GROWTH AND GROWTH HORMONES

8.1 Growth

Growth in plants, as in any organism, consists of an irreversible increase in size, which is commonly accompanied by increase in solid or dry weight and in the amount of protoplasm growth is essential character of life. In growth anabolic processes dominate over the catabolic processes and therefore growth is the final product of successful metabolism.

A correct definition of growth is difficult. In common parlance, the 'growth' may be applied to several things and situations. However, growth can be defined as a vital process which brings about permanent change in any plant or its part with respect to its size, form, weight and volume. Whole series of changes during life span of a plant or organism is termed as development. Growth is generally a quantitative matter and is concerned with increasing amount of organism. Development, on the other hand, is qualitative change referring to the changes in nature of growth made by the organism. Growth is measurable whereas the development is most commonly assessed by qualitative observation. During growth and development, there is formation of proteins and carbohydrates, thus increasing the protoplasm formation.

(1) **Regions of growth :** In unicellular plants there is overall growth and not confined to any specific region but in multicellular plants growth is restricted to specific regions having meristematic cells. On the basis of their position in the plant body (higher plants) meristematic cells. On the basis of their position in the plant body (higher plants) meristems are divided into three main categories.

(i) Apical meristems, (ii) Intercalary meristems, (iii) Lateral meristems

(i) **Apical meristems :** These meristems are found at shoot and root apex. As a result of activity of these meristems plant increases in length. In angiosperms and gymnosperms there is a group of meristematic cells but in bryophytes and pteridophytes there is a single tetrahedral cell found at the shoot apex.

(ii) **Intercalary meristems :** These meristems are found above the nodes. As a result of the activity of these meristems increase in length takes place. e.g., *Bambusa*.

(iii) **Lateral meristems. :** These meristems are made up of cells which divide in radial direction only. They form laterally placed new cells towards the centre and periphery. Cork cambium (phellogen) and vascular cambium are the examples of lateral meristems. Increase in girth of shoots and roots take place because of the activity of this cambium.

(2) **Phases of growth :** Growth is not a very simple process. Before completion of this process a meristematic cell has to pass through three phases.

(i) Cell division

(ii) Cell enlargement

(iii) Cell maturation (differentiation)

(i) **Cell division (Formative phase) :** A cell is metabolically highly active at the time of cell division. Its cellular mass increases and replication of genetic material (nucleic acids) takes place. Growth as a result of divisions is based on mitotic cell division. In the stage of mitosis each chromosome is split lengthwise into two homologous chromatids which pass equally into daughter cells. As a result of division each cell is only half the size of parent cell. These cells then proceed to enlarge.

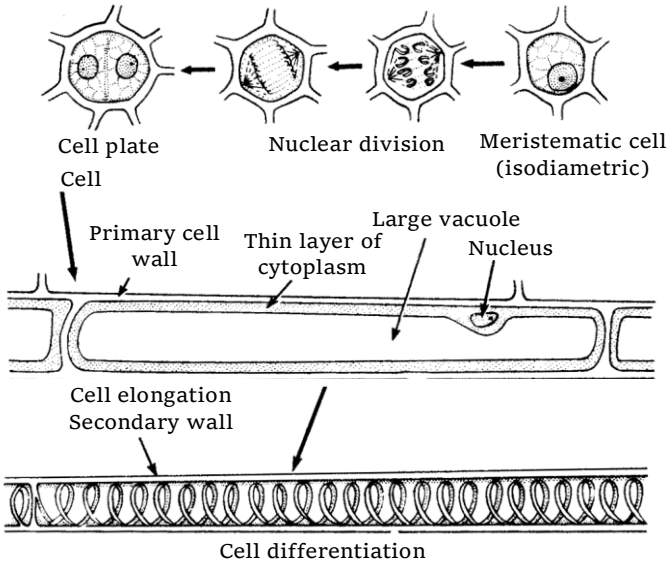


Fig : Showing cell formation, cell elongation and cell differentiation

(ii) **Cell enlargement :** Cell division is followed by cell enlargement. The cell increases in size due to vacuolation (by absorption of water). A big central vacuole appears which pushes the cytoplasm to be limited to a thin boundary layer against the cell wall. The new cell wall materials is synthesized to cope with the enlargement. The cell enlargement has been explained in two different ways. According to the first view, the tergour of the cell increases. As a result, certain gaps or lacunae appear in the cell wall. The new wall material is deposited in the lacunae between particles of the old wall (intus-ucception) or below the lacunae (apposition). The other view considers that as a result of growth of the cell wall the volume of the cell increases.

(iii) **Cell maturation (Differentiation) :** Cell differentiation following cell division and cell enlargement leads to the development of specialized mature tissue cell , e.g., some cells are differentiated into xylem tracheids and trachea and some others into sieve tubes and companion cells.

(3) **Growth curve :** The rate of growth varies in different species and different organs. In certain species of plants such as *Cacti*, the rate of growth is exceedingly slow. In many plants, the growth rate is phenomally rapid e.g., the young leaf sheath of banana grows for a time at the rate of almost three inches per hour. Growth begins slowly, then enters a period of rapid enlargement, following which it gradually decreases till no further enlargement occurs. The mathematical curve which represents this variation in growth rate is some what flattened S-shaped curve or sigmoid curve. Time in which growth takes place has been called grand period of growth. This term was coined by **Sachs**. The analysis of growth curve shows that it can be differentiated into three phases :

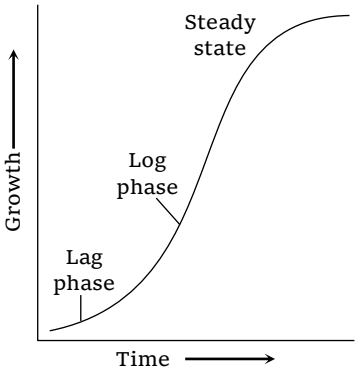


Fig : A typical S-shaped grand period of growth curve

(i) **Lag phase :** It represents initial stages of growth. The rate of growth is very slow in lag phase. More time is needed for little growth in this phase.

(ii) **Log phase** (**Exponential phase**) **:** The growth rate becomes maximum and more rapid**.** Physiological activites of cells are at their maximum. The log phase is also referred to as **grand period of growth**.

(iii) **Final steady state** (**Stationary phase**) **or Adult phase :** When the nutrients become limiting, growth slows down, so physiological activities of cells also slows down. This phase is indicated by the maturity of growth system. The rate of growth can be measured by an increase in size or area of an organ of plant like leaf, flower, fruit etc. The rate of growth is called efficiency index.

In many plants another phase is also evident in their growth curve. This is called linear phase or phase of maximum growth rate. Sachs called it as grand phase.

(4) **Measurement of growth :** Growth in plants can be measured in terms of (i) increase in length, e.g., stem, root (ii) increase in volume, e.g., fruit, (iii) increase in area, e.g., leaves (iv) increase in diameter, e.g., tree trunk. (v) increase in fresh or dry weight. The following methods are designed to measure growth in length.

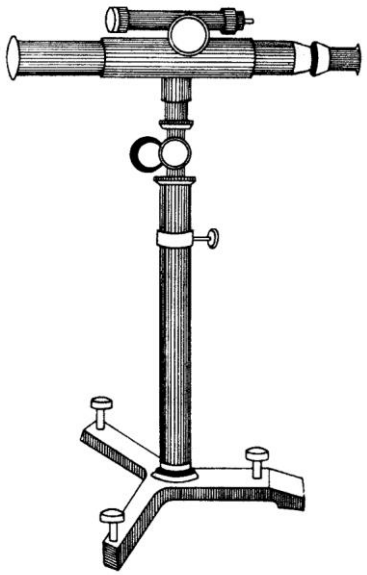


Fig : Horizontal microscope for measurement of growth

The following methods are designed to measure growth in length :

(i) **Direct method :** It is the simplest method of measuring growth and involves measurement of growth between two marked points directly by a scale at regular intervals. This is not much used as in this case, growth over short periods cannot be measured.

(ii) **Horizontal microscope** (**Travelling microscope**) **:** In this method, tip of a growing plant is marked with the help of Indian Ink and horizontal microscope is focussed at the point. After a day or two, marked point is obserbed by microscope. It is little bit raised. Distance between the two readings shows the actual growth of a plant. It can be used for measuring growth of plants in the field.

(iii) **Auxanometer :** Several kinds of auxanometers have been devised to measure the growth in length of a plant**.** Two of them are given below :

(a) **Arch auxanometer :** It conists of a vertical stand with a pulley. Attached to the pulley is a pointer which moves on an arc scale. A silken thread is passed over the pulley, one end of which is tied to the plant apex and the other carries a weight enough to keep the thread stretched. As growth occurs the pulley moves, causing the pointer to move on the scale. Growth can be calculated on the basis of the distance moved by the pointer on the arc and the length of the pointer as follows.

$$\text{Growth of plant in length} = \frac{\text{Distance travelled by pointer} \times \text{Radius of pulley}}{\text{Length of pointer meausred from the centre of the pulley}}$$

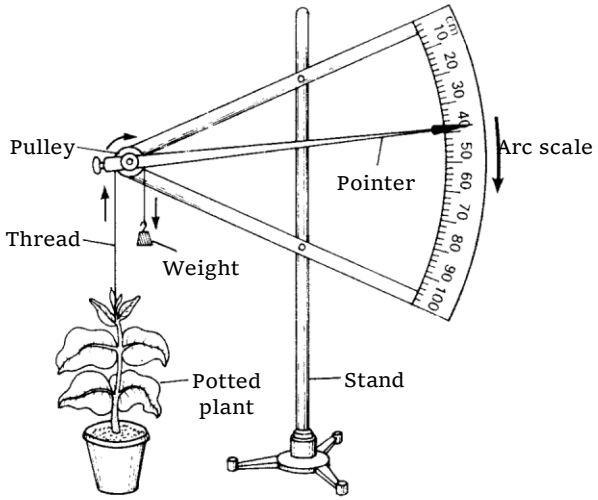


Fig : Arc auxanometer (arc indicator) for measurement of growth

(b) **Pfeffer's auxanometer (Automatic auxanometer) :** It is composed of two pulleys (large and small), revolving cylinder covered with a smoked paper, stand and 3 weights. The two pulleys magnify the growth.

$$\text{Magnification} = \frac{\text{Radius of larger pulley}}{\text{Radius of smaller pulley}}$$

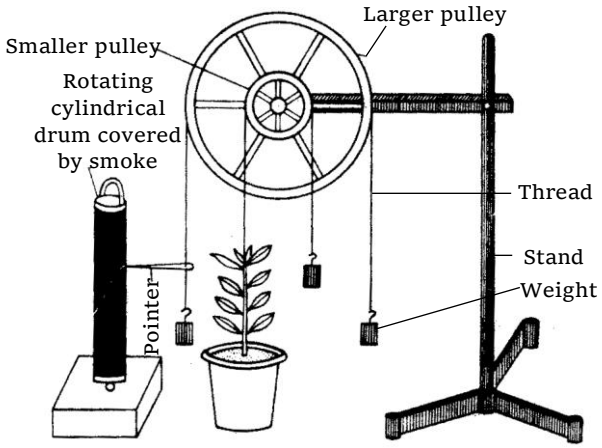


Fig : Pfeffer's

One end of thread is tied to the tip of stem and other end is tied to a small weight. The thread is passed over the smaller pulley. One more thread having small weight on its both sides passes over the larger pulley. One side of this thread bears pointer towards the revolving cylinder, which is in close contact with the smoked paper.

Revolving of cylinder takes place by the start of clock work. If growth occurs, two pulleys move by the downward movement of weight which is attached to the tip of stem. There is ring like and stair case like marking developed on the smoked paper. However, if no growth occurs, a horizontal line is formed on the smoked paper.

(iv) **Bose's crescograph :** The crescograph invented by **Sir Jagdish Chandra Bose** is a more delicate instrument and gives magnification upto 10,000 times. The rate of growth of root can be measured by the use of a **root auxanometer**.

(5) **Factors influencing rate of growth :** Growth is affected by the factor which affect the activity of protoplasm. It is affected by a large number of factors both environmental and physiological. Physiologogical factors such as absorption of water, minerals, photosynthesis, respiration etc, and

environmental factors including climatic and edaphic both. The effect on these factors on one region of plant are also transmitted to other region of the plant.

Since growth is a resultant of many metabolic processes, it is affected by many external and internal factors, which are as follows,

(i) **External factors**

(a) **Light :** Light affects variously e.g., light intensity, quality and periodicity.

- **Intensity of light :** In general, light retards growth in plants. High light intensities induce dwarfing of the plant. Plants at hill tops are short whereas those of a valley are quite tall. Very weak light induces the rate of overall growth and also photosynthesis. Development of chlorophyll is dependent on light and in its absence etiolin compounds in formed which gives yellow colour to the plant. The phenomenon is called etiolation. Similarly high light intensity affecting indirectly increases the rate of water lose and reduces the rate of water growth.

- **Quality of light :** The different colours (different wavelengths) affect the growth of plant. In blue-violet colour light internodal growth is pronounced while green colour light reduces the expansion of leaves as compared to complete spectrum of visible light. The red colour light favours elongation but they resemble etiolated plants. Infrared and ultraviolet are detrimental to growth. However, ultraviolet rays are necessary for the development of anthocyanin pigments in the flowers. Blue and violet colours increase size of lamina of leaf.

- **Duration of light :** There is remarkable effect on durtion of light on the growth of vegetative as well as reproductive structures. The induction and suppresion of flowering are dependent on duration. The phenomenon is termed photoperiodism.

(b) **Temperature :** Temperature has pronounced effect on the growth of plant. The temperature cardinals for growth vary according to temperature zones. The minimum, optimum and maximum temperatures are usually 5^oC (arctic), $20 - 30^oC$ (temperate) and $35 - 40^oC$ (tropical). The optimum temperature needed for the growth of a plant is much dependent on the stages of development. Low temperatures during nights reduces the rate of respiration and high temperature during days increases photosynthesis accumulated photosynthate also increases growth the tomato plants do not grow well under uniform temperatures condition of day and night but they grow well under low night temperature (nyctotemperature) and flucuating day temperature (phototemperature). This response of plant to temperature variation is called **thermoperiodicity**. When plants are exposed to extremes of temperature they get injured and the injuries are called descication, chilling and freezing.

Due to hot or cold spells of wind, when the transpiration exceeds absorption, the plant tissue gets injured and the injury is called **desiccation**. If a plant of hot climate is exposed to low temperature it gets injured and the injury is called **chilling**. During winter, in hill plants water is withdrawn from the cell into the intercellular space. As a result, the dehydrated protoplasm coagulates. There is inter and intracellular ice formation due to further lowering of temperature and as a result the plant tissue is injured. This injury is called **freezing**. A plant develops high osmotic concentration of the cell sap and a thick bark to withstand these injuries. Besides, it also shows formation of seeds, spores, tubers etc. when the temperature goes down.

(c) **Water :** As water is an essential constituent of the living cell, a deficiency of water causes stunted growth. Moreover unless the cells are in a turgid condition, they cannot divide and unless new cells are added up by the activity of the meristems, growth cannot take place. water is also essential for photosynthesis not only as a raw material, but also for the photosynthetic activity of the cells. Water is also essential for the translocation of mineral salts and ready-made food to the growing regions of the plants. Without food supply growth cannot take place.

(d) **Oxygen :** In poorly aerated soil there is low concentration of oxygen and a high concentration of CO_2. Under such conditions plants usually show stunted growth. Normal growth of most plants occurs only when abundant oxygen is present since O_2 is important for respiration. It has been reported that oxygen plays some important role during GI stage of cell division.

(e) **Mineral salt :** Absence of essential mineral salts results in abnormal growth. For example, the absence of nitrogen prevents protein-synthesis, while the absence of iron prevents chlorophyll formation and thus leads to pale and sickly growth of plants, known as **chlorotic condition.**

(f) **Pollutants :** Several pollutants such as automobile exhaust, peroxyacetyl nitrate (PAN), pesticites etc have detrimental effect on plant growth. Some plants are very sensitive to certain pollutants. Citrus and Gladiolus are very sensitive to fluorides. Poor growth of tobacco is observed in regions where ozone concentration is high. White pine cannot survive under high O_3 concentration. Cotton plants are, similarly very sensitive to ethylene.

(g) **Carbon dioxide :** CO_2 is essential for photosynthesis and hence nutrition. Due to change in photosynthetic rate, with the increase or decrease in CO_2 concentration, the plant growth is also affected.

(ii) **Internal factors :** Amongst internal factor i.e., age, health, hereditory factors, growth regulator, nutritional relations, etc. growth regulators are very important. Some of the internal factors are :

(a) **Nutrition :** It provides raw material for growth and differentiation as well as source of energy. C/N (carbohydrate/protein) ratio determines the type of growth. High C/N ratio stimulates wall thickening. Less protoplasm is formed. Low C/N ratio favours more protoplasm producing thin walled soft cells. According to law of mass growth, the initial rate of growth depends upon the size of germinating structure (seed, tubes, rhizome, bulb, etc.)

(b) **Growth regulators** : These are manufactured by living protoplasm and are important internal growth regulators which are essential for growth and development. These growth regulators include several phytohormones and some synthetic substances.

8.2 Growth hormones and Growth regulators

The term hormone used by first **Starling** (1906). He called it stimulatory substance. The growth and development in plants is controlled by a special class of chemical substances called hormones. These chemicals are synthesized in one part of the plant body and translocated to another where they act in a specific manner. They regulate growth, differentiation and development by promoting or

inhibiting the same. They are needed in small quantities at very low concentrations as compared to enzyme. They are rarely effective at the site of their synthesis.

Thus, growth hormones also called **phytohormones** term given by Thimann (1948), it can be defined as 'the organic substances which are synthesized in minute quantities in one part of the plant body and transported to another part where they influence specific physiological processes'. Sometimes the term growth regulators is misled with phytohormones. The term phytohormones as the definition indicates, is implied to those chemical substances which are synthesized by plants and thus, they are naturally occurring. On the other hand, there are several manufactured chemicals which often resemble the hormones in physiological action and even molecular structure. Thus the synthetic substances which resemble with hormones in their physiological action are termed as growth regulators.

Phytohormones can have a promoting or inhibiting effect on a process. A particular hormone may promote certain processes, inhibit some others and not effect many others. In general, developmental processes are controlled by more than one growth regulator. They may act synergistically *i.e.*, in a cooperative and beneficial manner (e.g., morphogenesis by auxins and cytokinins) or antagonistically *i.e.*, in opposite manner (e.g., seed germination is promoted by gibberallin and is inhibited by abscisic acid). A group of plant hormones including auxins, gibberellins, cytokinins, ethylene and abscisic acid are presently known to regulate growth.

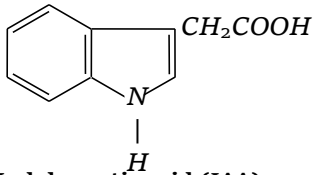
(1) **Auxins :** Auxins (Gk. *auxein* = to grow) are weakly acidic growth hormones having an unsaturated ring structure and capable of promoting cell elongation, especially of shoots (more pronounced in decapitated shoots and shoot segments) at a concentration of less than 100 *ppm* which is inhibitory to the roots. Among the growth regulators, auxins were the first to be discovered.

(i) **Discovery :** Julius Von Sachs was the first to indicate the presence of organ forming substances in plants. The existence of first plant growth hormone came from the work of Darwin and Darwin (1881). Darwin described the effects of light and gravity in his book, "Power of movements in plants". Darwin and his son found that bending movement of coleoptile of Canary grass (*Phalasis canariensis*) was due to exposure of tip to unilateral light. Boysen-Jensen (1910; 1913) found that the tip produces a chemical which was later named auxin. Paal (1914, 1919) removed coleoptile tip and replaced it asymmetrically to find a curvature. Auxin was first collected by Went (1928) from coleoptile tip of *Avena* . Went also developed *Avena* curvature test for bioassay of auxin. Kogl and Haagen. Smit (1931) introduced the term auxin.

(ii) **Types of auxins :** There are two major categories of auxins natural auxins and synthetic auxins.

(a) **Natural auxins :** These are naturally occurring auxins in plants and therefore, regarded as **phytohormones**. Indole 3-acetic acid (IAA) is the best known and universal auxin. It is found in all plants and fungi.

The first naturally occuring auxin was isolated by Kogl and Haagen-Smit (1913) from human urine. It was identified as auxin-a (auxentriolic acid, $C_{18}H_{32}O_5$). Later, in 1934 Kogl, Haagen-Smit and Erxleben obtained another, auxin, called auxin-b (auxenolonic acid, $C_{18}H_{30}O_4$) from corn germ oil (extracted from germinating corn seeds), and



Indole acetic acid (IAA)

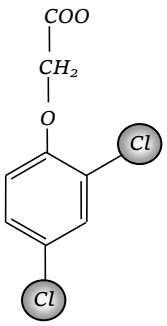
heteroauxin from human urine. Heteroauxin ($C_{10}H_9O_2N$) also known as indole-3-acetic acid (IAA), is the best known natural auxin, Besides IAA, indole-3-acetaldehyde, indole-3-pyruvic acid, indole ethanol, 4-chloro-idole actic acid (4-chloro-IAA) etc., are some other natural auxins.

Natural auxins are synthesized (Young) in physiologically active parts of plants such as shoot apices, leaf primordia and developing seeds, buds (apex), embryos, from amino acid tryptophan. In root apices, they are synthesized in relatively very small amount. Auxins show **polar** movement. It is basipetal (from apex to base) in stem but acropetal (from root tip towards shoot) in the root. Auxins move slowly by diffusion from cell to cell and not through the vascular tissues. Auxins help in the elongation of both roots and shoots. However, the optimum concentration for the two is quite different.

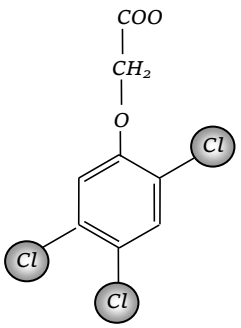
It is 10 *ppm* for stem and 0.0001 *ppm* for the root. Its translocation rate is 1–1.6 *cm/hr*. (In roots 0.1 to 0.2 *cm/hr*). Higher concentration of auxins show inhibitory effect on growth.

Natural auxins are of two types : free and bond auxins. The auxins which can easily be extracted are called **free auxins**, whereas auxins which are hard to extract and need the use of organic solvents are termed as **bound auxins**. The free form of auxin is active, while the bound auxin is inactive in growth. A dynamic equilibrium exists between these two forms.

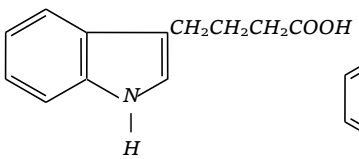
(b) **Synthetic auxins :** These are synthetic compounds which cause various physiological responses common to IAA. Some of the important synthetic auxins are 2, 4-D (2, 4-dichlorophenoxy acetic acid) is the weedicide, 2, 4, 5-T (2, 4, 5-trichlorophenoxy acetic acid), IBA (indole 3-butyric acid), NAA (naphthalene acetic acid, PAA (Phenyl acetic acid), IPA (Indole 3-propionic acid). IBA is both natural and synthetic auxin. Certain compounds inhibit action of auxin and compete with auxins for active sites are called antiauxins. *e.g.*, PCIB (p- chlorophenoxy isobutyric acid), TIBA (2, 3, 5-tri iodobenzoic acid). TIBA is used in picking cotton bolls.



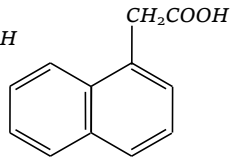
2, 4-dichlorophenoxy-acetic acid (2, 4-D)



2, 4, 5-trichlorophenoxy-acetic acid (2, 4, 5-T)



Indole Butyric acid



Naphthalene acetic acid

(iii) **Bioassay of Auxins :** Testing of biological activity (growth) of a substance (auxin) by employing living material is called bioassay. Auxin bioassay is also quantitative test as it measures amount of effect in response to a particular concentration of auxin.

(a) **Avena coleoptile curvature test :** *Avena* curvature test carried out by F.W. Went (1928), demonstrated the effect of auxins on plant growth by performing some experiments with the oat (*Avena sativa*) coleoptile.

- When the tips of the coleoptiles were removed, no growth took place.
- When the freshly cut coleoptiles were placed on agar blocks for a few hours (during this period auxin diffused into the agar block) and then the agar blocks were placed on the cut ends of the coleoptile, growth occurred.
- When the agar block with the diffused substance was placed laterally on the cut tip of the coleoptile, only that side of the coleoptile elongated resulting in a curvature.

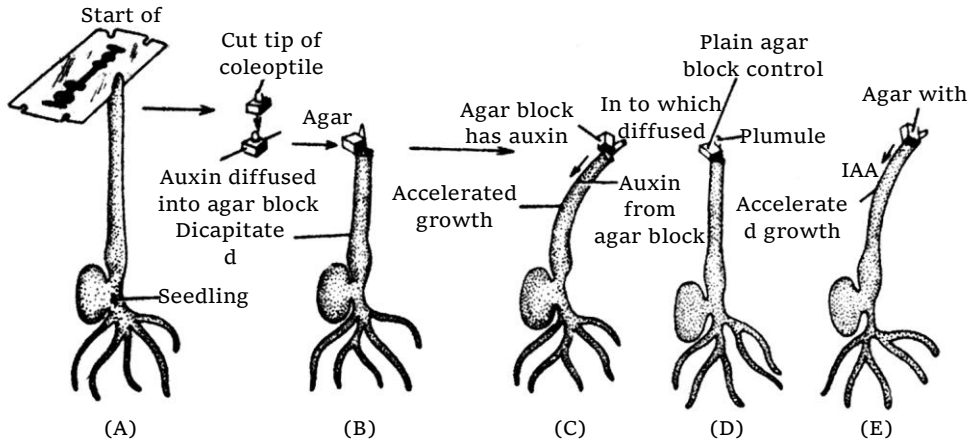


Fig : Oat coleoptile experiment

(b) **Split pea stem curvature test :** This test was also discovered by Went, 1934. Dark germinated seeds of pea are decapitated. About half an inch part of stem between 2nd and 3rd node is removed and split longitudinally. It is then floated on the test solution contained in a beaker. At first, negative curvature occurs due to water uptake. Then positive curvature occurs which is proportional to the log of the concentration of auxin.

These experiments indicated that some substance is synthesised in the coleoptile tip is translocated downward. He called this substance auxin.

(c) **Root growth inhibition test (Cress root inhibition test) :** Sterilized seeds of cress are germinated over moist filter paper. Root lengths are measured. 50% of seedlings are placed in test solution while the rest are allowed to grow over the moist filter paper. Lengths of roots are measured after 48 hours. Seedlings placed in test solution show very little root growth while the roots of controlled seedlings show normal growth. The degree of root growth inhibition is proportional to auxin concentration.

(iv) **Functions of auxins :** Auxins control several kinds of plant growth processes. These are as follows :

(a) **Cell elongation :** Auxins promote elongations and growth of stems and roots and enlargement of many fruits by stimulating elongation of cells in all directions.

The auxins cause cell enlargement by solubilisation of carbohydrates, loosening of microfibrils, synthesis of more wall materials, increased membrane permeability and respiration.

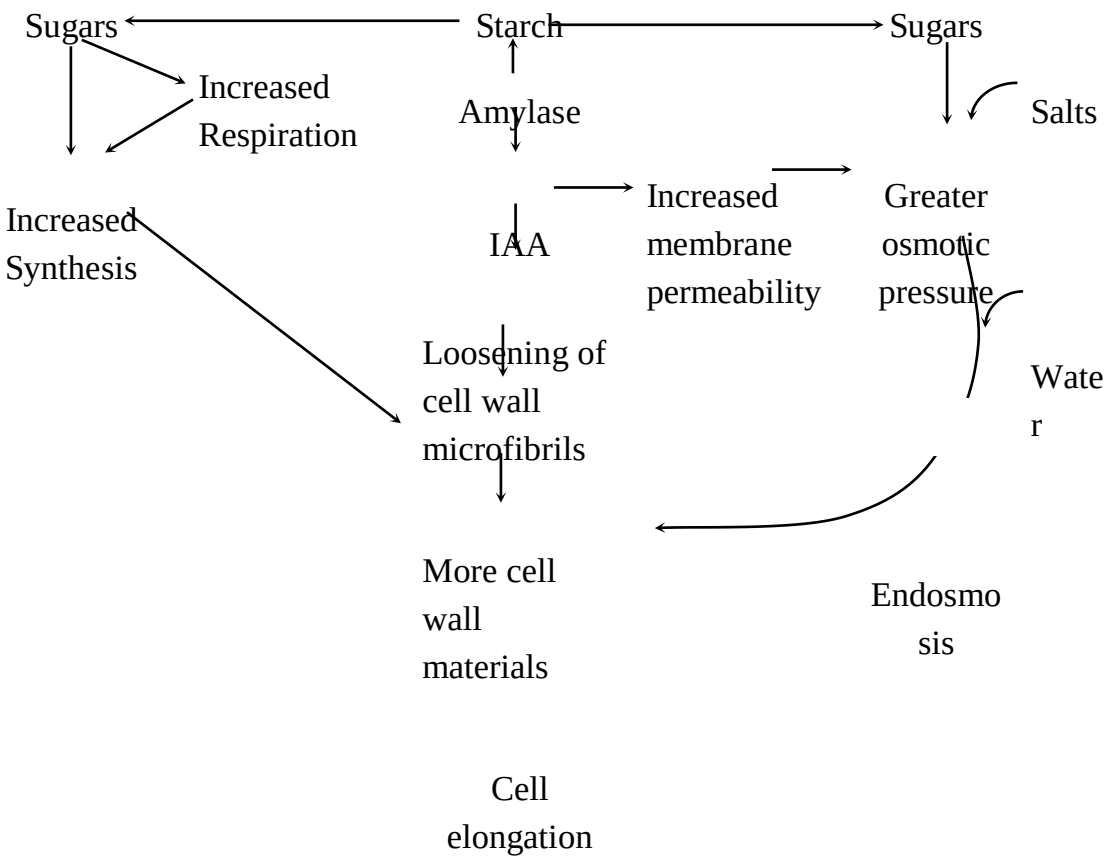


Fig. Action of IAA in cell elongation.

(b) **Apical dominance :** In many plants, the apical bud grows and the lower axillary buds are suppressed. Removal of apical bud results in the growth of lower buds. The auxin (IAA) of the terminal bud inhibits the growth of lateral buds. This phenomenon is known as apical dominance.

This property of auxins has found use in agriculture. Sprouting of lateral buds (eyes) of the potato tuber is checked by applying synthetic auxin (NAA).

(c) **Control of abscission layer :** Auxin inhibits abscission of leaves and fruits. Abscission layer is produced when the auxin content falls below a minimum**.** Addicot and Lynch (1951) put forward **auxin gradient theory** about abscission :

- No abscission if auxin content is high on the organ side.
- Abscission layer begins formation when auxin content becomes same on stem and organ sides.
- Abscission is favoured when auxin content is low on the organ side.

Premature drop of fruits such as apple, pear and citrus can be prevented to a great extent by spraying the trees with a dilute solution of IAA, NAA or some other auxin.

(d) **Weed control :** Weeds are undesirable in a field with a crop. Weeds cause competition for water, mineral, light and space. This causes poor yield. By the spray of 2, 4-D, broad-leaved weeds can be destroyed but 2, 4-D does not affect mature monocotyledonous plants.

(e) **Root differentiation :** Many new plants are usually propogated by stem cutting e.g., Rose, *Bougainvillea*. If we dip the lower cut end of a cutting in dilute solution of auxins (specially IBA gives very good results) very soon large number of roots are developed on the cut ends due to which these cuttings develop into successful plants.

(f) **Parthenocarpy :** It is the process of formation of fruits without fertilization. Such fruits are called as parthenocarpic fruits and are without seeds. Parthenocarpy can be induced by application of IAA in a paste form to the stigma of a flower or by spraying the flowers with a dilute solution of IAA. Banana, oranges and grapes are now-a-days grown parthenocarpically on commercial scale.

(g) **Control of lodging :** In some plants when the crop is ripe and there is heavy rain accompanied by strong winds, the plants bends as a result of which the ear (inflorescence) gets submerged in water and decays. If a dilute solution of any auxin is sprayed upon young plants the possibility of bending of plants is reduced as the stem becomes stronger by the application of auxins.

(h) **Flowering :** In pineapple, NAA promotes flowering. In lettuce, auxins help in delaying the flowering. In cotton plants, the use of auxins increases the cotton seeds production.

(i) **Differentiation of vascular tissues :** Auxins induce the differentiation of xylem and phloem in intact plants and also in callus produced *in vitro* during tissue culture experiments.

(j) **Sex expression :** The spray of auxins increases the number of female flowers in cucurbits. In maize application of NAA during the period of inflorescence differentiation can induce formation of hermaphrodite or female flowers in a male inflorescence.

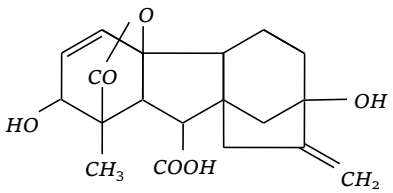
Thus auxins cause femaleness in plants.

(k) **Healing :** Healing of injury is effected through auxin induced division in the cells around the injured area. The chemical was formerly named traumatic acid or traumatin.

(l) **Nodule formation :** In legumes, IAA is known to stimulate nodule formation.

(m) **Respiration :** According to French and Beevers (1953) the auxin may increase the rate of respiration indirectly through increased supply of ADP by rapidly utilizing the ATP in the expanding cells.

(2) **Gibberellins :** Gibberellins are weakly acidic hormones having gibbane ring structure which cause cell elongation of intact plants in general and increased internodal length of genetically dwarfed plants (i.e., corn, pea) in particular.



Gibberellic acid

(i) **Discovery :** Gibberellins were first isolated from the fungus *Gibberella fujikuroi* (*Fusarium moniliforme*) the causal organism of Bakanae disease or **foolish seedling** disease of rice plants in Japan by **Kurosawa** in 1926. The characteristic symptoms of this disease are abnormal growth of stem and leaves, thin plants with long internodes, early flowering or death before flowering and fruiting.

In 1939, Yabuta and Sumiki and coworkers working in Tokyo isolated an active substance from the fungus and called it Gibberellin A. This gibberellin preparation was probably a mixture of several gibberellins. The first gibberellin to be obtained was Gibberellin A-3. Cross *et al.* (1961) explained the detailed structure of gibberellic acid. Now 60 gibberellins have been identified from different groups of plants (algae, fungi, mosses, ferns, gymnosperms and angiosperms).

Many of them occur naturally in plants. *Gibberella Fujikuroi* has as many as 15 gibberellins. A single plant also possesses a number of gibberellins. All the different types of gibberellins, known so far, have gibbane skeleton and are acidic in nature. Therefore, these are termed as GA_1 $(C_{19}H_{24}O_6)$, GA_2 $(C_{19}H_{26}O_6)$, $GA_3(C_{19}H_{22}O_6)$, GA_4 $(C_{19}H_{24}O_5)$ and so on. Of these gibberellic acid or gibberellin $A_3(GA_3)$ is the commonest. Gibberellins are synthesised in plants in leaves of buds, developing embryos, root tips, young apical leaves, shoot tips and seeds. Gibberellins are transported readily in the plant, apparently moving passively in the stream either in xylem or phloem. Their transport in non-polar. Anti-gibberellins like malic hydrazide, phosphon D, Alar and chorocholine cheoride (CCC) or cycocel are also called antiretardants (stimulates flowering and inhibits the growth of nodes). Commercial production of GA is still carried out by culturing this fungus in large vats.

(ii) **Mechanism of action :** Gibberellins are closely related with steroids. Gibberellins exhibit ecdysome like effects. Ecdysome is a moulting hormone. The steroids have very specific effect in depressing genes and thus activating specific genes. Another significant gibberellin treatment is production of enzymes like amylase and protease. It is also considered that the effect of gibberellin is indirect.

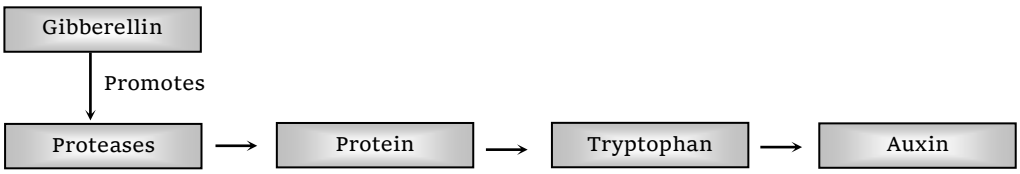


Fig. Role of gibberellin in synthesis of auxin.

According to this view gibberellins show its physiological effects by altering the auxin status of the tissue.

(iii) **Bioassay of gibberellin :** Gibberellin bioassay is performed through dwarf maize/pea test and cereal endosperm test.

(a) **Dwarf pea bioassay :** Seeds of dwarf pea are allowed to germinate till the just emergence of plumule. GA solution is applied to some seedlings others are kept as control. After 5 days, epicotyl length is measured. Increase in length of epicotyl over control seedlings is proportional to GA concentration.

(b) **Barley endosperm bioassay :** Endosperms are detached from embryos, sterilized and allow to remain in 1*ml* of test solution for 1-2 days. There is build up of reducing sugars which is proportional to GA concentrations. Reducing sugars do not occur in edoperms kept as control.

(iv) **Functions of gibberellin**

(a) **Stem elongation :** The gibberellins induce elongation of the internodes. The cell growth is promoted by the increase in the hydrolysis of polysaccharides. It also increases the elasticity of cell wall. The elongation of stem results due to rapid cell division and cell elongation induced by gibberellins.

(b) **Leaf expansion :** In many plants leaves become broader and elongated when treated with gibberellic acid. This leads to increase in photosynthetic area which finally increases the height of the plant. Interestingly, gibberellins show no effect on roots.

(c) **Reversal of dwarfism :** One of the most striking effects of gibberellins is the elongation of genetic dwarf (mutant) varieties of plants like corn and pea. It is believed that dwarfism in the mutant variety of plant is due to blocking of the capacity for normal gibberellin production (deficiency of gibberellin). When gibberellin is applied to single gene dwarf mutants e.g., *Pisum sativam, Vicia faba* and *Phaseolus multiflorus*, they grow to their nomal heights. It is further interesting to note that application of gibberellins to normal plants fail to show any remarkable effects.

(d) **Bolting and Flowering :** Gibberellins induce stem elongation in 'rosette plants' e.g., cabbage, henbane, etc. Such plants show retarded internodal growth and profuse leaf development. In these plants just prior to the reproductive phase, the internodes elongate enormously causing a marked increase in stem height. This is called bolting.

Bolting needs long days or cold nights. It has been further noticed that if cabbage head is kept under warm nights, it remains vegetative. The exogenous application of gibberellins induced bolting in first year itself in plants like cabbage (normally bolting occurs next year due to effect of endogenous gibberellins).

(e) **Enzyme formation :** One of the most dramatic effects of GA is its induction of hydrolytic enzymes in the aleurone layer of endosperm of germinating barley seeds and cereal grains. GA stimulates the production of digestive enzymes like proteases, α-amylases, lipases which help to mobilise stored nutrients. GA treatment stimulates a substantial synthesis of new mRNA. Thus GA acts to uncover or depress specific genes, which then cause the synthesis of these enzymes. It is assumed that GA acts on the DNA of the nucleus.

(f) **Breaking of dormancy :** Gibberellins overcome the natural dormancy of buds, tubers, seeds, etc. and allow then to grow. In this function gibberellins act antagonistically to abscisic acid (ABA).

(g) **Parthenocarpy :** Gibberellins have been considered to be more effective than auxins for inducing parthenocarpy in fruits like apple, tomato and pear. GA application has also resulted in the production of large fruits and bunch length in seedless grapes.

(h) **Sex expression :** Gibberellins control sex expression in certain plants. In general, gibberellin promote the formation of male flowers either in place of female flowers in monoecious plants such as cucurbits or in genetically female plants like *Cannabis, Cucumis*.

(i) **Substitution for vernalization :** Vernalization is the low temperature requirement of certain plant (i.e., biennials) to induce flowering. The low temperature requirement of biennials for flowering can be replaced by gibberellins.

(j) **Malt yield :** There is increased malt production when gibberellins are provided to germinating barley grains (due to greater production of α-amylase).

(k) **Delayed ripening :** Ripening of citrus fruits can be delayed with the help of gibberellins. It is useful in safe and prolonged storage of fruits.

(l) **Seed germination :** Gibberellins induce germination of positively photo-blastic seeds of lettuce and tobacco in complete darkness.

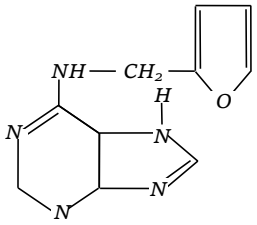
(3) **Cytokinins (Phytokinins) :** Cytokinins are plant growth hormones which are basic in nature, either aminopurine or phenyl urea derivatives that promote cell division (cytokinesis) either alone or in conjugation with auxin.

(i) **Discovery :** The first cytokinin was discovered by Miller, Skoog and Strong (1955) during callus tissue culture of *Nicotiana tobaccum* (tobacco).

It was synthetic product formed by autoclaving Herring sperm (fish sperm) DNA. This synthetic product was identified as 6-furfuryl amino-purine and named as **kinetin**. He found that normal cell division induced by adding yeast extract.

Various terms such as kinetenoid (Burstran, 1961), phytokinin (Dendolph *et al.* 1963) phytocytomine (Pilet 1965) have been used for kinetin like substances but the term cytokinin proposed by Letham (1963) has been widely accepted. Letham *et al.* (1964) discovered first natural, cytokinin in unripe maize grain (*Zea mays*). It was named as **zeatin** (6 hydroxy 3 methyl trans 2-butenyl amino purine).

About 18 cytokinins have been discovered, e.g., dihydrozeatin, IPA (Isopentenyl adenine), benzyl adenine. The most widely occurring cytokinin in plant is IPA. It has been isolated from *Pseudomonas tumefaciens*. Many are found as constituents of tRNAs. Cytokinins are synthesized in roots as well as endosperm of seeds. Coconut millk and Apple fruit extract are rich in cytokinins. Cytokinins in coconut milk called coconut milk factor.



Kinetin (6-furfuryl

Kinetin (6 furfuryl amino purine) is a derivative of the nitrogen base adenine. Plant physiologists use the term cytokinins to designate group of substances that stimulate cell division in plants. Cytokinins are prdouced in actively growing tissues such as embryos, developing fruits and roots. Kinetin is the derivative of purine base adenine, which bears furfuryl group at 9 position which migrated to 6 position of the adenine ring during autoclaving of DNA. According to **Fox** (1969) cytokinins are substances composed of one hydrophilic group of high specificity (adenine) and one lipophilic group without specificity.

Cytokinin is transported to different parts of the plant through xylem elements. According to Osborne and Black (1964), the movement of cytokinin is polar and basipetal.

(ii) **Mechanism of action :** Most known cytokinins have an adenine nucleus with purine ring intact with N^6 substituents of moderate size. Cytokinins never act alone. In conjugation with auxins, they stimulate cell division even in permanent cells. It was noticed by Skoog and Miller that callus cultures grew slowly on basal medium, but growth could be promoted by adding hormones like IAA and cytokinins. No response occurred with auxin or cytokinin alone. When both the hormones are present in equal amount, cells divide rapidly but fail to differentiate. However, when quantity of cytokinins is more than auxins, shoot bud appears from callus. With more concentration of auxins, roots develop fast. The similarity in structure of most cytokinins to adenine, a constituent of DNA and RNA suggests that basic effect of cytokinin might be at the level of protein synthesis.

(iii) **Bioassay of cytokinins :** Bioassay is done through retention of chlorophyll by leaf discs, gains of weight of a tissue in culture, excised radish cotyledon expansion, etc.,

(a) **Tobacco pith culture :** Tobacco pith culture is divided into two weighted lots one supplied with cytokinin and the other without it. After 3-5 weeks, increase of fresh weight of treated tissue over control is noted. It is a measure of stimulation of cell division and hence cytokinin activity.

(b) **Retardation of leaf senescence :** Leaves are cut into equal sized discs with the help of a cutter. They are devided into two lots. One lot is provided with cytokinin. After 48-72 hours, leaf discs are compared for chlorophyll contents. Cytokinin retards chlorophyll degradation.

(c) **Excised radish cotyledon expansion :** Excised radish cotyledons are measured and placed in test solution as well as ordinary water (as control). Enlargement of cotyledons indicates cytokinin activity.

(d) **Root inhibition test :** Kiraly and his coworkers (1966) used root inhibition test for cytokinin bioassay. They found, that amount of root inhibition of actively growing seedlings is related to cytokinin activity.

(iv) **Functions of cytokinins**

(a) **Cell division :** Cytokinins are essential for cytokinesis and thus promote cell division. In presence of auxin, cytokinins stimulate cell division even in non-meristematic tissues. In tissue cultures, cell division of callus (undifferentiated mass of parenchyma tissue) is enhanced when both auxin and cytokinin are present. But no response occurs with auxin or cytokinin alone.

(b) **Cell enlargement and Differentiation :** Under some conditions cytokinins enhance the expansion of leaf cells in leaf discs and cotyledons. These cells considered to be mature and under normal conditions do not expand. Cytokinins play a vital role in morphogenesis and differentiation in plants. It is now known that kinetin-auxin interaction control the morphogenetic differentiation of shoot and root meristems.

(c) **Delay in senescence :** Cytokinin delay the senescence (ageing) of leaves and other organs by controlling protein synthesis and mobilization of resources (Disappearance of chlorophyll). It is called Richmond Lang effect. It was reported by Richmond and Lang (1957) while working on detached leaves of *Xanthium*.

(d) **Counteraction of apical dominance :** Auxins and cytokinins act antagonistically in the control of apical dominance. Auxins are responsible for stimulating growth of apical bud. On the other hand, cytokinins promote the growth of lateral buds. Thus exogenous application of cytokinin has been found to counteract the usual dominance of apical buds.

(e) **Breaking of dormancy :** Cytokinins breaks seeds dormancy of various types and thus help in their germination. They also induce germination of positively photoplastic seed like lettuce and tobacco even in darkness.

(f) **Accumulation and Translocation of solutes :** Cytokinins induce accumulation of salts inside the cells. They also help solute translocation in phloem.

(g) **Sex expression :** Cytokinins promote formation of female flowers in some plants.

(h) **Enzyme activity :** Cytokinins stimulate the activity of enzymes especially those concerned with photosynthesis.

(i) **Parthenocarpy :** Development of parthenocarpic fruits through cytokinin treatment has been reported by Crane (1965).

(j) **Pomalin :** A combination of cytokinin (6-benzladenine) and gibberellin (GA_4, GA_7) called pomalin is particularly effective in increasing apple size.

(k) **Initiation of interfasicular cambium :** Cytokinins induce the formation of interfasicular cambium in plants e.g., *Pinus radiata*.

(l) **Nucleic acid metabolism :** Guttman (1957) found a quick increase in the amount of RNA in the nuclei of onion root after kinetin treatment.

(m) **Protein synthesis :** Osborne (1962) demonstrated the increased rate of protein synthesis on kinetin treatment.

(n) **Flowering :** Gibberellins also play an important role in the initiation of flowering. Lang (1960) demonstrated that added gibberellin could substitute for the proper environmental conditions in *Hyoscyamus niger* which requires long day treatment for flowering. Such effects of gibberellin are common among vernalised and long day plants.

Gibberellin is also known to play essential role in germination of cereal seeds.

(4) **Ethylene :** Ethylene is a gaseous hormone which stimulates transverse growth but retards the longitudinal one.

(i) **Discovery :** The effect of ethylene had been known since long. Kerosene lamps and hay have been used to fruit merchants to hasten colour development (ripening) in fruits. These effects are due to ethylene. **Neljubow** (1901) observed that ethylene gas alters the tropic responses of roots. **Denny** (1924) reported that ethylene induces ripening of fruits. **Crocker** *et al.* (1935) identified ethylene as natural plant hormone.

Ethylene is produced in plants from the amino acid methionine. It is synthesized in almost all plant parts-roots, leaves, flowers, fruits, seeds. It is more synthesized in nodal regions. Maximum synthesis of ethylene occurs during climacteric ripening of fruits. High concentration of auxin induce ethylene formation. When a fruit ripens its respiration rate gradually decreases but it is reversed by a sharp increase called climactric. Some of the inhibitory effects earlier attributed to auxin are known to be caused by ethylene.

The commercial product for providing ethylene is ethaphon (2-chloroethyl phosphoric acid). Ethaphon is a liquid from which ethylene gas is released, hence this substance is used for artificial ripening of fruits.

(ii) **Bioassay of ethylene :** It is done on the principle of triple response which includes three characteristic effects of ehtylene on etiolated seedlings of pea-viz.

- Swelling of nodes,
- Inhibition of elongation of internodes of stem,
- Induction of horizontal growth of stem against gravity.

(a) **Triple pea test :** Pratt and Biale (1944) developed this method for bioassay of ethylene which base on the physiological effect of ethylene to cause

- Subapical thickening of stem,

• Reduction in the rate of elongation and

• Horizontal nutation (transverse geotropism) of stem in etiolated pea seedlings. In presence of ethylene, epicotyls show increase growth in thickness and reduced rate of longitudinal and horizontal growth.

(b) **Pea stem swelling test :** Cherry (1973) used pea seedlings to measure ethylene concentration by marked increase of stem swelling expressed as a ratio of weight to length. In one *ppm* of ethylene the ratio is about 4.0.

(iii) **Functions of ethylene**

(a) **Fruit growth and Ripening :** Ethylene promotes fruit growth and its ripening. The harmone is used in the artificial ripening of climacteric fruits (e.g., Apple, Banana, Mango).

(b) **Transverse growth :** Ethylene inhibits longitudinal growth but stimulates transverse growth so that stem looks swollen.

(c) **Epinasty (leaf bending) :** Epinasty represents more growth on upper surface of leaf than on lower surface. Epinasty is said to be controlled by ethylene in many plants.

(d) **Abscission :** Ethylene stimulates formation of abscission zone in leaves, flowers and fruits.

(e) **Apical dominance :** Ethylene inhibits the growth of lateral buds and thus cause apical dominance (in pea). It is believed that auxin might be functioning partly through synthesis of ethylene in causing apical dominance.

(f) **Root initiation :** In low concentration, ethylene stimulates root initiation and growth of lateral roots and root hair.

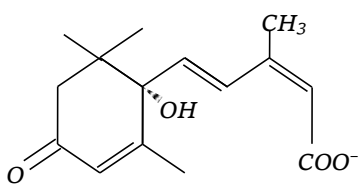
(g) **Flowering :** Ethylene stimulates flowering in pineapple and related plants though in other cases, the hormone causes fading of flowers. Fading flowers of *Vanda* are known to release ethylene. Sleep disease (inrolling of petals in blossomed flowers) in due to ethylene.

(h) **Sex expression :** Ethylene application increases the number of female flowers and fruits in cucumber plants.

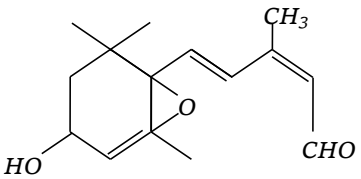
(i) **Dormancy :** It breaks dormancy of different plant organs but not of lateral buds.

(5) **Abscisic acid (ABA) :** Abscisic acid is a mildly acidic growth hormone, which functions as a general growth inhibitor by counteracting other hormones (auxin, gibberellins, cytokinins) or reactions mediated by them.

(i) **Discovery :** The hormone was first isolated by Addicott *et al*. (1963) from cotton balls. They named it as abscisin II. Simultaneously, Wareing and Cornforth isolated a substance that can induce bud dormancy. They named the substance as **dormin**. Later, both these substances were found to be the same and were named as **abscisic acid**. It is produced in many parts of the plants but more abundantly inside the chloroplasts of green cells. The synthesis of abscisic acid is stimulated by drought, water logging and other adverse environmental conditions. Therefore, it is also called stress hormone. The hormone is formed from mevalonic acid or xanthophylls. Chemically it is dextro-rotatory cis sesquiterpene. The hormone is transported to all parts of the plant through diffusion as well as through conductive channels.



Abscisic acid (ABA)



Xanthoxine

In some plant tissues (especially in young shoots) occurs a related compound called **xanthoxine**.

Whether xanthoxine is an intermediate of the ABA-biosynthesis or whether it is an independent product remains unknown. The structure indicates that both ABA and xanthoxine are terpene derivatives. This was proven when it could be shown that radioactively labelled mevalonic acid is integrated into ABA though it does not elucidate which intermediates are produced. Two alternative biosyntheses have been discussed :

(a) ABA is a degradation product of xanthophyll (especially of violaxanthin).

(b) ABA is produced from a C_{15} precursor using a separate pathway and is thus independent from the carotenoid/xanthophyll metabolism.

The first idea seemed initially more plausible since the structures of xanthophylls and ABA correspond to a large degree. *In vitro* occurs conversion only upon exposure to strong light and with an extremely low yield, though.

(ii) **Bioassay of abscisic acid**

(a) **Rice seedling growth inhibition test :** Mohanty, Anjaneyulu and Sridhar (1979) used rice growth inhibition method to measure ABA like activity. The length of second leaf sheath after six days of growth is measured.

(b) **Inhibition of α-amylase synthesis in barley endosperm test :** ABA inhibits the synthesis of α-amylase in the aleurone layers which is triggered by gibberellins. Goldschmidt and Monselise (1968) developed the bioassay method to estimate ABA activity by determining the extent of inhibition of α-amylase synthesis induced by treating barley seed endosperm with GA.

(iii) **Functions of abscisic acid**

(a) **Control :** It keeps growth under check by counter acting the effect of growth promoting hormones, i.e., auxins, cytokinins and gibberellins. As growth is primarily controlled by gibberellins, abscisic acid is popularly called antigibberellic hormone. It will inhibit seed germination, growth of excised embryos, growth of Duckweed and other plants.

(b) **Dormancy :** Abscisic acid acts as growth inhibitor and induces dormancy of buds towards the approach of winter. Dormancy of seeds is mainly caused by abscisic acid. Because of its action in inducing dormancy abscisic acid (ABA) is also called dormin. The buds as well as seeds sprout only when abscisic acid is overcome by gibberellins.

(c) **Abscission :** ABA promotes the abscission of leaves, flowers and fruits in plants.

(d) **Senescence :** Abscisic acid stimulates senescence of leaves by causing destruction of chlorophyll (an effect opposite to that of cytokinins) and inhibition of protein and RNA synthesis. The effect, however, can be reversed by application of cytokinins in *Lemna*.

(e) **Antitranspirant :** Abscisic acid can be used as 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.

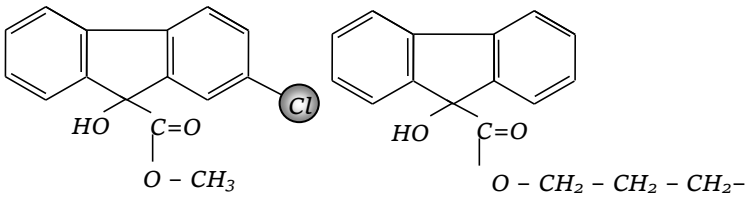
(f) **Hardiness :** Abscisic acid promotes cold hardiness and inhibits growth of pathogens.

(g) **Flowering :** ABA delays flowering in long day plants. However, in some short day plants (e.g., strawberry, black current) it promotes flowering.

(h) **Rooting :** Abscisic acid can be used to promote rooting in many stem cuttings.

(6) **Wound hormone or Traumatic acid or Necrohormone : Haberlandt** (1913) reported that injured plants cells release a chemical substance (wound hormone), which stimulate the adjacent cells to divide rapidly in order to heal up the wound. **English** *et al*. (1939) finally isolated and crystallized this wound hormone and named it as Traumatic acid. Although traumatic acid has been found to be very active in inducing meristematic activity in uninjured green bean pods, but it is not effective in most of the plant tissues including tobacco pith tissues.

(7) **Morphactins :** Morphactins are synthetic growth regulators which act in variety of ways on the natural regulation mechanisms of plants. The important ones are phenoxyalkancarboxylic acid (synthetic auxin), substituted benzoic acids, Malic acid hydrazide, Fluorene-9 carboxylic acids and their derivatives, Chlorflurenol, Chloroflurun, Flurenol, Methylbenzilate, Dichlorflurenol, etc. Morphactins have fundamental action on morphogenesis of plants and this characteristic designation (morphactins) is derived from morphologically active substances.



Morphactins IT 3456 and IT 3233

The actions of these substances are systematic and after their uptake they are transported and distributed not polarly (as seen by IAA) but basi- and acropetally. Generally these are growth inhibitors. These contain 'fluorene ring' in their structure.

(i) **Functions**

(a) **Seed germination :** In general, morphactins inhibit germination seeds particularly the emergence of the radicle from the seed shell. This property can be counteracted with GA_3 and almost completely by cytokinins. The germination of fern spores is also delayed by morephactins.

(b) **Growth seedling :** Morphactins inhibit the growth of seedling affecting the shoot and often also root. With this property they show a similarity with cytokinin. The inhibitory effect of seedling shoot growth can be partly counteracted with GA_3 but not the inhibition of root growth.

(c) **Stem elongation :** They have inhibitory effect on the stem elongation. Increased concentration produces dwarfing in the plants. The inhibitory effect of morphactins is not only observed in stem elongation but also on the new growing shoot organs.

(d) **Polarity of cell division :** Denffer and others (1969) observed in the dividing cells of the root tips of *Allium* that treatment of morphactin (CFI) results in random orientation of the mitotic spindle and plane of cell division, i.e., they exercise depolarisation during cell division.

(e) **Histogenesis and Morphogenesis :** Morphactins induce anomalies espicially in new-formed organs in case of *Begonia*. Formation of cornets (fusion of leaf with stem) and ochria (fusion of calyx with other floral parts). The single flowers and the number and differentiation of floral organs were reduced.

(f) **Apical dominance and branching :** Morphactins treatment with grasses and cereals increased tillering and also increased number of lateral buds and stimulated extension growth of lateral shoots.

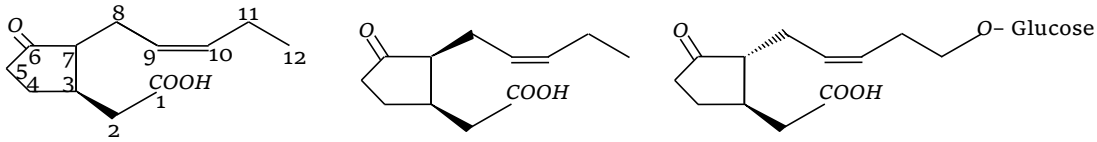
(g) **Prolonged bud dormany :** The emergence of buds from the storage organs of various perennial species is delayed when plants are treated with morphactins as reported in *Solanum tuberosum* and *Malus sylvestris*.

(h) **Root growth and Root branching :** Lateral buds are inhibited or retarde and primary roots are promoted at low concentration but inhibited at higher concentration of morphactins. In general, the action of morphactins on the longitudinal growth of the roots system may be considered as the reverse of their action on the shoot system.

(i) **Realisation of flowering :** Morphactins have also been found effective on flowering stimulation, sequence of flowering, position and number of flowers, formation of flowers, inflorescence and parthenocarpy, etc.

(j) **Depot effect :** First morphactine are accumulated in plants and after sometime show their effect.

(8) **Jasmonic acid (Jasmonates) :** According to Parthier (1991), jasmonic acid and its methyl esters are ubiquitous in plants. They have hormone properties, help regulating plant growth, development and they seem to participate in leaf senescence and in the defense mechanism against fungi.



Jasmonic acid

Just like all other plant hormones jasmonates have both activating and inhibiting effects. Synergistic and antagonistic effects on other hormones have also been observed. Jasmonate derivatives induces the accumulation of proteins so-called jasmonate-induced-proteins that were found in all plant species tested. Their accumulation can also be caused by desiccation or ABA effects. Jasmonate-induced-proteins are of varying molecular weights, and molecules of different size classes have immunologically been shown to be related. The major portion of these proteins is not glycosylated, has no proteolytic activity and is metabolically stable. Labelling with immunogold and electron microscopy showed that some of them are located within the nucleus, while others were detected in the vacuole. None have ever been found in mitochondria. Their synthesis can be inhibited by cycloheximid, but not by chloramphenicol. Chloramphenicol affects mitochondrial proteins. Jasmonate-induced-proteins are lacking in roots, in bleached leaves and in leaves of chlorophyll-deficient *Hordeum vulgare* mutants. They exist in etiolated leaves, though. Jasmonates do not only regulate the transcription of these proteins, they do also influence the rate of translation of different groups of mRNA. They do, for example, decrease the production rate of several essential housekeeping proteins.

Just like ABA jasmonates inhibit a premature germination of the oil-containing seeds of *Brassica* and *Linum*. After germination they induce the synthesis of the seed storage proteins Napin and Cruciferin as well as that of several more elaiosome-associated proteins.

(9) **Calines (Formative hormones) :** Certain other natural growth hormones in plants called as calines or formative hormone which are throught to be essential for the effect of auxin an root, stem and leaf growth they are :

(i) **Rhizocaline or Root forming hormone :** It is produced by the leaves and translocated in a polar manner down the stem.

(ii) **Caulocaline or Stem forming hormone :** It is produced by the roots and is transported upward in the stem.

(iii) **Phyllocaline or Self forming hormone :** It is produced probably by the cotyledons. It stimulates mesophyll development in the leaves and is synthesized only in the presence of light.

None of these caline has yet been isolated.

(10) **Vitamins**

- The term vitamin has been derived from vital amine. They are heterogenous group of organic compounds which are needed in very small quantities (as accessory food factors) for different metabolic processes.
- They are essential for normal growth and development and maintenance of health as well as vigour.
- Vitamins are synthesised by plants and microbes, though they are required by all types of organisms.
- Most of the vitamins functions as coenzymes and prosthetic groups of various enzymes connected with protein, fat and carbohydrate metabolism.
- Vitamin K is component of electron transport chains. Some vitamins are essential in maintaining cell membranes and acting as antioxidants. Therefore, vitamins are important growth regulators.
- Vitamins are of two types : Fat soluble- it includes vitamins A, D, E and K, water soluble – vitamin B complex and vitamin C.

Important Tips

- The double sigmoid growth curve occurs in some fruits e.g., Grapes, plum.
- Measurement of growth in young root by making it at 1mm intervals with Indian Ink was first done by Strasburger.
- Inflexion point is the point at which growth begins to decline (beginning of decelerating phase) after the exponential increase.
- 20000 tons of Avena tips give 1g of IAA.
- The development of shoot and root is determined by cytokinin and auxin ratio.
- IBA is the most potent root initiator.
- Mixture of 2, 4-D and 2, 4, 5-T (dioxin) is given the name 'Agent orange' which was used by USA in Vietnam war for defoliation of forests (i.e., in chemical warfare).
- At 260λ, it is dextrorotatory, whereas at 280λ, it is leavorotatory and this phenomenon is known as cotton effect.

- In glass houses when plants are kept on artificial light and temperature, then this method is called phytotron and is applicable in agriculture, horticulture and tissue culture.
- When each meristem influences other meristems then this phenomenon is called growth correction.
- Dinitrophenol when comes in contact with any plant which destroy them. Such herbicide is called contact herbicide.
- Ethylene like special chemicals are called sterenes and a natural pollutant.
- ABA is used in dryfarming.
- Malic hydrazide is a growth retardant which checks cell division. So during seed storage this is applied for checking sprouting of potato tubers so that the importance of potato may be lowered down.
- In lower plants or thalophyta diffused growth is present.
- When AMO 1618 sprayed on aerial parts of the plants, it inhibits the growth. It is used during wave for destroying plants.
- Dalapon (2-2 dichloropropionic acid) is a herbicide.
- Auxin and Cytokinin in combined form shows synergistic effect (affects development of physical structure).
- Growing zone present 1 cm at root tip, 2-5 cm at shoot tip.

8.3 Physiology of flowering

Flower is a modified shoot specialized to carry out sexual reproduction of the plant. Flower initiation takes place by the transformation of vegetative apex into reproductive structure. Hence, it signifies a transition from vegetative to reproductive phase. The pattern and timing of flower initiation varies from species to species. A flower must attain a stage of ripening before it flowers. The period of maturity after which plant can produce flowers if exposed to inductive conditions is called **ripeness of flower**. The external conditions necessary for the initiation of flowers in a plant are called **inductive conditions**. The duration for which inductive conditions are required for inducing the flowers in a plant is called the inductive period. The external conditions under which plant continues to grow vegetatively for unlimited period are called **non-inductive conditions**. Daily and season fluctuations in a particular location. Daily and season fluctuations in a particular location are directly related with latitude. At equator, day length is of 12 hours throughout the year, temperature also remains constant at equator. Long warm days of summer are distinct from short cold days of winter. Such variations in environment can be observed as one moves away from equator. Flowering in a plant occurs at a particular time of the year and controlled by many morphological and environmental conditions. Two important controlling factors are photoperiod or light period, i.e. photoperiodism, low temperature i.e. vernalization

(1) **Photoperiodism (Light period):** The effects of photoperiods or daily duration of light periods (and dark periods) on the growth and development of plants, especially flowering is called photoperiodism. The role of photoperiodism in the control of flowering was demonstrated for the first time by W.W Garner and H.A.Allard (1920). They observed that Maryland Mammoth variety of tobacco could be made to flower in summer by reducing the light hours with artificial darkning. It could be made to remain vegetative in winter by providing extra light. Later, it was found that most plants would flower only if they were exposed to light for less or more than a certain period, the critical photoperiod, each day. Subsequently, it was observed that in light dark cycle, dark period is crucial in initiating flowring and not the light period as thought earlier. On the basis of length of photoperiod requirements of plants, the plants have been classified into following categories.

(i) **Short day plants (SDP):** These plants initiate flowering when the day length (Photoperiod) become shorter than a certain critical period. The critical day length differs with different species. The short day plants remain vegetative, if the day length exceeds the critical periods. Most of winter flowering plants belong to this category e.g. cocklebur (*Xanthium*), *Chrysanthemum*, sugarcane, tobacco (Mutant Maryland Mammoth), soyabean, strawberry etc.,

(ii) **Long day plants (LDP):** These plants begin flowering when the day length exceeds a critical length. This length too differs from species to species. The long day plants fail to flower, if the day length is shorter than the critical period. Some common examples of long day plants are spinach (*Spinacea oleracea*), henbane (*Hyoscymus niger*), radish, sugar-beet, wheat, lattuce, poppy, larkspur, maize etc.

(iii) **Day neutral plants:** These plants can flower in all possible photoperiods. The day neutral plants can blossom thorughout the year. Some common examples of this category of plants are cucumber, cotton, sunflower, tomato, some varieties of pea, etc

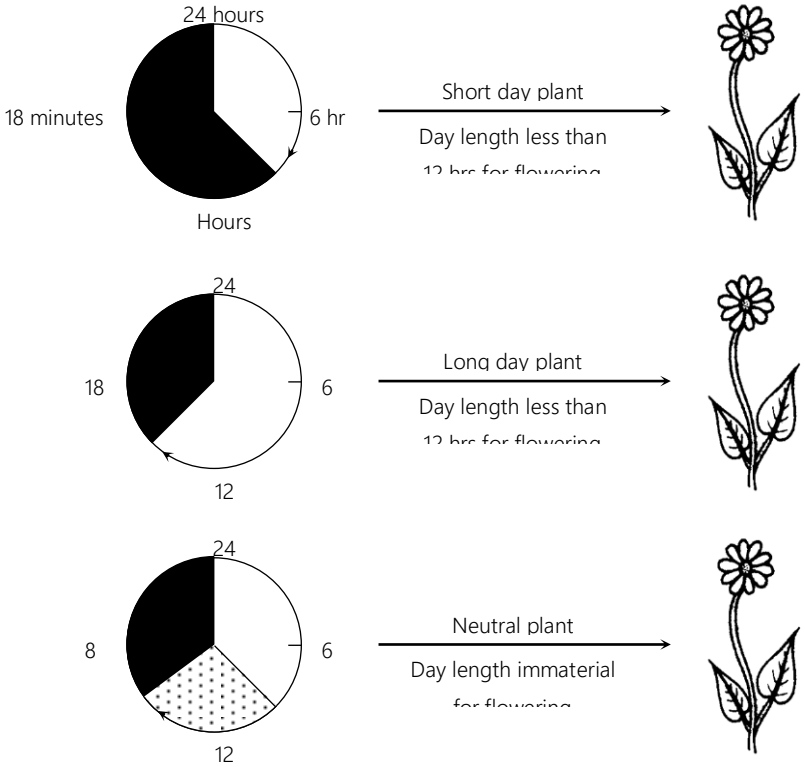


Fig : The day-length requirements for flowering in three catagories of plants

(iv) **Intermediate plants :** These plants flower only under day lengths within a certain range usually between 12-16 hours of light but fail to flower under either longer or shorter photoperiods. Examples of intermediate plants are *Mikania scandens, Eupatorium hyssopi folium* and *Phaseolous polystacous.*

(a) **Ampiphotoperiodic plants:** Such plants ramain vegetative on intermediate day length and flower only on shorter or longer day lengths. Example of such plant is *Media elegans.*

(b) **Short long day plants:** These plants require short photoperiods for initiation of flowering and long photoperiods for blossoming. Examples of these plants are some varieties of *Triticum vulgare, Secale cereale*.

(c) **Long short day plants:** These plants require long photoperiods for initiation of flowering and short photoperiods for blossoming some common examples of these plants are *Bryophyllum, Cestrum*.

Critical period: Critical photoperiod is that continuous duration of light, which must not be exceeded in short day plants and should always be exceeded in long day plant in order to bring them to flower. There is no relation with the total day length. Thus, the real distinction between a SDP and LDP is whether flowering is induced by photoperiods shorter or longer than the critical period. The critical day length for *Xanthium* (a short day plant) is 15. 6 hours and that for *Hyoscymus niger* (a long day plant) is about 11 hours, yet the former is SDP as it flowers in photoperiods shorter than its critical value, whereas the latter is LDP requiring photoperiods longer than its critical value. Both *Xanthium* and *Hyoscymus niger* flower with 14 hours of light per day. Thus, day length in which a plant flowers is no indication of its response class in the absence of further information.

(2) **Skotoperiodism (Dark period):** When photoperiodism was discovered, the duration of the light period was thought to be critical for flowering. Subsequently, it was found that when the long night period was interrupted by a brief exposure to light, the short day plants, failed to flower. Thus, for flowering, these plants require a long night or critical dark period rather than a short day length. Similarly, long day plants respond to nights shorter than the critical dark period. Curiously, they do not need an uninterrupted dark period, Therefore, a short day plant is also called **long night plant** and a long day plant as a **short night plant**.

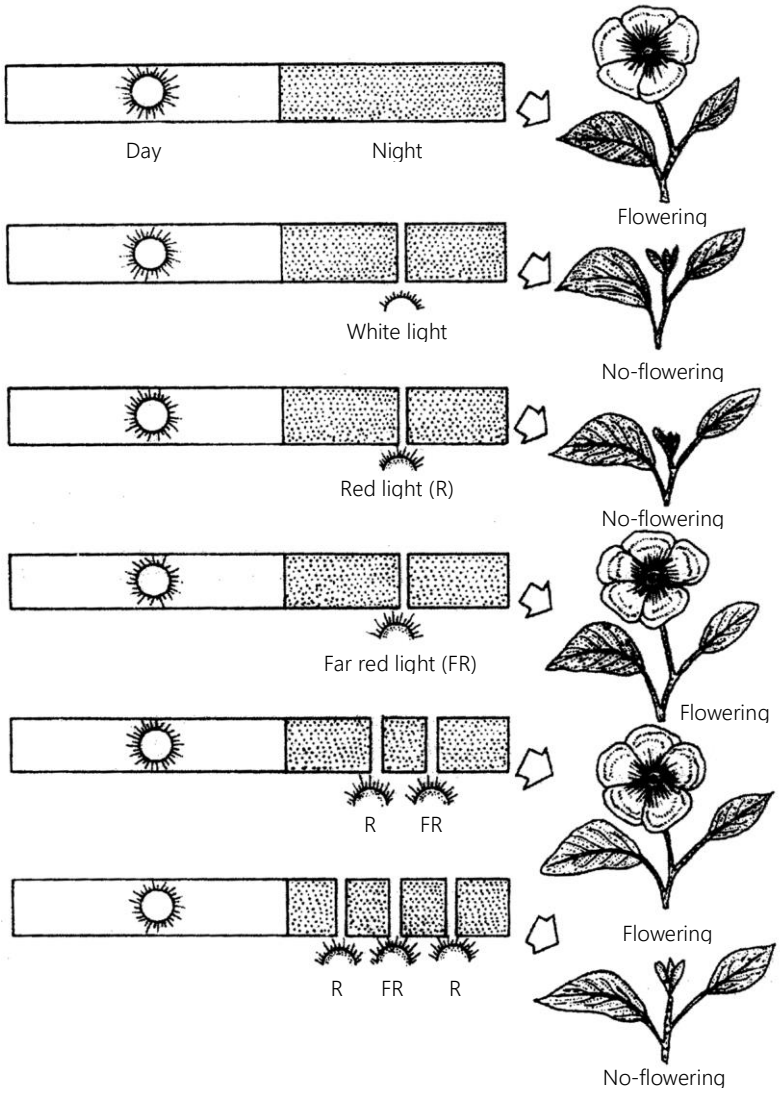


Fig : Effect of night (Dark) interruption on flowering in a short-day plant

In the night interruption experiments, when the short day plants were exposed to a flash of light before achieving a critical dark period, flowering was prevented. It is called **light break reaction**. If this was followed by exposure to far-red light (740 *nm*), the effect was reversed. Red, far red exposures given in succession showed that plant response is determined by the last exposure. Thus, photoperiodic response (flowering) is a phytochrome mediated process. The phytochorme shows reversible change is red (660*nm*) and far-red (730*nm*) wavelength.

On absorbing red light P*r* is converted into P*fr*. The *Pfr* becomes P*r* either rapidly by absorbing far-red light or slowly in darkness. Thus, darkness or far-red light promotes P*r* formation and stimulates flowering in short day plants, on the contrary, sunlight or red light promotes P*fr* formation and stimulate flowering in long day plants.

(3) **Mechanism of photoperiodism**

(i) **photoperiodic perception:** Experiments have demonstrated that photoperiodic stimulus is perceived by the fully developed leaves. Very young or first few leaves are commonly insensitive. In *Xanthium* (a short day plant) single leaf or even one eight part of a leaf was sufficient for this purpose. Further, a single leaf exposed to short days was able to induce flowering, when it was grafted on to a plant kept under non- inductive conditions.

(ii) **Photoperiodic induction:** Conditions under which the effect of suitable cycle of light and dark periods can persist in a plant and leads to flowering is called photoperiodic induction. It generally occurs when the plant has achieved certain minimum vegetative growth.e.g. 8 leaves in *Xanthium strumarium*. Minimum vegetative growth provides the plant with ripeness to flower. Some plants are however, exception to it and can be photo induced even in their cotyledonary stage.e.g. *Chenopodium rubrum*. The minimum number of appropriate photoperiods (inductive cycle) required for induction varies from species to species e.g. one for *Xanthium*.

(iii) **Photoreceptor:** The chemical which perceives the photoperiodic stimulus in leaves is phytochrome. The wavelengths of light are absorbed by the leaves. This becomes evident by the fact that defoliated (leaves removed) plant does not flower. Presence of even a single leaf is sufficient to receive required amount of photoperiod. Partially mature leaves are more senstitive to light while very young or mature leaves are much less sensitive to photoperiodic induction.

Garner and Allard's early worked led to the discovery, isolation and much of the characterization of the pigment responsible for absorbing light involved in photoperiodic phenomenon of plants. Borthwick, Hendricks and their colleagues later termed this pigment phytochrome. Pigment was isolated by Butter *et al*. (1959). This pigment controls several light dependent developmental processes in plants besides flowering, phytochrome exist in two interconvertible forms. The red (660*nm*), absorbing form *Pr* and the far red (740 *nm*), absorbing form P*fr* . P*r* is converted to P*fr* on absorbing far red light. P*fr* is converted to P*r* rapidly absorbing far red light or slowly in darkness. The slow conversion to red absorbing form is under thermal control. During the day when white light available, P*fr* accumulates in the plant. This form of phytochrome is inhibitory to flowering in short day plants and stimulatory to flowering in long day plants. In evening, P*fr* undergoes thermal and spontaneous

decay to change into P*r*. This pigment is stimulatory to flowering in short day plants and inhibitory to flowering in long day plants.

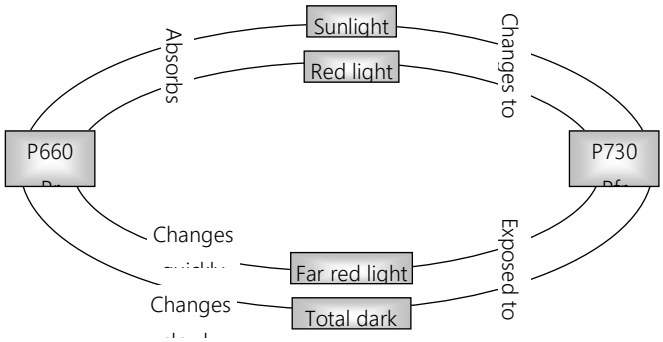


Fig : The phytocrome concept

Therefore, in SOP interruption of dark periods with a flash of red light converts *Pr* into *Pfr* and flowering is inhibited.

(a) **Structure/Chemistry of phytochrome:** The clarification of he chemical structure of phytochorme was due to isolation efforts and purification of phytochrome from several plant sources by Borthwick, Hendricks and their colleagues. Phytochrome was initially isolated from cotyledons of etiolated turnip seedlings. Siegelman and Firer were responsible for a highly purified extract that led to further purifications and analysis of the phytochorme structure.

Phytochrome is a chromoprotein with a chromophore (Pigment coloured protein) prosthetic group (e.g. chromoprotein). The chromophore group is a linear tetrapyrrole that differs in the conformation and absorption spectrum of its *Pr* state clearly from its *Pfr* state. A similar group with comparable conformational changes occurs in the bilirubins of red algae, though they bear an ethyl group instead of the vinyl group at their D-ring. Further there is probably one chromatophore for each phytochrome molecule. The chromatophore is linked to the protein at ring III. Apparently the photo-conversions of the *Pr* and *Pfr* forms involve electronic changes in ring I, with either addition or loss of a proton. Conformational (structural) changes in the protein probably contribute to dark conversion and possibly decay.

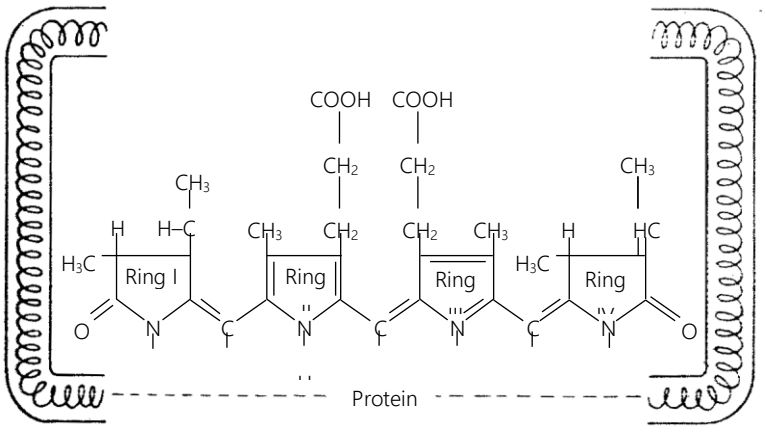


Fig : Structure of chromophore of phytochrome and its relation with protein element

The protein is a dimer of two identical subunits with molecular weights ranging from 120000 to 127000 in different plant species. It is an allosteric protein.

(b) **Importance of phytochrome :** Phytochrome is located in plasma membrane. Phytochorme far red *Pfr* form is considered to be biologically active form and is responsible to initiate a number of physiological process such as.

- Elongation of stem and leaves.
- Plastids morphology and differentiation of stomata.
- Seed germination.
- Photoperiodism and transpiration.

(iv) **The florigen complex (Flowering hormone):** When the proper amount of light is perceived by leaves, they produce a chemical (flowering hormone), which undergoes stabilisation in dark. Later on, this chemical passes to shoot apex and causes its differentiation into flowering shoot.

The various experiments discussed in the foregoing section provide strong evidence for the production of flowering hormone in plants under suitable photoperiods. **Chailakhyan** (1936) a Russian investigator on photoperiodism, proposed that it be called **'florigen'**. According to him (1958) the "Florigen complex" the true flowering hormone includes two groups of substances formed in leaves :

(a) **Gibberellins :** Which are necessary for formation and growth of stem.

(b) **Anthesins :** Substances which are necessary for flower formation.

Acting together Gibberellins and Anthesin produce the effect as ascribed to florigen.

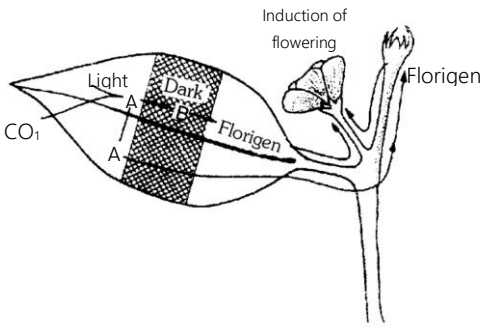


Fig : Photoperiodic induction and formation of florigen which is translocated to growing point for

The flowering stimulus moves readily not only through the plant but also from plant across the graft union between a flowering plant and a non-flowering or vegetative plant. Lang performed grafting experiments and demonstrated that every type of grafting is possible e.g., intervarietal, interspecific and intergeneric.

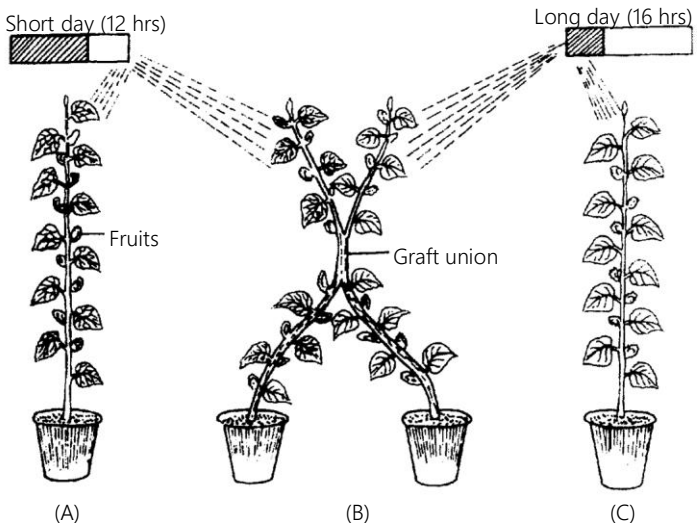


Fig : Demonstration through grafting showing that flower inducing stimulus is a chemical

(v) **Photomorphogenesis:** When plants are grown in continuous darkness they become etiolated i.e. such plants are longer, weaker, having yellowish half opened leaves, while light grown plants do not show such conditions. When etiolated plants are kept in light they gradually develop green colour and become normal. The effect of light in reversing etiolation involves two kinds of action; one the biochemical level for the synthesis of the chorophyll and secondly at the level of morphogenesis light acts to promote expansion of the leaves and inhibits elongation of the internodes. This phenomenon is called photomorphogenesis and is independent of the direction of light.

The action spectrum of photomorphogenesis reveals that plants are most sensitive to red light, but blue light is ineffective.

(4) **Vernalization:** Many plants, especially biennials do not flower before they experience a low temperature. They grow vegetative during the warm season, receive low temperature during winter, grow further and then bear flowers and fruits. Russian agronomist Lysenko coined the term vernalization (1929-30). According to him vernalization may be defined as the method of inducing early flowering in plants by pretreatment of their seeds at low temperatures. Chourad (1960) has defined it as the acquisition or acceleration of the ability to flower by chilling treatment. The low temperature requirement for flowering was first noticed by Klipport (1857) while working with winter varieties of cereals such as wheat, barley, oat and rye. He observed that, these varieties when sown in spring failed to flower the same year but grow vegetatively. Such winter varieties, when sown in the autumn, they flowered in spring of the same year.

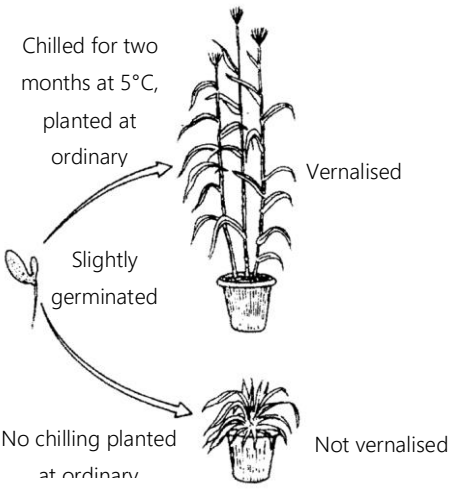


Fig : Experiment to show effect of vernalization on winter Rye.

(i) **Site of vernalization**: The stimulus of vernalization is perceived only by the meristematic cells such as shoot tip, embryo tips, root apex, developing leaves etc.

(ii) **Requirement of vernalization :** Vernalization treatment requires three conditions (a) **Low temperature** – Low temperature required for vernalization is usually 0-4^{o}C is most of the cases. The chilling treatment should not be immediately followed by high temperature (*i.e.*, about 40^{o}C), otherwise the effect of vernalization is lost. This phenomenon is called **de-vernalization.** (b) **Duration of low temperature treatment** – It varies from species to species from a few houses to a few days, (c)

Actively dividing cells- Vernalization stimulus is perceived only by actively dividing cells. Therefore, vernalization treatment can be given to the germinating seeds or whole plant with **meristematic tissues** and other conditions are (d) **Water-** Proper hydration is must for perceiving the stimulus of vernalization (e) **Oxygen –** Aerobic respiration is also a requirements for vernalization.

(iii) **Process of vernalization:** Usually vernalization treatment is given to the germinating seeds. The seeds are moistened sufficiently to allow their germination.They are then exposed to a temperature of 0-4^{o}C for a few weeks and sown to the fields. Lysenko develops the process of vernalization it is completed in two stages.

(a) **Thermostage:** Germinating seeds are treated with 0-5^{o}C in presence of oxygen and slight moisture. The seed dormancy is broken.

(b) **Photostage:** The stage is very essential to initiate the reproductive phase. After vernalization plants must be subjected to a correct photoperiod in order that they may produce flower.

(iv) **Mechanism of vernalization :** The stimulus received by the actively dividing cells of shoot or embryo tip is translocated to all parts of the plant and prepare it to flower. The stimulus has been named as **vernalin** (reported by Mechlers). It can be passed from one plant to another through grafting in case of Henbane but not in others. However, vernalin has not been isolated and identified. In some plants cold treatment can be replaced by gibberellins. It was reported by Lang. It has also been observed that the endogenous level of gibberellins enhances in vernalized plants. Therefore, it is suggested that the stimulus of vernalization that induces flowering could be particular gibberellin or a mixture of gibberellins. However, the correct mechanism is still not known and needs through investigation.

(v) **Importance of vernalization**

(i) Vernalization is believed to overcome some inhibitor and induce synthesis of growth hormones like gibberellins.

(ii) It reduces the vegetative period of plant.

(iii) It prepares the plant for flowering.

(iv) It increases yield, resistance to cold and diseases.

(v) Vernalization can remove kernel wrinkles in wheat.

(vi) Vernalization is beneficial in reducing the period between germination and flowering. Thus more than one crop can be obtained during a year.

8.4 Senescence and Death

Plant and their parts develop continuously from germination until death. The production of flowers, fruits and seeds in annuals and biennials leads to senescence. The latter part of the developmental process, which leads from maturity to the ultimate complete loss of organization and function is termed senescence. Several workers equate ageing and senescence as same process. Ageing is a sum total of changes in the total plant or its constituents while senescence represents degenerative and irreversible changes in a plant. The study of plant senescence is called **phytogerontology**.

(1) **Types of senescence :** Plant senescence is of four types- whole plant senescence, shoot senescence, sequential senescence and simultaneous senescence. The last three are also called **organ senescence**.

(i) **Whole plant senescence** : It is found in monocarpic plants which flower and fruit only once in their life cycle. The plants may be annual (e.g. rice, wheat, gram, mustard etc.), biennials (e.g. cabbage, henbane) or perennials (e.g. certain bamboos). The plant dies soon after ripening of seeds.

(ii) **Shoot senescence:** This type of senescence is found in certain perennial plants which possess underground perennating structures like rhizomes, bulbs, corm etc. The above ground part of the shoot dies each year after flowering and fruiting, but the underground part (stem and root) survives and puts out new shoots again next year. e.g. banana, gladiolus, ginger etc.

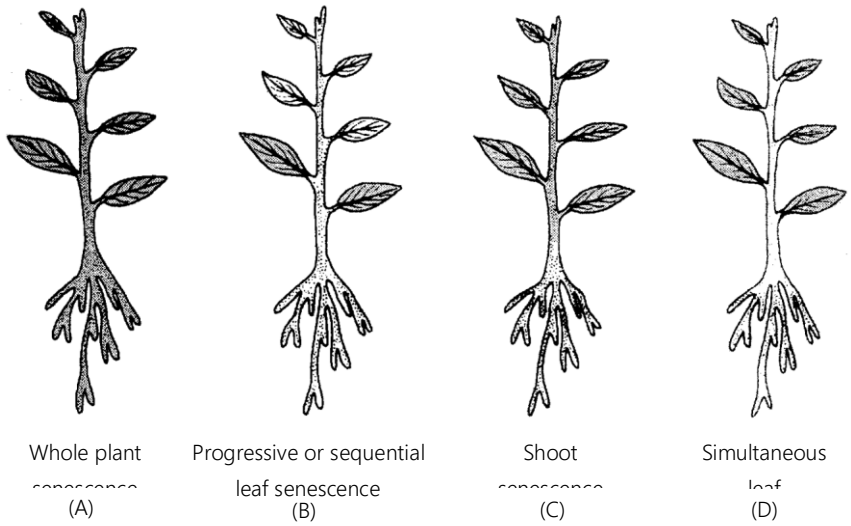


Fig : Types of plants and senescence (shaded region is the part undergoing senescence)

(iii) **Sequential senescence:** This is found in many perennial plants in which the tips of main shoot and branches remain in a meristematic state and continue to produce new buds and leaves. The older leaves and lateral organs like branches show senescence and die. Sequential senescence is apparent in evergreen plants e.g. *Eucalyptus, Pinus,* Mango.

(iv) **Simultaneous or synchronous senescence:** It is found is temperate deciduous trees such as elm and muple. These plants shed all their leaves in autumn and develop new leaves in spring. Because of this shedding of leaves, autumn season is also called fall. e.g. Dalbergia, Elm, Mulberry, Poplar.

(2) **Theories of senescence:** Several theories have been put forth regarding senescence. Some important ones are given below.

(i) **Wear and tear:** According to this theory, senescence occurs due to loss of activity and cells undergo wear and tear due to disintegration of organelles.

(ii) **Toxicity:** It is viewed that senescence takes place due to accumulation of toxic and deleterious substances in all.

(iii) **Loss of metabolites**: It is assumed that senescence leads to gradual depletion of essential metabolites in a cell.

(iv) **Genetic damage**

(v) **Differences between senescence, ageing and death**

Characters	**Senescence**	**Ageing**	**Death**
1. Definition	**Senescence:** It refers to all collective, progressive and deteriorative process which ultimately leads to complete loss of organization and	**Ageing:** It includes all the chemical and structural changes, which occur during the life span of a plant or its organ.	**Death:** It is the ultimate termination of functional life of plant part.

	function.		
2. Changes	It includes only degenerative and deteriorative changes in a plant or its parts.	It is sum total of metabolic changes that occur in plant or its parts.	It is a regular feature of the annual cycle of plants which is usually preceded by senescence.
3. Occurrence	Senescence occurs as a result of ageing and leads to death.	Ageing is a permanent feature of all living organisms.	Death is a permanent feature of all living organisms.

(3) **Characteristics of ageing and senescence**

(i) There is general decline in metabolic activities decline in ATP synthesis and also decreased potency of chloroplast.

(ii) Decrease in RNA and DNA

(iii) Decrease in semipermeability of cytoplasmic membranes.

(iv) Decrease in the capacity to repair and replace wornout cells.

(v) There may be accumulation of chromosomal aberrations and gene mutations with advancing age as a result of these changes protein synthesis becomes defective.

(vi) Increased production of hydrolytic enzymes such as proteases and nucleases.

(vii) Deteriorative change in cell organelles and membranes.

(viii) Decrease in the internal content of auxin and cytokinins and increases in the production of abscisic acid or ethylene.

(4) **Importance of senescence :** Biologically senescence and death have following advantages :

(i) It maintains efficiency since the old and inefficient organs are replaced by young efficient part like leaves, buds, flowers and fruits. etc.

(ii) During senescence, the cellular breakdown results in release of many nutrients including amino acids, amides, nucleotides, simple sugars and minerals. The same are withdrawn from the senescing organs into the main trunk and later utilised in the growth and developed of new parts.

(iii) Shoot senescence is a mechanism to help the plants perennate during the unfavourable periods.

(iv) Simultaneous or synchronous leaf fall occurs in autumn prior to winter. It reduces transpiration, which is essential for survival in survival in winter, when the soil in frozen and roots can not absorb water.

(v) Litter of fallen leaves and twigs is an important source of humus and mineral replenishment for the soil.

8.5 Abscission

The process of shedding of leaves, fruits or flowers by a plant is called abscission. The shedding of plant parts takes place by the formation of a special layer of cells called abscission layer, within the region of attachment. The middle lamella between certain cells in this layer in often digested by polysaccharide hydrolyzing enzymes such as cellulase and pectinases.

Certain other degenerative changes also occur making the region soft and weak. The organ from the plant is then easily detached whenever there is heavy rainfall or wind, etc.

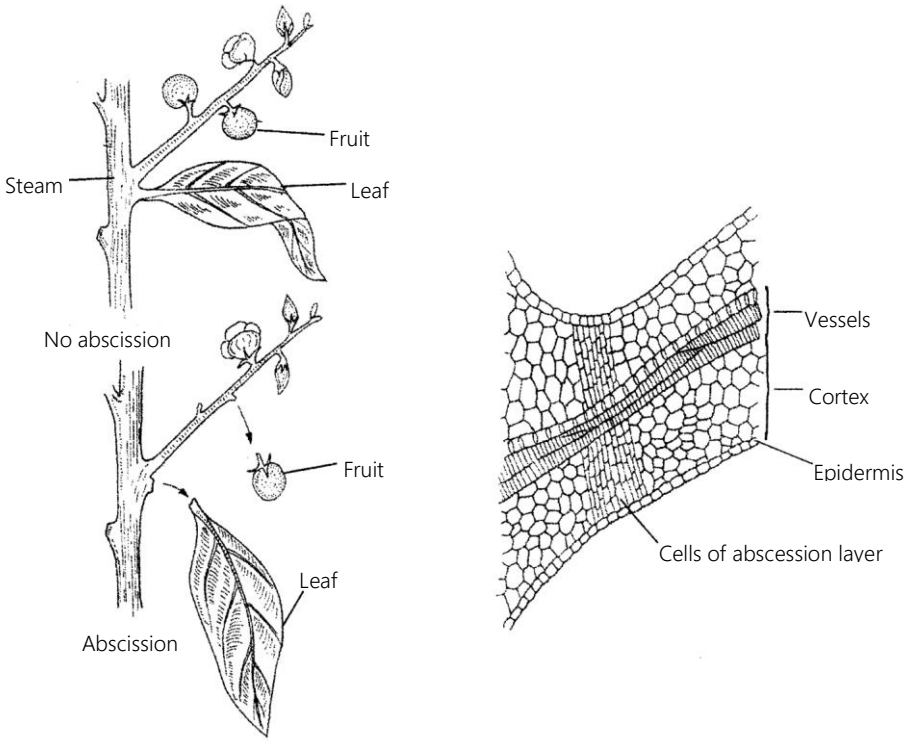


Fig : Leaf and fruit abscission due to the formation of abscission layer

The abscission occurs due to a change in the hormonal balance. It has been observed that the abscission layer formation occurs rapidly when the auxin gradient becomes less i.e., less auxin on distal side than the proximal side of the leaf, flower or fruit. The plant hormones like ethylene and abscissic acid promote the abscission. A high concentration of auxin prevents the formation of a abscission layer.

Dormancy and germination of seeds

(See detail in Embryology module -II)

Important Tips

- SDP's contain anthesins and synthesize gibberellic acid for flowing. Whereas LDP's contain GA and synthesize anthesins for flowering.
- Leaves show maximum expansion in violet light.
- Impaction is the treatment given to seeds when they are shaken vigorously.
- The term negative growth is sometime used for senescence.
- Knott (1934) found that the locus of photoperiodic induction is the leaves.
- Wellensick (1964) found that the locus for perception of cold treatment is the meristmatic cells (at all places) especially the shoot apex .
- Reduced availability of auxin stimulates leaf fall while presence of auxin slows down leaf fall. Cytokinin prevent senescence through stimulating anabolic activity. They are called artiageing hormones Florigen hormone synthesized in the leaves.

8.6 Plant movements

Movement is a change in position or place of an organ or organism. The movements in plants is not as much apparent as in the case of animals. But plants also show movements though they are fixed. They show movements of their parts. Such movements are not apparent except when observed after a time interval. They can however, be seen with the help of time lapse cameras.

Usually higher plants exhibit growth movements. Plants show movements in response to a variety of stimuli. Stimulus can be defined "as a change in external or internal environment of an organism that elicits response in the organism". The reaction of plant to a stimulus is known as response". The power or ability of a plant to respond to a stimulus is called sensitivity or reactivity or irritability.

The movements which occur without the effect of external stimulus are called autonomic or spontaneous movements. Thus spontaneous movements are brought by definite internal stimulus. And if the movements are produced in response to external stimulus, they are known as paratonic or induced movements.

The area which perceives a stimulus is called perceptive region, while the plants part showing the response is known as responsive region. The minimum duration or time required for a stimulus to be applied continuously on the perceptive region to produce visible response is called presentation time. The duration between the application of stimulus and production of visible response is called latent time or reaction time.

Classification of plant movements

Plants movements are broadly classified into two types:

1. Movements of locomotion
2. Movements of curvature

(1) **Movements of locomotion:** In this case, plant moves physically from one place to another. The movements of locomation are of two type-autonomic (occurs spontaneously) or paratonic (induced by external stimuli).

(i) **Autonomic movement of locomotion** : These movement of locomotion are due to internal stimuli they are of following types.

(a) **Ciliary movements**: Certain motile algae (e.g. *Chlamydomonas, Volvox*, etc). Zoospores and gametes of lower plants move from one place to another by means of cilia or flagella.

(b) **Amoeboid movements:** It is the movement of naked mass of protoplasm by means of producing pseudopodia like process e.g. members of Myxomycetes (slime fungi).

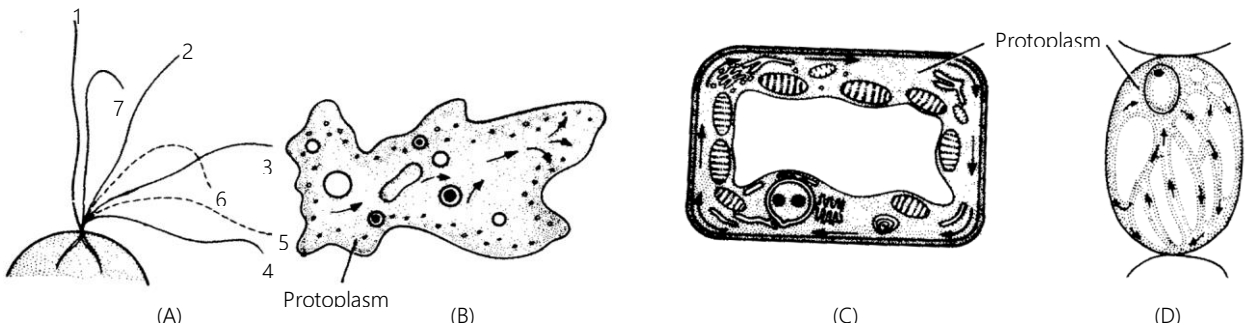


Fig : Locomotory movements (A) Ciliary (B) Amoeboid (C) Rotation (D) Circulation

(c) **Cyclosis:** These are movements of cytoplasm with is a cell (also called protoplasmic streaming). These are of two types.

- **Rotation:** When the protoplasm moves around a single central vacuole in either clockwise or anticlockwise direction e.g. leaf cells of *Hydrilla*, *Vallisneria*.
- **Circulation:** When the movement of protoplasm accurs around different *vaculoes* in different directions within the cell e.g. staminal hair of Tradescantia, shoot hairs of gourds.

(d) **Excretory movements :** Apical part of oscillatoria like a pendulum. It is considered that such movements are due to exerction of substances by the plants. (movements opposite to the side of exerction).

(ii) **Paratonic movement of locomotion (Tactic movement):** These movements take place in whole small plants. e.g. chlamydomonas or small free ciliated organs e.g. gametes. These movements are due to external factors like light, temperature or chemicals and are of following types.

(a) **Phototactic movements or phototaxisms:** It is the movement of free living arganism towords or away from light. e.g. movement of *Chlamydomones, Ulothrix, Cladophora, Volvox* etc. towards suitable light intensity. Three types of arrangement present in columular cells in chloroplast of dorsiventral leaves.

- **Parastrophe :** In intense (maximum) light chloroplast cells arranged in longitudinal wall as a sequence manner.
- **Apostrophe :** In minimum light chloroplast cells arranged in different manner.
- **Epistrophe:** In dark chloroplast cells are arranged in transverse wall as sequence manner.

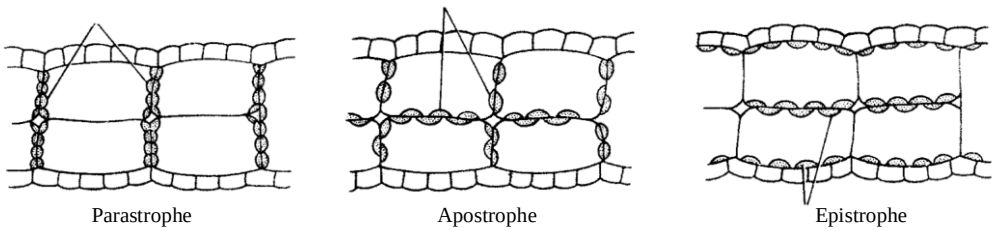


Fig : Photolactic movements on leaf of *Lemna*

(b) **Chemotactic movements or chemotaxisms :** It is the movement of plant or plant parts from one place to another towards or away from chemical substance. e.g. Male gametes (antherozoids) of bryophyta move towards archegonia under the influence of sugars produced by neck canal cells and also in pteridophyta male gametes move towards archegonia due to the malic acid produced by disintegration of neck canal cells and ventral canal cells.

(c) **Thermotactic movements or thermotaxism:** It is the movement of free living organism in response to external stimuli of temperature. e.g. *Chlamydomonas* move from cold water to medium warm water and from very hot water to medium temperature.

(2) **Movement of curvature :** In these cases, plants are fixed, thus they fail to move from one place to another. Somehow, movement is noticed in the form of bend or curvature on any part of the plant. Movement of curvature can be classified into.

(A) Mechanical movement

(B) Vital movement

(A) **Mechanical movements:** These movements depends upon the presence or absence of water and occurs in non-living parts of plants. It is of two types.

(i) **Hydrochasy:** This movement occurs due to the absorption of water.

Example: (a) Peristomial teeth of moss protrude out when the capsule is dry and curve when capsule is wet.

(b) Spores of the *Equisetum* coil and uncoil in the presence and absence of water respectively.

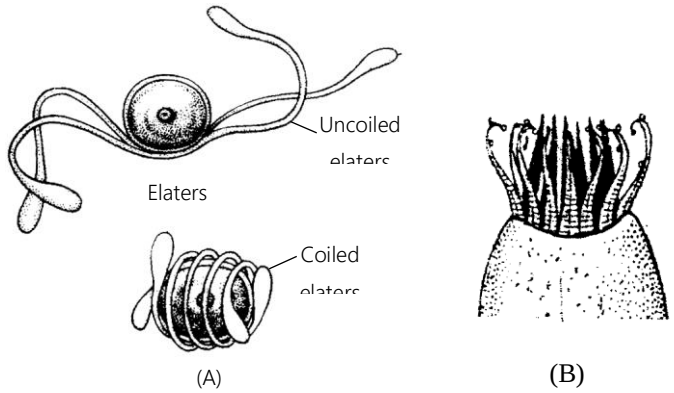


Fig : (A) *Equisetum* spore (B) Peristomial teeth of moss

(ii) **Xerochasy :** This movement occurs due to the loss of water.

Example: When water is lost from the annules of the sporangia of fern, it burst from stomium and spores are thus liberated out.

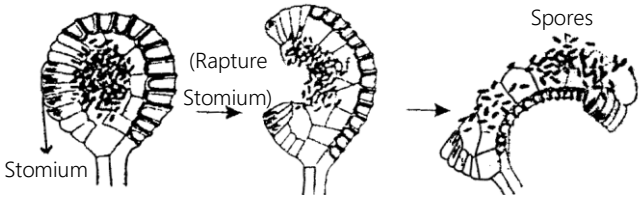


Fig : Movements in the annulus of fern sporangium

(c) **Vital movement:** These movement are of two types :

(i) **Growth movements :** These movements are due to unequal growth in different parts of an organ and are irreversible.

They are further divided into two types-autonomic (occurs spontaneously) and paratonic (induced by external stimuli).

(a) **Autonomic growth movements**

- **Nutation (Nutatory movements):** These movements occur in the growing stem of twiners and tendrils. The stem exhibits a kind of nodding movements in two directions. This is because the stem apex shows more growth on one side at one time and a little later there is a greater growth on the opposite side. It is called **nutation**. In spirally growing stems the region of greater growth passes gradually around the growing point resulting in the

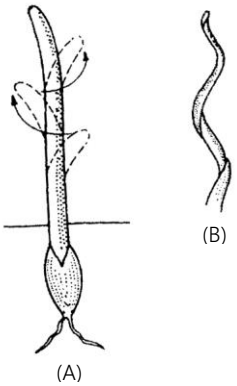


Fig : Nutations :
(A) Nodding movement
(B) Circumnutation

spiral coiling of stem and tendrils. Such a movement is called circumnutation. Coiling of a tendril after coming in contact with a support is a **thigmotropic movement**.

- **Nastic movements:** They are non-directional movements in which the response is determined by the structure of the responsive organ and not the direction of the stimulus. The responsive organ has an asymmetrical or dorsiventral structure. Greater growth on one side causes the organ to bend to the opposite side. Greater growth on the adaxial side is called **hyponasty**. e.g. circinate coiling and closed sepals and petals in a floral buds. Whereas more growth on abaxial side is called **epinasty**. e.g. opening of fern leaf and spreading of sepals and petals during opening of the floral bud.

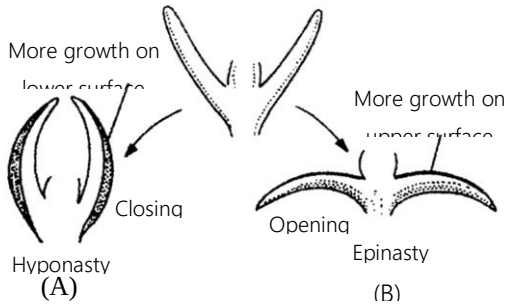


Fig : Nastie movements (A) Hyponasty, (B) Epinasty

(b) **Paratonic growth movement (Tropic movements or tropism):** These are movements of curvature brought about by more growth on one side and less growth on the opposite side of plant organ induced by some external stimuli. Depending upon the nature of stimuli these movements are of the following type.

- **Phototropism (Heliotropism):** When a plant organ curves due to unilateral light stimulus it is called phototropism. Some parts of the plant e.g., stem moves towards light. These organs are called **positively phototropic.** Some other organs e.g., roots move away from light and they are called **negatively phototropic.** If we keep a plant in a dark chamber (Heliotropic chamber) with an opening on one lateral side the stem tip moves towards light i.e., towards opening. Phototropism of stem and root are due to differential hormonal effect. Violet blue light is most effective. Photoreceptor seems to be a carotenoid. Young stems are positively phototropic, leaves diaphototropic, shoots of Ivy plagio-phototropic, roots either non phototropic or negatively phototropic (e.g. white mustard, Sunflower). Mechanism is believed to be Cholodny-Went theory which states that unilateral light produces more auxin (IAA) and hence more growth on the shaded side resulting in bending.

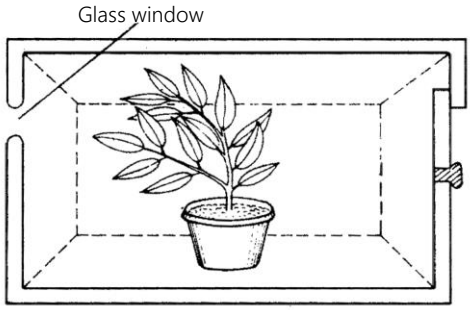


Fig : Heliotropic chamber showing positive photoropism in shoot

- **Geotropism (Gravitropism) :** Growth of movements induced by the stimulus of gravity are known as geotropism.

Generally, the primary root grows towards the force of gravity and hence is positively geotropic. The stem coloptile and phematophores grows away from the force of gravity and is **negatively geotropic**. The secondary roots and stem branches arise at angle less than 90^{o}. They are thus **plageotropic**. Certain undergorund stems such as rhizomes, stolons of potato are oriented at right angle to the direction of force a gravity and are called **diageotropic**. Some of the lateral organs (e.g. corolloid roots of *Cycas*) possess little or no geotropic sensitivity, they are called **ageotropic**.

If some seedlings are kept in a dark chamber in different directions, root always move downwards and shoot away from the gravitational force.

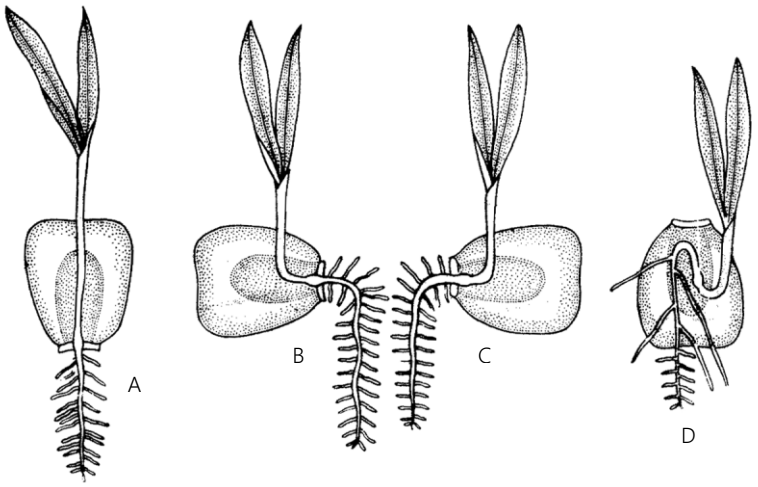


Fig : Geotropism in maize seedings. Grains are placed in soil in different positions but in all cases the roots grow downwards and the shoot

According to Cholodny-Went theory there is more auxin on the lower side of both stems and roots. In stem higher auxin concentration increases growth while in roots it inhibits growth. Therefore, stem grow more on the lower side while roots grow more on the upper side causing the stem to bend upwardly and roots to bend downwardly. Another theory is statolith theory which states that perceptive regions contain statoliths (microscopic particles). Change in their position causes irritation and hence differential growth. Clinostat / Klinostal is a instrument which can eliminate the effect of gravity and allow a plant to grow horizontly by slowly rotating it.

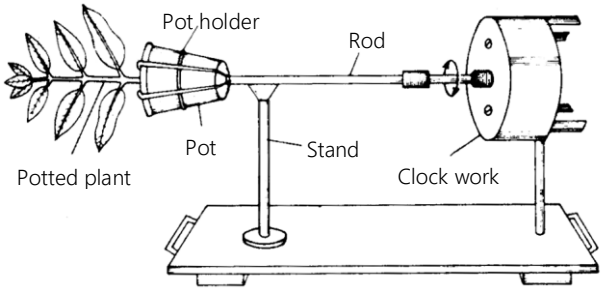


Fig : A Clinostat : If not rotated shoot curves upward. If rotated the shoot grows straight.

The main axis of which is attached to a rod. On the top of the rod is attached a flower pot. The clinostat is kept in a horizontal position as shown in fig. When the clock axis rotates the flower pot also rotates. As a result of this the plant grows horizontally as the effect of gravity is nullified by clinostat. If the clock of the clinostat is stopped the rotation of the plant stops, the shoot apex moves upward (negative geotropism) and the root apex moves downwards (positive geotropism).

• **Hydrotropism:** Growth movements in response to external stimulus of water are termed as hydrotropism Roots are positively hydrotropic (i.e. bend towards the source of water).

Stem are either indifferent or negatively hydrotropic. Positive hydroptropic movement of the roots is stronger than their geotropic response. In case of shortage of water, roots bend towards the sewage pipes and other sources of water in disregard to the stimulus of gravity.

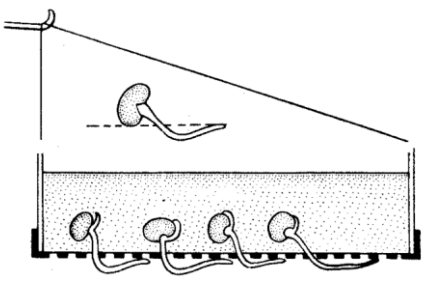


Fig : Hydrotropism in young roots

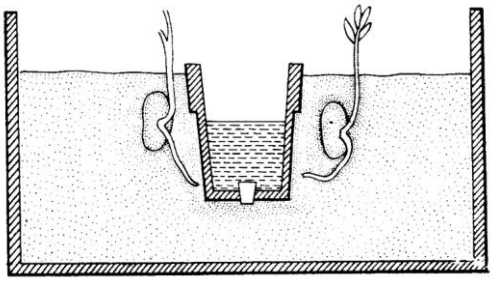


Fig : Hydrotropism in roots in the centre is a porous pot filled with water

• **Thigmotropism (Haptatropism):** The movement which are due contact with a foreign body. It is most conspicuous in tendrils which coil around support and help the plant in climbing. The most sensitive regions are the ones which are actively growing. Tendrils also show mutations which help them to come in contact with the support. e.g. Tendrils of cucurbitaceae, petiole of clematis, leaf apex of Gloriosa.

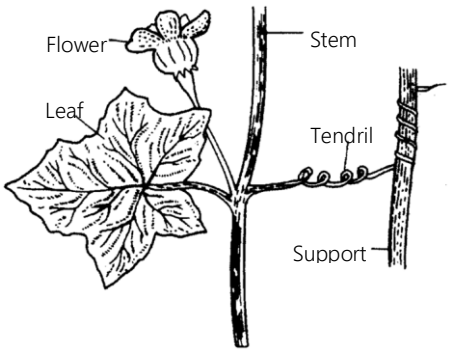


Fig : Thigmotropic curvature in Cucumber tendril

• **Chemotropism:** When a curvature takes place in response to a chemical stimulus. The growth of pollen tube through stigma and style towards the embryo sac occurs with the stimulus of chemical substances present in the carpel or movement of fungal hyphae towards sugars and peptones.

• **Thermotropism :** Curvature of plant parts towards normal temperatures from very high or very low temperatures. E.g., peduncles of Tulip, Anemone.

(ii) **Variation movements (Turgor movements):** These movements are caused by turgor changes especially due to efflux and influx of $\mathbf{K^+}$ **ions.** (swelling or shrinkage of living cells due to change in osmotic potential) and are reversible. Variation movements are further divided into two types- **Autonomic** (not induced by external stimuli) and paratonic (induced by external stimuli).

(a) **Autonomic variation movement:** These movement of variation, which occurs without the external stimulus. Rhythmic autonomic turgor changes produce jerky rising and falling of two lateral leaflets in Indian Telegraph plant (Desmodium gyrans). Here, large thin walled motor cells found at the leaflet bases regularly lose and gain water bringing about changes in turgor pressure.

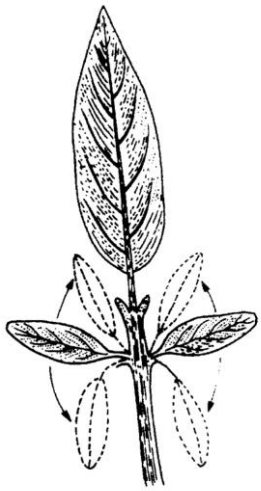


Fig : Autonomic variation movements in the leaves of Desmodium gyrans (telegraph plant)

Motor (Bulliform) cells present in the epidermal cells of some grasses cause their folding and unfolding movements (hydronasty).

(b) **Paratonic variation movement (Nastic movements).** These movements of variation are determined by some external stimuli such as light, temperature or contact but the direction of response is prefixed (not determined by the direction of stimuli). Nastic movements are of the following types.

• **Nyctinastic (sleeping) movements:** The diurnal (changes in day and night) movements of leaves and flowers of some species which take up sleeping position at night are called nyctinastic movement. Depending upon the stimilus they may be photonastic (light stimulus) or thermonastic

(temperature stimulus). Maranta (Prayer plant), an ornamental house plant provides most common examples of nyctinastic response.

- **Photonastic movements:** Leaves of *Oxalis* take up horizontal position in sunlight and droop down during night. Many flowers open during the day and close during night or cloudy sky e.g., *Oxalis.*

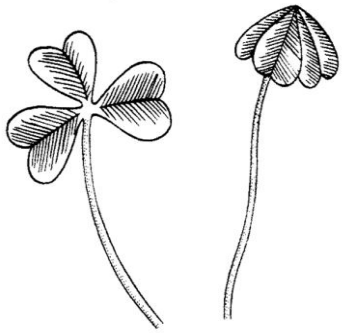


Fig : Oxalis-showing photonastic movement of the leaf (A) Open leaf during day (B) Closed leaf during night

- **Thermonastic movements:** Flowers of tulips and crocus open during high temperatures and close down during low temperatures.

- **Thigmonastic (Haptonastic) movements:** When marginal glandular hair of *Drosera* come in contact with some foreign body e.g., body of insect, they show haptonastic movements. Due to this the insect comes in contact with the central glandular hair which after being stimulated bring the marginal glandular hair on the body of insect. These later movements are chemotropic whereas the previous movements of marginal glandular hair is chemonastic movement Drosera shows both nyctinasty and thigmonasty movements.

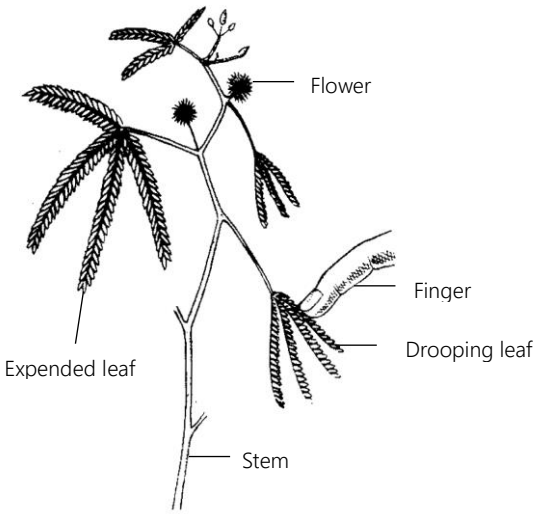


Fig : *Mimosa pudica* : Showing seismonasty A. Normal leaf B. Drooping leaf

- **Seismonastic movements:** This type of movement is bought about in response to external stimulus of shock or touch. The best example of seismonastic movement is the leaves of sensitive plant *Mimosa pudica* (Touch me not). It shows both nyctinastic (Sleeping movement) and seismonastic movement (shock movements) The leaves are compound with four pinna and each pinna bears numerous pinnules. Pulvini are present at the base of petiole, subpetiole and still other tertiary petioles. Pulvini are swollen areas consisting of large number of loosely packed parenchymatous cells separated by large number of intercellular spaces. The central portion of the pulvinus is traversed by vascular strand. The cells of the upper half of pulvinus have thick cell walls and the cells of the lower half have thin walls.

If the flowerpot is moved or leaf or any other organ of the plant is touched, the stimulus reaches the base of the leaf. Owing to this stimulus the turgor of lower half of pulvinus is lost and the leaf droops. After

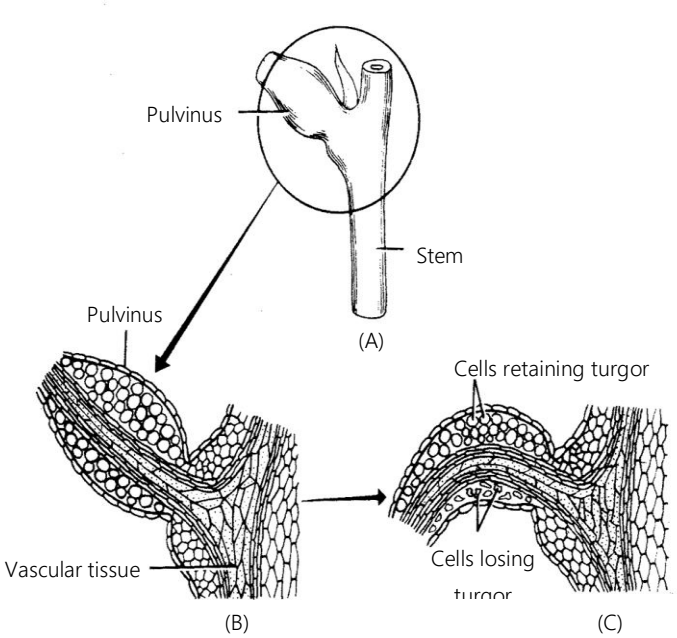
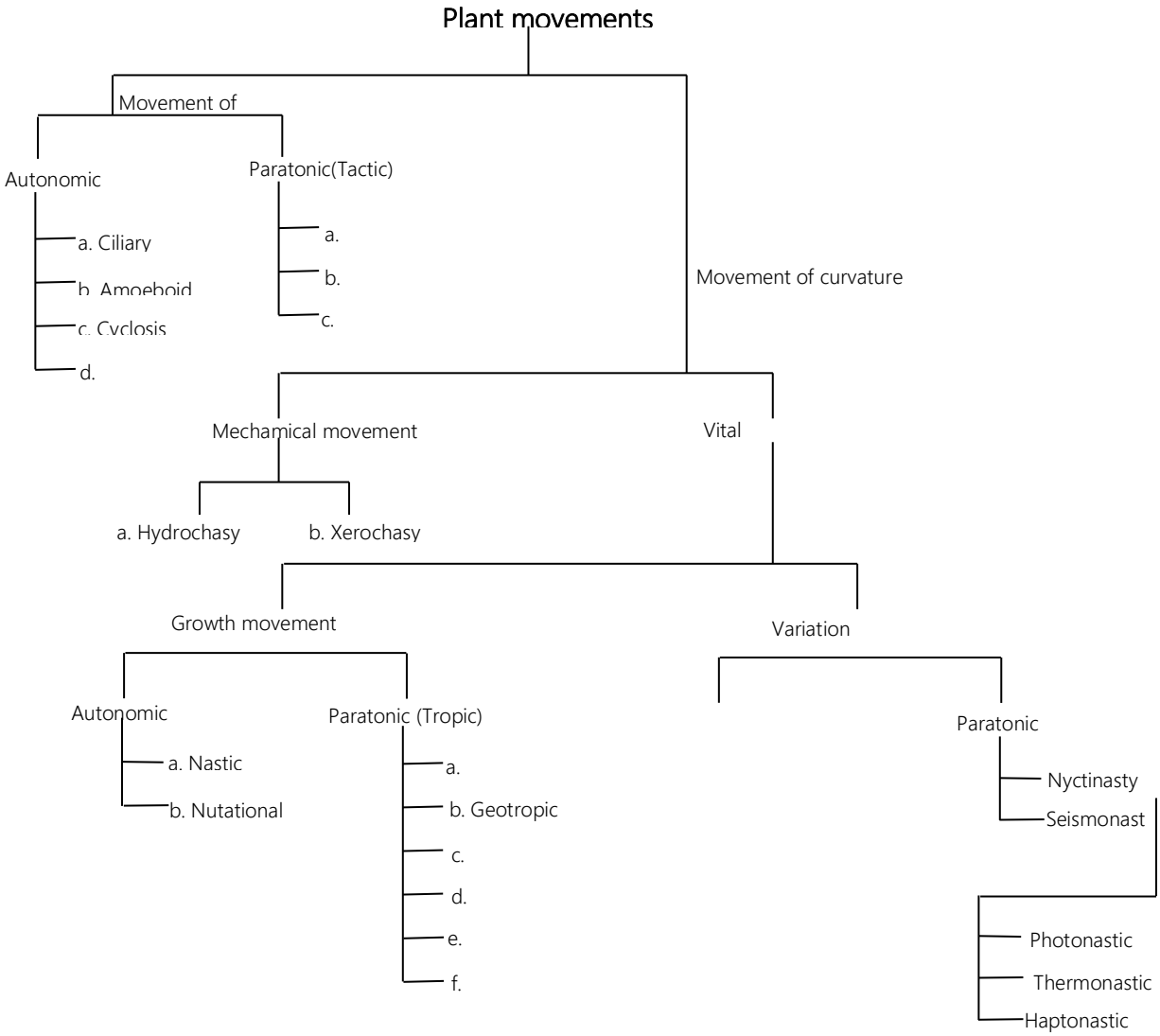


Fig : *Mimosa pudica* : showing seismonasty (A) Pulvinus in normal stage (B) Pulvinus in normal stage in L.S. (C) Pulvinus L.S. of drooped leaf

some time the cells of the lower half of pulvinus becomes turgid again and the leaf attains its erect position. According to Snow (1924) and Bose (1926), chemical or hormone is produced at the place of touch and it travels through xylem, phloem and pith outwards and downwards finally to reach the pulvini. At pulvinus K^+ are released into intercellular spaces. As a result, exosmosis takes place. Due to loss of turgor pressure typical drooping occurs. With a strong stimulus, pulvini gets folded in such a way that pinnules curve upwardly. The pinnae come close and finally main petiole droops down. When this response period is over (about 10 minutes), K^+ ions are released back, turgor is regained and the leaflets open out. It is assumed that from the point of stimulus the message to respond travels in waves through the plant at the speed of 1 cm per second. It is further interesting to note that electric impulses called action potentials like nervous message in animals have been observed in *Mimosa pudica*.



Important Tips

- Physical movements: Unstimulated movements caused by mechanical tensions (e.g. dehiscence of Balsam, clam and Squirting cucumber fruits) and hygroscopicity (Shrinkage/ xerochasy and swelling/ hydrochasy, e.g., dehiscence of fern sporangium,peristome teeth of moss).
- Vital movements: Movements due to internal change (autonomic) or in response to stimulus (paratonic/ induced).
- Autonomic movement: Spontaneous movements.
- Paratonic movements: Induced movements
- Chemotactic movements Antherozoids of Marchantia move towards open archegonia in response to certain protiens, in other bryophytes by sucrose, in most pteridophytes by malic acid while citric acid causes movements in lycopods. Zoospores of moulds swim towards acidic pH where decaying organic matter is present.
- Geotropism/Gravitropism (i) It is variable in the floral stalk of Poppy-positive in bud state and negative at maturity of flower. (ii) Haberlandt (1900) and Nemec (1900) put forward statolith theory of graviperception. (iii) Root cap perceives the stimulus of gravity. It is believed to produce an inhibitor like abscisic acid or IAA oxidase which diffusing basipetally reduces growth on the lower side and causes bending.
- Geotropic stimulus is perceived by root cap in case of root by stem apex in case of stem.

- Movement due to air are called aerotropism e.g. positively aerotropic peneumatophores and movement induced by injury is called traumatropism

ASSIGNMENT

GROWTH

Basic Level

1. The *S*-shaped growth curve and grand period of growth may change with
(a) Sudden fluctuation in light intensity (b) Change in temperature
(c) Fluctuation in humidity (d) It remains unaffected

2. After achieving its maximum, the growth decreases slowly during the phase of
(a) Cell maturation (b) Cell division (c) Cell differentiation (d) Cell enlargement

3. Which of the following instrument can be used to record plant growth by seconds (*i.e.* in fraction of a minute)
(a) Arc auxanometer (b) Arc indicator (c) Space marker disc (d) Crescograph

4. Most important division for the growth of a plant is
(a) Mitosis (b) Meiosis (c) Amitosis and fission (d) All of the above

5. Which of the following factors affect growth to a great extent
(a) Duration of light (b) Direction of light (c) Intensity of light (d) Wavelength of light

6. Two seeds are germinated, *A* in light and *B* in dark. Which of the two grows much taller in initial stage
(a) $A > B$ (b) $B > A$
(c) $A = B$ (d) No growth occurs in any of them

7. The effect of oxygen supply on growth is
(a) Positive (b) Negative
(c) In some plants it is positive while in others it is negative (d) None of these

8. When food supply is poor, the rate of growth is
(a) Fast (b) Slow (c) Intermediate (d) Nil

9. Which of the following remains unchanged at the end of growth
(a) Hormones (b) Enzymes (c) Vitamins (d) Nucleotides

10. The excess amount of CO_2
(a) Retards growth (b) Accelerates growth
(c) Affects the growth slowly (d) Does not affect growth

11. Most dominant direct factor which influences the growth of plants is
(a) Light (b) Temperature (c) Soil (d) Wind

12. When tropical plants are shifted to temperate climate, they do not grow. This is due to
(a) Dessication (b) Freezing injury (c) Chilling injury (d) Poor illumination

13. The correct sequence of cellular growth stages is
(a) Division $\rightarrow$ differentiation $\rightarrow$ elongation (b) Division $\rightarrow$ elongation $\rightarrow$ differentiation
(c) Differentiation $\rightarrow$ division $\rightarrow$ elongation (d) Elongation $\rightarrow$ differentiation $\rightarrow$ division

14. A bifacial organ bends towards, where

(a) Growth is more (b) Growth is slow (c) Darkness is there (d) None of these

15. Crescograph was prepared by

(a) Bose (b) Strasburger (c) Went (d) None of these

16. Where would you look for active cell division in plant

(a) In the pith cells (b) In the cells of cortex

(c) In the internodal region (d) At the tip of root and shoot

17. Maximum growth takes place in

(a) Green light (b) Red light (c) Blue light (d) Ultraviolet light

18. The type of growth of bands in conifers is

(a) Lateral (b) Delinquent (c) Caudex (d) Excurrent

19. The process of growth is determined by

(a) Increase in size (b) Increase in size and dry weight

(c) Increase in weight only (d) Increase in dry weight

20. Growth is maximum in the zone of

(a) Cell division (b) Cell elongation (c) Cell maturation (d) All of the above

21. Growth is a

(a) Unidirectional backward (b) Reversible (c) Unidirectional forward (d) None of these

22. Which of the following plays a prominent role in leaf growth

(a) Carbonate (b) Nitrate (c) Sulphate (d) Phosphate

23. The growth pattern of a plant is different from the growth pattern of an animal in having

(a) Lacalized growth centres (b) Indefinite life span

(c) Both the above (d) Diffused growth

24. In lag phase, growth is

(a) Slowest (b) Fastest (c) Intermediate (d) No growth at all

25. Energy for the early growth of a developing bean embryo comes from

(a) Sunlight (b) Water in the soil (c) Food in the soil (d) Leaves in the seed

26. Auxanometer is meant for

(a) Respiratory activity (b) Photosynthetic activity

(c)Growth activity (d) The amount of auxins

27. Phytotron is a device by which

(a) Electrons are bombarded (b) Protons are liberated

(c) Plants are grown in controlled environment (d) Mutations are produced in plants

28. Two climatic factors which affect growth are

(a) Light and wind (b) Light and temperature

(c) Rain and temperature (d) Atmospheric humidity and temperature

29. Each meristem influences other meristems. The phenomenon is

(a) Allometry (b) Growth correction (c) Lag phase (d) Auxetic growth

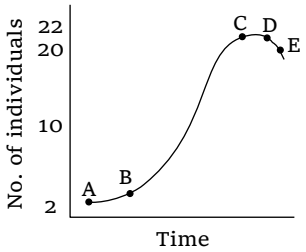
30. Growth plotted against time gives a

(a) Parabolic curve (b) Sigmoid curve (c) Upright line (d) Horizontal line

31. Temperature range for plant growth is

(a) 25°-35°*C* (b) 0°-35°*C* (c) 10°-50°*C* (d) 0°-20°*C*

32. Graph showing the growth of yeast, This is the type of growth curve noted for most organism. The log phase of growth is represented by



(a) Point A to B

(b) Point B to C

(c) Point C to D

(d) Point A to C

33. The segment C-D indicates a point where

(a) No new individuals are formed

(b) Death rate is zero

(c) The rate of formation and rate of death of individuals is the same

(d) The experiment stopped

34. The segment D-E indicates a period of

(a) Decline (b) Maturation

(c) Recommencement of growth (d) Active growth

35. When the rate of maximum growth is maintained for sometime, it is known as

(a) J-shaped phase of growth (b) Linear phase of growth

(c) S-shaped phase of growth (d) All the above

36. The growing zones of root and shoot are respectively

(a) 5 *cms* and 5-30 *cms* (b) 4.5 *cms* and 4-20 *cms*

(c) 2 *cms* and 3-18.5 *cms* (d) 1*cm* and 2-50 *cms*

Advance Level

37. Low *C/N* ratio favours

(a) Flowering (b) Vigorous vegetative growth

(c) Senescence (d) More flowering and poor vegetative growth

38. In blue-violet colour light

(a) Internodal growth is pronounced (b) Increase size of lamina of leaf

(c) Both (a) and (b) (d) Reduces the expansion of leaves

39. Which of the following light reduces the expansion of leaves

(a) Blue-violet colour (b) Green colour (c) Red colour (d) All the above

40. Which one of the following is the motivative force for growth

(a) Turgor pressure (b) Root pressure

(c) Atmospheric pressure (d) Osmotic pressure

41. How growth takes place in an organism

(a) By change of size

(b) By chemical reaction in cell

(c) By biochemical conversion of food into living matter

(d) By multiplication of cells or tissues

42. Distribution of growth in a root by marking it at equal intervals with Indian ink was originally studied by

(a) Bose (b) Strasburger (c) Went (d) Nitsch

43. The rate of growth is highest in

(a) Lag phase (b) Log phase (c) Steady state (d) None of the above

44. Plant growth in length is increased by

(a) Apical meristem (b) Lateral meristem (c) Dermatogen (d) Periblem

45. Plant response to environment is mainly through

(a) Induction of dormancy (b)Abscission of parts

(c) Synthesis of pigments (d)Growth

GROWTH HORMONES (INTRODUCTION)

Basic Level

46. In which of the following respect, the plant hormones differ from enzymes

(a) Required in less quantity (b) They are expanded in the process

(c) They release some energy (d) None of the above

47. If the growing coleoptile tip is cut

(a) Phototropism stops (b) Phototropism increase more

(c) Rate of photoperiodism remains unchanged (d) None of the above

48. Which of the following is plant hormone

(a) Auxin (b) Morphactin (c) Gibberellin (d) All the above

49. Phenyl acetic acid is a

(a) Natural plant hormone (b)A synthetic growth hormone

(c) Antihormone compound (d) None of the above

50. 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

51. Enzymes, vitamins and hormones can be classified into a single category of biological chemicals because all of them

(a) Aid in regulating metabolism (b) Are proteins

(c) Are synthesized within the body (d) Enhance the oxidative metabolism

52. Phytohormones are
(a) Hormones regulating growth from seed to adulthood
(b) Growth regulators synthesised by plants and influencing physiological processes
(c) Hormones regulating flowering
(d) Hormones regulating secondary growth

53. Who used the term '**phytohormones'** for plant hormone
(a) Balis (b) Morgan (c) Went (d) Thimann

54. Substances which originate at the tip of stem and root and control the growth of different organs are
(a) Enzymes (b) Hormones (c) Vitamins (d) Food substances

55. A tissue that does not form hormones is
(a) Xylem (b) Sclerenchyma (c) Both (a) and (b) (d) None of these

56. An apple tree can be made to bear large sized fruits by
(a) Decapitation (b) Defoliation
(c) Dehydration (d) Thinning of blossom.

57. Development of shoot and root is determined by **[**
(a) Cytokinin and auxin ratio (b) Enzymes
(c) Temperature (d) Plant nutrients

58. Plant growth hormones extracted from a fungus and a fish are respectively
(a) Gibberellins and zeatin (b)Ethylene and cytokinin
(c) Auxin and 2, 4-D (d)Gibberellin and kinetin

59. Name the scientist who discovered that decapitated coleoptile would resume photo-sensitivity and growth if severed tip is reattached through a gelatin disc.
(a) Darwin (b) Van Overbeek (c) Boyson Jensen (d) Paal

60. Stimulus in *Mimosa pudica* travels in the form of
(a) Auxin (b) Hormone (c) Alcohol (d) None of these

61. The term bioassay implies
(a) Writing an essay on living organisms
(b) Using living organisms in testing the biologically active chemicals
(c) Description of microorganisms
(d) Description of useful plants parts

62. Match the following

'A'	**'B'**
(1) Auxin	(I) Ripening and maturity of fruits
(2) Gibberellin	(II) Differentiation of xylem elements
(3) Cytokinin	(III) Prevention of genetic and physiological dwarfism
(4) Ethylene	(IV) Found from tumour tissue of tobacco

Correct matching is

	(1)	(2)	(3)	(4)
(a)	IV	III	II	I
(b)	IV	II	III	I
(c)	II	III	IV	I
(d)	III	IV	II	I

63. Which of the following technique is employed for the separation and identification of phytohormones

(a) Polarizing microscopy (b)Autoradiography

(c) Gas chromatography (d) Cell fractionation

64. Seedless fruits can be obtained by treating the unpollinated ovaries with

(a) Sucrose solution (b) Hormones (c) Pure lanolin (d) Colchicine

65. Evergreen trees remain green throughout the year on account of

(a) Absence of leaf fall (b) Leaves falling in small members at intervals

(c) Supply of the moisture throughout the year (d) Cold climate

66. Whose technique is employed for the extraction and elimination of hormones

(a) Beck (b) Beer (c) Garner (d) Allard

67. Phytohormones are used in

(a) Parthenocarpy (b) Grafting (c) Ripening of fruits (d) All of the above

68. In tissue culture experiments in tobacco callus, it was seen that when the culture medium contains 2 *ppm* of IAA and 2 *ppm* of kinetin an undifferentiated mass of callus is produced. If the ratio of kinetin to IAA is increased

(a) The callus size would increase by repeated cell divisions

(b) Root initiation would take place

(c) Shoot initiation would occur (d) The callus would die

69. Match the items of column I and column II

	Column I		Column II
a	Auxin	*p*	GA_3
b	Gibberellin	*q*	Indole acetic acid
c	Cytokinin	*r*	Abscisic acid
d	Dormin	*s*	Acetic acid
		t	Zeatin

(a) *a – q, b – r, c – p, d – t* (b)*a – q, b – s, c – p, d – t*

(c) *a – q, b – p, c – t, d – r* (d)*a – q, b – t, c – p, d – r*

70. Correct sequence of different stages of development is

(a) Fruiting → Flowering → Juvenility → Germination

(b) Germination → Juvenility → Flowering → Fruiting

(c) Flowering → Fruiting → Juvenility → Germination

(d) Juvenility → Flowering → Fruiting → Germination

71. Give below are assertion and reason. Point out if both are true with reason being correct explanation (a), both true but reason not correct explanation (b), assertion true but reason wrong (c), and both wrong (d). **Assertion**. Plants also have hormones called phytohormones. **Reason**. They increase the rate of reactions and thus allways accelerate growth and other related changes

(a) (b) (c) (d)

72. Induction of rooting in stem cutting would be most beneficial in

(a) *Marchantia* (b) Wheat (c) *Cuscuta* (d) *Bougainevillea*

AUXIN

Basic Level

73. What is the cause of excurrent habit in *Pinus*

(a) Presence of gibberellin (b)Presence of apical dominance

(c) High concentration of cytokinin (d)High concentration of ABA

74. Pruning makes the hedge plant dense because

(a) Injury induces dense growth

(b) Apical dominance is removed

(c) Root sprouts additional branches

(d) Pruning removes shade and allows germination of new seedlings to impart a dense growth

75. Which one of the following plant function is not generally governed or controlled by auxin

76. If the concentration of IAA is increased in the roots of a plant, the absorption of water would

(a) Increase (b) Decrease

(c) First decrease then increase (d) Remain unaffected

77. Seedless fruits can be obtained by treating a plant with

(a) Enzyme (b) Auxin (c) Vitamin (d) 70°*C* and light

78. Banana is a parthenocarpic fruit because

(a) It is 3*n* (b) It is vegetatively propagated

(c) Its ovary has high levels of auxin (d) It is treated with hormones

79. Flowering in pineapple is promoted by

(a) NAA (b) GA_3 (c) Short days (d) Cytokinin

80. Auxins are abundantly produced in

(a) Root (b) Meristematic region of the root

(c) Shoot (d) Meristematic region of the shoot

81. A substance which accelerates the growth in stem is

(a) Etiolin (b) Auxin (c) Vitamin (d) Enzyme

82. Substances which originate at the tip of the stem and control growth elsewhere are

(a) Food material (b) Auxins or hormones (c) Vitamins (d) Enzymes

83. Which of the following statement is false with respect to application of auxins

(a) Control direction of growth of plants

(b) Inhibits lateral bud growth

(c) Initiate and promote cell division actively particularly in tissue culture

(d) Produce and hyper elongation effect

84. Leaf and fruit fall occurs on abscission layer is formed when the content of

(a) Auxin increases (b) Auxin decreases

(c) Abscisic acid decreases (d) Gibberellic acid decreases

85. In tobacco, enzymatic activity can be retarded by

(a) Minerals (b) Auxins (c) By more N_2 (d) None of these

86. Which of the following has auxin like property

(a) α-naphthalene acetic acid (b) β-naphthalene acetic acid

(c) Both (a) and (b) (d) None of these

87. Which of the following is 2, 4-*D*

(a) 2, 4 dichloroacetic acid (b) 2, 4 dichloroacetaldehyde

(c) 2, 4 dichloropropane (d) 2, 4 dichlorophenoxy acetic acid

88. Indole propionic acid is a

(a) Toxic substance (b) Acid obtained from fruits

(c) A substance obtained from hormone (d) A derivative of carbohydrate

89. Who among the following discovered the *Avena* curvature test to find out the concentration of auxins

(a) F.W. Went (b) L.J. Audus (c) K.V. Thimann (d) F. Skoog

90. With which of the following process *Cholodny Went theory* is concerned

(a) Phototropism (b) Photomorphogenesis (c) Photorespiration (d) Photoperiodism

91. Which of the following is not a chracteristic of auxin

(a) Polar translocation (b) Delay in abscission

(c) Apical dominance (d) Induce lateral bud formation

92. Auxin-*B* was first isolated by

(a) Kogl and Erxlaben (b) Kogl, Erxlaben and Hagen Smit

(c) Miller and Skoog (d) Yabuta and Sumiki

93. Auxin was first of all chemically characterised by

(a) Julius Sachs (b) F.W. Went (c) Charles Darwin (d) Thimann and Skoog

94. Low concentration of auxin lowers the growth of

(a) Root (b) Stem (c) Leaves (d) Dicot plants

95. 2, 4-*D* is a

(a) Insecticide (b) Weedicide (c) Nematicide (d) Rodenticide

96. Apical dominance means
(a) Suppression of growth of apical bud by axillary buds
(b) Suppression of growth of axillary buds by presence of apical bud
(c) Stimulation of growth of apical bud by removal of axillary buds
(d) Inhibition of growth of axillary buds by removal of apical bud

97. Formation of auxin is checked by
(a) Photosynthesis (b) Photo-oxidation (c) Phototropism (d) Darkness

98. 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 light

99. Which of the following effects of auxins on plants is the basis for commercial application
(a) Callus formation (b) Curvature of stem
(c) Induction of root formation in stem cuttings (d) All of the above

100. Plant hormone which is translocated to other parts for growth of the plant is known as
(a) Indole acetic acid (b) Gibberellins (c) Cytokinins (d) None of these

101. Most of the information regarding auxins have been obtained from
(a) Rice plant (b) Maize grains (c) Avena coleoptile (d) Wheat ear

102. Which of the following is not naturally occuring plant hormone
(a) 2, 4-*D* (b) GA_2 (c) Gibberellin (d) IAA

103. Highest concentration of auxins exist in
(a) At the base of various plant organs (b) Growing tip of plants
(c) In leaves (d) In xylem and phloem cells only

104. A well known naturally occuring auxin is **or** A natural growth regulator (hormone) is
(a) 2, 4-*D* (b) Indole acetic acid (c) NAA (d) Malic hydrazide

105. During germination, stem grows upward and root goes downward because
(a) It depends upon light (b)Of auxin
(c) It does not depend on light (d) Of epinasty and hyponasty

106. Storage sprouting of potato tubers can be prevented by treatment with low concentrations of
(a) Nicotinamide (b) Naphthalene acetic acid
(c)Nitrogenous fertilizer (d) Natural sunlight

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

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

109. The chief role of auxin is

(a) Internodal elongation (b)Parthenocarpy (c) Cell elongation (d) None of these

110. One of the preventive methods of fruit drop is by spraying

(a) Auxin (b) Ethylene gas (c) Gibberellins (d) Cytokinin

111. Parthenocarpy is induced by

(a) ABA (b) Auxin (c) Zeatin (d) Cytokinin

112. IBA is a

(a) Auxin (b) Gibberellin (c) Kinetin (d) None of these

113. *Avena* coleoptile auxin is

(a) IBA (b) Indole 3-lactic acid (c) Indole 2-acetic acid (d) Indole 3-acetic acid

114. Who demonstrated that decapitated Canary grass, seedlings resume phototropic sensitiveness when cut tip is pasted back in its position

(a) Darwin (b) Paal (c) Boysen-Jensen (d) Went

115. Removal of apical bud results in

(a) Formation of new apical bud (b) Elongation of main stem

(c) Death of plant (d) Formation of lateral branching

116. Movement of auxin is

(a) Centripetal (b) Basipetal (c) Acropetal (d) Both (b) and (c)

117. A good crop of tea leaves from a single plant can be obtained by

(a) Removing the apical buds of the main shoot and the branches

(b) Cutting off the top of the plant and then applying auxin to the cut ends

(c) Supplying auxin from the tip of the plant as well as through roots

(d) Feeding auxin to the plant through roots

118. Which one of the following nutrients is concerned with the growth of the plants in view of their role in synthesis of auxin

(a) *S* (b) *Mn* (c) *Zn* (d) *K*

119. Which of the following induces femaleness in plants

(a) Auxin (b) Gibberellin (c) Cytokinin (d) Abscisin

Advance Level

120. Indole-3-acetic acid called as *auxin* was first isolated from

(a) Human urine (b) Corn germ oil (c) *Fusarium* (d) *Rhizopus*

121. 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 stimulate rapid regeneration

(d) None of these

122. 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 accumulates 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

123. The formula of auxin '*a*' is

(a) $C_{18}H_{30}$ (b) $C_{18}H_{32}$ (c) $C_{18}H_{40}O_5$ (d) $C_{18}H_{40}O_{10}$

124. The primary precurser of IAA is

(a) Phenyl alanine (b) Tyrosine (c) Tryptophan (d) Leucine

125. Antiauxin used in picking cotton bolls is

(a) 2, 4-*D* (b) TIBA (c) NAA (d) Both (a) and (b)

126. An important finding in Went's experiment was

(a) Unequal distribution of elongation promoting substance in *Avena* coleoptile

(b) Presence of elongation factor in all cells of root

(c) Curvature of coleoptile is proportional to auxin concentration

(d) Curvature occurred due to irregular elongation of cells

127. Apical dominance in higher plants is due to

(a) Balance between auxin and cytokinin (b) Enzyme activity and metabolism

(c) Carbohydrates (d) Photoperiodism

128. The number of auxins received from *Phaseolus vulgaris* is

(a) 2 (b) 3 (c) 4 (d) 8

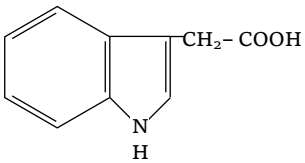
129. See the following structure of an auxin, that is

(a) IAA

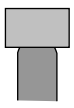
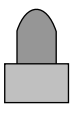
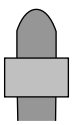
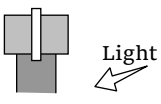
(b) Auxin *b*

(c) Auxin *a*

(d) None of the above



130. Which arrangement of an agar block on an oat coleoptile would result in IAA collecting in the agar

(a)  (b)  (c)  (d) 

131. Match the table

	I		**II**
(A)	Maheshwari	(i)	Pre-sowing treatment of seeds of *Phaseolus aureus* with IAA
(B)	Das	(ii)	*Avena* curvature test
(C)	Went	(iii)	Work on seedless fruit in *Cucumber*
(D)	Chakeravarty	(iv)	Successful culture of a ovule of *Papaver* using IAA and kinetin

Which of the following match is correct

	A	B	C	D
(a)	IV	III	II	I
(b)	I	II	III	IV
(c)	II	III	IV	I
(d)	III	I	IV	II

132. The discovery, that during light induced bending of stem the apex produces a diffusible chemical, was made by

(a) Charles Darwin and Francis Darwin (b) Boysen-Jensen and Paal

(c) Went (d) Van Overbeek

133. Which of the following effects of auxins on plants is the basis for commercial application

(a) Callus formation (b) Curvature of stem

(c) Induction of root formation in stem cuttings (d) Stem growth

134. Exactly opposite response of stem and root to gravity is because of

(a) Requirement of differential optimum concentration of auxin for elongation of stem and root cells

(b) Nature of these organs

(c) Position effect of these organs since embryonic stage in seed

(d) None of the above

135. Which is false about auxin ? It

(a) Promotes hyper elongation (b)Promotes cell division

(c) Promotes stem elongation (d)Inhibits lateral bud growth

136. I.A.A. was isolated by

(a) Kogl and Erxleben (b) Kogl and Haagen-Smit

(c) Erxleben and Haagen-Smit (d) Kogl, Erxleben and Haagen-Smit

137. Agent orange of Vietnam war was

(a) 2,4,5-T (b) 2,4-D (c) NAA (d)Mixture of (A) and (B)

GIBBERELLINS

Basic Level

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

139. 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

140. Gibberellins cause **or** Gibberellins stimulate
(a) Elongation of internodes (b) Curvature of coleoptile
(c) Cell division (d) Intiation of lateral roots

141. Which of the following exhibits a non-polar movement
(a) Auxin (b) Gibberellin (c) ABA (d) Auxin and cytokinin

142. The habit of a cabbage or acaulescent plant can be changed drastically by the application of
(a) IAA (b) GA_3 (c) ABA (d) 2,4-D

143. Gibberellic acid has been successfully used to induce flowering
(a) In short day plants under long day conditions
(b) In long day plants under short day conditions
(c) For some plants (d) None of the above

144. Which of the following is used to sprout the potato in winter
(a) Kinetin (b) Xylene (c) Ethylene (d) Gibberellin

145. Gibberellin is helpful in
(a) Elongation of plants (b)Inducing dwarfism (c) Fat hydrolysis (d) Protein synthesis

146. The hormone which was discovered through 'foolish seedlings' diseases of rice is
(a) Indole-3-acetic acid (b) Ethylene (c) Gibberellic acid (d) Kinetin

147. Gibberellins were first discovered in fungal genus
(a) *Mucor* (b) *Rhizopus* (c) *Agaricus* (d) *Fusarium*

148. Gibberellins promote
(a) Seed germination (b) Seed dormancy (c) Leaf fall (d) Root elongation

149. Which one does not affect apical dominance
(a) IAA (b) IBA (c) Gibberellin (d) Indole Acetaldehyde

150. Antigibberellin is
(a) Cycocel (b) Plastoquinone (c) IAA (d) Ubiquinone

151. The growth hormone, gibberellin, was discovered by
(a) Yabuta and Sumiki (b) Dutrochet and Dolk
(c) Donoho and Walker (d) Hashimoto and Rappaport

152. The fungus associated with discovery and source of gibberellins is

(a) *Fusarium oxysporum* (b)*Fusarium solanii*

(c) *Fusarium moniliforme* (d)*Fusarium longipes*

153. Gibberellins take part in

(a) Bolting of rosette plants (b)Replacing long day requirement

(c) Overcoming genetic dwarfism (d)All the above

154. Bakanae disease in the rice plants (paddy) is caused by

(a) Naphthalene acetic acid (NAA) (b)2, 4-Dichlorophenoxyacetic acid (2, 4-D)

(c) Gibberellic acid (GA) (d)Indole acetic acid (IAA)

Advance Level

155. Bioassay for gibberellin is

(a) Green leaf test/Richmond-Lang effect (b) Cell division/Bud induction test

(c) Dwarf maize/Barley aleurone test (d) *Avena* curvature test

156. At the onset of seed germination, the digestive enzymes amylase are produced by the action of

(a) Auxins (b) Gibberellins (c) Cytokinins (d) Ethylene

157. Gibberellin was first extracted from

(a) *Gibberella fujikuroi* (b) Algae

(c) Bacteria (d) Roots of higher plants

158. The number of gibberellins known till now is

(a) 15 (b) 26 (c) 38 (d) 60

159. Petals of which of the plant contains gibberellins

(a) *Cassia fistula* (b) *Rosa indica* (c) *Pisum sativum* (d) *Negella sativa*

160. Exogenous application of gibberellins induces male flower formation on genetically female plants in

(a) *Carica* (b) *Cucumis* (c) *Coccinia* (d) *Cucurbita*

CYTOKININ

Basic Level

161. Cytokinin firstly synthesized by

(a) Skoog and Miller (b) Letham (c) Bensan and Calvin (d) Thimman and Went

162. Name '*Zeatin*' was given by

(a) Skoog (b) Miller (c) Letham (d) Melver

163. Richmond-Lang effect is

(a) The effect of kinetins in delaying senescence

(b) The effect of colines on root and shoot formation

(c) The effect of traumatic acid in wound formation

(d)None of the above

164. Discovery of which one of following is connected with the use of an old sample of DNA in a culture medium

(a) Cytokinins (b) ABA (c) Vitamin *K* (d) Pantothanic acid

165. Cytokinin is a hormone whose main function is

(a) Induction of cell division and delay in senescence (b)To take part in cell division

(c) Refers to cell movements (d)To cause dormancy

166. An excised leaf does not turn yellow if it is induced to root. This is attributed to synthesis in root **or** Leaf aging is retarded by

(a) Ethylene (b) Cytokinins (c) Gibberellins (d) Auxins

167. Cytokinesis refers to

(a) Division of chromosomes (b) Division of cytoplasm

(c) Division of nucleus (d) None of these

168. Zeatin is a

(a) Vitamin (b) Growth inhibitor (c) Growth promotor (d) None of these

169. Cambial tissue of *pinus radiata* contains

(a) Auxins (b) Gibberellins (c) Cytokinin (d) None of the above

170. Which hormone is concerned chiefly with cell division in plants

(a) IAA (b) Kinin (c) GA_2 (d) 2,4-D

171. Which of the following is a coconut milk factor

(a) Auxin (b) Cytokinin (c) Morphactin (d) None of the above

172. A substance isolated from heiring sperm DNA and named as '*kinetin'* by

(a) Miller (b) Skoog (c) Saltza and Strong (d) All the above

173. Leaf fall can be prevented by

(a) Florigen (b) Auxin (c) Cytokinins (d) Abscisic acid

174. Which one induces flowering in short-day plants

(a) Auxin (b) Cytokinin (c) Gibberellin (d) Propylene

175. Cytokinin synthesis is maximum in

(a) Roots (b) Leaves (c) Shoot tip (d) Fruit

176. The morphogenetic property of cytokinin was experimentally proved first by

(a) Hanning (b) Guha and Maheshwari

(c) Skoog and Miller (d) Went

177. Guttman (1957) found a quick increase in the amount of RNA in the nuclei on onion root after

(a) Auxin treatment (b) Kinetin treatment (c)Gibberellin treatment (d)All the above

178. Which of the following is indispensable in all culture

(a) Gibberellin (b) Kinetin (c) Ethylene (d) Auxin

179. 6-furfuryl adenine is

(a) An auxin (b) A gibberellin (c) A cytokinin (d) A vitamin

180. The word "Cytokinin" which induces cell division was given by

(a) Yabuta (b) Brown (c) Letham (d) Fitting

181. The chief role of cytokinin is
(a) To check senescence
(b) To check evaporation
(c) To check abscission
(d) To mobilise solutes to different parts of plant and check senescence

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

183. Interfascicular cambium formation is induced by
(a) Auxin (b) Cytokinin (c) Gibberellin (d) Ethylene

184. Hormone that promotes growth of lateral buds/has negative effect on apical dominance is
(a) Cytokinin (b) Gibberellin (c) Auxin (d) Both (b) and (c)

185. Bananas can be prevented from overripening by
(a) Maintaining them at room temperature (b) Refrigeration
(c) Dipping in ascorbic acid solution (d) Storing in a freezer

186. Cytokinins are mostly produced in
(a) Shoot apex (b) Root apex (c) Young leaves (d) Lateral buds

187. Cytokinins
(a) Promote abscission (b) Influence water movment
(c) Help retain chlorophyll (d) Inhibit protoplasmic streaming

ETHYLENES

Basic Level

188. Ripening of banana is accompanied with
(a) Sudden rise in cytokinin (b) Sudden rise in auxin
(c)Sudden rise in ethylene (d) Sudden rise in gibberellin

189. Recognition of ethylene as a natural plant hormone was done by
(a) Haberlandt (b) Pratt Goeschi (c) Richmond Lang (d) Sorokin

190. Ethylene gas
(a) Is a saturated hydrocarbon
(b) Slows down the ripening of apples
(c) Retards ripening of tomatoes
(d) Speeds up maturation of fruits and early ripening of some fruits

191. Ethylene increases
(a) Respiration (b) Climactric temperature
(c) Photosynthesis (d) Transpiration

192. Highest proportion of ethylene is found in
(a) Fresh potato tuber (b) Green apple
(c) Green banana (d) Ripened banana

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

194. Unripened fruits are bitter in taste because of

(a) Sugars (b) Proteins (c) Acids (d) Tannins

195. Artificial ripening of fruits is accomplished by treatment with

(a) Sodium chloride (b) IAA (c) Ethylene gas (d) Kinetin

Advance Level

196. Which combination of gases is suitable of fruit ripening

(a) 80% C_2H_4 and 20% CO_2 (b) 80% CO_2 and 20% CH_2

(c) 80% CH_4 and 20% CO_2 (d)80% CO_2 and 20% O_2

197. Artificial ripening of which of the following fruits is useless

(a) Mango (b) Banana

(c) Grapes (d)Pomegranate/Coconut

198. Pineapple can be made to flower in off season by the application of

(a) Temperature (b) Zeatin (c) Ethylene / NAA (d) Short days

199. 'Climacteric' is

(a) A phenomenon related to fruit ripening

(b) The condition of a plant when all of its fruits are almost ripe

(c) The condition of a plant when most of its leaves have turned yellow

(d) None of the above

OTHER GROWTH REGULATORS

Basic Level

200. "Traumatin" is present in

(a) Old leaves (b) Cork (c) Wood (d) Injured portion

201. "Dormin" is a

(a) Growth promotor (b) Auxin (c) Abscisic acid (d) None of the above

202. "Morphactins" are

(a) Synthetic growth regulators (b)Synthetic auxins

(c) Synthetic gibberellins (d)None of the above

203. Elongation of internodes is inhibited by

(a) Gibberellins (b) Morphactins (c) Both (a) and (b) (d) None of the above

204. Abscisic acid controls

(a) Shoot elongation (b) Cell elongation and cell wall formation

(c) Cell division (d) Leaf fall and dormancy

205. Storage sprouting of potato can be prevented by

(a) IAA (b) Malic hydrazide (c) Cytokinins (d) Gibberellins

206. The following is a naturally occuring growth inhibitors

(a) IAA (b) ABA (c) NAA (d) GA

207. Xanthoxine is a

(a) Auxin (b) Gibberellin (c) Cytokinin (d) Dormin

208. Abscisic acid treatment results in

(a) Leaf expansion (b) Stem elongation (c) Stomatal closure (d) Root elongation

209. Caulocalines are formed in

(a) Root (b) Stem (c) Seed (d) Flower

210. Wound hormone is called

(a) Necrohormone (b) Hormone only (c) Auxins (d) Phyllocaline

211. Fromative hormone is

(a) Calines (b) Traumatic acid (c) Both (a) and (b) (d) None of the above

212. What is a stress hormone **or** The hormone produced during adverse environmental conditions is

(a) Benzyl aminopurine (b)Dichlorophenoxy acetic acid

(c) Ethylene (d)Abscisic acid

213. Bud dormancy is induced by

(a) IAA (b) GA (c) ABA (d) Ethylene

214. Which of the following is naturally occurring inhibitor of DNA synthesis and growth

(a) ABA (b) IAA (c) NAA (d) GA_3

Advance Level

215. Abscisic acid is an antitranspirant. It prevents transpiration by

(a) Forming a film impervious to water over the stomata

(b) Preventing K^+ ion uptake, thus decreasing the osmotic concentration of the guard cells and keeping them flaccid

(c) Inducing starch formation, thus decreasing the osmotic concentration of the guard cells and keeping them flaccid

(d) Increasing respiration, thus increasing CO_2 concentration in the guard cells which helps in keeping the guard cells flaccid

216. A substance which is used to stimulate the increase in size of the apple fruit is

(a) Morphactin (b) Promalin (c) Ethylene (d) Ethapone

217. Rhizocaline is a additional hormonal substance which is secreted by

(a) Cotyledons (b) Roots (c) Leaves (d) Stem

218. ABA possesses

(a) One symmetric carbon atom (b)One asymmetric carbon atom

(c) One symmetric and two asymmetric carbon atoms

(d)One asymmetric and two symmetric carbon atoms

PHYSIOLOGY OF FLOWERING (PHOTOPERIODISM AND VERNALIZATION)

Basic Level

219. The pigment involved in red-far red light interconversion is
(a) Cytochrome (b) Xanthophyll (c) Lycopen (d) Phytochrome

220. 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

221. In many plants the change over from vegetative to reproductive phase takes place in response to
(a) The length of the day (b) The severity of temperature
(c) Mainly the food material available in soil (d) Oxygen present in the air

222. 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

223. Which one of the following is an excellent example of physiological preconditioning
(a) Photosynthesis (b) Respiration (c) Photoperiodism (d) Vernalization

224. The term "*photoperiodism*" was proposed by **or** The phenomenon of photoperiodism in plants was discovered by
(a) Lysenko and Thimann (b)Blackmann and Skoog
(c) Garner and Allard (d)Chailakhyan and Borthwick

225. Skototropic movements are induced by
(a) Night (b) Light (c) Touch (d) Heat

226. Prolongation of continuous darkness will initiate
(a) Early flowering in short day plants (b) Delay flowering in short day plants
(c) Flowering will not be effected (d) None of these

227. Most of the plants are seasonal due to
(a) Photoperiodism (b) Phototropism (c) Photosynthesis (d) Photolysis

228. Which of the following is not short-day plant
(a) *Saccharum officinarum* (b)*Solanum tuberosum*
(c) *Glycine max* (d)*Brassica compestris*

229. What is the effect on the flowering of a plant if a flash of red light is followed by a flash of far-red light
(a) Flowering is increased (b)Flowering is decreased
(c) Flowering is stopped (d)Effect of red flash is reversed

230. A short-day plant was exposed to alternating red-far red treatments. What would happen if the last treatment was of far-red light

(a) Flowering would occur (b)Flowering would not occur

(c) Plant would etiolate (d)Plant would die

231. What will happen if several bulbs are lighted in soyabean fields in the night

(a) Production will be more (b) Production will be normal

(c) Production will be less (d) No effect

232. For short day plants, the critical period is

(a) Light (b) Dark (c) Ultraviolet rays (d) None of these

233. Which of the following process is called springization or springification

(a) Fertilization (b) Pollination (c) Vernalization (d) None of these

234. Phytochromes are active in

(a) Blue light (b) Green light (c) Red light (d) None of these

235. Name 'phytochrome' was given by

(a) Mothes (b) Borthwick and Hendrick (c) Sorokin *et al* (d) Wickson and Thimann

236. The practice of subjecting seeds to low temperatures for a period of time in order to cause growth and flowering during summer season is called

(a) Wintering (b) Vernalization (c) Devernalization (d) Thermolysis

237. Phytochrome is found in

(a) Algae (b)Fungi

(c) Vascular cryptogams (d)Flowering plants

238. 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

239. A hypothetical chemical involved in the flowering of plants is **or** Chemical agent which has important role in flowering is

(a) Gibberellin (b) Kinetin (c) Indole acetic acid (d) Florigen

240. Pigment phytochrome is involved in

(a) Phototropism (b) Photorespiration (c) Photoperiodism (d) Geotropism

241. A plant which needs not less than 10 hours of light to flower is

(a) Long day plant (b) Short day plant (c) Day neutral plant (d) None of these

242. Phytochrome is closely related to

(a) Chlorophyll '*e*' (b) Bacterio chlorophyll (c) Phycocyanin '*c*' (d) Carotenoid

243. Which of the following exerts profound effect on the reproductive growth of a flowering plant

(a) Quality (colour) of light (b) Quantity (intensity) of light

(c) Direction of light (d) Duration of light cycle

244. The flowering response of plant can be changed by
(a) Inducing mutations (b) Photoperiodic treatment
(c) Injecting enzymes (d) Somatic hybridization

245. 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*

246. Short night plants are
(a) Long day plants (b) Short day plants (c) Day neutral plants (d) None of the above

247. Which of the following is day neutral plant
(a) Tomato (b) Cotton (c) Sunflower (d) All the above

248. Garner and Allard have worked on
(a) Biloxy variety of soyabean (b) Maryland mammoth variety of tobacco
(c) Both (a) and (b) (d) None of the above

249. The short day winter annual pansy belong to genus
(a) *Iberis* (b) *Viola* (c) Mahua (d) *Papaver*

250. Types of plants that come to flower after exposure to short photoperiods followed by long photoperiods
(a) Intermediate plants (b) Day neutral plants (c) SLDP (d) LSDP

251. Vernalisation is
(a) Growth curve related to light (b) Effect of photoperiods on plant growth
(c) Speeding up ability to flower by low temperature treatment
(d) Diurnal photoperiodicity

252. Which does not take place in short day plants
(a) An interrupted critical dark period (b) Critical period is interrupted by light
(c) Dark period is interrupted by red light followed by far-red light
(d) Critical period is not interrupted by white or red light

253. Flowering dependent on cold treatment is
(a) Cryotherapy (b) Cryogenics (c) Cryoscopy (d) Vernalization

254. Florigen is produced in the region of
(a) Leaves (b) Fruit (c) Root (d) Trunk

255. Photoperiodic stimulus is picked up by
(a) Phytohormones (b) Stomata (c) Phytochrome (d) Enzymes

256. Hormone responsible for vernalization is
(a) Florigen (b) Colchicine (c) Abscisin (d) Vernalin

257. Who discovered the technique of converting winter variety into spring variety i.e., vernalization
(a) F.W. Went (b) Lysenko (c) Garner and Allard (d) Hendrics

258. Phytochrome was isolated by
(a) Butler *et al* (b) F. W. Went (c) R. Hill (d) Borthwick *et al*

259. If the tip of the seedling is cut off, growth as well as bending cease because it hampers
(a) Respiration (b) Photosynthesis
(c) Perception of light stimulus (d) Transpiration

260. Which wavelengths are the most effective in photoperiodism
(a) Green and yellow (b) Blue and red (c) Blue and violet (d) Red and far-red

261. A long day plant is
(a) Wheat / Spinach (b) Soyabean (c) Tobacco (d) *Xanthium*

262. Which one shows red ⇌ far-red interconversions
(a) Carotenoids (b) Cytochromes (c) Chlorophylls (d) Phytochrome

263. Photoperiodism influences
(a) Seed germination (b) Vegetative growth (c) Internode elongation (d) All of the above

264. Bolting does not require
(a) Short days (b) Long days
(c) Internode elongation in rosette plants (d) Cold nights

265. Pick up the correct explanation
(a) *Xanthium*-long day plant (b) Sunflower-short day plant
(c) Wheat-short day plant (d) Tomato-day neutral plant

266. A long day plant flowers only when it is exposed to
(a) Red light (b) Light more than critical day length
(c) Light equal to critical day length (d) Light less than critical day length

267. In short day plants, flowering is inhibited by
(a) Interruption of dark by white or red light (b) Dark interruption by far red light
(c) Dark interruption by red light followed by far red light
(d) Not possible

268. The relation of flowering to the lengths of light and dark period was investigated by two experiments. In one experiment, the plants were subjected to dark periods of various lengths while the light periods were kept at 4 hours. In the second experiment, plants were kept in dark periods of various lengths while the light periods were kept at 16 hours. The number of flowers formed in relation to these periods is shown in the table

Dark periods hours	**Flowers formed in experimental light periods**	
	4 hours	**16 hours**
8	0	0
10	0	0
12	4	6
14	5	7
16	5	8

These results indicate that flowering

(a) Requires long days (b) Is initiated by a long light period

(c) Is due to short light periods (d) Requires a minimum dark period

269. When all parts except the leaves of a short day plant are covered with a light-proof cover and then subjected to short day light/dark treatment, it will produce flower buds. When a portion of this plant is grafted on to another plant of the same species which has been prevented from flowering by excessive exposure to light this latter plant will also produce flower buds. Which is the best inference from this result

(a) Hormones can transmit information to all parts of plants

(b) Leaves are more sensitive to the photoperiodic stimulus than other parts of the plant

(c) The photoperiodic stimulus is received by the leaves and transmitted by a hormone

(d) The photoperiodic stimulus is received by all parts of the shoot and transmitted by a hormone

270. 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

271. The red-far red response is mediated by

(a) IAA (b) GA (c) CK (d) ABA

272. Physiologically active form of phytochrome is

(a) P_{660} (b) P_{730} (c) P_{860} (d) Mixture of all

273. What is the action spectrum of photoperiodism

(a) 430 and 660 *nm* (b) 640 and 660 *nm* (c) 660 and 730 *nm* (d) 700 and 900 *nm*

274. Which treatment is effective in red-far red response of plants

(a) First treatment (b) Last treatment

(c) Middle treatment (d) Sum total of treatment

275. Which is directly effected by light

(a) Photosynthesis (b) Flowering (c) Fertillization (d) Transpiration

276. If a plant subjected to continuous red light, phytochrome will show

(a) Increase synthesis (b) Decreased level

(c) Destruction (d) Destruction and synthesis remain in balance

277. *Chrysanthemum* flower in winter because or in evening because

(a) They are short day plants (b) They required low temperature treatment

(c) They are long day plants (d) Both (a) and (b)

278. Phytochrome is involved in

(a) Seed germination (b) Flowering (c) Chloroplast orientation (d)All the above

PLANT MOVEMENTS

Basic Level

279. Sleep movements in *Samanea saman* are regulated by

(a) *N* (b) *P* (c) *K* (d) *Mg*

280. If the stem grows towards sunlight and root grows just opposite to it, the stem movement is called

(a) Negative phototropic movement (b)Phototropic movement

(c) Positive phototropic movement (d)None of the above

281. Movements of leaves of sensitive plant, *Mimosa pudica* are due to

(a) Thermonasty (b) Seismonasty (c) Hydrotropism (d) Chemonasty

282. An apparatus commonly used to demonstrate phototropism is

(a) Heliotropic chamber (b) Clinostat (c) Arc Auxanometer (d) Potometer

283. Tertiary roots are

(a) Positively geotropic (b) Negatively geotropic (c) Plagiogeotropic (d) Ageotropic

284. Protoplasmic streaming movements are referred as

(a) Autonomic movements of locomotion (b) Thigmonasty

(c) Photonasty (d) Movements of curvature.

285. The best material for demonstrating streaming movements of protoplasm within living cells is

(a) Staminal hairs of *Tradescantia* (b) Onion peelings

(c) Pith cells (d) None of the above

286. Movements of tentacles in *Drosera* are

(a) Photonastic (b) Thermonastic (c) Thigmonastic (d) Seismonastic

287. Negative phototropism occurs in

(a) Root (b) Stem (c) Leaf (d) Flower

288. Pneumatophores show

(a) Positive geotropism (b) Negative geotropism (ageotropism)

(c) Thigmotropism (d) Negative phototropism

289. Factors which can modify geotropic responses are

(a) Root and shoot apices, temperature, light and atmospheric carbon dioxide

(b) Root and shoot apices, phytochrome, humidity and temperature

(c) Root and shoot apices, humidity and temperature

(d) None of the above

290. Nastic movements differ from tropic movements in being

(a) Movements of variation (b) Nondirectional

(c) Directional (d) Stimulated by chemicals.

291. Phototropism of stem and root are due to

(a) Differential hormonal effect (b) Epinasty and hyponasty

(c) Effect of light (d) Graviperception

292. Bending of stem towards light is
(a) Photoperiodism (b) Heliotropism (c) Photonasty (d) Hydrotropism

293. A potted plant placed near the window bends outwardly due to
(a) Greater oxygen availability to the tip (b) More auxin content on the shaded side
(c) Greater light availability to tip (d) Availability of necessary warmth to the tip

294. Jerky lateral leaflet movements of *Desmodium gyrans* are
(a) Negative geotropic movements (b)Positive geotropic movements
(c) Hydrotropic movements (d) None of the above

295. Opening of flower and drooping of a bud are
(a) Hyponasty (b)Epinasty
(c) Curvature movement (d)Spontaneous movements

296. Opening and closing of flowers represent a kind of
(a) Nastic movements (b)Tropic movements
(c) Nutation movements (d)Autonomic movements

297. Plant organs can detect a change in their orientation with respect of gravity
(a) Within a few seconds (b) Atleast a minimum of thirty minutes
(c) Atleast they have to be kept for a day (d) Atleast they have to be kept for a weak

298. Phototropism in shoots is attributed to or phototropic movements are due to
(a) Auxin (b) Gibberellins (c) Cytokinin (d) Abscisic acid

299. Thigmotropism is the response of the plant to
(a) Gravity (b) Water (c) Light (d) Contact

300. Positive geotropic response of root is
(a) Always (b) Rarely (c) Mostly (d) Nil

301. Both nyctinasty and thigmonasty are observed in
(a) *Drosera* (b) *Mimosa* (c) *Utricularia* (d) *Cuscuta*

302. On touching the leaves of *Mimosa pudica* droop down because of
(a) Seismonasty (b) Nyctinasty (c) Chemonasty (d) Thigmotropism

303. Clinostat is connected with
(a) Thigmotropism (b) Turgor changes
(c) Measurement of stomatal pores (d) Geotropism

304. Indian Telegraph plant is
(a) *Butea monosperma* (b) *Crotalaria juncea* (c) *Madhuca indica* (d) *Desmodium gyrans*

305. Tendrils exhibit/twining of tendrils is due to
(a) Thigmotropism (b) Seismonasty (c) Heliotropism (d) Diageotropism

306. Phototropic and geotropic movements are linked to
(a) Gibberellins (b) Enzymes (c) Auxin (d) Cytokinins

307. Geotropic response of roots is due to
(a) Inhibition of stem growth (b) More growth on lower side
(c) More growth on upper side (d) Uniform growth

308. Movement of sperms towards archegonial necks due to component of their exudate is
(a) Chemotropism (b) Chemotaxis (c) Phototaxis (d) Hydrotropism

309. Tropic movement is due to
(a) Cell elongation (b) Cell division (c) Both (a) and (b) (d) Cell thickening

310. Clinostat is employed in the study of
(a) Osmosis (b) Growth movements (c) Photosynthesis (d) Respiration

311. Closure of lid in Pitcher Plant is a
(a) Tropic movement (b) Turgor movement
(c) Paratonic movement (d) Autonomic movement

312. Movement of plant part in response to touch is
(a) Seismonasty (b) Thigmonasty (c) Nutation (d) None of the above

313. Some flowers (*e.g., Oxalis*) open in the morning and close during evening because of
(a) Photonasty (b) Phototropism (c) Phototaxis (d) Nyctinasty

314. Movements of tendrils in response to sensation of touch is
(a) Phototropism (b) Thigmotropism (c) Thigmonasty (d) Thermotropism

315. The leaves of *Mimosa pudica* (Sensitive Plant) droop down on touch because
(a) Plants have nervous system (b) The leaves are very tender
(c) The leaf tissues are injured (d) The turgor pressure of leaf base changes

316. Bulliform cells in grass leaves show
(a) Growth movements (b) Tropic movements (c) Nastic movements (d) Turgor movements

317. Example of positive geotropism is
(a) Closing of flowers (b) Upward growth of stem
(c) Downward growth of root (d) Lateral growth of root

318. Thigmotropism is best exhibited by
(a) Lamina (b) Tendrils (c) Root apex (d) Thorns

319. Which movement occurs due to external stimulus
(a) Tropic (b) Nastic (c) Tactic (d) All the above

320. Plant movement in response to diffuse stimulus of light is
(a) Phototropism (b) Photolysis (c) Phototaxis (d) Photonasty

321. Movement of Sunflower towards the direction of Sun in
(a) Photonasty (b) Phototropism (c) Nyctinasty (d) Seismonasty

322. Peristome teeth of moss shows
(a) Hydrochasy (b) Xerochasy (c) Hydrotropism (d) Chemotropism

323. Geotropic response is perceived by
(a) Mature roots (b) Elongating cells (c) Root cap (d) Root hairs

324. The minimum time interval required between application of stimulus and production of response is

(a) Presentation time (b) Relaxation time (c) Conversion time (d) Reaction time

325. The area of the plant which receives the stimulus is

(a) Perceptive region (b) Responsive region (c) Receptive region (d) Reactive region

326. The minimum time for which the stimulus must be applied in order to obtain a response is

(a) Conversion time (b) Conduction time (c) Presentation time (d) Reaction time

327. The area of photoperception is

(a) Region of elongation (b)Tip (c) Young leaves (d) Axillary buds

Advance Level

328. Clinostat is the apparatus used to

(a) Measure the rate of growth in plant (b) Measure the quantity of auxin in plant

(c) Measure the effect of light on plant (d) Eliminate the effect of gravity on plant

329. Sleep movements of leaves in certain plants are or photonasty is due to

(a) Excess of transpiration (b)The leaves getting tired of carrying on photosynthesis

(c) Decrease in the intensity of light (d)Differential growth at the base of leaf

330. What causes a green plant to bend towards light as it grows

(a) Because green plants need light to carry on photosynthesis

(b) Because green plants are phototropic

(c) Light stimulates, plant cells on the lighted side to grow faster

(d) Auxin accumulates on shaded side stimulating greater cell elongation

331. Two plants are fixed in two clinostats in a horizontal position. Clinostat **(a)** is rotated and clinostat **(b)** is stationary. What will happen

(a) In **a**, roots and shoots will move upwards. In **b**, roots and shoots will move downwards.

(b) In **a**, roots and stem will grow horizontal. In **b**, root will move downwards and stem upwards.

(c) In **a**, root and shoot will move downwards. In **b,** root and shoot will move upwards.

(d) In **a**, root will move downwards and stem upwards. In **b**, root will move upwards and stem downwards.

332. Leaf of Mimosa droops down on touching because of

(a) Water loss from leaflet bases

(b) Changes in water concentration

(c) Loss of water from cells to intercellular spaces in pulvinus and pulvinules

(d) All the above

MISCELLANEOUS QUESTIONS

Basic Level

333. Leaves of many grasses are capable of folding and unfolding because they
(a) Are very thin (b) Are isobilateral
(c) Have specialised bulliform cells (d) Have parallel vascular bundles

334. Growth of lateral branches is promoted by
(a) Removal of axillary buds (b) Auxin application over decapitated apex
(c) Auxin application over apical bud (d) Removal of apical bud

335. Growth hormone responsible for apical dominance is
(a) Auxin (b) Cytokinin (c) Gibberellin (d) Ethylene

336. In autumn leaf fall occurs because
(a) Formation of abscission layer at the bases (b) Leaf becomes heavy
(c) Leaf does not remain green (d) Of low temperature

337. For plant tissue culture which among the following is required
(a) Trypsin (b) Kinetin (c) Caffeine (d) Coumarin

338. The hormone capable of replacing the requirement of long photoperiods for flowering is
(a) Ethylene (b) Auxin (c) Gibberellin (d) Cytokinin

339. Dwarfness can be controlled by treating the plant with
(a) Cytokinin (b) Gibberellic acid (c) Auxin (d) Antigibberellin

340. Which can replace the requirement of vernalisation
(a) Cytokinin (b) Ethylene (c) Gibberellins (d) Auxin

341. Hormone primarily connected with cell division is
(a)IAA (b)NAA (c)Cytokinin/Zeatin (d)Gibberellic acid

342. During drought, plants develop hormone
(a) Indole acetic acid (b) Naphthalene acetic acid
(c) Indole butyric acid (d) Abscisic acid

343. Flowering of *Chrysanthemum* is inhibited by
(a) IAA (b) GA_3 (c) Cytokinin (d) Ethylene

344. Root cap takes part in
(a) Absorption of nutrients (b)Protection of root tip
(c) Control of geotropic movements (d)Both (b) and (c)

345. Which of the following is called as phytogerontological hormone
(a) Ethylene (b) Auxin (c) Gibberellin (d) Cytokinin

ANSWER

ASSIGNMENT (BASIC & ADVANCE LEVEL)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
d	a	d	a	c	b	a	b	b	b	b	c	b	b	a	d	b	a	b	b
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
c	b	c	a	d	c	c	b	b	b	b	b	c	a	b	d	b	c	b	a
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
c	b	b	a	d	a	a	d	b	a	a	b	d	b	c	d	a	d	c	b
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
b	c	c	b	b	c	d	c	c	b	c	d	b	b	c	a	b	c	a	d
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
b	b	c	b	b	c	d	c	a	a	d	b	b	b	b	b	b	a	d	a
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
c	a	b	b	b	b	d	b	c	a	b	a	d	a	d	b	a	c	a	a
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
b	c	c	c	b	c	a	d	a	b	a	b	c	a	a	b	d	b	b	a
141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
b	b	b	d	a	c	d	a	c	a	a	c	d	c	c	b	a	d	a	b
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
b	c	a	a	a	b	b	c	c	b	b	d	c	b	a	c	b	b	c	c
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
d	b	b	a	c	b	c	c	b	d	b	d	a	c	c	a	d	c	a	d
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220
c	a	b	d	b	b	d	c	a	a	a	d	c	a	b	b	a	b	d	c
221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
a	a	c	c	a	a	a	b	d	a	c	b	c	c	b	b	d	c	d	c
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
a	c	d	b	a	a	d	c	b	c	c	b	d	a	c	d	b	a	c	d
261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280
a	d	d	a	d	b	a	d	c	b	b	b	c	b	b	d	d	d	c	c
281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
b	a	d	a	a	c	a	b	c	b	a	b	b	d	b	a	d	a	d	c
301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320
a	a	d	d	a	c	c	b	a	b	c	b	a	b	d	d	c	b	d	c
321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340
b	a	c	d	a	c	b	d	c	d	b	c	c	d	a	a	b	c	b	c
341	342	343	344	345															
c	d	d	d	a															