15. PLANT GROWTH & DEVELOPMENT

- The zygote develops into a mature plant through **growth** and **differentiation**. Then they eventually die.

GROWTH

- **Growth** is an irreversible permanent increase in size of an organ or its parts or an individual cell.
- It involves metabolic processes that consume energy.
- Plant growth continues throughout the life due to the presence of **meristems** at certain locations in their body. Meristematic cells have the capacity to divide and self-perpetuate.
- **Types**-
  1. **Primary growth:** It occurs in r**oot** and **shoot apical meristem.** It causes the elongation of the plants along their axis.
  2. **Secondary growth** (In gymnosperms & dicots)**:** It occurs due to the **lateral meristems, vascular cambium** and **cork-cambium.** These meristems cause the increase in the girth of the organs.
- **Measurement of Growth**

  Growth is measured by parameters like increase in fresh weight, dry weight, length, area, volume & cell number.
- **Phases of Growth**

  3 phases: **Meristematic, elongation** and **maturation**.

I. **Meristematic phase:** It occurs in the meristems at the root & the shoot apex. Cells in this region have rich protoplasm and large conspicuous nuclei. Cell walls are primary, thin & cellulosic with abundant plasmodesmata.

II. **Elongation phase:** It occurs in the cells proximal (just next, away from the tip) to the meristematic zone. The cells have increased vacuolation, cell enlargement and new cell wall deposition.

III. **Maturation phase:** It occurs in the cells proximal to the phase of elongation. The cells are with maximum wall thickening and protoplasmic modifications.

Growth Rates

- It is the increased growth per unit time.
- It is of 2 types- **arithmetic or geometrical.**

ARITHMETIC GROWTH:

- In this, following mitotic cell division, only one daughter cell continues to divide while the other differentiates and matures.
- It is represented as: -

  On plotting the length of the organ against time, a linear curve is obtained.

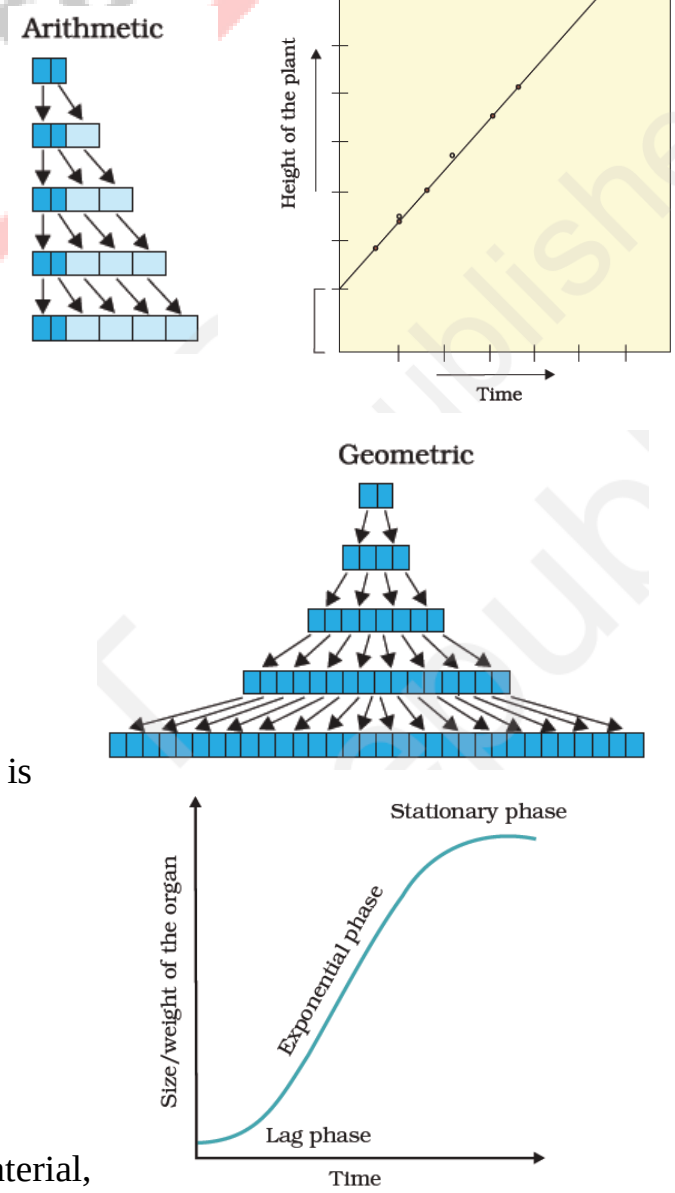
  Mathematically, it is expressed as

  $L_t = L_0 + rt$

  Lt = length at time‘t’

  L_0 = length at time ‘zero’

  r = growth rate / elongation per unit time.



GEOMETRICAL GROWTH:

- Here, both the daughter cells continue and retain the ability of mitotic cell division.
- This type of growth has 3 phases-

  (i) **Lag phase-** the initial stage having **slow** growth

  (ii)**Exponential phase-** growth increase at exponential rate

  (iii)**Stationary phase-** growth slows down due to limited nutrient supply.
- If we plot the parameter of growth against time, we get a typical **sigmoid (S) curve.**

➢ A sigmoid curve is a characteristic of living organism growing in a natural environment. It is typical for all cells, tissues and organs of a plant.

The exponential growth can be expressed as -

$$W_1 = W_0 e^{rt}$$

Where, W_1 = final size (weight, height, number etc.)

W_0 = initial size at the beginning of the period

e = base of natural logarithms

r = relative growth rate

t = time of growth

➢ **Relative growth rate (r)** is the measure of the ability of the plant to produce new plant material, referred to as **efficiency index.** Hence, the final size of W_1 depends on the initial size, W_0.

➔ Quantitative comparisons between the growths of living system can also be made in 2 ways:

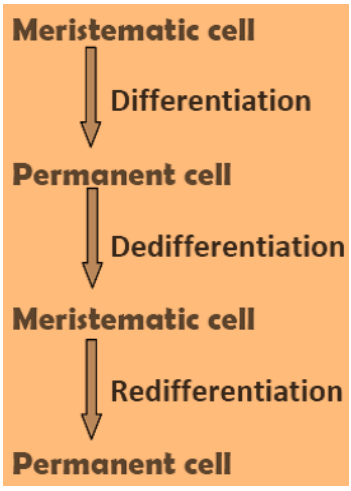
(i) **Absolute growth rate-** Measurement and the comparison of total growth per unit time**.**

(ii)**Relative growth rate-** Measurement of growth of the given system per unit time expressed on a common basis, e.g., per unit initial parameter.

Conditions for Growth

1. **Water:** It is essential for cell enlargement. Turgidity of cells helps in extension growth. Water also provides the medium for enzymatic activities needed for growth.
2. **O_2:** It helps to release metabolic energy for growth.
3. **Nutrients:** Macro & micro elements are needed for the synthesis of protoplasm and act as source of energy.
4. **Temperature:** Plants have an optimum temperature at which growth is maximum. Deviation from this range could be detrimental to its survival.
5. **Light** & **gravity:** Affect certain phases/stages of growth.

DIFFERENTIATION, DEDIFFERENTIATION & REDIFFERENTIATION



➢ **Differentiation** is the process in which the cells in meristems and cambium differentiate and mature to perform specific functions.

- In this process, cell walls and protoplasm undergo major structural changes. The capacity of cell division is lost.
  E.g. While formation of tracheary element-
  - Cells loss protoplasm
  - Develop very strong, elastic, lignocellulosic secondary cell walls, to carry water to long distances even under extreme tension.

➢ **Dedifferentiation** is the process in which living differentiated cells regain the capacity of division, under certain conditions.
E.g. Formation of interfascicular cambium & cork cambium from differentiated parenchyma cells.

➢ **Redifferentiation** is the process in which the dedifferentiated cells lose the capacity to divide but mature to perform specific functions.

- Plant growth is open, i.e., it can be indeterminate or determinate. Differentiation in plants is also open, because cells/tissues arising out of the same meristem have different structures at maturity.
- The final structure at maturity of a cell/tissue is also determined by the location of the cell.
  E.g. Cells positioned away from root apex differentiate as root-cap cells, while those pushed to the periphery mature as epidermis.

DEVELOPMENT

✓ It is a process that includes all changes in the life cycle of an organism from seed germination to senescence.

✓ **Plasticity** is the ability of plants to follow different pathways in response to environment or phases of life to form different kinds of structures.
Heterophylly (plant with more than 2 types of leaves) **due to phases of life:** E.g. In cotton, coriander and larkspur, the leaves of the juvenile plants and mature plants are different in shape.
Heterophylly due to environment: E.g. In aquatic plants like butter-cup, shapes of leaves produced in air (broad) and those produced in water (ribbon- shaped, linear and dissected) are different.

✓ **Factors controlling the development:**
  ➔ **Intrinsic factors:** intracellular (genetic) or intercellular factors (such as plant growth regulators).
  ➔ **Extrinsic factors:** light, temperature, water, O_2, nutrition, etc.

PLANT GROWTH REGULATORS (PHYTOHORMONES)

☯ **Plant growth regulators (PGRs)** are small, simple molecules that regulate growth of plants.

☯ Based on the functions, PGRs are divided into 2 groups.

A. **Growth promoters:** Promote cell division & enlargement, tropic growth, pattern formation, flowering, fruiting & seed formation.
E.g.: Auxins, gibberellins and cytokinins.

B. **Growth inhibiters:** For growth inhibiting activities like dormancy & abscission. Help in plant responses to wounds & stresses.
E.g.: Abscisic acid & ethylene.

➢ **Factors influencing the action of PGR:**
  - **Intrinsic factor:** Genomic control.
  - **Extrinsic factors:** Light and Temperature.

More in next page

ROLE OF LIGHT & TEMPERATURE ON FLOWERING

1. PHOTOPERIODISM

➢ The flowering response of plants to relative duration of day (duration of light) and night is called **photoperiodism**.

➢ Based on duration of light required, plants are 3 groups:

(a) **Long day plants:** Plants which require the exposure to light for a period greater than critical duration (12 hrs) for flowering.
(b) **Short day plants:** Plants which require the exposure to light for a period less than critical duration for flowering.
(c) **Day-neutral plants:** Flowering of these plants are not affected by duration of light exposure. These plants flowers after a period of vegetative growth.

➢ The site of perception of light/dark duration is the leaves. When the plants are exposed to the necessary photoperiod, the hormone migrates from leaves to shoot apices to induce flowering.

2. VERNALISATION

♥ *It is a low temperature treatment given for certain plants for flowering*. It enables the plant to have sufficient time to reach maturity.
E.g.:

1. Some food plants, wheat, barley, rye have two kinds of varieties:
   - **Spring varieties:** These are normally planted in the spring and come to flower and produce grain before the end of the growing season.
   - **Winter varieties:** Winter varieties are planted in autumn (if planted in spring would normally fail to flower or produce mature grain).

2. **Vernalisation in biennial plants:** Biennials are monocarpic plants that normally flower and die in the second season.
   E.g. Sugar beet, cabbages, carrots etc.
   Subjecting the growing of a biennial plant to a cold treatment stimulates a subsequent photoperiodic flowering response.

PHYTOHORMONES

Hormone	Discovery	Role	Remark
1. Auxins auxein'^{G}= to grow	➢ **Charles Darwin** & his son **Francis Darwin** observed that the coleoptiles of canary grass responded to unilateral illumination by growing towards the light source (**phototropism**). It was concluded that the tip of coleoptile caused the bending of the entire coleoptile. ➢ **F.W. Went** isolated a**uxin** from tips of coleoptiles of oat seedlings. ➢ First isolated from human urine.	(a) Help to **initiate rooting** in stem cuttings, (applied widely used for plant propagation). (b) Promote **flowering**. E.g. in pineapples. (c) To **prevent fruit and leaf drop** at early stages. (d) **Promote the abscission** of older mature leaves and fruits. (e) Induce **parthenocarpy**, e.g., in tomatoes. (f) Widely **used as herbicides**. 2, 4-D, widely used to kill dicotyledonous weeds, does not affect mature monocotyledonous plants.. (g) Controls **xylem differentiation** and helps in cell division. (h) **Apical dominance-** The process in which growing apical bud inhibits the growth of the lateral buds. . Removal of shoot tips (decapitation) results in the growth of lateral buds. It is applied in **tea plantations, hedge-making**.	♥ The term 'Auxins' is used to indicate **indole-3-acetic acid (IAA**) and other natural and synthetic compounds having growth regulating properties. ♥ Auxins are produced by the growing apices of stems & roots, from where they migrate to regions of their action. ♥ Based on origin- 1. **Natural- IAA** and **Indole Butyric Acid (IBA)** have been isolated from plants. 2. **Synthetic- NAA (Naphthalene Acetic Acid) and 2, 4-D (2, 4-dichlorophenoxyacetic)**.
2. Gibberellins	➢ **E. Kurosawa** reported the appearance of symptoms of the disease, 'bakane' (foolish seedling- a fungal disease of rice seedlings, caused by *Gibberalla fujikuroi*) in uninfected rice seedlings treated with sterile filtrates of the fungus. The active substances which are responsible for this disease was later identified as **gibberellic acid (GA).** ➢ GA_3 or Terpenes is the first discovered one.	(a) **Increase the length of axis**. E.g. for grapes stalks & sugar cane. (b) To elongate and **improve the shape** of fruits. E.g. apple. (c) **Delay senescence**. So, the fruits can be left on the tree longer so as to extend the market period. (d) GA_3 is used to **speed up malting process** in brewing industry. (e) **Accelerate the maturity period**. It leads to **early seed production**. (f) For **bolting** (internode elongation just prior to flowering) in beet, cabbages and many plants with rosette habit.	♥ There are more than 100 gibberellins in fungi and higher plants.
3. Cytokinins	➢ **F. Skoog** and co-workers observed that from tobacco stems, the **callus** (a mass of undifferentiated cells) proliferated only if the nutrients medium was supplemented with extracts of vascular tissues, yeast extract, coconut milk or DNA. ➢ Later identified the active substance as **kinetin** (an Adenine derivative) from the autoclaved herring sperm DNA.	(a) Play a role in **cytokinesis**. (b) Help to **produce new leaves** and chloroplasts in it. (c) Lateral shoot growth and adventitious shoot formation. (d) Help to **overcome the apical dominance**. (e) Promote **nutrient mobilization** which helps in the delay of leaf senescence.	♥ Kinetin does not occur naturally in plants. ♥ **Zeatin** is a cytokinin isolated from corn-kernels and coconut milk. ♥ Natural cytokinins are synthesized in regions where rapid cell division occurs (root apices, developing shoot buds, young fruits etc).
4. Ethylene	➢ **Cousins** confirmed the release of a volatile substance from ripened oranges that hastened the ripening of stored unripened bananas. Later this volatile substance was identified as ethylene.	(a) It has influences on **horizontal growth** of seedlings, swelling of the axis and apical hook formation in dicot seedlings. (b) It **promotes senescence** and **abscission** of plant organs especially of leaves and flowers. (c) It **induces fruit ripening**. It enhances the respiration rate during ripening of fruits (**respiratory climactic).** (d) It **breaks seed and bud dormancy**. (e) Promotes rapid **internode/petiole elongation** in deep water rice plants. It helps leaves/upper parts of the shoot to remain above water. (f) **Promotes root growth and root hair formation**. This helps the plants to increase their absorption surface. (g) Used to **initiate flowering** and for synchronising fruit-set in pineapples.	♥ Synthesized in large amounts by tissues undergoing senescence and ripening fruits. ♥ **Ethephon** (widely used ethylene) in an aqueous solution is readily absorbed and transported within the plant and releases ethylene slowly. - Speed-up ripening in tomatoes and apples - Accelerates abscission in flowers and fruits of cotton, cherry, walnut. - Promotes **female flowers** in cucumbers thereby increasing the yield.
5. Abscisic acid (ABA)	➢ In 1960s, **abscisic acid** reported as 3 kinds of inhibitors: ***inhibitor-B, abscission II*** *&* ***dormin***. It was proved that these were identical. ➢ It was discovered for its role in regulating abscission and dormancy.	(a) It acts as a general plant **growth** and **metabolic inhibitor**. (b) It **inhibits seed germination**. (c) It **stimulates the closure of stomata** in the epidermis and increases the tolerance of plants to various kinds of stresses. Therefore, it is also called the **stress hormone.** (d) It has an important role in **seed development, maturation and dormancy**. Seed dormancy by ABA helps to withstand desiccation. **(e)** It promote **abscission of leaves, flowers** and **fruits.**	♥ ABA is the **derivatives of carotenoids**.