PLANT GROWTH AND DEVELOPMENT

Growth

- Growth can be defined as an irreversible permanent increase in size of an organ or its parts or even of an individual cell.
- Growth is accompained by metabolic processes (both anabolic and catabolic), that occur at the expense of energy. e.g., expansion of a leaf is growth.

Q. How would you describe the swelling of piece of wood when placed in water ?
Ans. It is an example of imbibition not growth, it is an reversible increase.

Characterstics of plant growth

(1) Plant growth is generally indeterminate because plants retain the capacity for unlimited growth throughout their life.
This ability of 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.

(2) Plant growth is localised.
Reason : Plant growth is restricted to certain locations (apical meristems, intercalaxy meristems, lateral meristems) within plant body.

(3) Plant growth is open. In this form of growth new cells are always being added to the plant body by the activity of the meristem.

(4) Plant growth is of two types:
(i) 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.
(ii) 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).

Growth is measurable

Growth at cellular level, is principally a consequence 'of increase in the amount of protoplasm. Since increase in protoplasm is difficult to measure directly, one generally measures some quantity which is more or less proportional to it.
Growth is measured by a variety of parameters, they are :
(i) Increase in fresh and dry weight.
(ii) Increase in length e.g., length of pollen tube.
(iii) Increase in surface area e.g., growth in surface area of a leaf.
(iv) Increase in cell number e.g., maize root apical meristem can give rise to more than 17500 new cells per hour.
(v) Increase in cell size or volume. e.g., cells in a watermelon mayincrease in size upto 3,50,000 times.
(vi) Increase in girth e.g., increase in diameters of diameters root and dicot stem.

Methods of growth measurement

(a) By direct observation (b) By auxanometer
(c) By crescograph : This apparatus was developed by J.C. Bose.

Phases of growth

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

(i) Meristematic phase

(ii) Elongation phase

(iii) Maturation phase

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

(a) Cells are small in size with abundant plasmodesmal connections.

(b) Intercellular spaces are absent, if present then very small.

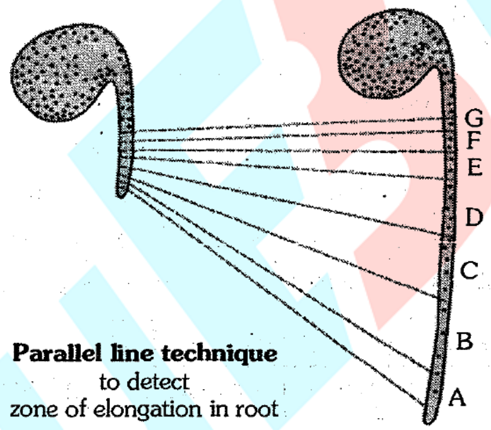
(c) Cell walls are primary in nature, thin and cellulosic.

(d) Cells are rich in protoplasm, possess large conspicuous nuclei.

(ii) Elongation phase : The cells proximal to the meristematic zone represent the phase of elongation. Cells in this region are characterized by :

(a) Increased vacuolation (b) Cell enlargement (c) New cell wall deposition

(iii) 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 or wall thickening and protoplasm modifications.

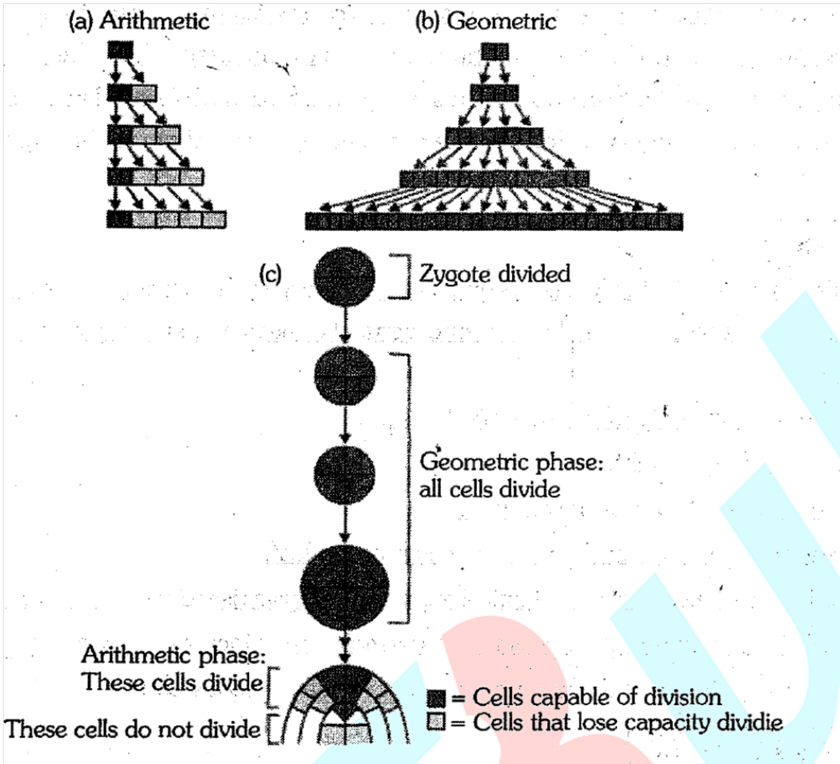


Parallel line technique
to detect
zone of elongation in root

Growth rates

The increased growth per unit time is termed as growth rate. Thus, rate of growth can be expressed mathematically. An organism, or a part of the organism can produce more cells in two ways :

(1) Arithmetic (2) Geometric



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

(1) Arithmetic growth : In arithmetic growth cell undergoes mitotic cell division and produce two daughter cells. Only one daughter cell continue to divide while the other differentiates and matures.

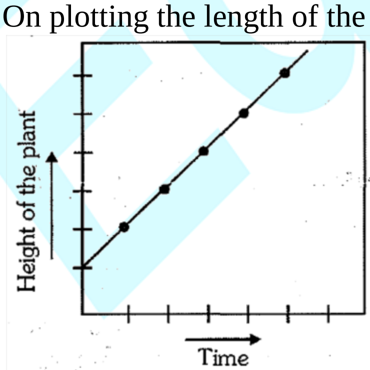
- The simplest expression of arithmetic growth is examplified by a root elongating at a constant rate.
- Mathematically, it is expressed as :

  $L_t = L_0 + rt$

  L_t = Length at time 't'

  L_0 = Length at time 'zero'

  r = Growth rate/elongation per unit time
- On plotting the length of the root against time, a linear curve is obtained.



(2) Geometric growth :

In geometric growth cell undergoes mitotic cell division and produce two daughter progeny. Both the progeny cells following mitotic cell division retain the ability-to divide and continue to do so.

Geometric growth has two phases- Lag and Log phase. When nutrients are limited the growth will be logistic which show sigmoid growth curve.

Sigmoid growth curve is divided into following three stages :

(a) Lag phase: It is initial stage, where growth is slow.

(b) Log phase: At this stage growth is rapid at exponential rate.

(c) Stationary phase : At this stage. the growth slows down leading to a stationary phase.

- The exponential growth can be expressed as :

  $w_1 = w_0e^{rt}$

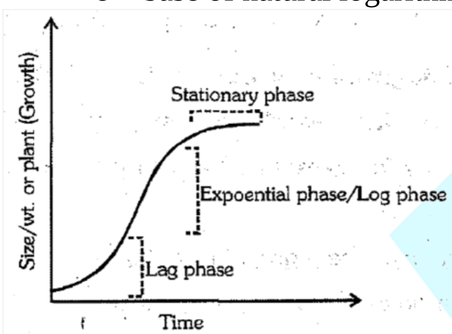
  w_1 = final size (weight. height. number etc.)

  w_0 = Initial size at the beginning of the period.

  r = growth rate

  t = time of growth

  e = base of natural logarithms



Here, 'r' is the relative growth rate and is also 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 upon the initial size, w_0.

- If we plot the parameter of growth against time, we get a typical sigmoid or s-curve.
- A sigmoid curve is a characteristic of living organism growing in a natural environment (limited resources).
- It is typical for all cells tissues and organs of plant. It is also idealised for cells in culture.

Q. What kind of a curve can you expect in a tree showing seasonal activities ?

Ans. Sigmoid or S-curve

Quantitative comparisions between the growth of living system can also be made in two ways :

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

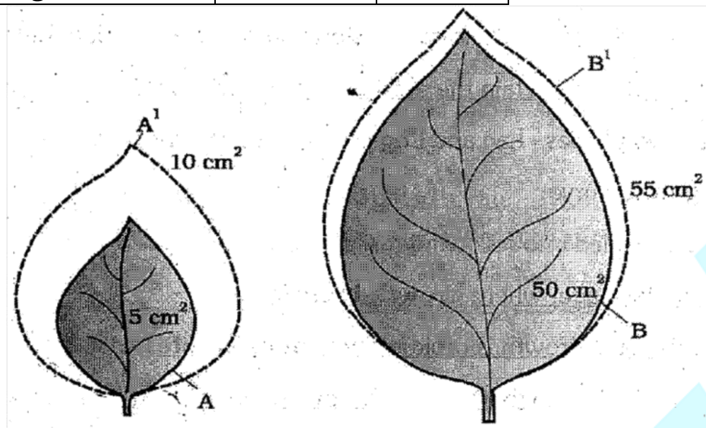
(ii) Relative growth rate : The growth of the given system per unit time expressed on a common basis. e.g. per unit initial parameter is called the relative growth rate.

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

Explaination : Two leaves A($5cm^2$) and B($50\ cm^2$) undergo growth for unit time (one week) and give A^1($10\ cm^2$) B^1($55\ cm^2$)

Growth rates	Leaf A	Leaf B

Absolute growth rate	5 cm^2	5 cm^2
Relative growth rate	100%	10%



Diagrammatic comparison of absolute and relative growth rates. Both leaves A and B have increased their area by 5 cm2 in a given time (one week) to produce A^1, B^1 leaves.

Conditions for growth : Necessary conditions for growth are :

(1) Water:

- The plant cells grow in size by cell enlargement which in turn requires water.
- Turgidity of cells help 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.

(2) Oxygen : Oxygen helps in releasing metabolic energy essential for growth activities.

(3) Nutrients : Macro and micro essential elements are required by plants for the synthesis of protoplasm and act as source of energy.

(4) Temperature : Every plant organism has an optimum temperature range best suited for its growth. Any deviation from this range could be detrimental to its survival.

(5) Environment signals :

(i) Light : Light is a stimulus for shoot growth. (positive phototropism).

(ii) Gravity : Gravity is a stimulus for root growth (positive geotropism)

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 protoplasms.

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

Q. How would you describe a tumour ?

Ans. Tumour is a product of dedifferentiation.

Q. What would you call the parenchyma cells that are rl'lade to divide under controlled laboratmy conditions during plant tissue culture ?

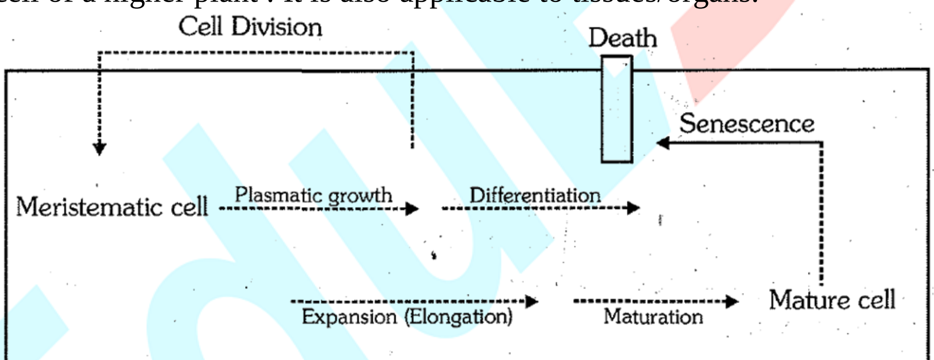
Ans. It is dedifferentiation and cells are dedifferentiated cells.

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.

Development : It is a term- that includes all changes that an organism goes through during its life cycle from germination of the seed to senescence.

Diagramatic representation of the sequence of processes which constitute the development of a cell of a higher plant : It is also applicable to tissues/organs.



Sequence of the development process in a plant cell

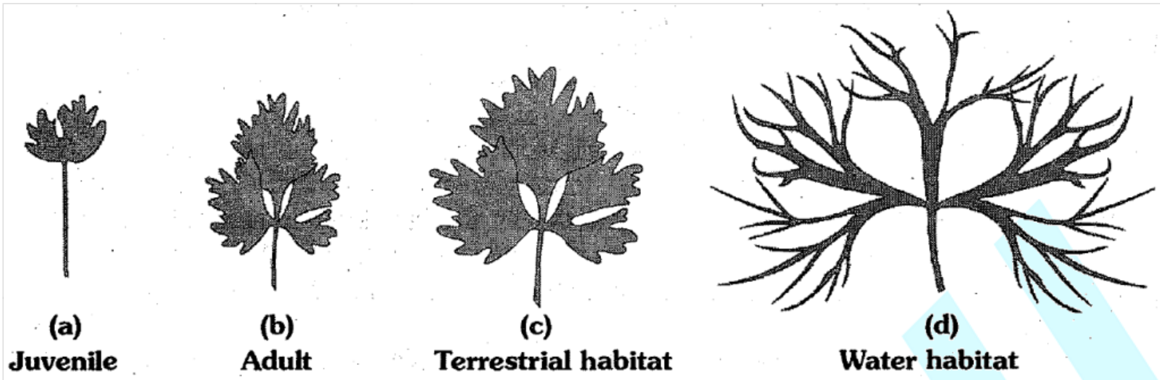
Plasticity : Plants follow different pathways in response to environment or phases of life to form different kinds of structures. This ability is called plasticity.

Example (i) : Developmental heterophylly in cotton, coriander and larkspur.

In such plants, the leaves of the juvenile plant. are different in shape from those in mature plant.

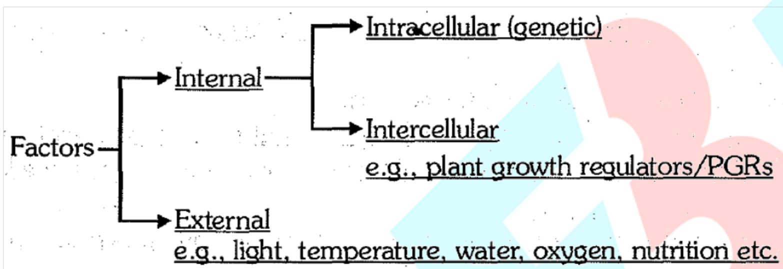
Example (ii) : Environmental Heterophylly in buttercup (Ranunculus).

In this plant leaves are different in shape produced in air from leaves those produced in water. (Buttercup is an emergent hydrophyte).



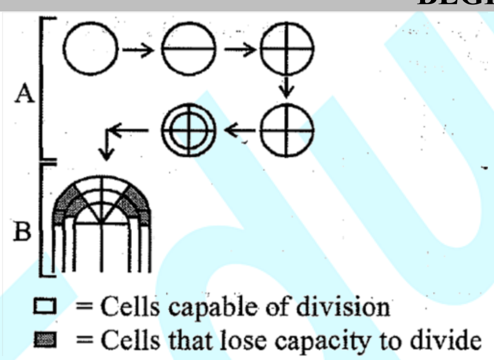
Heterophylly in larkspur (a, b) **Heterophylly in buttercup (c, d)**

- Thus growth, differentiation and development are very closely related events in the life of a plant. Broadly development is considered as the sum of growth and differentiation.
- Development in plants (i.e. both growth and differentiation) is under the control of intrinsic and extrinsic factors.



BEGINNER'S BOX-1

1.



Above diagram showing the development of embryo from zygote. From the following options choose the correct match for 'A' and 'B':-

	A	B
(1)	Arithmetic growth	Geometric growth
(2)	Geometric growth	Arithmetic growth
(3)	Arithmetic growth	Arithmetic growth
(4)	Geometric growth	Geometric growth

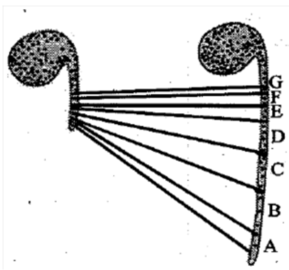
2. The type of growth, in which only one daughter cell among the two (produced by the division of meristem cell) retain the ability to divide, shows which of the following growth curves ?

(1) Linear curve (2) Sigmoid curve

(3) J-shape curve (4) Bell shape curve

3. Which of the following is an example of plasticity in plants ?
(1) Continuous addition of new cells in plant body.
(2) Cells arising out of the same meritem have different structure at maturity.
(3) Difference in shape of leaves due to phases of life or environment.
(4) Determinate growth in the some plant organs.

4.



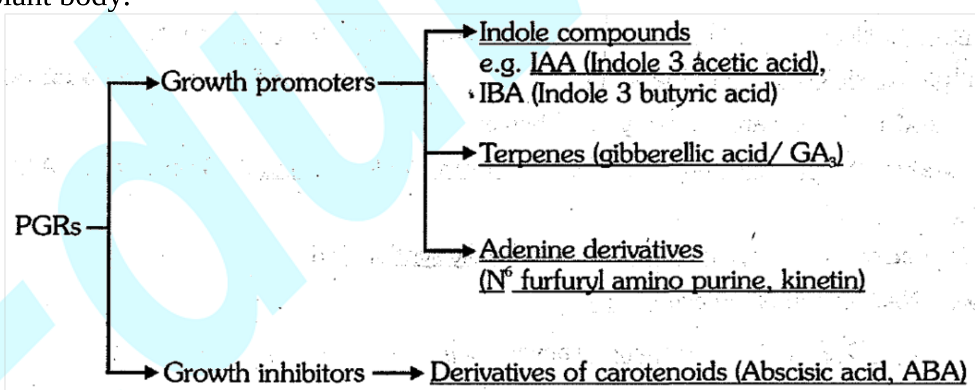
Above diagram shows the parallel line technique which is used :-
(1) to ensure the germination of seeds (2) to detect the zone of elongation
(3) to measure the growth rate (4) to measure the length of a plant

5. Which of the following matches is not appropriate regarding measurement of growth?

(1)	Dorsiventral leaf	Increase in surface area
(2)	Watermelon	Increase in size of cells
(3)	Maize root apical meristem	Increase in number of cells
(4)	Pollen tube	Increase in volume and fresh weight

Plant growth regulators (PGRs)

The plant growth regulators (PGRs) are small, simple molecules of diverse chemical composition. The PGRs can be broadly divided into two groups based on their functions in a living plant body.



- The gaseous PGR, ethylene, could fit either of the groups, but it is largely an inhibitor of growth activities.

AUXIN

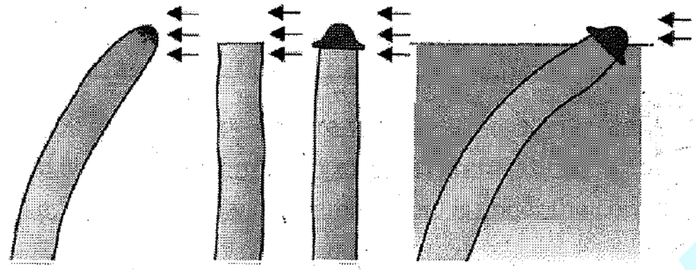
Auxin term is derived from Greek word 'auxein' which means to grow.

History :

Charles Darwin and his son Francis Darwin :

- 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 coleptile.



Series of experiments used to demonstrate that tip of the coleoptile is the source of auxin. Arrows indicate direction of light

F.W. went :

He is credited for :

- Discovery of auxin.
- Coined the term auxin.
- Isolated auxin from tips of coleoptiles of oat seedlings.
- Bioassay of auxin (Avena curvature test).

Kogl and Haagensmit :

First time isolated auxin from human urine.

Synthesis : Precursor of auxin is tryptophan. Zinc is also necessary for biosynthesis of auxin.

Auxins are generally produced by the growing apices of the stem and roots.

After synthesis auxins migrate to the' regions of their action. (Transporrt is Polar and basipetal)

Types of auxin : Auxins are of two types. They are :

(1) **Natural auxins :** Such auxins have been isolated from plants. e.g. indole 3 acetic acid (IAA). indole 3 butyric acid (IBA).

(2) **Synthetic auxins :** Such auxins have been artificially synthesised.

Examples : NAA (Napthalene acetic acid)

2.4-D (2. 4-Dichlorophenoxy acetic acid)

2.4.5-T (2. 4, 5-Trichloro phenoxy acetic acid)

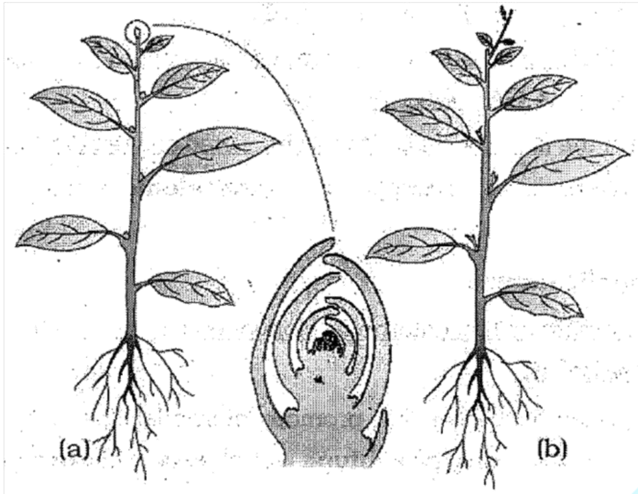
IPA (Indole Propionic/Pyruvic acid)

Both natural and synthetic auxins have been used extensively in agricultural and horticultural practices.

Physiological effects and aapplications :

(1) **Apical dominance :** "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 and in hedge-making.



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

(2) **Root initiation :** Auxins help to initiate rooting in stem cuttings. This application is widely used for plant propagation.
(3) **Flowering :** Auxins promote flowering in pineapple.
(4) **Abscission :** Auxins help to prevent fruit and leaf drop at early stages but promote the abscission of older mature leaves and fruits.
(5) **Parthenocarpy :** Auxin induce parthenocarpy in tomatoes.
(6) **Herbicide/weedicide :** Auxins used as herbicides. 2, 4 D widely used to kill dicotyledonous weeds. 2, 4 D does not affect mature monocotyledonous plants. It is used to prepare weed free lawns by gardeners.
(7) **Xylem differentiation :** Auxin controls xylem differentiation.
(8) **Cell division :** Auxins helps in cell division.
(9) **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

GIBBERELLINS

History :

- Japanese rice farmers observed some unusual rice seedlings in their paddy fields.
- Such rice seedling were excessively tall, pale, spindle shaped and sterile (do not wore seeds).
- These seedlings were suffering from a disease called 'bakane' (foolish-seedling) disease; caused by a fungal pathogen Gibberella fujikuroi.
- E. Kurosawa reported the appearance of symptoms of the disease in uninfected rice seedlings when they were treated with sterile filtrates of the fungus.
- The active substances were later identified as gibberellic acid.

- There are more than 100 gibberellins reported from widely different organisms such as fungi and higher plants. They are denoted as GA_1, GA_2, GA_3, and so on.
- GA_3 ($C_{19}H_{26}O_6$) was one of the first gibberellins to be discovered and remains the most intensively studied form.
- All GAs are acidic. Their precursor is acetyl CoA or mevalonic acid.

Physiological effects and applications :

(1) **Bolting :** Gibberellins promote bolting (intermodal elongation just prior to flowering) in beet. cabbages and many plants with rosette habit.

(2) **Overcome genetic dwarfism :** Gibberellins promote intermodal elongation in genetically dwarf plants like maize, Pisum, Vicia faba etc. Here only phenotype get change while genotype remains same.

(3) **Improve yield in sugarcane :** Sugarcane stores carbohydrate as sugar in their stems. Spraying sugarcane crop with gibberellins increases the length of the stem (intermodal elongation). thus increasing the yield by as much as 20 tonnes per acre.

(4) **Improve shape in apple :** Gibberellins, cause fruits like apple to elongate and improve its shape. (by intermodal elongation).

(5) **Improve yield in grapes :** Ability of gibberellins to cause an increase in length of axis (intermodal elongation) is used to increase the length of grapes stalks.

(6) **Senescence :** Gibberellins delay senescence. Thus, the fruits can be left on the tree longer so as to extend the market period.

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

(8) **Brewing industry :** GA_3 is used to speed up the malting process in brewing industry.

$$\text{Cereal starch} \xrightarrow[\text{Malting process}]{\substack{GA_3 \\ \downarrow \\ \alpha-\text{amylase}}} \text{Maltose}$$

(9) **Dormancy :** Gibberellins induce the synthesis of hydrolysing enzyme α-amylase, lipases and proteases. These enzyme hydrolyse the store food present in seeds and buds. This process result in breaking of their dormancy.

Bioassay of gibberellins :

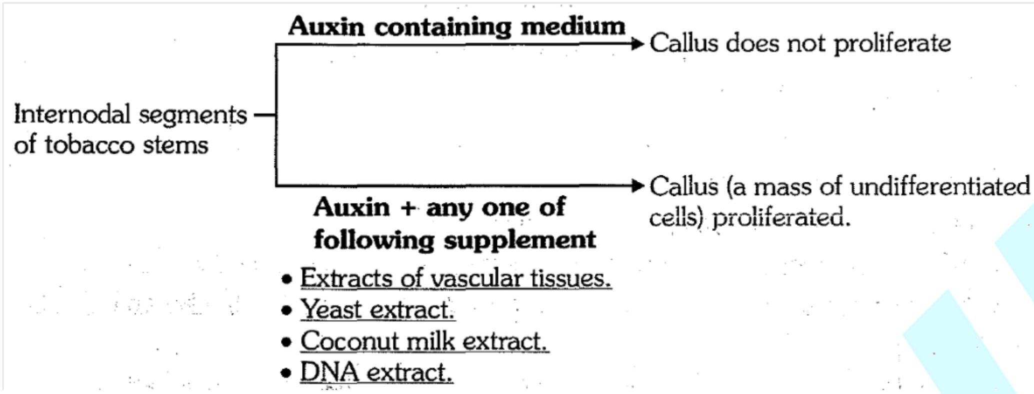
(i) Barley endosperm test (based upon α-amylase activity)

(ii) Dwarf pea and maize test (based upon intermodal elongation activity).

CYTOKININS

History :

F. Skoog and his Co workers :



Skoog and Miller : They identified and crystallised the cytokinesis promoting active substance that they termed kinetin. (a modified form of adenine, a purine).

Miller : He isolated an active substance from the autoclaved DNA of sperm cells of herring fish.

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.

  Synthesis : Natural cytokinins are synthesisedin regions where rapid cell division occurs, for example : root apices, developing shoot buds, young fruits etc. Root tips are major site of synthesis of cytokinins.

Physiological effects and applications :

(1) **Cell division :** Cytokinins have specific effects on cytokinesis (cytoplasmic division). It is considered as most important biological effect of cytokhlins.

(2) **Overcome apical dominance :** Cytokiniris promote the growth of lateral buds. This role of cytokinin is antagonist to auxin.

(3) **Senescence :** Cytokinins promote nutrient mobilisation towards young parts which helps in the delay of leaf senescence.

(4) Help to proguce new leaves.

(5) Help to produce chloroplast in leaves.

(6) Promote lateral shoot growth and adventitious shoot formation.

(7) Induce opening of stomata.

(8) **Tissue culture :**

- Cytokinin and auxin together cause dedifferentiation in differentiated parenchymatous cells in tissue culture.
- **Morphogenesis :**

  High concentration of cytokinins to low concentration of auxin = shoot differentiation

  High concentration of auxin to low concentration of cytokinin = root differentiation

Bioassay of cytokinin :

(i) Tobacco pith cell division test.

(ii) Chlorophyll preservation (retention) test.

ETHYLENE

History :

- H. H. cousins confirmed the release of a volatile substance from ripened oranges that-hastened the ripening of stored unripened bananas.

- The volatile substance was identified as ethylene ($H_2C=CH_2$), a gaseous PGR.

Synthesis:

- Methionine is a precursor of ethylene. Ethylene is synthesised in large amounts by tissues undergoing senescence and ripening fruits.
- Ethylene is one of the most widely used PGR in agriculture.
- The most widely used compound as source of ethylene is ethephon/CEPA (chloro ethyl phosphonic acid).
- Ethephon is an aqueous solution which is readily absorbed and transported within the plant and releases ethylene slowly.

Physiological effects and applications :

(1) **Fruit ripening :** Ethylene is highly effective in fruit ripening. It enhances the respiration rate during ripening of the fruits. This rise in rate of respiration is called respiratory climactic. e.g. tomato, apple, banana, oranges (Citrus).

(2) **Senescence and abscission :** Ethylene promotes senescence and abscission of plant organs especially of leaves and flowers.

- Ethephon is used to accelerates abscission in flowers and fruits (thinning of cotton, cherry, walnut).

(3) **Triple response :** Triple response of ethylene on plants include :
(a) Horizontal growth of seedlings
(b) Swelling of the axis
(c) Apical hook formation in dicot seedlings.

(4) **Dormancy :** Ethylene breaks seed and bud dormancy. Ethylene initiates germination in peanut seeds and sprouting of potato tubers.

(5) **Increase absorption surface :** Ethvlene promotes root growth and root hair formation thus helping the plants to increase their absorption surface.

(6) Ethylene is used to initiate flowering and for synchronising fruit-set in pineapples.

(7) Ethylene induces flowering in mango.

(8) Ethylene promotes female flowers in cucumbers (feminising effect). This result in increase of yield.

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

ABSCISIC ACID/ABA

History : During mid 1960s three independent researches reported the purification and chemical characterization of three different kinds of inhibitors :

Name of inhibitor	Researcher	Source
Inhibitor-B	Bennet Clark and Kefford	Dormant potato tubers
Abscissin-II	Addicot and Okhuma	Mature cotton fruits
Dormin	Waring and Robinson	Old betula leaves

Later ail the three were proved to be chemically identical and named abscisic acid (ABA).

Synthesis : Precursor of ABA is carotenoid (violoxanthin)

$$\text{Carotenoid (violoxanthin)} \xrightarrow{\text{oxidation}} \text{ABA}$$

Physiological effect and applications :

(1) ABA acts as a general plant growth inhibitor. (Inhibitor of plant metabolism)

(2) ABA inhibits seed germination.

(3) ABA stimulates the closing of stomata in the epidermis and increase tolerance of plants to various kinds of stresses. Therefore, ABA is also called stress hormone.

(4) 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 GA.

Q. Which one of the plant growth regulator would you use if you are asked to :
(a) Induce rooting in a twig.
(b) Quickly ripen a fruit
(c) Delay leaf senescence.
(d) Induce growth in axillary buds.
(e) 'bolt' a rosette plant.
(f) Induce immediate stomatal closure in leaves.

Ans. (a) Auxin (b) Ethylene, (c) Cytokinin, (d) Cytokinin, (e) Gibberellin, (f) Abscisic add

Q. What would be expected to happen if :
(a) GA_3 is applied to rice seedlings.
Ans. Rice seedlings become excessively tall, pale, spindle shaped and sterile, if excess of GA_3 is applied.
(b) Dividing cells stop differentiating.
Ans. Development hindered, because development is sum of growth plus differentiation.
(c) A rotten fruit gets mixed with unripe fruits.
Ans. Overripen or rotten fruits give out ethylene, which induces ripening of unripe fruits.
(d) You forget to add cytokinin to the culture medium.
Ans. Culture can not be initiated because, parenchyma cells that are made to divide under controlled laboratory conditions during plant tissue culture require both PGR i.e. auxin and cytokinin.

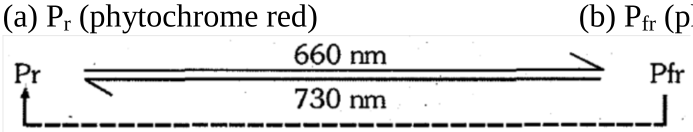
PHOTOPERIODISM

- Flowering in certain plants depends not only on a combination of light and dark exposures but also their relative durations. This response of plants to periods of day/night is termed as photoperiodism.
- This phenomenon was discovered by Gamer and allard in maryland mammoth (a mutant variety of tobacco) and blloxy soyabean.

Mechanism :

- Appropriate light/dark duration perceived by leaves with the help of a proteinaceous pigment (chromoprotein) called phytochrome.
- After suitable exposure a hypothetical hormonal substance (florigen) migrates from leaves to shoot apices for inducing flowering.
- Ultimately shoot apices modify into flowering apices.

Phytochrome : It is a chromoprotein pigment located on cell membrane. Phytochrome exists in two interconvert able forms :
(a) P_r (phytochrome red) (b) P_{fr} (phytochrome far red)



Garner and Allard based upon response of plants to periods of day/night, classified plants into following groups :

(1) Short day plants (SOPs) :

- Plants require the exposure to light for a period less than critical duration are called short day plants (SOPs).
  Examples: Tobacco, soyabean, Xanthium (cocklebur), Chrysanthemum, Dahlia, sugarcane, Cosmos, rice, Tagetes etc.
- They need a continuous or uninterrupted dark period for flowering. Thus, short day plants (SOPs) are also called long night plants (LNPs).
- In SDPs physiological active form of phytochrome is P_r. Therefore red light inhibits flowering and far red light promotes flowering.

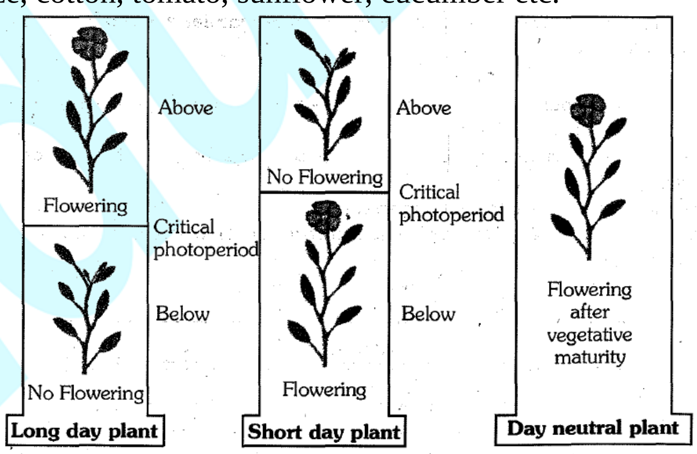
$$\frac{P_r}{P_{fr}} > 1$$

(2) Long day plants (LOPs) : Plants require the exposure to light for a period exceeding a well defined critical duration, are called long day plants (LOPs).
Examples : Hyoscyamus (Henbane), spinach,, Beta vulgaris (sugarbeet), radish, wheat, larkspur, barley etc.

- In LOPs physiological active form of phytochrome is P_{fr}. Therefore far red light inhibits flowering and red light promotes flowering.

$$\frac{P_{fr}}{P_r} > 1$$

(3) Day neutral plants (DNPs) :
Plants in which there is no such correlation between exposure to light duration and induction of flowering response. Such plants are called day neutral plants (ONPs).
Examples : Maize, cotton, tomato, sunflower, cucumber etc.



Photoperiodism : Long day, short day and day neutral plants

VERNALISATION

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

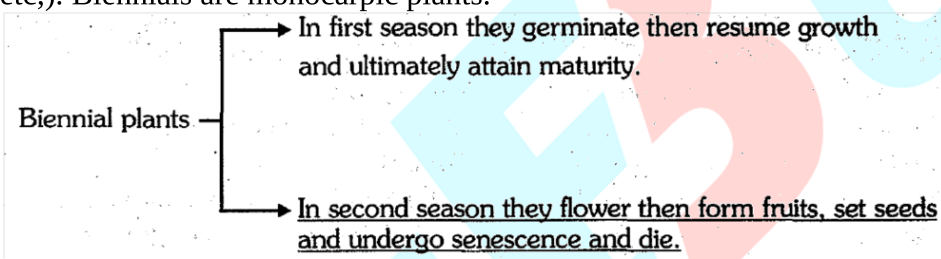
Requirements for success of vernalisation :

(1) Actively dividing cells
(2) Period of low temperature treatment
(3) Aerobic respiration
(4) Optimum hydration
(5) Optimum nutrition

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

Spring varieties	Winter varieties
They are normally planted in the spring and come to flower and produce mature grain before the end of growing season.	They are planted in late autumn. They germinate and over winter come out as small seedlings, resume growth in spring and usually harvested around mid-summer.

- Winter varieties however, if planted in spring would normally fail to flower or produce mature grains within a span of flowering season.
- Another example of vernalisation is seen in biennial plants (e.g. sugar beet, cabbages, carrots etc,). Biennials are monocarpic plants.



Significance : Vernalisatien prevents precocious reproductive, development late in the growing season and enables the plant to have sufficient time to reach maturity.

Some special points

- **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.
  It is widely known for its use by the U.S. military during the vietnam war from 1961 to 1971. The chemical eroded forest cover of 31,000 km^2
- Optimum concentration of auxin for shoot growth is 10-100 ppm while for root growth it is very low i.e. 0.0001 ppm. (at high concentration auxin inhibit root growth.)
- Gibberellins induce flowering in long day plants (LDPs) under non inductive photoperiods.
- Gibberellins is a substitute of vernalisation.
- Gibberellins is a substitute of red light requirement for seed germination in tobacco and lettuce (salad).
- Gibberellin is a male hormone (promote formation of male flowers)
- Auxin, gibberellins and ABA are acidic in nature while cytokinin is a basic hormone.
- The discovery of each of five major groups of PGR have been accidental.
- The role of PGR is of one kind of intrinsic control. Along with genomic control and extrinsic factors, they play an important role in plant growth and development.
- Delay of senescence mainly caused by cytokinin.
- Low level of auxin in a leaf as compare to stem is an indication that very soon leaf will shed.

- 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.

SEED DORMANCY

Seed dormancy refers in seeds to failure of a viable seed to germinate even when given favourable environmental condition. 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.

Reasons of seed dormancy :

(i) Impermeable and hard seed coat.

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

(iii) Immature embryo.

Breaking of dormancy :

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

(1) By Natural way :

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

(ii) Action of heat : 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

(2) 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 to that the seed can germinate.

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

BEGINNER'S BOX-2

1. Which of the following events in plants is not affected by interaction of more than one PGR ?
(1) Apical dominance (2) Abscission and senescence
(3) Dormancy in seeds/buds (4) Bolting process

2. Which of the following plant growth regulators, is derivative of accessory photosynthetic pigments?
(1) Abscisic acid (2) Gibberellic acid
(3) Indole-3-acetic acid (4) Ethylene

3. Which of the following applications of auxins is widely used for plant propagation?
(1) Selective killing of weeds to prepare weed free lawns
(2) Initiation of rooting in stem cuttings
(3) Promotion of flowering in pineapple

(4) Induction of parthenocarpy

4. Flowering in long day plants and short day plants does not occur when they are exposed to light for a period respectively -
(1) More than critical duration of light and less than critical duration of light
(2) Less than critical duration of light and more than critical duration of light
(3) Less than critical duration of light and less than critical duration of light
(4) More than critical duration of light and more than critical duration of light

5. Which of the following plant growth regulators helping the plants to increase their absorption surface?
(1) Auxin (2) Gibberellins (3) Cytokinin (4) Ethylene

BEGINNER'S BOX-1

1.	(2)	2.	(1)	3.	(3)	4.	(2)	5.	(4)

BEGINNER'S BOX-2

1.	(4)	2.	(1)	3.	(2)	4.	(2)	5.	(4)