15. Plant Growth and Development

Development is the sum of two processes growth and differentiation. The different types of cells organise to form tissues and organs of the plant. The development of a mature plant from a zygote follows a precise and highly ordered succession of events. During this process, a complex body i.e., plant is formed which constitutes the roots, leaves, branches, flowers, fruits and seeds.

The structures such as flowers, fruits and leaves show limited growth and dimensions due to which these appear and fall periodically whereas other structures like roots and stem remain intact and show unlimited growth. However, they also die ultimately with the death of the plant.

1. Growth

Growth is a fundamental characteristic of all living organisms. It is defined as an irreversible permanent increase in size, volume and weight of an organ or its parts or even of an individual cell. The growth of a part or whole of an organism is caused by synthesis of new materials intracellular i.e., within the cell and extracellular i.e., outside the cell, cell division and cell enlargement. For example, expansion of leaves and increase in height of a stem of a plant. Generally, growth is associated with high degree of metabolic activities which include both anabolic or synthetic activities and catabolic or breakdown reactions. During growth the rate of anabolism is more than catabolism. Both these activities require energy.

(1) Characteristics of Growth

- **Plant growth generally is indeterminate-**Plants have the capacity for indeterminate or unlimited growth which continues throughout their life. Due to this, the growth of a plant is known as unique. The growth of the plants is due to the presence of different meristems at specific locations in their body.

  Meristems are the cells which are capable of self-perpetuation i.e., has the power to continue indefinitely through division. The continued growth due to which new cells are always being added to the plant body by the activity of the meristem is called the open form of growth.

  If meristems cease to divide then they take a permanent shape and size to form various structures of the plant body which are specific to a particular function. e.g., Parenchyma provides elasticity and flexibility to the plant body and xylem helps in the conduction of water.

  These are the various examples of permanent tissues which are formed after the differentiation of meristematic tissues. The meristems such as root apical and shoot apical are responsible for the elongation or increase of length of the plants along their axis. When this type of growth or increase occurs in plants it is known as primary growth. Primary growth is the characteristic of all types of plants.

  In plants like dicotyledonous and gymnosperms, some meristems appear later in their life which are responsible for another type of growth known as secondary growth. It means the increase in the girth or diameter of plants. The meristems which appear in their later life are lateral meristems such as vascular cambium and cork cambium.

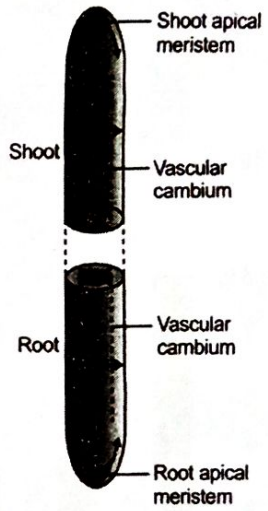


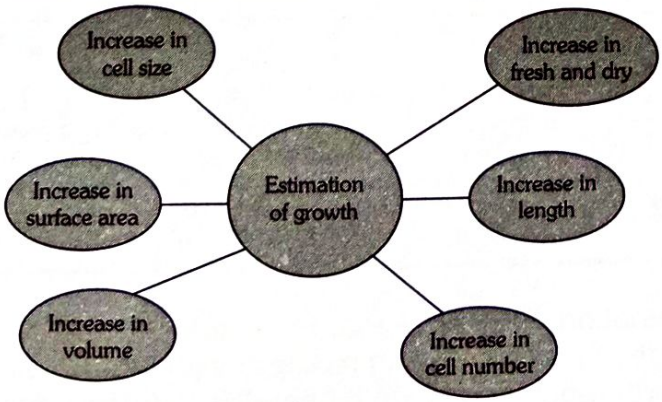
Fig.: Diagrammatic representation of locations of root apical meristem, shoot aplical meristem and vascular cambium. Arrows exhibit the direction of growth of cells and organ.

- **Growth is measurable**

  The growth which occurs at the cellular level is due to the increase in protoplasm content. This increase in protoplasm is difficult to measure directly. Therefore, growth can be measured by various parameters which are more or less proportional to it. These parameters are Increase in fresh weight and dry weight, Increase in cell size , Increase in surface area, Increase in volume , Increase in cell number ,Increasing in length.

Important-

Auxanometer is an instrument used to measure the growth in length of the plant.



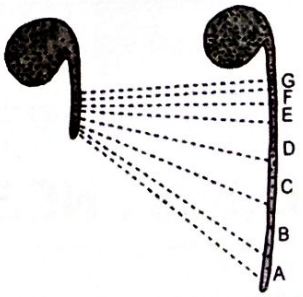


Fig. : Detection of zones of elongation by the parallel line technique. Zones A, B, C, D immediately behind the apex have elongated most.

(2) Phase of growth

- **Meristematic phase or phase of cell division :** It is the first phase of growth in plants which occurs in the areas where meristematic cells are present. For example, at shoot and root tip of the plants where meristems are constantly dividing. As a result this phase is also known as cell division. The cells at this phase of growth show following features they have dense protoplasm, contain large nucleus and have high respiration rate. The cell wall is made up of cellulose, thin with abundant plasmodesmatal connections so that cells can communicate with each other.

- **Elongation phase or phase of enlargement :** The cells present just next to the cells of meristematic zone represent the elongation phase. The cells found in this zone show the following features, vacuoles increase as growth occurs. The cell wall of the cells starts depositing new materials resulting in cell enlargement, size of the cells of this phase increases mainly due to vacuolation.
- **The Maturation phase or phase of differentiation :** The cells present just next to the cells of elongation phase represent the phase of differentiation. The enlarged cells develop into special or particular type of cells by undergoing structural and physiological differentiation.
- **Structural differentiation :** A cell attains a particular shape, size and internal constitution.
- **Physiological differentiation :** A cell attains a particular function. For example, absorption of water and minerals by root hair, photosynthesis by mesophyll cells etc. So, cells of this zone, attain their maximal size in terms of wall thickening and protoplasmic modifications. After differentiation, the mature cells do not grow further and remain unchanged till death.

(3) Growth rates

An organism or a part of the organism can produce more cells in a variety of ways. The increased growth per unit time is defined as growth rate. Thus, it can be expressed mathematically, being either arithmetical or geometrical.

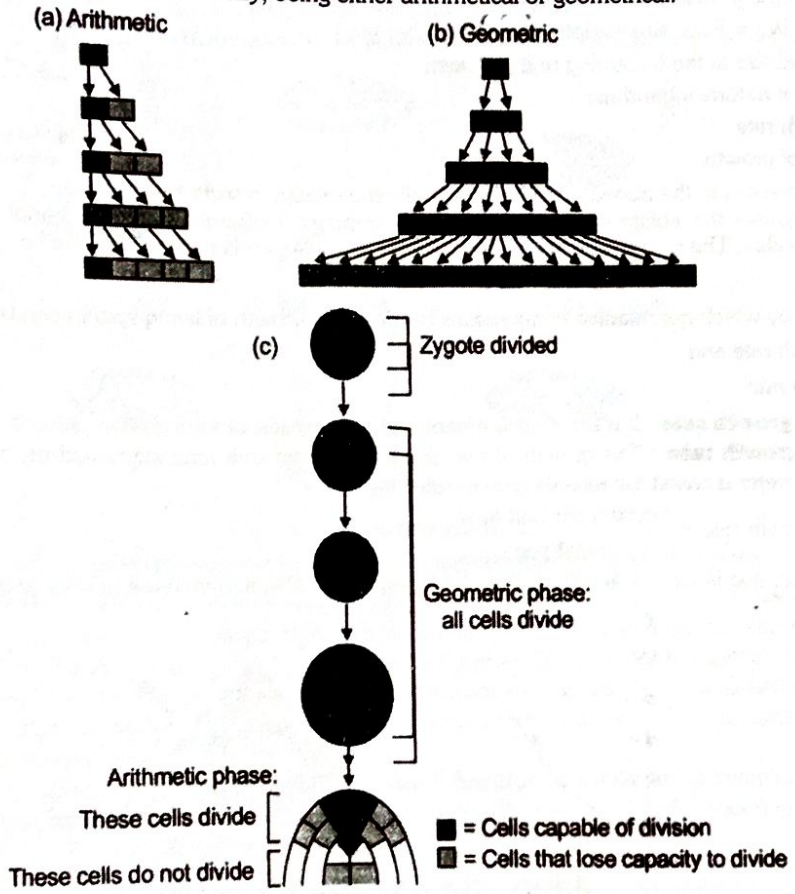


Fig.: Diagrammatic representation of : (a) Arithmetic (b) Geometric growth and (c) Stages during embryo development showing geometric and arithmetic phases.

- **Arithmetic growth :** It is the growth rate in which growth at a constant rate from the very beginning and progresses arithmetically. Here, following mitotic cell division only one daughter cell divides continuously whereas other cells undergo differentiation and become mature. For example, we can study the arithmetic growth pattern in root elongation where elongation occurs at a constant rate. If a graph is plotted by taking length of the organ of plant at *Y*-axis against the time at *X*-axis, a linear curve is obtained. Mathematically, it can be expressed by following equation.

$$L_t = L_0 = rt$$

Where L_t = length of the organ at time '*t*'

L_0 = Length of the organ at time 'zero'

r = Growth rate or elongation per unit time

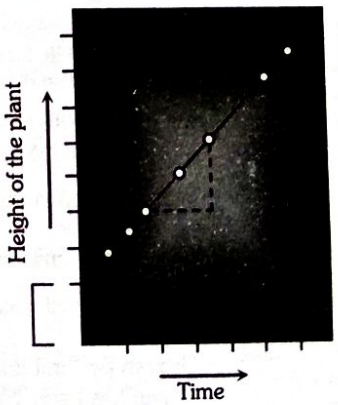


Fig : Constant linear growth, a plot of length *L* against time *t*

- **Geometrical growth :** It is a growth where every cell divides with all the daughters growing and dividing again. We can take the example of microorganisms to study the pattern of geometrical growth. In microorganisms, growth occurs when they are provided with enough food and space. During their growth, three phases can be observed.

a) **Lag phase :** This is the initial phase of growth when the rate of growth is very slow. It represents the beginning of growth of microorganisms where their cell number is small.

b) **Log phase or exponential phase** : In this phase, growth progress rapidly or exponentially i.e., reaches to its maximum. Here, both the progeny or daughter cells obtained after mitotic cell division have the ability to divide continuously. However, such a growth cannot be sustained for long and growth reaches to next phase.

c) **Stationary phase** : Due to the shortage of space, food and accumulation of toxins, growth slows down leading to a phase known as stationary phase.

If we plot all these phases graphically then we will obtain S-shaped or **sigmoid curve**.

Similarly, we can study the growth of cells, tissues and organs of a plant. For example, if we plot the parameters of growth such as size, weight of the organ at Y-axis against the time at X-axis, we get a typical sigmoid or S-shaped curve which explains the geometrical growth. But in a tree showing seasonal activities do not show a typical S-shaped curve. Here, the curve will show small steps indicating stoppage and resumption of growth every year.

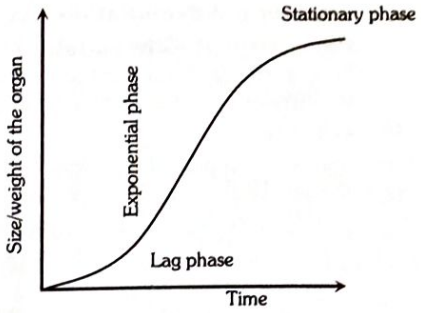


Fig : An idealized sigmoid growth curve typical of cells in culture, and many higher plants and plant organs

The geometric 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 growth

e = Base of natural logarithms

r = Growth rate

t = Time of growth

The 'r' expressed in the above equation is actually the relative growth rate which measures the ability of the plant to produce or synthesize new plant material. This ability of plant is referred as efficiency index. The overall size of any organ of the plant depends on its initial size i.e., W_0.

(4) Rates of Growth

There are two ways by which quantitative comparisons between the growth of living system can be made :

(a) Absolute Growth rate and

(b) Relative growth rate

- **Absolute growth rate** : It is the measurement and comparison of total growth per unit time.
- **Relative growth rate** : The growth of the given system per unit time expressed on a common basis, example, per unit initial parameter is called the relative growth rate.

$$\text{Relative growth rate} = \frac{\text{Growth per unit time}}{\text{Initial size}} \times 100$$

For example, two leaves, A and B of different size show an absolute increase in area at the given time to give leaves A^1 and B^1.

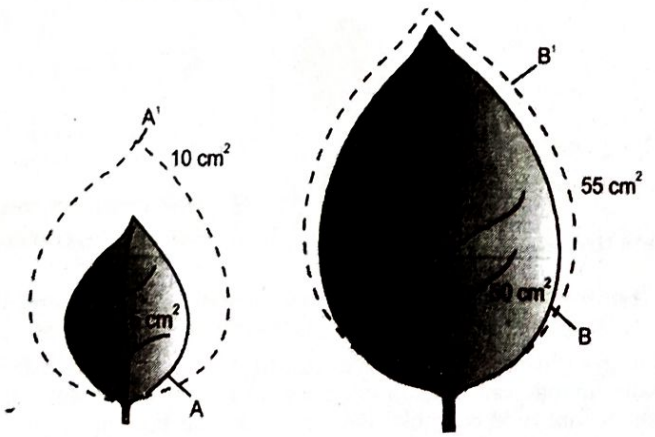


Fig. : Diagrammatic comparison of absolute and relative growth rates. Both leaves A and B have increased their area by 5 cm² in a given time to produce A', B' leaves.

The absolute growth rate of both the leaves A^1 and B^1 is same but if we calculate the relative growth rate, it is found that A^1 leaf has higher relative growth rate than B^1 leaf which can be proved by the following calculations.

$$\text{Relative growth rate (RGR) of } A^1 \text{ leaf} = \frac{5}{5} \times 100 = 100\%$$

$\because$ Growth per unit time $= 5cm^2$ initial size $= 5cm^2$

$$\text{Relative growth rate (RGR) of } B^1 \text{ leaf} = \frac{5}{5} \times 100 = 10\%$$

$\because$ Growth per unit time $= 5cm^2$ initial size $= 5cm^2$

A^1 leaf has been 100% relative growth is whereas B_1 leaf has 10% relative growth rate.

(5) Conditions for growth

The growth of a plant involves synthesis of more protoplasm, cell division, cell enlargement and cell differentiation. It is influenced by various factors which are discussed below :

- **Water :** It is an essential factor required for the proper growth of a plant. It is responsible for cell elongation and maintenance of turgidity of growing cells i.e., cells full with water. It also provides the medium for enzymatic activities which are needed for growth.
- **Oxygen :** The amount of oxygen available to the plants determines the amount of respiratory energy that can be utilized for biosynthetic activity i.e., anabolic activity required for growth. For example, in water-logging condition, the growth of root is inhibited due to the reduced availability of oxygen to roots.
- **Nutrients** : Macronutrients like C, O and micronutrients like Zn, Fe are the raw material for the synthesis of protoplasm. The initial rate of growth of a seed, tuber, bulb etc. depends upon the amount of nutrition contained in it.
- **Temperature :** A temperature of 28°-30° is optimum for the proper growth of most of the plants. If there is any deviation from this range, there could be detrimental or adverse consequences on the growth of the plant. For example, higher temperature above 45°C hinders growth due to excessive transpiration, denaturation of enzymes and coagulation of protoplasm.
- **Light :** It is not essential for early growth of the plant but growth is sustained only in its presence. It is required by the plant for tissue differentiation, synthesis of photosynthetic pigments and photosynthesis.
- **Gravity** : It determines the direction of orientation or movement of main root, stem and the branches borne over them.

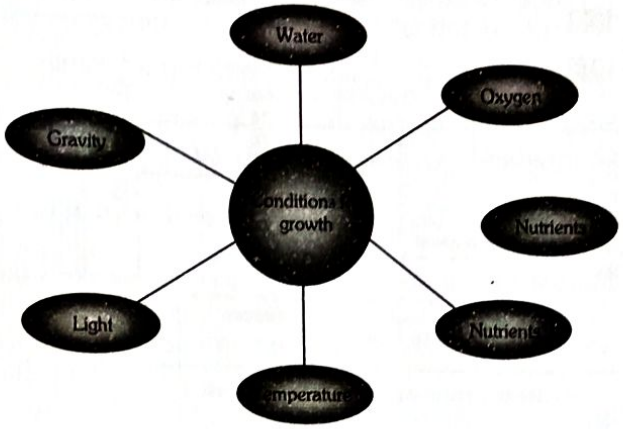


Fig. : Condition for growth

2. Differentiation

The phenomenon by which the cells derived from root apical meristem, shoot apical meristem undergo permanent changes in their structure, biochemistry, size, physiology of cell wall and protoplasm content. As a result these enable to perform a specific function.

Tracheary element : The tracheary element is formed by the process of differentiation where the cells elongate and loose their protoplasm to form tracheids. A strong, elastic lignocellulosic secondary cell wall develops which does not allow tracheids to collapse under extreme tension and allow it to carry water to long distances.

Chlorenchyma : It is specialised to perform photosynthesis which is developed due to formation of chloroplasts in the living thin-walled cells. Other structures found in plants such as aerenchyma, stomata, collenchymas, trichomes, root cap etc. are formed after the differentiation.

3. Dedifferentiation

During differentiation cells loose their ability to divide and form permanent cells. But some cells regain their capacity to divide under certain conditions. This phenomenon where certain living differentiated cells regain or attain their ability to divide and form new cells is known as dedifferentiation. A dedifferentiated tissue can act as meristem e.g., interfascicular vascular cambium, cork cambium, wound cambium. These are formed from fully differentiated parenchyma cells.

4. Redifferentiation

The dedifferentiation cells can again loose their capability to divide to form permanent cells specialised for a particular function. The process where the dedifferentiated cells again loose their ability to divide to form permanent cells is called redifferentiation. It is smaller to differentiation of cells and tissues formed by primary meristem. Examples – Secondary phloem, secondary xylem, cork, secondary cortex are some tissues formed through redifferentiation. Like growth differentiation is also open in plants. The same apical meristem produces parenchyma, fibres, xylem, phloem, collenchymas and epidermis. The final structure of a cell, formed at maturity is also determined by the neighbouring cells present in the tissue. For example, cells positioned away from root apical meristem differentiate as root cap cells, while those pushed to the periphery mature as epidermis.

5. Development

Development is the sequence of changes that occurs in the structure and functioning of an organism, organ, tissue or cell involving its formation, growth, differentiation, maturation, reproduction, senescence and death. Plant during its life cycle passes through development stages of seed germination, seedling, juvenile phase, maturation, flowering, seed formation and senescence. The conversion of one phase into next is also development e.g., leaf initiation to leaf expansion, vegetative or juvenile phase to reproductive phase i.e., flowering. Appearance of chloroplast in cells when exposed to sunlight is also a type of development. Development leads ultimately to senescence and then death.

The development process is not always straight. Plants show plasticity which means the ability of plant to follow different pathways and produce different structures in response to environment. Example of plasticity is heterophylly. Heterophylly is the phenomenon of appearance of different forms of leaves on the same plant. It can be seen or observed in plants like cotton, coriander and larkspur. In such plants, the leaves of the juvenile plants are different in shape from those of mature plants. On the other hand, difference in shapes of leaves can be observed in buttercup present in air and water. It means this plant show different shapes of leaves according to its habitat.

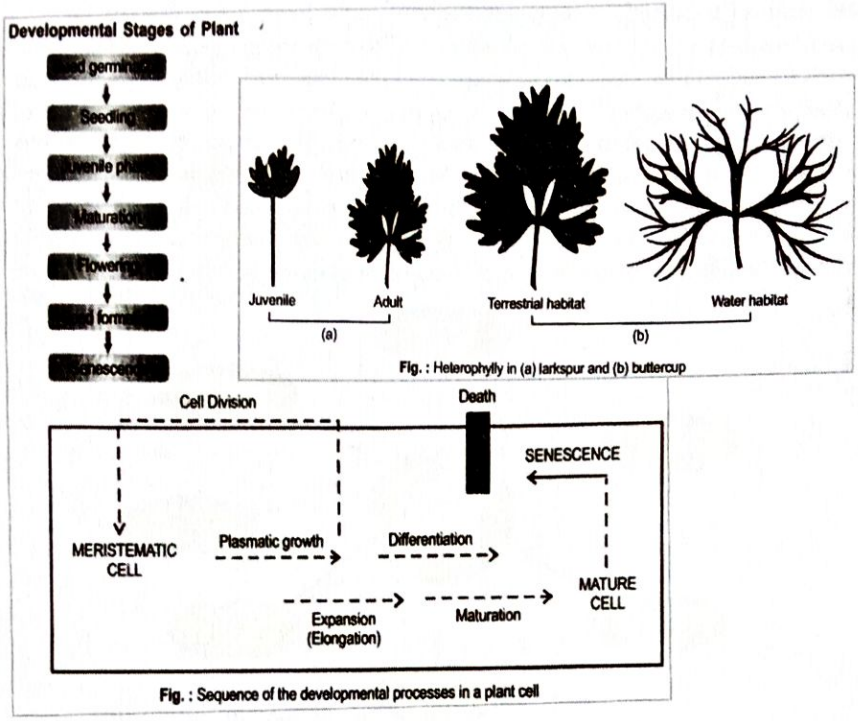


Fig. : Heterophylly in (a) larkspur and (b) buttercup

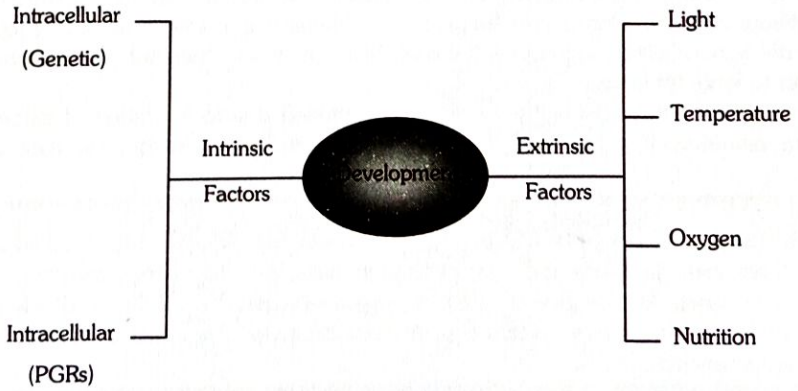
Fig. : Sequence of the developmental processes in a plant cell

There are various intrinsic and extrinsic factors which influence the development stages of a plant.

The intrinsic factors include genetic which are intracellular and chemical substances like PGRs which are intercellular.

The extrinsic or external factors are light, temperature, oxygen, CO_2, water nutrition etc.

These factors influence various events such as dormany, seed germination, flowering, and plant movements etc. occurring in plants during their development.



6. Plant Hormone

Plant growth regulators (PGRs) are small, simple organic substances of diverse or different chemical composition which are required in low concentration like hormones in animals. The PGRs influence physiological activities of plants leading to promotion, inhibition and modification of growth. Therefore, they are also called as plant growth substances, plant hormones or phytohormones. A plant hormone can be best defined as a chemical substance other than nutrients which regulate one or more physiological activities at the same site where it gets synthesised or away from that.

These phytohormones are composed of different types of chemical compounds which are as follows :

	Composition	Phytohormones
1.	Indole compounds	IAA – Indole 3-acetic acid, IBA – Indole butyric acid
2.	Terpenes	Gibberellic acid or Gibberllins (GAs)
3.	Adenine derivatives	N^6-Furfurylamino purine, kinetin
4.	Gases	Ethylene ($CH_2=CH_2$)
5.	Derivatives of carotenoids	Abscisic acid (ABA)

- **Classification of PGRs / Phytohormones**

On the basis of their functions performed in a living plant body, these can be broadly classified into two groups i.e.,

Plant growth promoters : These are the chemical substances involved in growth-promoting activities such as cell division, cell enlargement, tropic, growth, flowering, fruiting and seed formation. e.g., Auxin, gibberellins and cytokinin.

Plant growth inhibitors: These are the chemical substances such as ABA involved in growth-inhibiting activities like dormancy and abscission.

a) **Dormancy :** It is a period when growth and development are temporarily stopped. For example, failure of seeds to germinate due to the lack of favorable conditions in the environment.

b) **Abscission :** It is the falling or shedding of leaves, fruits and flowers.
One another type of phytohormone i.e., ethylene could fit either of the two above mentioned groups, but it is largely an inhibitor of growth activities.

- **Auxin**

The word auxin is derived from Greek word 'auxein' which means 'to grow'.

- **Discovery -** Auxin was the first hormone to be discovered. Charles Darwin and his son Francis Darwin observed that the stimulus of light was perceived by coleoptiles tip of canary grass but the bending response to unilateral light was produced at a distance in growth zone i.e., sub apical part.

After a series of experiments conducted by other scientists, it was concluded that the sensation picked up by the coleoptiles tip is transmitted to the sub apical part which bends towards the direction of light. As it was found that :

a) In an experiment if the coleoptiles tip was removed then there was no bending of shoot towards light because the stimulus of light was not perceived.

b) When coleoptiles tip was covered by an opaque tin foil cap, it could not perceive the stimulus of light and hence, no bending was observed.

- **Isolation-** Auxin was first isolated from human urine samples auxins do not have metabolic role so excreted out of the body. It was also isolated from the tips of coleoptiles of oat seedlings by F.W. went.
- **Occurrence -**They occur in the growing apices of the stems and roots from where migrates to their site of action
- **Types :** Auxins are of two types :

a) **Natural auxins :** These are produced by plants and can be isolated from them.
For example, IAA – Indole 3-acetic acid
IBB – Indole butyric acid

b) **Synthetic auxins :** These are produced artificially.
For ex. 2, 4-D – 2, 4-Dichlorophenoxyacetic acid NAA – Naphthalene acetic acid.
All these auxins have been used extensively in agricultural and horticultural practices.

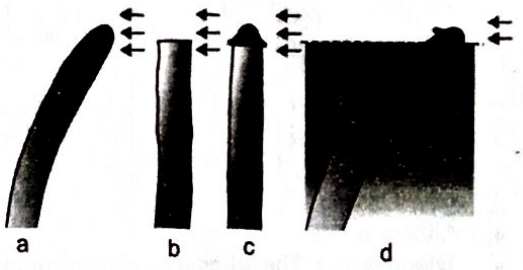


Fig. : Experiment used to demonstrate that tip of the coleoptile is the source of auxin. Arrows indicate direction of light.

- **Physiological effects / Functions of auxin**

a) **Abscission :** In the presence of normal level of auxin, plant organs such as fruits, leaves cannot abscise. Thus, auxin inhibits the abscission, it can occur only when auxin content or level decreases and a layer called abscission layer is formed between the organs like fruits, flowers etc. and the stem. Thus, auxin inhibits abscission of young leaves, fruits and flowers whereas it promotes the abscission of older mature leaves, fruits and flowers.

b) **Apical dominance** : It is the phenomenon by which the presence of apical bud does not allow the nearby lateral or axillary buds to grow. Apical buds secretes auxin which inhibits the growth of lateral buds. If the apical bud is removed (Decapitation), the lateral buds sprout i.e., start growing. However, if a paste containing auxin is applied on the cut portion of the decapitated shoot, the lateral buds remain inhibited in the similar way when apical bud was present. The removal of apical bud is done for the preparation of hedges and bushy growth in certain plants. For example, when the apical bud of tea plants is removed, the lateral buds start developing into branches. It is done to produce more number of leaves so that yield can be increased.

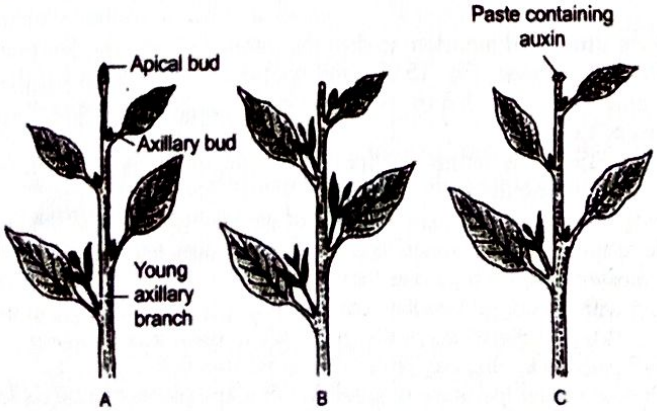


Fig. : Apical dominance and auxin. A, apical but intact. B, removal of apical bud and loss of dominance. C, auxin applied over cut end inhibits lateral bud growths as in apical dominance.

c) **Cell division and Xylem differentiation :** Auxin is responsible for initiation and promotion of cell division in cambium. It also controls the xylem differentiation.

- **Uses/Applications**

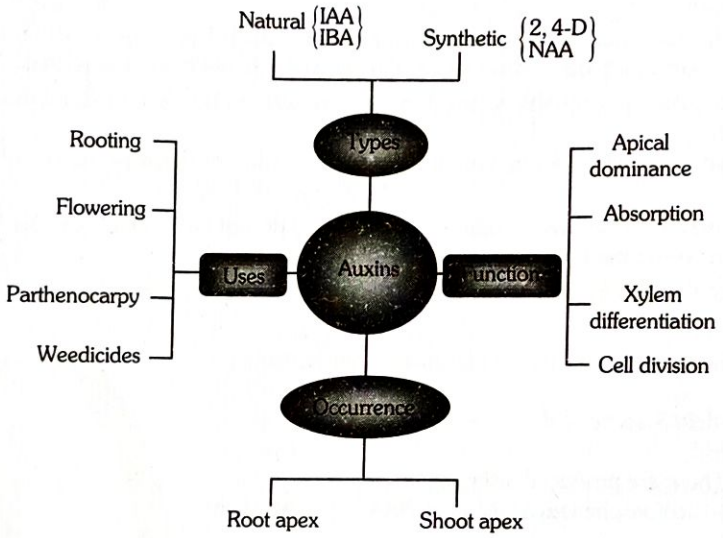
(1) **Rooting :** Auxin stimulates root formation on stem cuttings, particularly the woody ones. The common auxins used for inducing the rooting are NAA and IBA.

(2) **Flowering :** The dilute solutions of NAA and 2, 4-D are sprayed on litchi and pineapple which induce flowering in them. However, flowering in most plants can be inhibited by spraying high concentration of auxins. This effect is used advantageously to prevent flowering in lettuce, where only leaves are edible.

(3) **Parthenocarpy :** Auxins such as IAA and IBA in diluted form are used to produce parthenocarpic or seedless fruits e.g., tomatoes. It has been observed that the carpels (female part) producing parthenocarpic or seedless fruits like banana, grapes etc. have a higher internal production of auxins.

(4) **Weedicides :** Some synthetic auxins are used as weedicides. Weedicides are the chemicals used to kill weeds (unwanted plants) growing with the crops. 2, 4-D is widely used to remove broad leaves weeds or dicotyledonous weeds in cereal crops or monocotyledonous plants.

The auxins are also used by gardeners to prepare weed-free lawns. Thus, auxins are widely used in agricultural and horticultural practices.



- **Gibberellins**
- **Discovery :** The discovery of gibberellins is quite fascinating and dates back to about the same period when auxins were discovered, but it was only after 1950 that they came into prominence. A young Japanese scientist Kurosawa had been trying to find out why the rice seedlings infected by the fungus Gibberella fujikuroi (asexual stage Fushrium monoliforme) grew taller and turned very thin and pale.

These are the symptoms of 'Backanae disease' (meaning foolish) which is known to Japanese for over a century. In 1926, he succeeded in obtaining a filtered extract of this fungus which could cause symptoms of the Backanae disease in healthy rice seedlings. In 1935, Yabuta isolated the active substance which was quite heat stable and gave it the name gibberellin.

- **Functions of Gibberellins**

(1) Stem and Leaf Growth : Gibberellins help in cell growth of stem, leaves and other aerial parts. Therefore, they increase the size of stem, leaves, flowers and fruits.
Gibberellins, however, do not seem to play any such part in case of roots.

(2) Dwarf Shoots : Besides general increase in stem length, gibberellins specifically induce intermodal growth in some genetically dwarf varieties of plants like Pea and Maize. It appears that dwarfness of such varieties is due to internal deficiency of gibberellins.

(3) Bolting : Gibberellins induce sub-apical meristem to develop faster. This causes elongation of reduced stem or bolting in case of rosette plants (e.g., Henbane, Cabbage, Fig. 15.25) and root crops [e.g., Radish). A weekly doze of O.J mg gibberellic acid made cabbage plants to grow taller than 3.5 m. Normally bolting occurs at the onset of reproductive phase. It is favoured in nature by either cold nights or long days.

(4) Dormancy : Gibberellins overcome the natural dormancy of buds, tubers, seeds, etc. and allow them to grow. In this function they are antagonistic to abscisic acid (ABA).

(5) Seed Germination : During seed germination, especially of cereals, gibberellins stimulate the production of some messenger RNAs and then hydrolytic enzymes like amylases, lipases ribonucleases and proteases. The enzymes solubilize the reserve food of the seed. The same is transferred to embryo axis for its growth.

(6) Fruit Development : Along with auxin, gibberellins control fruit growth and development. They can induce parthenocarpy or development of seedless fruits from unfertilized pistils, especially in case of pomes (e.g., Apple, Pear).

(7) Flowering : They promote flowering in long day plants during non-inductive periods.

(8) Vernalization : Vernalization or low temperature requirement of some plants can be replaced by gibberellins.

(9) Sex Expression : Gibberellins promote the formation of male flowers on genetically female plants of Cannabis. They can also replace female flowers with male flowers on monoecious plants of cucurbits.

(10) Curvatures: In Sunflower, phototropic and geotropic responses of shoot tips are due to redistribution of gibberellins.

- **Uses of Gibberellins**

(1) Fruit Growth : Application of gibberellins increases the number and size of several fruits, e.g., Grape, Tomato. The hormone creates more room by increasing the size of stalks so that fruits can grow in size. Size and shape of Apple fruits is enhanced by application of GA_4 and GA_7mixture.

(2) Parthenocarpy : Seedless pomaceous fruits can be produced by application of gibberellins to un-pollinated flowers.

(3) Malt : Gibberellins (e.g., GA_3) increase the yield of malt from barley grains.

(4) Overcoming Dormancy : Gibberellins can be employed for breaking seed and bud dormancy. They induce germination of positively photoblastic seeds of Tobacco and Lettuce in complete darkness.

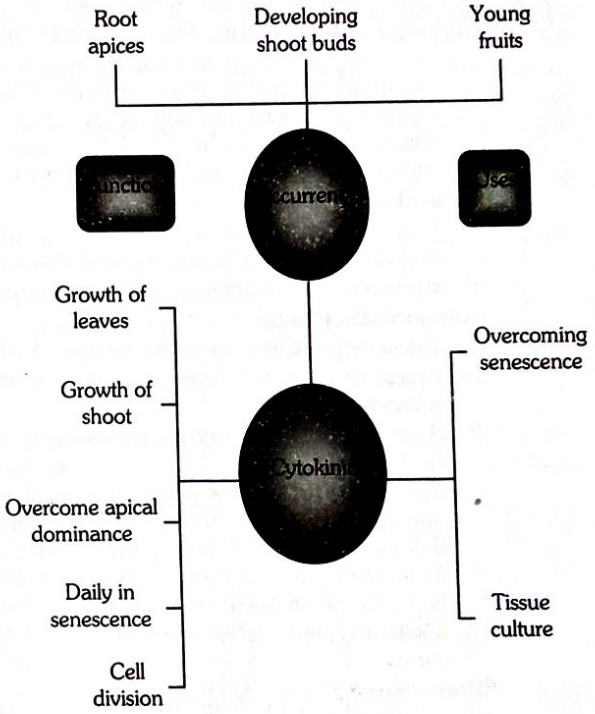
(5) Delayed Ripening : GA_7 delays senescence so that fruit can be left on the tree for longer period It extends period of marketing. Ripening of Citrus fruits can be delayed with the help of gibberellins. This is useful in storing the fruits.

(6) Flowering : Gibberellins can be used in inducing offseason flowering in many long day plants as well as plants requiring vernalisation.

(7) Sugarcane : Spraying of sugarcane crop with gibberellins increases length of stem and yield of sugarcane to as much as 20 tonnes/acre.

(8) Early Maturity : Juvenile conifers sprayed with mixture of GA_4 and GA_7 reach maturity quite early resulting in early seed production.

- **Cytokinins**



- **Discovery :** F. Skoog and his co-workers found that tobacco callus i.e., a mass of undifferentiated cells proliferated only when in addition with auxin, the culture medium is provided either with coconut milk or yeast extract DNA. Miller et al. discovered the first cytokinin from degraded product of autoclaved herring sperm DNA which had a powerful cytokinesis (division of cytoplasm) promoting effect. It is called kinetin (N^6-furfurylamino purine). It is a synthetic product and not occur naturally in plants.
- **Isolation :** The first natural cytokinin was isolated from unripe maize grains or kernels known as zeatin. It can also be isolated from coconut milk. Since the discovery of zeatin, several naturally occurring cytokinins, and some synthetic compounds with cell division-promoting activity have been identified.
- **Occurrence :** Cytokinins occur in regions where rapid cell division occurs such as root apices, developing shoot buds, young fruits etc.
- **Functions/Physiological effects**

a) Growth of leaves and shoot : It helps in the production of new leaves and chloroplasts in leaves. It also stimulates lateral shoot growth and adventitious shoot formation.

b) Apical dominance : Cytokinin initiates the growth of lateral buds despite the presence of apical bud. In the presence of cytokinins, supply of water and minerals increases to lateral buds. Therefore, the lateral buds grow even in the presence of apical bud.

c) Delay in senescence : Cytokinins delay the senescence (ageing) of leaves and other organs by controlling protein synthesis and mobilisation of nutrients as resources.

d) Cell division : Cytokinins are essential for cytokinesis i.e., division of cytoplasm. Along with auxin, cytokinin causes division even in permanent cells. These two hormones are also responsible for cell division in callus i.e., a mass of undifferentiated cells.

- **Uses/Applications**

a) Overcoming senescence : Cytokinin is used to delay the senescence of intact leaves and other plant parts.

b) Tissue culture : Cytokinin along with auxin are essential in tissue culture as they are required for cell division and morphogenesis/organogenesis.

Auxin concentration = Cytokinin concentration → Callus

Auxin concentration > Cytokinin concentration → Root

Cytokinin concentration ? Auxin concentration → Shoot

- **Abscisic acid** a mildly acidic growth hormone which functions as a general growth inhibitor.
- **Discovery :** During mid 1960s, three independent researchers reported the purification and chemical characterization of three different kinds of inhibitors – inhibitor B, abscission II and dormin. Later all the three were proved to be chemically identical. In order to avoid confusion the name abscisic acid was given.
- **Occurrence :** Dormant, buds, seeds.
- **Physiological effects / functions**

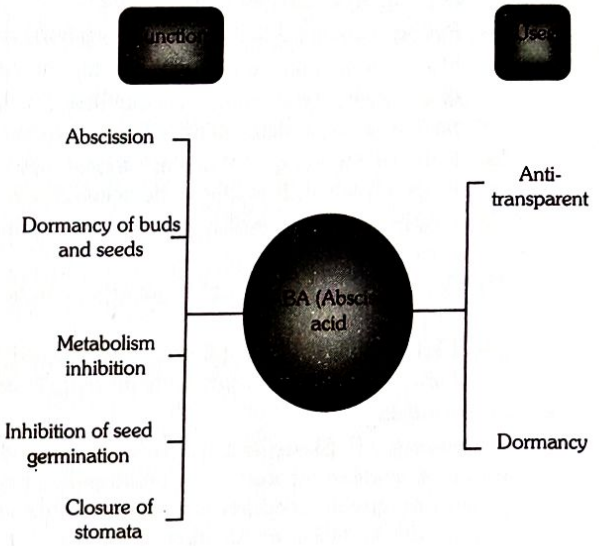
a) Abscission : ABA promotes abscission of flowers and fruits.

b) Dormancy of buds and seeds : ABA acts as a growth inhibitor and induces dormancy of buds and seeds. As ABA induces dormancy, it is also known as dormin. The buds as well as seeds sprout only when ABA is overcome by gibberellins.

c) Metabolism : ABA inhibits the protein and RNA synthesis and cause destruction of chlorophyll. As result senescence of cereal grains and thus inhibits their sprouting.

d) Inhibition of seed germination : Abscisic acid inhibits gibberellins mediated amylase formation during germination of cereal grains and thus inhibits their sprouting.

e) Closure of stomata : The concentration of ABA increases in the leaves of the plants during desiccation and other stressful conditions. As a result, stomata present in the epidermis of leaves close to prevent the loss of water i.e., transpiration. Therefore, it can also be known as anti transpirant. Thus, synthesis of ABA is stimulated by drought, water logging and other adverse environmental conditions. Therefore, it is known as stress hormone. In most situations, ABA acts as an antagonist to Gas that is why it is known as Anti GA.



- **Uses / applications**

a) Antitranspirant : Application of minute quantity of ABA to leaves reduces transpiration to a great extent through partial closure of stomata. It thus, conserves water and reduces the requirement of irrigation.

b) Dormancy : ABA is used to induce the dormancy of buds, seeds and organs. By inducing dormancy ABA helps the seed to withstand desiccation and other unfavourable factors. Thus, ABA plays an important role in seed development and maturation.

In plants, growth, differentiation and developmental processes are regulated by one or other hormone. The phytohormones can act individually, synergistically or antagonistically. Synergistic action means two or more hormones have combined effect while antagonistic means two hormones work in opposite manner.

Synergistic actions

a) Cell division : Both auxin and cytokinin promote cell division which shows their synergistic effect on cell division.

b) Abscission : Both ethylene and ABA are responsible for promoting the shedding of leaves, fruits and flowers

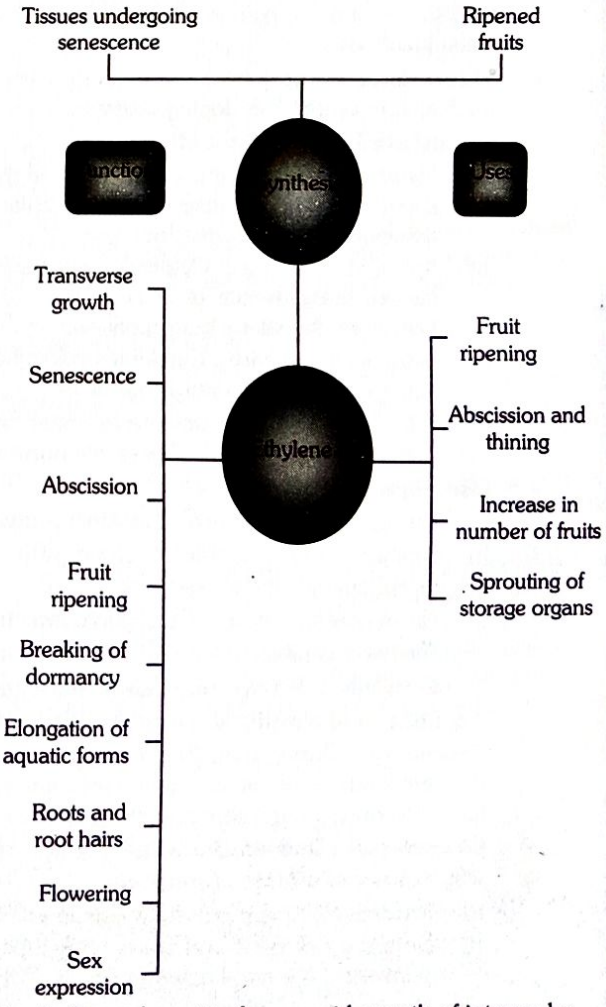
Antagonistic effects

(1) Dormancy : ABA induces dormancy of buds, seeds and storage organs whereas gibberellins inhibit it.

(2) Apical dominance : Auxin promotes the apical dominance whereas it is inhibited by cytokinin. Thus, these two hormones act antagonistically.

(3) Senescence : Senescence is prevented by auxins while it is stimulated by ABA.

The role of PGR is of only one kind of intrinsic control. Along with genomic control and extrinsic factors, they play an important role in the plant growth and development. Many of the extrinsic factors such as temperature and light, control plant growth and development via PGR. Some of such events could be dormancy, seed germination, flowering, plant movements etc. Let us try to understand some of these.



- **Ethylene**

It is a gaseous plant hormone.

Discovery : Cousins discovered and confirmed that ripe oranges emitted a volatile substance that brought about early ripening of unripe bananas kept nearby. Later on, this volatile substance was identified as ethylene.

Synthesis : It is synthesized in almost all plant parts like roots, leaves, flowers, fruits, seeds etc. The maximum synthesis occurs during ripening of fruits and in the tissues undergoing senescence i.e., ageing.

- **Physiological effects / functions**

a) Transverse or horizontal growth : Ethylene inhibits longitudinal growth but stimulates transverse growth of seedlings. It is also responsible for the formation of apical hook in dicot seedling and swelling of the axis due to which stem looks swollen.

b) Senescence : It promotes senescence of plant parts like leaves, flowers. It has been found that leaf senescence is largely caused by ethylene.

c) Abscission : Ethylene accelerates abscission i.e., shedding of leaves, flowers and fruits.

d) Fruit ripening : Ethylene is a ripening agent. It is involved in ripening of climacteric fruits. The climacteric fruits are fleshy fruits which show sudden sharp rise in the rate of respiration at the time of ripening. This sudden sharp rise in the rate of respiration is called respiratory climactic.

e) Breaking of dormancy : It breaks the dormancy of seeds, buds and initiates the germination of seeds such as peanut seeds. It also causes the sprouting of potato tubers.

f) Elongation of aquatic forms : Both stem and petiole elongation in submerged and partially submerged aquatic plants is promoted by ethylene. For example, leaves of rice seedlings remains out of water due to ethylene where it induces rapid growth of internodes and leaf bases.

g) Roots and root hairs : Ethylene induces development of adventitious roots on various types of cuttings. It promotes the development of lateral roots and growth of root hairs so as to increase the absorption surface.

h) Flowering : Flowering and fruit set are synchronized by ethylene in pineapples. It also initiates flowering in mango.

i) Sex expression : Ethylene increases the number of female flowers and fruits in certain plants like cucumber.

- **Uses/Applications**

Ethylene is one of the most widely used PGRs in agriculture as it regulates so many physiological processes which are discussed earlier. The most widely used compound as a source of ethylene is ethephon. The uses of ethylene are as follows :

a) Fruit ripening : Ethephon is used in artificial ripening. It is an aqueous solution which is readily absorbed and transported within the plant and releases ethylene slowly. Ethephon has the capacity to increase or hasten fruit ripening.

b) Abscission and thinning : It is used to accelerate or increase the abscission of flowers and fruits and also the thinning of fruits. e.g., cotton, cherry, walnut.

c) Increase in number of fruits : Application of ethylene in cucumber increases the number of female flowers thereby increasing the yield.

d) Sprouting of storage organs : The sprouting of storage organs such as rhizome, tubers can be enhanced by exposing them to ethylene.

7. Seed Dormancy

The seed undergoes a period of suspended growth and does not germinate as soon as it is formed. The suspension of growth is referred to as quiescence when it is due to exogenous factors, such as the environmental conditions. The seeds may be in a state of dormancy or rest due to endogenous control during which metabolic activity of the seed is greatly reduced. Quiescence is the condition of a seed when it is unable to germinate because the conditions for germination are not available.

Such seeds will germinate if they are supplied with water and suitable temperature. While dormancy is the condition of seed when it is unable to germinate in spite of the availability of all environments conditions suitable for germination.

Factors : Dormancy in seed may be due to impermeable or mechanically resistant seed coats, rudimentary or physiologically immature embryos and even due to the presence of germination inhibitors such as abscisic acid, phenolic acid, short chain fatty acids and coumarin.

Breakage of dormancy : Dormancy of the seed can be broken, or its duration can be reduced to initiate germination, by mechanical or chemical scarification of the seed coat, stratification of seeds or changing environmental conditions such as temperature, light and pressure. Scarification of seed involves scratching of seed coat to help break the dormancy caused by hard and impermeable seed coat. Stratification of seed is subjecting the moist seeds to oxygen for variable periods of low or high temperatures.

- **Germination of seed / seed germination**

The resumption of active growth of the embryo present in the seed after a period of dormancy is known as germination. For the germination of a seed, water temperature and oxygen are essential requirements. When a seed is provided with these essential requirements, it starts to germinate.

During this process, first structure developed within the seed is known as radicle. Radicle breaks the seed coat and passes downwardly in the soil to establish itself as the primary root.

Later it gives rise to tap root system. Soon after the elongation of the radicle, either hypocotyls or epicotyls shows active growth which pushes plumule out of the soil which from shoot system.

The growth of radical and plumule is due to the cell extension, division and initiation of several biochemical processes. The seed also needs a suitable temperature (optimum between 25° C to 35°C). Rate of respiration increases rapidly during germination.

In bean, hypocotyls grows actively and becomes curved. It brings the seed above the soil. After coming above the surface of the soil, the hypocotyl straightens. The loosened seed coats fall down. Now, epicotyl grows and the plumule gives rise to green leaves.

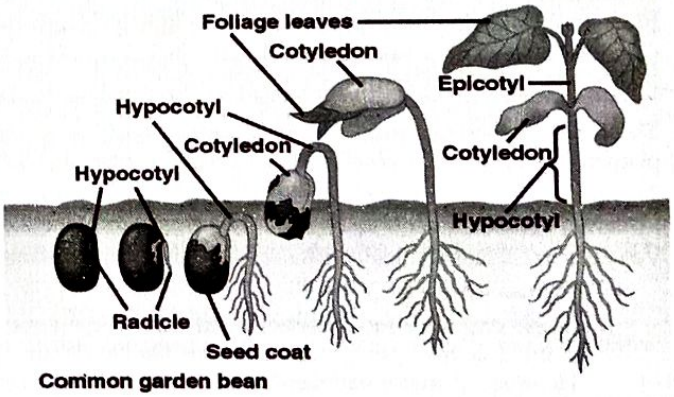


Fig. : Germination and seeding development in bean

- **Vivipary**

Vivipary is the germination of a seed while it is still attached to the parent plant and is nourished by it. It occurs in mangroove plants like Rhizophora and Sonneratia.

These plants grow in saline marshy habitats along sea shores. Seeds cannot germinate in such habitats due to excessive salt and deficiency of oxygen.

Mangroves plants have solved this problem through vivipary. The seed does not undergo dormancy, soon it germinates while present inside the fruit attached to parent plant. As the germinating seed forms a seedling, its weight increases and the seedling separates and falls down into the mud. The lateral roots then develop from radicle to help proper anchorage of the seedling.

- **Flowering**

Plants flower when they reach the reproductive phase. There are various parameters which influence the process of flowering. Two main phenomena involved in the flowering process are photoperiodism and vernalisation

8. Photoperiodism

The relative lengths of dark and light periods vary from place to place and from season to season which influence the flowering process to a great extent in different plants.

The length of light period is called photoperiod and the responses shown by the plants to changes in the relative lengths of dark and light period is called photoperiodism. Thus, plants exhibiting the response are known as photoperiodic plants.

Garner and allard, found that the tobacco plants could flower only if the plants were exposed to a number of short days. In autumn, this occurred naturally.

But in summers the plants did not flower even after attaining many heights, until and unless these were provided a number of short days of 7 hours in a greenhouse. When they examined more plants for this behavior, they found that plants differ in their requirements for day length.

Most plants can flower only if they were exposed to light for less or more than a certain period which is known as critical period. Accordingly, plants can be categorized which is as follows:

- **Long Day Plant**

  These plants flower when they receive long photoperiods or light hours which are above than a critical period. e.g., wheat, radish, sugar beet etc.

- **Short Day Plant**

  These plants flower when they are exposed to a photoperiod shorter than a critical period. Most of winter-flowering plants belong to this category. e.g., soya bean, tobacco etc.

- **Day Neutral Plant**

  These plants do not show any correlation between exposure to light duration and induction of flowering response. They can blossom throughout the year e.g., tomato, pepper, cucumber etc.

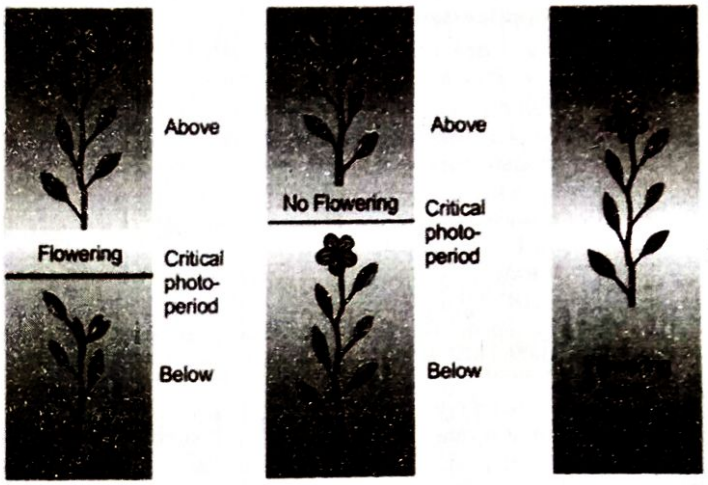


Fig. : Photoperiodism : Long day, short day and day neutral plants.

It is also interesting to note that before flowering, shoot apices modify themselves into flowering apices. Shoot apices of plants themselves cannot perceive photoperiods. The site of perception of light/dark is the leaves of plants. It has been hypothesized that there is a hormonal substance known as florigen which is responsible for flowering. When plants are exposed to the required inductive photoperiod, the hormonal substance i.e., florigen migrates from leaves to shoot apices for inducing flowering.

Importance of photoperiodism

- The knowledge of photoperiodic effect is useful to the commercial flower growers. It enables them to induce or retard flowering by regulating the photoperiodic and temperature conditions in glass houses to meet the demands of the market.
- The knowledge of photoperiodism is also useful in laying out gardens, orchards and planning crop pattern in a particular area.
- The knowledge of photoperiodism can be utilized in keeping some plants in vegetative growth to obtain higher yield of tubers, rhizomes etc., or keep the plant in reproductive stage of yield more flowers and fruits.

Important-

Phytochrome is a photoreceptor, a pigment that plants use to detect light.

9. Vernalisation

There are various plants for which flowering is either quantitatively or qualitatively dependent on exposure to low temperature. This phenomenon is termed vernalisation or it refers to promotion of flowering by a period of low temperature.

This phenomenon is termed vernalisation or it refers to promotion of flowering by a period of low temperature. Here, the stimulus is perceived by the mature stem apex, or by the embryo of the seed, but not by the leaves as in photoperiodism.

Vernalisation is seen in many winter annuals and biennial plants

- **Winter annuals**

  Some important food plants, wheat, barley, rye have two kinds of varieties – winter and spring. The 'spring' variety is normally planted in the spring season. In this variety, flowering and production of grain occurs before the end of the growing season. However, if winter varieties are planted earlier to their sowing period i.e., in spring season, this would result in no flowering and production of mature grains within a span of a flowering season. Hence, they are planted in autumn. They germinate and over winter come out as small seedlings, resume growth in the spring, and are harvested usually around mid-summer. Therefore, we can say that plants require a specific temperature.

- **Biennial plants**

  Biennial plants such as sugar beet, cabbages, carrots are monocarpic that normally flower and die in the second season. When growing biennial plants are subjected to a cold treatment, it leads to the stimulation of a subsequent photoperiodic response which results in flowering. The main role of vernalisation is to prevent the precocious i.e., reproductive development so that the plants have enough time to reach maturity.

  Importance of vernalisation

  Vernalisation can help in shortening the period between germination and flowering. Thus, more than one crop can be obtained during a year.

  Sowing of winter crops (cereals) in spring season after vernalisation can avoid killing of cereals in severe winter. Promalin is used to increase fruit size e.g., apple. Raphanus sativus is LDP. In SLDP initiation of flowering starts in short day conditions but flowering occurs in long day conditions.

  Photoperiodic stimulus is believed to be perceived by phytochrome. It is a blue green pigment existing in two interconvertible forms : P_{fr} or P_{730} (absorbs far-red lights) and P_r and P_{660} (absorb red light). By absorbing red light, P_r is converted to P_{fr} rapidly. P_{fr}, on absorbing far red light is converted to P_r rapidly. Darkness also causes this conversion. P_{fr} is physiologically active from; P_r is inactive.

  For SDP, $\frac{P_r}{P_{fr}} > 1$ while for LDP, $\frac{P_{fr}}{P_r} > 1$ is critical for flowering.

15. Plant Growth and Development – Multiple Choice Questions

1. Growth

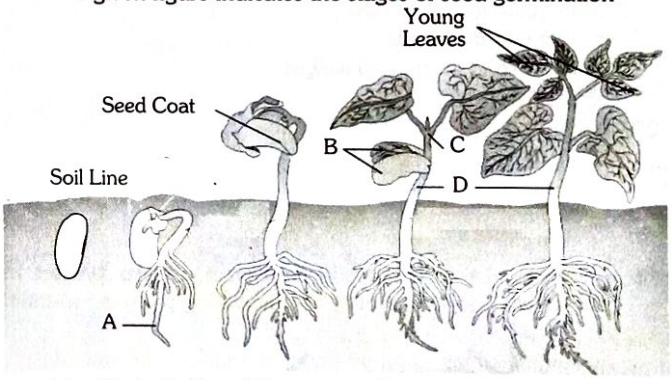
1. Which two factors primarily affect the developmental phase of growth of plants
   (a) Light and temperature
   (b) Rainfall and temperature
   (c) Light and wind
   (d) Temperature and relative humidity
2. Plant growth in length is increased by
   (a) Apical meristem (b) Lateral meristem
   (c) Dermatogen (d) Periblem
3. The growth involves
   (a) Cell division (b) Cell enlargement
   (c) Cell maturation (d) All the above
4. The rate of growth of any organism follows

   Or

   Typical growth curve in plants is
   (a) Hyperbola curve (b) J–shaped curve
   (c) Sigmoid curve (d) Parabola curve
5. Etiolation in plants is caused when they
   (a) Are grown in dark (b) Have mineral deficiency
   (c) Are grown in intense light (d) Are grown in blue light
6. To remove seed dormancy by mechanical removing of seed coat is called
   (a) Stratification (b) Scarification
   (c) Vernalization (d) Photoperiodism
7. The instrument by which the rate of growth of stem is accurately measured is

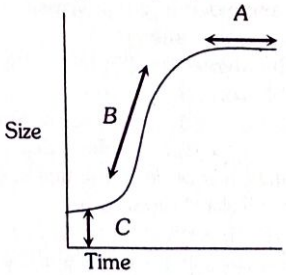
   Or

   Growth in length of a plant can be measured by
   (a) Hydrometer (b) Auxanometer
   (c) Osmometer (d) Potometer
8. Phytotron is
   (a) Fish culture (b) Plant hormone
   (c) Animal hormone (d) None of these
9. During cell enlargement phase of growth, molecules of new cell wall material are inserted between the original molecules of the stretched wall. This process is known as
   (a) Intussusception (b) Apposition
   (c) Integration (d) None of the above
10. Moving on a grass lawn facilitates better maintenance primarily owing to
    (a) Removal of apical dominance and promotion of lateral meristem
    (b) Removal of apical dominance
    (c) Wounding which stimulates rapid regeneration
    (d) None of the above
11. Which of the following instrument can be used to record plant growth by seconds *i.e.* infraction of a minute
    (a) Arc auxanometer (b) Arc indicator
    (c) Space marker disc (d) Crescograph
12. Evergreen trees remain green throughout the year on account of
    (a) The absence of leaf fall
    (b) Leaves falling in small numbers at intervals
    (c) Supply of the moisture throughout the year
    (d) Cold climate
13. Exponential growth occurs in
    (a) Yeast (b) Asexual reproduction
    (c) Bacterial (d) All of these
14. Highest growth is found in
    (a) Static phase (b) Exponential phase
    (c) Descending phase (d) Lag phase
15. Several horticultural techniques are followed for the production of 'bonsai' plants. One of them is a drastic pruning of the root system. Which of the following physiological factor is involved in that method
    (a) The inadequacy of mineral nutrients
    (b) Deficiency of auxins
    (c) Impairment of water absorption
    (d) Deficiency of cytokinins
16. The type of growth of bands in conifers is
    (a) Lateral (b) Delinquent
    (c) Caudex (d) Excurrent
17. The given figure indicates the stages of seed germination



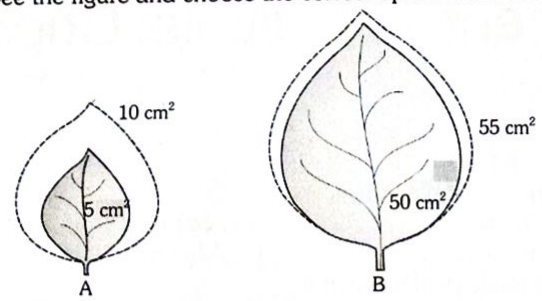
    Identify A, B, C and D respectively
    (a) Root hair, Cotyledons, Epicotyl and Hypocotyl
    (b) Mesocotyl, Cotyledons, Epicotyl and Hypocotyl
    (c) Radicle, Cotyledons, Epicotyl and Hypocotyl
    (d) Plumule, Cotyledons, Epicotyl and Hypocotyl
18. Which of the following is the primary motive force responsible for the growth
    (a) Root pressure (b) Turgor pressure
    (c) Osmotic pressure (d) DPD
19. Given below is a graph drawn on the parameters of growth versus time *A, B, C* respectively represent

    B, C respectively represent



    (a) Exponential phase, log phase and steady state phase
    (b) Steady-state phase, log phase and lag phase
    (c) Slow growing phase, lag phase and steady state phase
    (d) Lag phase, steady-state phase and logarithmic phase
    (e) Lag phase, log phase and steady state phase

20. See the figure and choose the correct option from the table



	A - Leaf		B - Leaf	
	AGR	**RGR**	**AGR**	**RGR**
(a)	0.5	100%	1.5	100%
(b)	5	100%	5	10%
(c)	100%	5	10%	5
(d)	1%	1	2%	2

21. Growth is maximum in the zone of
(a) Cell division (b) Cell elongation
(c) Cell maturation (d) All of these

22. Growth can be measured in various ways. Which of these can be used as parameters to measure growth
(a) Increase in cell number
(b) Increase in cell size
(c) Increase in length and weight
(d) All the above

23. Plasticity in plant growth means that
(a) Plant roots are extensible
(b) Plant growth is dependent on the environment
(c) Stems can extend
(d) None of the above

24. Senescence as an active developmental cellular process in the growth and functioning of a flowering plant is indicated in
(a) Annual plants
(b) Floral parts
(c) Vessels and tracheid differentiation
(d) Leaf abscission

25. Exponential growth in plants can be expressed as
(a) $L_t = L_0 + rt$ (b) $L_e = L_t rt$
(c) $W_1 = W_0 e^{rt}$ (d) $W_1 = W_0 e^{rt}$

2. Growth Hormones

1. In which of the following respect, the plant hormones differ from enzymes
(a) Required in less quantity
(b) They are expended in the process
(c) They release some energy
(d) None of the above

2. Phytohormones control
(a) Growth (b) Physiological functions
(c) Rooting (d) Flowering

3. The natural plant hormones were first isolated from
(a) Corn germ oil and human urine
(b) Cotton fruits, spinach leaves and rice plants
(c) Avena coleoptile spinach leaves and the fungus gibberellin
(d) Human urine and rice seedlings

4. Among plants 'pheromones' are secreted by the cells of following plants for the given function
(a) All plants for growth and development
(b) Yeast for facilitating mating
(c) All fungi for sexual reproduction
(d) *Rhizopus* for the formation of a zygospore

5. Who for the first time speculated the presence of organ forming substances in the plant now called hormones
(a) Darwin (b) Went
(c) Yabuta (d) Sachs

6. The term synergistic action of hormones refers to
(a) When two hormones act together but bring about the opposite effects
(b) When two hormones act together and contribute to the same function
(c) When one hormone affects more than one function
(d) When many hormones bring about any one function

7. Identify two physiological processes induced by two different Phytohormones having a common precursor which is formed due to the catalytic activity of pyruvic dehydrogenase complex
(I) More female flowers in cucumber
(II) α-amylase production in barley grain
(III) Acceleration of fruit ripening in tomato
(IV) Delay in sprouting of potato tubers
The correct combination is
(a) I, II (b) I, III
(c) II, IV (d) III, IV

3. Auxin

1. Apical dominance in higher plants is due to
(a) The balance between auxin and cytokinin
(b) Enzyme activity and metabolism
(c) Carbohydrates
(d) Photoperiodism

2. Which of the following is not naturally occurring plant hormone
(a) 2, 4–D (b) GA_2
(c) Gibberellin (d) IAA

3. Which of the following ion is pulled out in apoplast by the auxin during growth
(a) Na^+ (b) K^+
(c) Mg^{2+} (d) H^+

4. Levitt performed experiments. He observed that auxin treated cells were able to absorb water even when kept in a hypertonic solution. Which explains this observation best
(a) Auxin treated cells lose selective permeability
(b) ATP production increases and therefore much energy is available for active absorption
(c) Auxin lowers the water potential of cells
(d) Auxin increases the solute potential of cells

5. Both in callus and suspension cultures commonly used auxin is
(a) NAA
(b) IBA
(c) 2, 4-D
(d) 2,4,5-Trichlorophenoxy acetic acid
(e) Abscisic acid

6. One of the commonly used plant growth hormone in tea plantations is
(a) Ethylene (b) Abscisic acid
(c) Zeatin (d) Indole-3-acetic acid

7. Auxin in-plant is not meant for
(a) Cell elongation (b) Fruit ripening
(c) Cell division (d) Inhibit the root growth

8. The substances which have proved very effective to induce rooting from the cut end of the stem is
(a) Phenylacetic acid
(b) α–naphthalene acetic acid
(c) Indole acetic acid
(d) Indole butyric acid

9. Auxins originate at the tip of the stem and controls growth elsewhere. The movement of auxin is largely
(a) Basipetal (b) Acropetal
(c) Acropetal and basipetal (d) Centripetal

10. Which one among the following chemical is used for causing defoliation of forest trees
(a) Amo–1618 (b) Phosphon–*D*
(c) Maleic hydrazide (d) 2, 4-*D*

11. Which one of the following plant function is not generally governed or controlled by auxin
(a) Apical dominance (b) Phototropism
(c) Photosynthesis (d) Growth

12. Dr F. Went noted that if coleoptile tips were removed and placed on agar for one hour, the agar would produce a bending when placed on one side of freshly cut coleoptile stumps. Of what significance is this experiment
(a) It supports the hypothesis that IAA is auxin
(b) It demonstrated polar movement of auxins
(c) It made possible the isolation and exact identification of auxin
(d) It is the basis for quantitative determination of small amounts of growth-promoting substances

13. A green plant bends towards the source of light when exposed to the light on only one side, it bends towards the source of light as it grows. Which of the following is the best explanation of the phenomenon
(a) The apices of their stems are attracted by light
(b) They need light for photosynthesis
(c) Some auxins accumulate on the shaded side to induce greater cell elongation on that side
(d) Light stimulates the cells on the illuminated side to increase in length

14. Which of the following movements is not related to change in auxin levels
(a) Nyctinastic leaf movement
(b) Movement of roots towards soil
(c) Movement of sunflower tracking the direction of the Sun
(d) Movement of shoot towards the light

15. One of the synthetic auxins is
(a) NAA (b) IAA
(c) GA (d) IBA

16. Phototropism in shoots is attributed to
(a) Auxin (b) Gibberellins
(c) Cytokinins (d) Abscisic acid

17. Apical dominance in-plant is caused by
(a) High concentration of auxins in the terminal bud
(b) High concentration of gibberellins in the apical bud
(c) High concentration of auxins in the lateral bud
(d) The absence of auxins and gibberellins in the apical bud

18. Which of the following is not a physiological effect/an influence of auxin
(a) Initiates rooting in stem cuttings
(b) Promotes flowering
(c) Prevents fruit and leaf drop at early stages
(d) Inhibits the growth of lateral buds
(e) Promotes bolting

19. IAA and serotonin are derived (formed) from which of the following
(a) Tryptophan (b) Tyrosine
(c) Phenylalanine (d) None of these

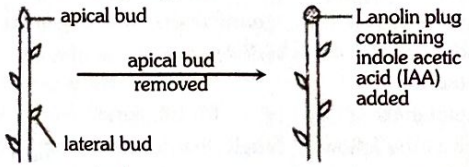
20. Bioassay for auxin is
(a) Avena curvature test (b) Green leaf test
(c) Dwarf maize test (d) Cell division test

21. Auxins are abundantly produced in
(a) Root
(b) Meristematic region of the root
(c) Shoot
(d) Meristematic region of the shoot

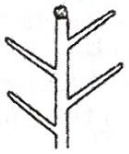
22. Abscission of fruits is prevented by
(a) *ABA* (b) Ethylene
(c) Cytokinin (d) *IBA*

23. Flowering in pineapple is promoted by
(a) *NAA* (b) GA_3
(c) Short days (d) Cytokinin

24. See the following diagram



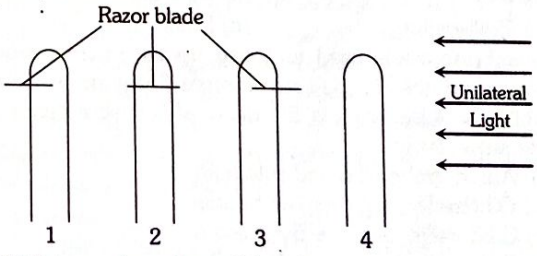
After two weeks the appearance of the shoot would be

(a)  (b) 

(c)  (d) 

25. The effect of apical dominance can be overcome by which of the following hormone
(a) IAA (b) Ethylene
(c) Gibberellin (d) Cytokinin

26. The given fig. shows 4 four coleoptiles set up at the start of an experiment



Which two coleoptiles will bend towards the light source
(a) 3 and 4 (b) 2 and 3
(c) 1 and 4 (d) 1 and 2

27. Antiauxin used in picking cotton balls is
(a) NPA (b) 2–4 D
(c) TIBA (d) Both (a) and (c)

4. Gibberellins

1. Specific property attributed to gibberellins is
(a) Shortening of genetically tall plants
(b) Elongation of genetically dwarf plant
(c) Promotion of rooting
(d) Yellowing of young leaves

2. Which of the following plant hormone substitutes for long photoperiods in flowering plants
(a) Auxins (b) Gibberellins
(c) Cytokinins (d) Ethylene

3. Cell elongation in internodal region takes place due to
(a) Gibberellins (b) Ethylene
(c) Cytokinins (d) Indole acetic acid

4. Which one of the following pairs, is not correctly matched
(a) Abscisic acid – Stomatal closure
(b) Gibberellic acid – Leaf fall
(c) Cytokinin – Cell division
(d) IAA – Cell wall elongation

5. Gibberellins differ from auxins since they produce
(a) Cell division (b) Stem elongation
(c) Root initiation (d) Shortening of Internodes

6. At the onset of seed germination, the digestive enzymes amylase are produced by the action of
(a) Auxins (b) Gibberellins
(c) Cytokinins (d) Ethylene

7. Which of the following breaks the dormancy of potato tubers
(a) *IAA* (b) *ABA*
(c) Zeatin (d) Gibberellin

8. Parthenocarpic tomato fruits can be produced by
(a) Raising the plants from vernalized seeds
(b) Treating the plants with phenylmercuric Acetate
(c) Removing androecium of flowers before pollen grains are released
(d) Treating the plants with low concentrations of gibberellic acid and auxins

9. Bakane disease in paddy is caused by
(a) Abscisic acid (b) Gibberellic acid
(c) Phenyl acetic acid (d) Naphthalene acetic acid

10. The rosette habit of cabbage can be changed by application of
(a) IAA (b) GA
(c) ABA (d) Ethaphon

11. To increase sugar production in sugarcanes, they are sprayed with
(a) IAA (b) Cytokinin
(c) Gibberellin (d) Ethylene

12. One hormone is used to speed up the malting process in barley, another is used to promote flowering in pineapple, while the third helps in the delay of leaf senescence. These are respectively
(a) Auxin, gibberellin and cytokinin
(b) Gibberellin, cytokinin and auxin
(c) Gibberellin, auxin and cytokinin
(d) Cytokinin, auxin and gibberellin
(e) Auxin, cytokinin and gibberellin

13. Which one of the following synthetic growth regulators are used to promote synchronized flowering in pineapple
(a) Benzyl aminopurine
(b) Phenylmercuric acetate
(c) Indolebutyric acid
(d) 2-chloroethyl phosphoric acid

5. Cytokinin

1. Which of the following is a coconut milk factor
(a) Auxin (b) Cytokinin
(c) Morphactin (d) None of the above

2. Cytokinins are formed in
(a) Roots (b) Leaves
(c) Fruits (d) Stems

3. All the cytokinins are
(a) Acidic (b) Aminopurines
(c) Phenol (d) Glucosides

4. The cut flowers and vegetables can be kept fresh for a long period by this plant hormone
(a) Gibberellins (b) Cytokinins
(c) Auxins (d) Ethylene
(e) 2,4-dichlorophenoxy acetic acid

5. Which of the following induces flowering in the short-day plant
(a) Gibberellins (b) Cytokinin
(c) Auxins (d) Ethylene

6. A plant hormone used for inducing morphogenesis in plant tissue culture is
(a) Abscisic acid (b) Gibberellins
(c) Cytokinins (d) Ethylene

7. A substance isolated from herring sperm DNA and named as '*kinetin*' by
(a) Miller (b) Skoog
(c) Saltza and Strong (d) All the above

8. The natural plant hormone isolated from corn kernels and coconut milk is
(a) Florigen (b) GA_3
(c) Free auxins (d) Zeatin

9. Match the following

A. IAA	i. Herring sperm DNA
B. ABA	ii. Bolting
C. Ethylene	iii. Stomatal closure
D. GA	iv. Weed-free lawns
E. Cytokinins	v. Ripening of fruits

Options :
(a) A-iv, B-iii, C-v, D-ii, E-i
(b) A-v, B-iii, C-iv, D-ii, E-i
(c) A-iv, B-i, C-v, D-iii, E-ii
(d) A-v, B-iii, C-ii, D-i, E-iv

6. Ethylene

1. The ripening of fruits can be hastened by treatment with
(a) Gibberellic acid (b) Indole acetic acid
(c) Florigen (d) Ethylene gas

2. Ethylene is a
(a) Gaseous hormone (b) Gaseous enzyme
(c) Liquid–gas mixture (d) Solid hormone

3. Pineapple can be made to flower in the offseason by
(a) Ethylene/*NAA* (b) Zeatin
(c) Short day (d) Temperature

4. Root development is promoted by
(a) Abscisic acid (b) Auxin
(c) Gibberellin (d) Ethylene

5. Artificial ripening of which of the following fruits is useless
(a) Mango (b) Banana
(c) Grapes (d) Pomegranate/Coconut

6. When an unripe banana is sealed in a polythene bag, it remains green for many days. But if an apple is also sealed in the same bag, the banana ripens and turns yellow within a few days. The reason is that Apple
(a) Removes O_2 released by the banana and thus promotes ripening
(b) Produces CO_2 which promotes ripening
(c) Removes CO_2 which inhibits ripening
(d) Releases ethylene which promotes ripening

7. ABA and Other growth regulators

1. The following is a naturally occurring growth inhibitors
   (a) *IAA* (b) *ABA*
   (c) *NAA* (d) *GA*
2. Elongation of internodes is inhibited by
   (a) Gibberellins (b) Morphactins
   (c) Both (a) and (b) (d) None of the above
3. Which one of the following generally acts as an antagonist to gibberellins
   (a) Zeatin (b) Ethylene
   (c) BA (d) IAA
4. *ABA* is involved in
   (a) Dormancy of seeds (b) Root elongation
   (c) Shoot elongation (d) Increased cell division
5. Which of the following hormone is responsible for senescence
   (a) *GA* (b) *ABA*
   (c) Auxin (d) Cytokinin
6. Which one of the following acids is a derivative of carotenoids
   (a) Indole butyric acid (b) Indole-3-acetic acid
   (c) Gibberellic acid (d) Abscisic acid
7. Choose the wrongly matched pair from the following
   (a) Auxins – "to grow"
   (b) Gibberellins – *Gibberella Fujikura*
   (c) Cytokinins – Herring sperm DNA
   (d) Abscisic acid– Flowering hormone
8. Leaf abscission, fruit fall, bud dormancy occurs by which phytohormone
   (a) Auxin (b) Cytokinin
   (c) Gibberellins (d) Abscisic acid
9. One of the most commonly detected inhibitors of germination is
   (a) Gibberellic acid (b) Abscisic acid
   (c) Pantothenic acid (d) Tartaric acid

8. Photoperiodism and Vernalization

1. Phytochrome is found in [BHU 1987; MP PMT 2007]
   (a) Algae (b) Fungi
   (c) Vascular cryptogams (d) Flowering plants
2. The red absorbing form of phytochrome gets converted to the far–red absorbing form after getting irradiated at
   (a) 660 *nm* (b) 730 *nm*
   (c) 530 *nm* (d) 660 *nm* to 730 *nm*
3. When the dark period of short-day plants is interrupted by a brief exposure of light, then the plant
   (a) Will not flower at all
   (b) Flower immediately
   (c) Give more flowers
   (d) Turn into a long day plant
4. Which of the following hormones can replace vernalization
   (a) Auxin (b) Ethylene
   (c) Gibberellins (d) Cytokinins
5. Through their effect on plant growth regulators, what do the temperature and light control in the plants
   (a) Apical dominance (b) Flowering
   (c) Closure of stomata (d) Fruit elongation
6. A hypothetical chemical involved in the flowering of plants is or Chemical agent which has an important role in flowering is
   (a) Gibberellin (b) Kinetin
   (c) Indole acetic acid (d) Florigen
7. In short day plants (SDP) flowering is induced by
   (a) Long night
   (b) Photoperiod less than 12 hours
   (c) Photoperiod shorter than initial value and uninterrupted long night
   (d) Short photoperiod and interrupted long night
8. With respect to photoperiodism, these are long day plant
   (a) Wheat, oat, soybean
   (b) Wheat, *Xanthium*, paddy
   (c) Wheat, poppy, soybean
   (d) Wheat, poppy, beet
9. A few normal seedlings of tomato were kept in a dark room. After a few days, they were found to have become white-coloured like albinos. Which of the following terms will you use to describe them
   (a) Etiolated (b) Defoliated
   (c) Mutated (d) Embolised
10. The wavelength of light absorbed by the Pr form of phytochrome is
    (a) 640 *nm* (b) 680 *nm*
    (c) 720 *nm* (d) 620 *nm*
11. Phytochrome becomes active in
    (a) Green light (b) Blue light
    (c) Red light (d) None of these
12. If a tree flowers thrice in a year (October, January and July) in Northern India, it is said to be
    (a) Photosensitive but thermo-insensitive
    (b) Thermosensitive but photo-insensitive
    (c) Photo and thermo-insensitive
    (d) Photo and thermosensitive
13. What will be the effect on phytochrome in a plant subjected to continuous red light
    (a) Level of phytochrome will decrease
    (b) Phytochrome will be destroyed
    (c) Phytochrome synthesis will increase
    (d) None of these
14. Which one of the following statements is true for the phytochrome
    (a) Phytochrome is a phytohormone
    (b) Phytochrome is a photosynthetic pigment
    (c) Phytochrome is a pigment that controls growth, photomorphogenesis and development of many plants
    (d) Phytochrome is a regulatory protein that controls several dark–dependent developmental processes
15. Importance of day length (Photoperiodism) in the flowering of plants was first shown in
    (a) Cotton (b) *Petunia*
    (c) *Lemna* (Photoperiodism) (d) Tobacco
16. Vernalisation stimulates flowering in
    (a) Zamikand (b) Turmeric
    (c) Carrot (d) Ginger
17. Short day plant is
    (a) Xanthium (b) Pisum
    (c) Cucumis (d) Avena
18. Biological clock in plants is controlled by
    (a) Phytochrome (b) Cryptochrome
    (c) Both (a) and (b) (d) Gibberellin
19. When flowering is regulated by the length of day and night, it is called
    (a) Photoperiodism (b) Phototropism
    (c) Nyctinasty (d) None of these

20. One set of a plant was grown at 12 hours a day and 12 hours night period cycles and it flowered while in the other set night phase was interrupted by a flash of light and it did not produce a flower. Under which one of the following categories will you place this plant
(a) Day-neutral (b) Short day
(c) Long day (d) Darkness neutral

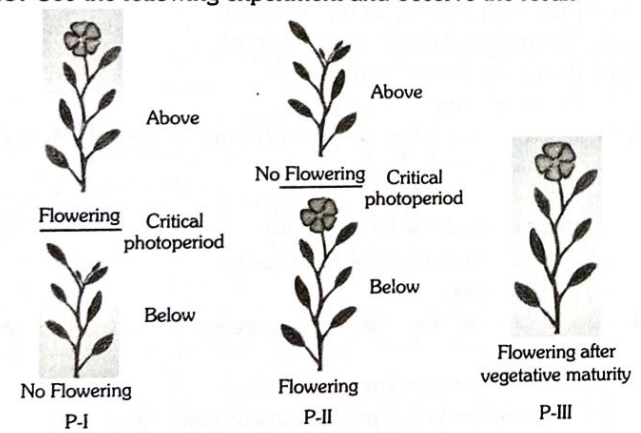
21. The low-temperature treatment that reduces the period between sowing and flowering is called
(a) Chemotaxis (b) Vernalization
(c) Freezing injury (d) None of the above

22. Phytochrome is used in
(a) Flowering only
(b) Seed germination only
(c) Transpiration only
(d) All physiological processes exhibited by the plants such as seed germination, flowering (photoperiodism), stem elongation and transpiration

23. Which of the following is a long day plant
(a) Mirabilis
(b) Glycine max
(c) Mirabilis Jalapa
(d) Spinacia oleracea (Spinach)

24. The phytochrome was discovered by
(a) Garner and Allard (b) W. Went
(c) F.F. Blackman (d) F.E. Fritsch

25. See the following experiment and observe the result



Now identify plants (P - I, II and III)
(a) P - I = Long day plant; P - II = Long day plant; P - III Day neutral plant
(b) P - I = Short day plant; P – II = Short day plant; P - III = Day neutral plant
(c) P - I = Short day plant; P - II = Long day plant; P - III Day neutral plant
(d) P - I = Long day plant; P - II = Short day plant; P - III = Day neutral plant

26. The photoperiod in plants is perceived at
(a) Meristem (b) Flower
(c) Floral buds (d) Leaves

27. Which wavelength of light is responsible for best flowering
(a) Red light (b) Blue light
(c) Green light (d) Daylight

9. NEET- AIMPMT/ CBSC-PMT

1. The viability of seeds is tested by **[2013]**
(a) 2, 6 dichlorophenol indophenols
(b) 2, 3, 5 triphenyl tetrazolium chloride
(c) DMSO
(d) Safranine

2. Plants having little or no secondary growth are **[2018]**
(a) Cycads (b) Conifers
(c) Deciduous angiosperms (d) Grasses

3. The pineapple which under natural conditions is difficult to blossom has been made to produce fruits throughout the year by application of **[2013]**
(a) NAA, 2, 4-D (b) Phenyl acetic acid
(c) Cytokinin (d) IAA, IBA

4. Which of the following prevents falling of fruits **[2001]**

Or

Fruit and leaf drop at early stages can be prevented by the application of **[2017]**
(a) GA_3 (b) *NAA*
(c) Ethylene (d) Zeatin

10. AIIMS

1. What is the cause of excurrent habit in *Pinus* **[1987]**
(a) Presence of gibberellin
(b) Presence of apical dominance
(c) High concentration of cytokinin
(d) High concentration of ABA

2. The hormone which was discovered through 'foolish seedling' disease of rice is **[1994]**
(a) Indole–3–acetic acid (b) Ethylene
(c) Gibberellic acid (d) Kinetin

3. Exogenous application of gibberellins induces male flower formation on genetically female plants in **[1986]**
(a) Carica (b) Cucumis
(c) Coccinia (d) Cucurbita

4. Which of the following causes delaying of senescence **[2001]**
(a) Cytokinins (b) Auxins
(c) Gibberellins (d) Ascorbic acid

5. Farmers in a particular region were concerned that premature yellowing of leaves of a pulse crop might cause a decrease in the yield. Which treatment could be most beneficial to obtain maximum seed yield **[2007]**
(a) Removal of all yellow leaves and spraying the remaining green leaves with 2,4,5-trichlorophenoxy acetic acid
(b) Application of iron and magnesium to promote synthesis of chlorophyll
(c) Frequent irrigation of the crop
(d) Treatment of the plants with cytokinins along with a small dose of nitrogenous fertilizer

6. Abscisic acid (ABA) is a stress-related hormone and it also **[2012]**
(a) Aids in fruit development
(b) Accelerates fruit ripening
(c) Stimulates mitosis
(d) Mediates stomatal closure

7. Pigment phytochrome is involved in **[1989]**
(a) Phototropism (b) Photorespiration
(c) Photoperiodism (d) Geotropism

8. The pigment involved in red–far red light interconversion is **[1987]**
(a) Cytochrome (b) Xanthophyll
(c) Lycopene (d) Phytochrome

9. Nicotiana sylvestris flowers only during long days and N. tobacum flowers only during short days. If raised in the laboratory under different photoperiods, they can be induced to flower at the same time and can be cross-fertilized to produce self–fertile offspring. What is the best reason for considering N. sylvestris and N.tobacum to be separate species **[2007]**
(a) They are physiologically distinct
(b) They are morphologically distinct
(c) They cannot interbreed in nature
(d) They are reproductively distinct

11. Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion

(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion

(c) If the assertion is true but the reason is false

(d) If both the assertion and reason are false

(e) If the assertion is false but reason is true

1. Assertion : "Touch" responses in *Mimosa* are an example of such movement.
Reason : Nastic movements occur in the direction of stimulus.

2. Assertion : Cytokinin are anti senescent.
Reason : Effects of cytokinins is antagonistic to ethylene.

3. Assertion : *Stratification* of seeds may promote their germination.
Reason : *Stratification* promotes gibberellin and cytokinins.

4. Assertion : Dark period play more important part in flowering than a light period.
Reason : Flowering occurs in the short-day plant if the dark period is interrupted by the light break.

5. Assertion : Gibberellins induce flowering in long day plants.
Reason : Genetically tall plant becomes dwarf by application of Gibberellin.

6. Assertion : Auxins promote apical dominance by suppressing the activity of lateral buds.
Reason : In agriculture, periodic pruning of shoot tips is done to make mulberry plants bushy.

7. Assertion : Photomodulation of flowering is a phytochrome-regulated process.
Reason : Active form of phytochrome (Pfr) directly induces floral induction in shoot buds.

8. Assertion : Ethylene cause climacteric ripening of fruits.
Reason : Climacteric fruits show a rise in respiration at the time of ripening.

9. Assertion : Phototropism is a directional growth movement.
Reason : Phototrophic movement occurs in the direction of light.

10. Assertion : Plant growth as a whole is indefinite.
Reason : Plants retain the capacity of continuous growth throughout their life.