organic (nitrogenous) bases – These are of two types.

(i) Purines – These are Adenine (A) and Guanine (G).

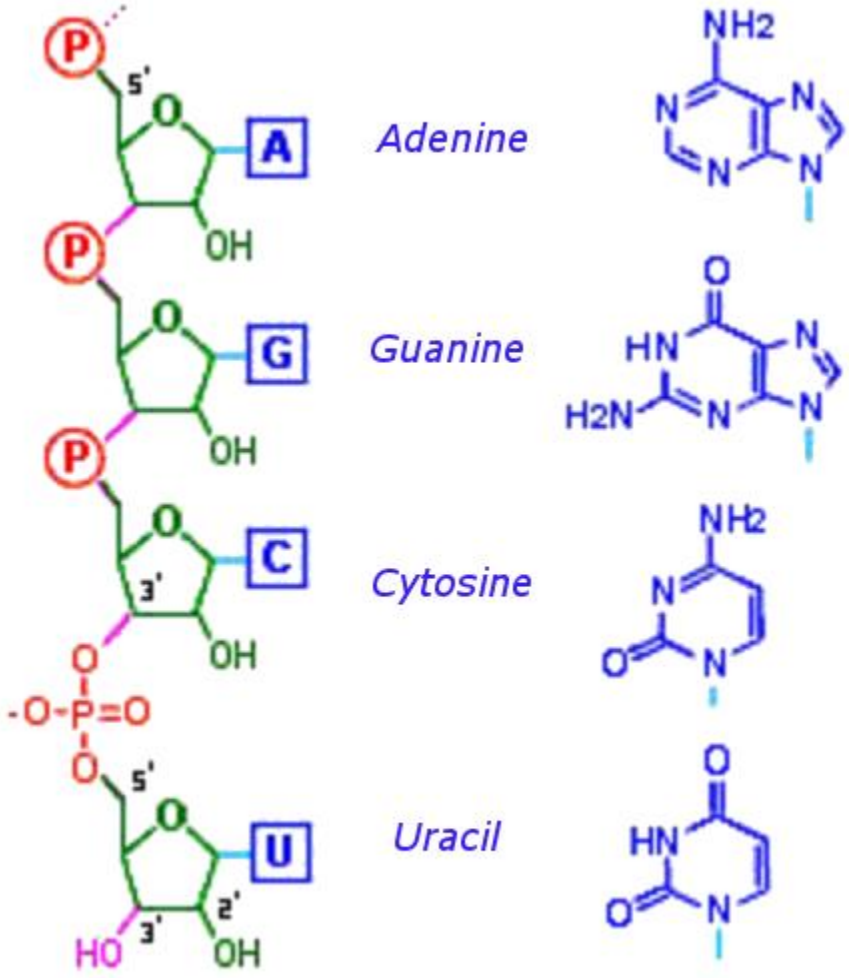
(ii) Pyrimidines - These are Uracil (U) and Cytosine.

(d) Chemical bonds: These are of two types:-

(i) Phosphodiester bonds – Which hold the nucleotides together.

(ii) Hydrogen bonds – Which hold together the complementary base parts in tRNA molecule.

Diagram to show structure of RNA:



Role of RNA.

The role of RNA is situational:-

1. **In the presence of DNA, RNA in collaboration with DNA.**

   Controls heredity.

Controls protein synthesis.

2. **In the absence of DNA, RNA alone.**

Controls heredity.

Controls protein synthesis.

Types of RNA

- **According to function and location in the cells, there are three types of RNA:-**

(a) Messenger RNA (mRNA).

- This is the type of RNA formed from one of the strands of DNA in the process called transcription.

Role of mRNA:-

- Messenger RNA carries the genetic code from DNA in the nucleus to the ribosome in the cytoplasm. This genetic code contains the information about the types of amino acids that should be joined together to form a protein molecule.

(b) Ribosomal RNA (rRNA).

- Ribosomal RNA (rRNA) or soluble RNA constitutes about 80% of the total RNA in the cell.
- Ribosomal RNA is synthesized by a special DNA found in the nucleolus at a special region called a nucleolar organizer.
- It makes a bulk of the ribosome.

Role of rRNA

(i) It is an integral part of the ribosome i.e large proportion of the ribosome is made up on rRNA.

(ii) It attracts other types of RNA i.e mRNA and tRNA towards the ribosome during protein synthesis.

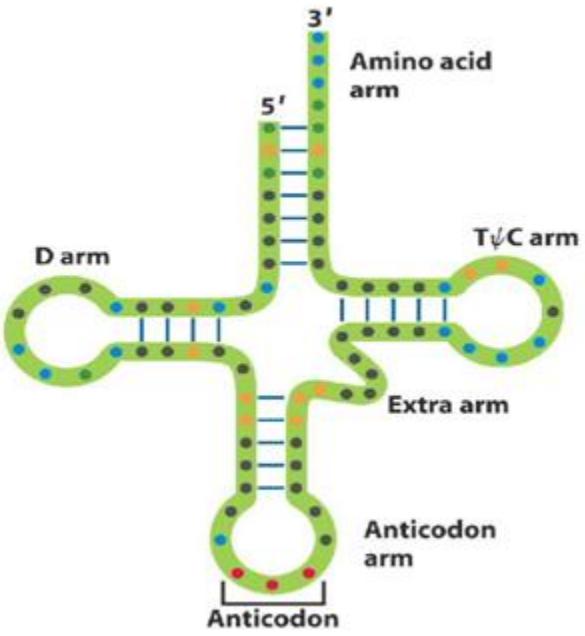
(c) Transfer RNA (tRNA)

- This constitutes about 15% of the total RNA in the cell.
- Structurally, tRNA is a clover – lead shaped molecule with a folded loop – like chain.
- The looping of the chain, results into pairing of the folded of organic bases. Hence the formation of hydrogen bonds.
- The molecule has got four active / recognition sites.

- The upper site recognizes an amino acid, where as the lower side (Anticodon) recognizes the mRNA. One of the sides recognizes the ribosome where as the other one recognizes in enzymes, amino – acyl tRNA synthetase.

  Role of tRNA

  The role of tRNA is to carry the activated amino acids from various parts of the cytoplasm to their binding site, the ribosome.



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  (B) DEOXYRIBONUCLEIC ACID (DNA)

  Chemical nature:-

  DNA is chemically composed of the following substances:

  (i) Deoxyribose sugar– This is a pentose (5 – carbon) sugar.

  (ii) Organic or nitrogenous bases – These are of two categories.

  (a) Purine bases – These are Adenine (A) and Guanine (G).

  (b) Pyrimidine bases – These are Cytosine (C) and Thymine (T).

  Base pairing rules:-

- Since DNA is double stranded molecule, the bases on the two strands appear in pairs being held together by the hydrogen bonds.
- The strands run in opposite directions, that is are Antiparallel.
- The base pairing rules make the chains, Complementary.
- According to Watson - Crick modal of DNA structure, a purine pairs with a pyrimidine. The rules are that:

  (a) Adenine pairs with thymine and the two bases are held together by two hydrogen bonds.

  (b) Cytosine pairs with guanine and the two bases are held together by three hydrogen bonds.

  (iii) Phosphate group – dividend from phosphoric acid.

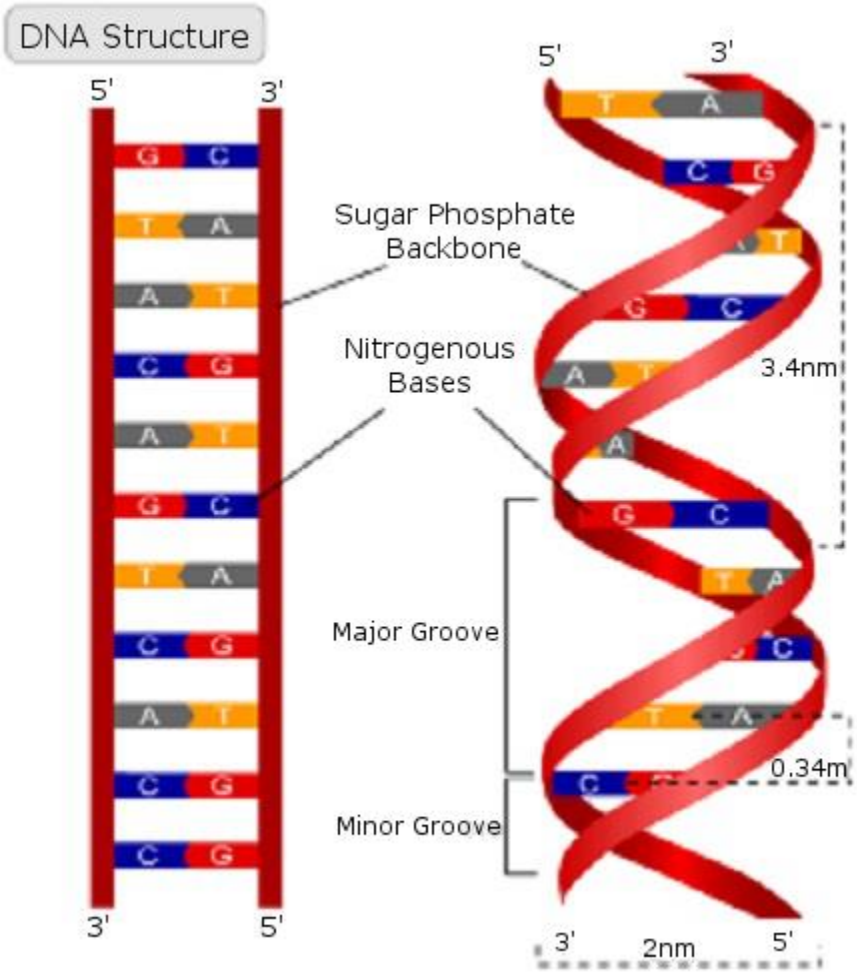
  (iv) Protein - Over the surface of DNA, there is a histone protein coat.

  (v) Chemical bonds - There are two types of chemical bonds.

  (a) Phosphodiester bonds – These hold the nucleotides together.

  (b) Hydrogen bonds – These hold the complementary base parts together.

Diagrammatic structure of DNA:-



- **Role of DNA in protein synthesis.**

  This role of DNA is that, it instructs the cell of the types of amino acid that should be initiated to form a protein molecule. That is the message contains the information about the types of amino acids that should be joined up forming the protein molecules

  Qn:-One of the characteristics of DNA as a hereditary material; is that it is metabolically very stable. State the features of DNA that account for this metabolic stabilit

  Answer;-

  The features of DNA account for this metabolic stability include the following:-

  (a) Possession of a histone protein coat

  (b) The helical nature, increases mechanical strength.

(c) The chemical bonds i.e hydrogen and phosphodiester bonds, increase mechanic strength.

Evidence for the role of DNA in inheritance

It took many years to clarify whether genetic material was the DNA or the protein the chromosomes. It was suspected that protein might be the only molecule with staff verify of structures to act as genetic material.

Evidence from bacteria:

In the days before development of antibiotics pneumonia was often a fatal disease. It was intended in developing a vaccine against the bacterium Pneumococcus which was one form of pneumonia.

Two forms of pneumococcus where known, one covered with a gelalinious capsule one violent (disease producing) and the other non – capsulated and non – violent. The capsule protected the bacterium in some way from attack by immune system of the host.

Griffith hoped that by injecting the patients with either the non – capsulated the heat – killed capsulated forms, their bodies would produce antibodies which would give protection against pneumonia. In a series of experiments he injected with both forms of pneumococcus and obtained the results shown in a table below. The dead mice revealed the presence of live capsulated forms their bodies. On the basis of these results Griffith concluded that something must be passing from the heat – killed capsulated forms to the live non – capsulated forms which caused them to develop capsule and become virulent.

However the nature of this transforming principle, as it was known was not isolated and identified until 1994.

Results of Griffth's experiments:-

Injected form of pneumococcus	Effect
Live non – capsulated	Mice live
Live capsulated	Mice live
Heat – killed capsulated	Mice live
Heat – killed capsulated	Mice live
Heat – killed capsulated + live non capsulated	Mice live

Later on analysis on the constituent molecule of heat – killed capsulated pneumococcal cells and testing their ability to bring about transformation in live non – capsulated cells. Removal of the polysaccharide capsule and the protein much from the cell extracts had no effect on the transformation, but the addition of the enzyme deoxyribonuclease (DNase), which hydrolyses (break down) DNA prevented transformation. Hence, demostration of the Griffth transforming principle basing on the fact of DNA.

Evidence from viruses:-

Experiment on bacteriophage which attacks the bacterium, it concluded that DNA physical and not the protein which is the hereditary materials.

DNA REPLICATION

DNA replication is a process whereby the exact copies of DNA (replicable) are produced by the old DNA molecules.

Significance of DNA replication:-

(i) Since it occurs prior to the nuclear division, DNA replication ensures that all newly formed cells have the same amount of DNA.

(ii) It ensures sameness and constancy of hereditary materials of the cells.

(iii) Occasional mistakes during DNA replication, results into genetic variations hence evolution.

(iv) If evidence mistake attracts uracil instead of thymine. RNA is constructed not DNA. This occurs when the enzyme fails to recognize the methyl group of uracil.

Mechanism of DNA replication:-

The two strands of a DNA unwind and separating thus acting as temperature to which a complementary set of nucleotides would attach by base pairing. In this way each original molecule of DNA give rise

to two copies with identical structures. In the presence of ATP an enzyme DNA polymerase links free DNA to form complementary bases.The unwinding of DNA, double helix is controlled by the enzyme

helicase. DNA polymerase then move along the strand resulting formation of complementary bases and hence a free nucleotide and finally extending new stand of DNA. As the enzymes continue to move

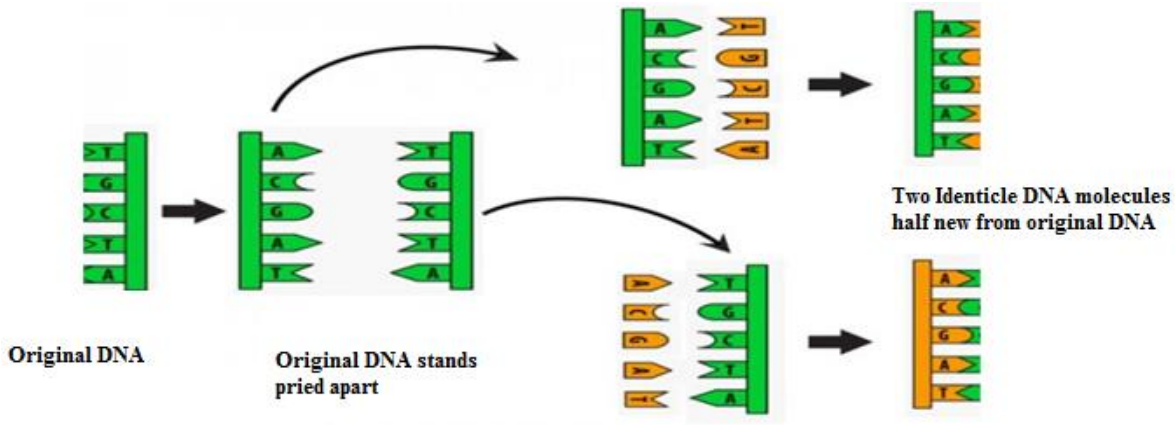
along one base at a time, the new DNA strand grows. This is called continuous replication in which one strand is copied before another strand.

The formation (copying) of another strand involves movement of DNA polymerase away from unwinding enzyme. This results in the small gaps being left at some points along the newly constructed DNA stand. These gaps are then sealed by an enzymes DNA ligase. This is called Discontinuous replication.

Semi – conservative replication

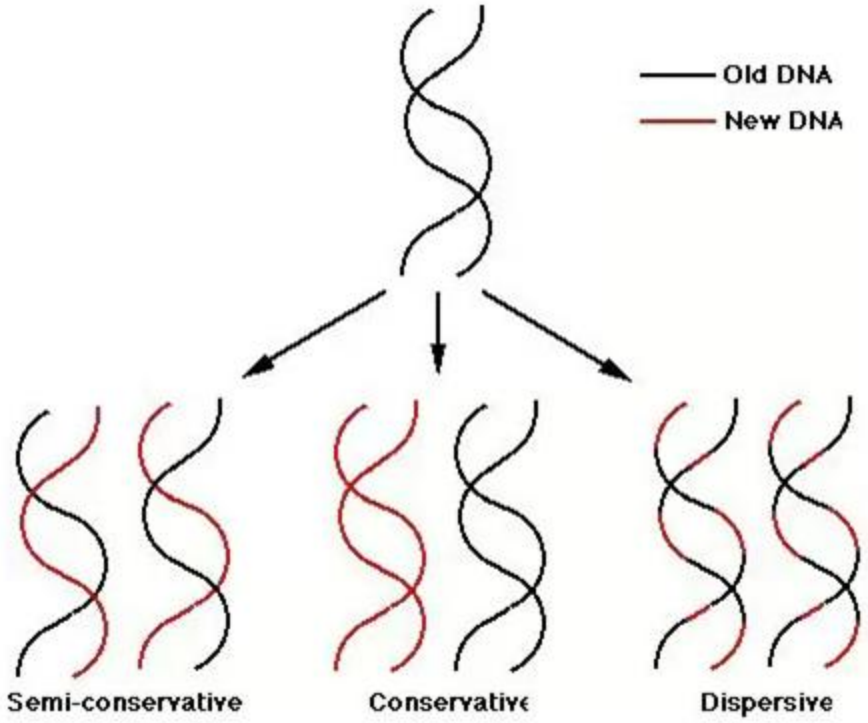
- In this method of replication, each newly formed double helix retains (conserves) of the two strands of the original DNA double helix.
- That is in each of the newly constructed DNA molecules, there is an old and new strand.

Illustration:-



1. A representative portion of DNA, which is about to undergo replication is shown.
2. DNA polymerase causes the two strands of the DNA to separate.
3. The DNA polymerase completes the splitting of the strand. Meanwhile free nucleotides are attracted to their complementary bases.
4. Once the nucleotides are lined up joined together. The remaining unwinded bases continue to attract these complementary nucleotides.
5. Finally the nucleotides are joined to form a complete polynudeotide chain. In this way two identical strands of DNA are formed. As each strand retains half of the original DNA material, this method of replication is called Semi – conservative method.

The tree theories of DNA replication illustrated



- **Differences between DNA and RNA:-**

	DNA	RNA
	Double stranded polynucleotide molecule	- Single stranded polynucleotide molecule.
	The pentose sugar is deoxyribose	- The pentose sugar is ribose
	The pyramidine base is Thymine	- The pyramidine base is uracil.
	It is found in molecules	- It is found in the cytoplasm
	It is constant in the cell	- The amount of RNA is variable
	It is more stable	- It is less stable.
	It has high molecular mass	- It has low molecular mass.
	The ratio of 'A' to 'T' and 'G' to 'C' is always 1.	- The ratio of 'A' to 'U' and 'G' to 'C' is variable

	Only one basic form, but with an infinity variety within that form.	- Three basic forms, messenger, transferred and ribosomal RNA
	Treatment	Stay exist temporary for short period

Study Questions:-

1. (a) What is DNA replication?

(b) Describe the mechanism of the process by which a DNA molecule is produced and explain why this is called a semi-conservative process

(c) Summarize the structural differences between DNA and RNA.

2. Summarize the structure differences between DNA and RNA

The nature of genes:-

What are genes?

Mendel defined gene as a unit of inheritance. This is an acceptable definition of gene but it does not tell us anything about the physical nature of gene.

Below are ways of overcoming this objection.

(i) A unit of recombination

It was shown that a gene was the shortest segment of a chromosome which is separated from adjacent segments by crossing over.

This definition regards gene as the specific region of chromosome determining a district chromosome in the organism.

(ii) A unit of function

It is known that genes are codes for proteins;

Therefore a gene is the DNA code for polypeptide.

Since some proteins are made up of more than one polypeptide chain and are coded by more than one gene.

The genetic code

The genetic code is the relationship between nitrogenous bases on the DNA and the acids.

It was suggested that the genetic information which passed from generation to and which controlled the activities of the cell, might be stores in the sequence for the production of protein molecules it become clear that these sequence of in the DNA must be a code for the sequence of amino acids in protein molecules relationship between bases and amino acids is known as the genetic code.

In other words the genetic code is a means by which the genetic information.

DNA controls the manufacture of specific proteins, by the cells.

The problems remained were to demonstrate that a base code consisted to break the code and to determine how the code is translated in to the amino acid sequence of a protein molecule.

The code is triplet code.

There are four bases in the DNA molecules, Adenine (A), Guanine (G), Thymine (T) and Cytosin.

Each base is a part of nucleotide and the nucleotides are arranged as a polynucleotide chain (strand). The sequence of base indicated by their first letters (alphabets) are responsible for carrying the code that

results in the synthesis of potentially infinite number of different protein molecules.

There are 20 common amino acids used to make protein and that the base in the DNA must code for. If one base determined the position of a single amino acid in the primary structure of a protein, the

protein could have four different amino acids. If a combination of base pairs coded for each amino acid then 16 acids could be specified into the protein molecule.

Only a code composed of three bases could incorporate all 20 amino acids into the structure of protein molecules.

It was therefore proved that the code is indeed a triplet code, meaning that three bases is the code for one amino acid.

Problems.

1. Using different pairs of the bases A, G, T and C list the 16 possible combinations of bases that can be produced.

Answer:-

Base	A	G	T	C
A	AA	AG	AT	AC
G	GA	GG	GT	GC
T	TA	TG	TT	TC
C	CA	CG	CT	CC

2. If four bases used singly would code for four amino acids, pairs of bases code for the 16 amino acids and triplets of bases code for 64 amino acids, deduce a material to expression to explain this.

Answer:-

4 bases used once = 4 x 1 = 4

4 bases used twice = 4 x 4 = 4^2 = 16

4 bases used thrice = 4 x 4 x = 64

The mathematical expression is X^y

Where: X = Number of bases and

Y = Number of bases used.

- It is thus a combination of three nitrogenous bases a three lettered ward of AGC, AUA, GCA etc.

Features (Characteristics) of the genetic code:-

1. It is a triplet of bases in the polynucleotide chain codes for an amino in the polypeptide chain.

2. The genetic code is degenerate i.e A given amino acid can be coded for by more to one code and (Codons-complementary triplets in the mRNA).

Example:

Amino acid	Carbon
Alanine	GCU
	GCC
	GAC
	GCG

3. The genetic code is universal i.e. the same triplet codes for the same amino acids all organisms.

4. The genetic code can be punctuated i.e. It has got the 'start' and 'end' signals.

5. The genetic code is non-over lapping. E.g. If the base sequence is ACAGAGUCGGAC, then this will be read as ACA/GAG/UCG/GAC and not ACA / CAG / AGA.

6. The genetic code sequence has got no camma e.g. AAU, GCG, GAC, etc. This is because the bases are continuously sequenced on the DNA or RNA strand.

Note: The type of code where the number of amino acids is less than the number of codons is termed as degenerate.

Nonsense codons – These codons do not code for amino acids, they pregimably mark the end point of 2 chains. They act as stop signals for the termination of polypeptide chains during translation.

PROTEIN BIOSYNTHESIS. 'DNA makes RNA and RNA makes Protein'

- Protein synthesis is a mechanism by which protein molecule is constructed by joining the amino acids with the peptide bonds according to the instruction in the mRNA coded from DNA.

1. Synthesis of amino acids.

2. Transcription (Formation of mRNA).

3. Amino acid activation.

4. Translation.

The site for protein synthesis is the ribosome.

These protein synthesized may have structural role such as Keratin and collagen, or a functional role such as insulin, fibrinogen and mostly important enzymes which are responsible for controlling all metabolism. It is the particular range of enzymes that determines what type of cell it becomes. This is the way in which DNA controls the activities of a cell.

The instructions and information for the manufactures of enzymes and all other proteins are located in the DNA. However, the actual synthesis of protein occurs in the ribosomes in the cytoplasm. Therefore a mechanism had to exist for carrying the genetic information's from the nucleus to the cytoplasm. This link was from messenger RNA.

Adaptations of the ribosome to protein synthesis

1. Presence of appropriate enzymes that catalyze the synthesis of polypeptide bonds between the amino acids.

2. Presence of receptor site for messenger RNA attachment.

3. Presence of rRNA for attracting other types of tRNA towards the ribosome.

4. Ability to read and 'translate' the message contained in the codes of mRNA.

Mechanism of protein synthesis:-

There are four main stages in the synthesis of protein:-

- **1. Synthesis of amino acids:-**

  In plants, the formation of amino acids occurs in mitochondria and chloroplast in a series of stages:

  (a) Absorption of nitrates from the soil.

  (b) Reduction of those nitrates to the amino group (NH_2).

  (c) Combination of those amino groups with a carbohydrate skeleton (eg. α - ketoglutarate from Krebs cycle).

  (d) Transfer of the amino group from one carbohydrate skeleton to another by a process called transamination.

  Animals usually obtain their acids from the food they ingest, although they have capacity to synthesize their own non- essential amino acids.

  2. Transcription (formation of mRNA).

- This is a mechanism by which the base sequence of a section of DNA representing gene, is converted into a complementary base sequence of mRNA.

- In this process a complementary mRNA copy is made from a specific region of the molecule which codes for a polypeptide.

Mechanism of transcription

A specific region of the DNA molecule, called Cistron, unwinds. This unwinding is a result of hydrogen bonds between base pairs in the DNA double helix being broken. This exposes the bases along each strand and one of these strands is selected as a template against which mRNA is constructed.

This mRNA molecule is formed by linking free nucleotides under the influence of RNA polymerase and according to the rules of base pairing between DNA and R

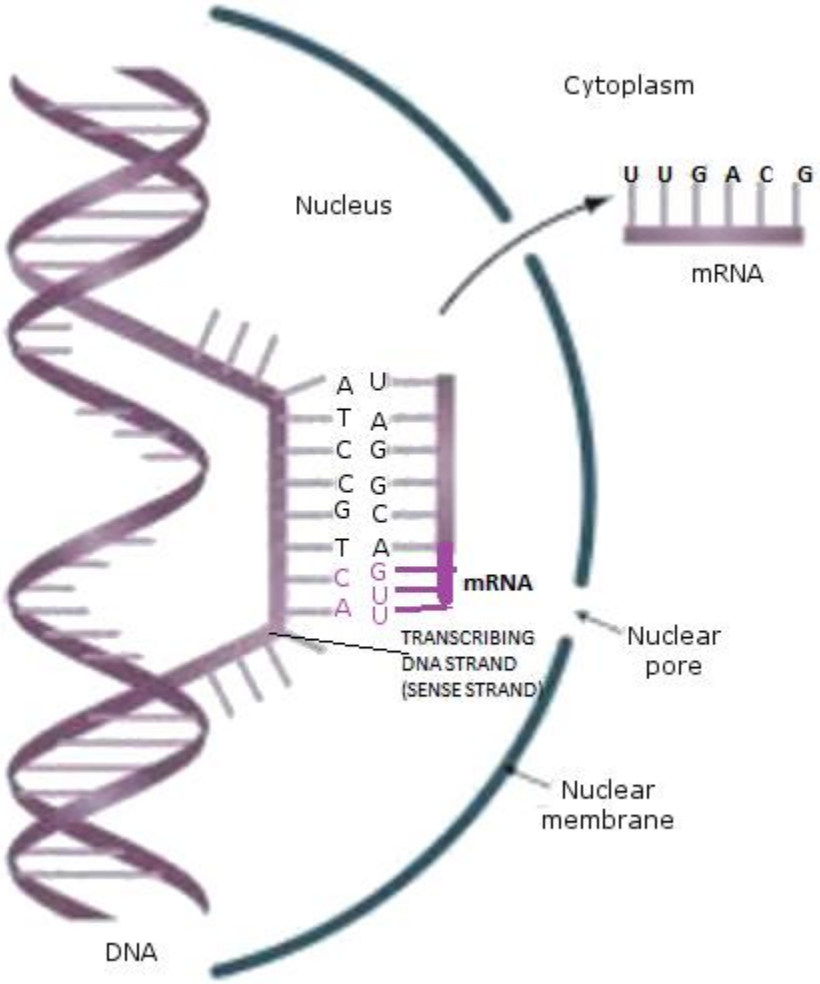
Table to show the RNA bases which are complementary to those of DNA:-

DNA bases	Complementary RNA bases
A (Adenine)	U (Uracil)
G (Guanine)	C (Cytosine)
T (Thymine)	A (Adenine)
C (Cytosine)	G (Guanine)

When the mRNA molecule has been synthesized they leave the nucleus via the nuclear pore and carry the genetic code to the ribosomes. Along the mRNA is sequence of triplet codes which have been determined by the DNA. Each triple called a codon.

When sufficient numbers of mRNA molecules have been formed from the gene the RNA polymerase molecule leave the DNA and the two strands ‘Zip up” reforming the double helix.

Illustration:-

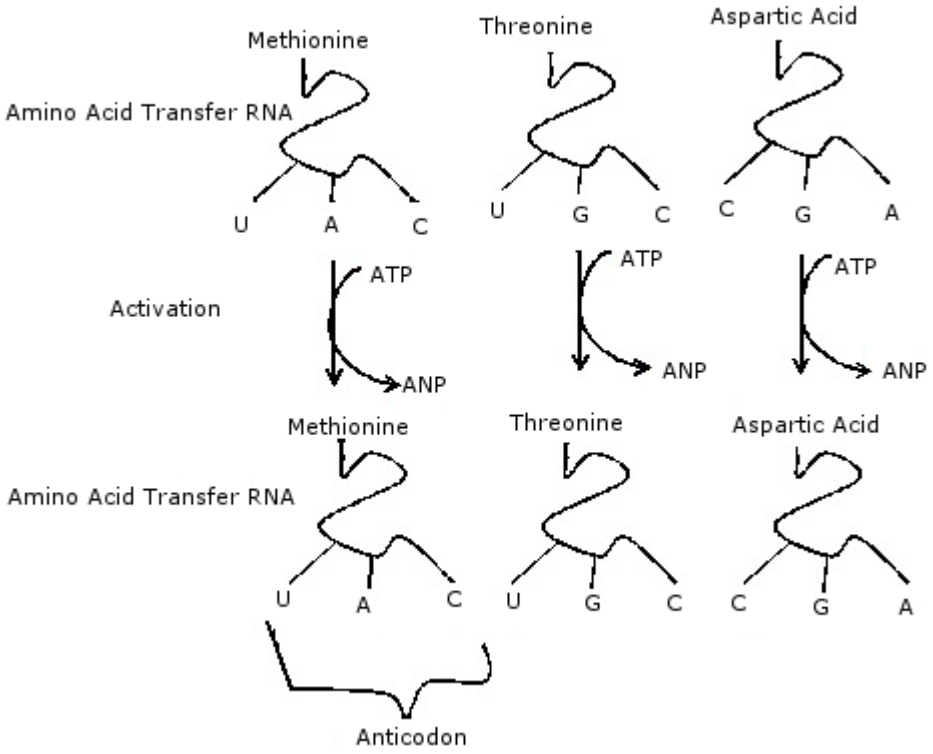


3. Amino acid activation

Activation is the process by which amino acids combine with tRNA using energy from ATP. Each type of tRNA binds with the specific amino acid which means there must be at least 20 types of tRNA.

Each type differs among other things in the composition of a triplet of bases called terminates in the CCA. It is to the free end that the individual amino is not known. The tRNA molecules with attached amino acids form an amino acid tRNA complex known as aminoacyl-tRNA and their formation is under the enzyme aminoacyl-tRNA synthetase. The combination now moves towards the ribosome.

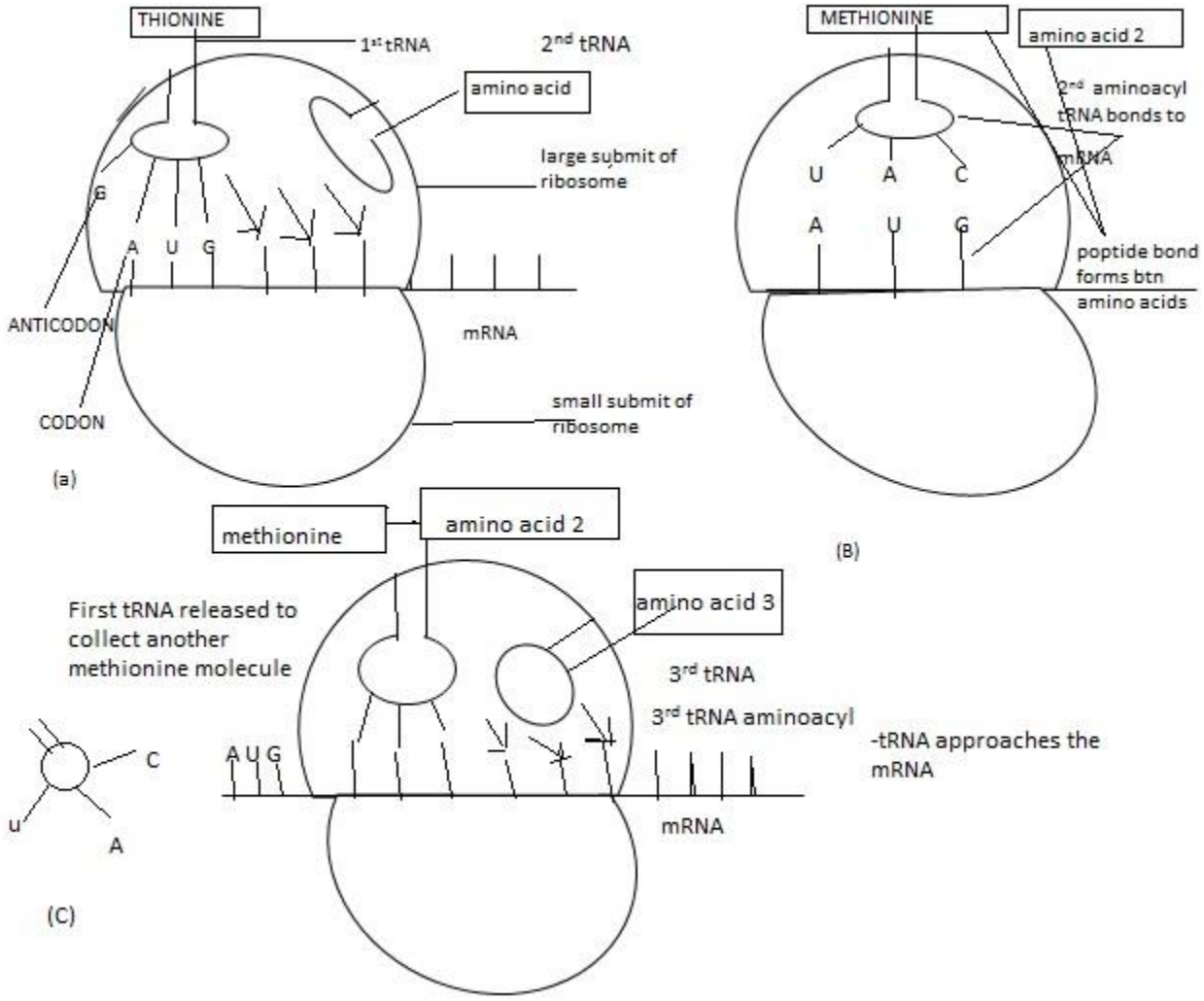
Illustration:-



4.Translation.

- Translation is the mechanism by which the sequence of bases in an mRNA molecule converted into a sequence of amino acids in a polypeptide chain.
- It occurs on ribosomes.
- Several ribosomes may become attached to a molecule of mRNA like bodies on string end a whole structure is known as polyribosome or polysome.
- The advantage of such an arrangement is that it allows several polypeptides to be synthesized at the same time.
- The first two mRNA codons (a total of 6 bases) enter the ribosome. The first codon binds the aminoacyl–tRNA molecule having the complemetary 'anticodon' and which is carrying the first amino acid (Usually – methionine) of the polypeptide being synthesized.
- The second codon then also attracts an amino acyl-tRNA molecule showing the complementary anticodon.
- The function of the ribosome is to hold in position the mRNA, tRNA and the association enzymes controlling the process until a peptide bond form between the adjacent amino

- acids.



- Once the new amino acid has been added to the growing polypeptide chain, the ribosome moves one codon along the mRNA. The tRNA molecule which was previously attached to the polypeplide chain now leaves the ribosome and passes back to the cytoplasm to be reconverted into a new aminoacyl – tRNA molecule.
- This sequence of ribosome 'reading' and 'translating' the mRNA code continues until it comes to a codon signaling 'stop'. These terminating codons are UAA,UAG, and UGA. At this point the polypeptide chain, now with its primary structure as determined by DNA, leaves the ribosome and translation is complete. The main steps involved in translation may be summarized under the following headings;-
    1. Binding of mRNA to ribosome.
    2. Amino acid activation and attachment to tRNA.
    3. Polypeptide chain initiation.
    4. Chain elongation.
    5. Chain termination.
    6. Fate of mRNA.

The polypeptides so formed must now be assembled into proteins. This may involve the spiralling of the polypeptides to give a secondary structure, its folding to give a tertiary structure and its combination with other polypeptides and or prosthetic group to give a quatenary structure.

If the ribosome is attached to ER (rough ER) the protein enters the ER to be transported.

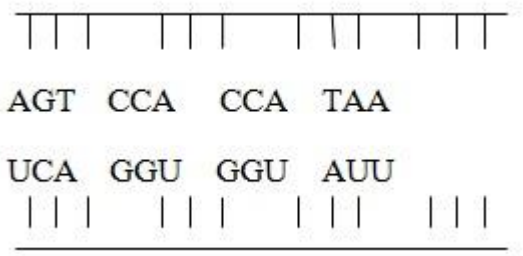
Question.(a) Describe how a single stand of mRNA is being constructed from one of the strands of DNA.

(b) If the base sequence on the portion of DNA strand is AGTCCACCATAA,

(i) What is the base sequence on the portion of mRNA constructed by this portion?

(ii) How many amino acid molecules are there in the base sequence given above?

SOLN



- Thus the base sequence on the mRNA will be UCAGGUGGUAAU

1. Since there are four triplets each responding a single amino acid, then there will be four amino acids.

Introns and exons.

It was discovred that the DNA of eukaryotic gene is longer than its corresponding mRNA. It should be the same length because the messenger RNA is a direct copy discovered that immediately after the mRNA is made, certain sections of the molecule out before it is used in transaction. The sections of the gene that code for the unused pieces of RNA are called Introns. The remaining sections of the gene the code for the protein and are called exons.

Summary:

Eukaryotic genes contain regions called Introns which do not code for the amino. The parts of the genes that code for amino acids are called exons.

MENDELIAN GENETICS

Gregor Johan Mendel did studies of genetics using the *Pisum sativan* (garden peaces).

He was trying to find the laws that govern the passage of characters from one generation to another.

He established that Pisum sativum had the following advantages over other species:-

1. They were several varieties available which had quite district characteristics.

2. The plants were easy to cultivate

3. The reproductive structures were enclosed by the petals, this made the plant self pollinating and hence producing varieties of the some characteristics (pure breading).

4. Artificial cross – breeding between varieties was possible and resulting hybrids were confertile.

Mono hybrid inheritance and the principle of segregation:-

- Monohybrid inheritance is a pattern of inheritance which involves two contrasting variations of only one characteristic.

  Example:

  Tall Vs short (height).

  Red Vs White (colour).

  Rough Vs Smooth (texture).

  Glossary of common genetic terms:-

  1. **Gene** -The basic unit of inheritance for a given characteristic.
  2. **Allele** - One of number of alternative forms of the same gene responsible for determining contrasting characteristics e.g. A or a (pared genes).

  3. Locus - Position of an allele within a DNA molecule. Alleles of one gene are on one locus.

  4. Homozygous - The diploid condition in which the alleles at a given locus are identical e.g. AA or aa.

  5. Heterozygous - The diploid condition in which the alleles at a given locus are different e.g. Aa.

6. Phenotype – The observable characteristics of an individual usually resulting from the interaction between the genotype and the environment in which development occurs e.g. Red, blue.

7. Genotype – The genetic constitution of an organism with respect to the allele under consideration e.g. AA2, A2, or did.

8. Dominant - The allele which influence the appearance of the phenotype even in the presence of an alternative allele e.g. A

9. Recessive – The allele which influence the appearance of the phonotype only be or in the presence of another identical allele e.g. a

10. F1 generation – The generation produced by crossing homozygous parents.

11. F2 generation – The generation produced by crossing two F1 organisms.

Basic Monohybrid ratio

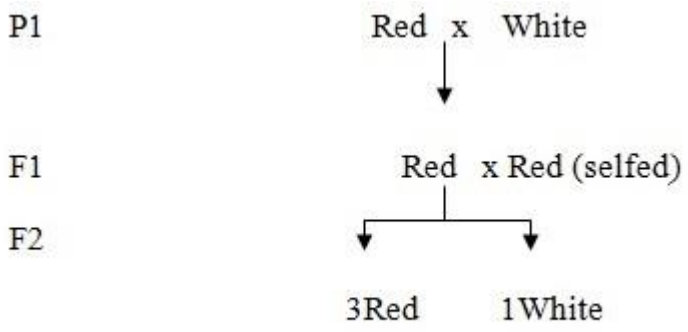
This is the phenotypic ratio contained in the F2 generation of the original pure parents.

The ratio is always 3:1

Mendel's experiment and the Monohybrid ratio

- In one of his experiments, Mendel crossed a red flowered plant from a pure line with a white flowered plant also from a pure line. Al the resulting F1 plants had red flowers.
- When the F1 members were selfed, the resulting F2 were a mixture of red and white phenotypes in the approximate ratio of 3:4.
- This is the basic monohybrid ratio obtained from a cross between two heterozygous individuals.

Illustration:-



Non coding DNA.

Though human DNA contains large number of genes, the problem is about 95% of the DNA appears to have no obvious function because it is non - coding. In other words does not code for proteins or RNA.

(i) The factor for redness was dominant over that for whiteness which was red.

(ii) The factor for whiteness was present in the F1 though not expressed effect was obscured by the factor for redness.

(iii) The characteristic red and the characteristic white remained unchanged. I.e.: There was no an intermediate colour.

(iv) Each characteristic is controlled by a pair of factors that segregate during gamete formation.

- This observation, suggested to Mendel the formulation of his first law "the law of segregation."

Assumptions:-

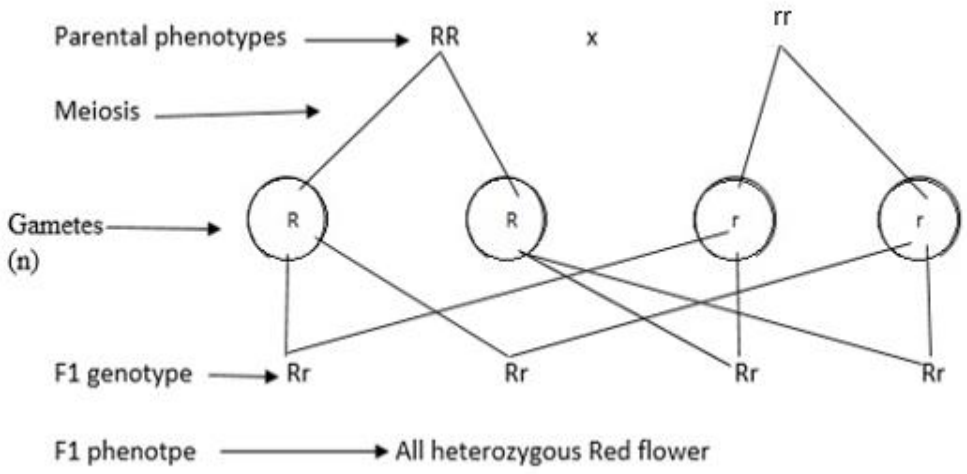
(i) Let 'R' be factor redness and 'r' factor for whiteness.

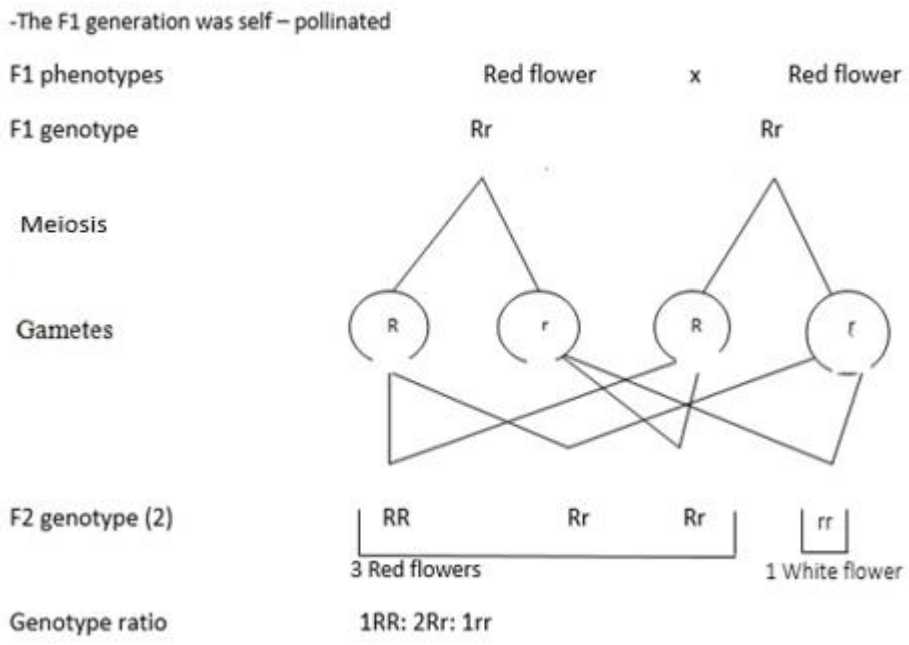
(ii) Let 'R' dominate 'r' so that when the two are together, only R is expressed.

(iii)Let each character be controlled by a pair of factors that segregate gametes formation.

Consider the following cross:-

Parental phenotypes Pure breeding Red flower x Pure bleeding White flower





Phenotypic ratio 3Red : 1White

Mendel's 1st law of inheritance (Law of segregation)

The law states that:-

"The characteristics of an organism are determined by internal factors which occur in pairs. Only one of a pair of such factors can be represented in a single gamete.

Meiotic explanation of Mendel's first law.

- Although Mendel knew nothing about Meiosis, but his first law is explained by Meiosis as follows:-
- During Meiosis, the paired homologous chromosomes, separate from each other as a result of which the gametes receive only one type of chromosome instead of the normal two.
- Alleles also occur in pairs at the homologous chromosomes, thus separation of homologous chromosomes occurs currently with the separation of alleles.
- Thus, there is similarity between separation of homologues chromosomes in Meiosis and segregation of Mendelian factors.

We know that Mendel's factors are specific portion of a chromosome called genes. We also know that the process which produces gametes with only one of each pairs of factors is Meiosis. On the basis of his results, Mendel had effectively predicted the existence of genes and Meiosis.

Methods used to solve Mendelian problems:-

(a) Algebraic method.

(b) Punnet square/chequer board method.

(c) Mendelian crosses/genetics diagrams

(A) Algebraic method

- Consider a cross between two tall plants both heterozygous for height.

P. Phenotype Tall x Tall

Genotype (2n): Tt x Tt

Meiosis ;

Gametes (n): (T + t) (T + t)

After fertilization: T2 + tT +t + T2

F1 genotypes (2n): TT + 2Tt + tt

3 Tall 1dwarf

- Punnet square will be discussed later.
- Mendelian cross, see above.

Symbols used in genetics:-

- In genetics any symbol can be used to represent any characteristics provided it is defined.
- However, it is common that a dominant characteristic is represented by the first latter of its name. Eg. R for red, T for tall, G for green etc. The characteristics will take the lower case letter of the dominant one e.g r white where R red is dominant to white. The symbol P1 stands for parents and F1 and F2 are filial generations 1 and 2respectively

Example: One of the causes of dwafirsm in man is the inheritance of dominant gene D. The allele for a normal height is d, Given that the genotype for Kijeba a man suffering from dwafirsm is Dd, work out the genotype and phenotype rations of the offspring if he marries.

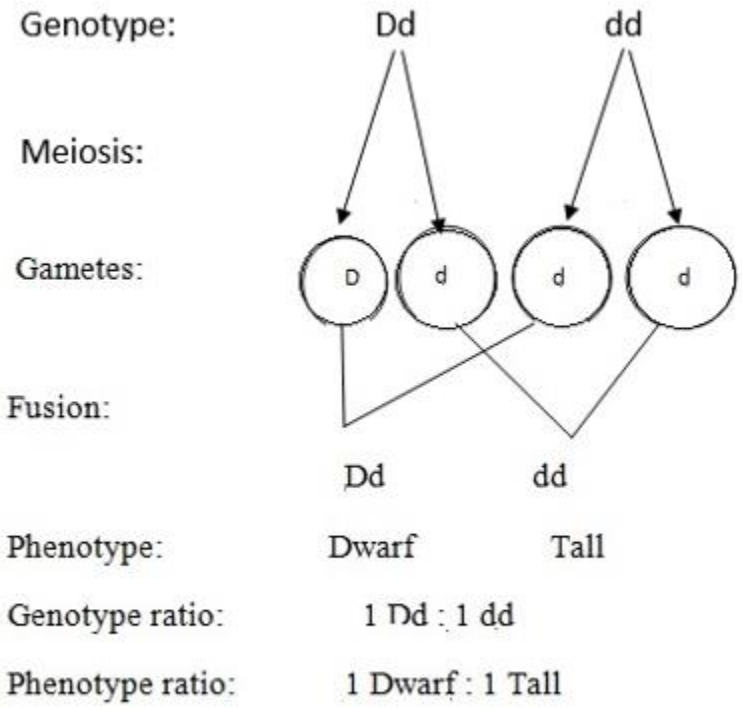
(a) A normal woman

(b) A dwarf woman

Solution:-

Given: D – allele for dwarfness

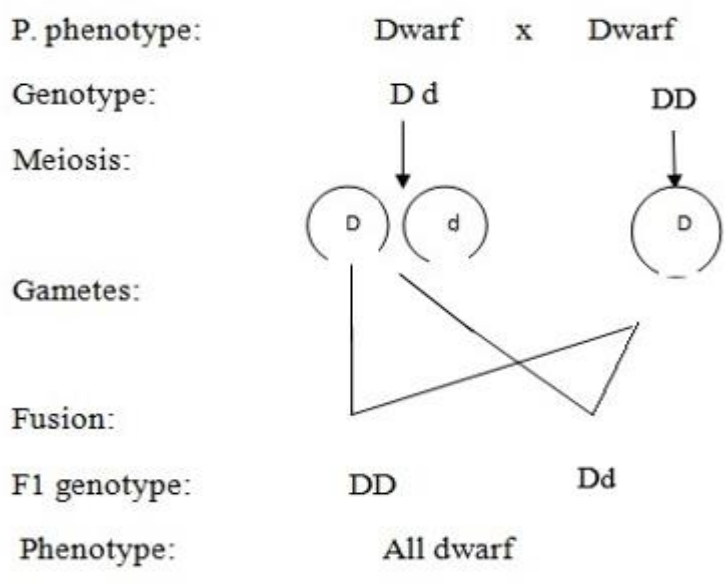
d – allele for tallness



(b) If he marries, the genotypes and phenotypes of there child will depend on the genotype of the woman.

(c) If she is homozygous tall, then half the offspring will be phenotype tall and the half short(dwarf) above reveals.

If she is homozygous dwarf, then the products will be.

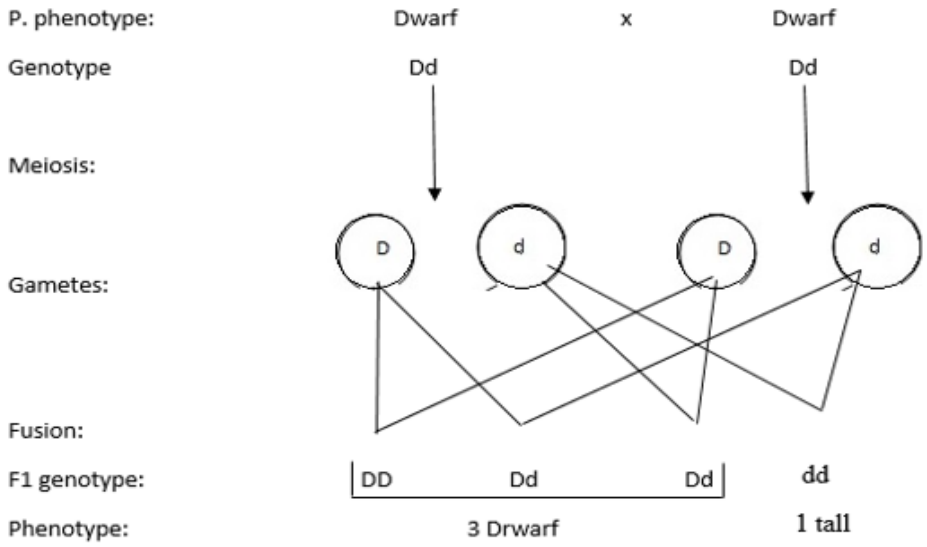


P. phenotype: Dwarf x Dwarf

Genotype: D d D d

The genotype ratio will be 1 DD: 1 Dd

If she is heterozygous dwarf, then the products will be.



Genotype ratio is 1DD : 2Dd: 1dd

Phenotype ratio is 3 Dwarf : 1 tall

BACK CROSS AND TEST CROSS

- Back cross – This is a cross between an organism and either of its parents.
- Test cross – This is a cross between an experimental organism with a dominant phenotype and that of a recessive phenotype, of its parent so as to determine the genotype of that experimental organism.

Explanations:-

One common genetic problem is that an organism which shows a dominant character has two possible genotypes.

Example

A plant producing seeds with round coats could either be homozygous dominant (RR) heterozygous (Rr). The appearance of the seeds (phenotype) is identical in both cases. However it is often necessary to determine the genotype accurately.

This involves the use of a technique known as Test mass in which an organisms is unknown genotype is crossed with the one whose genotype is accurately known.

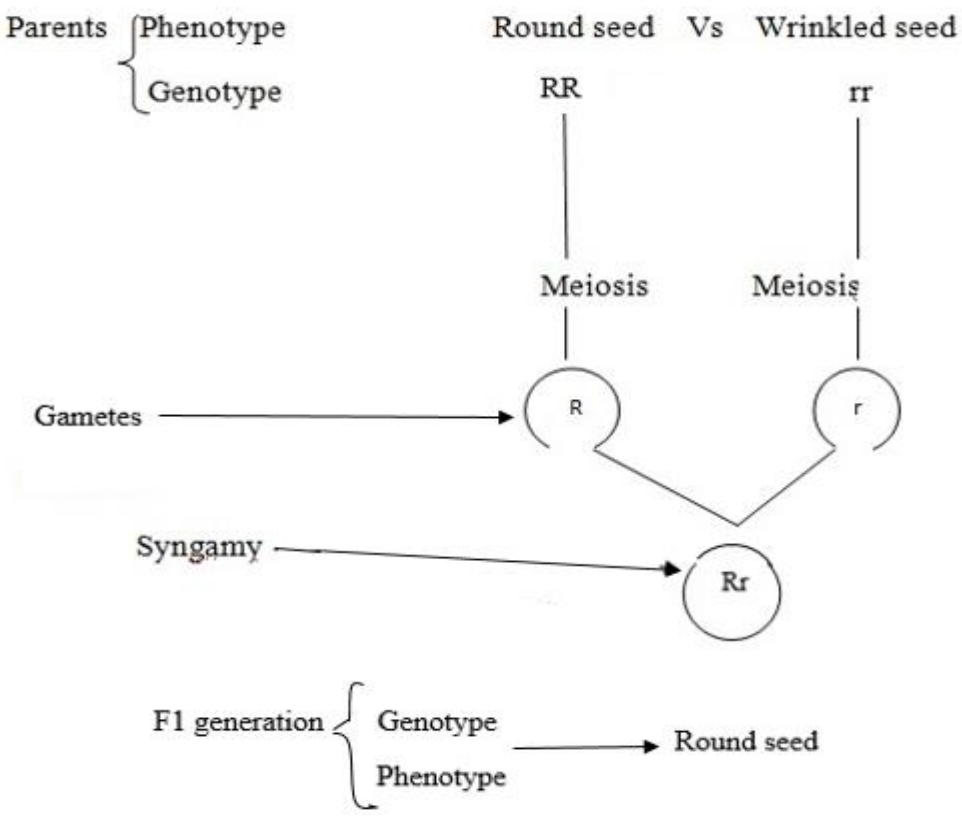
A genotype which can positively be identified from its phenotype alone is one which shows recessive features.

In the case of the seed coast, any pea seed with a linked coast must have the genotype "rr". By crossing the dominant character, the unknown genotype can be identified.

Let R = allele for round seeds

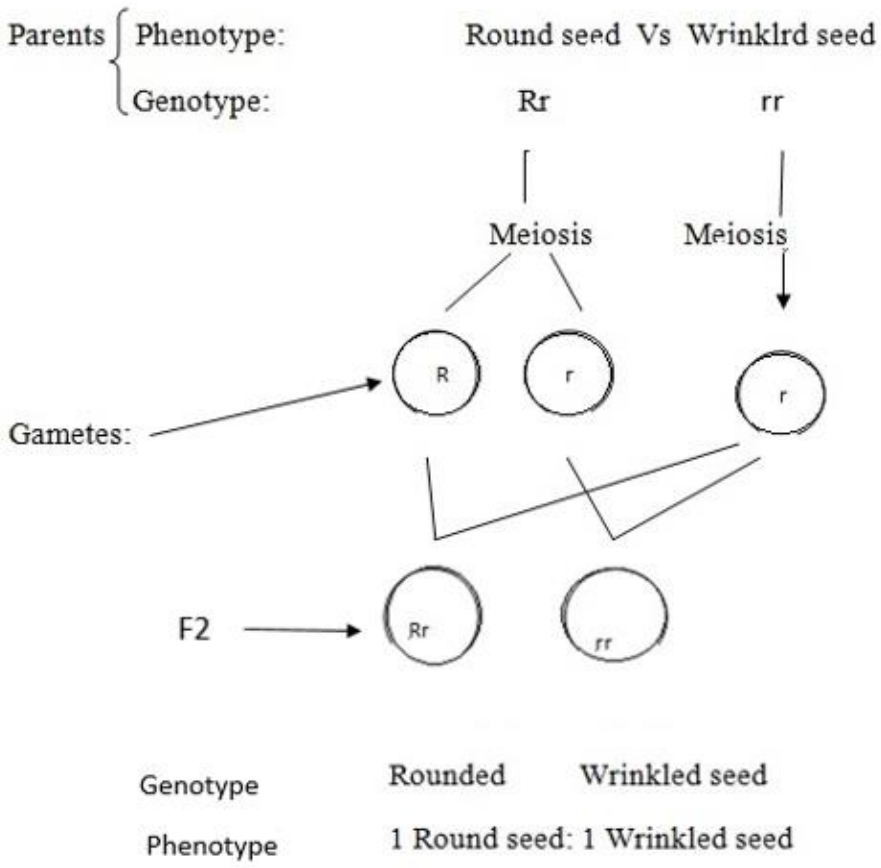
R = allele for wrinkled seeds

If the plant producing round seeds have the genotype RR.



Conclusion: The only possible offspring are plants which produce round seeds, thus the unknown genotype is RR.

If the plant producing round seeds have the genotype Rr.



This 1:1 ratio is the monohybrid test cross ratio obtained from a cross investigation between heterozygous dominant and a homozygous recessive.

Questions

1. If a pure strain of mice with brown-coloured fur are allowed to breed with a pure of mice with grey-coloured fur, they produce offspring with brown-coloured fur. If F1 mice are allowed to interbreed

they produce an F2 generation with fur coloured in proportional of three brown-coloured to one grey.

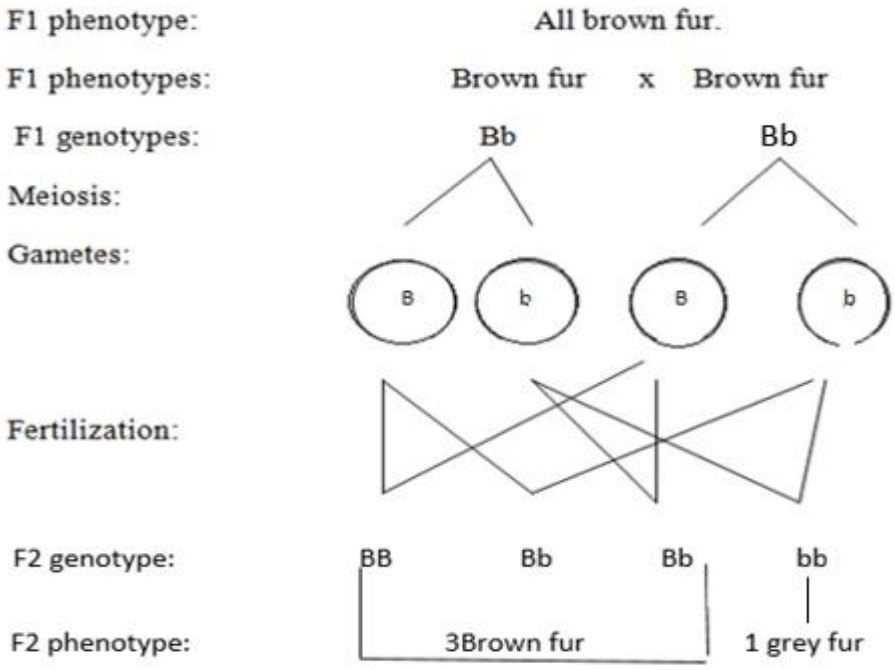
Explain their result fully.

What would be the results of meeting a brown – coloured heterozygote from the generation with the original grey – coloured parent?

Answer:-

Let: B represents brown fur (dominant)

b represents grey fur (recessive)



(b) Experimental phenotypes: Brown fur x Grey fur

Experimental genotypes (2n): Bb bb

Meiosis:

Gametes (n): B b b b

Random fertilization:

Offspring genotypes (2n): Bb Bb bb bb

Offspring phenotypes: 1 brown fur : 1 grey fur

Parental phenotypes: Brown fur x Grey fur

Parent genotype (2n): BB bb

Meiosis:

Gametes (n): B B b b

Fertilization:

F1 genotype: Bb Bb Bb Bb

F1 phenotype. All brown fur

NON – MONOHYBRID INHERISTANCE

This is a pattern of inheritance which involves more than one character. These may be two three etc.

Dihybrid inheritance and Mendel's Law of Independent assortment.

Dihybrid inheritance is the pattern of inheritance which involves inheritance of two characters simultaneously.

In one of his experiments Mandel investigated the inheritance of the seed shape (size Vs Wrinkled) and seed colour (Yellow Vs green) at the same time. He knew from the monohybrid crosses that the round seeds were dominant to wrinkled ones and yellow seeds were dominant to green. He chose to cross plants with both dominant seed (round and yellow) with one that were recessive for both (Wrinkled and green).

The F1 generation yield plants all of which produced round, yellow seeds – hard surprising as these are two dominant features.

F1 seeds were planted and then allowed to self pollinate. The resulting members were a mixture of phenotype in the following proportions:

315 Round yellow (Two dominant features).

701 Wrinkled yellow (recessive and Dominant).

108 Round green (Dominant and recessive).

32 Wrinkled green (Two recessive features).

- Those numbers represent an appropriate ratio of 9:3:3:1. This is the basic dihybrid ratio.
- In a dihybrid cross, characteristic behaves independently of the other i.e Each characteristics behaves as if it is in the monohybrid cross.

Now, treating each characteristic separately we have:-

(a) Considering seed texture (Ignore colour)

Round		Winkled
315 + 108		101 + 32
423		133
133		133
3	:	1

(b) Considering colour (Ignore seed texture)

Yellow		Green
315 + 101		108 + 32
416		140

140 140

= 3 : 1

- Thus, in the F2 generation of a dihybrid cross each characteristics, has a phenotype ratio of 3:1
- The binomial of the two ratios renders.

(3:1) (3:1) = 9:3:3:1

Thus, the dihybrid ratio is a binomial expression of two bases monohybrid rations.

Genetic representation of the dihybrid cross:-

Let R = allele for round seed

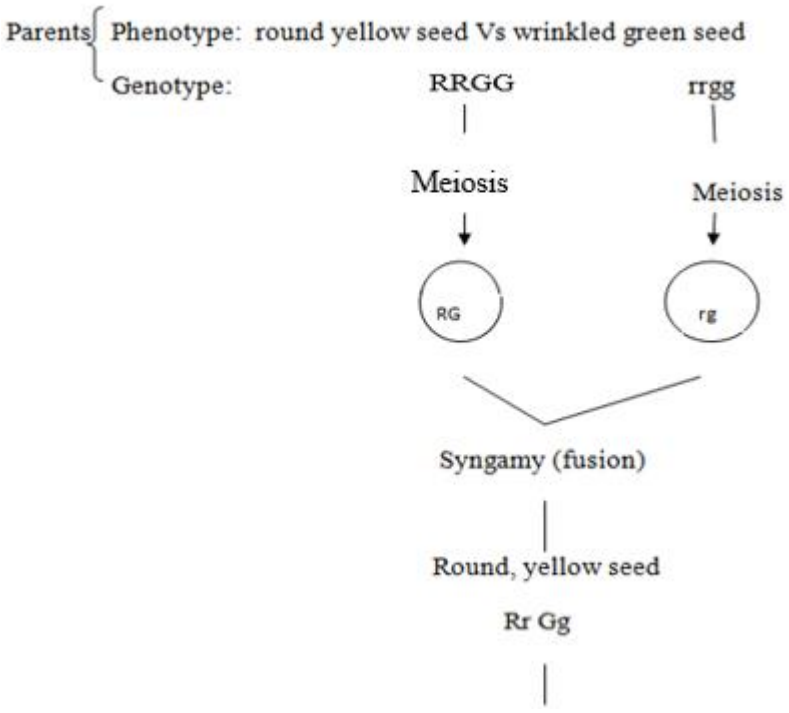
r = allele for wrinkled seed

G = allele for yellow seed

g = allele for green seed.

Parents Phenotype: round yellow seed Vs wrinkled green seed

Genotype: RRGG rrgg



Punnet square to show the fusion of gametes:-

Gamets	RG	Rg	rG	rg
RG	RRGG	RRGg	RrGG	RrGg
Rg	RRGg	RRgg	RrGg	Rrgg
rG	RrGG	RrGg	rrGG	rrGg
rg	RrGg	Rrgg	rrGg	rrgg

rrGg = Wrinkled, Yellow seed - 2

rrgg = Wrinkled, green seed - 1

rrGG = Wrinkled, Yellow seed - 1

Hence the ratio 9:3:3:1

How to calculate the genotype and phenotype ratio of a dihybrid cross.

There are two alternative ways:-

(a) By counting the number of boxes on the punnet square containing the genotype and phenotype of interest.

(b) Using a method based on the probability principle that:-

“The chances that a number of independent events will occur together, is square to the product of the chances that each event occur separately.”

From above example, there is a1 in 4 chance of any gamete containing any of the F2 allele combination shown above.

From a consideration of monohybrid inheritance where ¾ of the F2 phenotypes show the dominant allele and ¼ the recessive allele, the probability of the four alleles appearing in any F2 phenotype as

follows:

Round (dominant) ¾.

Yellow (dominant) ¾.

Wrinkled (Recessive) ¼.

Green (Recessive) ¼.

Hence the probability of the following combinations of alleles appearing in the F2 phenotypes is as follows:-

Round and Yellow = ¾ x ¾ = 9/16.

Round and green = ¾ x ¼ = 3/16.

Round and yellow = ¼ x ¾ = 3/ 16.

Wrinkled and green = ¼ x ¼ = 1/16.

Mendel's 2nd law of Inheritance (Low of Independent assortment)

In the dihybrid inheritance, Mendel realized that during gametes formation in each sex either one or another pair of factors may enter the same gametes cell (random combination) with either one or another

cell. The law states that:-"Any one of a pair of characteristics may combine with either one of another pair"

Meiotic explanation of Mendel's second low

Mendel's second law is explained by Meiosis as follows:-

- During gametes formation, the distribution of each allele from a homologous chromosome pair, is entirely independent of the distribution of alleles of another pair. It is the random alignment of the homologous chromosomes on the equator spindle in "Metaphase 1" and their subsequent separation in "Anaphase I" that leads to a variety of alleles in the gametes.

  Examples

  1. In the guinea pig (cavia), there are two alleles for hair colour, black and white, and two alleles for hair length short and long. In a breeding experiment the F1 phenotypes

produced from a cross between pure – breeding short black haired and pure - breeding, long white – haired parents had short black hair. Explain;

(a) Which alleles are dominant, and

(b) The expected proportions of F2 phenotypes.

Answer

(a) If short black hair appeared in the F1 phenotypes, then short hair must be dominant to long hair and black hair must be dominant to white.

(b) Let B represent black hair

b represent white hair

S represent short hair

s represent long hair.

F1 phenotypes Short black hair x short black hair

F1 genotypes (2n) SbBb SsBb

gametes SB Sb sB sb.

Gametes	SB	Sb	sB	sb
SB	SSBB	SSBb	SsBB	SsBb
Sb	SSBb	SSbb	SsBb	Ssbb
sB	SsBB	SsBb	ssBB	ssBb
sb	SsBb	Ssbb	ssBb	ssbb

9 short black hair : 3 short white hair : 3 long black hair : 1 long white hair

2. Flower colour in sweet pea plants is determined by two allelomorphic pairs of gene (R,r and S,s). If at least one dominant gene from each allelomoorphic is present in the flowers are purple. All other

genotypes are white. If two purple plants, each having the genotype RrSs, are crossed, what will be the phenotypic ratio of the offspring?

Parental phenotype: Purple x Purple

Parental genotype: RrSs x RrSs

gametes RS Rs rS rs

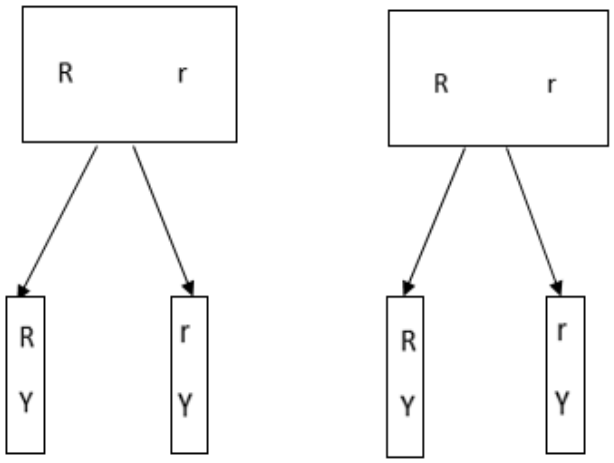
Gamete	RS	Rs	rS	rs
RS	RRSS	RRSs	RrSS	RrSs
Rs	RRSs	RRss	RrSs	Rrss
Rs	RrSS	RrSs	rrSs	rrSs
Rs	RrSs	Rrss	rrSs	rrss

Offspring phenotype: 9 purple : 7 white

3. Consider a pea plant with round yellow seeds of the genotype Rr Yy. This means there are two pairs of homologous chromosomes. One pair carrying the allele for the colour and another pair carrying the allele for the seed form (texture). Thus chromosomes carrying the alleles for seed colour are homologous with another as those for seed form.

- At Meiosis, the homologous chromosomes come together (assort), but they carry themselves on the spindle independently of each other. They may arrange themselves in one of the following way

or



RrYy: Ry, RY, rY, ry

Question:-

(i) State Mendel's laws of inheritance.

(ii) State the observations made by Mendel that led him to formulate his laws of inheritance.

(iii) Discuss in fully as you can how the behaviour and movement of chromosomes during meiosis, explain Mendel's laws of inheritance.

NECTA 1973

In guinea pig, rough coat is dominant over smooth coat and black coat is dominant over white coat. When a rough black guinea pig was crossed with a rough white guinea pig the offspring obtained were.

328 rough black

311 rough black

111 smooth black

110 smooth white

What were the genotypes of the parents?

Soln

Let - R- rough coat

r- smooth coat

B- black coat

b- white coat

- In the dihybrid cross, each character behaves independently of the other. Thus considering coat texture we have:-

Rough	Smooth
328 + 311	110 + 111
639	221
221	221

= 3 : 1

This is a basic monohybrid ratio obtained from a cross involving two heterozygous individuals. Thus, the genotype of the rough coat with respect to this gene was Rr.

Considering coat colour.

Black	White
328 + 111	311 + 110
439	421
421	421

= 1 : 1

- This (1:1) is a monohybrid test cross ratio obtained from a cross of a heterozygous dominant and a homozygous recessive.
- Therefore the genotype of a black coat was Bb and that of a white coat
- Therefore, the genotypes of the parents were:-

  Rough black : RrBb

  Rough white : Rrbb

  5. A tall plant with red flowers, form a true breeding line was crossed with a short plant with white flowers. One of the resulting plants was crossed in short red flowered plant unknown parentage.

  This cross gave the following results:-

109 - short white

38 - tall red

29 - tall white

100 - short red

(i) Interprete the results.

(ii) What was the phenotype of the plants produced by cross I?.

Solution

According to Mendel's 2nd law, in a dihybrid cross, each characteristic behaves independently of the other.

- Thus, treating each characteristic separately we have:

Short		Tall
109 + 100		38 + 29
209		67
67		67
= 3	:	1

- This is a basic monohybrid ratio obtained from a cross between two heterozygous plants

- From this ratio, short is dominant over tall.

Colour

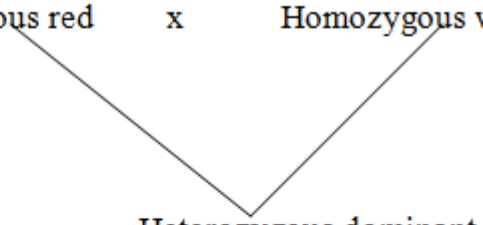
White		Red
109 + 29		38 + 100
138		188
138		138
1	:	1

- This is a monohybrid test cross ratio obtained when a homozygous recessive is crossed with a heterozygous dominant.

Consider the two crosses for colour only

CROSS I:

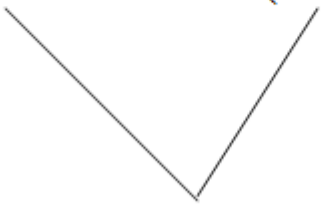
P1 Homozygous red x Homozygous white



Heterozygous dominant

CROSS II:

Heterozygous dominant x Red (Unknown parentage)



1 White : 1 red

Heterozygous dominant x Red (Unknown parentage)

1 White : 1 red

From the above cross, the red colour was recessive to white.

Defn: of symbols

Let: W = White

w = red

S = short

s = tall

P1 phenotypes: Short white x Tall red

Genotypes (2n): SSWW sssw

Meiosis: ↓ ↓

Gametes (n): SW sw

Fusion:

F1-genotype : SSWw

Phenotype: All short white

CROSS II

P1 Phenotype: Short white x Short red

SsWw Ssww

SW Sw Sw.sw

sW,sw

Punett square to show the fusion of gametes.

Gametes	SW	Sw	sW	Sw
Sw	SSWw	SSww	SsWw	Ssww
sw	SsWw	SSww	ssWw	ssww

The phenotypes are:-

3 short white

3 short red

1 Tall white

1 Tall red

(ii) From cross 1 above, the phenotypes of the product was short white.

6. Two form IV students Sophia and Issa were eager to put into practice their genetic knowledge. They carried out the following crosses:-

CROSS I

A pure breed plant for terminal purple flowers was crossed with a home plant for axial white flowers.

CROSS II

A plant with axial purple flowers of unknown percentage was crossed with one of the products of the first cross. This cross produced the following results.

338 axial white flowers.

109 terminal purple flowers.

84 terminal white flowers.

304 axial purple flowers.

- Due to their elementary knowledge in genetics, Sophia and Issa failed to interprete their results.

- Using your advanced biology knowledge, show how Issa and Sophia could;

(i) Interprete their results

(ii) Identify the genotypes and phenotypes of the plants produced in the first cross.

Solution;-

(i) According to Mendel's second law, each characteristic in a dihybrid cross behaves independently of the other. Thus, treating each characteristic separately we have.

- Considering position of the flowers, we have:-

Axial		Terminal	
338 + 304		109 + 34	
$\frac{642}{193}$		$\frac{193}{193}$	193
= 3	:	1	

This is a basic monohybrid ratio obtained given a cross between two heterozygous individuals.

From this ratio, axial flowers are dominant over terminal flowers.

Considering colour of the flowers:-

Purple	White
304 + 109	338 + 84
413	422
413	413

= 1 : 1

This is a monohybrid test cross ratio obtained from a cross between a heterozygous dominant and homozygous recessive.

Considering the two crosses for flower colours only.

CROSS I

P1 Homozygous x Homozygous

Purple White

Heterozygous dominant

CROSS II

P2 – Heterozygous dominant x Purple

1 purple : 1 white

Since this ratio is obtained when a heterozygous dominant is crossed with homozygous recessive, then purple was recessive and white was dominant.

Definition of symbols:-

Let:- A - axial

a - terminal

W - white

w - purple

Punett square to show the fusion of gametes:-

Gametes	AW	Aw	aW	aw
Aw	AAWw	AAww	AaWw	Aaww
Aw	AaWw	Aaww	aaWw	aaww

The phenotypes are in the following proportions-

3 Axial white

3 Axial purple

1 Terminal white

1 Terminal purple

The results Issa and Sophia have been interpreted since the ratio obtained corresponds with the figures given.

From Gross 1 above, the genotype and phenotype of the products of the flowers cross are AaWw and axial white respectively.

MERITS AND DEMERITIS OF MENDEL

MERITS:-

Mendel was successful in his work where others had failed.

He was very systematic and scientific in his researches and data analysis and for this reason he managed to come out with the laws of inheritance.

He realized the role of gametes in the transfer of genetic information from parents to the offspring.

The secret behind Mendel's success is within the following facts:-

Preliminary investigations were carried out to obtain familiarity with experimental organisms.

He paid attention to one characteristic at a time.

He used organisms with limited continuous variations

Meticulous care was taken during data collection and analysis so as to avoid introduction of contaminating variables.

He collected sufficient data to have statistical significance

DEMERITS:

The shortfalls of Mendel include the following:-

His gametes describe only the diploid sexually reproducing organism. The haploid organisms such as Bryophylum are not explained.

(b) His gametes is only based on the dominating- recessiveness principle's but not all the time that one characteristic is dominant over the other.

(c) Not all the time genes assert freely. Linkage enterferes was free assortment.

(d) Mendel did not consider gene interaction such as epistesis collaboration, lethal genes etc all of which interfere with his basic ratio.

More examples:

1. The position of starch in pollen grains in maize is controlled by the presence of one allele of certain gene. The other allele of that gene results in starch being deposited. Explain in terms of reasons why half the pollen grains produced by a heterozygous plant contain starch.

   Solution:

   The two alleles segregate during metaphase I and anaphase I.

2. Calculate the number of different combination of chromosomes in the pollen grains of the cross (cross balance) which has a diploid number of six (2n = 6).

   Solution

   The number of different combination of chromosomes in the pollen grants cell is calculated, using the formula 2n, whore n is the haploid number of chromosomes.

   Since 2n = 6, n = 3

   Therefore, combination = 23 = 8

NON – MENDELIAN GENETICS

This is simply a pattern of inheritance in which the basic Mendelian ratios are modified.

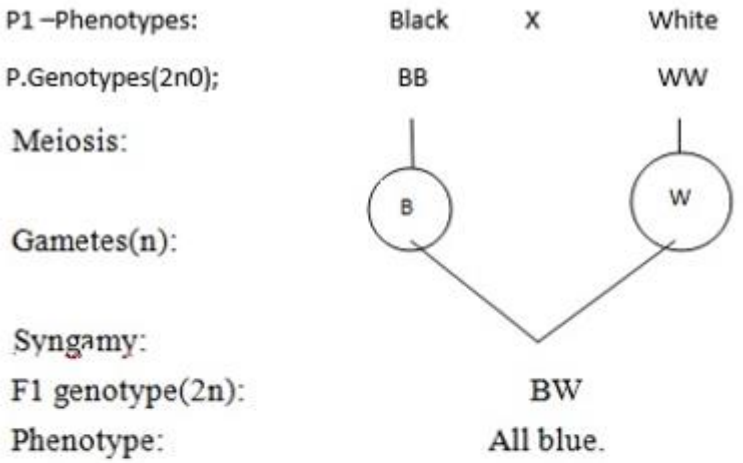
Examples:

INCOMPLETE DOMINANCE (under gene interactions)

Incomplete dominance/ Blending – Is a type of inheritance in which there occur the apparent failure of one allelic gene to dominate the other that when the two genes are together, they produce a character between them.

Example

A cross between a white Andalusian (fowl) and a black Andalusian produce a blue variety in the F1 generation. When the F1 members are selfed, the F2 individuals are a mixture of phenotypes ie: black, blue and white in the ratio of 1:2:1



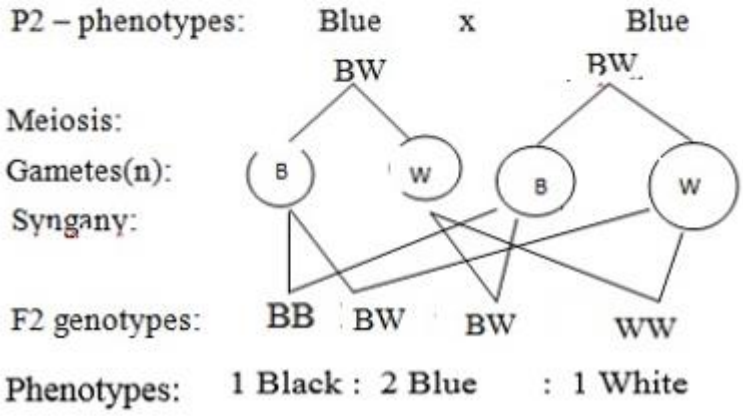


Illustration:

3.

Genotype ratio: 1 BB : 2 BW : 1 WW

Phenotype ratio: 1 black : 2 blue : 1 white

QN. NECTA 1993

A genetist who was verifying Mendel's first law and second law crossed 45 homozygous red flowered plants with 45 homozygous white flowered plants. The resulting F1 were 530 plants all with pink flowered plants, the seeds obtained were planted and F2 offspring with the following phenotypes were obtained.

1292 red flowered.

2570 pink flowered.

1290 white flowered.

(a) Illustrate using symbols the crosses made and the results obtained in the experiment described above.

(b)(i) What is the name above experiment?

(ii) How do the above observations differ from the results of Mendelian work which led him to formulate his laws of inheritance?

(c) Describe the genetical test you would carry out to prove weather not the appearance of the pink flower in the above experiment is true deviation from Mendel's principles of inheritance (20marks).

Solution:

(a) Let R – allele for red colour.

W – allele for white colour.

RW – genotype for pink colour (flower).

P1. Phenotype: Red x White

P.genotype(2n): RR WW

Meiosis:

Gametes (n): R W

Synagarry:

Genotype (2n): RW

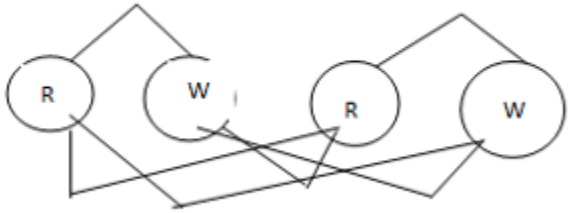
Phenotype: All the F1(530) plants are pink flowered

P2. Phenotype: Pink x Pink

P. genotype (2n): RW RW

Meiosis:

Gametes(n):



Fusion:

F2 genotypes (2n): RR RW RW WW

The F2 members are 1292 red flowered, 2570 Pink flowered, 1290 White flowered

(b) (i) The name of the mode of inheritance is Incomplete dominance inheritance.

(ii) The observation differ from Mendelian principles in that, the inheritance the flower colour does not follow the dominance – recessiveness principle.

All the F1 offsprings are pink flowered instead of them to show the dominant colour from either of the experiment is fully dominance or fully recessive. In the Mendelian experiment, when F1 are selfed

the resulting one in the dominance-recessive phenotypes ratio is of 3:1. But in this experiment, selfing the F1 individuals give 1:2:1.

(c) The genetical test to be carried out is back test cross in which the pink flowers plant will be test crossed with either of the homozygous plants say red flowered plant RR.

The result of the test cross above will give products of red (RR) and pink (RW) in the ratio of 1:1.

- The above results show a siltation of RW (Pink) and RR (red). This can prove that there has been no true blending, has occurred in F1 generation then we could expect offspring which were again all pink flowers.
- The appearance of pink colour trait in the F1 generation is not a true deviation from Mendel's laws; otherwise the gene for red could not be reviewed unchanged.
- It was just observed when in the presence of WW (White) while its identity was being retained.

  Thus, the inheritance of the flower colour in the experiments precisely obeys Mendel's principle of inheritance only the phenotype ratios are different.

  Partial dominance (Co dominance & Incomplete dominance)

Sometimes both alleles express themselves in the phenotype, but one more so than another. This is an intermediate stage between complete dominance and co dominance.

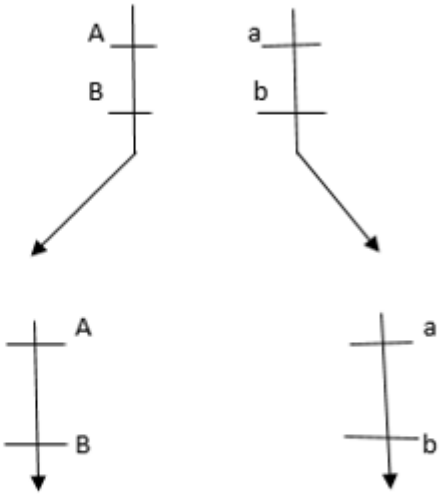
LINKAGE

For just 23 pairs of chromosomes to determine the many thousands of different human characteristics, it follows that each chromosome must possess many different genes.

Any two genes which occur in the same chromosome are said to be linked. All the genes on a single chromosome form a linkage group.

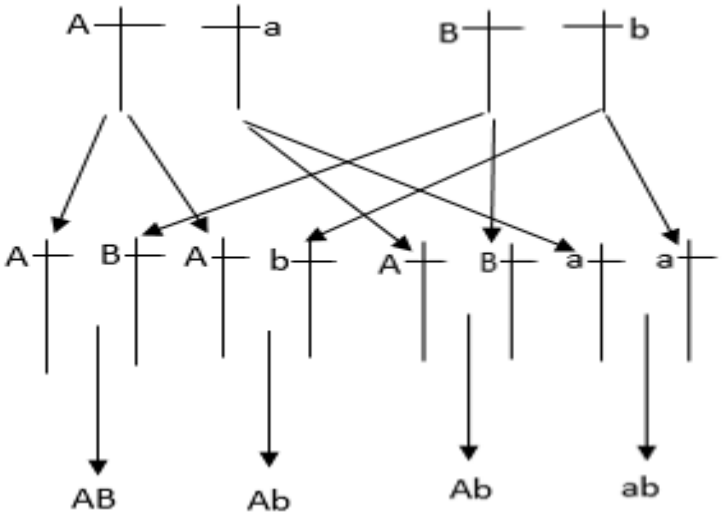
Under normal circumstance, all the linked genes remain together during cell division and so pass into the gamete, and hence the offspring, together. They not therefore segregate in accordance with Mendel's law of Independent Assortment.

The figure below shows the different gametes produced if a pair of genes A and B are linked rather than on separate chromosomes.



Possible types of gamete	AB	ab

If gene A and B occur on separate chromosomes ie. are not linked



NOTE: Linked genes do not confirm to Mendel's principle of independent assortment, therefore they fail to produce the expected 9:3:3:1 ratio in a breeding situation involving the inheritance of two pairs

of contrasted characters (dihybrid inheritance).

Crossing over and crossover values (COV)

During cross over (in chiasmata formation), the alleles of parent linked group separate and new associations of alleles are formed in the gamete cells, a process known as genetic recombination.

Offspring formed from these genes showing 'new' combinations of characteristics are known as recombinants. Hence crossing over is a source of variations.

The recombination frequency (COV) is calculated using the formula

$$\frac{\text{no. if individual showing recombination} \times 100}{\text{no. of offspring}}$$

Gene mapping

Calculation of COV enables geneticists to produce maps showing the relative positions of genes on chromosome. Chromosome maps are constructed by directly converting the COV between genes into

hypothetical distances along the chromosomes.

Sex determination

Sex is a state of being male or female.

In human there are 23 pairs of chromosomes of these 22 pairs are identical in both sexes. The 23rd pair, however is different in the male from the female.

The 22 identical pairs are called autosomes, the 23rd pairs are referred to as sex chromosomes or heterosomes.

In females the two sex chromosome are identical (X chromosomes) are said to be Homogametic, while in males the two chromosomes are non- identical (Y – chromosome is smaller in size than X –

chromosome) and are said to be Heterogametic.

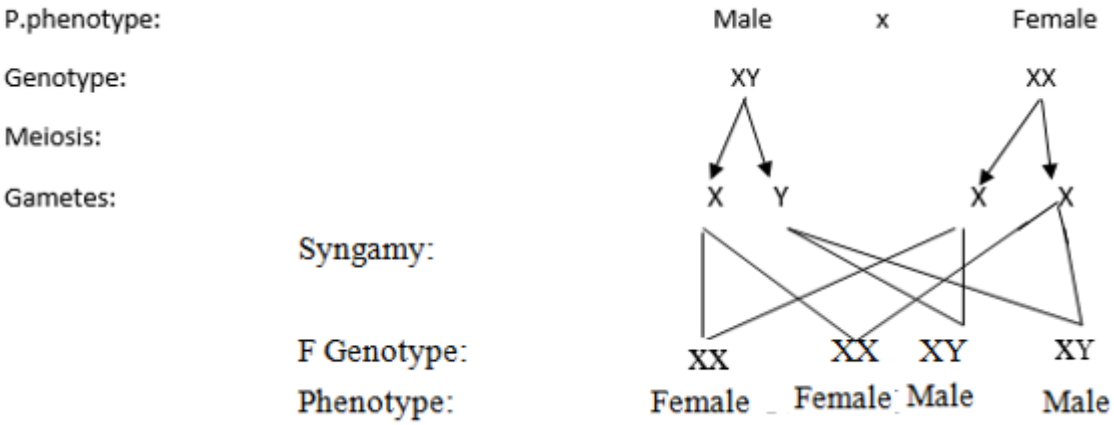
Unlike other features of an organization, sex is determined by chromosomes rather than genes.

Humans of genotype XXY are phenotypically male, while genotypes with just one X chromosome (XO) are phenotypically female. This suggests that the presence of the Y chromosome which makes the human male, in its absence the sex is female. How does the Y chromosome determine maleness?

The Y chromosome possesses several copies of a testicular differentiating gene which codes for the production of a substance that causes the undifferentiating gonads to become testes. In the absence of the gene and hence this substance, the gonads develop into ovaries.

- In humans, sex is determined by the type of sex chromosome contained in the spermatozoa that fuses with an X – chromosome of the egg cell.
- If the X – chromosome bearing sperm fuses with an X- chromosome of the egg cell, the resulting zygote will develop into a female (XX).
- If the Y- chromosome bearing sperm fuses with an X – chromosomes of the egg cell, the resulting zygote will develop into a male (XY).

Consider a cross below



From this cross it is evident that;

(i) The chances of a zygote develop into a male or female are 50%

(ii) The sex of the individual before to be born is determined by the father.

Sex determination differs in other organisms. In birds, most reptiles and fish and all butterflies, the male is the homogametic sex (XX) and the female is from the cross, all the resulting individuals are phenotypically normal with all females beings carriers.

Questions.1.A certain species of flies has, the following genetic attributions

1. Female flies have two X- chromosomes (XX).
2. Male flies have one X- and one Y – chromosome.
3. Y chromosome does not bear extra genes.
4. Eye colour is sex linked and red colour is dominant over white eye colour trait.

What will be the genotype and phenotype of the female and males in the F1 and F2 when;

1. White eyed female is crossed with a red eyed male.
2. A homozygous red eyed female is crossed with a white eyed male.

2.Siku and her brother Juma have their elder brother who is haemophilic. They and their parents are normal but they are worries that they may have haemophilic children in future. If they approach you for help how would you advice them?

3. A homozygous purple flowered short-stemmed plant was crossed with a homozygous stemmed-flowered long stemmed plant and the F1 phenotypes had purple flowers and short stems. When the F1

4. generation was test crossed with a double homozygous recessive plant the following progency were produced.

52 Purple flower, short stem.

47 Purple flower, long stem.

49 red flower, short stem.

45 red flower, long stem.

Explain these results fully.

The F1 phenotypes show that purple flower and short stem are dominant and red flower and long stem are recessive. The approximate ratio of 1:1:1:1 in a dihybrid cross suggests that the two genes controlling the characteristics of flower colour and stem length are not linked and the four alleles are situated on different pairs of chromosomes (see below).

Let P- Purple flower

p - Red flower

S – Short stem

s – Long stem

Since the parental sticks were both homozygous for both characteristics the genotypes must be PpSs.

Test cross phenotypes: Purple flower short stem x red flower, long stem

Test cross genotype: PpSs ppss

gametes	PS	Ps	ps
ps	PpSs	Ppss	ppss

Meiosis:

Gametes (n):

Random fertilization

(shown inpunett square):

Offspring genotypes (2n)

(Listed in each square):

Offspring phenotypes: 1 purple flower, short stem : 1 purple flower, long stem.

1 red flower, short stem : 1 red flower long stem.

MULTIPLE ALLELISM

Multiple alleles are those alleles of a single locus when there are more than alternatives in a population.

In humans, the inheritance of the ABO blood groups is determined by a gene which has different alleles. Any two of these can occur at a single locus at one time.

Allele A causes production of antigen A on red blood cells.

Allele B causes production of antigen B on red blood cells.

Allele O causes no production of antigens on red blood cells.

Alleles A and B are codominant and allele O is receive to both.

The transmission of these alleles occurs in normal Mendelian fashion.

A cross between an individual of group AB and one of group O therefore gives rise to individuals non of whom possess either parents blood group.

Test cross phenotypes: Purple flower short stem x red flower, long stem

Test cross genotype: PpSs ppss

Meiosis:

Gametes (n):

Random fertilization

(shown in punnett)

gametes	PS	Ps	ps
ps	PpSs	Ppss	ppss

Phenotype: blood group AB x blood group O

		gametes	
		I^A	I^B
gametes	I^O	$I^A I^O$	$I^B I^O$

Paternity suits.

Although blood group cannot prove who a father of a child is, it is possible to use inheritance to show that an individual could not possibly be the father.

Imagine a mother who is blood group B having a child of blood group O. She claims the father is man whose blood group is found to be AB. As the child is group O, its only possible genotype is $I^O I^O$. It

must therefore herited one I^O allele from each parent. The mother, if $I^B I^O$ could donate such an allele. The man with blood group AB can only have the genotype $I^A I^B$. He is unable to donate an I^O allele

and cannot therefore be the father.

Dominance series

Coat colour in rabbits is determined by a gene C which has four possible alleles.

Alleles C^F determines full coat colour and is dominant to

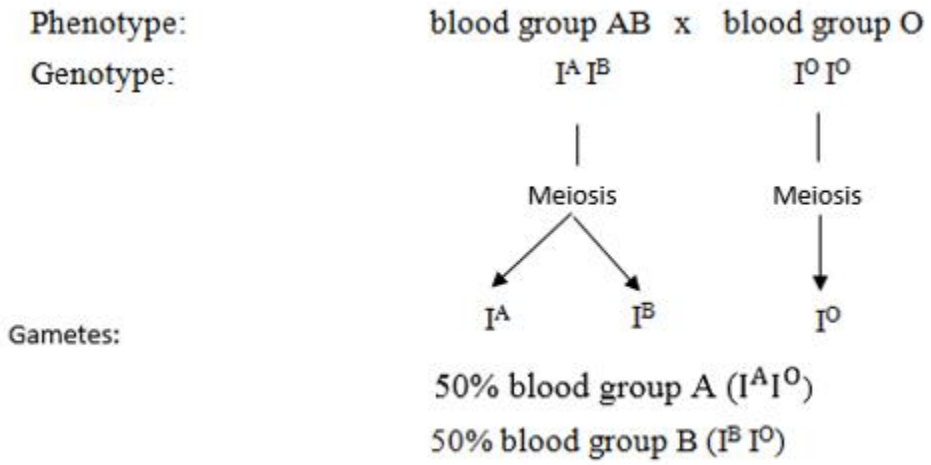
Allele C^{CH} which determines chinchill a coat and is in turn dominant to

Allele C^H which determines Himalayan coat and is in turn dominant to

Allele C^A which determines albino coat colour.

There is therefore a dominance series and each type has a range of possible genotypes.

Inheritance is once again in normal Mendelian fashion.



Other characteristics controlled by multiple alleles are coat colour in mice, eye colour.

Worked examples

1. A woman of blood group A claims that a father of blood group B is the father of her child whose blood group is O. How far are the woman's claims valid?

   Answer.

   If both are heterozygous for their blood groups, then the woman's claims are valid, but if either of them is homozygous for the blood group then women's claims are invalid.

2. Anna is a woman married to John. This couple once had a child, Kitto was one day discovered that his parents were in bad terms. John claims that Kitto is an illegitimate child but Anna is opposing the case. Blood tests rewards that John is of type A and Kitto is of blood group O. Anna's mother blood type is B and Anna's father blood group type is AB. Using this information alone

   (i) Suggest the possible genotype for Anna, show how you determine genotype.

   (ii) Show dearly whether Kitto is or he is not an illegitimate child of the said family.

   Solution:

1. Since Kitto is of blood group O, then his genotype is of no doubt.

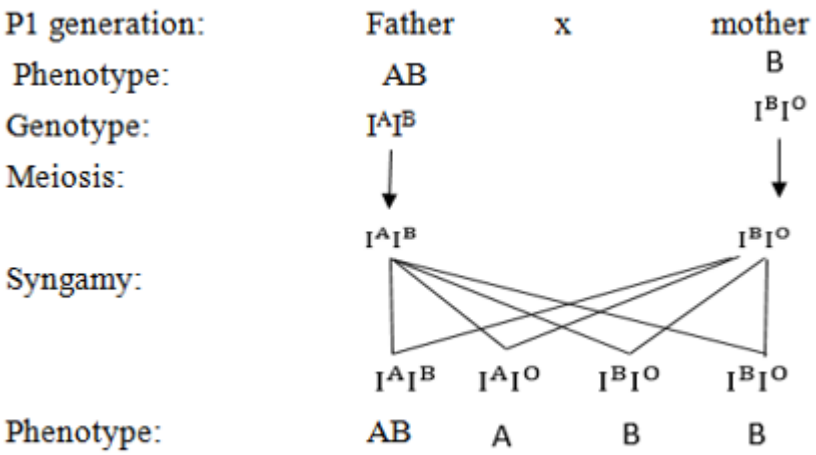
   This implies that the genotype for Anna should have an allele I^O considering Anna's parents we have:

   Mother: Blood group B whose possible genotypes are $I^B I^B$ or $I^B I^O$

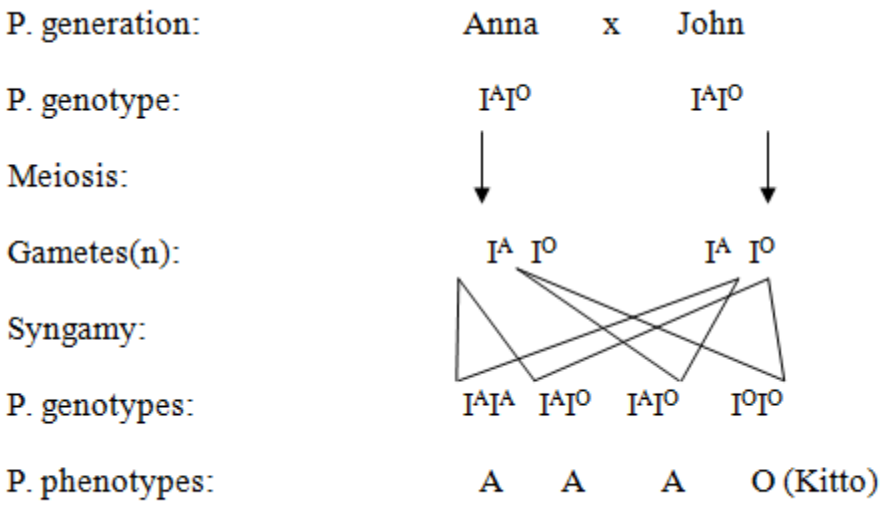
   Father: Blood group AB whose possible genotype is $I^A I^B$

- But for Anna to have an allele I^O in her genotypes, the mother should bear the allele I^O. Thus, the genotypes should be $I^B I^B$

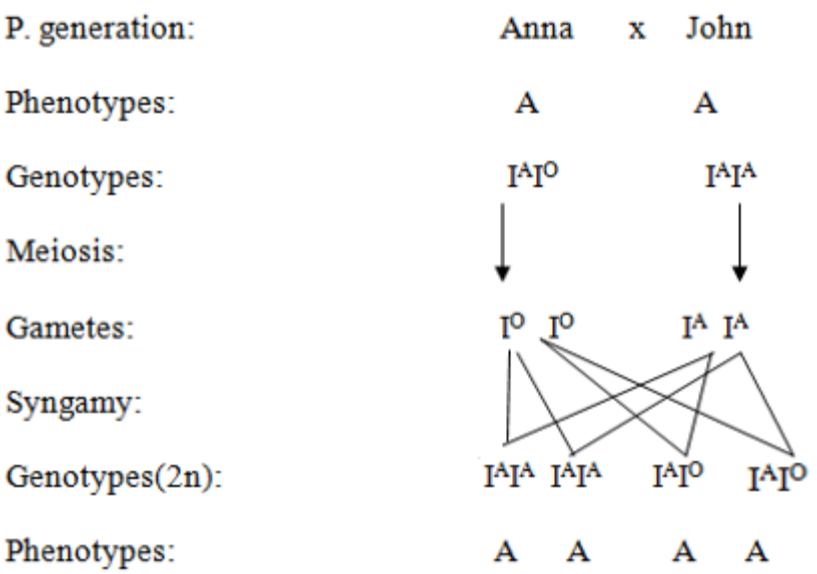
A cross between Anna's parent reveals the following;



1. Since Anna is heterozygous for her blood group and John is of blood group A, then the legitimacy of Kitto will depend on John's genotype. If he is heterozygous for his blood group, then Kitto is a legitimate child as the cross below reveals.



If John is homozygous for his blood group, then for sure, Kitto is an illegitimate child of the family.



3. Write an essay on the statement that "the knowledge on the inheritance of blood group can be used to tell for sure that "the baby is not Yours" rather than the baby is yours"

4. Mama is a form six student with blood group A. She recently has a baby whose father she insisted was her fellow student Kashesha. Kashesha refused paternity and this paternity case was taken to court where the following facts were established. Kashesha's mother blood group A; Kashesha's father blood group B. Baby blood group O. Based on this factor explain whether the law will accuse or excuse Kashesha.

Sex Limited and sex influenced characters:

Sex limited characters are those characters that are concerned to only one sex eg. baldness, beards and Adam's apple in males and enlarged breasts and hips in females.

The development of such character is controlled by sex hormones, they are thus said to be sex influenced characters.

PEDIGREE ANALYSIS

Pedigree is a sequential arrangement of individual in a given family to show the passage of certain character from one generation to another.

In analyzing a pedigree the first individual to show the characters of interest is called a propositous

Features of a pedigree.

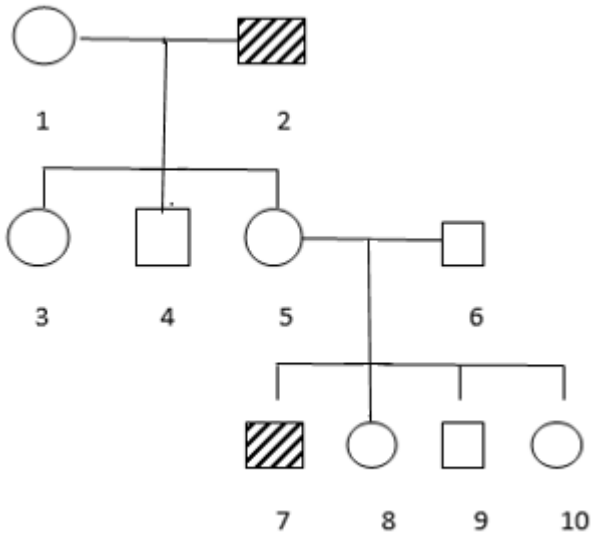
(i) Circles represent females, squares represent males.

(ii) Shaded figures show a phenotypic expression of the character, open figures represent a normal phenotype.

(iii) Parents are connected by a horizontal line as children are connected to parents by vertical line.

Worked examples

1. Study the pedigree shown below, circles represent females, squares represent males, shaded figures represent colour blindness, open figures represent normal phenotype



(i) What is the probable genotype for 1?

(ii) What are the possible genotypes for 5 and 9?

(iii) If 8 marries a normal man, what are the chance that she will have a colour blind son?

Solution

Consider the following genetic attribute;

X^NX^N – Normal female.

X^NX^n – Carrier female.

X^nX^n – Colour blind female.

X^NY – Normal male.

X^nY- Colour blind male.

(i) The possible genotype for 1 is X^NX^N ie: homozygous normal.

(ii) The possible genotypes for, 5 is X^NX^n ie: heterozygous normal

(iii) Since 8 was born from a certain mother, she has 50% chance of receiving an allele for colour blindness.

There are also 50% chances that the allele will pass to the son.

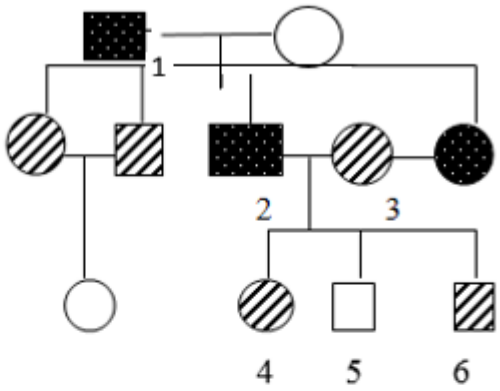
Thus, the chances of 8 to have a colour blind son are:

½ x ½ x ½ = 1/8

(a) State Mendel's laws of inheritance.

(b) In dogs coat colour is determined by a series of multiple alleles. The allele A^s produces a uniformly dark coat, the allele a^y produces a tan coat and the allele a^t produces a spotted coat. The dominance heredity achy is $A^s > a^y > a^t$ which means A^s is dominant to both a^y and a^t where a^y is dominant to a^t only.

A family tree for dogs showing their coat colours is given below;



-Dark male.

-Dark female.

-tan male.

- tan female.

-Spotted male.

–Spotted female

1. State the genotype of each of the individuals 1 – 5
2. By means of genetic diagram deduce the possible genotypes and phenotypes of the puppies which could be produced by mating between individual 4 and 6

Solution

(b) (i) Given dominance hierachy $A^s > a^y > a^t$

Phenotype: Possible genotypes

Dark: A^sA,^{s} A^sa^y,A^sa^t

Tan: a^ya^y,a^ya^t

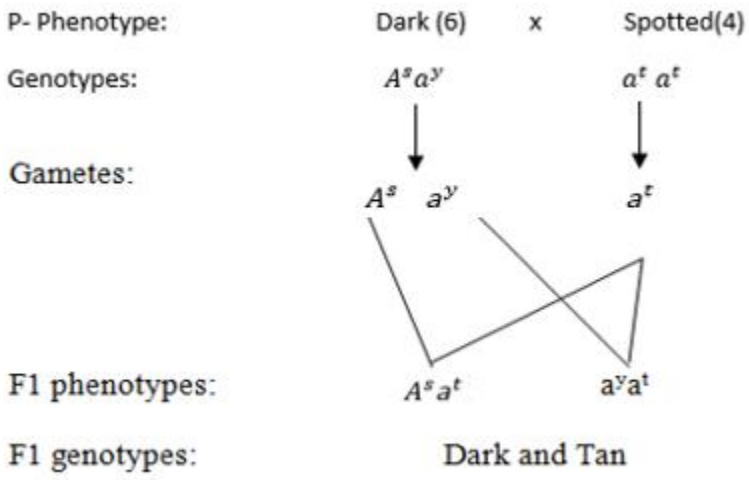
Spotted: a^ta^t

Thus, the genotypes are:

Individual	**Genotype**
1	A^sa^y

2	A^sa^t
3	a^ya^y
4	a^ta^t
5	a^ya^t

Crossing between individual 4 and 6



More examples:

1. In cats, the genes controlling the coat colour are carried on the X chromosome and are codominant. A black coated female mated with a ginger coat produced a litter consisting of black male and tortoise shell female kittens. What is the expected F2 phenotypic ratio? Explain the results.

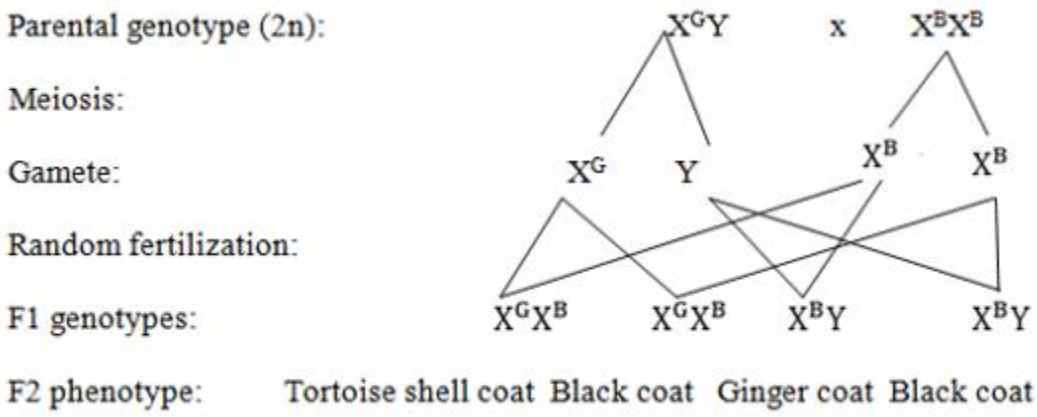
   Soln:

   Let B represent black coat colour.

   G represent ginger coat colour.

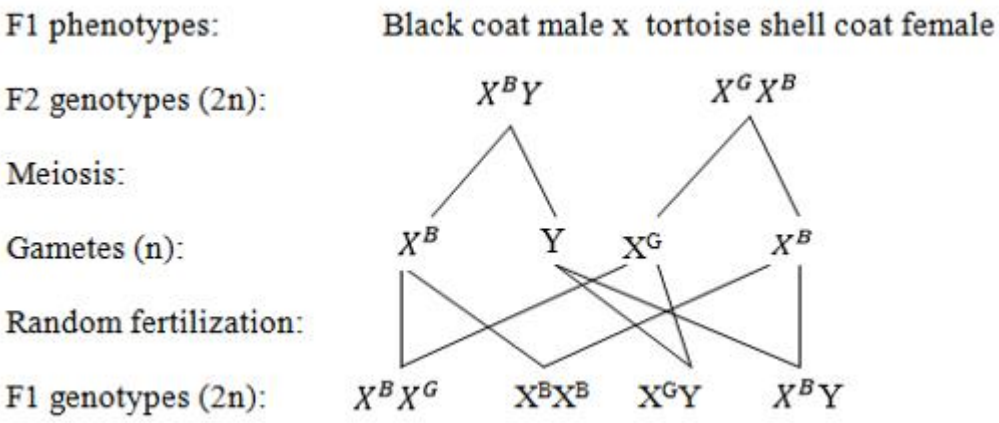
   XX represent female cat.

   XY represent male coat.



Colour female colour female colour male colour male

(The parental female must be homozygous for black coat colour since this is the only condition to produce a black coat phenotype).



F2 phenotypes: Tortoise shell coat colour female : black coat colour female : ginger coat colour male : black coat colour male

2. (a) Explain using appropriate genetic symbols, the possible blood groups of children whose parents are both heterozygous, the father being blood group A and mother B.

   (b) If these parents have non – identical twins, what is the probability that both twins will have blood group A?

   Answer

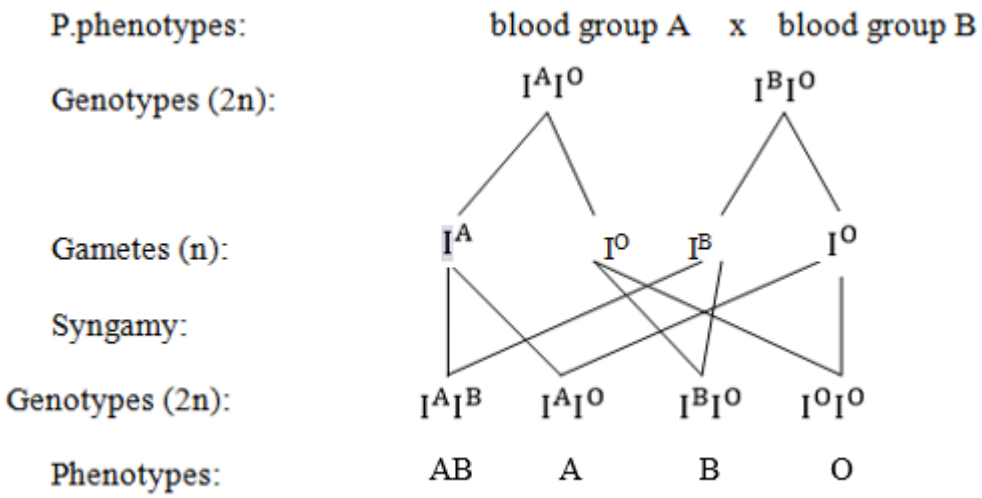
   (a)Let: I represent the gene for blood group

A Represent the allele A (equally dominant)

B Represent the allele B

O represent the allele O (receive)

(b) There is a probability of ¼ (25%) that each child will have blood group A. So the probability that both will have blood group A is ¼ x ¼ = 1/16 (6.25%)



GENE INTERACTION

In dihybrid crosses, two or more genes interact to determine a single phenotype. Such an interaction may modify the basic ratios.

Examples of gene interaction are:

(a) Lethal genes.

(b) Epistasis.

(c) Collaboration (Gene complex).

(d) Multiple gene interaction.

(e) Complementary genes.

(a) Lethal genes.

A lethal gene is that dominant or recessive gene which when occur in the homozygous state causes death to its bearer. eg : Sickle cell anaemia in humans.

Lethal genes may affect several characteristics including mortality.

Example

Consider the inheritance of fur colour in mice. Wild mice have grey coloured fur, a condition known as agouti. Some mice have yellow fur. Cross breeding yellow mice produces offspring in the ratio 2 yellow fur : 1 agouti fur. These results can only be explained on the basis that yellow is dominant to agouti and that all the yellow coat mice are heterozygous. The typical Mendelin ratio is explained by the fetal death of homozygous yellow coat mice.

Explanation of this rests on the fact that examination of the uteri of pregnant yellow mice from the above crosses revealed dead yellow features. Similar examination of the uteri of crosses between yellow fur and agouti fur mice revealed no dead yellow features. The explanation is that this cross would not provide homozygous yellow (YY) mice.

Let Y represent yellow fur (dominant).

y represent agouti fur (recessive).

P. phenotypes: Yellow fur x yellow fur

Genotypes (2n): Yy Yy

Meiosis:

Gametes (n): Y y Y y

Syngamy:

P. genotypes (2n): YY Yy Yy yy

Phenotypes: 1 yellow fur : 2 yellow fur : 1 agouti fur

NB: the ratio 2:1 talks of lethal. The gene for yellow is dominant for fur colour of the cat, the genotype Yy produce yellow cost but it is for viability. Hence gene YY represents lethal combination.

(b) Epistasis.

Epistasis arise when the allele of one gene suppress or marks the action of another.

Definition;

Epistasis is the type of gene interaction in which one gene (epistatic gene) effect the phenotype expression of the other (hypostatic gene).

An example occurs in mice where three genes determine the coat colour. However the absence of a dominant allele at one of the loci results in no pigment being produced and the coat being albino. This occurs regardless of the genes present at the other loci, even if these produce normal coat colour. The gene at third locus clearly suppresses the action of the others.

Example

In white leghorn fowl, plumage colour is controlled by two sets of genes, including the following: W (white) dominant over w (colour).

B (black) dominant over b (brown).

The heterozygous F1 genotype WwBb is white. Account for this type of gene interaction and show the phenotypic ratio of the F2 generation.

Answer.

Since both dominant alleles W, white and B, black are present in the heterozygous F1 genotype and the phenotype is white, it may be concluded that the alleles show an epistatic interaction where the white allele represents the epistatic gene.

The F2 generation is shown below:-

Using the symbols given in the question.

F1 phenotypes: White cock x White hen

F1 genotypes: WwBb WwBb

Gamete	WB	Wb	wB	wb
WB	WWBB	WWBb	WwBB	WwBb
Wb	WWBb	WWbb	WwBb	Wwbb
Wb	WWBb	WWbb	WwBb	Wwbb
wb	WwBb	Wwbb	wwBb	wwbb

F2 phenotypes: 12 white colour : 3 black colour : 1 brown colour

(Symbols)

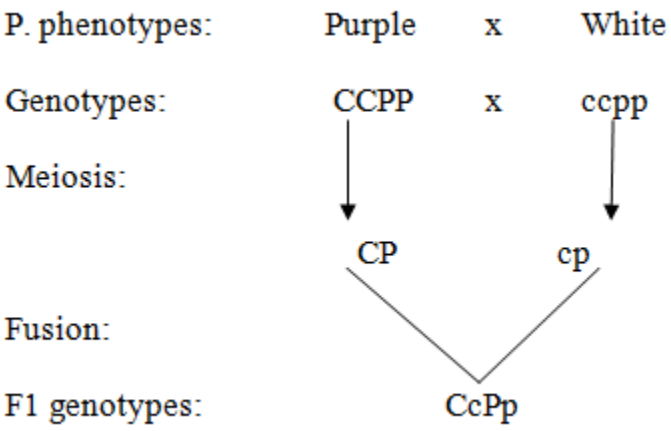
Definition: Epistatic/Inhibiting gene are recessive genes which when occur in a genotype it surfers the showing up of another gene.

(c) Collaboration (complex gene/simple Gene Intervention).

- Collaboration occurs when two genes controlling the same character, interacts to produce a single character phenotype which neither could produce alone.
- An example of each collaboration genes is seen in the inheritance of the shape of the comb in domestic cowl (chicks).
- One gene, P – produces a rose comb where as its recessive allele, p produces a single comb.
- Another gene R produces a rose comb where as its recessive allele, r also produces a single comb.
- When P and R occurs together (codominance), they collaborate to produce a walnut comb.Consider the case below:-

Phenotype	Possible genotype
Pea	PPrr or Pprr
Rose	ppRR or ppRr
Single	pprr
walnut	PPRR, PPRr, PpRR or PpRr

Consider the cross below:-



Selfing PpRr gives 9 Walnut comb : 3 pea comb : 3 rose comb : 1 single comb

(d) Complementary genes.

These are genes which are mutually dependent. Neither of them produces a given phenotype in the absence of the other.

Example

-In sweet peas, purple colour of the flowers is controlled by two genes C and P. In the absence of either the flowers are white one gene (C) regulates the production of raw materials for formation of a purple pigment where as another gene (P) regulates the conversion of raw materials into a purple pigment.

Consider a dihybid cross between a purple flowered plant and a white flowered plant

Phenotype: All purple.

Selfing the F1 plants we have:

P2. Phenotype: Purple x Purple

Genotype: CcPp CcPp

F2 genotype: 9 C – P 3 C-pp 3 ccP 1 ccpp

Phenotype: purple - White White White

From the above cross, the F2 phenotype ratio is 9:7 instead of the normal 9:3:3:1. The last three phenotype classes have been combined.

(e) Polygenic inheritance (Multiple gene interaction).

Multiple gene interaction (polygenic inheritance) is a type of gene interaction in which a single character is controlled by a series of genes each exerting its effect on the present phenotype in an additive fashion.

Many genes acting together are referred to as polygenes.

Polygenes give rise to continuous variation.

VARIATION

Variations are differences among the individuals of the same species.

Those variations which can be inherited are determined by genes. These are called genetic or inheritable variations.

Some variations are determined by the individual's environment and are known as acquired characteristics. Acquired characteristics such as big muscles developed from training and exercise are not inherited. Inheritable variations may be caused by mutation or by new combination of genes in the zygote. Non inheritable variations arise and disappear from a species when the individuals die.

In genetics we are concerned with inheritable variations. Many variations are controlled by genes. There are two types of inheritable phenotypic variations.

(i) Continuous variation and

(ii) Discontinuous variation.

Discontinuous Variation

This occurs when an organism must either have or not have a certain character.

There is no gradual change between the two extreme. This case of variation produces organisms with a clear cut differences between them and with no intermediate between them.

Such characteristics include sex where an individual is male or female, eye colour, blood group, finger prints, tongue rollers, non-tongue rollers.

Characteristics showing discontinuous variation are usually controlled by one major gene which may have two or more allelic forms.

Discontinuous variation cannot be altered by environment. For example you cannot change your blood group by altering your diet.

Continuous Variation

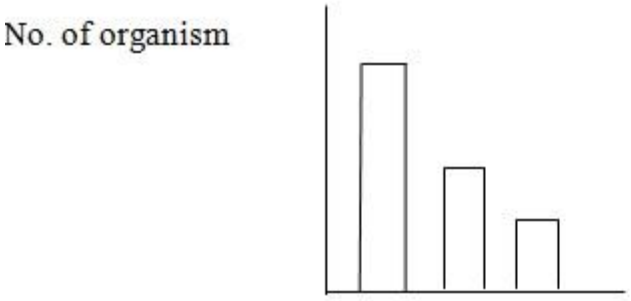
Continuous variation occurs when every member of species shows a certain characteristic but not to the same extent.

Some examples of such characteristics are hand span in humans, length of tail in other animals, number of leaves per plant, body weight and height of the people of the same age. These characteristics vary continuously in the population.

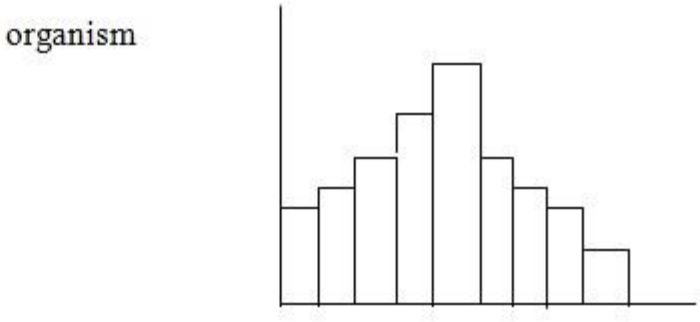
Characteristics which show continuous variation are controlled by the combining effect of a number of genes called polygenes and any character which results from the interaction of many genes is called polygenic characters.

HISTOGRAMS

(a) Non continuous variation



(b) Continuous variation



Characteristic

Environmental influence

One of the reasons for continuous variation is that all phenotypic characters are influenced by the effects of the environment.

Many continuously variable characteristics are affected by environment or by what happens during individual's life time. For example a genotypically tall organism may be dwarfed by not getting enough food or balanced diet and therefore appear similar to a child whose genotype is for shortness.

No character of any organism can be said to be completely due to effects of heredity (nature), or due to environment (nurture). Environment and heredity always interact in producing the phenotype.

Origins of variation:

Variation may be due to,

(i) Environment effect e.g.: Diseases and Nutritional standards.

For example: The action of sunlight on a light coloured skin may result in it becoming darker. Such changes have little evolutionary significance as they are not passed from one generation to the next.

(ii) Genetic factors.

These are much more important to evolution as they are inherited. These genetic changes may be the result of the normal and frequent reshuffling of genes which occur during sexual reproduction, or as a consequence of mutations.

Reshuffling of genes:

The sexual process in organisms has three inbuilt methods of creating variety.

1. The mixing of two different parental genotypes where cross-fertilization occurs (Fertilization)
2. The random distribution of chromosomes during metaphase I of meiosis (Independent assortment).
3. The crossing over between homologous chromosomes during prophase I of meiosis.

Mutations and deleterious genes

Definition

Mutations are sudden unpredictable changes that occur in the chromosome or genes and they may alter the phenotype expression of an organism.

In other words, mutations are defined as changes in the amount or structure of DNA of an organism as well as arrangement of DNA.

Mutation is a sudden inheritable change of the genotypes.

Significance of mutations

1. Mutations are rare events because DNA and chromosomes are stable structures.

   When they occur they provide a source of new variability which is necessary for organisms to adapt to constantly changing physical and biological environment.

2. Mutation is the only means by which new genes arise there by acting as raw material for organic evolution.

   NOTE: In diploid types the mutant gene, may be dominant, receive or intermediate to its effect. The most common mutants are recessive.

- Only mutations occurring in the gametic cell can be inherited from one generation to another where as those mutations of the somatic cells are not inherited by the dominant cells. These are thus called SOMATIC MUTATIONS.
- Qn: Why somatic (autosomal) mutations are not inherited?

Causes of mutations:

- The substances that cause mutation are called Mutagens or Mutagenic agents. The organism that has undergone mutation is called Mutant.

- The mutagenic substances thus include,

1. Electromagnetic radiations such as X – rays, UV – radiations, É¤- ray etc.
2. High energy particles such as α – particles, β – particles, cosmic particles.
3. Chemicals such as caffeine, formaldehyde, some constituents of tobacco, for preservatives and pesticides.
4. Abrupt temperature changes.

Types of mutations:

1. **Gene mutations**

- This is a type of mutation in which the DNA structure or chemistry of gene on a single locus is changed.
- Since a single locus is affected then this type of mutation is also called Point mutation.
- In protein Biosynthesis, we saw that the genetic code, which ultimately determines an organism's characteristics, is made up of a specific sequence of nucleotide on the DNA molecule. Any change to one or more of those nucleotides will produce the wrong sequence of amino acids in the protein it makes. This protein is often an enzyme, which may have a different molecular shape and be unable to catalyze its reaction. The results will be that the end product of the reaction cannot be formed. This may have an effect to an organism.
- Gene mutations are not easily detected by the microscope and they can be passed over several generations without being expressed in the phenotype.

Forms of gene mutation:

1. **Dedication** – a portion of a nucleotide obtain becomes repeated.
2. **Addition** (insertion) – an extra nucleotide sequence becomes inserted in the chain.
3. **Deletion** – a portion of the nucleotide chain is removed from the sequence.
4. **Inversion** – a nucleotide sequence becomes separated from the chain.
5. **Substitution** – one of the nucleotide is replaced by another which has different organic base.

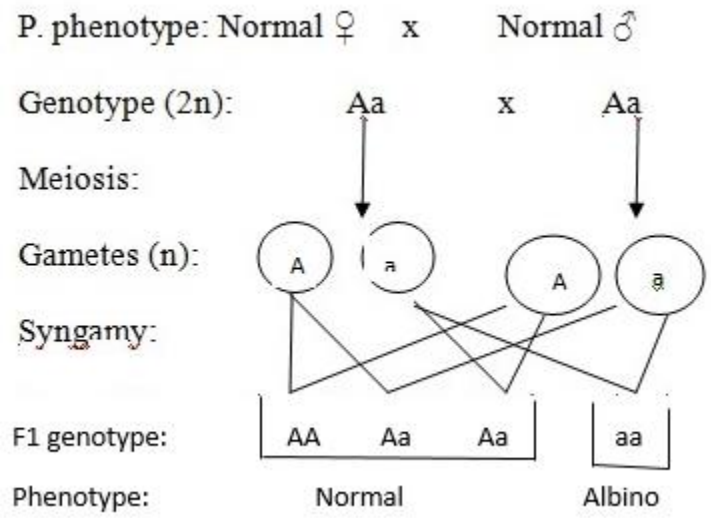
Example of gene mutations:

1. **Albinism**

- This is a type of gene mutation resulting from base substitution in which the correct base sequence is substituted for by incorrect base sequence.
- The result of this substitution is the failure of the enzyme tyrosinase to convert an amino acid tyrosine into melanin. Hence absence of pigment melanin and hence development of a light coloured skin (albinism).
- Albinism is caused by a recessive allele (a) whose dominant allele (A) produces normal skin colours pigment.

Consider a cross between two normal individuals producing an albino.

Mutation occurs during meiosis where a chromosome/gene may be Deleted, Duplicated, inverted or substituted, in the presence of mutagens.



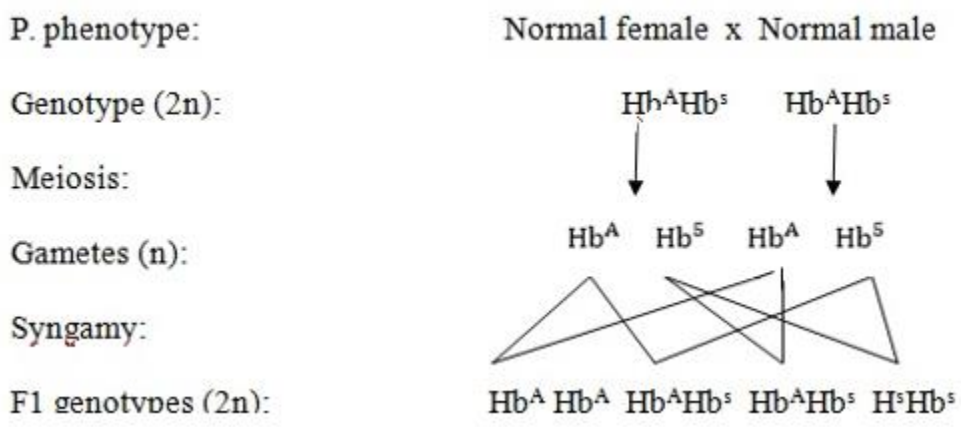
1. **Sickle cell anaemia**

- This is a bases substitution type of gene mutation.
- It results into development of an individual with abnormal haemoglobin which causes sickling of the red blood cells.
- In sickle cell anaemia, the replacement of a base in the DNA molecule results in the wrong amino acid being incorporated into two of the polypeptide chains which make up the haemoglobin molecule. The abnormal haemoglobin makes the red blood cells to become sickle – shaped, resulting in anemia and possible death.
- The synthesis of normal haemoglobin in the body is controlled by a pair of gene with the genotype AA (Hb^AHb^A).
- The mutated gene known as haemoglobin S (Hb^sHb^s) is recessive and is the one which causes sickle cell anaemia.
- An individual with the genotype Hb^AHb^s (heterozygous stickler, a condition known as sickle cell trait) has no effect, rather the genotype gives an advantage such as a genotype produces normal shaped red blood cells: However, they are likely to lose their shape when the tension of O_2 get lowered.
- When plasmodium enters such a cell, the tension of O_2 in the cell get lowered consequently the cell sickles up.
- These mis-shaped cells are cleared from the blood system by the spleen together with the parasites contained in them. In this way the person is said to be resistant to Malaria and the situation is referred to as heterozygous advantage.

Sickle cell anaemia is characterized by the following features;

- Sickling of the red blood cells.
- Severe and eventually lethal anaemia as the Hb is inefficient at carrying O_2.
- Abnormal joint pains.
- Enlarged spleen.
- **Resistance to Malaria for sickle cell trait.**
- **Blocked blood vessels depriving organs of O_2 and permanently damaging.**

Consider a cross below:



(b) **Chromosome Mutations**

These are results of changes in number or gross structure of the chromosomes. Such mutations are called chromosomal abberations.

Changes in whole sets of chromosomes

Sometimes organisms occur that have an additional whole sets of chromosomes.

Instead of having haploid set in the sex cells and a diploid set in the cells, they have several complete sets. This is known as polyploidy.

Where three sets of chromosomes are present, the organism is said to be triploid, with four sets, it is said to be tetraploid (4n).

If gametes are produced which are diploid and these self fertilizer, a tetraploid is produced. If instead the diploid gametes fuses with a normal haploid gamete, a triploid results. Polyploidy can also occur when whole sets of chromosome doubled after fertilization.

Tetraploids have two complete sets of homologous chromosomes which can undergo pairing during gamete production in meiosis. Triploids are thus sterile and hence propagation by asexual means.

Significance of polyploidy:

It is associated with advantageous features eg: Increased size, hardiness and resistance to disease. This is called hybrid vigour.

Most of our domestic plants are polyploids producing large fruits, storage organ flowers or leaves.

Forms of polyploidy

There are two forms namely;
(i) Auto polyploidy.
(ii) Allopolyploidy.

Auto polyploidy

This condition may arise naturally or artificially as a result of an increase in number of chromosomes within the same species.

1. **Allopolyploidy**

   This condition arises when the chromosome number in a sterile hybrid become doubled and produces fertile hybrids.

   F1 organisms are sterile as they cannot form homologous chromosome pairs during meiosis. This is called hybrid sterility. However, the multiples of the original number of chromosomes are fertile.

   Changes in chromosome number (Aneuploidy)

1. **Aneuploidy** – A condition in which changes may involve the loss or gain of single chromosomes.

   In this condition, half the daughter cells produced have an extra chromosome (n + 1),

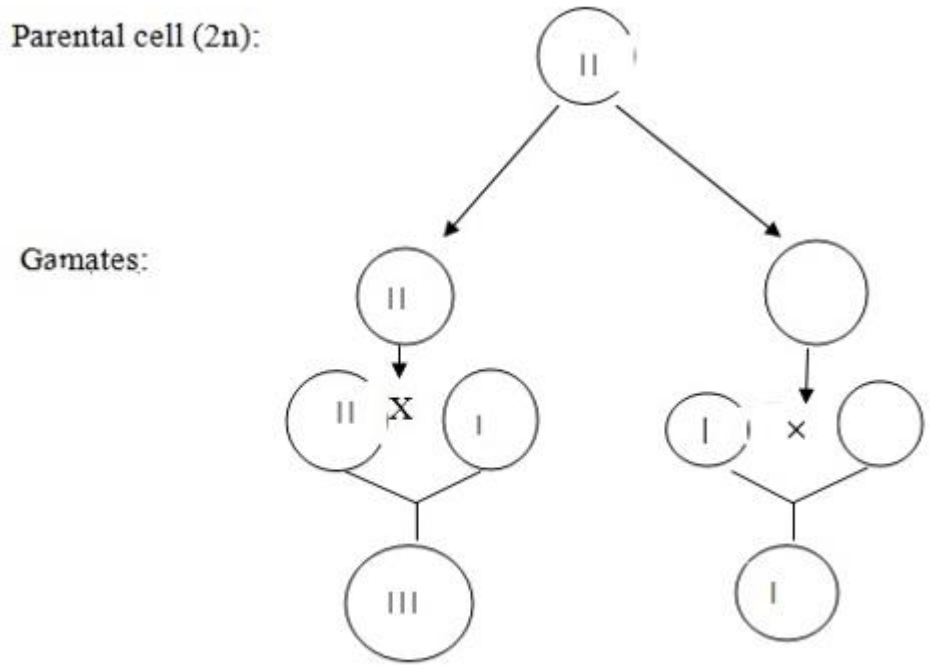
   (2n + 1) etc, whilst the other half have a chromosome missing (n – 1), (2n – 1)

   and so on.

Anaeuploidy arise from the failure of a pair of chromosomes to separate during gamete formation. This may lead to formation of gamete cells containing more or few chromosome. This is known as non- disjunction.

Fusion of either of these gametes with a normal haploid gamete produces a zygote with an odd number of chromosomes. They are usually abnormal.

Non disjunction in gamete cell formation



Consequence of non- disjunction in humans (Genetic disorders)

Down's syndrome (Mongolism) *** sex symptoms on next pages ***

In this case 21st chromosome fails to segregate and the gamete produced possesses chromosomes. The fusion of this gamete with a normal one with 23 chromosomes results in the offspring having 47 (2n + 1) chromosomes. This leads to a presentation of three copies of chromosomes, a condition known as trisomy, hence down syndrome is also known as trisomy 21.

- A Mongol is characterized by the following feature:
- Big head, protruding tongue, flat facial features, puffy eyes, mental retardation, sterility and short life expectancy.
- Non disjunction in the case of Down's syndrome appears in the production of ova rather than sperm.

- The chances to have a mongol child increases with an increased age of the mother. At the teenage, the chance is one in many thousands at age of 40 - 45, the chances are 35% and above.

Kilinefelter's syndrome (in feminized males)

This is a male genetic disorder in which the victim has got 47 (2n + 1) chromosomes instead of 46.

- It is due to an extra X chromosome. The genotype is therefore XXY instead of normal XY. It is like Mongolism, an example of trisomy.
- It may occur during spermatogenesis or during oogenesis.

Symptoms:

- Infertility – sperm are never produced.
- Usually taller than average.
- Enlarged breasts.
- Enlarged hipbone.
- Very small testes.
- Low intelligency.
- Little facial hair.
- Smooth skin texture.
- Voice pitched higher than normal.

Treatment – Male hormones can be given. Breast then returns to normal size and the condition is diagnosed only after puberty.

1. **Turner's syndrome** (XO)

- This is a female genetic disorder in which there are only 45 chromosomes. Patients can be described as incompletely developed females.
- The sex constitution is said to be XO.

Symptoms:

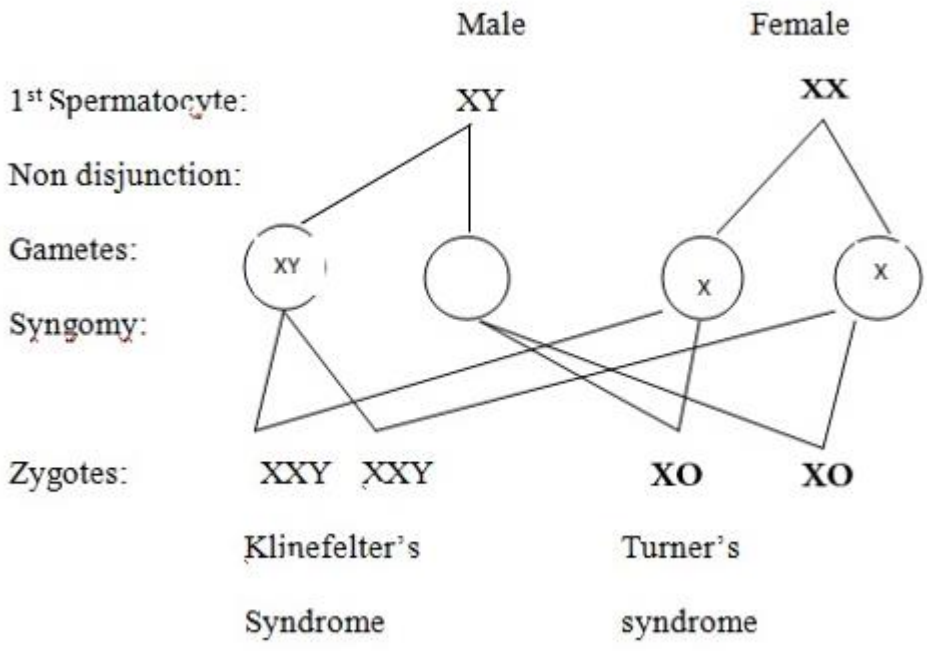
- Infertility – ovaries as are absent.
- Small uterus.
- Shortness of stature.
- Broad chest with widely spaced nipples.
- Under developed breasts.

Treatment:

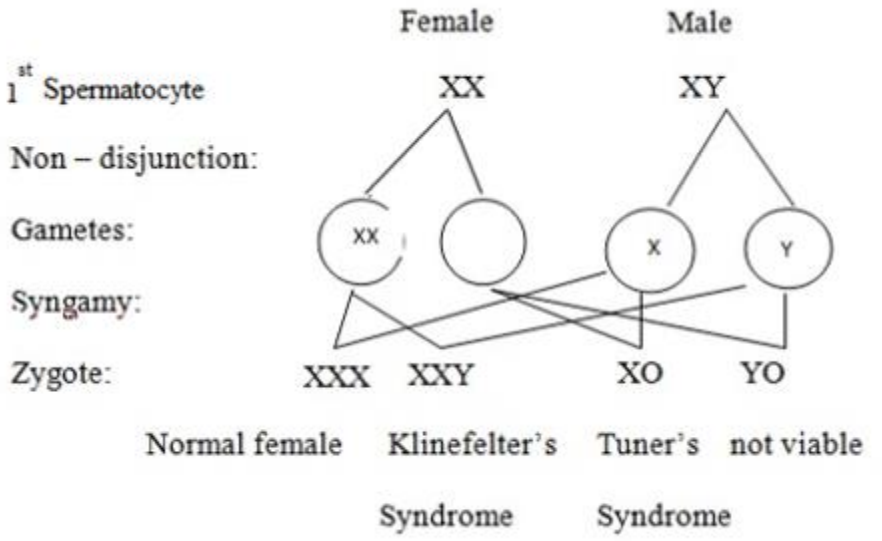
From the age of puberty, a woman is given female sex hormones to make female develop breasts & have periods. Though this does not cure infertility.

Explanation of Klinefelter's syndrome and Turner's syndrome as a result

(a) Non – disjunction of the father's sex chromosomes



(b) Non – disjunction of the mother's sex chromosomes



Changes in the chromosome structure

There are four types:

1. **Deletion** – a portion of a chromosome is lost. As it involves the loss of genes, it can have a significant effect on an organism's development, often proving lethal.
2. **Inversion** – a portion of chromosome become deleted, but becomes reattached in an inverted position. The sequence of genes on this portion is reversed and therefore the phonotype is changed although the overall genotype is unchanged.

   This indicates that the sequence of genes on the chromosome is important.

3. **Translocation** – a portion of chromosome becomes deleted and rejoins at a different point on the same chromosome or with a different chromosome.
4. **Duplication** – a portion of chromosome is doubled resulting in repetition of a gene sequence.

   Qn Discuss the genetic disorders that may result due to non – disjunction of somatic and sex chromosome during meiosis.

   GENETIC ENGINEERING (Recombinant DNA technology)

   Definition: Genetic engineering or recombinant DNA technology is defined as the manipulation of DNA of one organism (donor) and its transfer into another organism (the host) where its combines with that of the host organism.

   Where it combines with that of the host organism

- **To create as new gene combination, genetic engineers must be able to**

1. Located a specific gene in the donor cell.
2. Modify the donor DNA in a highly selective way.
3. Isolate the located gene.
4. Transfer the modified DNA into the host cell in such away the gene will be expressed strongly enough to be practical use.

Techniques used to manipulate DNA

- The manipulation of DNA involves three techniques each of which uses specific enzyme or group of enzymes.
- The molecules to modify DNA (the enzyme used) are;

1. Reverse transcriptase

- This catalyses the synthesis of DNA from RNA.

2. Restriction endonucleases

- These are used to cut DNA at specific sections.

3. DNA Ligase

- This joins the donor and vector DNA section so as to form a recombinant DNA molecule.
- The techniques of recombinant DNA technology are:-

1. Splitting the DNA molecule into smaller portions using restriction endonuclear which are specific to particular base sequences on the DNA.
2. Copying the required DNA section using the enzyme reverse transcriptase which controls the synthesis of DNA from the RNA. The resulting DNA is called copy or complementary DNA

   (cDNA).

3. Adding the gene the vector DNA.
4. Formation of recombinant DNA molecule with vector.
5. Joining the DNA portions together using DNA ligase enzyme.

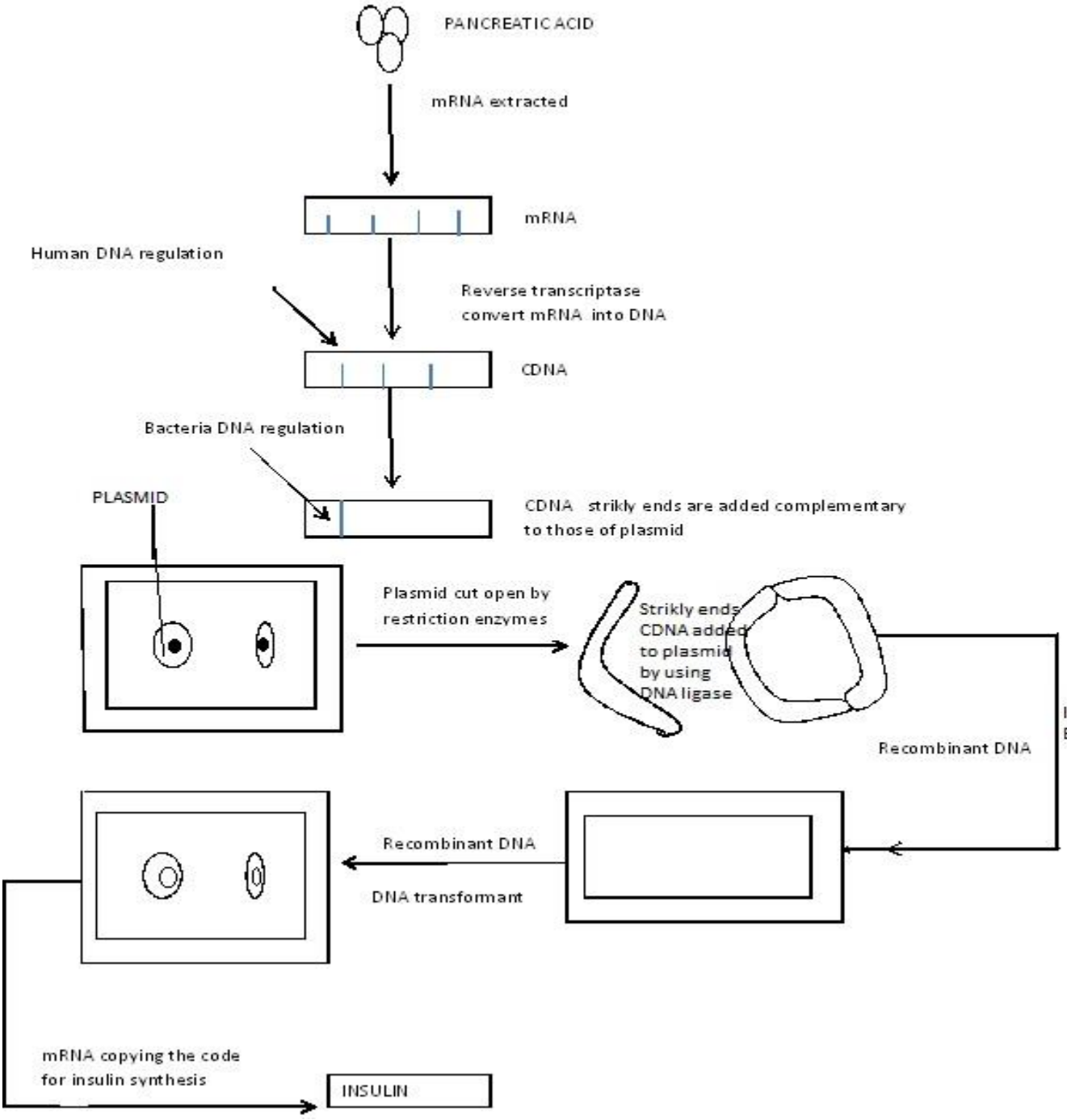


Illustration: Consider the diagram below showing the synthesis of insulin

Question

Define the terms:-

1. (b) Gene cloning.

   (c) Transgenic organism.

SOLN

1. A clone is a group of cells of similar characteristics that are able to replicate and produce more cells.
2. Gene cloning is a process whereby multiple copies of a given gene are produced which may then be used to manufacture larger quantities of valuable products.
3. A transgenic organism is a genetically modified organism (GMO) ie: the organism formed as a result of genetic engineering. New genes are added into embryo of an organism.

MERITS AND DEMERITS OF GENETIC ENGINEERING

1. **Merits of genetic engineering**

1. Synthesis of hormones such as insulin, growth hormones etc.
2. Production of vaccine and antibiotics. Already interferon has been synthesized by genetic engineering.
3. Increases plant resistance to pests eg: cotton and potatoes.
4. Improves quality and quantity of animal products such as milk.
5. It offers endless opportunities to manipulate DNA.

1. **Demerits**

1. The materials contained in the manipulated DNA, are likely to undergo mutation.
2. The use of genetic engineering in the manufacture of biological weapons is a mis-application of genetics.
3. The use of GMO's for human consumption is dangerous as it increases cancer chances.
4. Some practices of Genetic engineering may not be in line with ethical and moral values.

Phenlyketonuria (PKU)

- PKU is a recessive autosomal condition.
- The disease is due to inability to convert the amino acid phenylalanine to another amino acid, tyrosine.

Phenylalanine

Hydrolase.

Phenylalanine (PAH) Tyrosine.

The enzyme PAH is normally there in the liver.

As a result of phenylalanine builds up in the body and the excess is converted into toxins which affect mental development.

Affected children appear normal at birth because, while in their mother's uterus during pregnancy, excess phenylalanine moves across the placenta and is removed by the mother's liver. If not treated soon, harmful effects are noted.

Identifying PKU in new born babies

- Few days later after birth, blood test is carried on and higher level than normal of phenylalanine is detected.

Qn:Why the baby not tested when is first born?

Answer

Its excess phenlylalanine is removed by the mother while it is in the uterus. It takes a few days for the levels of phenylalanine to build up.

Genetic screening and parental diagnosis:

Genetic screening is the detection of mutant genes in an individual.

There are three situations where genetic screening is of particular relevance namely;-

1. Prenatal diagnosis.
2. Carrier diagnosis.
3. Predictive diagnosis.

Prenatal diagnosis

This is the use of modern medical techniques to identify any health problems of the unborn baby.

It includes the detection of genetic disease. If such a disease is detected, it is usually possible to provide counseling about the quality of life the child can expect and other potential problems. The parents are usually also given the option to abort.

Carrier diagnosis:

This is the identification of people who carry a particular genetic disease, usually with no visible symptoms or harm to themselves.

Predictive diagnosis:

This is the prediction of a future disease which you are likely to suffer as a result of your genes but not yet produced any symptoms.

Chorionic villus sampling (CVS)

- A small sample of chorion is withdrawn for examination.
- The cells of the chorion are derived from the zygote, so are genetically identical to the embryo. The chromosomes are examined (Karyotype analysis) and the sex of the child can also be seen.
- The rise of miscarriage is higher than Amniocentesis.

Amniocentesis

- This involves analysis of amniotic fluid.
- Amniotic fluid is genetically identical to chorion and zygote.

Mixed concepts

Successfulness of Mendel in his experiment was due to the following reasons.

1. He chose pea plants (P. sativum) in his crossing. Why?

   Reasons:

- P. sativum has short life span.
- P. sativum has many contrasting characters (about 32 contrasting characteristics).
- A plant is Bisexual.

1. He was Imaginative in ratio determination and careful, he covered the stigma with muslin cloth which allowed respiration but prevented pollens of one plant from reaching another plant.
2. He did his experiments in a large scale to avoid (eliminate) the effects of mutation.
3. He was intelligent as he used mathematical concepts in explaining the ratio of the results he got.

Modern Mendelian laws (1^{st} Law & 2^{nd} Law)

1. The characteristics of an organism occur in pairs of chromosomes which divide during meiosis such that only one of each chromosome appears in gametes.
2. Alleles occur in pairs, they divide by meiosis and during fertilization, zygote is formed from random fertilization in which any of the allele from each pair may combine with the other.

Application of Genetic engineering

1. **Medicine**

1. The gene in man that codes for insulin is transferred in the bacterium, Escheriachia coli to produce pure insulin in large quantities.
2. Human growth hormone, somatotrophic hormone can be extracted from the pituitary glands of dead bodies.
3. Blood clothing factors such as fibrinogen needed by haemophiliacs are produced.
4. Vaccines are produced from viruses.

1. **Biological Warfare**

   Micro – organisms that cause diseases have been used in wars.

   The micro organisms are cloned and thrown into the territory of the enzyme.

   Infections of this bacteria (micro-organism) causes death within few days.

(c) Agriculture

1. Research is being done to produce plants that are capable of fixing nitrogen without relying on nitrogen fixing bacteria.
2. Genetically modified organisms are used to break down wastes from homes and industries.
3. Frozen embryos may be separated into cells, which can be made to grow into new embryos if implanted into the uterus.
4. Some plants such as pyrethrum are being propagated through tissue culture.

1. **Genetic disorders**

1. Pregnant woman can be told whether the fetus had deformities or not and hence prepare for its birth or terminate it.
2. Normal genes can be introduced into the embryos to curb or cure genetic disorder such as sickle – cell anemia.
3. Genetic engineers are designing to produce human like creatures as sources of human spare parts in surgeries and transplants.

Examples of monohybrid inheritance:

1. **Rhesus factor** – In which an organism is either positive or negative.
2. **Albinism** – If dominant for skin pigmentation (AA or Aa), then an individual is normal though in the later case, he/she is a carrier.

   But if recessive homozygous, then an individual is albino.

3. **In maize seeds** – The seeds are either dominant white or recessive.

How genetic engineering is done

A section of DNA, extracted from an organism or synthesized artificially, is usually translocated to a bacterium or virus. The bacterium or virus used in genetic engineering is called transgenics. Inside the bacterial cell is a structure called plasmid.

The plasmid is split open by some enzymes called restriction endonucleases so as to allow the foreign DNA to enter.

A given restriction enzyme cuts the bacterial plasmid open at specific sites where is determined by the sequence of base in that region. This same enzyme cuts foreign DNA wherever an identical base sequence occurs.

This procedure of splitting open the bacterial plasmid and inserting the foreign DNA is called gene splicing.

The foreign DNA and the plasmid join up, and so the foreign DNA gets incorporated into the plasmid. The enzyme DNA ligase is responsible for joining the foreign DNA and plasmid. The result of the combination is called recombinant DNA.

The foreign DNA replicates along with the rest of the plasmid every time the bacterial cell divides.

The bacterium is selected because it replicates quickly and the offsprings resemble parents.

Once the bacterium has taken up a piece of foreign DNA successfully, it may divide repeatedly into a population of bacterial cell all of which contain replicas the foreign DNA.

This production of large quantities of identical genes by means of genetic engineering is called gene cloning. This technology is currently being used in production of human insulin to save diabetes.

Application of Genetics

1. **Plant and animal breeding**

It has been observed that crossing two genetically dissimilar organisms of the same species produces organisms that possess beneficial characteristics not shown by either of the parents.

The individual that results from crossing two individuals with contrasting characters is called a hybrid. In cattle, milk production, quick maturation and beef production can be obtained through hybridization.

For example: The Hereford, English breed shows high beef production and quick maturation.

The Boran from Tanzania shows disease resistance and grows on dry pasture.

A cross between the Herefore bull and a Boran cow produces a hybrid of all these qualities.

2. **Blood transfusion**

Blood transfusion is the transfer of blood from one person, the donor, into the stream of another person, the recipient.

Before blood transfusion, blood is tested to determine the blood group and Rhesus factor. If the blood of the donor is not compatible with the blood of the recipient, agglutination occurs.

The ABO blood group system and the Rhesus antigens are used to settle parentage disputes.

3. **Genetic counseling**

Genetic information is used to advise couple who have hereditary disorders about the chances of children inheriting the disorders.

Genetic information could also be used in choosing marriage partners.

Symptoms of Down's syndrome:

- Mental retardation.
- Straight hair.
- Increased risk of infections particularly respiratory and ear infections.
- Short stature.
- Heart defects.

PLEIOTROPY

Pleiotropic genes are genes that code for a specific mutabollic process and at the same time affecting other metabolic processes.

eg. In cystic fibrosis, A gene that codes for secretion of Cl^- also induce secretion of viscous (thick) mucus in the lungs, pancreases and gut.

QNS

1. (a) Define the term sex limited traits giving one example of a disorder that expresses it.

1. Define the term sex influenced characters giving one example of a disorder that expresses it.

2. Describe the following disorders showing clearly its mode of inheritance;

1. Tuner's syndrome.
2. Klinifelter's syndrome.

1. (a) Explain the following ratios using genetic crosses;

1. 9:3:4 cross (2) gives answer.
2. 9:7
3. 9:3:3:1 under non Mendelian trend of inheritance.
4. 3:3:2
5. 2:1
6. 1:2:1 under non Mendelian trend of inheritance cross (3).

(b) Outline;

(i) How a peptide bond is formed.

(ii) The characteristics of genetic material.

1. Why are most lethal genes recessive?

Perform below crosses and see if ratios can provide solutions to question (2) (a)

1. Agouti x Albino. Where; A-Agout.

   AaCc Aacc C-Black.

2. Agouti x Agouti.

   AaCc AaCc

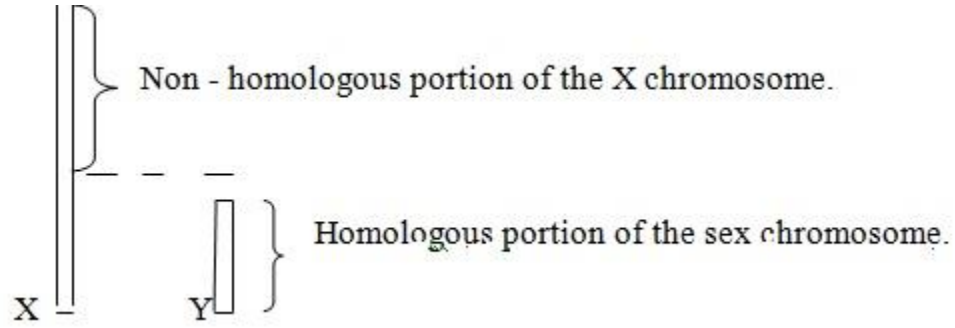
3. Agouti x Albino.

   AaCa aacc

Heterogemetic sex (XY). In some insects, while the female is XX, the Y chromosome is absent in the male, which is therefore XO. In the fruit fly Droasphila, the female is XX and the male is XY.

SEX-LINKAGE

- Sex linkage refers to the carrying of genes on the sex chromosomes.
- The X chromosome carries many such genes, the Y chromosome has very few.
- The non – homologous part of the X – chromosome with Y – chromosome is the one which bears extra genes.



- Those genes that are inherited together with sex chromosomes are called sex – linked characters (traits).
- Two well known sex-linked genes in humans are those causing haemophilia and pale green colour blindness. Both are linked to the X-chromosome and both occur almost exclusively in males.

For the condition to arise in females, requires the double recessive state and as the recessive allele is relatively rare in the population, this is unlikely to occur. In females the recessive allele is normally masked by the appropriate dominant allele which occurs on the other X – chromosome. These heterozygous females are not themselves affected but are capable of passing the recessive allele to their offspring.

For this reason such female are termed Carriers.

When the recessive allele occurs in males it expresses itself because the Y – chromosome cannot carry any corresponding dominant allele.

HAEMOPHILIA

Hemophilia is the inability of blood to clot, leading to slow and persistent bleeding especially in the joints. Unlike colour blindness it is potentially lethal.

Hemophilia is a sex linked character caused by a recessive allele which is carried by the X – chromosome.

Consider the following genetic attributes:-

X^HX^H – Normal female.

X^HX^h – Normal but carrier female.

X^hX^h – Hemophilia female.

X^HY – Normal male.

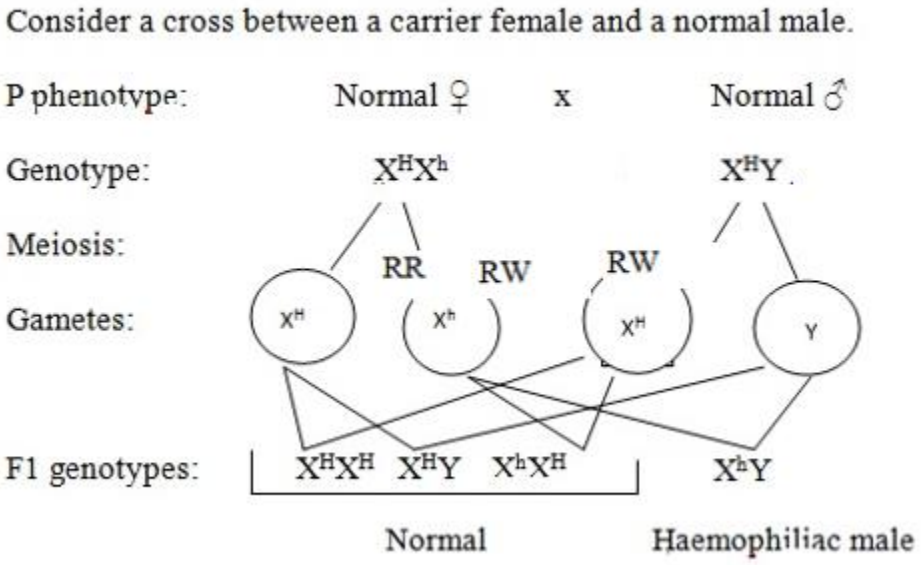
X^hY – hemophilia male.

- Hemophilia females are rare in nature because:-

1. Mostly, they do not grow beyond the first menstrual flow.
2. For a female to have haemophilia, both X – chromosomes must bear the allele h, in the heterozygous state, one is normal.

   Example

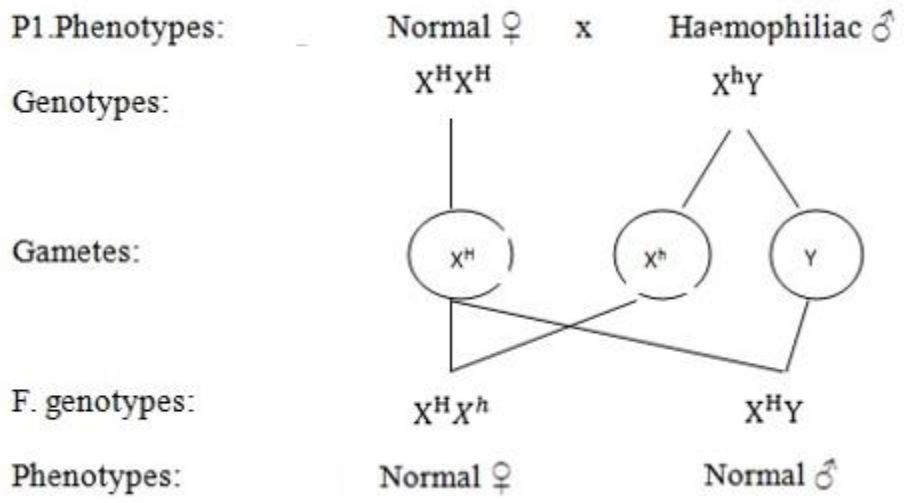
   Consider a cross between a carrier female and a normal male.



From the cross,

1. All the females are phenotypically normal.
2. 50% of the males, are hemophiliac.

- Considering a reciprocal cross we have



REPRODUCTION

Is the ability of an organism to produce an individual of its type in order to increase the number of individuals of that species.

MEANS OR TYPES OF REPRODUCTION

1. Asexual reproduction.
2. Sexual reproduction.

ASEXUAL REPRODUCTION

Asexual reproduction is the type of reproduction which does not involve the fusion of gametes.

CHARACTERISTICS.

1. Proceeds without fusion of gametes (asexual).
2. A single parent is capable of asexual reproduction.
3. It is a product of mitosis.
4. It occurs fast enough to prevent the chances of occurring of sexual reproduction.
5. It has few stages before the offspring are produced.

ADVANTAGES

1. It is a quick process yielding a substantial number of offspring to increase the chances of survival of the species during unfavourable environmental conditions.
2. It eliminates the possibilities of occurrence of sexual reproduction.

3. No changes of genetic makeup as the process is a product of mitosis. This is a way of maintaining good qualities in a population.
4. No mixing of materials from more than one parent therefore contamination and infections are minimized.

DISADVANTAGES

1. Fast yielding of offspring leads to overcrowding and hence competition over necessities of life among organisms e.g. light, food, mineral salts, air etc.
2. The DNA replication does not mutate it produces daughter cell exactly the same as the mother cell no variation. This makes the individual less potential evolve into new species and cope with the

   environmental challenges.

3. It may be a way to propagate defective gene into species/progeny the defective gene may affect the entire population.
4. The process involves no mixing of gene from the two different parents this eliminates the diversity or divergence among the individuals of the same species hence limits the advancement of the entire

   species.

The lower species lies only on mutations as the main form of diversification and adaptation e.g. viruses and bacteria that reproduce asexually survive in harsh environment e.g. antibiotic resistant bacteria

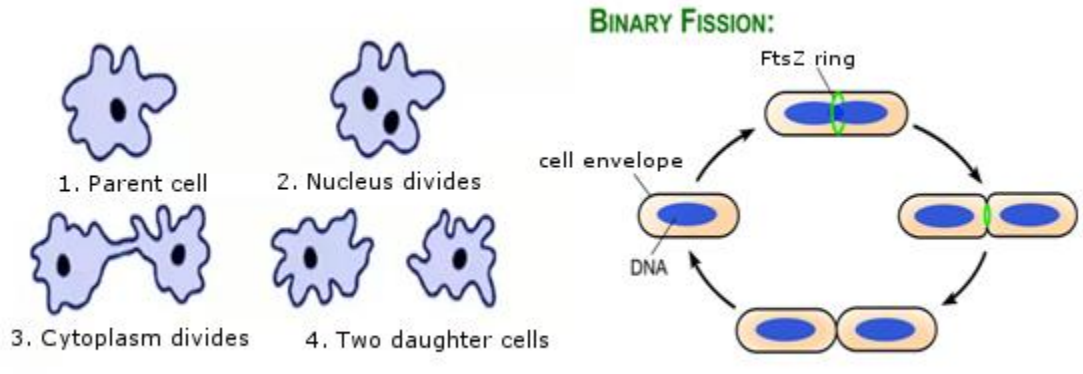
and HIV viruses that mutate when patients do not take a combination of drugs. Mutations may be occurring slowly and hence the organism may fail to cope with the environmental conditions.

Sexually reproducing organisms on the other hand combination of some of variation (mutation, gene recombination, random alignment of chromosomes at metaphase I and the subsequent movement,

crossing over) which ensure diversity in their species and hence survival value.

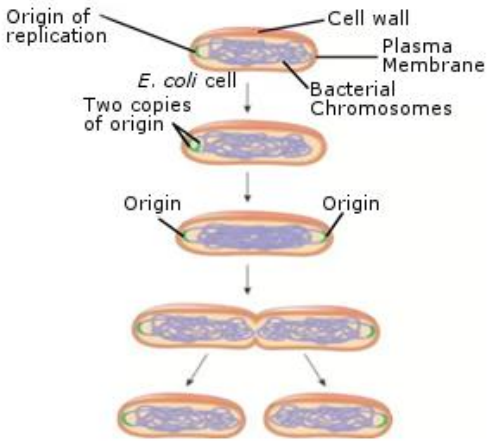
TYPES OF ASEXUAL REPRODUCTION

1. **Binary fission**



1. **Multiple fission**

   Is the repeated division of cells to form more than two daughter cells e.g. Plasmodium which has infected liver cells.

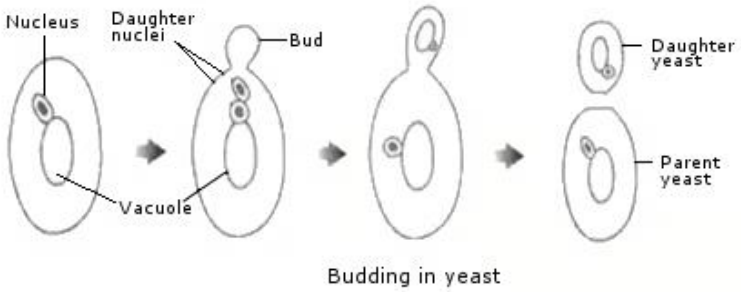


2. **Budding**

   E.g. Yeast, Hydra.

   Definition:

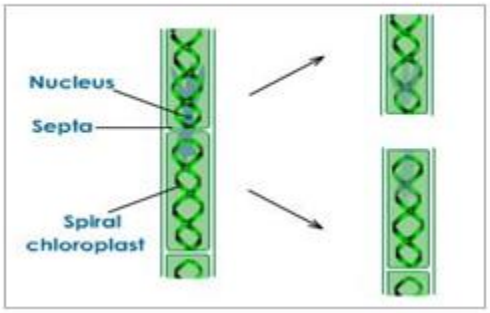
   Budding is the form of asexual reproduction in which new individual is produced as an outgrowth (bud) of the parent and later is released as independent identical copy of the parent.



Budding in yeast

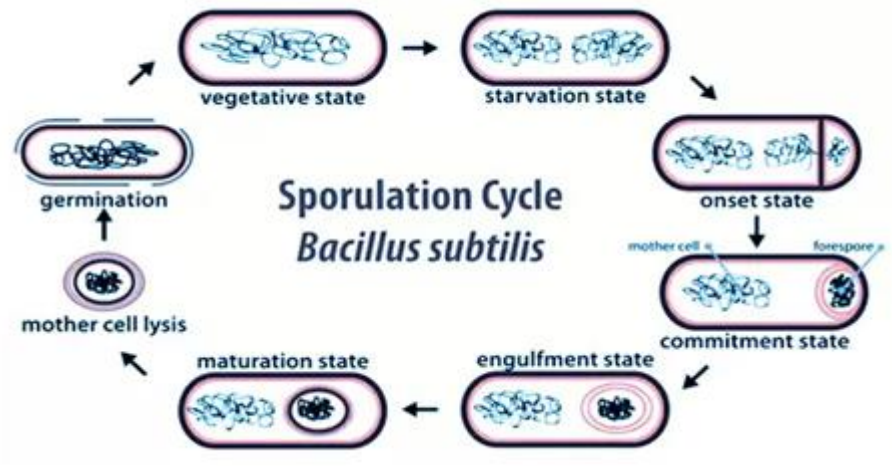
3. **Fragmentation** E.g. spirogyra, ribbon, worms.

   Is a form of asexual reproduction by which organism breaks into two or more parts each of which grows into a new individual.



4. **Sporulation**

   Is the form of asexual reproduction which involve production of spores which are then dispersed for germination to grow into a new individual e.g. fungi, plants.



5. **Vegetative propagation**

   Is the form of asexual reproduction in which a bud grows and develop into a new plant.

   Eg. A stem of cassava develops into a cassava plant.

   SEXUAL REPRODUCTION.

   Sexual reproduction is the production of new organism by combining the genetic material of two sex cells (gametes) from either a single parent or two different parents.

   The two main processes of sexual reproduction are:-

1. Meiosis which involves halving the number of chromosomes.
2. Fertilization involving the fusion of two gametes and the restoration of the original number of chromosomes.

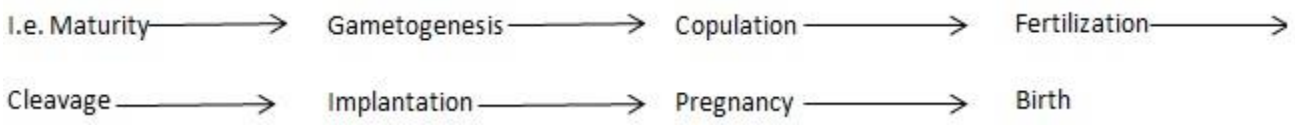
- During meiosis the chromosomes of each pair usually cross over to achieve homologous recombination during sexual fertilization.

PROPERTIES OF SEXUAL REPRODUCTION

1. It involves the application of gametes (sex cells) hence termed sexual reproduction. The two sex cells may come from two different parents (i.e. dioecious) or from single parent (i.e. monoeciousness).

   The sex cells can be isogametes (i.e. gametes of same morphology from lower animals to higher animals respectively.

2. The organisms carrying out sexual reproduction may be monoecious or dioecious.
3. The process involves lots of stages which may delay the product.



4. The process is associated with lots of risks e.g. risk to miss a mate, to miss fertilization etc.
5. Provides variation among the offsprings by its;

- Meiosis involving crossing over which produce, recombinant chromosomes and normal chromosomes.
- Random fertilization where genes are randomly mixed (i.e. random combination of genes occurs due to any sperm fertilize the given egg).

6. The process is affected by age where the young and old cannot reproduce while adults can**.**

ADVANTAGES OF SEXUAL REPRODUCTION

1. It involves more space for genetic shuffling which leads to the evolution of the organism.
2. It produces variation in the offspring when crossing over during prophase I and random assortment during metaphaseI occurs. Variation will increase the survival of the species and prevent from

   extinction.

3. The process delays the production of offspring due to age factor. The delayed product is a natural way to reduce over population hence less competition among organisms.

DISADVANTAGES OF SEXUAL REPRODUCTION

1. Very uncertain especially for external fertilization where the sperm has to meet the ovum outside, this might not occur; the process of fertilization might fail on the way to produce the zygote.

   Even in internal fertilization so many risk of missing a mate, killing of sperms by acidic fluids in female reproductive organs etc reduces the probability of occurance of sexual reproduction.

2. Maturity of offspring is slowly achieved.

   This delays their production of offspring and may lead to extinction of the species in case of disaster.

Despite the setback sexual reproduction is the primary method of reproduction for the vast majority of microscopic organisms including almost all animals and plants. This is the most preferred type of reproduction because it allows the population to change (evolve) rapidly in response to a changing environment through recombination of alleles which makes organism vary.

MEIOSIS:

Meiosis is the type of nuclear division which result with four daughters cucle each havinghalf the number of chromosomes of the parent cell. It is also termed as REDCTION DIVISION as it reduces the number of chromosomes from diploid (2n) to haploid (n). it is mainly a means of gametes formation …….

The human gamete has 23 chromosomes, 33 of which are autosomes and 1 sex chromosome of sparm cell has 23 chromosome

i.e. 22A + 1 sex chromosome

22A + x or y sex chromosome

An ovam:

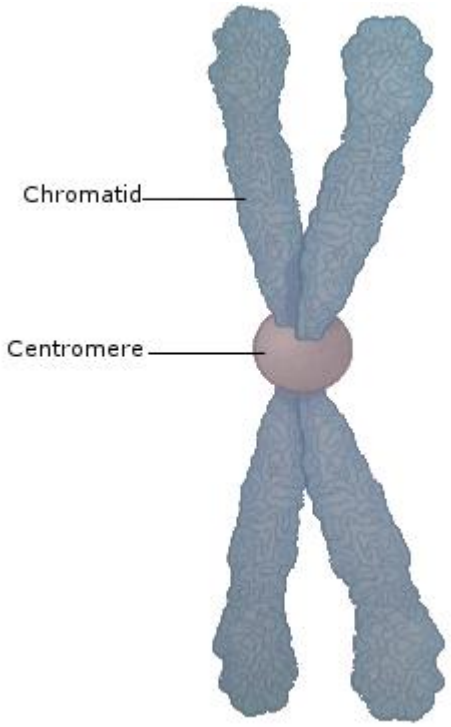
22A + 1 sex chromosome

22A + x chromosome

SOME TERMS USED:

1. CHROMOSOME: A thread like structure visible in the nucleus of a cell during nuclear division
2. SEX CHROMOSOE: Chromosomes responsible for determination of sex of an individual
3. AUTOSOME: Chromosome responsible for determination of characters other than sex

Fig .Structure of Chromosome



1.

PHASES OF MEIOSIS:

Meiosis is a long process as it passes through two cycles to completion

(a) Meiosis I or first meiotic division

(b) Meiosis II or second meiotic division

1. MEIOSIS I

This reduces the number of chromosomes to half.

Meiosis I has the following phases:

(i) Interphase I

(ii) Prophase I

(iii) Metaphase I

(iv) Anaphase I

(v) Telophase I

(i) INTERPHASE I

It is a preparatory phase during which the nucleus is about to start dividing. The events of interphases one include the following:

(a) Replication of organalles

(b) Increase in size of the cell

(c) Replication of most of DNA and histories

(d) The chromosomes replicate so that each of them exist as a pair of chromotids being joined together by the centromere

(e) The chromosomal material will but no structure is clearly visible except the nucleoli

(ii) POOPHASE I

This is the largest of all stages. It is often described in five stages consecutive stages namely:

(a) Laptotene

(b) Zygotene

(c) Pachytene (lezypadid)

(d) Diplotene

(e) Diakinesis

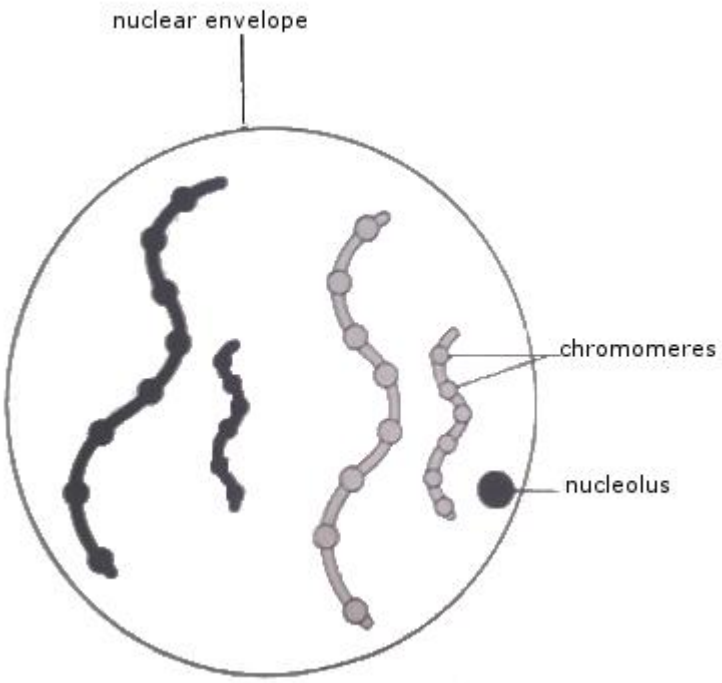
(a) LEPTOTENE (thin tread stage)

Leptetene stage initiates meiosis. During this stage:

(i) Chromosomes appear as unioiled thread like

(ii) Chromosomes appear to be longitudinally single

(iii) Chromosomes appear to have dense granules which occur at irregular intervals along their lengths. These are called choromosomeres

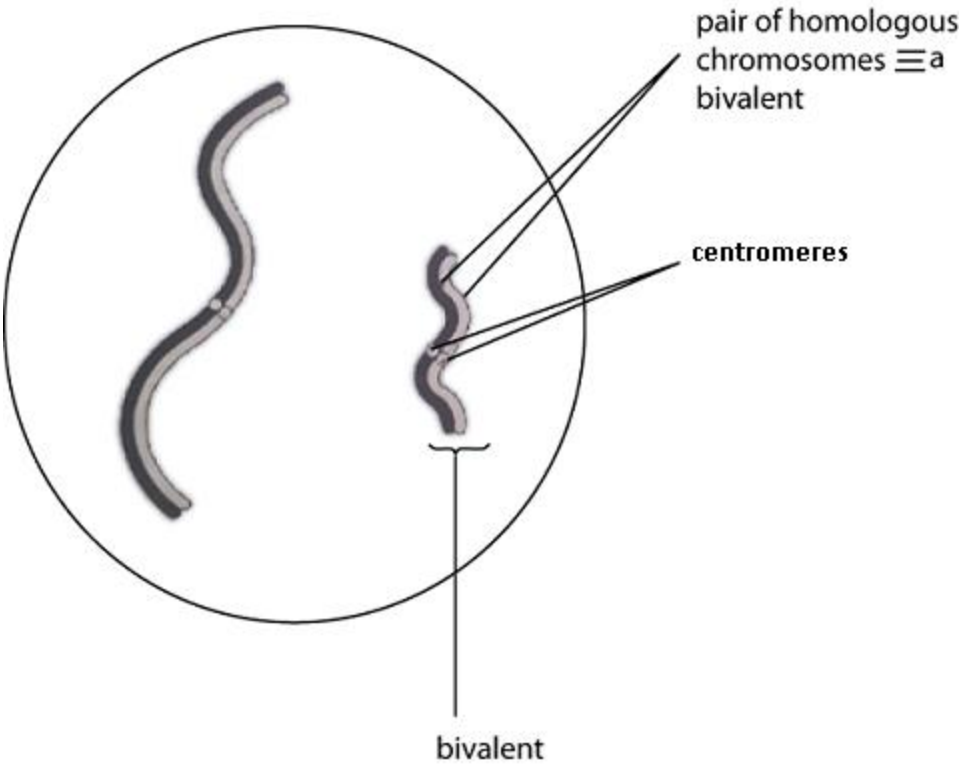


(b) ZYGOTENE (pairing stage)

This is initiated by the movement of chromones in the zygotene stage.

(i) Homologous chromosomes more close to one another and up they lie side by side, chromosomere by chromosomere under the influence of attraction force called SYNAPTIC FORCE

(ii) Synapsis begins at one or more points along the chromosome and unites along the entire length



(c) PACHYTENE (Thickening stage)

During pachytene

(i) Chromosomes are thickened and shorted by coiling and become visible

(ii) The nucleolus is attached to particular chromosomes

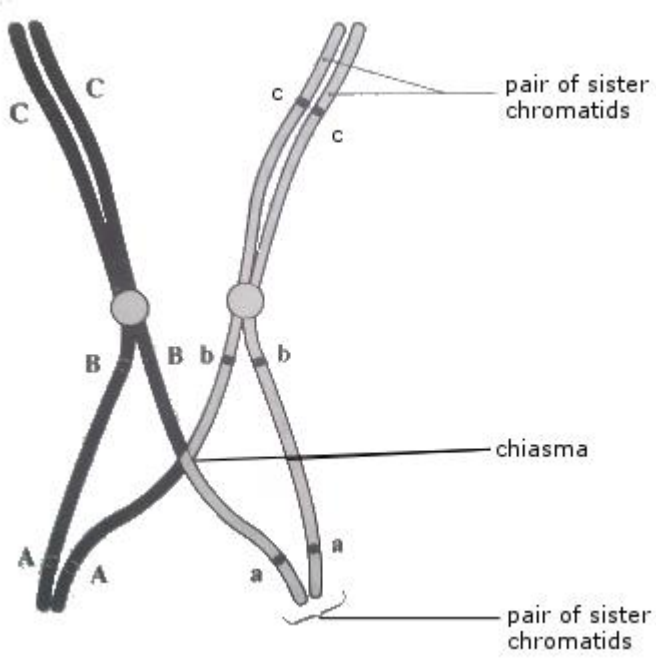
(iii) The synaptic force of attraction start to lapse and homologous chromosomes start to separate from each other.

Each chromosome appears a double structure.

(d) DIPLOTENE (Duplication stage)

(i) There is a complete duplication of each chromosome to produce two chromatids, thus each bivalent has four chromatids

(ii) The chromatids of homologous chromosomes cross over one another. At the point called chiasmata or cros over the number of chiasmata to be formed depends on the length of the chromosome. At the chiasmata, chromosomes breaks and rejoin, thereby exchanging hereditary materials. As a result, genes from materinal chromosomes exchange with genes from paternal chromosomes leading to new gone combination in the resulting chromatids. This is a means of bringing about variation



(e) DIAKINESIS (Moving apart stages)

During Diakinesis:

(i) The nucleolus detaches from its special bivalent and disappears.

(ii) The chiasmata tend to lose their original position and move towards the ends of chromosomes

(iii) The bivalent become considerably more contructed

(iv) Chromotids if homologous chromosomes continue to repel

(v) The contriolas of present migrate to the poles

(vi) The nuclear membrane starts to disintegrate and spindle fibre start to form

Study problem:

1. Describe the events of prophase of meiosis I and comment on biological consequences of chiasmata formation.

MATAPHASE I

During Metaphase of meiosis

(i) The bivalent are arranged across the equitorial plate of the spindle with each centromere equidistant from the equatorial plate

(ii) The nuclear membrane has broken down completely

(iii) The spindle fibre forms and hold the centromers at the equator

ANAPHASE I

During this phase:

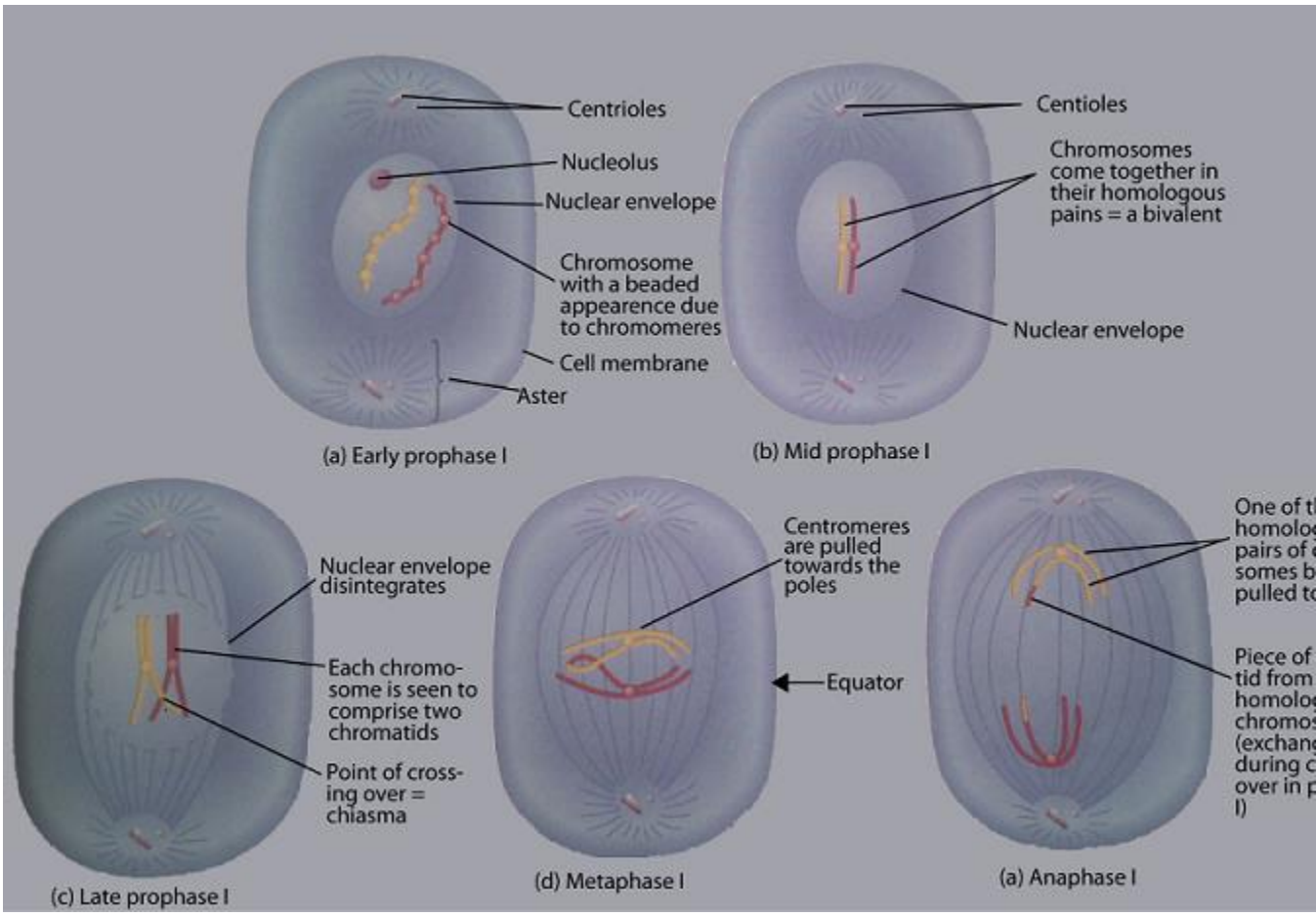
(i) The two centromenes of each bivalent do not divide, instead the siste chromatids separate

(ii) The centomere pairs move toward the opposite poles

(iii) The chiasmata contents completely breakdown

(iv) The chromosome are separate into two haploid sets of chromosomes in the daughter cells.

TELOPHASE I



This marks the end of meiosis. During this phase,

(i) The homologous chromosomes arrive at the opposite poles

(ii) Spindle fibre disappears, chromatids uncoil and the nuclear membrane rejoin around each pole

(iii) Cytoplasm dividing to form two daughter cells

N.B: In many plant cells there is no telephase, cell wall formation on interphase I. the cell pass straight from anaphase to prophase II.

INTERPHASE II

This occurs in animal cell only is there is no interphase II in plant cell. Replication of DNA doe snot occur and energy stores of the cell increases. This stage is followed by meiosis II. The behavior of chromosomes in meiosis II is the same as that in meiosis I.

PROPHASE II

During this phase:

(i) Nucleoli and nuclear membrane start to disintegrate

(ii) The chromatids shorter and thicken

(iii) Cantoriols if present move to opposite poles the cell

(iv) Spindle fibre appear

METAPHANE II

The chentromeres align at the equator of the spindle

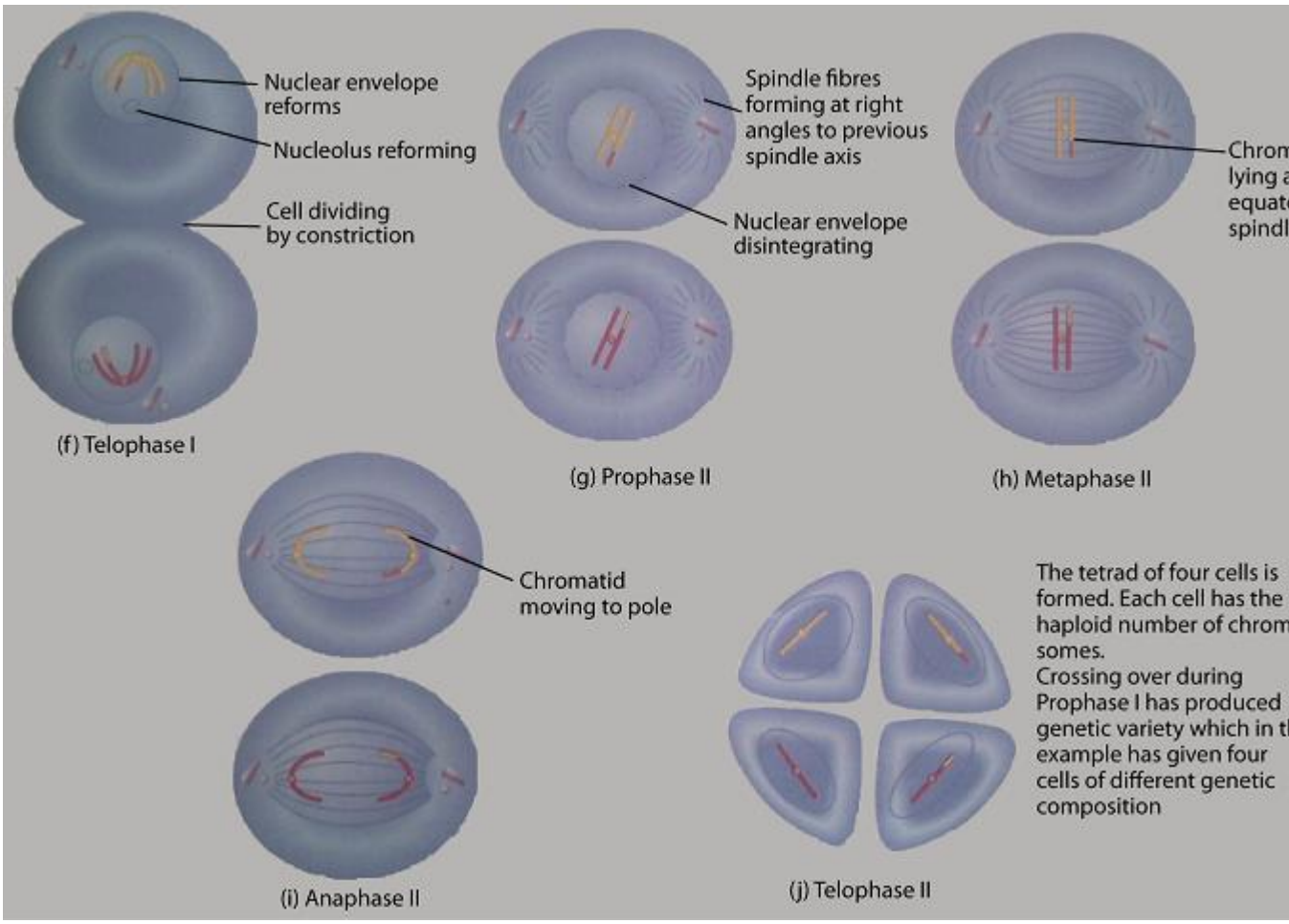
ANAPHASE II

(i) The centromeres divide

(ii) The spindle fibres shorters and pull the centromeres to opposite poles

(iii) The eytoplasm started to cleave

TELOPHASE II



- The chromosomes uncoil

- Spindle fibre disappear

- nuclear membrane reforms followed by complete cytokinesis

- Four daughter cells are formed each with half the number of chromosomes of the parent cell

SIGNIFICANCE OF MEIOSIS:

It insures constant chromosome number to all species which reproduce sexually. This is because during gametes formation. The number of chromosomes is reduced to half and restored at fertilization.

(ii) It provide opportunities for new gene combination through chiasmata formation. Hence a mechanism of variation.

DIFFERENCE BETWEEN MEIOSIS AND MITOSIS

STAGE	MITOSIS	MEIOSIS
Prophase	- chromosomes not visible - Homologous chromosome remain separate - No chiasmata formation	- chromosomes visible - Homologous chromosomes pair up - chiasmata formation take place
Metaphase	- chromaitd pairs line up on the equator of the spindle centromores line up on the equator	- this occur in metaphase II but no metaphase I - centromere line equidislent aove and below the equater of the spindle
Anaphase	-chromatids separate number of chromosome present as parent cell - Separated chromatids identical	- chromosomes separate in Anaphase I, chromatids separate in Anaphase II - The separated chromosomes and chromatids may not be identical - Half the number of chromosomes is present in daughter cell
Telophase	- Both homologous chromosomes are in each daughter cell	- only one of each pair of homologous chromosome is in each daughter cell
Occurance	- occurs in the formation of somatu cells	- Occurs in the formation of gametes and spores

STAGES OF SEXUAL REPRODUCTION

Sexual reproduction involves the following stages:-

1) gametogenesis
2) Copulation
3) Fertilization
4) Cleavage
5) Implantation
6) Pregnancy
7) Parturition(birth)
8) Parental case.

1. **GAMETOGENESIS.**

   Definition:

   Gametogenesis is the general process of gametes formation in both male and female reproducing sexually.

- Meiosis is the process by which gametes are formed can also be called gametogenesis literally 'creation of gametes'.
- The type of meiosis in male organism forms a spermatogonium to a primary spermatocyte a secondary spermatocyte a spermatid and finally a spermatozoid is spermatogenesis.

Definition:

Oogenesis is the process of meiosis in female organism from oogonium to a primary oocyte, a secondary oocyte and then an ovum (egg cell).

- The primordial germ cells once they have been populated the gonalds proliferate into sperm (in testes) or ova (in the ovary).

SPERMATOGENESIS

- In male testis there are tiny tubules (seminiferous tubules) containing diploid cells called spermatogonia that develop into mature spermatozoa (spermatozoa are the mature male gametes in many sexually reproducing organisms).
- In spermatogenesis i.e. a process during which spermatogonia (sperm cells) multiply giving rise to other spermatogonia restoring their population and to other which mature to spermatocyte.
- Around the periphery of the seminiferous tubules are located specialized cells known as spermatogonia.

  Spermatogonia are diploid cells set aside early in embryonic development. They may divide by mitosis to generate more spermatogonia or by meiosis to produce spermatids each of which will differentiate into a mature sperm cell.

- Spermatogonia destined to undergo meiosis first differentiate into primary spermatocytes which undergo two successive meiosis divisions.
- After meiosis I the produced cells are called secondary spermatocyte which each in turn undergoes the secondary division become spermatids each containing a unique set of 23 single chromosomes that ultimately mature into four sperm cells (spermatozoa).

- **The seminiferous tubular contain two types of cell;**

1. **Germ cells**; these undergo the two division of meiosis to form the spermatozoa
2. **Sertoli Cells**: Acts as nerve cells ensuring that the germ cells have adequate nourishment.

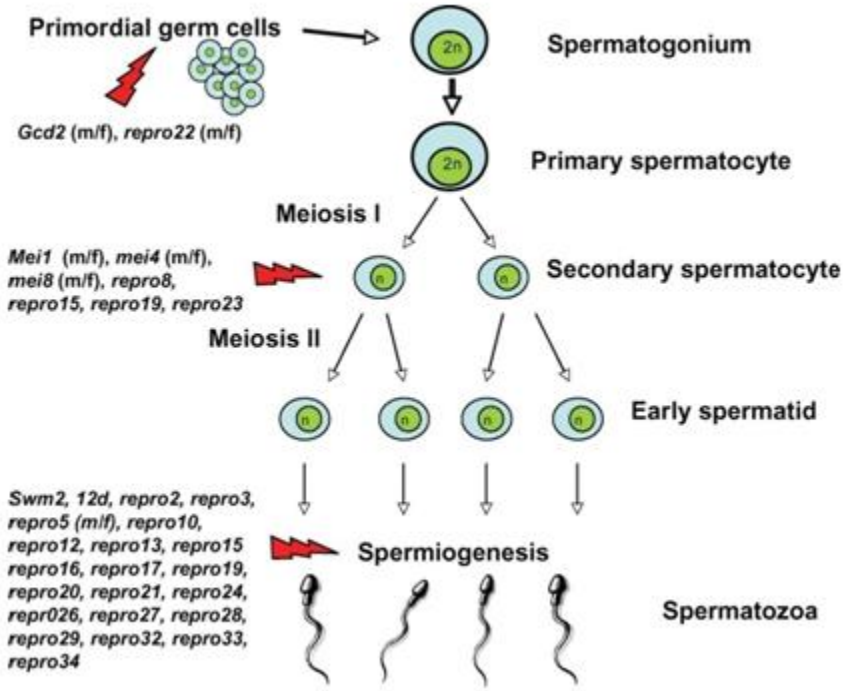


Fig: The stages of spermartozoa formation.

- Spermatids undergo transformation in order to become spermatozoa

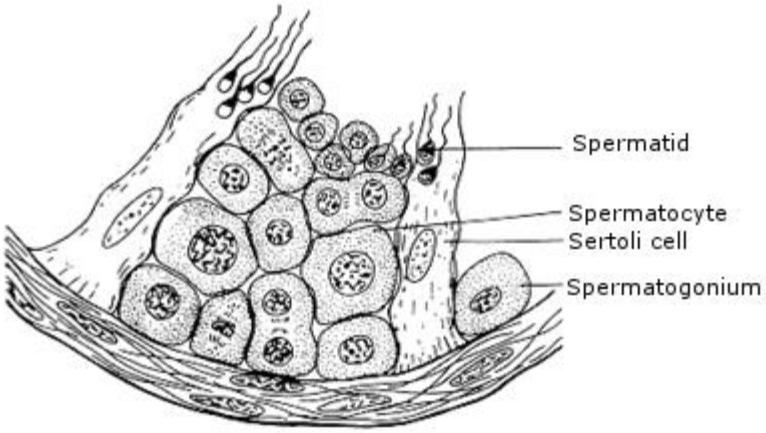


Fig: Diagram showing the structure of part of the wall of seminiferous tubule.

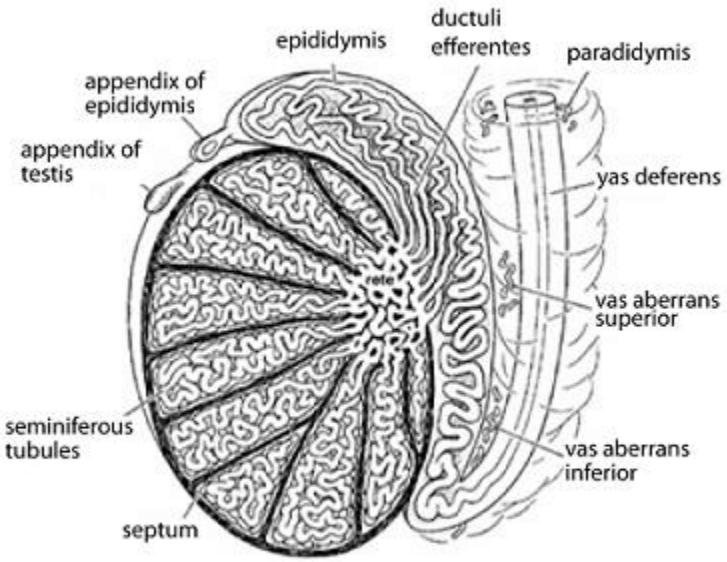


Fig: Simplified diagram showing the structure of the human testis and tubes carrying sperms from seminiferous tubule to urethra.

SPERMATOGENESIS

- Occurs in seminiferous tubules.
- Stored in epididymis.

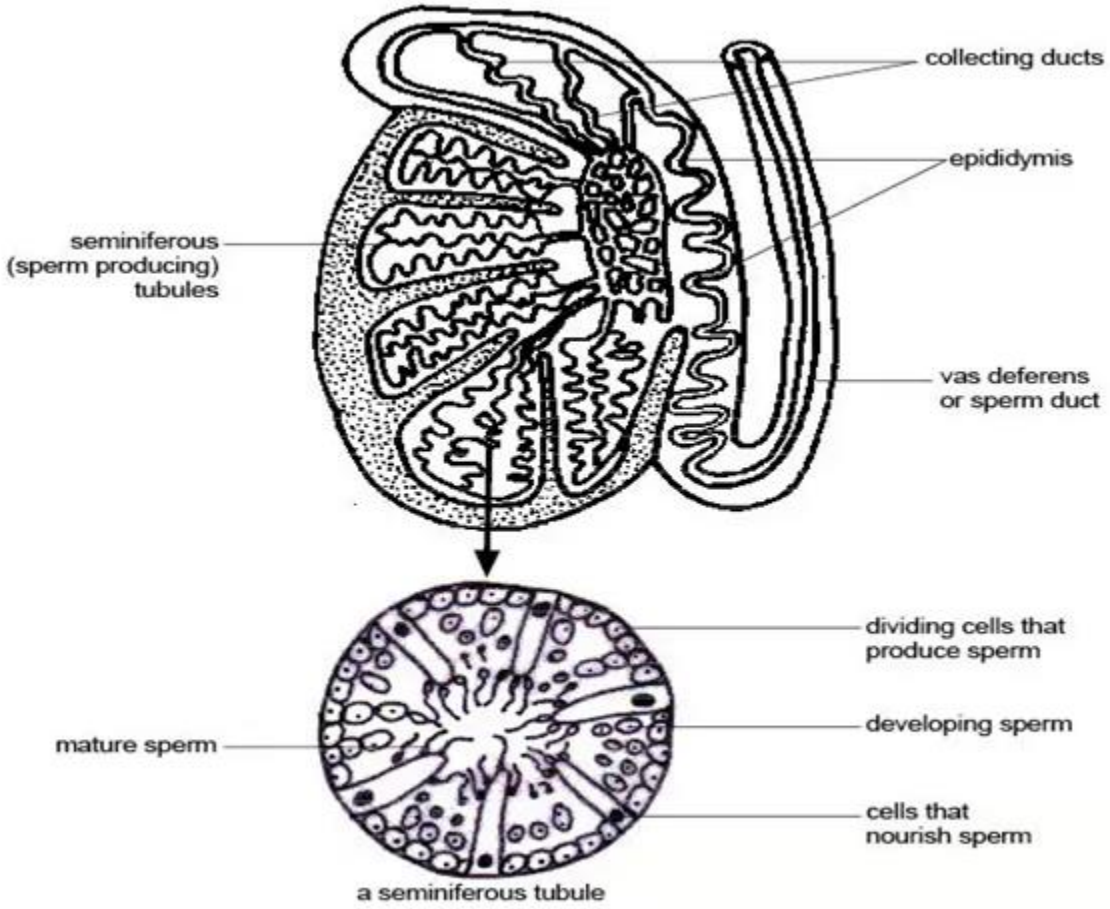
Process:

1. Diploid spermatogonia divide by mitosis from germinal epithelium (germinal epithelial cells).
2. Some of them grow to produce diploid primary spermatocytes.
3. Diploid spermatocytes undergo first meiotic division to form two haploid secondary spermatocytes.
4. Haploid secondary spermatocytes undergo second meiotic division to form haploid spermatids.
5. These grow in shape and become spermatozoan.
6. The sertoli cells provide nutrition and protection against body immune system.

From the figure

The interior of the testis, site of spermatogenesis within the seminiferous tubules of the testis cells called spermatogonia develop into sperm, passing through spermatocyte and spermatid stages. Each

sperm passes as a long tail coupled to a head which contain a haploid nucleus.



MECHANISM OF SPERMATOGENESIS

The process of spermatogenesis is divided into the following phases (as shown below):-

1. Multiplication phase.

2. Growth phase.

3. Maturation phase.

4. Metamorphosis.

1. MULTIPLICATION PHASE

- Also known as spermatocytogenesis.
- Here the sperm mother cells present in the germinal epithelium of the seminiferous tubules divide repeatedly by mitosis to form a large number of diploid rounded sperm mother cells called spermatogonia.

Some of these sex cells move towards the lumen of seminiferous tubules and enter growth phase. These cells are called primary spermatocytes. The primary spermatocytes are diploid and contain (44 + XY)

chromosomes.

Some of these cells produced by the division of spematogonia remain in the original condition and continues to divide giving rise to primary spermatocytes such cells are known as stem cells.

2. **GROWTH PHASE**

During this phase, spermatocyte as well as its nucleus enlarges in size. It gets ready to undergo meiotic division.

3. MATURATION PHASE

Each diploid primary spermatocyte undergoes meiosis I which is a reduction division.

Two daughter cells are formed with 'n' number of chromosomes. The daughter cells are called secondary spermatocytes are haploid and much smaller comparatively containing (22 + X) or (22 + Y)

chromosomes.

The secondary spermatocyte undergoes the second meiotic division (equational). This results in the formation of four daughter cells known as spermatids

4. **METAMORPHOSIS.**

The spermatids formed as a result of maturation division in a typical animal cell with all the cell organelles present in it. In this form it cannot function as a male gamete. So many changes take place to change

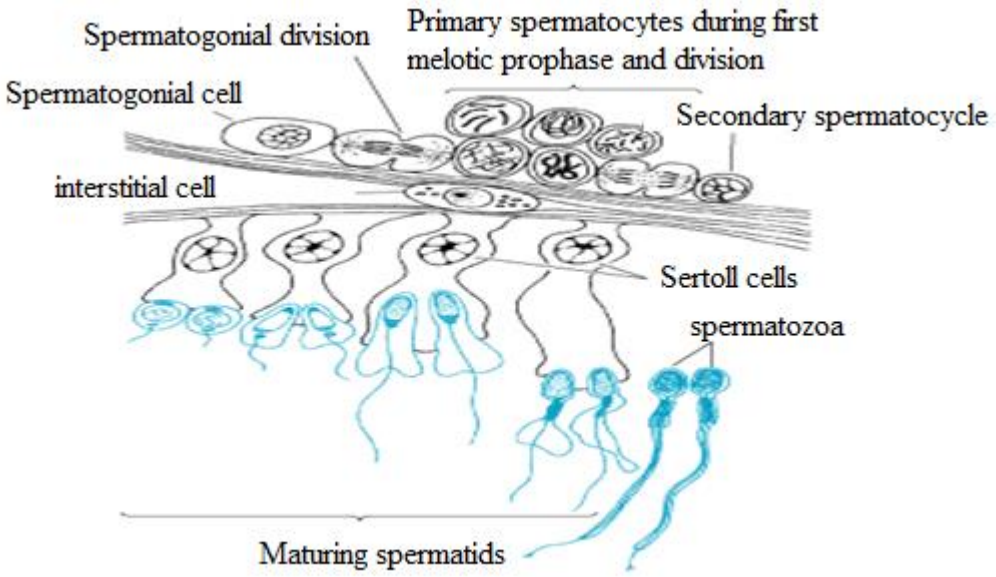
the non – motile spermatid into motile spermatozoa.

The main aim of the changes is to increase the motility of the sperm. These changes are:-

1. Nucleus shrinks by losing water and DNA becomes closely packed.
2. An acrosome is formed from the Golgi complex.
3. An axial filament of the tail of the spermatozoa is formed from the distal centriole of the spermatid.
4. Mitochondrial ring is formed from the mitochondria around the distal centrioles and is called.
5. Much of the cytoplasm of the spermatid is lost and the remaining cytoplasm forms a sheath around the mitochondrial spiral. This is known as manchette.

- During the process of differentiation, the developing sperms have their head embedded in the sertoli cells which are thought to provide nutrition for the developing sperms because their cytoplasm contains large stores of glycogen which diminish as spermatid mature.

  [NB: There is no direct evidence for this nutritional function of the sertoli cells, but some sperms of male sterility are associated with the failure to product normal sertoli cells]



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Cellular events in human spermatogenesis

Sertoli cells support the developing gametes in the following ways:-

1. Maintain the environment necessary for development and maturation via the blood test is barriers.
2. Secretes substances initiating meiosis.
3. Secretes supporting testicular fluid.
4. Secrete the androgen – binding protein which concentrates high quantities of testosterone in close proximity to the developing gametes.

Testosterone is produced by intestinal cells (leydig cells) which reside adjacent to the seminiferous tubules.

1. Secrete hormones affecting pituitary gland control of spermatogenesis, particularly the polypeptide hormone, inhibin.
2. Phagocytise residual left over from spermiogenesis.

3. Release anti – mullerian hormone (AMH) which prevents formation of the mullerian duct/oviduct.

NB: Seminiferous epithelium in sensitive to elevated temperature in humans and will be adversely affected by temperature as high as normal body temperature.

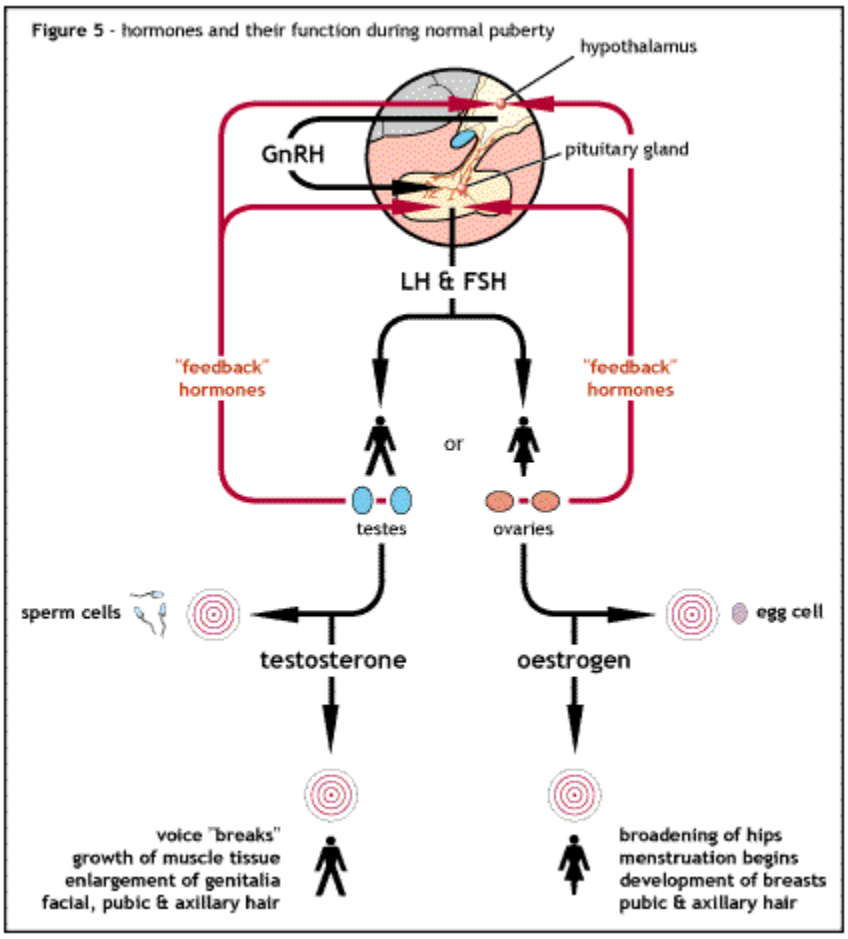
Consequently, the testes are located outside the body in a sack of skin called the scrotum. The optimal temperature is maintained at 2^0C (man) -8^0 C below body temperature.

This is achieved by regulation of blood flow and positioning towards and away from the heat of the body by the cremasteric muscle and dartos smooth muscles in the scrotum.

- Dietary deficiency (such as vitamins B, E and A), anabolic steroids, metals (calcium and lead) X – ray exposure, dioxin, alcohol and infectious diseases will also adversely affect the rate of spermatogenesis.

- The hormonal control of spermatogenesis varies among species. In humans, the mechanisms are not known completely, however, it is known that initiation of the spermatogenesis occurs at puberty due to the interaction of the hypothalamus pituitary gland and leydig cells.

- The hormones that are closely related to spermatogenesis are the lutenizing hormone, the follicle stimulating hormone (FSH) and testosterone (T).
- LH controls spermatogenesis via the secretion of testosterone by leydig cells (3, 4, 5). Testosterone mainly acts onto sertoli cells by increasing their responsiveness to FSH and simultaneously inhibits the secretion of LH by the mechanism of feed back upon the hypothalamus and the pituitary.
- FSH controls the maturation of the spermatic epithelium by acting directly on the sertoli cells.
- Finally the protein which binds to the androgens (ABP) is produced by the sertoli cells.



Hormonal interaction in the hypothalamus pituitary

- FSH is necessary to develop the ABP production by the sertoli cells and to develop the blood testis barrier and other functions of these cells.

  Once the sertoli function is developed, testosterone alone will maintain spermatogenesis. The yield of spermatozoa is increased if FSH is present.

- The FSH is known to increase the yield of spermatogonia by preventing atresia of differentiating spermatogonia.

Normally 50% of spermatogonia can also be reduced by increased sexual activity.

FSH levels in males are environmentally influenced, increased by sexual activity and decreased by inhibin.

- Androgens are transported from the site of production (leydig cells) to influence the developing germ cells.

- ABP produced by the sertoli cells and shed into the adluminal compartment, assists in the role as well as transporting large amount of androgens to epididymis.

First stimulates ABP synthesis under the action of androgen influence.

Testosterone induces and maintains spermatogenesis acting through the sertoli cells or through spermatogenetic cells.

- The testis also secretes some other hormones that participate in the regulation of spermatogenesis, but their cells are not closely understood. These include:-

i) Estradiol formerly known as female sex hormone. These estradiol receptors are widely distributed in testicular cells, suggesting a role of oestrogens in the regulation of testicular function.

The receptors are localized in the nuclei of spermatogonia, spermatocytes and early developing spermatids of adult men.

ii) Inhibin – (Inh – b), this is produced by the sertoli cells and controls the secretion of FSH from the pituitary and consequently the spermatogenesis, via a negative feedback mechanism. Low blood concentration of inh – b of ten reflect in a disorder of spermatogenesis.

iii) Antimullerian hormone

Exclusively secreted by the sertoli cells and represents a prelocious hormonal index of their function.

Its production is influenced by transcriptional factors testosterone, FSH and spermatocytes at prophase I. It prevents formation of mullerian duct.

SUMMARY:

Mechanism of hormonal control of spermatogenesis:

- The hypothalamus secretes gonadotrophin releasing hormone (GnRH) which travels in a small vein from the hypothalamus to the pituitary gland.
- GnRH stimulates in turn the anterior pituitary gland to secrete two hormones know as gonadotrophins. (A gonadotrophin is a hormone that stimulates a gonad, in this case the testis). These gonadotrophins are follicle stimulating hormone (FSH) and lutenizing hormone (LH). Also secreted in female they are glycoproteins.
- FSH acts by stimulating spermatogenesis by stimulating the sertoli cells to complete the development of spermatozoa from spermatids.
- LH stimulates the synthesis of the hormone testosterone by the leydig cells (interstitial cells) of the testis. It is therefore known interstitial cells stimulating hormone (ICSH) in the male

- Testosterone stimulates growth and development of the germinal epithelial cells (spermatogonia) to form sperms and also work with the FSH to stimulate the sertoli cells.

The negative feedback mechanism operates where by an increase in the level of testosterone results in a decrease in secretion of GnRH from the hypothalamus, this in turn results in declining levels of LH and FSH.

The testosterone also acts directly on the anterior pituitary gland to reduce LH secretion but this effect is weaker.

When the rate of spermatogenesis in high, inhibin (a glycoprotein hormone) is released, it acts on the anterior pituitary gland to reduce the secretion of FSH by negative feedback mechanism.

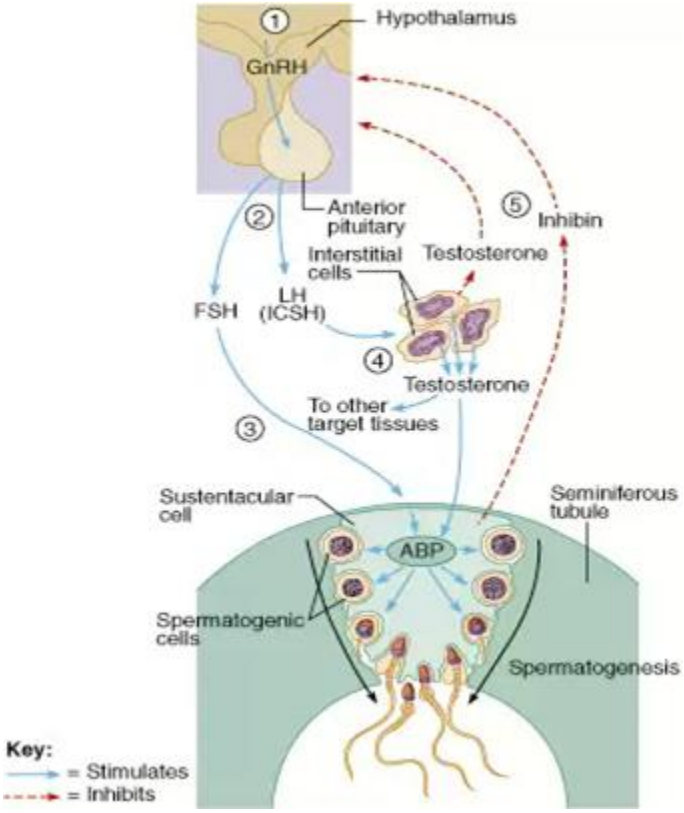
It also has a slight effect in the hypothalamus reducing GnRH secretion. When the rate of spermatogenesis low, inhibin is not secreted and FSH stimulates spermatogenesis.

THE ROLE OF CYCLIC AMP

Both FSH and LH acts by causing the release of cyclic AMP (Adenosine monophosphate) within the cells they stimulate.

Cyclic AMP is the second messenger system. It is released into the cytoplasm and then passes to the nucleus where it stimulates the synthesis of enzymes. In the case of LH, for example enzymes are

involved in the synthesis of testosterone from cholesterol.



STRUCTURE OF MATURE HUMAN SPERMATOZOANS

Structurally, a spermatozoan is divided into three pieces:-

I) Head piece

- This consists of a nucleus and small portion of cytoplasm.
- At the tip of the head, there is a special structure called acrosome. Acrosome is a collection of lysosomes; it thus contains very powerful hydrolytic enzymes known as proteases and hyaluronidases.

II) Middle piece

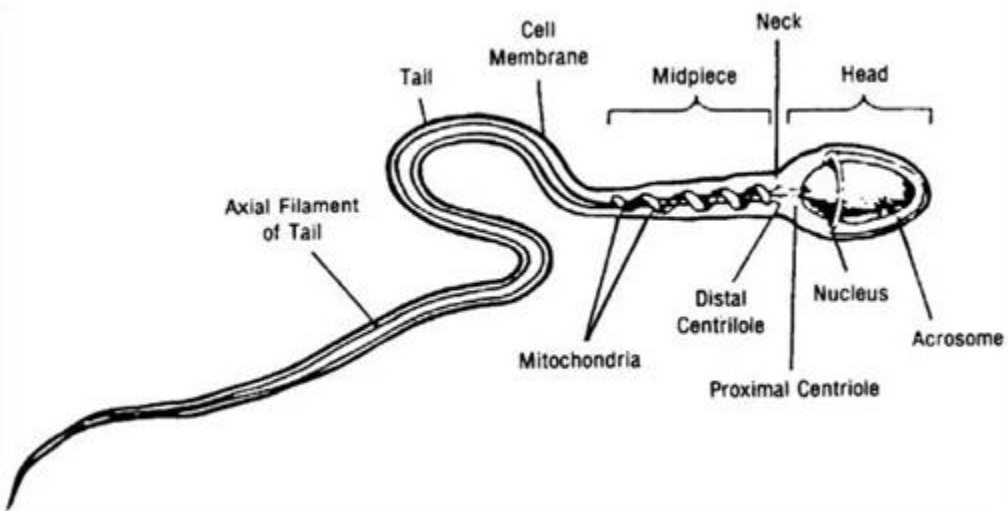
This is largely consisting of mitochondria. These provide energy for propelling the spermatozoans towards the egg cell. The head and middle peace together constitute the principal peace.

III) The tail piece

- It consists of the flagellum made of axial fillaments that continue from middle peace. The flagellum serves in:-

- Propelling the spermatozoans towards the egg cell.

- Orienting the spermatozoans so that it properly binds itself into the egg cell.
- At the end of the flagellum is a hair like extension called the end piece.



Structure of mature human sperm

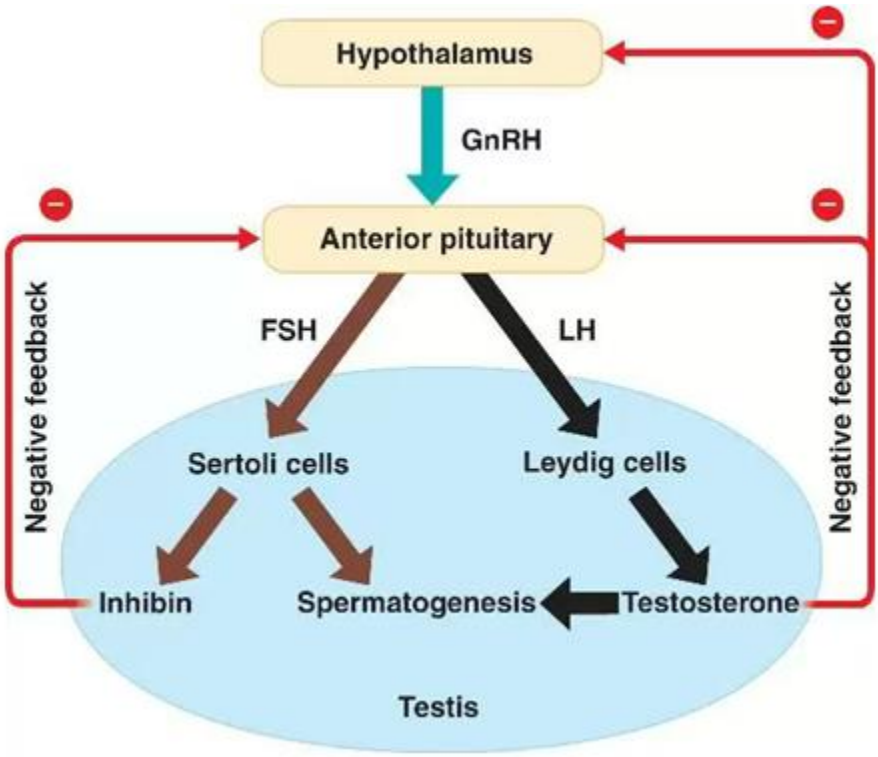
ROLE OF SPERMATOZOAN.

- The role is to carry the paternal gamete materials into the egg cell so that after fertilization, the genetic makeup of the zygote is the mixture of the two maternal and paternal gamete materials.

HORMONAL CONTROL OF SPERM PRODUCTION

1. When the level of testosterone is low, the hypothalamus secretes a releasing hormone (called gonadotrophin releasing hormone or GnRH) in the blood.
2. This peptide hormone flows in the blood directly to the pituitary a pre-sized organ hanging from the base of the brain where it stimulates the two peptide hormone, lutenising hormone (LH) and follicle stimulating hormone (FSH).
3. These hormones (called gonadotrophins, since they stimulate gonalds) then move through blood stream and activate cells in the testis. LH triggers the intestinal cells to produce and secrete testosterone.
4. FSH cause supporting cells (sertoli cells) to enhance formation of sperms.
5. Soon the sperm count rise. Mean while, testosterone circulate in the blood stream at higher levels and the interconnected loop feeds back on itself. High testosterone levels signal the hypothalamus to produce less releasing hormone.
6. This inturn suppress the release of LH and FSH and without them less testosterone and fewer sperms are manufactured. In addition testosterone causes supporting cells in the testes to release the peptide hormone inhibin, which helps to inhibit FSH production.

When testosterone level drops too low again the hypothalamus is once more activated and the whole cycle starts again.



ADAPTATIONS OF THE SPERMATOZOANS.

The adaptations of the spermatozoans to its function include the following:-

1. It has an acrosome that contains enzymes for digesting the egg cell membrane.
2. It has numerous mitochondria that produce energy necessary for propelling the spermatozoans towards the egg cell.
3. It has flagellum for propelling the spermatozoans for proper binding on the egg cells.
4. Ability to sense the chemical attractants secreted egg cell so that its movement is directed toward source of chemicals.
5. Ability to recognize and hence bind itself into the receptor sites on the surface of egg cells.
6. Light nuclei and head piece following their changes, this enables it to move faster towards the egg cell.

OOGENESIS

- Oogenesis begins soon after fertilization as primordial germ cell travel from the york sac to the gonalds, where they to proliferate mitotically.
- The gem cells multiply from only a few thousands to almost 7 million.

- They become oocytes once they enter the stages of meiosis several months after birth, now called primordial germ cells surrounded by fellicle cells from the somatic line. The oocytes are then arrested in the first meiotic phase until puberty.
- At puberty between 4 to 10 follicles begin to develop although only 1 – 2 are actually released.
- Surrounding each oocyote is a zona pellucida membrane granule and the cell layer.
- Each oocyte finishes its first meiotic division creating a secondary oocyte and polar body which serves no further functions.
- It begins the next meiotic cycle and is arrested in its second metaphase, at which point it is released from the ovary in ovulation.
- It will not finish the meiosis cycle until it encounters the stimuli of a sperm.

SUMMARY:

Oogenesis

At birth.

1. Diploid cells in the ovary divide by mitosis from oogonia.
2. Oogonia undergo meiosis I division to form primary oocyte steps at prophase I.
3. These remain in the follicles.

At puberty.

1. Primary oocyte completes the 1st complete meiotic division to form polar bodies and secondary oocyte.
2. Secondary oocytes undergo 2nd meiotic division and steps at metaphase II.
3. Secondary oocyte is shed from ovary, if fertilized it complete its 2nd meiotic division to form ovum and polar bodies.

- Formation of the ovum involves substantial increase in cell volume as well as the acquisition of organelles that adapt the egg for reception of the sperm nucleus and support of the early embryo.
- In the fetal ovary of mammals the oogonia undergoes meiotic divisions until the birth of the foetus, but the process involves the destruction of the majority of the developing ova by the seventh month of gestation reduces the number of oocytes from millions to a few hundred around the time of birth, the mitotic divisions ceases altogether and the fast female contains its full complement of potential ova.

Weak of gestation	Stages	No of germ cells
¾	Primordial cells in the endoderm of the yolk sac.	
5 - 6	Premeiotic cells oogonia.	10,000

8	Propagation by mitosis.	500,000
8 -20	Mitosis, meiosis atresia maximum at week 20.	6 – 700,000
20 -40	Reduction of oocyte, 80% of germ cells are lost.	1-2,000,000
Birth to puberty	Further oocytes are lost by atresia.	

- Unlike the formation of sperm in which the two divisions of meiosis produce four equivalent daughter cells, the cytoplasm of the oocyte is divided unequally so that three polar bodies with reduced

  cytoplasm and one oocyte are final products.

- Egg cytoplasm contains large stores of ribonucleic acid RNA in the form of ribosomal messenger and transfer RNA. These RNA's direct the synthesis of proteins in the early embryo and have decisive

  influence on the course of development.

DEVELOPMENT OF GERM CELLS IN THE OVARY

Following the immigration of the primordial germ cells into the gonadal ridge, they proliferate are enveloped by coelomic epithelial cells and form germinal cords that though keep their connection with the

coelom epithelium.

In the genital primodium, the following processes take place;

- A wave of proliferation begins that lasts from 15th weak to the 7th month.

Primary germ cells arise in the cortical zone via mitosis of oogonia dones, bound together in cellular bridges that happen in rapid succession.

The cell bridges are necessary for a synchronous onset of the subsequent meiosis.

- With the onset of meiosis earliest in the prophase in the 12th week the designation of the germ cells change. They are now called primary oocyte.

- The primary oocyte become arrested in the diplotene stage of prophase I the prophase of the 1st meiotic division.
- Shortly before birth, all the total oocytes in female ovary have attained this stage.

The meiotic resting phase that then begins is called the dictyotene and it lasts till puberty during which each month and each month thereafter until menopause a pair of primary oocyte complete the first meiosis.

- Only few oocytes, secondary oocyte plus one polar body though reach the 2nd meiosis and the subsequent ovulation. The remaining oocytes that mature each month become atretic.
- The primary oocytes that remain in the ovaries stay in the dictyotene stages up to menopause. In extreme cases without ever maturing during the menstrual cycle.
- From birth, there are thus two different structures to be distinguished that at least conceptually do not develop further synchronously.

1. Female germ called primary oocyte and which can develop further only during and after puberty hormonal cycle is necessary.
2. Follicular epithelium, that can develop further from the primordial follicle via several follicle stages while oocytes remain in their primary states.

- The developmental sequence of the female germ cell is as follows:-

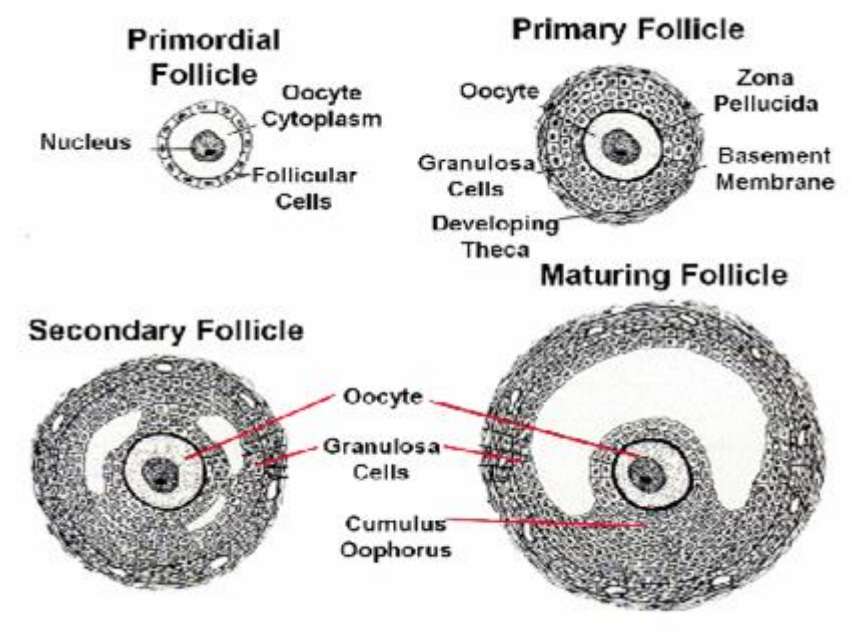
Primordial germ cell → ooginium → primary oocyte
Primary oocyte in the dictyotene.

The continous of the development/maturation of the oocyte begins again only a few days before ovulation.

- The developmental sequence of a follicle goes through various follicle stages.

Primordial follicle → primary follicle → secondary follicle → tertiary follicle

- Since the follicle can die at any moment in this development (atresia) not all reach the tertiary follicle stage.



PRIMARY OOCYTE

- In the first week of the cycle the maturation of the oocyte in its associated follicle depends on the progress of maturation of the surrounding follicle cell.
- The fittest follicle with its oocyte becomes the dominant follicle in the second cycle week and later the graafian follicle.
- Up to just days before ovulation, the maturation of the oocyte consists in its ingestion of substances growth of the yolk, they are supplied by the granulose cells. This exchange of substances is mediated through cytoplast processes of the granulose cells that are anchored through zona pellucida at the ocoyte substance.
- The oocyte nucleus is also matured in the last days before the LH peak.

Up to this point it was arrested in the extremely elongated prophase (a dictyotene) of the first meiotic division, the corrested condition that has existed since the foetal period.

- Through the maturation the nucleus stages in the darkness of the prophase and prepares itself for the completion of the first meiosis which is triggered by the LH peak.

With the LH peak, the following maturation steps are now triggered in and around the oocyte up to ovulation.

In the oocyte:

- Termination of the first meiosis with ejection of the first polar body.
- Begin of the 2nd meiosis with arrest in the metaphase.
- Maturation of the oocyte cytoplasm by preparing molecules and structures that will be needed at the time of fertilization.

In the follicle:

- The granulosa cells that sit just outside on the zona pellucida withdraw their processes from oocyte surface back into the pellucida zona. These processes were in charge of transferring substances to

  the oocyte.

- The periritelline space forms between the oocyte and the pellucida zona. This space is necessary for allowing division of the oocyte and for harbouring the first polar body formed in the division.
- Loosening of the granulosa cells in the vicinity of the cumulus oophorus and proliferation of the granulosa cells.
- Increasing the progesterone concentration in the follicle fluid via increased production in the granulosa cells.

Termination of the first meiosis

- The spindle apparatus for dividing the chromosomes has formed and oriented itself radically in the cellular surface.
- The first polar body will arise at the spot where the spindle apparatus is anchored on the cellular surface.

The process of the granulosa cells have refracted from the oocyte surface into the pellucida zona and this leads to the formation of the pervitelline space, in this space the ejection of the 1st polar body takes place as a sign that the 1st meiosis has ended.

- With the end of the first meiosis the name of the changes from primary oocyte to secondary oocyte.

The secondary oocyte

- Through the effect of LH on the granulosa cells, these have begun to loose their cellular bends and to multiply.
- They produce progesterone that is released into the fellicle fluid.
- Though the separation of the homologous chromosomes in the first meiosis a haploid (reduplicate) set of chromosomes is now to be found in the secondary oocyte.

The role of progesterone in the follicle fluid

Progesterone has the following two main tasks in the follicle fluid:-

- It stimulates the further maturation of the oocyte.
- During ovulation, it enters the fallopian tubes and guides the formation of a concentration gradient for attracting the sperm cells.

The follicle that is about to rapture:-

- Besides the hormones the granulosa cells also secrete an extra – cellular matrix, mainly hyaluronic acid, into the follicle fluid.

The cumulus cell bonds loosen further in this way together with the enclosed oocyte they free themselves from where they were attached to the follicular wall and in the follicle.

The wreath of granulosa cells that enclose the oocyte is called the corona radiate.

- The oocyte has now ended all the steps of maturation that were set into motion by the LH peak.
- The molecular and structural preparations for the time following the penetration by the sperm cell have now been made in the cytoplasm.
- A spindle apparatus (2^{nd} meiosis) has again been able to form with the chromosome in the equational level (metaphase plate)
- The spindle is once more anchored radially to the cell membrane near the polar body.

The same processes of the spindle formation also take place in the polar body.

NB: The second meiosis is arrested in this position.

- Final steps of the maturation namely the freezing for the second meiosis are first completed by the second oocyte when the spermatozoa have penetrated the oocyte.
- The follicle and the oocyte are now ready for ovulation that takes place roughly 38 hrs after the LH peak.

ADAPTATION OF THE EGG CELL

1. Has microvilli for nutrient absorption from follicular cells.

Follicular cells are the cells that usually surround the ovum when more layers are formed they tend to push away the follicular cells.

NB: The follicular cells are not part of the egg cell.

1. It has stored food for zygote and embryo utilization (i.e. the yolk sac).

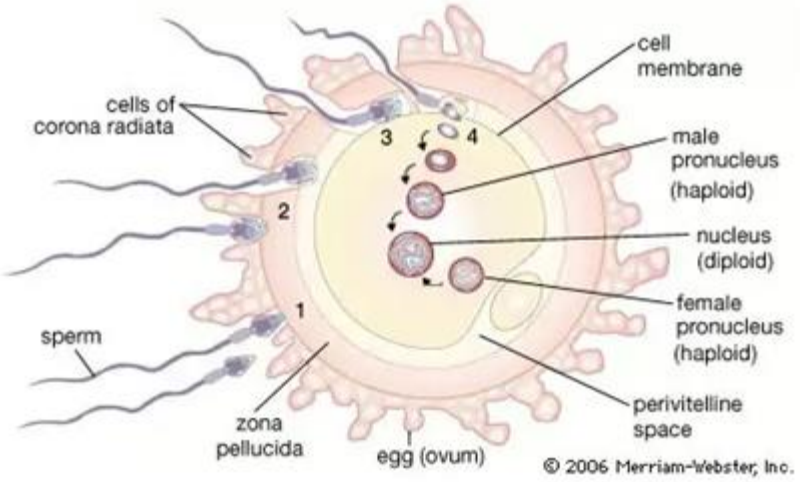


Fig: The egg cell

Fig: The egg cell

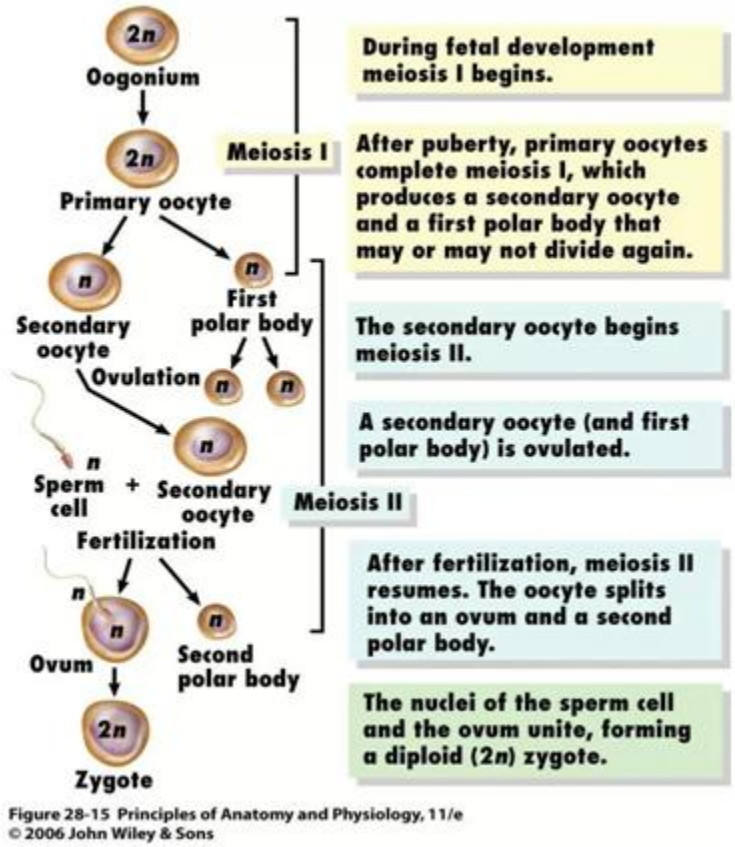


Figure 28-15 Principles of Anatomy and Physiology, 11/e
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Fig: The stage of oogenesis

1. Has cortical granules (Act as vesicles) that act to prevent polyspermy during fertilization.

This is done through two ways:-

- The process occurs very quickly and uses the same mechanism as in a chemical transmission of impulses. It occurs soon after the entry of a sperm cortical, are found in the cytoplasm.

They fuse with the membrane to release chemicals which haidens the membrane forming the fertilization membrane that prevents the entry of sperms.

- Destruction of the sperm receptor sites. The sperms have sensors and ova have receptors- sperms move towards the ovum (like magnetic substance) chemotactically. The sperms receptor sites found

  on the ovum are destroyed immediately after the entry of a sperm. This is done by the cortical granules.

  2.Have receptor sites for spermatozoa to bind during fertilization.

  3.Produce chemicals that attract sperms.

DIFFERENCES

	SPERMATOZOA	**EGG CELL**
	Small in size.	Larger than a sperm.
	Has a large nucleus.	Has a smaller nucleus.
	Has a very small amount of cytoplasm.	Has a very large amount of a cytoplasm.
	No food reserves (does not store food).	Stores large amount of food.
	Has acrosome.	Has no acrosome.
	No cortical granules.	Has cortical granules.
	Has head, middle piece principal and end piece.	No such division.
	No microvilli.	Has microvilli.
	Single layered.	Multi layered.

	It has flagellated and motile.	It lacks flagellum and non motile.
	It has numerous mitochondria.	Has few mitochondria.

DIFFERENCE BETWEEN OOGENESIS AND SPERMATOGENESIS

	SPERMATOGENESIS	OOGENESIS
	Differentiation follow offer its meiotic division they are farmed only until the end of meiosis.	- Egg grows primarily in extend period of prophase i.e. prophase that is secondary oocyte is already matured.
	It occurs in male gonads i.e. testis.	- It occurs in female gonad i.e. ovaries.
	Four sperms are produced from one spermatogonium.	- Only one ovum is produced from one oogonium.
	The spermatocyte sperm mother cell divides by meiotic division into four equal sized cells and all the four cells are transformed into spermatozoa to act as reproductive unit.	-The oocyte divides unequally and produces a large sized ovum and three small sized bodies or polocytes which are sexually inert only ovum acts as reproductive unit.
	Spermatozoa are produced in large number.	-Ova are produced in large number.
	Spermatozoa are minute yolkless and motile.	- Ova are much large, often with yolk and non-motile.
	Continous production process although from puberty to old age sperm cells are being endangered, the production is subject to extreme fluctuations regalding both quality and quantity.	- Using up the oocyte generated before birth, continual decrease of the oocyte, beginning with the foetal period-exhaustion of supply at menopause.
	During foetal period no meiotic division, no germ cell production.	- During focal period, entering meiosis (arrested in dictyotene stage), there is a production of entire supply of germ cells.

FERTILIZATION

Is the process whereby the nucleus of the male gamete fuses with that of the female gamete to form diploid zygote nucleus.

- This process occurs high up in the fallopian tube. Before fertilization the spermatozoa has to undergo capacitation.

CAPACITATION

Is the mechanism by which the spermatozoa undergo activation before fertilizing the ovum. It takes about 7 hours and involves the following processes.

1. Removal of a layer of glycoproteins and plasma proteins from the outer layer/surface of spermatozoa; glycoprotein are added by the epididymis while the plasma proteins are from the semen. These are removed by the enzymes in the uterus.

   Removal of cholesterol which toughens the sperm membrane and prevents premature release of acrosomal enzymes from the sperm head membrane by the enzyme in the uterus.

   The advantage of capacitation is that it prevents the wastage of sperms. The membrane becomes more permeable to Ca^{2+} ions.

   The calcium ions (ca^{2+}) **have two factions:-**

- Increase/enable the beating of the sperm flagellum.
- Promote acrosomal reaction.

MECHANISM OF FERTILIZATION

Fertilization comprises of two types of chemical reactions:-

1. Acrosomal reactions.
2. Cortical reactions.

STEPS:

1. The sperm migrates through the coat of follicle cells and binds to a receptor molecule in the zona pellucida of the egg.
2. The binding includes the acrosomal reactions in which the sperm releases digestive enzymes into the zona pellucida. These enzymes are proteases (acrasome) and hyalurionidase. The latter digests the hyaluronic acid which binds granulosa cells together.
3. With the help of this hydrolytic enzyme, the sperm reaches the egg and the membrane protein of the sperm binds to the receptor on the egg membrane.

   This induces the influx of Ca^{+} ions that depolarize the egg membrane. This is the first block of polyspermy.

4. The plasma membrane fuses making it possible for sperm nucleus to enter the egg.
5. The sperm egg cell fusion causes Ca^{2+} influx.

This inturn triggers a cortical reaction in which secretions beneath zona pellucida. These secretions swell up with water, push any remaining sperms away from the egg and creating impermeable fertilization membrane. Then the enzymes harden the zona pellucida. This functions as the flow block to polyspermy.

6. The nucleus of the secondary oocyte is triggered to undergo meiosis II which produces an octid is transformed into an ovum. The nucleus of the ovum and that of spermatozoa bulge becoming pronida which later fuse in the actual act of fertilization forming zygote.

NB: If not fertilized, the secondary oocyte dies off ovulation and never finishes meiosis.

POST – FERTILIZATION CHANGES IN THE EGG

After fertilization, the following changes occur in the egg.

1. The zygote becomes ready for the cleavage and for the formation of the embryo.
2. The oxygen consumption of the zygote increases enormously.
3. The metabolic rate of the zygote increases greatly for instance the amount of amino acids and the permeability of the plasmalema of the egg increases the volume of the egg decrease the exchange of phosphate and sodium ions between the zygote and the surrounding media, diffusion of the calcium ions from the egg started and the hydrolysing activities of the
4. Protein synthesis in started.

SIGNIFICANCE OF FERTILIZATION

1. The fertilization ensures the usual specific diploid of the organisms by the fusion of the male and female pronuclei.
2. The fertilization establishes definite polarity in the eggs. This fertilization provides new genetic constitution to the zygote.
3. The fertilization activates the egg for the cleavage.
4. Fertilization provides a new genetic constitution to the zygote.
5. Fertilization combines characters or two parents thus introducing variations and making the resulting individual better equipped for the struggle for existence. This happens only in cross fertilization.
6. The fertilization also increases the metabolic activities and the rate of protein synthesis of the cell.

THE CONCEPT OF STERILITY

STERILITY:

Is the failure of the matured mammal to fertilize or to be fertilized.

CAUSES OF INFERTILITY

FEMALE INFERTILITY STERILITY/INFERTILITY	**MALE**
i) Failure to ovulate due to hormonal causes.	- Absence of sperm due to blockage of tubes between the testes and seminal vesicles.
ii)Uterus damage, pregnancy cannot be maintained (occurrence of miscarriage).	- Low sperm count.
iii)Damage to the oviduct due to tubal diseases hence oviduct is blocked.	- Production of abnormal sperm.
iv) Cervix damage due to abortion or difficult birth hence inability to produce cervical mucus for sperm to reach the egg.	- Autoimmunity: Antibodies are made by the male body which attract the sperm reducing sperm count.
v)Antibodies to sperm.	- Impotence.

IMPOTENCE:

Is the failure of penis to erect, this can be temporary i.e. reversible impotence caused by such factors as;-

1. Depression due to social, economic and ethnic reasons.
2. Fear due to inferiority complexity, disease contraction, hesitating to commit sin.

Also impotence can be permanent irreversible due to genetic disorder, diseases, hormonal problems etc.

Copulation – (i.e. seduction, romance and the subsequent intercourse) ensures the transfer of sperms from the male reproductive organs to female reproductive organs for fertilization.

DEVELOPMENT OF THE ZYGOTE AND EMBRYO

This includes 5 stages:
1)Cleavage
2)Blastulation
3)Gastrulating
4)Neurilation
5)Organogenesis

CLEAVAGE

- Two hours after fertilization the zygote divides mitotically to form two cells.
- The process by which the zygote divides is called cleavage and the resulting cells are called blastomeres.
- After 6 hours the zygote cleaves for the second time forming four blastomeres.
- Initially the process is regular but with time it becomes irregular in where it produces a ball of cells called MORULA.
- Cleavage does not lead to increase in size of the morula because cells still in the zona pellucida.
- The process takes place 72 hours.

Cleavage increases surface area to volume ratio of each cell which enhances:-

- Rapid nutrient uptake i.e. food and oxygen.
- Waste removal.

- Cleavage also forms many cells which will form different types of embryonic tissues.

BLASTULATION

Is the process whereby morula is transformed into a blastula or blastula or blastocyst.

- While cleavage is taking place the zygote is in the oviduct moving slowly by the beating action of the cilia in the oviduct (tubules). When it reaches in the uterus the hard zona pellucida gets peeled off by the enzymes in the uterus and leaves an outer layer of cells called trophoblast.

The cells in the centre of the morula migrate and accumulate at one end where they form an inner cell mass; the result of this cellular migration is the formation of the fluid filled cavity called bastocoel.

IMPLANTATION

Is the process whereby the blastocyst embades into the uterine wall.

- As soon as the trophoblast is in contact with the uterine wall it starts secreting enzymes that eat through the endometrium wall thereby pouring a way for blastocyst to embed.

Trophoblast develop finger like processes called trophoblast villi (chorion villi) which are for the absorption of nutrients from the uterine wall. The trophoblast is also endocrine in function as it secretes a human chorionic gonadotrophs hormone (HCG).

The function of the HCG is like that of LH.

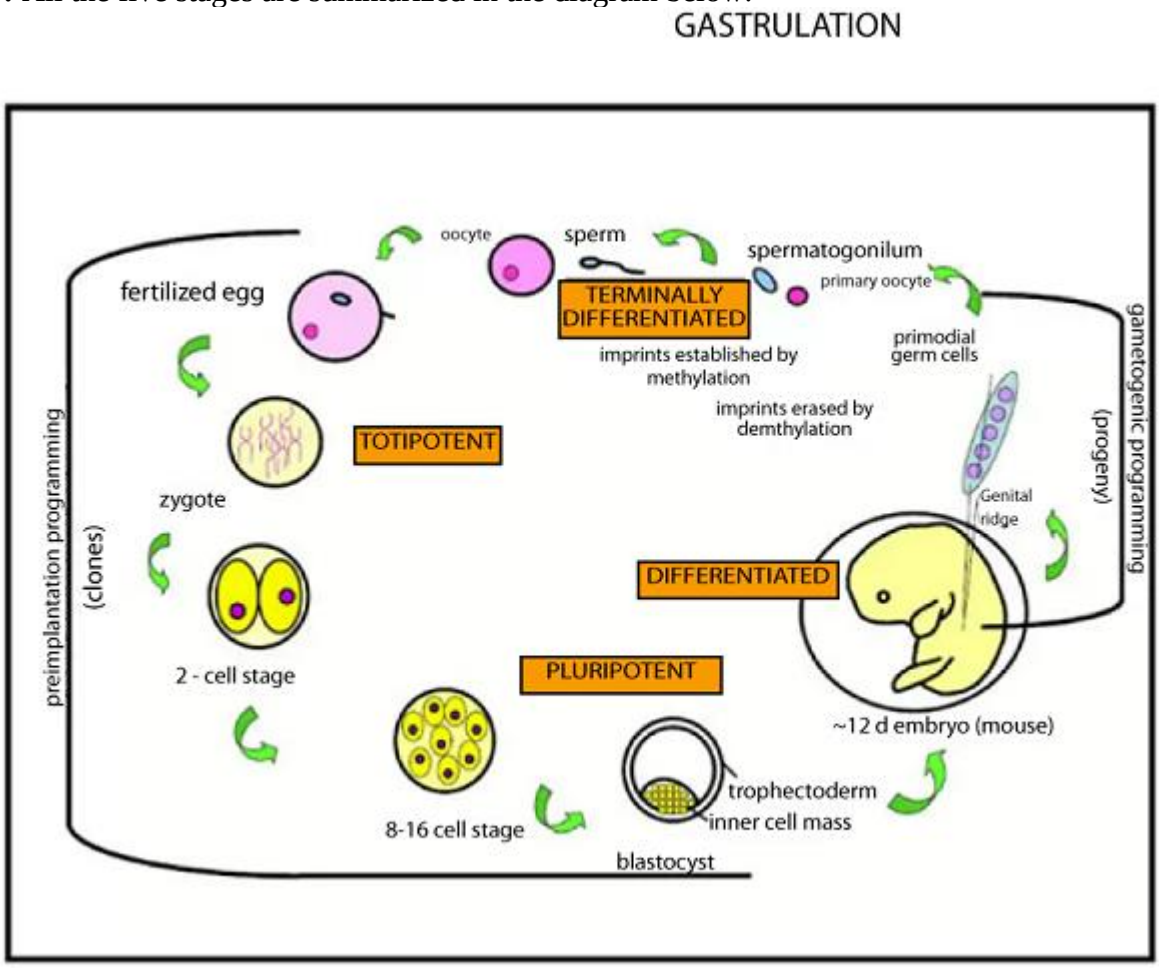
- To maintain the corpus luteum secretion of oestrogen and progesterone also done.
- Inhibit menstruation to pregnant woman.
- Forms the basis of the pregnancy test (urine – pregnancy test UPT) dip the litmus paper into the urine if you see two red marks; the person is pregnant; if only one colour is seen then the person is not pregnant.
- The process of penetrating in the uterine wall continues until finally the blastocyst becomes completely embeded in the glands and blood vessels of the uterus. This is the actual act of implantation.

GASTRULATION

This is transformation of blastula into germ layer called gastrula.

- It s a stage at which the embryo develops germ layer.
- During gastrulation, the cells on one side of the embryo inviginates forming a small pore called blastopore.
- The process ends when germ layers are ready formed.

NB: All the five stages are summarized in the diagram below:-



Through this pore, blastopore about half of the cell from outside move to the inside and at this point, the embryo is said to turn on itself.

The result of this cellular migration is the development of two germ layers, the outer (ectoderm) and the inner (endoderm).

The blastocoel becomes an archenteron the future digestive tract. The blastopore is the future anus.

Finally the third layers the mesoderm form between the ectoderm and endoderm forming a three layered embryo.

- Gastrulation is important in placenta development because cell's location in a particular layer determines its fate e.g.

  Ectoderm - Develops nervous system, sense organs, epidermis the skin, hair nails and skin glands, neural egest.

Mesoderm – Develops into bones blood, muscles, dermis of the skin and reproduction system.

Endoderm – Develops digestive and respiratory system and many glands.

EXTRA EMBRYONIC MEMBRANES AND THEIR ROLES

After implantation the embryo develops four membranes. They are called extra embryonic membranes because they are found outside the embryo and these include:-

i) Chorion
ii) Amnion.
iii) Allantos.
iv) York sac.

I. CHORION

This is the outer most membrane which is derived from the trophoblastic cells.

It has villi that forms the part of the placenta, therefore the roles of chorion are;-

1. To form parts of the placenta.
2. To absorb nutrients from the mother to the foetus means of villi.
3. Since it is an outer member, it then protects the foetus.

II. AMNION

This is the innermost membrane which lines the cavity surrounding the embryo.

This cavity (amniotic cavity) is filled with the amniotic fluid secreted by the amniotic cells.

The amniotic fluid acts as shock absorber cushioning the embryo against mechanical and physical shock.

III. ALLANTOIS

This is a sack like outgrowth which develops from embryonic gut; it fuses with the chorion at the point called allantois-chorion where the placenta develops.

As the embryo continues to grow the allantois develops into umbilical cord the tube which carries blood vessels (embryonic) to end from the chorionic villi.

IV. YOLK SAC

This has got no obvious function in humans and other mammal it becomes buried in placenta.

In reptiles and birds the yolk sac is important as it absorbs food from the yolk and transfers it to the midgut of the developing embryo.

PLACENTA

- A placenta begins when extension of chorionic villi penetrates more and more deeply into the endometrium like the roots of a tree in the 'soil' uterus.
- As they digest their way through the uterine blood vessels the villi become surrounded by pools of free blood the latter forms placental sinuses.
- A placenta is a linking structure between the foetus and the mother. It is the structure that partly develops from the mother and parity develops from the embryo. It thus has the foetal and maternal side.
- At the placenta, the materials are exchanged between the foetus and the mother. However, their vascular systems are not in physical contact. The exchange of materials is therefore by simple diffusion.

Why are the material and foetal blood not allowed to mix?

Maternal blood is under relatively higher pressure compared to foetal blood; this could damage the delicate tissues of the developing foetus

If the two bloods were to mix, the foetal blood could be recognised as a foreign by maternal blood. The maternal blood immune system could respond by killing the foetus.

This is because half of the genetic materials come from the father and so the foetal cells are not identical to those of the mother.

i) Progesterone.

ii) Oestrogen.

iii) Human chorionic gonadotrophic hormone.

ROLES OF PLACENTA

1. It allows the exchange of materials between the foetus and the mother without mixing up the two blood.
2. It is a means of passage of oxygen, water, acids, glucose (i.e. nutrients) to the foetus (acts as intestine).
3. Means of passage of carbondioxide, urea and other wastes from the foetus to the mother so as to allow the excretion by the mother and prevent harmful substances to accumulate in the foetus i.e. acts as lungs and kidneys.
4. Allows certain antibodies to pass into the foetus providing it with some immunity against diseases. This is called Natural passive immunity.

5. It protects the foetus by preventing certain pathogens and their toxins from crossing the placenta. Though, some manage to cross. Eg. Treponema pallidum (for syphilis) and HIV.
6. It prevents hormones and some chemical substances like alcohol to pass through the foetus.

Qn:

Placenta serves as a link between foetus and mother. At the same time it acts as a barrier between them. By reference to the functions of placenta explain what those statements mean.

Placenta as a link	**Placenta as a barrier**
• O_2, H_2O, food, salt from the mother to the foetus.	• Prevent blood mixing. • CO_2 and other nitrogenous wastes from foetus to mother. • Prevent high maternal blood affecting foetus directly.
• Partly antibodies from the mother to the foetus. • Filter out some hormones • Partly filter out some pathogens.	

TWINS PUZZLE AND MULTIPLE BIRTH

MULTIPLE BIRTH AND THEIR CAUSES:

Multiple birth are cases in which more than one baby are born from the same mother and they result from the same pregnancy.

- In mammals like cats, rabbits, dogs and pigs multiple birth are common cases as the ovulation several oocytes are released each of them is fertilized by separate spermatozoan.

  Humans are commonly giving birth to only one young individual.

Multiple birth occurs due to;

1. More than one secondary oocyte being released at ovulation and then fertilized by spermatozoa.

2. One ovum being fertilized by spermatozoan and zygote cleave into 2,3 ...etc blastomeres each of which develops into an embryo after separation.

TWINS

Defn: Are two or more babies born from the same mother as a result of the same pregnancy.

TYPES OF TWINS:

1. **Identical twins**

- Result from the same zygote/one zygote hence called monozygotic twins. For the development of identical twins to occur the zygote cleaves into two or more blastomeres.

These separate from one another and upon implantation each one of them develops into an embryo.

- In rare cases, separation of the blastomere fails at some points. Thus leads to twins remaining linked, such twins are referred to as SIAMESE TWINS.
- The identical twins share the same placenta and they are in the same chorion and amnion.
- Since they develop from the same zygote such twins are of the same genetic constitution and of the same sex.

2. Flatenal/Non identical twins

- They develop from two different zygotes hence they are called dyzyotic twins.
- In this case two different ova from different ovaries are fertilized by two different spermatozoa forming two different zygotes, which implant in the uterus.
- Each of these twins develops in its own placenta and its own embryonic membranes since they develop from different zygotes. Then the zygotes are genetically different and not necessary of the same sex.

DIFFERENCES

IDENTICAL TWINS		**NON- IDENTICAL TWINS**
	They result from one zygote.	Results from two different zygotes.
	Share the same placenta.	Each has its own placenta.
	Enclosed in the same membrane.	Each has its own membrane.

	They are of the same genetic makeup.	Genetically different.
	They are of the same sex.	They may be of different sexes and can be a girl/boy.

BIRTH(PARTUIRITION)

Birth is a process whereby the fully developed features expelled out of the mother's womb after the GESTATION period is complete.

THE PROCESS OF BIRTH/LABOUR

The labour occurs in three stages shown by distinct events. These events are longer in primigravide than in multigravide.

THE FIRST STAGE

This is the stage of labour pains. During this stage the fully developed foetus has its own hypothalamus stimulated to release ACTRF which in turn stimulates the release of ACTH from the foetal pituitary gland.

The ACTH stimulates foetal gland (adrenal) to release cortical steroids. The released cortico steroids pass across the placenta and enter the maternal circulatory system where they perform the following:-

I) They cause increase in prostaglandins (secreted by uterus).

II) They cause decrease in progesterone following the decrease in progesterone.

- The pituitary gland is allowed to release oxytocin.
- The inhibitory effect on myometrium contraction is removed and prostaglandins power the contraction.

  Oxytocin therefore causes the contractions of the myometrium where as the prostaglandins secreted by uterus increase the power of contraction. These contractions of myometrium sum up to labour pains.

- As the uterine walls continue to contract, the cervix dilates under the influence of hormone called relaxin. The amnion and chorion rupture releasing the amniotic fluid through the cervix breaking of water. Contractions continue from top to bottom forcing the baby out of the womb.

- The body gets engaged into the pelvis and following further contraction, the foetal head gets into the cervix where it causes irritation and increases powers of contraction.

The first stage of labour is terminated .When the diameter of the head is equal to the diameter of the cervix.

THE SECOND STAGE

Is the stage where by the baby is completely delivered out of the mother's womb.

- As soon as the baby is out, the umbilical cord is ligatured at two points and a cut is made between the two ligatures so as to make the baby totally separated from the mother's physiological reliance.

THE THIRD STAGE

This is the stage during which the placenta and the extra embryonic membranes after birth is delivered.

The birth of after birth is due to dramatic contraction of the uterus which causes the placenta to detach from the uterine wall.

It is important that after birth is not allowed to remain inside for a long time as its decomposition leads to blood passing.

PARENTAL CARE

This comprises of all activities the parents do for the better growth and bringing of their offspring or the offspring of the near relative.

ASPECTS OF PARENTAL CARE

1. **Nutrition -3 month**

The body has to be fed on the nutritious food substances, for proper growth and development. After birth, the baby is fed on breast with from its mother.

Breast feeding is highly recommended because mother's milk contains all important food substances needed by the baby at every stage of its development.

The first milk that a baby is sucking from the mother's breasts is a special one as it is called colustrum.

This is a yellowish fluid that contains antibodies to provide immunity to the baby. After the first three months, the child continues to be supplied with extra proteinous food substances such as cow's milk,

eggs, fish, beef etc. for proper growth and development.

1. **Protection**

- Most of the mammalian parents protect their young against

a) Disease: by providing health services ensuring hygienic handing of food etc.

b) Climate changes: by providing warmth to the babies.

c) Predators/enemies: mothers become agressive to ensure that their young ones are not reached.

2. **Social interaction/Education**

The young ones must learn how to interact with others and fit into the social structure around them. The youngs need early experience with their parents in order to depend on themselves and to learn

to live actively in the social unit.

Parental care involves the:-

1. Learning of language.
2. Teaching the language.
3. Formal education (For human beings, primary, secondary up to tertiary education) thereafter a person becomes independent.

REPRODUCTIVE CYCLES

In order to syncronise the favourable conditions to sexual reproduction, sexual reproduction is naturally in cycle.

For example; plant flowering is at the same date year after year; bleeding (menstruation) of a mature primate is on the same date month after month etc.

In mature female mammals, there is a sexual reproduction cycle, this is known as oestrus cycle (ovarian cycle).

At the onset of puberty there are approximately 400,000 primordial follicles and single follicles in all stages of maturity in the ovary. Ooctyes contained in the primordial follicles migrate out of the extragenital

structures of the coelomate epithelium into the stroma of the primary bipotent gonalds as oogonia during embryonic development.

These then divide mitotically of the roughly 400,000 follicles that are present in the two ovaries at the beginning of sexual maturity, only around 480 reach the graafian follicle stage and are thus able to

release oocytes (ovulation).

- This number is simply derived by multiplying the number of oocytes of cycles per year (12) and the number of years in which a woman is fertile (40).

Cyclic ovarian functions entailing follicle formation, ovulation, corpus luteum development and luteolysis is regulated by the hypothalamus pituitary system as well as by intraovarian mechanisms

hypothalamus, pituitary and ovary are there by in dynamic interaction.

OESTRUS CYCLE

Defn:

Oestrus cycle is the total time taken for the development and degeneration of an ovarian follicle.

- In some mammals, this period occurs once in a year, they are said to be monoestrus eg. fox.
- Note that; menstrual cycle in human, oestrus cycle in other mammals.

The discharge of the blood marks the end of oestrus cycle in higher mammals of order primate.

- In most mammals, this period is occurring many times in a year, so they are polyestrus.

PHASES OF OESTRUS CYCLE(VERY MINOR)

1. **Anoestrus** – Period during which no visible sexual activity in females.
2. **Proestrus** – Period during which graafian follicle develops into ovary and secrete oestrogens. Also called follicular phase.
3. **Oestrus** (heat) – Ovulation normally occurs, the female is ready to mate and becomes sexually attractive to male.
4. **Met oestrus** (luteal phase) - corpus luteum develops from raptured follicle.
5. **Dioestrus** – Progesterone secreted by corpus luteum prepares uterus for implantation.

SIGNIFICANCE OF OESTRUS CYCLE

Since it is characterised by ovulation and hence increase sexual urge of female, then it is important in that copulation is syncronised with fertilisation.

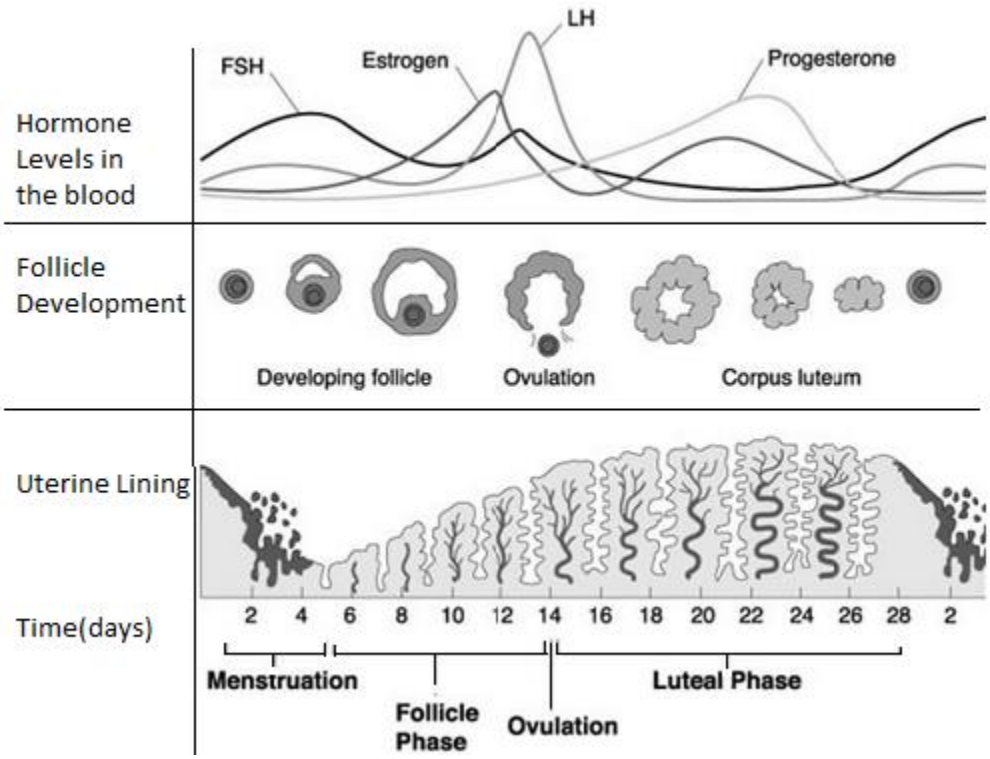
MENSTRUAL CYCLE

- This approximately monthly cycle of events associated with ovulation that replaces the oestrus cycle in most primates i.e. human chimpanzee, gorilla, baboon etc.
- The lining of the uterus becomes progressively thicken with more blood vessels in preparation for implantation of a fertilized egg (blastocyst).
- Ovulation occurs during the middle of the cycle (fertile period). If fertilization does not occur the uterine lining breaks down and discharged is known as period.

In women the fertile period is 11 – 15 days after the end of the last menstruation.

EVENTS OF MENSTRUAL CYCLE/OESTRUS CYCLE

1. Day 1 and 2 anterior pituitary gland releases. FSH and LH.
2. These hormones travel by blood and reach the ovary.
3. They stimulate the granulosa cells to secrete oestrogen.
4. Oestrogen thickens endometrium and inhibits FSH and LH.
5. Day 12 LH level rises.
6. It stimulates granulosa cells to stop producing oestrogen and start release progesterone.
7. Causes ovulation.
8. At day 14, secondary oocyte bursts out of the ovary.
9. Granulosa cells filled with yellow substance to form corpus luteum.
10. Corpus luteum secretes progesterone.
11. Endometrium thickens.
12. Inhibits FSH and LH.
13. Drop in FSH and LH stops progesterone and oestrogen level going up because granulosa cells are no longer stimulated.
14. Endometrium no longer thickens and lack of progesterone and oestrogen stimulate the anterior pituitary gland to release FSH and LH.
15. Cycle begins again.



The figure above shows morphological and endocrinological changes during various phases of the cycle.

PHASES OF MENSTRUAL CYLE

1.FOLLICULAR PHASE

This is characterised by:-

- Increased TSH from pituitary gland.
- Production of LH from pituitary gland.
- Development of follicle.

2.OVULATION

This involves the release of secondary oocyte after maturation of graafian follicle. This process in controlled by LH. One follicle rapidly out places the others and attains a diameter of up to 2.5 cm. This follicle is called mature vesicular (graafian follicle).

It is produced from the surface of the ovary like a bluster. As it develops the primary oocyte completes meiosis I producing a secondary oocyte. This begins meiosis II.

3.LUTEAL PHASE

Development of corpus luteum following ovulation; the rapture of graafian follicles develops into a yellow body mass called corpus luteum. The latter is endocrine in function and thus it secretes two hormones. Progesterone (large amount) and oestrogen (small amount).

4.MENSTRUATION

This is characterised by withdrawal of progesterone following the regression of corpus luteum also discharge of blood from vagina.

EVENTS OF MENSTRUAL CYLCLE

The events of menstrual cycle involves:-

1. Ovarian cycle – ovaries.
2. Uterine cycle – uterus.

In women, the rythmic hormonal influence leads to the following cyclic events.

1. The ovarian cycle (follicle maturation) that peaks in the ovulation and the subsequent luteinization of the granulosa cells.
2. Cyclic alternation of the endemetrium that prepare the uterine mucosa to fertilized oocyte (as 'nest' thene).

1. THE OVARIAN CYCLE

- A rule, the ovarian cycle lasts 28 days (in majority).

  It is divided into two phases:

  i. Follicle phase: Requirement of a so called follicle and within this selection of the mature follicle. This phase ends with ovulation. Oestrogen (estradiol) is the steering hormone normally it last 14 days

  but this varies considerably.

  ii. Luteal phase: Progesterone production by corpus luteum.

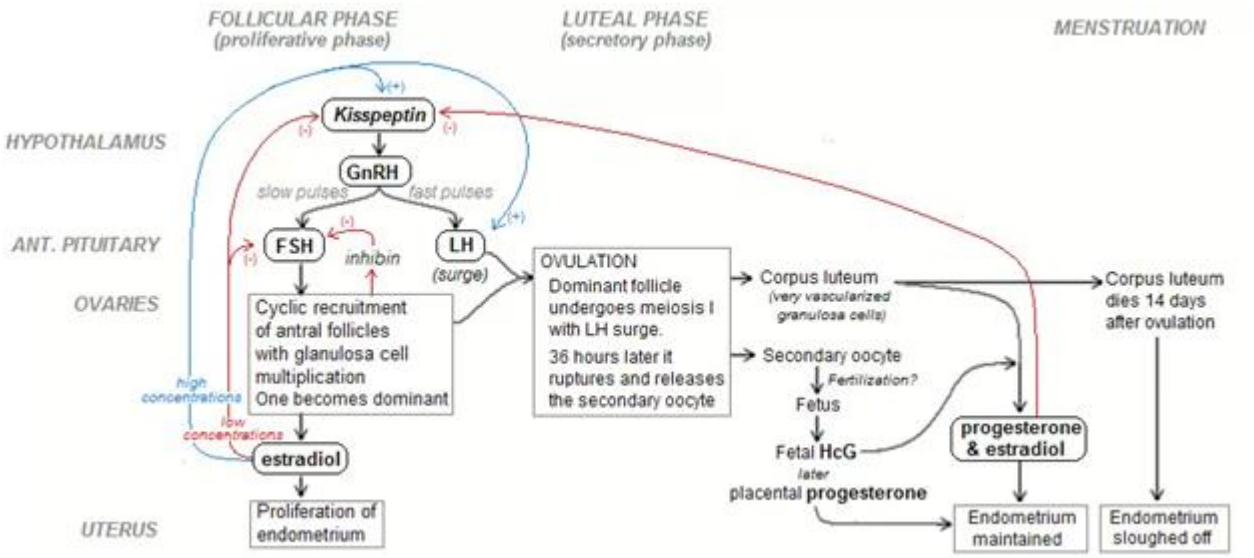
- The control circuit of the hormonal cycle has two essential elements:-

  i. The pulsative liberation of GnRH as well as FSH and LH.

  ii. The long – loop feedback effect of oestrogen and progesterone on the hypothalamic hypophysical system.

HORMONAL CONTROL OF EGG PRODUCTION AND UTERINE PREPARATION

1. When levels of progesterone and oestrogen in the blood are low, the hypothalamus is triggered to secrete releasing hormones (GnRH).
2. The releasing hormone stimulates the pituitary gland to produce FSH and LH which travel in the blood stream to the ovary.
3. The FSH stimulates follicles to grow but usually only one follicle with its oocyte mature each month.



Fg: Interaction between hypothalamus pituitary gland and ovary representation of -ve and +ve feedback mechanisms.

1. The follicle grows rapidly and secretes increasing amount of oestrogen.
2. This hormone oestrogen causes the uterine lining to become thicker and more heavily supplied with blood.
3. On about the 14th day of a 28 days cycle the pituitary gland secretes a large pulse of LH and additional FSH and these trigger the oocyte to complete the first meiotic division it began before birth.
4. The developing follicle then rapture and releases the egg.
5. Once the ovum has left the ovary and begins its trek down the oviduct, the follicular cells left behind in the ovary enlarge and form a new gland the corpus luteum (literally yellow body).
6. The corpus luteum cells continue to secrete oestrogen but they begin now for the production of large quantities of progesterone as well.
7. Together oestrogen and progesterone promote the continual build up of the uterine lining.
8. The hormones as well inhibit the hypothalamus from making releasing factors and the pituitary from releasing FSH and LH.
9. If the ovum does not encounter sperm on its down ward journey and it is therefore not fertilized diminishing levels of LH and FSH allows the corpus luteum to degenerate on day 24 of a cycle.

10. Corpus luteum thus releases less and less oestrogen and progesterone.
11. As these hormones diminish; the endometrium begins to slough off and an approximately five days long period of menstrual flow starts making the beginning of the next cycle.

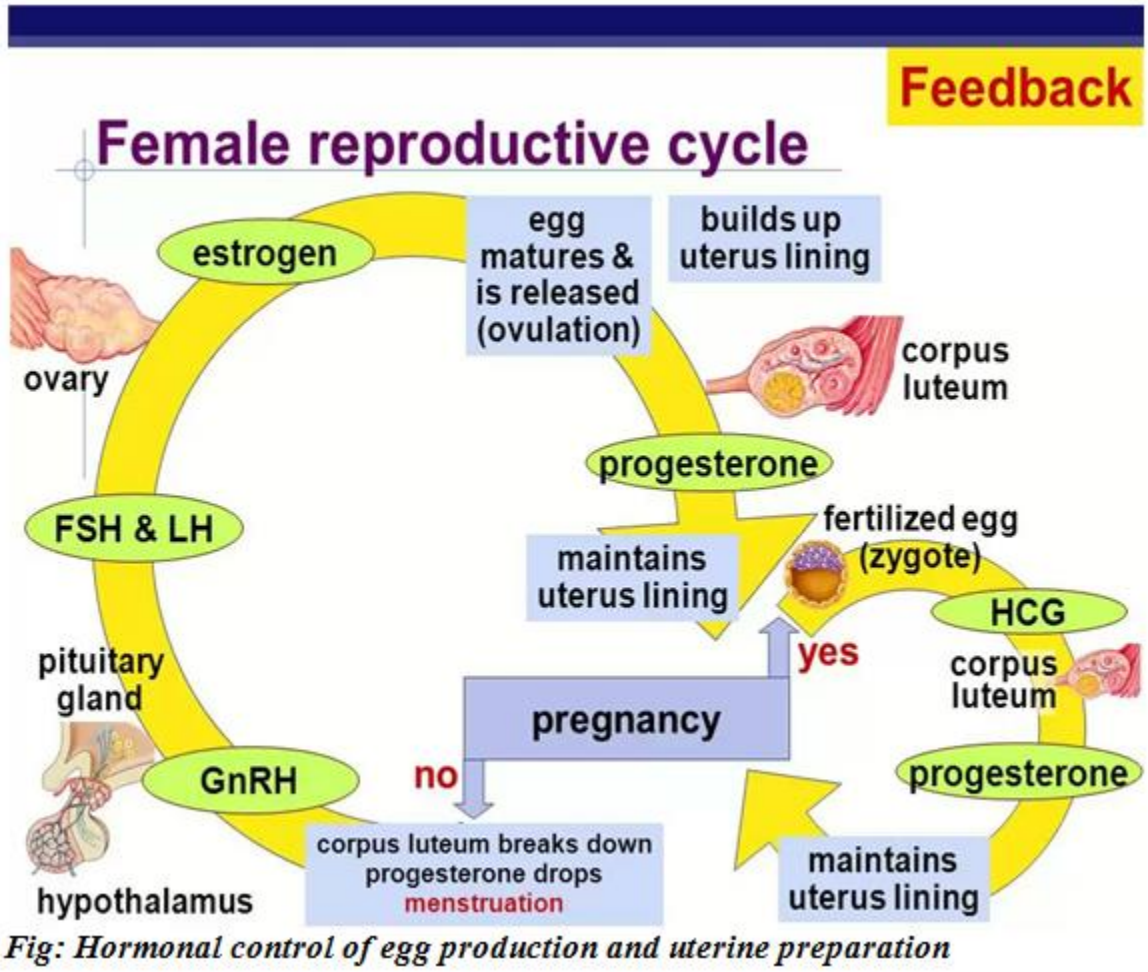


Fig: Hormonal control of egg production and uterine preparation

Fig: Hormonal control of egg production and uterine preparation

The control of the circuit of the hormonal cycle:

The control begins in the hypothalamus which produces gonadotrophin releasing hormone.

- The GnRH is received by receptors in the anterior pituitary gland which responds by releasing follicle stimulating hormone (FSH) and lutenizing hormone (LH) in a pulsatile manner.
- At the beginning of the development, the granulosa cells express FSH receptors which stimulate growth of the follicle. Theca cells express receptor for LH which stimulates the growth of corpus luteum.

Theca cells also produce andogens which the granulosa cells convert into oestrogen.

Oestrogen acts back on the anterior pituitary gland to further FSH and LH surges, and also supports the growth of the endometrium.

- At some point the dominate follicles begins to secrete inhibin, which acts back on anterior pituitary gland to stop producing FSH. Only the dominant follicle which is now FSH independent will continue to

  grow.

- During further growth/development; the granulosa cells increase their FSH receptors and express LH while the theca cells increase LH receptors.

- This surge in hormone receptor results in ovulation.

- After ovulation, if fertilization occurs; the corpus secretes progesterone that supports the further growth of endometrium. If, however fertilization does not occur, then the hormone level drops the

  corpus luteum breaks down, no longer secrete progesterone, so that the endometrium sloughs off producing menstruation.

- It is estimated that lens than 1% of all follicles reach the stage of the graafian follicle with 99% of follicles degenerating by apoptosis programmed cells death is an energy dependent process

  accompanied by DNA degeneration.

- The corpus luteum develops out of the raptured follicle immediately following ovulation corpus luteum is a vascularized version of the previous a vascular follicular epithelium with its intergration into the

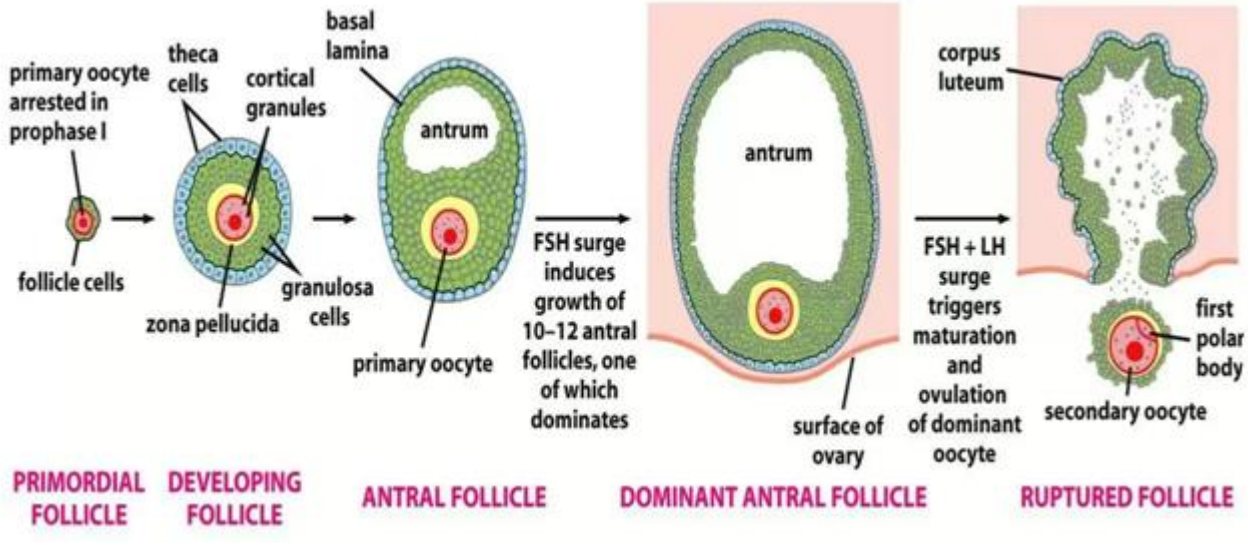
  circulatory system and the expression of the low density lipoprotein receptors, the follicular epithelial cells are able to take up cholesterol from the periphery and use it for progesterone biosynthesis.

NB:

The origin of germ cells (gametes) is of special interest because the differentiation of these cells is responsible for continuing life cycle. The initial determination of cells as premordial germ cells occurs very

early in mammals, where all of the meiotic and differentiation into oocytes before or just after

birth, but ovulation does not take place until much later.



In any case the final production and delivery of the fully competent eggs or sperm require complex hormonal stimulation that occurs in adult, after the reproductive organs are fully mature.

- If fertilization does not occur, corpus luteum regresses leaving a scarred area called corpus luteum albicans (white body). This leads to subsequent decrease in the level of progesterone.

  As this happens, FSH is no longer inhibited and therefore its level increases in the blood. This marks the beginning of ovarian cycle

2. UTERINE CYCLE

Is a repeating series of changes in the structure of uterus.

It takes 21 – 35 days. It is divided into:-

1. Menses
2. Proliferation phase.
3. Secretory phase.

1. **The Menstrual phase** (menses)

   This involves the shading of the epithelial lining of the endometrium. This phase and the process associated with it are explained as follows;

Following the regression of the corpus luteum, the level of progesterone in the blood decrease. This leads to the construction of spiral arteries that supply oxygen to the endometrium thus receive

small amount of oxygen and consequently die.

By negative feedback, the spiral arteries then dilates allowing more blood to flow towards the dead cells in the uterine walls.

The pressure exerted by the blood causes the wall to disintegrate and flow out together with variable amount of blood in the menstrual flow. Usually endometrium sloughts out in patches.

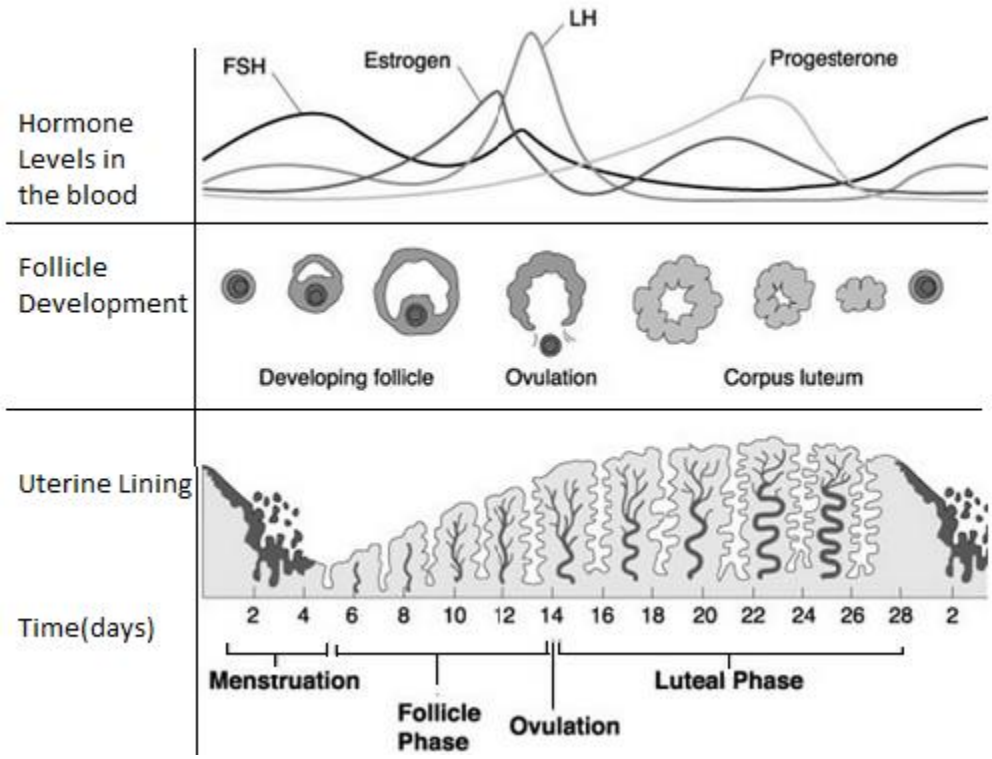
2. **Proliferation phase** (Proliferative phase)

   Involves the rapid proliferation multiplication of the endometrium under the influence of oestrogen from developing follicle.

3. **Secretory phase**

   During this phase, progesterone from corpus luteum gland and this maintains the lining of the uterus in receptive state for implantation of the zygote.

Fig: Uterine cycle



DIFFERENCES

	OESTRUS CYCLE	**MENSTRUAL CYCLE**
	Common to lower mammals eg. Cats, dogs, caw etc.	- Is characteristics to the higher mammals of the order primate eg. Human beings, chimpanzee, gorilla, monkey etc.
	In oestrus cycle, the endometrium cycle is absorbed if conception does not occur during the cycle.	-Animals with menstrual cycle shed the endometrium through menstruation.
	In species with oestrus cycle, females are generally only sexually active during the oestrus cycle. This is referred to as in heat.	- Females of species with mentrual cycle can be sexually active at any time in their cycle even when they are not about to ovulate.
	Period of heightened sexual activity conciding with ovulation is the most prominent event.	- Menstruation, the discharge of blood and uterine lining is the most prominent event.

	Occurs less frequently eg. once per year.	- Occurs more frequently than oestrus cycle eg. once every month.

NOTE:- Humans unlike some other species have once obvious external signs to signal receptivity at ovulation (concealed ovulation).

- Research has shown however, that women tend to have more sexual thoughts and are most prone to sexual activity right before ovulation.

SIMILARITIES BETWEEN OESTRUS AND MENSTRUAL CYCLE

- Both comprises of recurring physiological changes that are induced by reproductive hormones in most mammalian placental females.
- Both start after puberty in sexually mature females and are interrupted by oestrus phases, continue until menopause.

METAMORPHOSIS

Definition:

Metamorphosis is the change of form of an organism in the course of its development.

- Metamorphosis is caused by hormones from the brain and three other endocrine structures two of which are the corpus allatum and corpus cardiacum which are extensions of the brain.

1. **BRAIN**

   This has neuro – secretory cells for secretion of the brain hormone (BH); This influences the secretion of ecdysone (a hormone controlling ecdysis) hormone from the pro-thoracic glands. The ecdysone

   hormone is stored in the thoracic gland.

2. **CORPUS ALLATUM**

   This is an extension of the brain which secretes juvenile hormone (JH). This JH is dominant during the larval stage controls growth and moulting.

3. **CORPUS CARDIACUM**

It is also extension of the brain which basically receives brain hormone from the neuro-secretory cells of the brain, stores it before pouring it out.

4. **PROTHORACIC GLAND**

It secretes a prothoracic gland hormone (PGH) or ecdysone hormone. This is secreted when JH diminishes and it controls the process of population and emergency of an adult from the pupa. It is also

controlling ecdysis.

TYPES OF METARMORPHOSIS

1. **COMPLETE** (holometabolous) **METAMORPHOSIS**

Type of metamorphosis in which four stages are involved

I.e. egg ⟶ larva ⟶ pupa ⟶ adult.

Example: - Housefly, butterfly.

Fig: life cycle of a butterfly

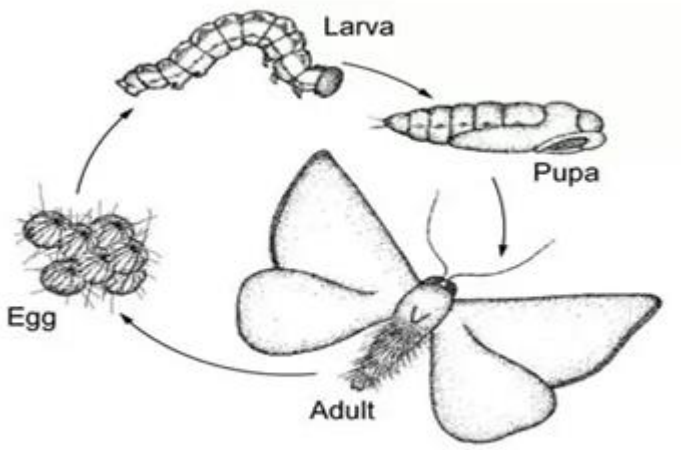


Fig: life cycle of a butterfly

The embryo of an insect (for example a moth butterfly, beetle or fly) which undergo complete metamorphosis develops into a young form called a larva which appears very different from the adult.

Larvae lack many of the structures of the adult.

- Butterfly larva has no wings and lacks compound eyes and jointed legs. They have become little more than feeding machines whose primary function is to find and consume food.
- Once it has reached a certain size, the lava stops feeding and becomes a pupa by enclosing itself in the protean case within the case tissues are broken down and recognised so that they undergo a

  remarkable transformation to the adult form, the imago.

- Once the adult has emerged from the case with fully developed wings, it can no longer moult. This restricts growth.

1. **INCOMPLETE** (hemimetabolous) **METAMOPHORSIS**

Is the type of metamorphosis in which an insect develops through three stages.

I.e. egg ⟶ nymph ⟶ adult.

Example:- grasshopper, cockroach or locust undergo incomplete metamorphosis.

- The embryo of an insect such as grasshopper, cocroach or locust undergo incomplete metamorphosis.

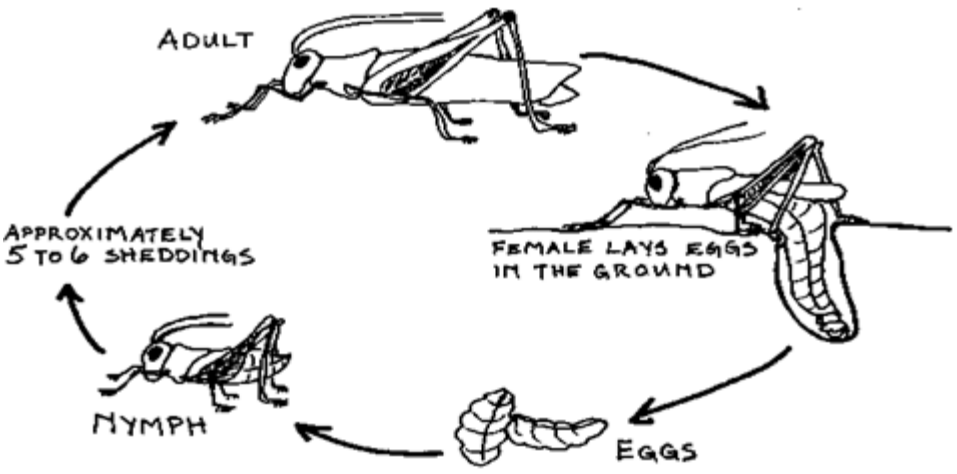


Fig: life cycle of a grasshopper

- It develops into a nymph which closely resembles the adult form but which has a number of adaptive features which enables it to live in different habitat and eat different good from the adult.

- In order to grow the nymph moult several times and go through a number of developmental stages called instars. The instar emerges as the adult with all the adult organs.

ADVANTAGES OF METAMORPHOSIS

1. Metamorphosis enables juvenile and adult forms to live different habitats and exploit different resources. This reduces competition between the different developmental stages.
2. Metamorphosis allows the larva and adult stages to become highly specialized for particular functions; usually the larval stage is specially adapted for feeding and the adult for reproduction.

REPRODUCTION IN FLOWERING PLANTS

- The reproductive structure of the flowering plant is the flower.

GAMETOGENESIS IN FLOWERING PLANTS

- as in animals, gametogenesis in flowering plants is the formation of gametes producing cells, the microspores s and the megaspores. The process whereby the microspores are produced is called Microsporogenesis where as megaspores are produced during megasporogenesis. The former forms pollen embryo female gamete.

DEVELOPMET OF POLLEN GRAINS: MICROSPOROGENESIS:

This occurs in the pollen sacs of the others, in these sacs each pollen or mother cell (2n) undergoes meiosis I to produce two haploid cells. Each of the resulting daughter cells undergoes meiosis II to produce a total of four haploid cells the four cells separate and each cell

develops a thick wall over it. This wall is called an exine inside which lies an intine. Te pollen grain at this stage is equivalent to the microspore.

Its nucleus divides by mitosis to produce two nucleus the generation nucleus and the pollen tube nucleus

SEXUAL REPRODUCTION IN PLANT

Sexual reproduction in angiosperms occurs in the gametophyte generation. The structure for sexual reproduction is the flower.

It is within the flower where spore and gametes are developed.

GAMETOGENESIS

Occurs in two ways:-

(i) Microsporogenesis.

(ii)megasporogenesis.

MICROSPOROGENESIS

Is the process by which mature plant produces male gametes (pollen grains or microspores) at anthers of a flower.

The process takes place in the lobes of the anther.

MECHANISM:-

The microspore mother cell pollen mother cell 2n also called primary microsporocyte, undergo meiosis I to produce two haploid cells (dyad).

The products of meiosis I undergo meiosis II producing 4 cells (tetrad). The cells in the tetrad get separated from one another and cell (microspore pollen grain) secretes an additional wall over the present wall.

The nucleus of the pollen grain divides mitotically to produce two nuclei, the pollen tube, nucleus and the generative nucleus.

- At this point the pollen grain and its contents if referred to as the male gametophyte because the male gametes will develop from the generated nucleus.

- The mature pollen grain has two walls; the inner (INTINE) and the outer (EXINE). Exine has various pits (Sculptures).

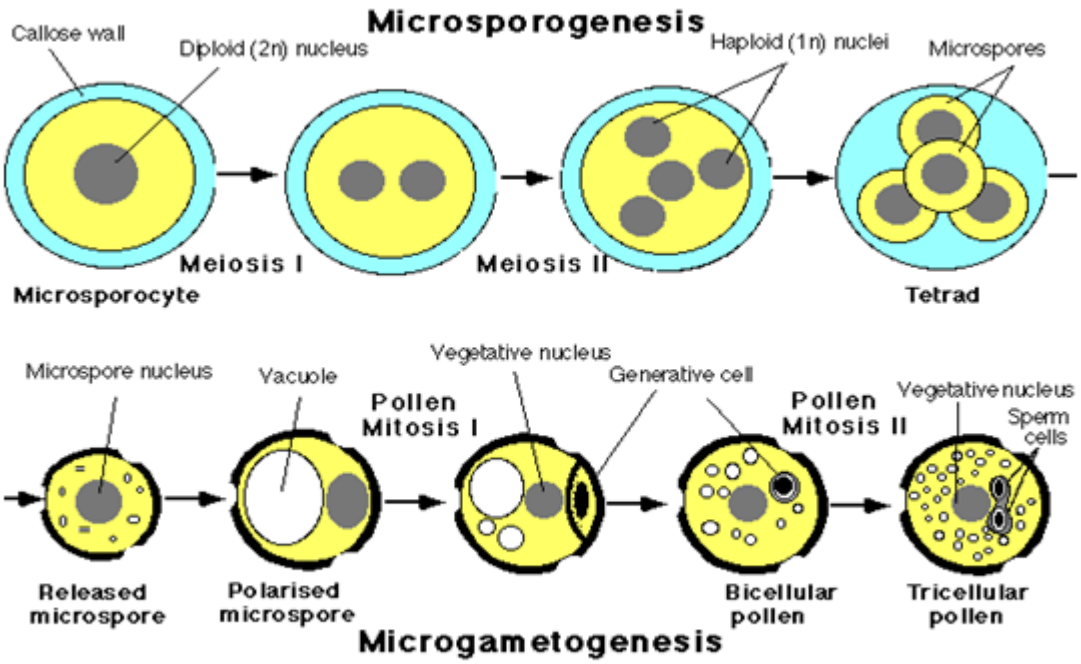


Fig: microsporogenesis

MEGASPOROGENESIS

This is the development of the embryo sac (megaspore). The process takes place in the ovule of the ovary.

MECHANISM

The megaspore mother cell (2n) undergo meiosis to produce two cells (n) but only one continues to develop under the influence of nutrients from nucleus and become the embryo sac.

- The nucleus of the embryo sac divides mitotically three times to produce 8 nuclei the antipodals migrate, polar nuclei remain at the centre and 3 nuclei the female gamete and sinergid migrate to the microphylen end.
- Soon after mitosis the embryo sac and its content is referred to as the female gametophyte because one of the nuclei is the female gamete.

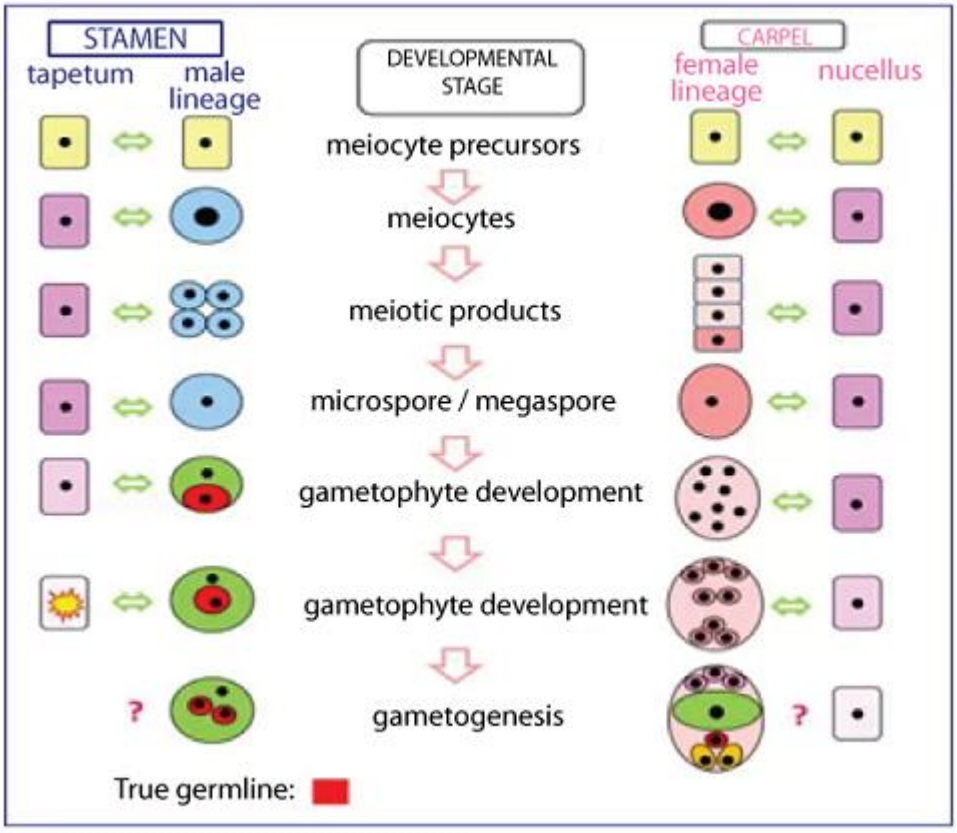


Fig: Development of embryo sac and female gamete.

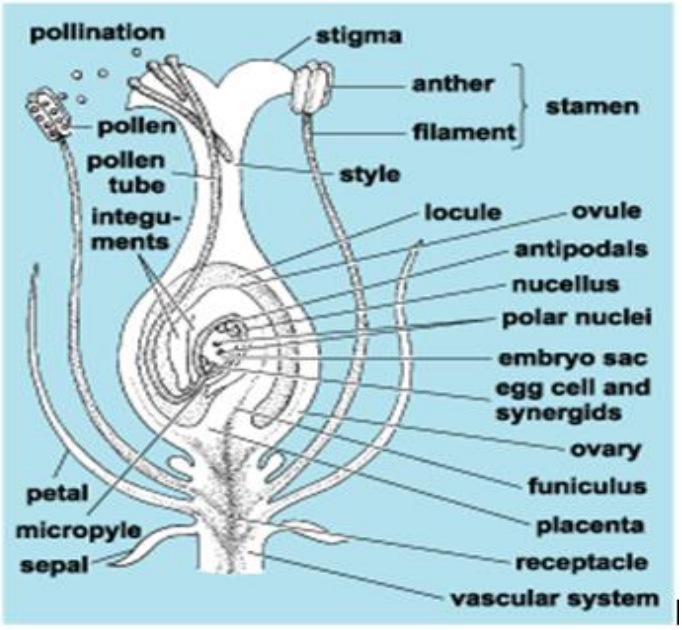


Fig: Is carpel at fertilization. Note that, ovule which becomes the seed after fertilization, contains both diploid parent tissue and haploid embryo sac tissue.

DOUBLE FERTILIZATION AND ITS CONSEQUENCES

Double fertilization is a unique characteristic of the angiosperm. It is a result of multinucleate of the pollen grain and embryo sac.

Definition: Double fertilization is a type of fertilization which occurs in the flowering plant where the two types of nuclear fusion take place.

First: The male gamete nucleus fuses with the female gametes of the embryo sac to form the zygote (2n).

Second: The second male gamete fuses with diploid nucleus (resulting from the fusion of 2 polar nuclei) forming a primary endosperm (3n).

MECHANISM OF DOUBLE FERTILIZATION

The process of double fertilization is proceeded by pollination during which the pollen grain lands on the stigma.

- As the pollen grain lands on the stigma the style tissue stars to secrete sugary solution including sucrose solution. The solutions are absorbed by the pollen grain which consequently swells.
- As a result of swelling; the intine wall grows through the exile via one of the pits as pollen tube under the control of pollen tube down the style.
- As the pollen tube continues to grow, the generative nucleus in the pollen grain divides by mitosis to produce two male gametes. In embryo sac, the two pollen nuclei fuse producing a diploid nucleus and the antipodal as the sinergid degenerate.
- The embryo sac thus remains with only two nuclei an ovum (n) and a diploid nucleus resulting from the fusion of the polar nuclei.
- The pollen tube continues to grow chemotactically towards the embryo sac under influence of chemicals secreted by the embryo sac. As the pollen tube reaches the micropyle, the following occurs in the pollen tube:-

1. The tip of the pollen tube bursts.
2. The contents of the pollen grain are discharged into the vicinity of the embryo sac.

Fertilization occurs following the discharge of contents of pollen grains. It is a double fertilization

How?

i. The haploid male gamete fuses with the female gamete to form a diploid zygote nucleus.
ii. The second haploid male gamete fuses with the diploid (resulting) from the fusion of two polar nuclei to form a triploid primary endosperm nucleus.

ECOLOGY

Ecology is a scientific study of relationship of organism with their natural surroundings

OR

- Is the study of relationships of living organisms to each other and their surrounding (physical surrounding)

Importance of studying Ecology

- It gives us scientific foundation of understanding some fields of studies such as agriculture which concern with crop cultivation and animal husbandry, forestry, fishery and so on
- The study of ecology gives us the basis for predicting and remedying environmental degradation (how to conserve environment)
- Help us to understand the likely consequences of massive interventions in the environment e.g. construction of huge dams, deforestation to open space for plantation, agriculture e.t.c
- Ecology is an important interdisciplinary science linking physical, biological and social science.
- Ecology has given rise to a growing public awareness on environmental issues. This has given rise to development of laws on environment protection, formation of new political perspective e.g. environmentalism in Europe, emergence of environmental consultancies, development of environmental data services / base, e.t.c.

Definition of terms

1. **Environment** Refers to the surrounding of organisms. OR

- Everything that surround an organism and influence it.

1. **Population** is a group of organisms of one species occupying a defined area or habitat at the same time.**Community** – Any group of organisms belonging to a number of different species that co-exist in the habitat or area and interact through trophic and spatial relationship.
2. **Ecosystem** – A community of organisms and their physical environment interacting as an ecological unit.
3. **Habitat** is a typical environment of a particular organism or population or community.

OR

An area occupied by a particular organism or population or community.

1. **Biosphere** – Is the total volume of the earth in which life permanently exists.

Approaches to Ecology

A proper understanding of ecology requires simultaneously consideration of all factors interacting in a particular place.

Ecologists adopt one of the several main approaches when undertaking a new investigation.

Five approaches can be identified.

- Ecosystem Approach

This approach focuses on the flow of energy and cycling of matter in the ecosystem i.e. between the living and non-living component of the ecosystem. In this approach an ecologist relationship (such as feeding) between organisms and environment rather than description of the species.

- Community Approach.

This focuses in particular on the biotic component of the ecosystem. In this approach e.g. one examines the plants, animals and microbiology of recognizable biotic unit such as wood land, grass land and heat land. The functional aspects of physical environment is not studied in detail, it emphasis on identification and description of species present and factor that control their presence. Community approach is synonymous to synecological approach.

- Population Approach (Ant ecological approach)

This approach focuses on identification and description of individual species in relation to its environment.

- Habitat Approach

This focus on description of typical environment of a particular organism, population, community or ecosystem.

- Evolutionary and historical approach
- This focuses on the changes that have occurred in the organisms over time and the development of technology and culture of the human species.

THE ECOSYSTEM

- The ecosystem refers to a community of organisms and their physical environment interacting as an ecological unit.
- The term describe the whole complex of organisms living together as a sociological unit and its habitat.

Component of the Ecosystem

- The ecosystem is made up of living and Non- living components
- The living component of the ecosystem is known as biotic component, these include plants, animals, microorganisms e.t.c
- The Non- living component is known as Abiotic component. The Non- living component of an ecosystem is divided into:-
- Soil
- Water
- Climate

Soil and water contain a mixture of inorganic and organic nutrients.

Climate includes environmental variables such as light, air, water, temperature.

ENERGY FLOW AND NUTRIENT CYCLING

The essence of ecological studies lies in understanding how connections between the different organisms and their Abiotic environment work.

Energy flow and biochemical cycling are important functional links between the different ecosystems.

The two factors maintain the stability of the ecosystem. Stability of ecosystem means that the ecosystem can adjust to changes within itself.

The ecosystem is also sustainable i.e. it continues on its own without the necessity for human intervention.

Energy is defined as the capacity to do work.

Living organisms are likened to machines in that they require energy to keep them working i.e. to stay alive.

The Ecosystem like machines is kept working by an input of energy and nutrients. The ultimate source of energy in the ecosystem is the sun.

The sun is a star which releases vast amount of solar energy in space. The solar energy is captured by autotrophs in photosynthesis converting it into chemical energy (in form of food sources)

In the Biotic component photosynthetic organism utilize the sun’s energy directly and pass it to the other components of the ecosystem.

The energy is passed from the photosynthetic organism to the other through feeding relationship. The passage of energy through various component of the ecosystem is known as Energy flow. It

is referred to as energy flow rather than energy circulation because (the energy released from the sun after passing through the component of ecosystem does not go back to the sun it is dissipated in the atmosphere as heat remain locked in some component of the ecosystem) it is changed into forms which cannot be used again by the system mainly heat energy.

BIOCHEMICAL CYCLING (Cycling of Matter)

The chemicals found in living organisms are derived originally from the abiotic components of the ecosystem such as soil, water, air to which eventually return by the way of decomposition dead organic matter.

Bacteria and fungi bring about decomposition obtaining the energy from the dead organism in the process.

Biochemical cycling is the constant cycling of chemical matters needed by living organisms within the ecosystem, the process is called biochemical cycle since both living and non- living part of the ecosystem is involved.

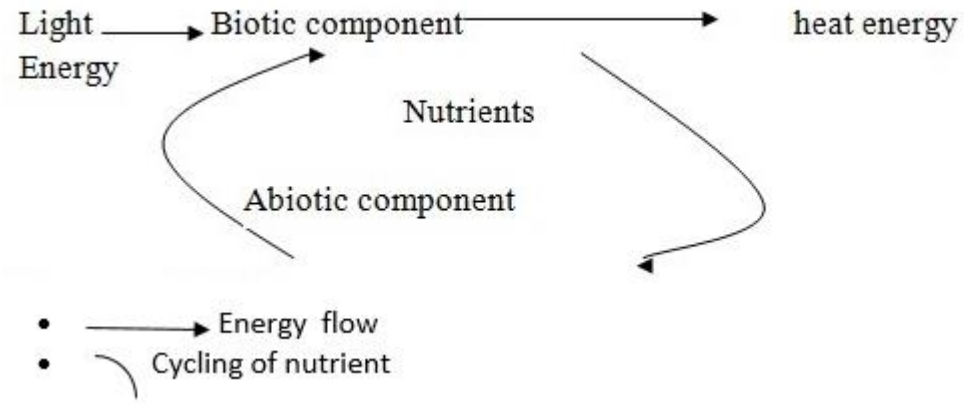
Light Biotic component heat energy

Energy

Nutrients

Abiotic component

- Energy flow
- Cycling of nutrient



ENERGY TRANSFER

The concept of food chain, tropic level and food web.

Energy containing organic molecules produced by autotrophic organisms is the source of food (materials and energy) for heterotrophic organisms.

Green plants, algae and some few bacteria (blue – green bacteria) are photosynthetic. Green plants mainly convert sunlight energy into chemical energy (food) which is used by animals some animals feed on plants in turn these animals are fed on by other animals. In this way the energy is transferred through a series of organisms.

FOOD CHAIN

Refers to the series of organisms each feeding on the proceeding organism and providing raw materials and energy for the next organism.

Each food chain starts with producers

- **Producers** – are the autotrophic organisms or the organisms which in turn are eaten by other organisms.

On the basis of food relations the biotic components of the ecosystem can be put into the following categories.

1. **Producers:** These are autotrophs which synthesis the food using sunlight energy.

They include green plants, algae, protoctists and phototrophic bacteria.

Major producers of the aquatic ecosystem are algae, often minute unicellular algae that make up the phytoplankton on the surface layer of the oceans and lakes.

On land the producers are large plants, namely angiosperms and conifers which form the forest grass lands.

- Consumers

These are heterotrophs that obtain energy from producers directly or indirectly.

They can be put in various categories.

- Primary consumers

These are consumers that feed on producers.

They are referred to as herbivores on land; typical herbivores include insects as well as reptiles, birds and mammals.

In aquatic ecosystem (fresh water and marine) the herbivores are typically small crustaceans and molluscs. Most of these organisms such as water fleas, cope pods, crab larvae, barnacles and bivalves are filters feeders.

- Secondary consumers.

These are consumers that feed on herbivores

They are carnivores i.e. feed on flesh

Examples of secondary include carnivores such as wolf, snake.

- Tertiary consumers

These organisms feed on secondary consumers (the carnivores)

Example are carnivores like lion, tiger, hawk e.t.c

NB:

Secondary and tertiary consumers may be

Predators which hunt capture and kill their prey

Carrion feeder which feed on corpses

Parasites – in which case they are smaller than their host.

DECOMPOSERS AND DETRIVORES

Decomposers – Are microorganisms mainly fungi and bacteria which live as saprophytes and feed on dead organic matters. They secrete digestive enzymes on to dead materials and absorb the product of digestion.

Detrivores – These are organisms that feed on small fragments of decayed or dead materials termed detritus.

Many small animals feed on these, contributing it to the process of breakdown, because of combined activities of the true decomposers. (Fungi and bacteria) and detrivores (animals), they lead to the breakdown or decomposition of material.

Examples of detrivores are the earth worm

Decomposers and detrivores form their own food chain.

TROPHIC LEVEL

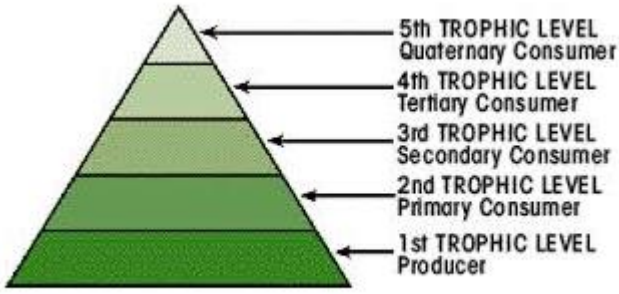
Refers to the stages of food chain

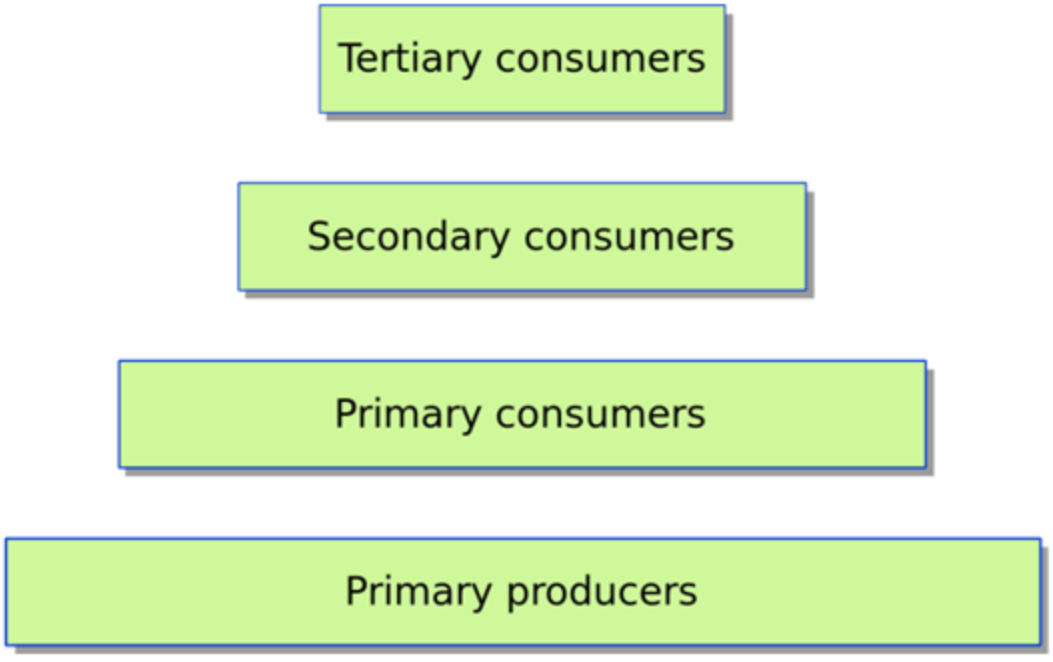
Each group of organism in a food chain form the tropic level (trophos – feeding).

The energy flows one way through various trophic levels.

There are usually four or five trophic levels and seldom more than six. Why?

- Energy decreases as one move from one trophic level to another. There is less energy to support the organisms.
- The first Trophic level is occupied by producers (autotrophs).
- The second trophic level is occupied by the herbivores
- The third trophic level is occupied by secondary consumers – the carnivores.
- The fourth trophic level is occupied by the carnivores (Tertiary consumers)



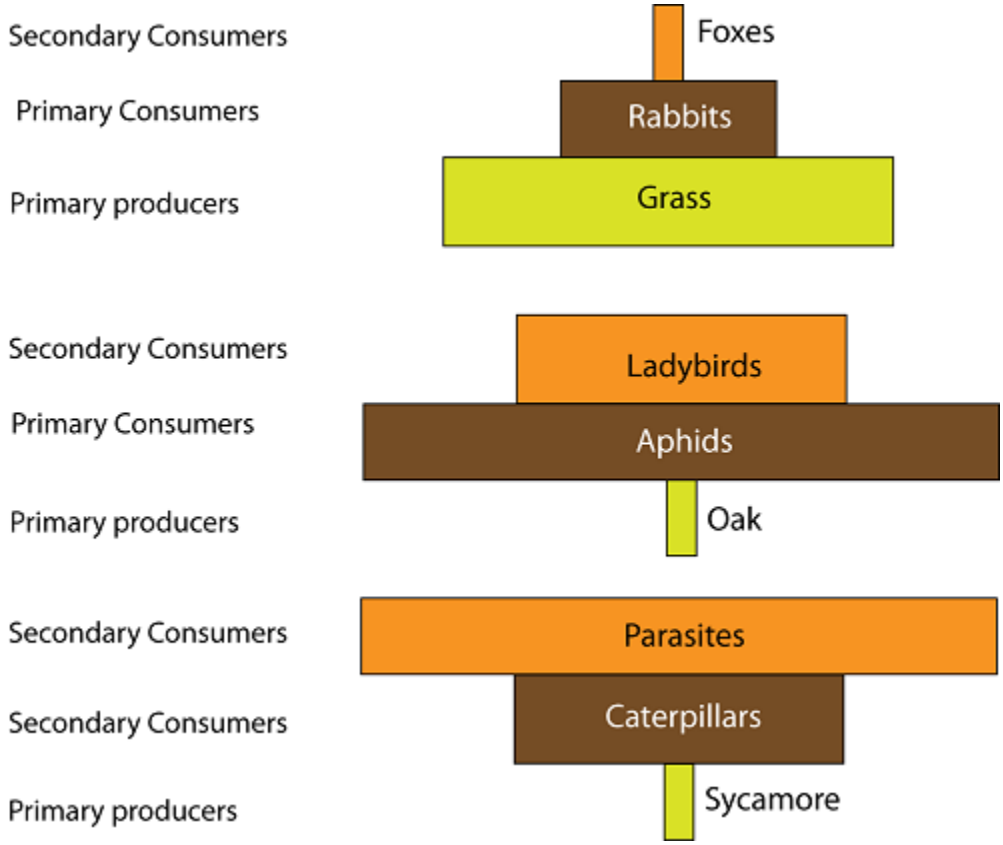


ECOLOGICAL PYRAMIDS

Feeding relationship and energy transfer through the biotic component of ecosystem may be quantified and show diagrammatically as ecological pyramids. These shows the induced changes within a single system. Ecologists use these pyramids in gathering data for quantitative comparison of all major world ecosystem.

Pyramids of Numbers

In ecosystems the smaller organisms usually outnumber the large organisms. Pyramid of numbers shows the number of organisms in each trophic lever and how they change in successive levels of ecosystem.
.In a trophic lever based pyramid of numbers the organisms of a given area are first counted and then grouped in their trophic levers.
.There is a progressive decrease in the number of animals at each successive level
.Plants in the first trophic level often outnumber animals at the second trophic level but it will depend on the relative size of organism



Types of Pyramid of numbers.

Pyramid of Biomass

This take consideration of the total mass of the organisms (biomass) estimated at each trophic level. Ideally the dry mass is compared.

The estimation of dry mass is done by weighing representative individuals (sampling).

The rectangle is drawn in proportation of the mass at a particular trophic level. The biomass at the time of sampling is considered.

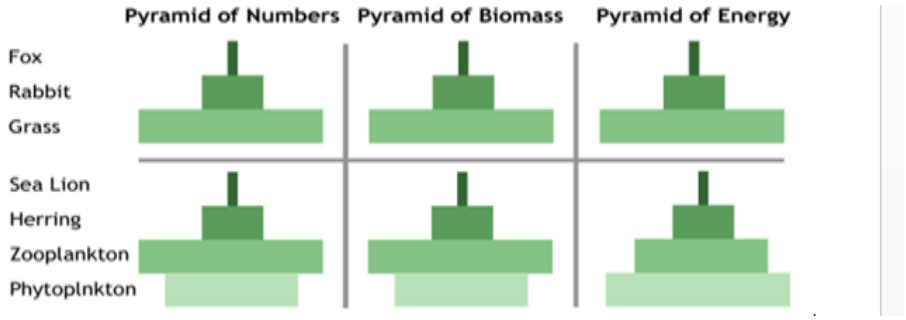
This is known as the standing mass or standing crop mass.

Drawback of Pyramid of Biomass

- It is more laborious and expensive in terms of time and equipment.
- It does not allow for changes in biomass at different time of the year e.g. deciduous tree have a large biomass in summer than in winter, when they have shed their leaves.
- The rate at which the biomass accumulates is not taken into account. A mature tree has a large biomass which increases slowly over many years.

Inverted pyramids of biomass are obtained only for aquatic ecosystem. This frequently happens in food chains which start with phytoplankton. These organisms are very small and have a much more rapid town over than their 200 plankton predators.

The pyramid of biomass can be bulged at the middle.



- They do not show the rate production (productivity that is the amounts of materials and energy passing from one trophic level to the next).

In a given period of time, period such as one year for example a fertile, intensively grazed pasture may have a small standing crop of grass but higher productivity.

Pyramid of Energy

These are type of ecological pyramid drawn based on the amount of energy at each trophic level.

This shows how much energy passes from one trophic level to the next the length of the producers bar is proportional to the amount of solar energy annually in photosynthesis.

The length of other basis shows the rate at which energy passes along the food chain.

The pyramids of energy take into account the rate of production in contrast to pyramids of numbers and biomass which depict the standing states of organisms at a particular moment in time. The energy at each trophic level is estimated by establishing of the energy value for that trophic level.

NB: The transfer of energy from producers to primary consumers is less efficient than between the other trophic level.

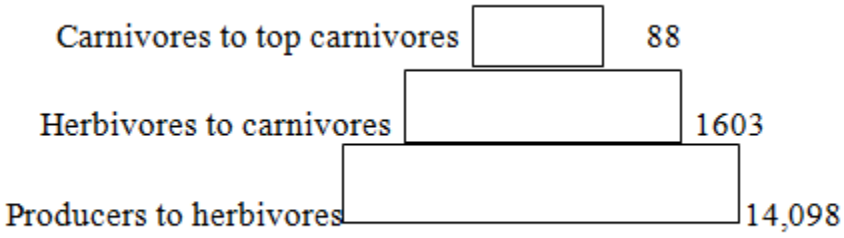
The average efficiency of transfer from plants to herbivores is about 10% and from animals to animals is 20%.

Like other type of ecological pyramids, the energy decreases as you move from lower to higher trophic levels.

The following are the possible causes of this:

- Some energy is used for metabolic activities at each trophic level, mainly respiration.
- A lot of energy is lost in form of heat hence is not available in the ecosystem energy lost in respiration cannot be transferred to other living organisms.
- Some energy is locked in animal or plant parts which cannot be eaten e.g. Bones, horns, nails, and feathers of animals and cellulose materials of plants which are indigestible.
- Organisms do not assimilate some of the materials taken in as food.
- The consumer population is unable to harvest enough of the food population.

The diagram below represents a pyramid of energy for an aquatic ecosystem.



Carnivores to top carnivores 88

Herbivores to carnivores 1603

Producers to herbivores 14,098

pyramid of energy for silver springs, Florida (energy flow in KJ m^{-2} $yr^{-1)}$

NB:
Each bar of a pyramid of energy represents the amount of energy per unit area or volume that flow through that trophic level in given time period.

Usefulness of Pyramid of Energy.

- It takes into account the rate of production, in contrast to pyramids of numbers and biomass which depict the standing states of organisms at a particular moment in time.
- It allow different ecosystem to be compared including the relative importance of population within one ecosystem.
- They tell how much energy is required to support each trophic level because only a proportion of energy in a level is transferred to the next.
- Energy pyramid are never invested nor do they have a central bulge
- Energy pyramids are more informative than the pyramid of number and biomass.
- Input of solar energy can be added as an extra rectangle at the base of pyramid of energy.

Disadvantages of Ecological Pyramid of energy.

- They are the most difficult to obtain data
- They are not an accurate method of representing energy content of the ecosystem.

General criticisms of Ecological pyramids

- The pyramids of numbers, biomass and energy depend on assigning living organisms to trophic level. While the correct level is obvious for plants and obligate herbivores. Many carnivores and omnivores eat a varied diet and thus their trophic level varies according to the food selected.
- It is hard to fit dead material (detritus) and other waste together with their consumers into conventional pyramids. These materials are important as a food source.

BIOCHEMICAL CYCLES – The cycling of Matters

The chemicals found in living organisms are derived originally from the abiotic components of the ecosystem such as soil, water and air to which they eventually return by way of the decomposition of waste products or dead bodies of organisms. Bacteria and fungi bring about decomposition; obtain energy from the waste products and dead organisms in the process.

Biochemical cycling is the constant cycling of chemical materials needed by living organisms within the ecosystem.

The process is called biochemical cycle since both living and non-living parts of the ecosystem is involved.

Distinction between chemical cycling and energy flow.

Chemicals in the ecosystem are constantly recycled and used again, on the other land; energy transferred within the ecosystem is changed into forms which cannot be used again by the system, mainly heat energy. Because some of the energy is lost we cannot talk of recycling rather than the flow of energy through the ecosystems.

To maintain the ecosystem, frequent and regular inputs of solar energy is needed.

Cycles can be recognized for all chemical elements that occur in living systems. The biogeochemical cycles for carbon (C), Nitrogen (N), Sulphur (S) and Phosphorus (P) are very important. These elements from the major macronutrients in Biochemical cycles for Nitrogen and carbon.

NITROGEN CYCLES

Nitrogen is an abundant element in the atmosphere. Nitrogen makes up about 78% of the atmosphere by volume, yet very few organisms can use this gaseous nitrogen directly instead they depend upon soil minerals, especially nitrates as their source of nitrogen plants cannot incorporate nitrogen into organic compounds and therefore depend on various types of bacteria to make nitrogen available to them.

Nitrogen deficiency commonly limits plant growth. This is the main reasons that nitrogen is commonly applied in the form of artificial fertilizers.

The nitrogen cycle can be summarized as follow.

- Nitrogen Fixation

This refers to the conversion of the free nitrogen (N_2) in the atmosphere into nitrates, ammonia or other ammonium compounds. This is accomplished in several way

i.Biological fixation – This occurs when nitrogen (N_2) is reduced and added to organic compound by action of Nitrogen – fixing bacteria such as Azobacter and clostridium, the cyano bacteria in aquatic system and some free living bacteria in the soil are able to reduce nitrogen gas to ammonia (NH_3).

Other nitrogen – Fixing bacteria e.g.: Rhizobium infects and lives in modules on the roots of leguminous plants. They make reduced nitrogen and organic compounds available to the host plants.

ii.Electrochemical and photochemical fixation

In this process nitrogen gas is converted to nitrate (NO_3) in the atmosphere by lightening and other cosmic radiations on oxygen and Nitrogen lightening and other cosmic radiation provide high energy needed for nitrogen to react with oxygen.

iii.Industrial fixation – Fixed by chemical fertilizer industries to the nitrogen cycle when they convert nitrogen gas to nitrate for use as fertilizers.

- Nitrification
- **Nitrification** is the production of nitrates. Nitrogen is converted to Nitrate (NO_3^-) in several ways.

- By lightening and other cosmic radiation

- By the action of nitrifying bacteria ammonia (NH_3) in the soil is converted to Nitrates by certain soil bacteria in a two – step process flost, nitrite producing bacteria convert ammonia to nitrite (NO_2^-) this is achieved by free living bacteria such as Nitrosomonas.

$2NH_3 + 3O_{2+}\ 2NO_2^- + 2H^+ + 2H_2O$

Ammonia oxygen nitrite hydrogen ion water

The second step involve the oxidation of the Nitrite by other free living bacteria e.g. Nitrobacteria and nitro coccus

$2NO_2^- + O_2\ 2NO_3^-$

- Humans make a most significant contribution to the nitrogen cycle when they convert nitrogen gas to nitrate for use in fertilizer.

- Nitrogen used by plants and animals.

Plants take the nitrates from the soil and form proteins. When animals eat plants the proteins are converted into animal proteins. The breakdown of protein is excreted in the form of urea or uric acid or ammonium compounds. In the soil or water, decomposition of the waste takes place and nitrogen is converted back to free nitrogen involving number of steps.

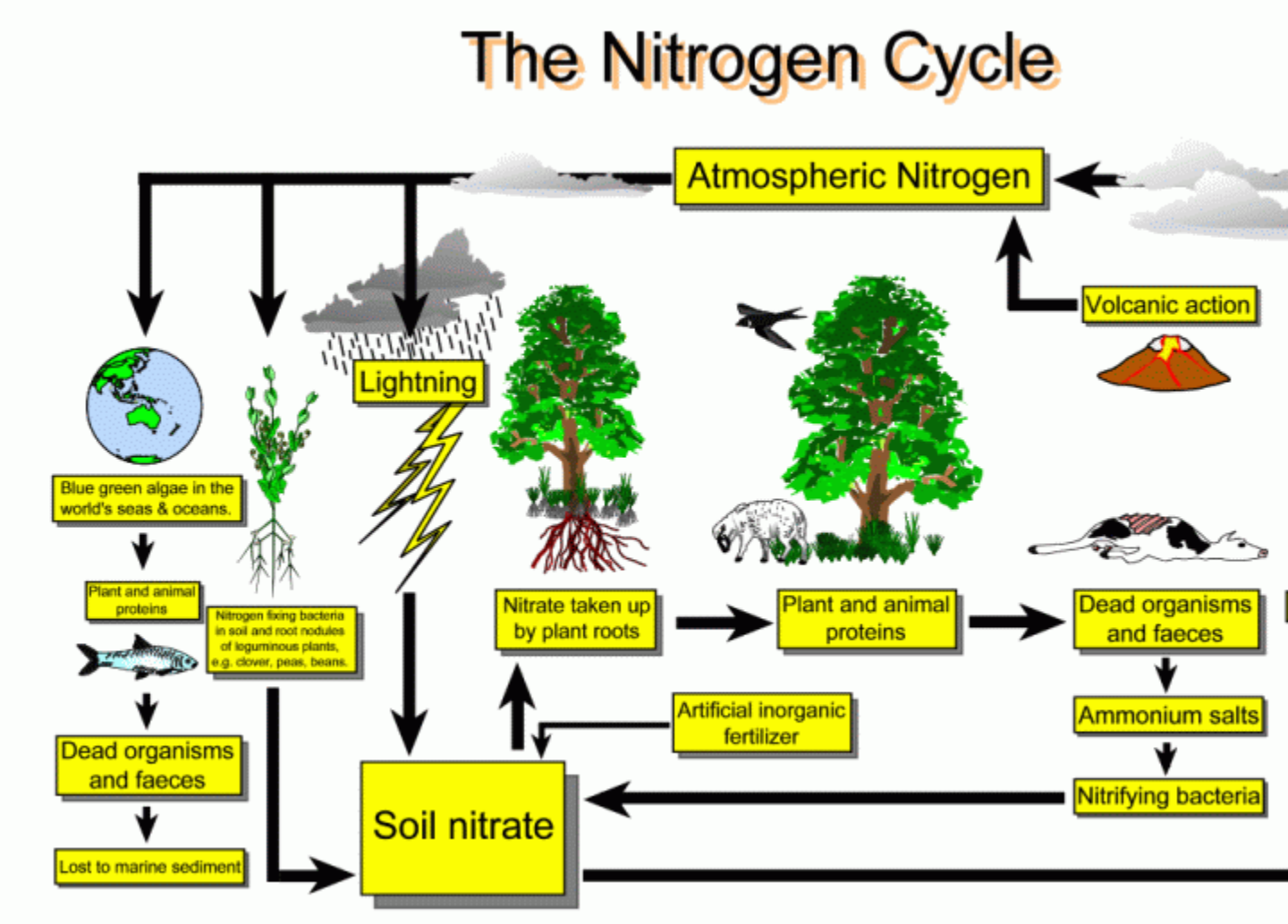
- Decomposition by Microorganisms

Like Actinomycetes and fungi and by ammonofying bacteria. These convert wastes and decayed and dead boodles to ammonia or ammonium compounds.

- Denitrifying bacteria

Denitrification is the conversion of nitrate to nitrogen gas. These are denitrifying bacteria in both aquatic and terrestrial ecosystem. Examples

are the Pseudomonas and Thiobacillus, Detoxification counter balance nitrogen fixation but not completely. More nitrogen fixation occurs especially due to fertilizer production.



CARBON CYCLE

Carbon is an element found in all organisms. It is a basic building block of all living things it is essential part of carbohydrates, fats and proteins. Carbon is present in the atmosphere as carbon dioxide the carbon enters the ecosystem through the producers.

In carbon cycle organisms in both terrestrial and aquatic ecosystem, exchange CO_2 from the air and through photosynthesis they incorporate carbon into food that is used by themselves and heterotophs.

When any organism respires a portion of carbon is returned into the atmosphere as CO_2.
In aquatic ecosystem, the exchange of CO_2 with atmosphere is indirect. Carbon dioxide from the air combines with water to give carbonic acid, which break down to bicarbonate ions.

(HCO_3^-). Bicarbonate ions are the source of CO_2 for algae, which produce food for themselves and for heterotrophic.

Similarly when aquatic animals respire, the CO_2 they give off becomes bicarbonate. The amount of bicarbonate in water equilibrates with the amount of CO_2 in air.

Carbon cycle can be summarized as follows.

- The producers (green plants and algae) use CO_2 to make food.
- Herbivores eat plants and carbon gets into the body of carnivores.
- Both plants and animals respire. The process returns CO_2 to the atmosphere.
- When plants and animals die, the decomposers break down dead bodies and carbon is released to the soil where it is absorbed by plant roots.

Some organic matter does not decompose easily instead, it build up in the earth's crust oil and coal were formed from the building of the plants and animal's matters millions of years ago.

The burning of fossil fuels has added much of carbon in the atmosphere in form of CO_2.

Reservoirs of Carbon

- Oceans and seas are large reservoir of carbon in form of HCO_3^-. This can be used to build up shells of marine organisms. Some reaction change bicarbonate into CO_2 that return to the atmosphere.
- Living and dead organisms contain organic carbon and serve as one reservoir for carbon cycle.

Living things particularly trees remains of plants and animals are estimated to hold billions of tons of organic carbon.

Some plants and animals remains before complete decomposition, were subjected to physical process that transformed these into coal, oil and natural gas. We call the material fossil fuels.

- Calcium carbonate that accumulate in limestone and calcium carbonate in carbonate shells.

  The influence of Human on carbon cycle

  The activities of human beings have increased large amount of CO_2 in the atmosphere. These activities includes:

- Burning of fossil fuels e.g.; coal and oils used for running machines and automobiles. These results into release of much CO_2 and other gases in the atmosphere.
- Burning of fuel wood i.e. firewood and charcoal

- Deforestation i.e. destruction of forests through burning on cutting trees.

  Deforestation reduces the total world volume of photosynthetic materials and thus reduces consumption of atmospheric carbon dioxide in photosynthesis.

  Removal of the tree canopy exposes the forest floor to sunlight and warmer temperatures. In forest or woodlands with significant filter and soil humus contents this expose will favor accelerated rates of decomposition and carbon dioxide release.

ECOLOGICAL NICHE

Ecological niche is the ecological team which is used to refer to the physical space as well as its functional role of a particular group of organisms.

Ecological niche have been defined in different ways.

- The niche of organism is defined as its profession or total role in a community, e.g. an organism can be producer, consumer, predator, scavenger or a decomposer.

- Defined as a place occupied by a species in an ecosystem and the way it use the resources of the ecosystem.

- The niche of an organism means its place in a biotic environment and its relation to food, enemies, habits and biological factors.

  A Population of each species within a community has a separate need. No two species within a community can have the exact same need. If two species do occupy the same need, it leads to competition until one is displaced.

Similar habitat in the world have similar ecological niches but may have different animals e.g. Open grasslands all over the world produce a need for fast running herbivores like horses, kangaroo, and antelopes.

ECOLOGICAL SUCCESSION

Formation of a community

A group of organisms of different populations co. existing in the same habitat

- Community ecology focuses on the development and stability of the communities.

A community is built up over a period of time

Does the community remain the same indefinitely?

A community is a dynamic unit

- A stable community is established through number of stages which are orderly.
- During the time of development there will be an orderly and progressive replacement of one community by another till a relatively stable community is established. This is called ecological succession.
- Ecological succession is the process in which a community is evolved from simple beginning to more complex which is more or less stable. A complete succession is called a sere.

A sere is made up of a number of several stages.

- A complete stable community is called a climax community.

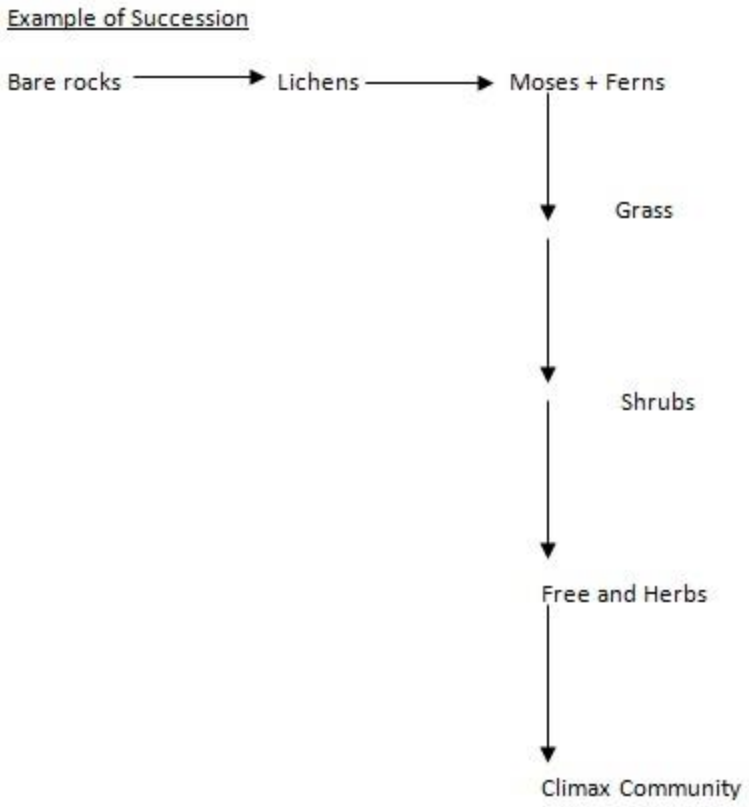
Types of Ecological succession

- Primary succession
- Secondary succession

1. **Primary succession** – Is a type of succession when the community is established where no community has previously existed.

E.g. On sandunes, volcanic island larva flows (bare rocks). The area is devoid of any organisms.

2.Secondary succession – Occurs where a community has been disrupted and the surface is completed or largely devoid of vegetation. It may be due to earth quake, fire or even clearing of forest by man.



METHODS OF STUDYING ECOLOGY

Sampling Technique

Sampling technique is a method of establishing a sample.

Sample – is a number of items all things taken from large group and used to provide information about the whole group.

Types of sampling

(i) Random sampling

- Is a type of sampling in which every item of the universe has an equal chance of inclusion in the sample

(ii) Systematic sampling

- It involves selection of every in the item in a list (an element of randomness is introduced into this kind of sampling by using random numbers to pick up the unit to which to start.

(iii) Stratified sampling

- Is a type of sampling in which the population is divided into several sub population on that are individuals more homogenous group than the total population.

The size of a sample (sample size)

- This refers to the number of item to be selected from the set of objects (population or universe) to constitute a sample excessively.

ADVANTAGES OF SAMPLING

- It makes the study easier since few organisms are involved.
- Since only few organisms are under study this save time and reduce the financial cost if large group of organisms were to be studied.

Sampling methods

- By transects
- By quadrants
- Point frame
- Pit fall
- Box trapping.
- Ways of establishing a sample
- Transects – line transect
- Belt transect.
- Quadrants – quadrat
- Pin frame (point quadrant)
- permanent quadrat.

Line transect

- Is a method where a tape or string is run along a ground in a straight line between two points or poles .

Belt transect

- A belt transect is simply a strip of chosen width through the habitat made by setting up two line transects say 0.5m to 1m a part.

What is a Quadrant?

- A quadrant frame is a metal of wooden frame preferably collapsible to facilitate carrying, which forms a square of known area such as $0.25m^2$ or $1m^2$
- The way a quadrant is used

i) Random throw

ii) Used with line transects

- The use of these methods depends on (number of factors) nature of investigation.

Other types of quadrants

Pin frame (point quadrant).

- This is a frame bearing a number of holes through which a pin "such as knitting needle can be passed"

Permanent quadrant

- This is used in long term ecological investigation involving the study of community change (succession or seasonal changes).

Other methods

- Computer program
- Direct observation
- Photographs
- Pit fall trap
- Box trapping

Capture – recaptured methods

This methods involves capturing the organisms, marking it in some way without causing it any damage and replacing it so that it can resume a normal role in a population e.g. Fish are netted.

$$\text{Estimated total population} = \frac{\text{No. of organisms x No of organisms In initial sample x in second sample}}{\text{No. of marked organism captured.}}$$

- The capture – recapture method of sampling is used to try to estimate the entire population, a sample of animals is caught and tagged their number noted and then released into their habitat. Later another sample is captured and the proportion of tagged animal in this sample should be representative of the proportion of tagged animal in the whole population and then the total population size can be estimated using this formula.

  Total = original no tagged x total recaptured

  No. of tagged on recapture

  Some examples of how to use this formula

  Example 1

  50 animals are caught and tagged and released. Later 220 animals are caught and it is noted that 35 of their animals are tagged. What will be the total population estimate?

$$\text{Total} = \frac{\text{original No. tagged x total recaptured.}}{\text{No. of tagged on recaptured}}$$

  = 50 × 220 ÷ 35

  = 314.28

  Example 2.

  A biologist caught 100 deers in a forest, tags them and releases them back in the forest. A year later he caught 90 of which 12 had tags, estimate the total population of the dear.

$$Total = \frac{100\ x\ 90}{12}$$

$$= 750$$

The use of quadrats direct observation and photography are known as direct counting methods, where as capture recapture technique is indirect counting method.

Different methods that are used to establish the samples provide the means of calculating three aspects of species distribution.

- Species density

This is the number of individual of a given species in a given area such as 10 per meter^{2} (10m^{-2})

- Species Frequency

This is measure of the probability (chance) of finding a given species with any one throw of a quadrat in a given area.

Example:

If the species occur once in any 10 quadrats it has a frequency of 10%.

- Species cover

This is a measure of the proportion of ground occupied by the species and gives an estimate of the area covered by the species as a percentage of the total area.

Capture method by removal

- In this method the number of animals captured is recorded and the animal kept. This procedure is repeated a further three times and the gradually reducing number recorded. A graph is plotted of number of animals captured per sample against the previous cumulative number of animal captured. By extrapolating the line of the graph to the point at which no further animal would be captured (i.e. number in sample = 0)

Example

Sample	No. in sample	Cumulative sample size
1.	120	0
2	93	120
3	60	213

Population dynamics

- A group of organism of the same species occupying a particular species and usually isolated to some extent from other similar groups by geographical factor / topography.

- Population studies are not just about the number of a given species living in a given area at given moment in time but it includes also how population grow, how population is maintained and how and why population decline.

Define population dynamics

- Population dynamics is the study of how and why population size changes over time. It examines the characteristics of a group of organisms such as density, natality (birth rate), survival ship, age structure, migration and from of growth of the population.

The population size – refers to the number of individuals / species in a population.

Factors that affect the size of population

1. Birth rate (Natality rate)

2. Mortality rate

3. Migration

Population size increase or decrease depending on the number of factors

What causes population increase?

Population size increases as a result of immigration from neighboring populations or by reproduction of individuals within a population. Reproduction is expressed as birth rate or natality.

Birth rate – refers to the number of Youngs produced per female per unit time (usually per year)

Population size may decrease as result of emigration or death (mortality). In population biological mortality strictly means rate of death it can be expressed in terms of percent or numbers per thousand dying per year.

Population growth – Refers to the increase in population.

Population growth can decline in characteristics ways

The factors that affect population growth

- Reproductive potential of the organism
- The rate of reproduction given unlimited environmental resource.
- Environmental resistance
- This is the sum of total limiting factor both biotic and abiotic which act together to prevent the maximum reproductive potential from being realized. It includes external factor such as predation, food supply, heat, light and space, and internal regulatory mechanisms such as intra specific competition and behavioral adaptation.

Factors within the species which affects population growth

Population growth may change as a result of changes in birth or death rate. Food shortage and increase in predation are two factors which have direct effect on mortality.

Birth rate is affected by two regulatory mechanisms;

- The territorial behavior
- Physical effects of over crowding

Many animals exhibit territorial behavior

A territory – is an area usually fixed in location that individuals defend and from which other members of the same species are usually excluded.

- Territories are typically used for feeding, mating, rearing of young or combination of these activities.
- Territorial animals benefit in several ways they have exclusive access to food supplies and breeding areas within their territories.
- Also familiarity with their areas help them to obtain food there and avoid predators
- Moreover they can care for their young without interference from other individuals of the same species.

Over crowding

In a number of mammals high population density reduces greatly the birth rate even if there is good shortage.

Various hormonal changes occur which affect the reproductive behaviors in a number of ways e.g. Failure to copulate infertility, number of abortion and eating of the young by the parents all increase and parental care disease.

Factors between species which affect population growth

A number of well recognized types of interactions may occur between populations of different species. These are termed as interspecific interaction, population from different trophic levels may also interact as for e.g. in case of predator- prey relationship and host parasite relationship.

- Population growth curves
- Two basic forms of growth curves can be identified.

- The j-shaped growth curves

- The S-shaped growth curves or sigmoid growth curve.

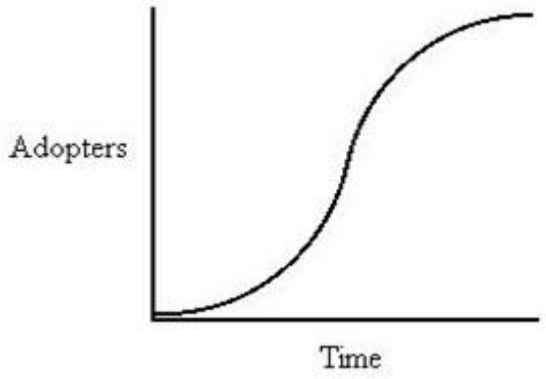
The S- Shaped or sigmoid growth curve

This describes a situation in which in new environment, the population density of an organism increases slowly initially, as it adapt to new conditions and establish itself, then increases rapidly approaching an exponential growth rate. It then shows a declining rate of increase until zero population growth rate is achieved where rate of reproduction (Natality) equals rate of death (mortality).

The slowing rate of population growth result from increasing competition for a essential resources such as food or nesting material.

The decline in growth rate continues until eventually feedback in terms of increased mortality and reproduction fails (fewer mating, stress induced abortion) reduces population growth rate to zero.

This type of population growth is said to be density dependant since for a given set of resources, growth rate depends on the numbers present in the population.



- J-Shaped growth curve

- This type of growth curves describes a situation in which after initial establishment phase (lag phase) population growth continues in an exponential form until stopped abruptly as the environmental resistance becomes suddenly effective.

- Growth is said to be density independent since regulation of growth rate is not tied to the population density until the final cash.

- The crash may be triggered by factor such as seasonality or the end of a breeding phase, either of the organism itself or of an important prey species. It may also be associated with a particular stage in a life cycle such as seed production or it may be included by human intervention.

BIOMES

- A biome is a large region in the biosphere that possesses characteristic physical condition on that support organisms which show adaptations to those condition found there.

OR

- Is a collection of similar ecosystem in a particular region of the earth, it could be a habitat or zone such as desert forest, grassland or water bodies such as ocean, lakes etc.

OR

- Is a largest terrestrial communication or a largest ecological unit.

- A biome has a specific kind of plants and animal species within a geographical area that has distinct climatic conditions. A biome is a product of physical factors that influence the rainfall, temperature and light.

Example of terrestrial biomes.

A major biomes includes

- Tundra
- Northern coniferous forest or Taiga
- Deciduous forest
- The Mediterranean shrub
- Tropical savannah
- Grassland

- Desert

Biomes that involve aquatic ecosystems

- Marine environment
- Fresh water environment
- Human population is the most abundant (about 7 billion) which is next to certain species of fishes and insects.
- Human population is widely distributed on earth in almost all climatic conditions from arctic to Antarctica.
- The population differ economically, socially, culturally and color and height in different part of the world.
- The study of trends in human population growth and the prediction of future development is known as demography.

  Demography involves the study of various parameters along with number and proportion of different age group, educational requirements training and employment.

  Factors affecting patterns of human population.

  The human population growth patterns differ in different region of the world due to various factors some of these are discussed below;

- Climatic and Edhapic factor

The region of extreme heat like deserts or extreme cold like Arctic and Antarctica are less populated.

- Location of natural resources
- Transport facilities.
- Industrial development and education

  Demography factor

  The birth rate and death rate of a population determine an overall population growth. It varies in different countries.

Human population growth patterns

- Rate of growth of human population is not uniform in all the countries, the developed countries have stable or negative growth rate (both the birth and death rate are low).

The developing countries have high birth rate and the population is increasing at an enormous rate.

- Rate of growth differ among different group of people within a country.
- The population of the urban areas is leading to overcrowding and is causing adverse environmental implications.

POPULATION EXPLOSION AND THEIR CONSEQUENCES

The human population as a whole is growing exponentials having doubled three times in the last three centuries, it now stand at 6 billion and may reach 8 billion by the year 2020.

Most of the increase is due to improved health and technology which have decreased the death rate. The human population faces uncertain feature, although some are optimistic about our ability to expand, earth's carrying capacity, others are concerned that our increase in numbers may damage the biosphere beyond repair.

Human impact on the ecosystem

Since the development of agriculture and technology on increasing human impact on the environment has occurred. In last two centuries especially wide spread industrialization has lead to potentially damaging environmental pollution.

POLLUTION

- Is the release into the environment of substances or energy in such quantities and for such duration that they cause harm to the people or other organisms or their environment.
- The harmful substances are collectively known as pollutants
- Pollutants destroy the natural quality of the environment.

Example of pollutants

- Agricultural chemicals such as fertilizers, pesticides and herbicides
- Industrial by products or emissions such as sulphur dioxide, mercury, carbon monoxide, CFC'S lead, cadminium
- Sewage
- Smog

- Oils
- Radiations such as gamma rays, x-ray
- dusts

CONSERVATION

Natural resources:-

- Materials form the natural environment / ecosystem that man can use.

Types:

- Renewable resources: - Are those which can be replaced within a short period of time after being used e.g. water, wildlife forest e.t.c.
- Non- renewable resources: - Cannot be easily replaced within a short – time e.g. tonsil foils, minerals.

Conservation – retaining the status quo through careful management i.e. preservation of species, habitats and living system from harmful influence of man this avoiding decline and extinction of species and permanent detrimental / degradation to the environment.ã€€

Reasons for conservation

We conserve to maintain world ecosystems by conserving the terrestrial, aquatic & aerial habitats,

- Ethical reasons – cultural, tradition, religious beliefs, political persuasion, shape our attitude toward nature.
- Nature does not exist simply for humans to transform & modify because all living species have a right to coexist with us on earth. Man has no right to cause the extinction or to diminish the quality of life of any organism.
- Custodianship – Man has to pass on to the future generations to all the diversity of life & quality of environment that we inherited.
- Athletic reasons – Humans derive pleasure from pleasant environment & the presence of other living organisms.
- Local national & international organization exist worldwide to promote wildlife contribute to our immediate needs e.g. in forestry many plant species have important medical uses.
- Fisheries from water bodies as direct source of food

- Agriculture – We have to conserve food stocks and soil quality for crops.
- Usage of pollinating insects & beneficial predators in pest control.

ECOLOGICAL / SCIENTIFIC REASONS

- Maintenance of balanced biochemical cycles to avoid pollution & regulation of the earth's climatic conditions.
- To avoid deforestation & desertification.
- To avoid loss of vegetation cover this may affect soil erosion leading to accumulation of mud on river beds & costs.
- Reduce extinction of species to retain diversity gene pool (retaining biodiversity)
- To preserve care species that may have generation potential.
- To minimize effects of mining / drilling/ urbanization.

Measures Taken to conserve the environment / Need for sustainable use of environment resources.

- People should be educated on the importance of our environment by:-
- Encouraging them to plant trees
- Encouraging the use of organic manure & good agricultural practices in agriculture such as terrace farming on hill sides, crop rotation.
- Discouraging harmful traditions such as burning / slash method of farming to clear the land.
- Legislation
- Laws that govern the protection of national parks/ grass kinds & punishments for those who start bush fires
- Laws that protect the endangered species as a means of preventing extinction e.g. rhino
- Some animal species must be regulated to avoid over – population e.g. wild beasts.
- Reduction of pollution e.g. by using lead free petrol, alternate energy source (solar power, ethanol cars) use of bio degradable products, recycle waste such as paper to avoid deforestation, glass & cans water as resource & its sources must be preserved. Government should increase biodiversity by increasing botanical gardens, seed banks & field gene banks.
- Sustainability – exploitation of natural resources & conserving then for future generations.

WASTE MANAGEMENT

- Avoid excessive use of chemicals such as pesticides and herbicides.
- Encouraging biological control.

BIOLOGICAL CONTROL

- Is the artificial control of pests & parasites those which compete with human for food or damage the health of humans or livestock by the use of organisms or their products & therefore it is based on predator – prey relationship. The control agent either control the pest by feeding on it (lady bird or aphids, caterpillars larvae of butterflies & moths) are parasitized by bacillus species or by causing disease to the pests e.g. Virus sprays on army worm caterpillar.

Aim of biological control

- Is to bring the population of the pest down to a tolerable level and not to eradicated by its natural enemy.

Advantages

- It doesn't pollute the environment
- It's easy to apply as it doesn't involve the use of sophisticated machine
- Its effective through generations as the pest will not develop resistance to the predator as it is with the pesticides & herbicides. Thus time to time application is not important.
- The predator eliminates or feeds / affects the intended organisms or i.e. it is selective.
- It is cheap.

Disadvantages:

- The beneficial organisms may also be eliminated due to lack of food if it dominates the harmful organisms or pest which may cause / lead to disruption of food chain.
- The predator (agent) may turn into a pest by feeding on other useful organisms instead of feeding on the intended organisms' e.g. after controlling the pest population it may become a pest itself.
- It's expensive i.e. involves studying the biology of the pest & the predator & this may take a long time.

- If important agents / predators may fail to survive when the environment of the new country changes.

- Biological control may not be effective if the pest outbreak is high because the agent/ predators are fairly slow to react / to eat to large numbers of pests. The population of pest species left may still be great enough to continue causing damage.

EVOLUTION

ORGANIC EVOLUTION.

- Organic evolution is a gradual change in the genetic composition of organisms in a population during successive generations leading to formation of new species from pre-existing species.

FORCES/PRESSURES LEADING TO ORGANIC EVOLUTION

1. **PRIMARY FORCES:** Are the ones which must be there for new species to be formed from pre-existing species. Thus, if absent no organic evolution takes place.

These forces include:

- Mutation
- Gene recombination
- Natural section

NB: Natural selection must be present with either one of the two forces (mutation and or gene recombination)

2. **SECONDARY FORCES:** These are forces that modify rate of organic evolution i.e. if present, rate of evolution of the species are faster, but it absent the rate is slower.

These include:

- Gene flow
- Genetic drift

- Breeding
- Adaptive radiation/geographic isolation

THEORIES OF ORIGIN OF LIFE

1. Special creation

- Species are immutable (not changing)

- Life was created by a supernatural power at a particular time i.e. God made living things once upon a time and whatever is existing today is a result of reproduction. If God wants a new species he just

  says BE and there it is.

Strength of the theory:

- **Faith** i.e. believing and accepting this with no evidence.

Weakness of the theory:

- Cannot be proved or disapproved by science as science goes with experiments and observation.

2. Spontaneous Generation

- This theory was common in ancient Chinese, Babylonian and Egyptians
- Nature passes from lifeless to animals in an unbroken sequence.
- Particles of matter contained an active principle which could produce a living organism under favourable conditions. This active principle was present in fertilized eggs, seed, sunlight, wheat, decaying meat, natural forces and decaying earth, mud.
- Van Helmont (15^{th} century) did an experiment which gave rise to mice in 3 weeks; the raw materials were a dirty shirt, wheat grains and a dark cupboard. The active principle was thought to be human sweat.

Strength of the Theory

- Life arises from non-living matter on a number of separate occasions.

Weakness of the theory

- In the experiments, there were no controls, in which each variable could systematically be eliminated.

3. Cosmozoan theory (Panspermia theory)

There has been an extra-terrestrial organ i.e. life arose on this planet from somewhere else. life could have arisen once or several times at different times and on several parts of the universe.

Strength of the theory

- The sightings of UFO's, care drawings of rocket like objects and 'spacemen' and reports of encounters with aliens provide the background for this.

Weakness of the theory

The theory does not talk about the origin of life but perpetuation of it.

THEORIES AND MECHANISM OF ORGANIC EVOLUTION

LAMARCKIAN EVOLUTION

His account for mechanism of evolution is based on the following:

1. Change in the environment creates new needs
2. Use and disuse of organs (organs are elastic)
3. Inheritance of acquired characteristics.

SELECTION

Selection is a process by which organisms, which are better adapted to surrounding, survive and breeds, while those less adapted fail to do so.

Importance of selection:

It has adaptive significance in

1. Perpetuating those organisms' with better traits and thus ensure survival of these organisms.
2. Selection determines which genes (alleles) pass to the next generation by virtue of the differential advantage; they exhibit as expressed as phenotypes therefore Selection pressure increases or decreases the spread of alleles, within the gene pool and the changes can be evolutionary.

TYPES:

1. Natural selection
2. Artificial selection (selective breeding)

NATURAL SELECTION

- Is a selective force such as natural disasters (drought, floods, earthquakes, diseases, fire), competition for food, water, mates, breeding areas operate on the variations are selected out by natural selection.
- A greater proportion of the offspring in the next generation will be products of the suitable variants. This leads to changes in the gene frequency of the population, which can lead to evolutionary change.

ARTIFICIAL SELECTION

- Man selects animals and plants with traits he wants for mating, propagation, and pollination.
- The individuals lacking desired qualities are prevented from mating by sterilization, segregation.
- Members of the species selected are those that show favourable variations such as increased yield of eggs, milk, fruits, wool, early maturity such as cereal crops, resistance to diseases and hardness.
- Man exerts a directional selection pressure which leads to changes in alleles and genotype frequency within the population.

Importance: Continued selective breeding by human has produced varieties, new breeds, strains, races, sub-species of animals and plants of agricultural importance.

Types of Artificial Selection

- Inbreeding
- Out breeding

INBREEDING:

- Inbreeding is a process involving selective reproduction between closely related organisms in order to retain and propagate the desired traits e.g. between offsprings produced by the same parent.
- It is practiced in breeding show animals such as cats and dogs. It is used by livestock breeders to produce cattle, pigs, poultry and sheep with high yield of milk, meat, eggs, wool resp.
- Prolonged inbreeding can lead to reduced fertility especially when breeding livestock.
- It can lead to reduced variability of the genome (sum of alleles of an individual).

Solution

- Resort to out breeding after several generations of inbreeding.

Forms/mechanisms of inbreeding:

- Self fertilization

OUTBREEDING

- Involves crossing individuals from genetically distinct organisms i.e. between different varieties or strains and sometimes closely related species.
- The offspring's of such a cross are hybrids. It is applied mostly in plant breeding and commercial production of meat, wool and eggs.
- The hybrids show hybrid vigour (phenotypes show traits which are superior to either of the parental stocks. Increased vigour results from increased heterozygosity in gene mixing.

Limitations of out breeding:

Interbreeding F1 for a long time decreases hybrid vigour (heterozygosity) due to increase in homozygosity.

SPECIATION

Speciation is a process by which new species are formed from pre-existing species.

Alternative ways of defining a species:

Biological aspect	Definition
Breeding	A group of organisms capable of inter breeding and producing fertile offspring
Ecological	A group of organism sharing the same ecological niche; no two species can share the same ecological niche
Genetic	A group of organic showing close similarity in genetic karyotype.
Evolutionary	A group of organic sharing a unique collection of structural and functional characteristics from certain ancestors.

TYPES OF ISOLATION

Geographical isolation

- A population which normally interbreeds freely may be separated by physical barriers/geographical barriers such as mountain ranges, deserts, oceans, rivers and canals etc. Under such circumstances,

  the separate groups (demes) of the same species can no longer interbreed i.e. prevented from meeting hence barrier to gene flow.

- Each side of a barrier has different environment conditions and thus new selective forces begin to operate.
- The population will eventually be so different that they can no longer interbreed even if the physical barrier were to be removed therefore new species have been formed hence evolution.
- This type of isolation may also be referred to as allopatric speciation.

Reproductive isolation/Physiological isolation

Groups live side by side but fail to produce fertile offsprings and to interbreed. This is due to the fact that the groups have accumulated sufficient structural, functional and behavioural characteristics difference that when mixed inter breeding does not occur. This is realised through

(a) Mechanical isolation

- In case of animals, genitalia of 2 groups are incompatible i.e. failure of male penis to enter the female vagina and no successful copulation.
- In case of plants related species of flower are pollinated by different animals.
- Gametes are prevented from meeting

(b) Seasonal isolation

(c) Behavioural isolation

- Occurs where animals exhibit courtship patters.
- Mating only results if the courtship display by one sex results in acceptance by the other sex e.g. in some fish and birds.

NB: In some cases, fusion of the gametes may not occur sperms reach the ovum, pollen grains reach the embryo sac but the gametes may be incompatible and might not fuse.

Post zygotic mechanisms (Barriers affecting hybrids)

Hybrid inviability: Hybrids are produced but fail to develop to maturity; for example hybrids formed between northern and southern races of the leopard frog (rana pipiens) in North America.

Hybrid sterility: Hybrids fail to produce functional gametes, for e.g. the mule (2n=63) results from the cross between the horse (equals equus, 2n = 60) and the ass (Equals hemionus, 2n = 66).

Hybrid breakdown: F1 hybrids are fertile, but the F2 generation and backcrosses between F1 hybrids and parental stocks fail to develop or are infertile for e.g. hybrids formed between species of cotton

(genus Gossypium).

Types of speciation

(a) Allopatric Speciation:

Characterized by the occurrence at some stage of spatial separation. Geographical barriers may produce a barrier to gene flow because of spatial separation. This inability of organisms or their gametes to meet leads to reproductive isolation drift in small populations lead to changes in allele and genotype frequencies. Prolonged separation of populations may result in them becoming genetically isolated even if brought together and thus arising of new species.

- Example, the variety and distribution of the finch species belonging to the family Geospizidae on the Galapagos Islands. It is suggested that an original stock of finches reach the Galapagos Islands from the mainland of S. America and, in the absence of competition from endemic species. (Representing relaxed selection pressure), adaptive radiation occurred to produce a variety of species adapted to the particular ecological niche. The various species are believed to have evolved in geographical isolation to the point that when dispersal brought them together on certain islands they were able to co-exist as separate species.
- Involves evolution/formation of species as a result of population being separated by the geographical barrier.

(b) Sympatric speciation

- Genetic differences may accumulate allopathically in populations which have been geographically isolated for a much shorter period of time. If these populations are brought together, hybrids may form where these overlap. E.g. both the carrion crow and the hooded crow are found in the British Isles.
- The carrion crow is common in England and Southern Scotland. The hooked crow is found in the north of Scotland. Hybrids formed from the mating of the two occupy a narrow region extending across central flow between the populations of the 2 crows.
- In time selection against cross-breeding may occur leading to speciation in the same geographically area, hence sympatric speciation.
- This speciation does not involve geographical separation of populations at the time at which genetic isolation occurs. It requires the development of some form of reproductive isolating mechanism which has arisen by selection within a geographically confined area. This may be structural, physiological, behavioural or genetic.
- Involves formation of new species not involving any geographical isolation, but formed by other isolations e.g. physical.

  Genetic recombination brings about variation to crossing over between non sister chromatids prophase I & meiosis, random assortment of the homologous x – somes and their movement to different cds. Also random fertilization.

- These variations are inherited, some being useful to the organisms gives the organism a slightly better chance of survival and some are less useful. Incase of environmental change over a long time
- In a course of time the surviving forms, may be sufficiently different from the original species that they can be called new species.

Mutation is sudden/spontaneous/abrupt change in the amount or chemical structure of DNA molecule. The changes create genetic variation among members of the same species. If the mutation confers/gives an advantage to the organism that under selective environmental selective pressure, it will be selected for against the less fitted mutants. The selected ones will have a reproductive advantage and will reproduce more offspring. This process may result into formation of a new species different from its predecessor e.g. Biston, introduction of antibiotics in 1940 a strong selective pressure for strains of bacteria that have genetic capability of resistant to antibiotics as a result of mutation.

Natural Selection

The environmental changes are the main mechanism for effecting natural selection.

Mechanisms for natural selection

- Individuals in a given population which are less fit are gradually eliminated while those with adaptive features are being favoured.
- Organisms with variations (variation could have arisen from genetic recombination and or mutation) best adapted to the environment have a reproductive advantage thus producing more offsprings than the one of the favoured individuals increase while that of the unfavoured individuals decreases.
- If the trend is maintained over a long time, a new species may arise e.g. evolution of Biston Bitullaria Carbonica is due to industrial revolution in UK which produced a lot of SO_2. The SO_2 made the leechens black and so camouflaging the black moth while the white one Biston Bitullaria Typical was preyed upon the birds. The black gene arose by mutation.

Geographic isolation

Two or more populations of the same species, occupying the same habitat become separated by a physical barrier like mountains, rivers, valleys. In such a situation, the gene pools of each population do not mix with one another i.e. no gene flow. Each population try to adapt itself to the changing environment. The less fit individuals are eliminated and the more fit keep on increasing in number. As the process of adaptation continues for a long time in the different geographical areas, the population becomes distinctly different from each other. Hence new species have arisen e.g. Galapology, finches, Ilamas and camels.

How changes in the environment create needs?

- Animals and plants respond to the environment by becoming better adapted to them.

- As environmental conditions change it may lead to changes in behavioural pattern which can require increased use/disuse of certain organs.
- Those organs which are frequently used will become stronger and develop and vice versa.
- Developed structures are inheritable thus acquired characteristics e.g. webbed feet in ducks, long necks in giraffes, limbless, snakes.

Example

- The long neck and legs of modern giraffes were the results of generations of short necked and short legged ancestors feeding on leaves at progressively higher levels of trees.
- The slightly long necks and legs produced in each generation were passed onto the next generation.

In a course of time, the whole population contained long necked and legged giraffes which we see today.

Hence they are evolved.

- The case of webbed feet ducks also applies.

Strength of theory

- He was correct by saying that change in environment creates new needs e.g. webbed toes.
- The theory was useful in bringing up the idea of evolution i.e. created the foundation for Darwin and Wallace.
- This theory applied explained the existence of vestigial organs i.e. when not in use; the organs will disappear or become non-functional.
- He emphasized on the rate of the environment in producing the change in the individual.

Weakness of the theory

Inheritance of acquired characteristics was not true e.g. the son of a boxer would not necessarily be a boxer, because the change in the environment led to the change in behavioural pattern which did not

affect the gametes which were means of passing the straits to the next generation.

DARWIN'S THEORY

Was based on natural selection and survival of the fittest

Essential features:

1. Over production of offsprings
2. Constancy in number of population
3. Struggle for existence due to competition

4. There is variation among organisms
5. Survival of the fittest
6. Formation of new species

Observations

1. Individuals within a population have a great reproductive rate.
2. The number of individuals in a population remains approximately constant due to environmental factors such as food, space, light, water, breeding sites, etc.
3. Variations exist within individuals in a population.
4. Those surviving individuals have a reproductive advantage and will give rise to next generation which are better adapted to the environment.

Deductions

- From 1 and 2, many individuals fail to survive or reproduce therefore there is "struggle for existence" due to competition.
- From 3 and 4, in the struggle for existence, individual showing variation has adapted to the environment and will be favoured than others, who are not adapted.

Strength of the theory

- In absence of environmental factor every species tends to over produce remains fairly constant

- High mortality rate especially in young occur and so only a few reach the reproductive age.
- Competition occurs between organisms for the available resources and therefore there is struggle for existence.
- There are variations among individuals.
- In struggle for survival individuals with variation will reach reproductive maturity.
- Favorable traits of these individuals will be passed on to the next generation and thus the survival of fittest.

Weakness of the theory:

- The theory does not explain the (origin of the specie)
- The theory does not explain the (existence of vestigial) structure.
- According to the theory, the cause of imp (variations) complex structures among individuals which result information of new species are not explained e.g. imitation, polyploidy and meiosis)
- The theory is silent on how (variations are passed) to the offsprings from one generation to the next.
- The theory does not explain on the (survival of the unfit individuals) in nature that reaches reproductive age.
- The theory does not explain (how natural selection occurs)

- Does not explain how variations arise.
- Does not explain the difference between environmental and genetic variation.

According to Darwin:

- There are many populations of giraffe which could progressively reproduce.
- However, their number remains constant
- The giraffes were of many variations; some short, long and middle necked so in the struggle for existence, the short and middle necked would not survive and die out therefore the survival of fittest.
- Long necks would reach for higher trees and therefore reproductive age and the next generation were of many giraffes with long necks, where as the short necked giraffes perished and in course of

  time, due to natural selection, we have the long necked giraffes at present.

- Similar explanation for development of webbed feet in duck and development of limbless snakes.

EVIDENCE FOR ORGANIC EVOLUTION

There is several evidence

1. PALAENTOLOGY

Palaeontology is the study of fossils

Definition: Fossils are any form of preserved remains thought to be derived from living organism over millions of years.

- They are formed from preserved hard parts of an organism e.g. bones, teeth and shells. These are found in sedimentary rocks formed from deposition of mud, silt, or sand one thousands to millions of

  years.

S/N.	TYPES OF FOSSIL	FASSILISATION PROCESS	EXAMPLES
1.	Entire organism	Encased in tar Frozen into ice during glaciations	"Mummies" found in asphalt and lakes of California. Woolly mammoths in Siberian

2.	Hard skeletal materials	Trapped by sedimentary sand and clay which form sedimentary rocks e.g. limestone, sand store	Bones, shells and teeth
3.	Impressions	Impressions of remains of organic in fine grained sediments on which they died.	Feathers of Archaeopteryx in upper Jurassic. Jelly fish in Cambrian in British carboniferous leaf impressions.
4.	Imprints	Footprints, traits, tracks and tunnels of various organisms made in mud are rapidly baked and filled with sand and covered by further sediments.	Dinosour foot prints and tail scrapings indicate size and posture of organism
5.	Coprolites	Faecal pellets prevented from decomposing, later compressed in sedimentary rocks often contain evidence of food eaten e.g. teeth and scales.	Cenozoic mammalian remains.

Evidence:

- Deeper layers usually contain simpler forms of organisms much older compared to upper layers which are complex but young i.e. most fossils occur in sedimentary simple structure fossils. Younger rocks

  contain more varieties of fossils with increasing complex structure.

- Fossils show gradual change from one form to another as we move from the deeper layer cupboards.
- Therefore changing environment may have favored a mechanism for evolutionary change that account for a progressive change in the structure of the organic e.g. fossils we have today.

Archaeopteryx – reptilia and aves

Symoria - amphibia and reptilian

Synognathics – reptilia and mammals

- Fossil record is not continuous i.e. missing links due to unfossilization of some soft bodied organisms on, dead organisms of decay rapidly or they may have been eaten by scavengers or they have not

  been discovered yet.

2. COMPARATIVE ANATOMY/ MORPHOLOGY

Likenesses in anatomy among different kinds of organisms produce evidence that evolution has taken place as revealed by homologous analogous organs.

Homologous structures – Structures performing different functions but showing a common ancestral origin some position in the embryonic state and have the same microscopic origin of tissue.

Organs with different functions with similar basic form, microscopic structure, embryonic development but different functions due to changing environment. E.g. ear bones – jaw of fish, haters (hind pair of

wings in most insects have been modified in dipteral to form natters) to maintain balance during flight, pentadactyl limb, fertilized ovary wall, mouth parts of insects.

Analogous Structures:

Different ancestral origin and development but with same function e.g. eyes of vertebrates and cephalaploid molluscs, winds of birds and insects.

Vestigial Structures;

Structures which have ceased in function due to course of time and are passed non-function due to course of time and are passed non-functional from generation to generation. These are homologous to

structures that are functional in other organisms e.g. appendix in humans is vestigial but in herbivores, it is for digestion, the coccyx in humans and tails in crocodiles.

Snakes have no limbs but some function less limb bones can be found in the skeleton of some insects; other reptiles like lizards have limbs suggesting that ancestors of snakes had limbs.

3. BASIC BIOCHEMISTRY

Basic cellular structure – known to occur in large number of groups of organisms e.g. nucleic acid in all organisms e.g. Genetic code/DNA is the same in many organisms and there is very basic similarities in

chemical processes taking place in cells; chlorophyll in all photosynthetic plants, chtochronein

all aerobic respiring organism and energy stored in ATP within cells. In vertebrate Hb is for transport of O_2 and

haemocyanin in insects (common pigment) genetic code is the same, therefore protein synthesis is similar (but diff sequence of amino acid) ATP molecules in all Eukaryotic plants and animals.

Basic physiological processes: a great similarity in the physiological processes among different groups.

The above suggest a common ancestral origin from which these features are inherited.

4. **BIO – GEOGRAPHY**

- There is no even distribution of species on the earth due to continental drift which separated the land mass organisms were isolated.
- Different zones have their characteristic flora and fauna though they may have same climatic conditions e.g. elephants are found in Africa and India but not in South America which has similar habitat Britain (England Ireland) with similar climatic conditions have different flora/plants (veg) and fauna/animals (climate).
- The above suggest that the species have originated from a particular area.
- To avoid overcrowding the intra and inter specific competition, the organisms disperse/spread.
- In the new area, the organisms undergo adaptive radiation to cope up with the new condition.
- The climatic/topographical and other.

Steady State

- Life has no origin
- This theory assets that the Earth had no origin, has always been able to support life, has changed remarkably little, if at all and that species had no origin
- This theory proposes that species never originated, they have always existed and that in the history of species the only alternatives are for its nos. To vary, or for it to become extinct.