GROWTH AND DEVELOPMENT:

Key words

1. ***Growth*** is the permanent increase in the size and dry mass of an organism or its part. Growth is due to synthesis of protoplasm or extracellular substances (cell division, cell elongation)
2. ***Development***: is an irreversible increase in complexity of an organism or its part, which occurs as of growth and differentiation.
3. ***Cells differentiation***: modification in structure of cell to become specialized and perform specific function.

The factors which affect growth in organisms

- ✓ Nutrient supply.
- ✓ Hormonal level e.g. auxins in plants.
- ✓ Temperature, light, oxygen level and water availability
- ✓ Genes.
- ✓ pH of soil

WAYS OF MEASURING GROWTH

- Increase height, increase in length, dry mass, increase in fresh mass, and measuring the leaf surface area

Advantages of measuring growth by increase in height or length

- It is easier to measure the length or height of the organism or part of the organism
- It doesn't involve killing of the plant

Disadvantages of measuring growth by increase in height or length

- Shoot may grow in length but not increase in dry mass.
- There is a lot of variation in length or height compared to mass e.g. leaves may have different lengths but the same height

Advantages of measuring growth by increase in mass

- It represents the whole organism or structure. Fresh mass or dry mass may be measured. It can be a better method of measuring agricultural yields
- ***Dry mass*** is the mass obtained after removal of water from an organism.

Advantages of measuring growth by dry mass

- More reliable than measuring increase in fresh mass because living organisms especially the plants can lose or gain water depending on availability irrespective of growth
- Dry mass contains energy that can be traced back to photosynthesis

Disadvantages of measuring growth by increase in dry mass

- Difficult and time consuming because sample have to be dried to constant mass
- Requires killing of organisms during removal of water
- Growth in plants may take place with a little or no change in dry mass e.g. towards the end of a growing season growth comes slowly to a halt

Differences between growth in animals and growth in plants

Growth in plants	Growth in animals
✓ Growth occurs in specific regions (at shoot tips, root tips and buds)	✓ Growth occurs over the whole body.

✓ Growth occurs throughout the life.	✓ Animals when young and stop growing at maturity.
✓ Increase in cells size is due to increase in number of cells and absorption of water.	✓ size increase due to increase in the number of cells
✓ Most plant cells can differentiate into different cell types	✓ Only stem cells can differentiate into other cell types.

GROWTH IN PLANTS:

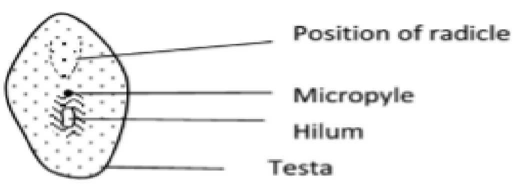
SEED STRUCTURE:

A seed is mature and fertilsed ovule.

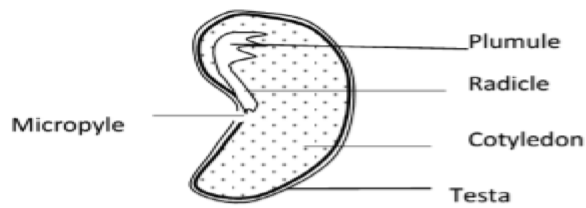
Longitudinal section of a monocot and dicot seed

A labeled diagram of a seed

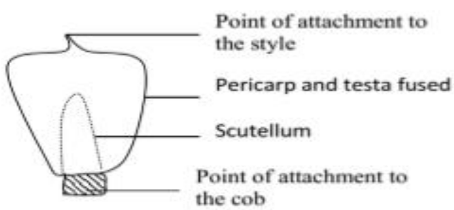
(a) External structure of a dicot seed



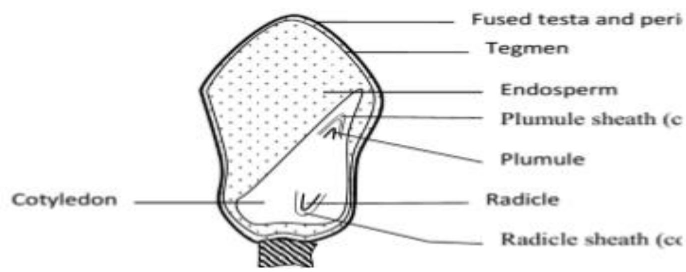
(b) internal structure of dicot seed.



© external features of monocot seed



(d) Internal structure of monocot seed



The main parts of a seed: differences

- ***Testa*** (seed coat): A tough outer covering which protects the seed from mechanical damage. Tegmen is the membrane inside the testa.
- ***Hilum*****:** is a scar, a spot where the seed was attached to the fruit or pod
- ***Micropyle:*** small hole through which water and air enter the seed
- ***Radicle:*** embryonic root. It grows into the root system
- ***Cotyledons*** (Embryonic leaves), store food for the germinating seed i.e. for plumule and radicle. When plumule and radicle grow, they use food stored in the cotyledon. In some seeds food is stored in the endosperm.

Functions of the parts of a seed during germination

1. ***Cotyledons.*** Monocots have one cotyledon while dicots have two cotyledons. In dicots food is stored in cotyledons while in most monocots and some dicots food is stored in the Endosperm. These are known as Endospermic seeds. The cotyledons of dicots protect the young leaves during germination and turn green to manufacture additional food for the seedling.
2. ***Radicle (young root).*** Develops into the root during germination. In monocots the radical is protected by the radical sheath called coleorhizae.
3. ***Plumule (young shoot).*** Develops into the shoot of the plant during germination. In monocots plumule is protected by plumule sheath called coleoptile
4. ***Micropyle.*** Allows oxygen and water to enter the seed during germination**.**

SEED DORMANCY

This a state where a ***viable seed*** is incapable of germinating when all conditions are favorable.

Biological importance of seed dormancy

- ✓ gives embryo time to reach maturity
- ✓ Gives time for dispersal of seed to new suitable habitats.
- ✓ Allows seeds survive adverse conditions. (prevents seeds from germinating when conditions are unfavorable increasing chances of survival)
- ✓ Enable seeds to be stored for long periods in soil hence conserving many plant species in the soil seed banks.
- ✓ Ensures that seeds germinate when competition for resources (light and water)are minimal
- ✓ Prevents seeds from germinating in fruits, preventing wastage of crops in the garden.

The factors which cause seed dormancy

- ✓ presence of germination inhibitors (presence of abscisic acid)
- ✓ Immaturity of the embryo which maybe undergoing further development before it can germinate.
- ✓ Impermeability of the testa/seed coat
- ✓ Absence or inactivity of growth hormones/enzymes/gibberellins/cytokinins
- ✓ Extreme/unsuitable temperature
- ✓ absence of light
- ✓ lack of oxygen
- ✓ lack of water/dryness

Conditions necessary to break seed dormancy:

- ✓ Scarification (physical or chemical treatment of seeds to remove the impermeable seed coat.)
- ✓ vernalisation/cold treatment in some seeds like wheat
- ✓ burning/nicking/expose to heat e.g. wattle seeds
- ✓ provide gibberellic acid which inactivates/destroys germination inhibitors
- ✓ Providing oxygen, water and suitable temperature.

GERMINATION

Germination is the process by which a seedling emerges from an embryo of a seed.

Conditions for germination

- ***External conditions:*** Suitable temperature**,** Moisture **&** Oxygen
- ***Internal conditions:*** Enzymes**,** Energy ***& seed*** viability:

Seed viability: is the ability of a seed to germinate under favourable conditions. Seeds damaged by rodent, insects and fungus fail to germinate under favourable conditions.

Condition	**Role during germination**
Water	• Softens the seed coat/testa • Imbibition (uptake of water) by seeds make the seed swell and break the testa • Activates enzymes which hydrolysed stored food in the seeds • Transports soluble food substances to the growing regions • Dissolves and removes germination inhibitors • Growth and elongation of new cells • Medium for metabolic reactions in the seeds • Used in hydrolysis of stored food
Oxygen	• Used for aerobic respiration to provide energy for germination

Warmth/ optimum temperatures.	• Suitable temperature is required for optimum activity of enzymes during germination. The optimum temperature for germination of most seeds is between 28°c and 37°c.

END OF THE LESSON:

EXPERIMENTS ON GERMINATION:

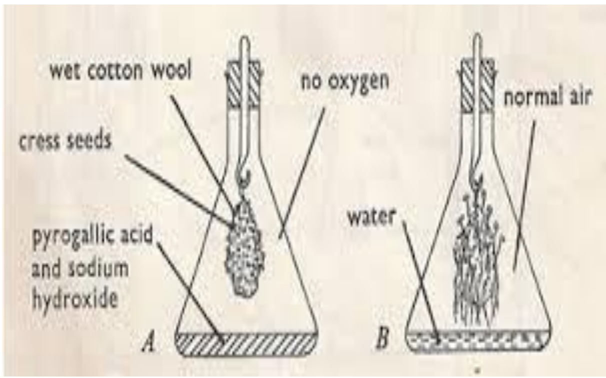
(a) ***An experiment to show that oxygen is necessary for germination***.

Materials. : 2 Conical flasks**,** Water, Cork **,** Alkaline sodium Pyrogallol, Seeds**,** Cotton wool Bean seeds**,** Ignition tube

Procedure.

- Place soaked seeds on moist cotton wool and suspend in the two conical flasks with the aid of thread and cork.
- Pour some sodium pyrogallol solution in flask A and pure water in flask B.
- Leave the setup, for 5 days in a warm place.

Set up/ diagram



Observation.

Seeds in conical flask B germinate while those in conical flask A do not germinate.

Conclusion: Oxygen is necessary for germination**.**

Explanation. Sodium pyrogallol in Flask A absorbs all the oxygen in the flask.

(b) An experiment to show that water is necessary for germination.

Materials.

- Two test tubes.
- Cotton wool
- Water.

Procedure/ method.

- In the test tube 1, place dry seeds on dry cotton wool while in test tube 2, place soaked seeds on moist cotton wool soaked in water.
- Keep in set ups in a warm place for 5 days.

Observation.

Germination occurs in test tube 2 but does not take place in test tube 1 with no water.

Conclusion. Water is necessary for germination.

(c) ***An experiment to show that suitable temperature is necessary for germination*****.**

Materials.

- 2 test tubes, Water, Fridge, Thermometer, Cotton wool.

Procedure.

- Set up two test tubes and put moist cotton wool on both of them.
- Add soaked seeds in each of the test tubes.
- Place test tube 1 in a fridge 0oc and place test tube 2 in a warm place.
- Leave the set up for 5 days.

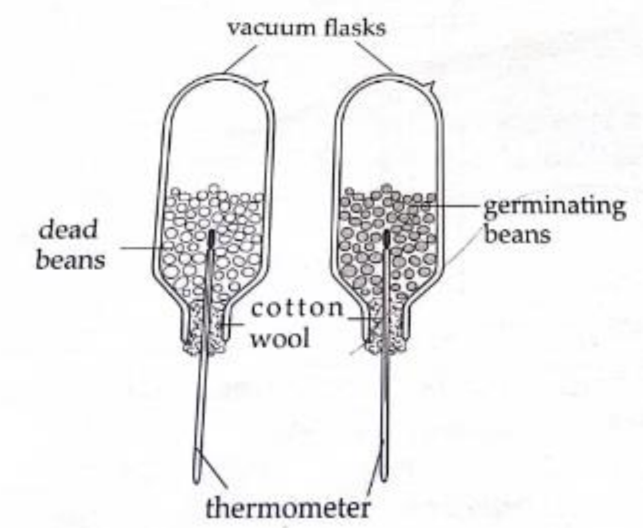
Observation. Germination occurs in test tube 2 but not test tube 1.

(a) An experiment to show that heat is produced during respiration by germinating seeds.

Materials:

- ✓ Two vacuum thermos flasks
- ✓ Two thermometers
- ✓ Cotton wool
- ✓ Two clamp stands
- ✓ A dilute disinfectant e.g. formalin (formaldehyde) or sodium hypochlorite or
- ✓ Viable pea seeds.

Set up



Procedure

- ✓ Obtain two vacuum thermo flasks A and B. Vacuum thermo flasks are used instead of glass flasks so that variation in the surrounding temperature do not affect the temperature of the flasks (or to prevent heat loss/gain)
- ✓ Obtain two sets of viable pea seeds in equal quantities.
- ✓ The first set of moist germinating pea seeds are placed in flask A.
- ✓ The second set of boiled pea seeds soaked in formalin is placed in flask B. The seeds flask B are boiled to kill cells and soaked in formalin to kill bacteria and fungi (or kill micro-organism) which would respire and produce heat.
- ✓ A thermometer is dipped in peas of each flask. The use of the thermometer is to detect any temperature changes.
- ✓ Each flask is plugged with cotton wool (and not rubber corks) to allow free air circulation.
- ✓ The flasks are then placed upside down by use of stands. The flasks are kept upside down for the following reasons: (i) so that it is easier to read the thermometers, (ii) so that few seed required to make contact with thermometers, (iii) so that drainage of excess water is possible.
- ✓ The experiment is left for a period of about 1 week as the temperature changes are noted in each flask.

Observation

- ✓ The temperature rises on the thermometer in flask A
- ✓ Temperature on thermometer in flask B remains constant**.**

Explanation:

- ✓ The temperature rises on the thermometers in flask A due to heat produced by germinating seeds.
- ✓ The temperature on the thermometer in flak B remain constant because seeds killed by boiling would not respire and so did not produce heat.

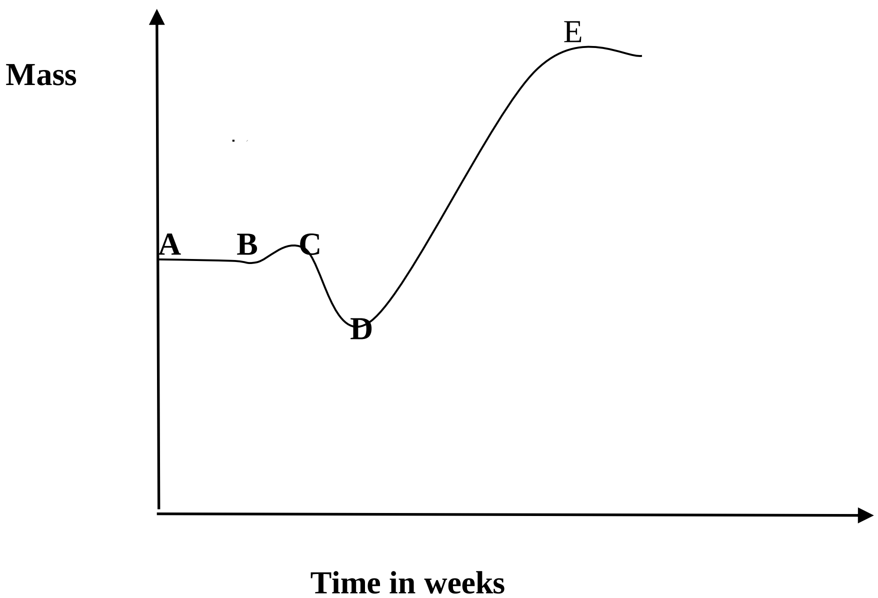
Conclusion

✓ Heat is produced during respiration in germinating peas.

Physiological changes that take place in a seed during germination.

- The seed absorbs water through the micropyle. The seed swells and splits the seed coat and enzymes are activated.
- In presence of oxygen, optimum temperature and water, food reserves in the seed are hydrolysed or broken down into soluble diffusible form by active enzymes. This causes reduction in dry mass of the seed.
- soluble food diffuses to the growing embryo
- Oils and carbohydrates provide energy
- Simple sugars converted to cellulose to form cell wall
- Amino acids are used to make protoplasm
- Rate of respiration increases rapidly leading to increase in temperature of the seed.
- The radicle emerges first and grows down wards to form the root system. The plumule develops into a shoot.
- The development of the root and the shoots leads to increase in dry mass of the embryo. Shoots start carrying out photosynthesis while cotyledons whether away.

Change in mass of seed from germination onwards



A-B: at the beginning, the mass of the seed is constant because the seed is still dormant and has not yet started germinating

B-C: the weight of the seed increases moderately because it has absorbed water and germination has started.

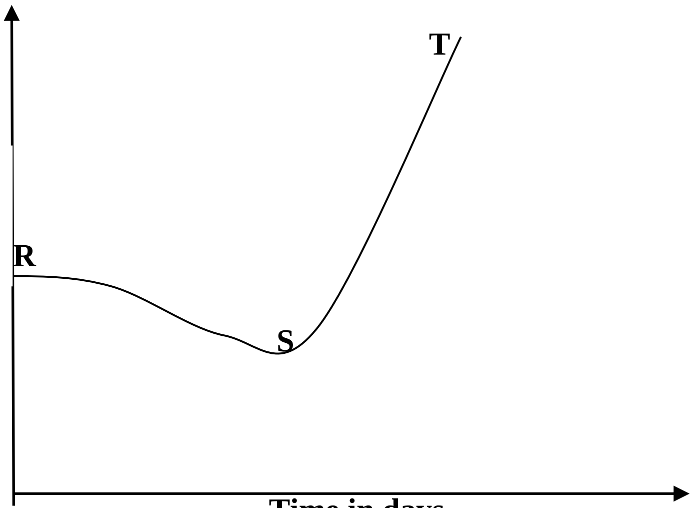
C-D: the weight of the seed decreases gradually because stored is broken down to provide energy for the growing embryo for growth.

D-E: the weight of the seedling increases rapidly because; the cells of the embryo are dividing rapidly to increase the mass/weight of the seedling, the first foliage leaves have developed, Carrying out photosynthesis hence increasing the mass of the seedling, and the root system has been established, absorbing a lot of water & mineral salts hence increasing the mass of the seedling.

Beyond point E, the plant weight may remain constant or start to decrease due to production of seeds, fruits which are dispersed. The plant gradually dies.

Changes to dry mass or weight of a seedling is the weight of seedling after the water content has been removed.

Dry mass



Time in days

R-S: at the beginning, the dry weight of the seedling decreases gradually because stored is broken down in the process of respiration to provide energy for the growing embryo. There is little or no growth. This is called the **lag phase.**

S-T: there, the dry weight of the seedling increases rapidly because; the cells of the embryo are dividing rapidly to increase the mass/weight of the seedling, (new tissues are being formed) the first foliage leaves have developed, carrying out photosynthesis producing more food than it can use for respiration hence increasing the mass of the seedling.

Note: **How stored food is used during germination**

- Starch is converted to maltose and glucose which are reducing sugars.
- Glucose is then broken down to produce energy (ATP) for growth.
- Lipids are converted to fatty acid and glycerol which are broken down to release energy during respiration.
- Proteins are converted to amino acids which are used to make new cells.

Types of germination

1. ***Epigeal germination***

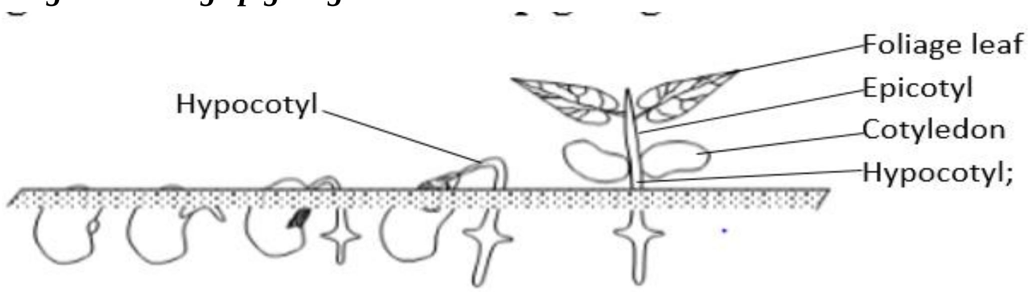
   This is the type of germination where cotyledons appear above the ground due to rapid elongation of the hypocotyl (region of the stem just below the cotyledons) that pushes the cotyledons above the ground. This takes place in common bean, soya, and castor oil. Sun flower etc.

   Stages of Epigeal germination.

- The seed absorbs water through the micropyle and the testa softens.

- Enzymes in the seed are activated by water and they then hydrolyze stored food in the cotyledons.
- Soluble food products are transported to the growing regions (radicle and plumule).
- The seed swells, the testa burst sand the radicle grows down wards.
- The radicle develops root hairs for absorption of water and mineral salts.
- The hypocotyl elongates and curves up through the soil carrying cotyledons and the testa up through the soil.
- On reaching the soil surface, the hypocotyl straightens and pulls the cotyledons out of the soil while they are still closed to protect the delicate plumule.
- The cotyledons open, turn green, expand and start carrying out photosynthesis.
- The cotyledons become smaller and finally fall off.

Drawing illustrating epigeal germination:



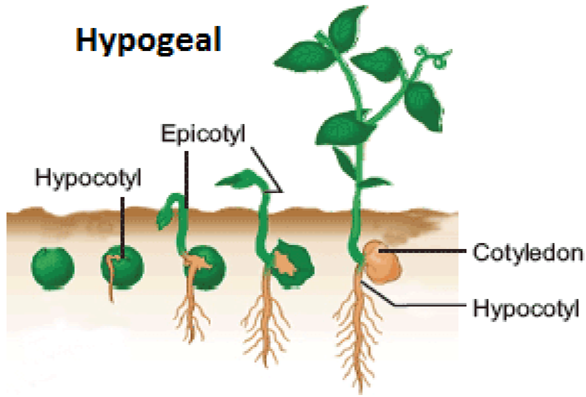
2. ***Hypogeal germination:***

Hypogeal germination is the type of germination where cotyledons remain underground. It is brought about by rapid elongation of the epicotyl (region of the stem above the cotyledon stalk) which pushes the plumule up while cotyledons remain in the soil. It takes place in maize, sweet pea, and sorghum.

Stages of Hypogeal germination.

- ✓ The endosperm absorbs water and swells.
- ✓ Enzymes in the seed are activated, they hydrolyze stored food in the endosperm.
- ✓ Soluble food is transported to the growing parts of the embryo (plumule and radicle).
- ✓ The coleorhiza (radicle sheath) elongates and pierces through the soft testa.
- ✓ The radicle elongates and pierces through the coleorhiza and then develops root hairs for absorption of water and mineral salts.
- ✓ The epicotyl elongates and pushes the plumule sheath (coleoptile) above the ground.
- ✓ The plumule pierces through the plumule sheath and exposes the foliage leaves to light.
- ✓ Foliage leaves unroll and begin photosynthesis.
- ✓ Cotyledons remain underground and continue to hydrolyze stored food in the endosperm and pass it to the growing regions.
- ✓ When food reserves are exhausted (finished) cotyledons wither and drop off.

Drawing illustrating hypogeal germination



Differences between Epigeal and hypogeal germination.

Epigeal Germination	**Hypogeal Germination.**
Hypocotyl elongates rapidly compared to the epicotyl.	Epicotyl elongates more rapidly compared to the hypocotyl.
Cotyledons lifted above the ground	Cotyledons remain underground.
Cotyledons turns green to carry out photosynthesis.	Cotyledons don't turn green.
Radicle emerges first followed by plumule.	Plumule and radicle emerge at the same time.
Food is stored in the cotyledons.	Food is stored in the endosperm.
Less food is stored in the cotyledons	More food is stored in the cotyledons.
First leaves are protected by the cotyledons.	First leaves are protected by the coleoptile.
Cotyledons expand and split the testa (seed coat).	Cotyledons remain in the seed coat.
Primary root persists as a tap root.	Primary root abort and it is replaced by fibrous roots.
Takes place rapidly.	Takes place slowly.

Advantages of Epigeal germination.

- ✓ Young leaves are protected by the cotyledons.
- ✓ The cotyledons turn green and manufacture additional food for the seedling.
- ✓ The plant establishes itself quickly due to initial rapid growth.

Disadvantages of Epigeal germination.

- ✓ The plant shoot (cotyledons and the young leaves) are exposed to herbivores and extreme weather conditions.
- ✓ The seed requires nutrients, rich soils and enough sunlight if they are to germinate because the cotyledons store less food.

Advantages of hypogeal germination.

- ✓ Seeds can germinate in soil with little nutrients and in absence of sunlight because there is a lot of stored food in the cotyledons. Such seeds can germinate in the forest floor.
- ✓ The shoot is not exposed to herbivores during germination.

Note: Within the same genus, one species can adopt hypogeal germination while another can epigeal germination e.g. the common bean *Phaseolus vulgaris* undergoes epigeal germination while the runner bean (*Phaseoluscoccineus*) and broad bean *Viciafaba* show hypogeal germination.

MERISTEMATIC TISSUE

This is a tissue that consists of undifferentiated cells that actively divide by mitosis to produce new tissues that cause the plant to grow. The word meristem means dividing.
Meristems are found in regions of active growth in plants: they include;-

Characteristics of meristematic cells

- Have dense cytoplasm
- Have thin cell walls
- absence of vacuoles/cell sap
- are un differentiated.

The location and function of meristematic tissues in plants:

1. **Apical meristem**: Located at tips of roots and shoots; responsible for increase length of stem and roots/primary growth.
2. **Intercalary meristem**: Found at bases of internodes. Are responsible for elongation of internodes and increase in leaf sheath in grasses.
3. **Lateral meristems (cambium)**: They are found near the periphery of stem and root. It is responsible for secondary growth/growth in girth of stem and root/lateral growth. They are of two types: vascular cambium and cork cambium

(i) ***Vascular cambium.*** This is found in between the xylem and the phloem, cells here divide to produce secondary xylem and secondary phloem leading to increase in the width (girth)/ circumference of the stem this is called **secondary growth**

(ii) ***Cork cambium***. This gives rise to periderm which replaces the epidermis during secondary growth in dicot stems.

4. ***Pericycle***. This is found in the roots, it produces lateral/secondary roots
5. ***Axillary buds.*** Meristematic tissue in axillary buds divide to produce new shoots or flowers.

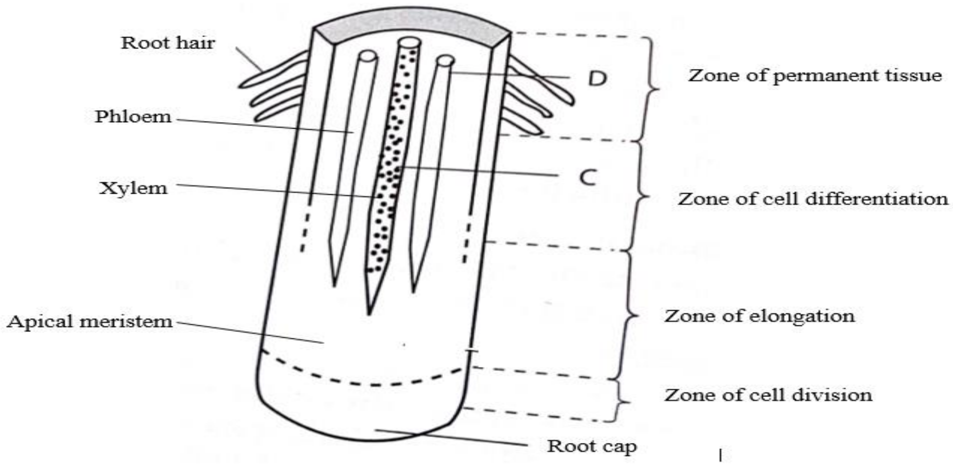
PRIMARY GROWTH

Is the increase in length of stems and root. It is as a result of cell division (mitosis) and cell elongation in the root and the shoot tips.

How primary growth occurs:

- Primary growth occurs at tips of shoots and roots which are the apical meristem;
- ***Cells in the zone of cell division:*** In this zone cells rapidly divide by mitosis caused by apical meristem there by increase in number of cells. Cell in this zone have thin cell wall, dense cytoplasm and no vacuoles. Some cells remain meristematic while other cells from the region of cell elongation. This region does not show any elongation.
- Cells in the zone of cell elongation: cells elongate in this zone by taking up water through osmosis and assimilating food. Hence cells in this zone are enlarged to maximum size, vacuole start forming and enlarging.
- Zone of cell differentiation: cells attain permanent size, large vacuole and thickened cell wall. In this zone the cells differentiate into tissue specialsed for specific functions. Some of the specialsed tissues that form in this zone (in case of roots): piliferous layer, cortex, vascular bundles, endodermis and Pericycle.
- In the shoots, apical meristems give rise to leaf primordia (extensions on the sides of the apical meristem) which envelop the apex to form a bud. The bud protects the delicate inner cells. The meristematic cells of the leaf primordia divide mitotically to form leaves.
- In roots the meristem is protected by root cap. After cells differentiate the form permanent tissues

Diagram of the longitudinal section a dicot root tip to show regions of primary growth



➔ ***Think what is D and C?***

Experiment to determine the region of most rapid elongation in the root

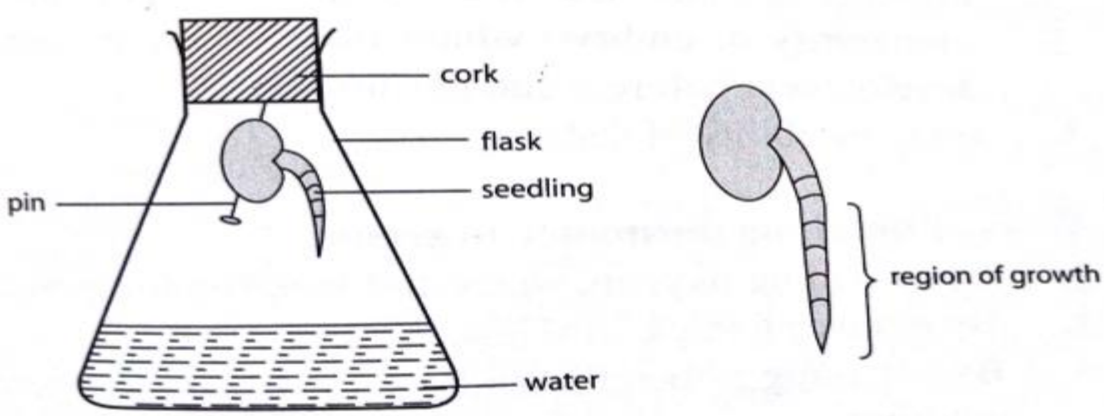
Materials:

Cork, conical flask, water, Indian water proof ink, pin, bean seedling and ruler

Procedure:

- Viable bean seedlings are soaked for about 3 days. Then two bean seedlings with straight radicles are selected.
- The radicals of these seedling are marked with Indian water proof ink at 2mm intervals
- The seedlings are then pinned to the bottom of a cork which is then fixed in the mouth of the conical flask with little water as shown in the diagram below.
- The flask is placed in a dark place to allow the radicle to grow for about 2 days.
- The gaps on radicle are measured again using a ruler after two days.

Set up



Observation:

There is little or no change in distance between the marks at the tip of the radical and the top near the cotyledons while the distance between the marks in the region just above the tip of the radical are gets further apart.

Conclusion:

Region of growth in a root is a short distance located above the tip of the root.

SECONDARY GROWTH IN PLANTS

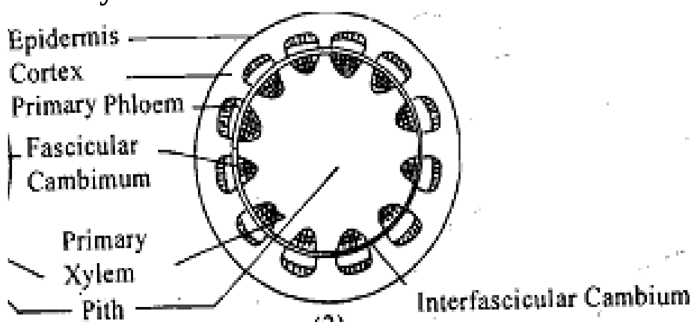
Secondary growth refers to increase in the thickness (girth) of plant shoots and roots. It occurs in all dicots except herbaceous dicots. However monocots do not undergo secondary thickening.

Secondary growth results in formation **permanent tissues** and is also termed as secondary thickening.
Secondary growth is brought about by the division of **cambium ring (vascular cambium)**.
When the cambium ring divides, it forms the secondary xylem on the inside and secondary phloem on the outside. The cambium is responsible for the formation of wood in dicots.

Importance of Secondary growth

- Its responsible for healing of wounds by forming callus tissue on shoots and roots
- Increases the girth of stems and roots to provide extra support for the plant.
- It is responsible for regeneration of plant parts.

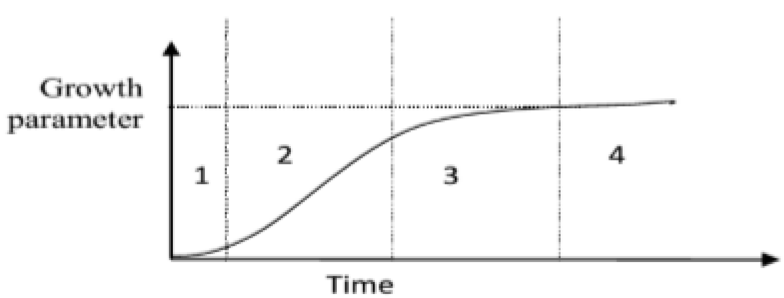
Transverse section of dicotyledonous stem



Growth in animals

Unlike plants, growth in animals is not localized in certain parts. It occurs throughout the body and it is controlled by hormones. The hormones involved in growth include growth hormone, testosterone, thyroxin and oestrogen.
However, there is variation in growth of animals. Mammals and many other animals exhibit **continuous growth**. They don't stop growing from birth to maturity even though their rate changes. The growth of humans and other mammals ceases at maturity.
Arthropods on the other hand usually have a number of periods of extremely rapid growth followed by periods in which there is no growth. This growth pattern is termed as **discontinuous growth**.
Metamorphosis is the change in form or structure of an organism from the young stage to the adult stage. Metamorphosis takes place in sponges, cnidarians, flat worms, annelids, arthropods and amphibians.
Types of growth curves:
There are two main types of growth curves.
Sigmoid and intermittent growth curves.

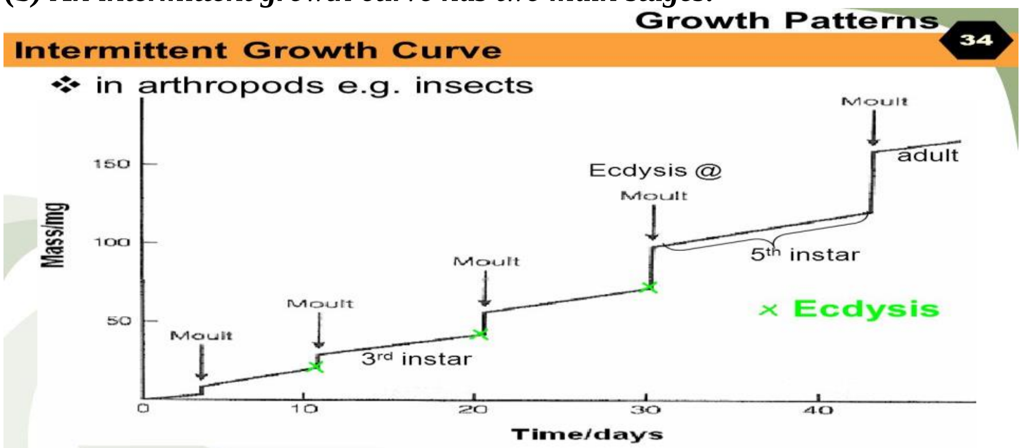
(a) Sigmoid growth curve:



The different phases/stages of the sigmoid growth curve:

- ***1-Lag phase***: Slow growth rate at first; because the organism adapting to the environment
- ***2-Exponential phase*****:** rapid growth due to birth rate which is higher than death **rate.** Organisms already adapted
- ***3- Stationery phase (plateau)***
- There is no growth. Birth rate equals death rate (equilibrium), due to Lack of nutrients, accumulation of toxic waste products
- ***4-phase of decline:*** growth reduces: due to
  - Depletion of nutrients, accumulation of toxic wastes, lack of space
  - Some individuals old hence not reproducing
  - Death rate higher than birth rate

(b***) An intermittent growth curve has two main stages:***



- In arthropods, There is a period of rapid growth during moulting; followed by a phase of no growth and this repeats until an adult is formed. Point x represents moulting/ecdysis.
- This curve is seen in arthropods such as insects.
- Growth in in arthropods is intermittent (takes place during some time only because their hard cuticles (exoskeleton) does not expand to cause growth
- The cuticle must be shed off first to allow further growth
- The shedding of the exoskeleton is called ecdysis or moulting
- When moulting has taken place animal grows but growth stops when the exoskeleton hardens again

Metamorphosis of a frog

The female frog lays eggs then they are fertilized by externally by the male to form a zygote. The zygote divides several times forming an embryo, several organs and gills develop from the embryo. The embryo depends on food in the yolk of the egg.

After 21 days the embryo hatches into a tadpole. The tadpole attaches itself to a weed. It grow until it is big enough to swim, this can take 3 days to 3 weeks depending on the type of the frog. The tadpole feeds on algae and breaths using external gills.

After about 5 weeks the tadpole starts to grow hind legs, followed by fore legs and then lungs which do not or work until the tadpole metamorphosis into an adult which can live on land.

Importance of metamorphosis

- Larvae can move from place to place, this aids dispersal of organisms and enables them to colonize new habitats.
- The larvae and the adult evolve different mechanism for avoiding predators; this increases the chances of survival.
- Reduced competition for food between the larvae and the adults

- Different stages in a life cycle occupy different habitats for example the adult frog lives in water.
- Organisms can survive harsh conditions like winter or summer. E.g. most insects survive this stage in pupa form.
- In liver fluke and tape worms the larval forms produce other larvae by a sexual reproduction this increases the rate reproduction and the chances of survival.
- In some organisms there is specialization of labor where the larval is for feeding and growing while the adult stage is for reproduction.

END GROWTH AND DEVELOPMENT

CELL DIVISION, GENETICS & EVOLUTION

→***Introduction:*** Living things arise from other living things through reproduction. Children tend to resemble their parents and this occurs through genetics.

Key word:

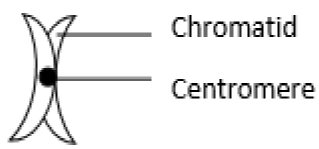
- ✓ ***Genetics*** is a branch of science dealing with the study of **heredity/inheritance**.
- ✓ ***Heredity***: is the process by **characters** are passed from parents to children. In science children are **called offspring or progeny**.

Characters are also called **traits**. Examples of inheritable characters in humans include: hair texture, height; skin color, body build and hair color, blood groups, gender/sex.

Genetic materials:

The genetic material of the cell is found in the nucleus; and it consists of ***Deoxyribonucleic acid (DNA)***. The genetic material (DNA) is made up of ***chromosomes***: which are the thread like structures in the nucleus that carry genes. In DNA, genes are found at sites called **loci** (singular = locus**).** A chromosome consist of a pair of chromatids joined at the ***centromere.***

<u>Illustration of chromosomal structure</u>



Cell division:

Cell division is the process by which new cells arise from already existing cells. There two types of cell division and these include **Mitosis** and **Meiosis**.

1. ***MITOSIS***

Mitosis is defined as a type of cell division by which a parent cell gives rise to *<u>two identical daughter cells</u>* each having exactly the *<u>same number of chromosomes</u>* as the parent cell.

Process of mitosis:

Mitosis takes place in five stages namely: →Use '***IPMAT***' to remember the correct order.

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

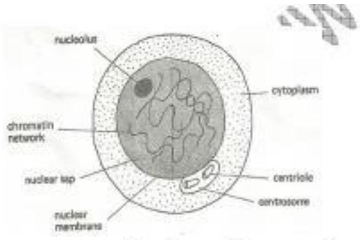
Interphase (First stage or preparatory stage of mitosis/resting stage)

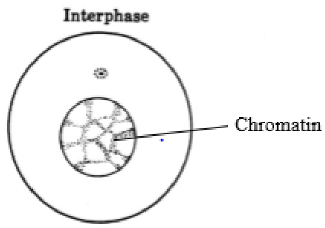
During this stage:

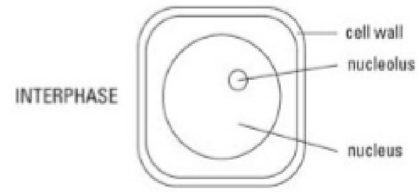
- ✓ Chromosomes are thin and not visible: (at this stage they are long, thin and twisted thread-like structures in the nucleus called chromatin)
- ✓ The genetic material doubles (or replicates); i.e. DNA and hence chromosomes replicate.
- ✓ The cell builds up a large store of energy.
- ✓ New cytoplasmic organelles (e.g. mitochondria, ribosomes, chloroplasts etc.) are formed

- ✓ Centrioles replicate such that each daughter cell can finally takes one.

Illustration of an animal cells at interphase — plant cell at interphase







Note: when a chromosome replicates, it becomes double stranded. ***A chromatid*** is a single strand of replicated chromosomes.

Prophase (second stage of mitosis)

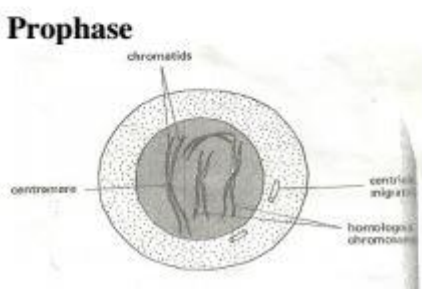
(a) Early prophase

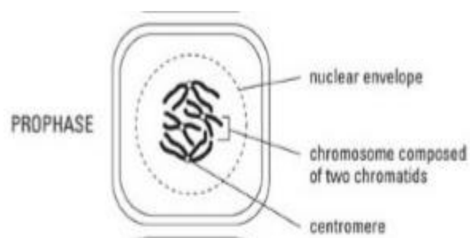
- ✓ Chromosomes condense (or thicken) and become visible.
- ✓ Each chromosome is seen to consist of a pair of chromatids lying parallel to each other and associated at the centromere.
- ✓ Centrioles appear and divide into two; and move to opposite ends of the nucleus to form poles.

(b) **Late prophase**

- ✓ Spindle fibers form. Spindle fibre are protein in nature; and are formed by the Centrioles now lying opposite ends of the nucleus forming poles, the middle of which is called the equator.
- ✓ Nucleolus disappears.
- ✓ Nuclear membrane breaks down. This is the last feature of this phase.

Animal cell at prophase — *plant cell at prophase*

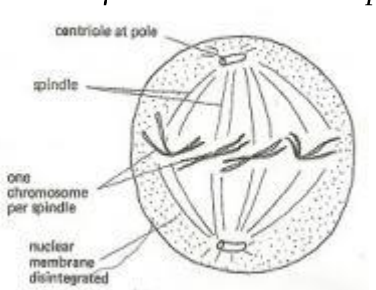


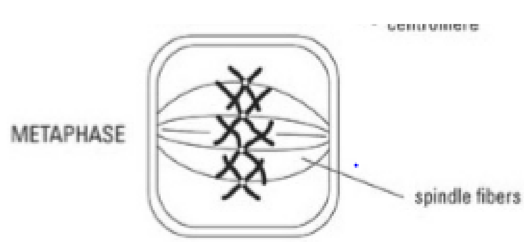


Metaphase (third stage of mitosis)

- ✓ Chromosomes line up at the equator; which is the central plane of the cell.
- ✓ Chromosomes become attached to the spindle fibers by their centromeres and the sister chromatids become oriented towards opposite poles.
- ✓ Homologous chromosomes do not associate.

Illustration of animal cell at metaphase — *plant cell at metaphase*



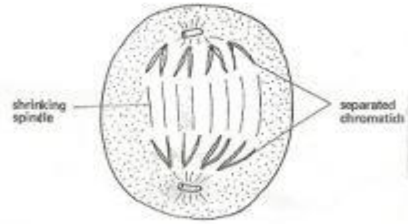


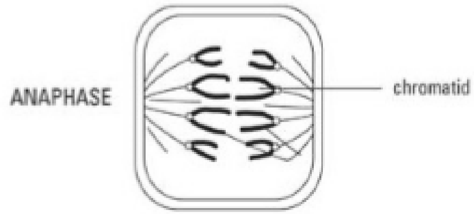
Anaphase (fourth stage of mitosis)

- ✓ Centromeres divide and the two sister chromatids separate.
- ✓ The daughter chromatids, now chromosomes move towards the opposite poles; due to the pulling action of the spindle fibers, using energy in form of ATP from respiration.

- ✓ This stage ends when the daughter chromosomes have reached the opposite poles.

Animal cell ***plant cell***

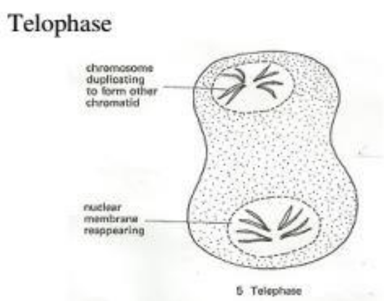


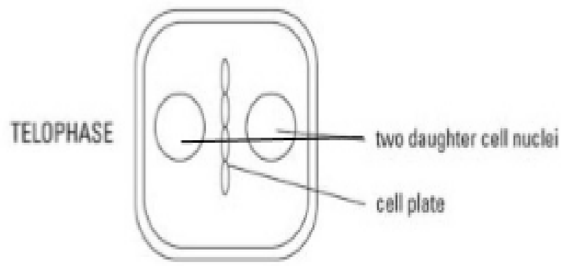


Telophase (the last stage of mitosis)

- ✓ Nuclear membrane reappears around each set of daughter chromosomes/chromatids. At the same time, chromosomes uncoil into long chromatin.
- ✓ The spindle fibers shrink and disappear
- ✓ The cell membrane starts to constrict in the middle of the cell; causing appearance of a furrow across the cell.
- ✓ The furrow deepens and divides the cell into two halves.
- ✓ In this way, two cells are formed from one cell and each daughter cell has exactly the same number of chromosomes as the parent cell.

Illustration of a cell at Telophase





Significance of mitosis

1. Brings about growth of organisms by increasing the number of new cells.
2. It is the basis of asexual reproduction; which brings about population growth.
3. It ensures that each cell in the body is genetically identical even after a tissue is injured.
4. Important in replacing worn-out cells, wound healing and tissue regeneration through formation of new cells.
5. Maintains genetic stability in asexually reproducing individuals since it does not involve genetic variation/crossing over.
6. Maintains chromosomal number/diploid state when a single somatic cells divides.

Where mitosis occurs;

- ✓ Mitosis occurs in ordinary/ somatic cells e.g.

In plants, mitosis occurs in:

- ✓ Meristematic (growing) tissues at the tips of the roots and shoots
- ✓ Cambium tissues.
- ✓ Buds

In animals, mitosis occurs in.

- ✓ The somatic cells e.g. bone cells, Malpighian layer of the epidermis of the skin

The major features of mitosis are:

1. Duplication of chromosomes
2. Division of the cytoplasm and nucleus
3. Formation of two daughter cells
4. Preservation of the chromosome number

MEIOSIS

Meiosis is defined as a type of cell division where by four daughter cells are formed from one parent cell and each daughter has a half the number of chromosomes of the parent cell. In other words, meiosis is a type of cell division where by four haploid daughter cells are formed from one diploid parent cell. The term **haploid** is denoted by (**n**) and is the condition, whereby each formed daughter cell, has half the number of chromosomes as that of the parent cell.

The process of meiosis:

Like mitosis, meiosis is composed of 5 stages i.e. Interphase, Metaphase, Anaphase and Telophase. Meiosis however is divided into the first stage i.e. Meiosis I/first meiotic division and the second stage i.e. Meiosis II/second meiotic division.

The process of Meiosis I

This consist of: Interphase, ***Prophase I, Metaphase I, Anaphase I, Telophase I***

Interphase

This is the first stage of meiosis I and the features of this stage are the same as those of Interphase of mitosis i.e.

- ✓ Chromosomes are thin and not visible.
- ✓ The genetic material doubles (or replicates); i.e. DNA and hence chromosomes replicate.
- ✓ The cell builds up a large store of energy.

Prophase I

- ✓ During this stage the chromatins, thicken, shorten, and become visible ***chromosomes.***
- ✓ Then, synapsis (or formation of bivalents) occur. In ***synapsis*** is a process whereby ***homologous chromosomes*** pair up, become attached and their chromatids coil/spiral together producing **a bivalent.**
- ✓ Afterwards, the homologous chromosomes slightly separate and remain in contact at a position called ***chiasma*** (plural ***chiasmata*****).**
- ✓ Portions of non-sister chromatids of both chromosomes break at the chiasmata and become exchanged, a process known as **crossing over.** Crossing over enhances gene mixing and hence leads to genetic variation (differences)
- ✓ The Centrioles migrate towards opposite poles and start manufacturing spindle fibers.
- ✓ The nucleolus shrinks and disappears. The nuclear membrane also shrinks.

Note: ***key vocabulary***

1. ***Homologous chromosomes:*** is a pair of chromosomes having the same structure (i.e. same size and shape) but differ in their chemical composition.
2. ***Synapsis:*** is the coming together of homologous chromosomes such that they become attached and their chromatids spiral together forming bivalents, resulting in crossing over.
3. ***Bivalent:*** is a pair of homologous chromosomes during synapsis of the first meiotic division.
4. ***Chiasma***: is a point where two adjacent chromatids of homologous chromosomes join or coil over each other during crossing over.
5. ***Crossing over:*** is the exchange of genetic material between two non-sister chromatids of homologous chromosomes.

Synapsis: pairing or coiling together of chromatids of adjacent chromosomes

Metaphase I

- ✓ The nuclear membrane continues to shrink and eventually disappears.
- ✓ The spindle fibers become fully formed.
- ✓ Homologous chromosomes assemble on the spindles fibers, while in association.
- ✓ Homologous chromosomes slightly separate from each other, and project themselves towards the opposite poles.
- ✓ In ***Late Metaphase I:*** Homologous chromosomes project/point towards opposite poles.

Anaphase I

- ✓ The homologous chromosomes start to move and migrate towards the opposite poles.

Telophase I

- ✓ The cell membrane begins to constrict in the middle of the cell
- ✓ Spindle fibers disappear
- ✓ Nucleolus and nuclear membrane reappear.
- ✓ Chromosomes become thin, long and coiled chromatins
- ✓ The cell membrane further constricts until the cell divides into 2 daughter cells, each with half the number of chromosomes to that of the parent cell
- ✓ In **Late Telophase I:** Each formed daughter cell undergoes the second meiotic division leading to formation of 4 daughter cells each with half the number of chromosomes of the parent cell.

Meiosis II:

- ✓ *Note: The changes Meiosis II are the same as those of mitosis.*

Summary of Meiosis II

Significance of meiosis

- ✓ Formation of gametes; which serves as a basis for sexual reproduction.
- ✓ Allows to retain the diploid state of the organism at fertilization in every generation.
- ✓ Brings about genetic variation due to genetic mixing caused by crossing over.
- ✓ Formation of spores which is the basis of reproduction in lower organism.
- ✓ Brings about evolution due to genetic variation. (increases chances of survival of species through formation of improved varieties)

Where does meiosis occur?

- In animals, Meiosis occurs in testes and ovaries.
- In plants, Meiosis occurs in ovary and anther heads.

Comparison between mitosis and meiosis

(a) Similarities between mitosis and meiosis:

In both:

- ✓ Interphase, Prophase, Metaphase, Anaphase and Telophase are involved.
- ✓ spindle is formed.
- ✓ nucleus and nuclear membrane disappear during metaphase.
- ✓ Energy in form of ATP is used.
- ✓ daughter cells from a parent cell.
- ✓ The nucleus and cell divides.
- ✓ homologous chromosomes assemble on the spindle fibers
- ✓ Chromosomes shorten and thicken.

(b) Differences between mitosis and meiosis

Mitosis	***meiosis***
1. Occurs in somatic cells.	*Occurs in gamete producing cells.*
2. Two daughter cells are formed from one cell	*Four daughter cells are formed from one cell*
3. Daughter cells are diploid	*Daughter cells are haploid*
4. Involves two nuclear divisions	*Involves one nuclear division*
5. Mainly for gamete formation	*Mainly for growth.*
6. Bivalents are not formed	*Bivalents are formed.*
7. No crossing over	*Crossing over occurs*
8. Synapsis does not occur	*Synapsis occurs*
9. No chiasmata are formed.	*Chiasmata are formed*
10. Homologous chromosomes assemble on the fibers without association.	*Homologous chromosomes assemble on the spindle with association.*
11. No genetic variation occurs	*Leads to genetic variation.*
12. Sister chromatids migrate towards opposite poles	*Homologous chromosomes migrate to opposite poles during Anaphase I*
13. Does not lead to evolution.	*Leads to evolution*

14. Serves as a basis for asexual reproduction	*Serves as a basis for sexual reproduction*
15. Take a short period of time.	*Takes a long period of time.*

GENETICS