ALLEN CAREER INSTITUTE KOTA (RAJASTHAN)

path to success

PRE-MEDICAL

BOTANY

ENTHUSIAST | LEADER | ACHIEVER

STUDY MATERIAL

Plant growth and Development

ENGLISH MEDIUM

Copyright Statement

PLANT GROWTH AND DEVELOPMENT

01. INTRODUCTION

- Growth is regarded as one of the most fundamental and conspicuous characteristics of a living being.
- Growth can be defined as an **irreversible permanent** increase in size of an organ or its parts or even of an individual cell.
- Generally, growth is **accompanied by metabolic processes (both anabolic and catabolic), that occur at the expense of energy.** Therefore, for example, expansion of a leaf is growth.

02. GROWTH

(1) PLANT GROWTH GENERALLY IS INDETERMINATE

- **Plant growth is unique because plants retain the capacity for unlimited growth throughout their life.**
- This ability of the plants is due to the presence of meristems at certain locations in their body. The cells of such meristems have the capacity to divide and self-perpetuate.
- The product, however, soon loses the capacity to divide and such cells make up the plant body.
- This form of growth wherein new cells are always being added to the plant body by the activity of the meristem is called the **open form of growth**
- **Plant growth is of two types :**
  - **Primary growth :** Root apical meristem and shoot apical meristem are responsible for the primary growth of the plants and principally contribute to the elongation of the plants along their axis.
  - **Secondary growth :** In dicotyledonous plants and gymnosperms, the lateral meristems (vascular cambium and cork cambium) are responsible for secondary growth and contribute to the increase in the girth of the organs (root, stem).

(2) GROWTH IS MEASURABLE

At cellular level growth can be measured by measuring the increase in the amount of protoplasm but it is very difficult to measure directly, so growth is measured by a variety of parameters, some of which are :-

- Increase in fresh weight
- Increase in dry weight
- Increase in surface area/volume
- Increase in number or size of cells.

One single maize root apical mersitem can give rise to more than 17,500 new cells per hour, whereas cells in a watermelon may increase in size by upto 3,50,000 times. In the former, growth is expressed as increase in cell number; the latter expresses growth as increase in size of the cell. While the growth of a pollen tube is measured in terms of its length, an increase in surface area denotes the growth in a dorsiventral leaf.

Growth is measured by Auxanometer.

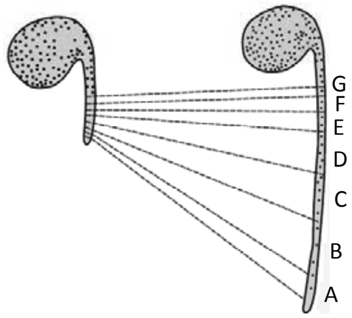
(3) PHASES OF GROWTH

The period of growth is generally divided into three phases, namely :

(A) Meristematic phase

(B) Elongation phase

(C) Maturation phase



Detection of zones of elongation by the parallel line technique. Zones A, B, C, D immediately behind the apex have elongated most.

NCERT XI Page No. 241, Figure, No. 15.3

(A) Meristematic phase :

The constantly dividing cells, both at the root apex and the shoot apex, represent the meristematic phase of growth. The cells in this region are characterised by :

- Cells are small in size with abundant plasmodesmatal connections.
- Intercellular spaces are absent, if present then very small.
- Cell walls are primary in nature, thin and cellulosic.
- Cells are rich in protoplasm, possess large conspicuous nuclei.

(B) Elongation phase :

The cells proximal to the meristematic zone represent the phase of elongation.

Cells in this region are characterised by :

- Increased vacuolation
- Cell enlargement
- New cell wall deposition

(C) Maturation phase :

The cells more proximal to the phase of elongation represent the phase of maturation. Cells of this zone, attain their maximal size in terms of **wall thickening** and **protoplasm modifications.**

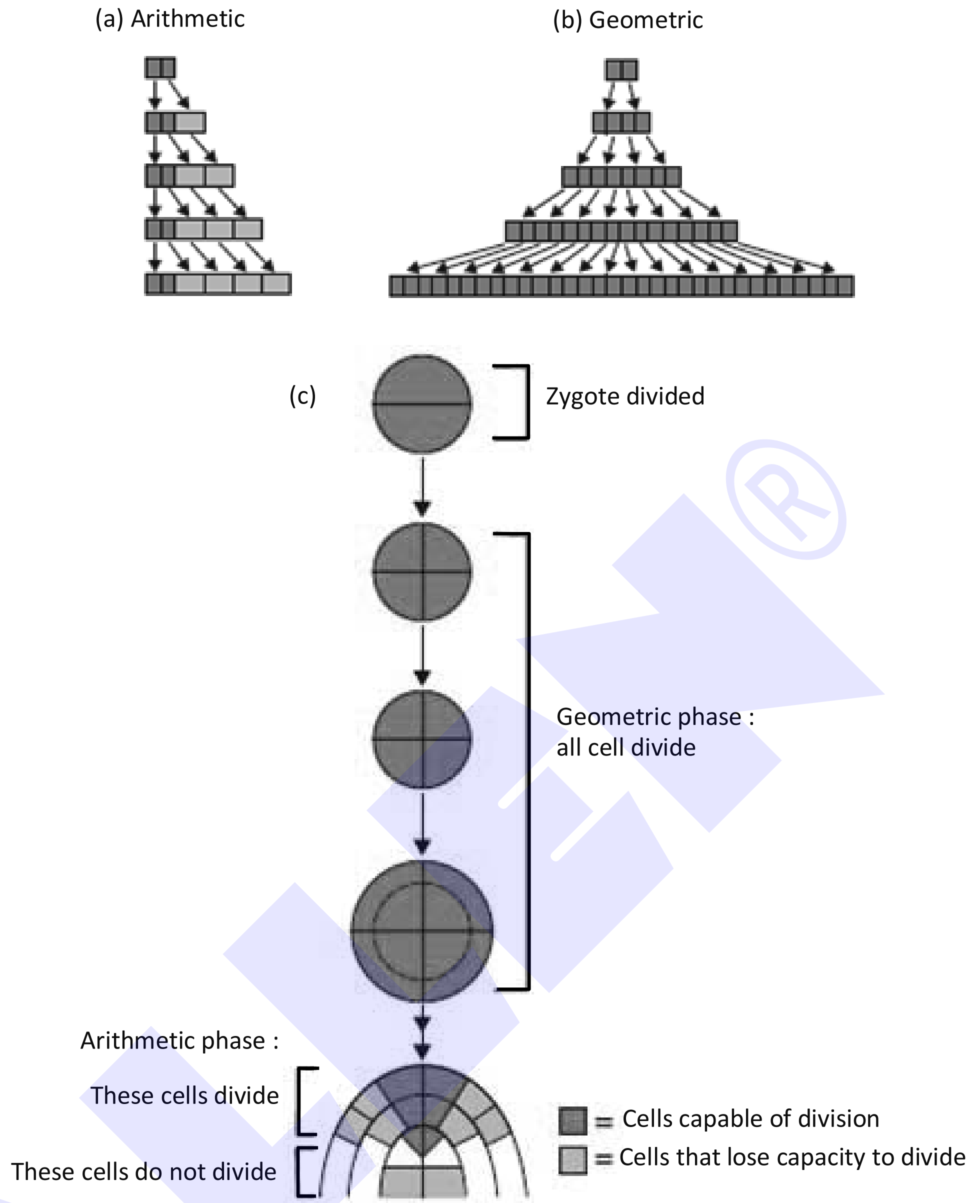
(4) GROWTH RATE

- Increased growth per unit time is termed as growth rate.
- The growth rate shows an increase that may be arithmetic or geometric.

(A) Arithmetic growth :

In arithmetic growth **only one daughter cell** among the **two further divides while other differentiates and become mature (stop dividing).**

- **Ex. Root & Shoot elongation at constant Rate.**



Diagrammatic representation of : (a) Arithmetic (b) Geometric growth and (c) Stages during embryo development showing geometric and arithmetic phases

NCERT XI Page No. 242, Figure No. 15.4

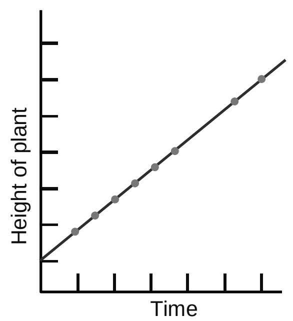
- It is mathematically expressed as :-

  $\boxed{L_t = L_0 + rt}$

  where L_t : length at time 't'

  L_0 - length at time 'zero'

  r - growth rate / elongation per unit time.



NCERT XI Page No. 243, Figure No. 15.5

- It's curve is linear.

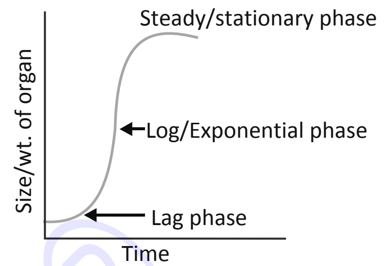
(B) Geometric Growth :

Here **both the progeny cells following mitotic divisions** retain the ability to divide and continue to do so.

Ex : Early embryonic development/division in zygote, division in unicellular organism.

It is mathematically represented as :

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



NCERT XI Page No. 243, FigureNo. 15.6

Where W_1 - final size (Weight, height, number etc.)

W_0 - initial size at the begining of period.

r - growth rate

e - base of natural logarithms.

- Here r = relative growth rate and is also the measure of the ability of the plant to produce new plant material, referred to as **efficiency index.**
- In most systems the initial growth is **slow (lag phase)** and it increases rapidly thereafter at an exponential rate **(log or exponential phase),** it is also called as **"grand phase of growth".** However, **with limited nutrient supply,** the growth slows down leading to a **stationary phase or steady phase.** If we plot the parameter of growth against time, we get typical **sigmoid or S-curve. A sigmoid curve is a characteristic of living organisms growing in a natural enviroment.** It is typical for all cells, tissues and organs of a plant.

(C) Quantitative comparisons between the growth of living system can also be made in two ways :

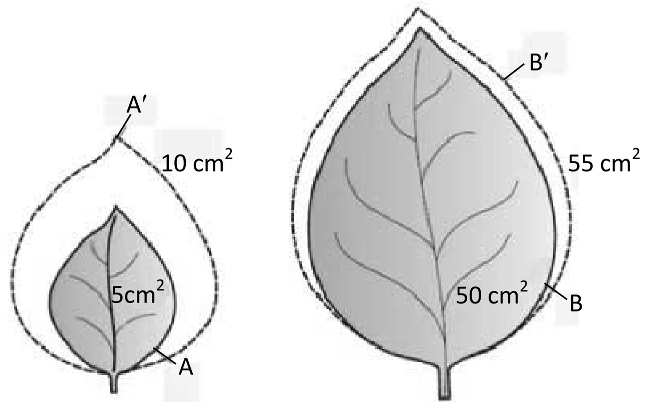
(i) Absolute growth rate : Measurement and comparison of total growth per unit time is called the absolute growth rate.

(ii) Relative growth rate : The growth of the given system per unit time expressed on a common basis, e.g., per unit initial parameter is called the relative growth rate.

$$\text{Relative growth rate} = \frac{\text{Growth of the given system per unit time}}{\text{Initial parameter}} \times 100$$

Explaination : Two leaves A ($5cm^2$) and B ($50\ cm^2$) undergo growth for unit time (suppose one week) and give A' ($10\ cm^2$) and B' ($55\ cm^2$)

Growth rates	Leaf A	Leaf B
Absolute growth rate	$5\ cm^2$	$5\ cm^2$
Relative growth rate	100%	10%

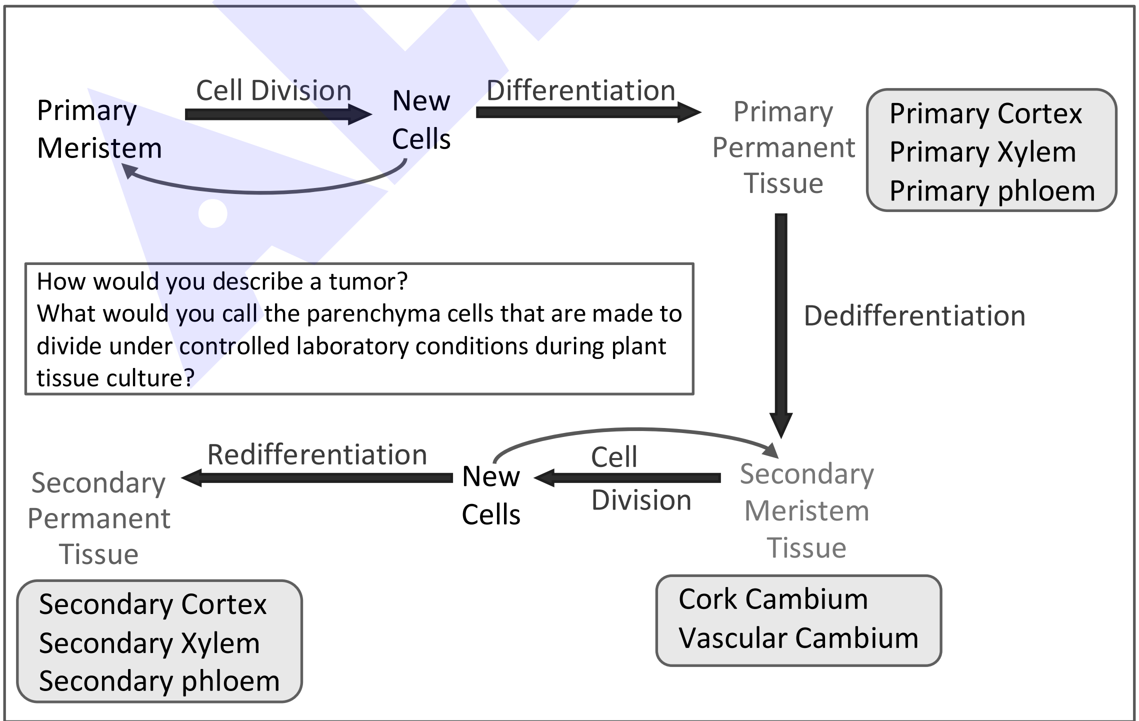


NCERT XI Page No. 244, Figure No.15.7

(5) CONDITIONS FOR GROWTH

- **Water, oxygen and nutrients** are very essential for growth. The plant cells grow in size by **cell enlargement** which in turn **requires water.** Turgidity of cells helps in extension growth. Thus, **plant growth** and **further development is intimately linked to the water status of the plant.** Water also provides the medium for enzymatic activities needed for growth.
- **Oxygen** helps in **releasing metabolic energy** essential for growth activities. **Nutrients** (macro and micro essential elements) are required by plants for **the synthesis of protoplasm** and act as source of energy.
- In addition, every plant organism has an optimum temperature range best suited for its growth. Any deviation from this range could be detrimental to its survival. Environmental signals such as light and gravity also affect certain phases/stages of growth.

03. DIFFERENTIATION, DEDIFFERENTIATION AND REDIFFERENTIATION



Differentiation : The cells derived from root apical, shoot apical meristems and cambium differentiate and mature to perform specific functions. **This act leading to maturation is termed as differentiation.**

- During differentiation cells undergo few to major **structural changes both in their cell walls** and **protoplasm.**

Example : To form a tracheary element, the cells would lose their protoplasm. They also develop a very strong, elastic lignocellulosic secondary cell walls, to carry water to long distances under extreme tension.

Dedifferentiation : The living differentiated cells, that by now have lost the capacity to divide can regain the capacity of division under certain conditions. This phenomenon is termed as **dedifferentiation.**

Example : Formation of secondary meristems (interfascicular cambium and cork cambium) from fully differentiated parenchyma cells.

Redifferentiation : Cells of secondary meristems are able to divide and produce cells that once again lose the capacity to divide and mature to perform specific functions. Such cells are called redifferentiated and phenomenon is termed as **redifferentiation.**

List of tissues in a woody dicotyledonous plant that are the products of redifferentiation :

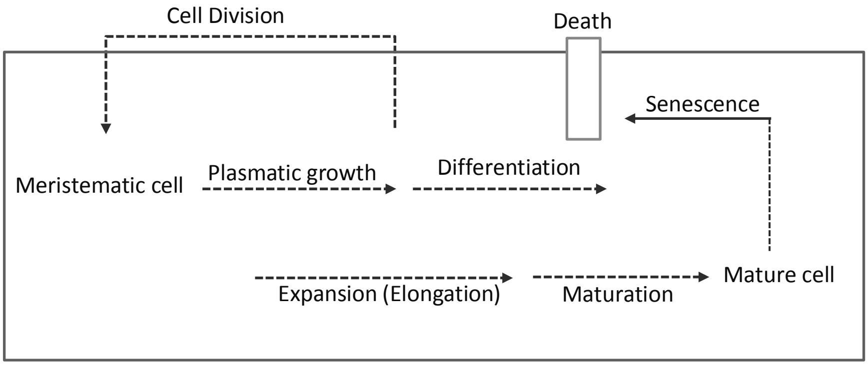
- Secondary xylem
- Secondary phloem
- Cork or phellem
- Secondary cortex or phelloderm

Differentiation in plants is **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 within the plant body.

Example : Cells postioned away from root apical meristems differentiate as root cap cells, while those pushed to the periphery mature as epidermis.

04. DEVELOPMENT = GROWTH + DIFFERENTIATION

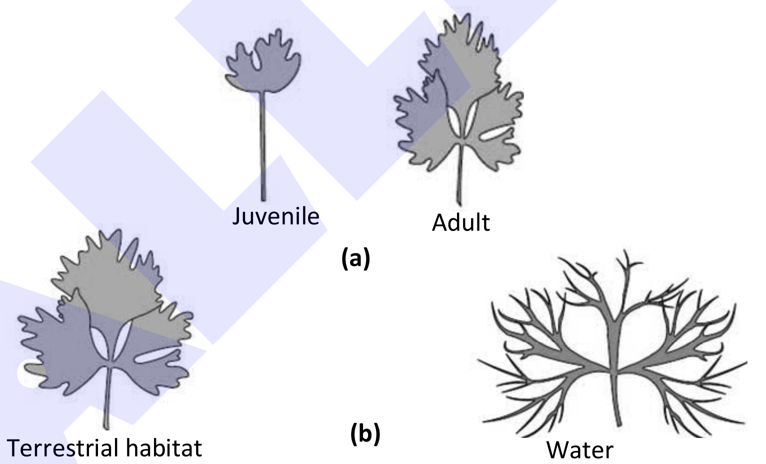
Development is a term that includes all changes that an organism goes through during its life cycle from germination of the seed to senescence. Diagrammatic representation of the sequence of processes which constitute the development of a cell of a higher plant is given in following diagram. It is also applicable to tissues/organs.



Sequence of the development process in a plant cell

NCERT XI Page No. 246, Figure No. 15.8

- **Plants follow different pathways in response to environment or phases of life to form different kinds of structures.** This ability is called **plasticity**, e.g. **heterophylly in cotton, coriander and larkspur.** In such plants, the leaves of the juvenile plant are different in shape from those in mature plants.
- On the other hand, difference in shapes of leaves produced in air and those produced in water in buttercup ***(Ranunculus)*** also represent the heterophyllous development due to environment. **This phenomenon of heterophylly is an example of plasticity.**



Heterophylly in (a) larkspur and (b) buttercup

NCERT XI Page No. 246, Figure No. 15.9

- **Development is considered as the sum of growth and differentiation,** which is controlled by both extrinsic (environmental) and intrinsic (internal) factors.
  - **Extrinsic factors -** light, temperature, water, oxygen, nutrition.
  - **Intrinsic factors -** genetic factors (Intracellular) and **PGR (Intercellular)**

Golden Key Points

- Growth is **accompanied by metabolic processes (both anabolic and catabolic), that occur at the expense of energy.**
- Form of growth wherein new cells are always being added to the plant body by the activity of the meristem is called the **open form of growth.**
- Differentiation in plants is **open** because cells/tissues arising out of the same meristem have different structures at maturity.
- Development is a term that includes all changes that an organism goes through during its life cycle from germination of the seed to senescence.
- **Phenomenon of heterophylly is an example of plasticity.**

BEGINNER'S BOX

INTRODUCTION, GROWTH, DIFFERENTIATION, DEDIFFERENTIATION AND REDIFFERENTIATION, DEVELOPMENT

1. To measure the growth in maize root apical meristem most appropriate parameter, is :-

(1) surface area (2) volume
(3) size of cells (4) number of cells

2. In which phase of growth cells attain their maximal size in terms of wall thickening and protoplasm modifications?

(1) Meristematic phase (2) Elongation phase
(3) Maturation phase (4) Division phase

3. Which of the following is correct sequence of phases in sigmoid growth curve?

(1) Lag, exponential, stationary (2) Stationary, lag, exponential
(3) Lag, stationary, exponential (4) Exponential, stationary, lag

4. In plants, growth and differentiation respectively are :-

(1) closed and open (2) open and open
(3) open and closed (4) closed and closed

5. Which of the following respectively are intercellular and intracellular intrinsic factors affecting plant development?

(1) Water and PGR (2) Genetic factors and PGR
(3) PGR and Nutrients (4) PGR and Genetic factors

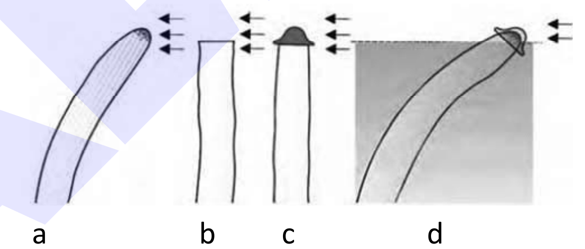
05. PLANT GROWTH REGULATORS (PGRs)

(1) CHARACTERISTICS

- **PGRs are also called plant growth substances or plant hormones or phytohormones.**
- The PGRs can be broadly divided into two groups based on their functions in a living plant body. One group of PGRs are involved in growth promoting activities, such as cell division, cell enlargement, pattern formation, tropic growth, flowering, fruiting and seed formation. These are also called plant growth promoters, e.g., auxins, gibberellins and cytokinins.
  - **Indole compounds (indole-3-acetic acid = IAA) $\Rightarrow$ Auxin**
  - **Adenine derivatives (N^6-furfurylamino purine = kinetin) $\Rightarrow$ Cytokinin**
  - **Terpenes (gibberellic acid = GA_3) $\Rightarrow$ Gibberellin**
- The PGRs of the other group play an important role in plant responses to wounds and stresses of biotic and abiotic origin. They are also involved in various growth inhibiting activities such as dormancy and abscission. The PGR abscisic acid belongs to this group. The gaseous PGR, ethylene, could fit either of the groups, but it is largely an inhibitor of growth activities.
  - **Derivatives of carotenoids (abscisic acid = ABA)**
  - **Gases (ethylene = C_2H_4).**

(2) THE DISCOVERY OF PLANT GROWTH REGULATORS

- Interestingly, the discovery of each of the five major groups of PGRs have been accidental. All this started with the observation of Charles Darwin and his son Francis Darwin when they observed that the coleoptiles of canary grass responded to unilateral illumination by growing towards the light source (phototropism). After a series of experiments, it was concluded that the tip of coleoptile was the site of transmittable influence that caused the bending of the entire coleoptile. Auxin was isolated by F.W. Went from tips of coleoptiles of oat seedlings.



NCERT XI Page No. 247, Figure No. 15.10

- The 'bakanae' (foolish seedling) disease of rice seedlings, was caused by a fungal pathogen *Gibberella fujikuroi*. E. Kurosawa (1926) reported the appearance of symptoms of the disease in rice seedlings when they were treated with sterile filtrates of the fungus. The active substances were later identified as gibberellic acid.
- F. Skoog and his co-workers observed that from the internodal segments of tobacco stems the callus (a mass of undifferentiated cells) proliferated only if, in addition to auxins the nutrients medium was supplemented with one of the following: extracts of vascular tissues, yeast extract, coconut milk or DNA. Miller et al. (1955) later identified and crystallised the cytokinesis promoting active substance that they termed kinetin.

- During mid-1960s, three independent researches reported the purification and chemical characterisation of three different kinds of inhibitors: inhibitor-B, abscission II and dormin. Later all the three were proved to be chemically identical. It was named abscisic acid (ABA).
- 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 gaseous PGR.

(3) PHYSIOLOGICAL EFFECTS OF PLANT GROWTH REGULATORS

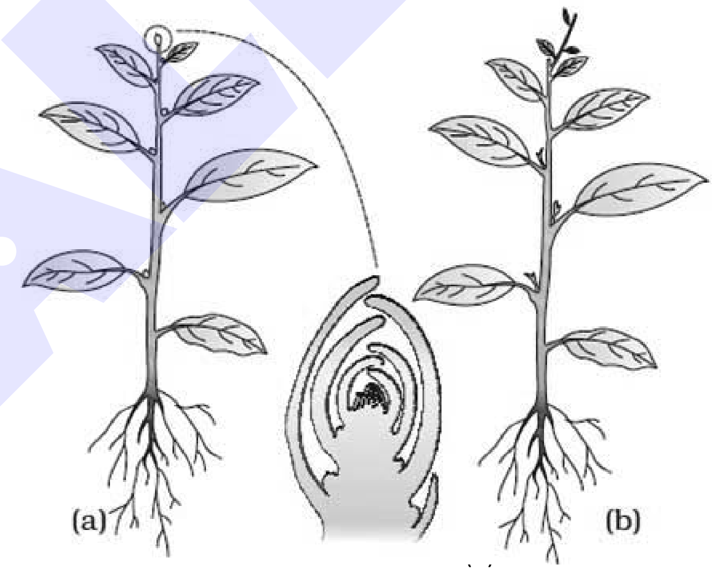
(A) Auxins

- **Term Auxin derived from Greek word 'auxein' which means to grow.**
- Biosynthesis of auxin occurs by **tryptophan (amino acid) in the presence of** Zn^{++} **ion.**
- **Natural auxin :** IAA (Indole Acetic acid) & IBA (Indole Butyric acid)
- **Synthetic auxin :** NAA (naphthalene acetic acid), 2,4-D (2, 4-dichlorophenoxyacetic) and 2,4,5-T (2, 4, 5-trichlorophenoxyacetic)
- **Biosynthesis of auxin occurs at both shoot and root apex and transport of auxin is polar.**

(i) **Apical Dominance (Characteristic function of auxin) :-**

In most higher plants, the growing apical bud inhibits the growth of the lateral (axillary) buds, a phenomenon called apical dominance.

- **Removal of shoot tips (decapitation) usually results in the growth of lateral buds. It is widely applied in tea plantations, hedge - making.**



(a) A plant with apical bud intact
(b) A plant with apical bud removed
Note : the growth of lateral buds into branches after decapitation.

NCERT XI Page No. 249, Figure No. 15.11

(ii) **Cell Division & Cell Enlargement : Mainly cell elongation. Helps in cell division. Auxin also controls the xylem differentiation.**

(iii) **Root initiation :-** Rooting **on stem cuttings (widely used in plant propagation)** is promoted by IBA & NAA.

(iv) **Prevention of Abscission :-** IAA, NAA help to prevent fruit and leaf drop at early stages but promote the abscission of older mature leaves and fruits.

(v) **Flower initiation :-** Auxin promotes **flowering in Pineapple & Litchi plants.**

(vi) **Parthenocarpy :- Seed less fruits** can be produced by spray of IAA. eg. **Tomato.**

(vii) **Selective weed killer :- 2, 4-D is widely used to kill Dicot weeds, does not affect monocot plants.**

(viii) **Potato dormancy :** MH (maleic hydrazide) and α NAA keep lateral buds of potato tubers dormant. Thus, potato tubers can be stored for longer durations.

Bioassay of auxin :

Bioassay is a biological testing of a substance (PGR) on a plant or its parts.

(a) *Avena* curvature test.

(b) Root growth inhibition

(B) Gibberellins

- More than 100 type of Gibberellins (GA_1, GA_2 GA_3 .... GA_{100}) are known. **GA_3** was one of the first gibberellins to be discovered and remains the most intensively studied form. All GA_3 are acidic.
- **They are synthesised in buds, shoot, root and germinating seeds.**

(i) **Stem/internode elongation (characteristic function of gibberellins) :-** Gibberellins also promotes bolting (internode elongation just prior to flowering) in beet, cabbages and many plants with rosette habit.

(ii) **Elongation of genetically dwarf plants :-** When gibberellins are applied to **dwarf Maize, *Pisum* etc.** plants become tall.

(iii) **Seed germination :-** Gibberellin induces the synthesis of hydrolysing enzymes like amylase, lipases & proteases in seeds and these enzymes help in seed germination.

(iv) Gibberellin has ability to cause an increase in length of axis is used to increase the length of grapes stalks. Gibberellins, cause fruits like apple to elongate and improve its shape.

(v) GA_3 is used to speed up the malting process (malt formation) in brewing (wine) industry.

(vi) **Increase height of Sugarcane plant :-** Sugarcane stores carbohydrate as sugar in their stems. Spraying sugarcane crop with gibberellins increases the length of the stem, thus increasing the yield by as much as 20 tonnes per acre.

(vii) GA delays the senescence in plant parts so the **fruits can be left on the tree longer so as to extend the market period by application of GA.**

(viii) **Spraying juvenile conifers with GAs, hastens the maturity period, thus leading to early seed production.**

Bioassay of gibberellins :

(a) Barley endosperm test (based upon α-amylase activity)

(b) Dwarf pea and maize test (based upon internodal elongation activity).

(C) Cytokinin (CK)

- Cytokinins have specific effects on cytokinesis, and were discovered as kinetin (a modified form of adenine, a purine) from the autoclaved herring sperm DNA. Kinetin does not occur naturally in plants. Search for natural substances with cytokinin-like activities led to the isolation of zeatin from corn-kernels and coconut milk.
- Cytokinins are derivative of **Adenine nitrogen base.**
- Natural cytokinins are synthesised in regions where rapid cell division occurs, for example, root apices, developing shoot buds, young fruits etc.

Cytokinin + Gibberellin = Pomalin (Apple size enlarger)

(i) **Cell Division (Characteristic function of cytokinin)**

(ii) **Morphogenesis :-** Morphogenetic changes (Root and shoot development) are induced by cytokinin and auxin in tissue culture.

$\dfrac{\text{Low CK}}{\text{High Auxin}} \rightarrow$ root differentiation

$\dfrac{\text{High CK}}{\text{Low Auxin}} \rightarrow$ shoot differentiation

(iii) **Overcome apical dominance :- CK promotes growth of lateral buds.**

(iv) **Delay in senescence (Richmond Lang Effect) :- Senescence is delayed by CK as help in nutrient mobilisation. Also help to produce new leaves and chloroplasts in leaves.**

(v) **Promotes lateral shoot growth and adventitious shoot formation.**

Bioassay of cytokinin :

(a) Tobacco pith cell division test.

(b) Chlorophyll preservation (retention) test.

(D) Ethylene

- Ethylene can be included in both groups growth promoter and growth inhibitor but mainly it is a growth inhibitor hormone.
- Ethylene is a simple gaseous PGR. It is a hydrocarbon reported as a fruit ripening hormone.
- One of the most widely used PGR in agriculture.
- Biosynthesis of Ethylene takes place by methionine amino acid. Ethylene is synthesised in large quantity by ripening fruits and senescent organs.

(i) **Ripening of fruits** in apple and tomato. **Ethephon** or **CEPA** (Chloro Ethyl Phosphonic Acid) is most widely used compound as source of ethylene. Ethylene enhances the respiration rate during ripening of the fruits. This rise in respiration is called respiratory climactic.

(ii) **Stimulation of senescence & abscission of flower and fruit.** (Thinning of cotton, cherry, walnut.)

(iii) **Flowering and synchronising fruiting in pineapple.** It also induces flowering in mango.

(iv) **Triple response on stem :-**

(a) Apical hook formation in dicot seedlings

(b) Swelling of axis

(c) Horizontal growth of seedlings

(v) **Promotes root growth :-** Ethylene promotes root growth and also stimulates the formation of root hairs, thus helping the plants to increase their absorption surface.

(vi) **Femaleness (Feminising effect) in cucumbers.** (Promotes female flowers to increase the yield/production)

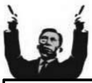
(vii) **Ethylene breaks seed and bud dormancy, initiates germination in peanut seeds, sprouting of potato tubers.**

(viii) **Ethylene promotes rapid internode/petiole elongation in deep water rice plants.** It helps leaves/upper parts of the shoot to remain above water.

(E) Abscisic Acid (ABA)

- As mentioned earlier, abscisic acid (ABA) was discovered for its role in regulating abscission and dormancy.
- But like other PGRs, it also has other wide ranging effects on plant growth and development.
- It acts as a general plant growth inhibitor and an inhibitor of plant metabolism.
- ABA is mainly synthesised in senescent organs, old leaves.

- ABA is also known as **stress hormone** because ABA stimulates the closure of stomata and increases the tolerance of plants to various kinds of stresses.
  - (i) **Induces senescence and abscission –** ABA causes senescence and abscission of leaves and fruits **by increasing the activity of cellulase & pectinase enzymes.**
  - (ii) **Induces Bud & Seed Dormancy – ABA increases bud & seed dormancy (Inhibits seed germination). ABA plays a major role in seed development, maturation and dormancy.**
  - By inducing dormancy, ABA helps seeds to withstand dessiccation and other factors unfavourable for growth.



In most situations ABA act as an antagonist to GAs

06. PHOTOPERIODISM

- Flowering in certain plants depends not only on a combination of light and dark exposures but also on their relative durations. This response of plants to periods of day/night is termed as **photoperiodism.**
- The phenomenon of photoperiodism was first discovered by **Garner** & **Allard** on **Maryland mammoth (a mutant variety of Tobacco) and Biloxy soyabean.**
- **Garner** & **Allard** classified the plants in following groups -

(1) SDPs (SHORT DAY PLANTS)

- **These plants flower on exposure to photoperiod shorter than their Critical day length or critical photoperiod.**
- In SDPs the **dark period is critical and must be continuous.** Thus SDP are also called as **LNP (Long Night Plants).** If this **dark period is interrupted even with a brief exposure of light, the SDP will not flower.**
- Examples of SDPs :- **Tobacco, Soyabean, *Xanthium* (Cocklebur),** *Chrysanthemum,* Dahlia, Sugarcane, *Cosmos,* Rice etc.

(2) LDPs (LONG DAY PLANTS)

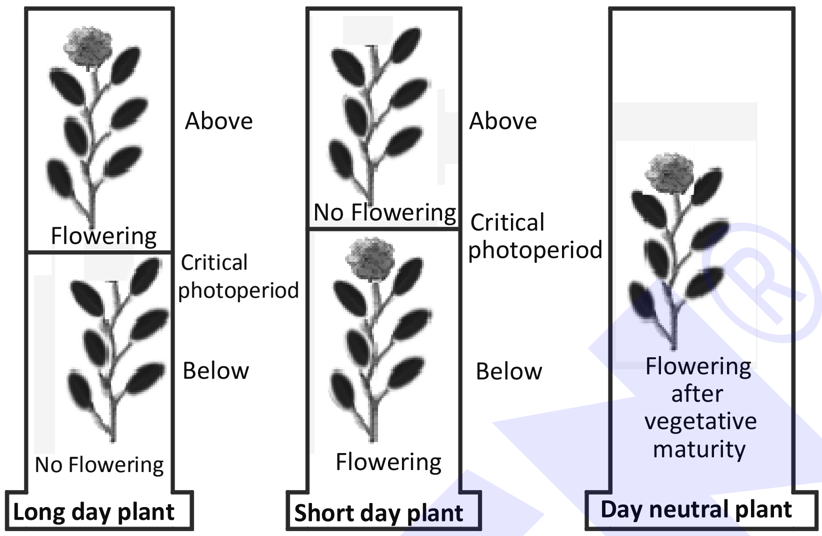
- **These plants flowers when they are exposed to photoperiod longer than their critical day length or critical photoperiod.**
- **A brief exposure of light in the dark period stimulates flowering in LDPs.**
- The **light period is critical for LDPs.**

  Ex. : **Henbane (*Hyoscyamus*), Spinach, Sugarbeets, Wheat, Larkspur, Barley.**

(3) DNPs (DAY NEUTRAL PLANTS)

- These plants do not need a specific light period for the flowering.

  Ex. **Maize, Cotton, Tomato, Sunflower, Cucumber**



Photoperiodism : Long day, short day and day neutral plants

NCERT XI Page No. 251, Figure No. 15.12

(4) PHYTOCHROME

- A light sensitive pigment **phytochrome (a chromoprotein) is responsible for flowering induction** and is present in leaves.
- **Phytochrome exists in two different forms –**

  Pr (Phytochrome Red)

  Pfr (Phytochrome Far Red)
- Both forms of phytochromes are photobiochemically interchangeable into each other.

In LDP flowering inhibit

In SDP stimulates

$$Pr \underset{\text{Far red light (730 NM)}}{\overset{\text{Red light (660 NM)}}{\rightleftharpoons}} Pfr$$

Dark

In SDP flowering inhibits

In LDP stimulates

- Phytochrome - **Pfr (P_{730}) is active form** which controls many photophysiological processes in plants like - flowering, seed germination etc.
- **Stimulation of critical photoperiod is perceived by leaves.**
- It has been hypothesised that there is a hormonal substance that is responsible for flowering. This hormonal substance **migrates from leaves to shoot apices for inducing flowering.**

07. VERNALISATION OR YAROVIZATION OR SPRINGIFICATION

- In some plants flowering is either quantitatively or qualitatively dependent on exposure to low temperature. This phenomenon is termed as **vernalisation.**
- "Vernalisation refers specially to the promotion of flowering by a period of low temperature".

Requirements for success of vernalisation :

(a) Actively dividing cells

(b) Period of low temperature treatment

(c) Aerobic respiration

(d) Optimum hydration

(e) Optimum nutrition

- After perception of suitable low temperature period, a hypothetical hormonal substance (vernalin) is produced.
- Some important food plants, wheat, barley, rye have two kinds of varieties :

(i) Spring varieties

(ii) Winter varieties

Spring varieties are normally planted in the spring and come to flower and produce mature grain before the end of growing season.

- Winter varieties, however, if planted in spring would normally fail to flower or produce mature grains within a span of flowering season so they are planted in autumn. They germinate and over winter come out as small seedlings, resume growth in spring and usually harvested around mid-summer.
- Vernalisation prevents precocious reproductive development late in the growing season and enables the plant to have sufficient time to reach maturity.
- Another example of vernalisation is seen in **biennial plants (e.g. sugarbeet, cabbages, carrots etc.).** Biennials are monocarpic plants.

Biennial plants —
→ In first season they germinate then resume growth and ultimately attain maturity.
→ In second season they flower then form fruits, set seeds and undergo senescence and die.

- **Agent orange :** It is a mixture of equal parts of two herbicides, 2, 4-D and 2,4,5-T. Agent orange is a herbicide and defoliant chemical.
- Gibberellins induce flowering in long day plants (LDPs) under **non inductive photoperiods.**
- Gibberellin is a substitute of vernalisation.
- Gibberellin is a male hormone (promote formation of male flowers)
- For every phase of growth, differentiation and development of plants, one or the other PGR has some role to play. Such roles could be complimentary or antagonistic. These could be individualistic or synergistic.

08. SEED DORMANCY

- Seed dormancy refers to failure of a viable seed to germinate even when given favourable environmental conditions. Such seeds are understood to be undergoing a period of dormancy which is controlled not by external environment but are under endogenous control or conditions within the seed itself.

(1) REASONS OF SEED DORMANCY

(i) Impermeable and hard seed coat.

(ii) Presence of chemical inhibitors such as abscisic acids, phenolic acids, para-ascorbic acid.

(iii) Immature embryo.

(2) BREAKING OF DORMANCY

- This dormancy however can be overcome through natural means and various other man-made ways :

(A) By Natural Way :

(i) Action of sunlight : Exposure to light breakdown the germination inhibitors.

(ii) Action of heat or temperature : Exposure to heat, breakdown the germination inhibitors.

(iii) Passage through digestive tracts of animals : When seeds pass through digestive tract of animals hard seed coat become soft due to action of enzymes. Enzymatic action also eliminate inhibitors.

(iv) By microbial action

(B) By Artificial Way :

(i) Stratification : Physiological dormancy is broken by exposure in cold temperature.

(ii) Scarification : It is breaking of dormancy by nicking seed coat with sharp knife and abrade seed with sandpaper or by vigorous shaking.

(iii) Water : Soaking seeds in water overnight softens a hard seed coat enough to allow moisture inside so that the seed can germinate.

(iv) Application of certain chemicals : Gibberellic acid and nitrates are often used to break seed dormancy.

Golden Key Points

- The gaseous PGR, ethylene, could fit either of the groups, but it is largely an inhibitor of growth activities.
- **Removal of shoot tips (decapitation) usually results in the growth of lateral buds. It is widely applied in tea plantations, hedge making.**
- Gibberellins induce **internode elongation just prior to flowering in Rosette plants (Beet and Cabbage),** this phenomenon is known as **Bolting effect.**
- Search for natural substances with cytokinin like activities led to the isolation of zeatin from corn-kernels and coconut milk.
- **Ethephon** or **CEPA** (Chloro Ethyl Phosphonic Acid) is most widely used compound as source of ethylene.
- ABA is also known as **stress hormone.**
- A light sensitive pigment **phytochrome (a chromoprotein) is responsible for flowering induction** and is present in leaves.
- **Stimulation of critical photoperiod is perceived by leaves.**

BEGINNER'S BOX — PLANT GROWTH REGULATORS, PHOTOPERIODISM, VERNALISATION, SEED DORMANY

1. Which of the following plant growth regulators was isolated from a fungus?

(1) Gibberellin (2) Ethylene
(3) Cytokinin (4) Auxin

2. Chlorophyll preservation test is used for bioassay of :-

(1) auxin (2) gibberellin
(3) cytokinin (4) ethylene

3. Sprouting in potato tubers can be induced by :-

(1) ABA (2) Ethylene
(3) Auxin (4) Cytokinin

4. Which of the following is a short day plant (SDP) ?

(1) Wheat (2) Barley
(3) Henbane (4) Tobacco

5. Which of the following are often used to break seed dormancy?

(1) Abscisic acids (2) Nitrates
(3) Phenolic acids (4) Para-ascorbic acids

BEGINNER'S BOX ANSWER KEY

INTRODUCTION, GROWTH, DIFFERENTIATION, DEDIFFERENTIATION AND REDIFFERENTIATION, DEVELOPMENT

Que.	1	2	3	4	5
Ans.	**4**	**3**	**1**	**2**	**4**

PLANT GROWTH REGULATORs, PHOTOPERIODISM, VERNALISATION, SEED DORMANY

Que.	1	2	3	4	5
Ans.	**1**	**3**	**2**	**4**	**2**

ESSENCE

- **Development is the sum of two processes – Growth and differentiation**
- Growth is accompanied by metabolic processes – both catabolic and anabolic, that occur at the expense of energy.
- Plants show **open form of growth** – new cells are always being added to the plant body
- In **Arithmetic growth only one daughter cell continuous to divide** while other differentiate and matures.
- Root elongation at constant rate is the expression of arithmetic growth.
- In **Geometric growth both daughter cells continuously divide.** It attain sigmoid curve if space and food is limited.
- Plant growth is open can be determinate (In Plant organs like leaf, fruit, flower) or Indeterminate (In shoot & root apices).
- **Plant differentiation is also open** – Same meristem have different structures at maturity.
- Final structure at maturity of cell/tissue is determined by location of cell within the plant body.
- Plant follows different pathways in response to environment or phases of life to form different kinds of structure, this ability called **Plasticity.**
- Heterophylly in Buttercup, cotton, coriander and larkspur is an examples of plasticity.
- Development in plants is under control of extrinsic (light, temperature, water, oxygen & nutrition) and Intrinsic (Intracellular – genetic and intercellular – PGR) factors.

PHOTOPERIODISM :-

Influence of relative duration of light & dark on flowering.

- LDP – needs light exposure more than critical light period.
- SDP – needs light exposure less than critical light period.
- DNP – No correlation between exposure of light durations & induction of flower.
- **Site of perception of light & dark duration are leaves.**

  It has been hypothesised that there is a hormonal substance move from leaves to shoot apex to induce flowering.

VERNALISATION :-

Qualitative or quantitative dependence of flowering on low temperature exposure.

- It prevent precocious reproductive development late in growing season and it enables the plant to have sufficient time to reach maturity.
- Vernalisation applicable on winter varieties of wheat, rye & barley as well as on biennials such as sugarbeet, cabbages & carrots.

Plant Growth Regulator	**Auxins** Indole compounds (indole 3-acetic acid, IAA)	**Gibberellins** terpenes (gibberellic acid, GA_3)	**Cytokinin** adenine derivatives (N_6-furfurylamino purine, kinetin)	**Ethylene** gases (ethylene, C_2H_4)	**Abscisic acid** derivatives of carotenoids (abscisic acid, ABA)
Discovery	F.W. Went from tips of coleoptiles of oat seedlings	From a fungal pathogen *Gibberella fujikuroi by* E. Kurosawa (1926)	F. Skoog (By use of extracts of vascular tissues, yeast extract, coconut milk or DNA in plant tissue culture) Miller et al. (1955) – term Kinetin	H.H. Cousins (1910) - Volatile substance from ripened oranges	During mid-1960s, three independent researches found - inhibitor-B, abscission II and dormin. Later it was named abscisic acid (ABA)
Members	**Natural** - IAA and indole butyric acid (IBA) **Synthetic** - NAA (naphthalene acetic acid) and 2, 4-D (2, 4-dichlorophenoxyacetic)	Denoted as GA_1, GA_2, GA_3 and so on. Gibberellic acid (GA_3) - most intensively studied form.	**Natural** – Zeatin **Synthetic** – Kinetin		
Physiological Effects	▪ Apical dominance. ▪ Help to initiate rooting in stem cuttings ▪ Promote flowering in pineapples. ▪ Prevent fruit and leaf drop at early stages but promote the abscission of older mature leaves and fruits. ▪ Induce parthenocarpy, e.g., in tomatoes. ▪ Widely used as herbicides. 2, 4-D, (kill dicot Weeds) used to prepare weed-free lawns. ▪ Controls xylem differentiation and helps in cell division.	▪ Increase the length of grapes stalks. ▪ Cause fruits like apple to elongate and improve its shape. ▪ Delay senescence. Fruits can be left on the tree longer (extend the market period.) ▪ Speed up the malting process. ▪ Increases the length of the sugarcane stem, (increasing the yield by as much as 20 tonnes per acre.) ▪ Spraying juvenile conifers hastens the maturity period (early seed set) ▪ Promotes **bolting** (Internode elongation just prior to flowering) in beet, cabbages and many plants with **rosette habit**.	▪ Natural cytokinins are synthesised in regions where rapid cell division occurs, for example - root apices, developing shoot buds, young fruits etc. ▪ Helps to produce new leaves, chloroplasts in leaves, lateral shoot growth and adventitious shoot formation. ▪ **Help overcome the apical dominance.** ▪ Promote nutrient mobilisation which helps in the **delay** of leaf **senescence.**	▪ Fruit ripening. **(Respiratory climactic.)** ▪ Breaks seed and bud dormancy, initiates germination in peanut seeds, sprouting of potato tubers. ▪ Promotes rapid internode/petiole elongation in deep water rice plants. ▪ Also promotes root growth and **root hair formation.** ▪ Used to initiate flowering and for synchronising fruit-set in pineapples. ▪ Induces flowering in mango. ▪ Thinning of cotton, cherry, walnut. ▪ Promotes **female flowers in cucumbers.**	▪ Acts as a **general plant growth inhibitor** and an inhibitor of plant metabolism. ▪ ABA inhibits seed germination. ▪ ABA stimulates the closure of stomata and increases the tolerance of plants to various kinds of stresses **(stress hormone).** ▪ ABA plays an important role in **seed development, maturation and dormancy.** ▪ By inducing dormancy, ABA helps seeds to withstand desiccation and other factors unfavourable for growth. ▪ In most situations, ABA acts as an **antagonist to GAs.**
Bioassay	a) *Avena* curvature test. b) Root growth inhibition test (In high concentratrion)	a) Barley endosperm test (based upon α-amylase activity) b) Dwarf pea and maize test (based upon internodal elongation activity).	a) Tobacco pith cell division test. b) Chlorophyll preservation (retention) test.	**Triple response:** a) Horizontal growth of seedlings b) Swelling of the axis c) Apical hook formation in dicot seedlings.	