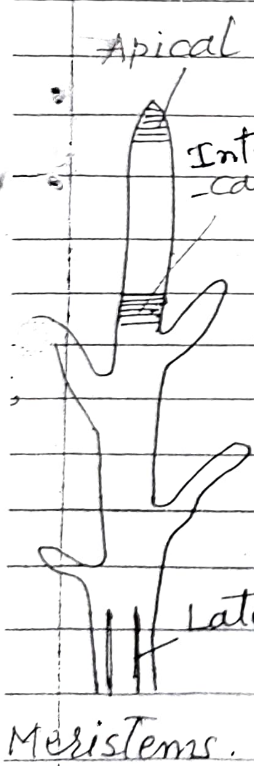
Unit-III : Growth & Developments

★ Growth :-

Growth is an important characteristics of a living structure. It is a very complex process and can not be easily defined. One important aspect of growth is the permanent change in size, ie. an increase in length or volume. Another aspect of growth is visualized in the form of an increase in dry weight.

Growth may be broadly defined as, "A permanent and irreversible change in size of a living structure alongwith increase in dry weight."

Growing points (Meristems) & Phases of growth :

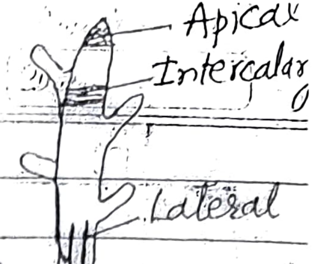


Growing points / Meristems :-

Growth in a plant is generally ~~related~~ limited to regions of growing points, known as meristems. The important growing points present in the root apex and stem apex are called apical meristems, & growth due to them is known as primary growth. The formation of tissues of a plant & the increase in length of the plant are due to primary growth.

In certain kinds of plants, eg: bamboo, mint, etc, increase in length is also due to intercalary meristems. These are actually a part of ~~meristem~~ apical meristems, which get separated from the apex by intervening permanent tissues. These meristems are of temporary nature.

A third type of growing point is known as lateral meristems, which is responsible for thickness of the plant in girth. This is called the secondary growth. Cambium & cork cambium are examples of lateral meri



Growing points / Meristems:-

Meristems are of three types.

1. Apical meristems:-

They lie at the apex of stem and roots of vascular plants. Very often, they are found at the apex of leaves. Due to their activity, the organ increases in length (primary growth).

2. Intercalary meristems:-

These are the portions of apical meristem that have separated from apex during development by permanent tissues and left behind due to growth of apical meristem. They are internodal in position and found at the base of internode or leaf base. They are common in stem of grasses (Bamboo and mint). These meristems are short-living and ultimately disappear and becomes permanent tissue.

3. Lateral meristems:-

These are composed of initials which divide periclinally and increase diameter of stem. They are responsible for sec. growth (growth in thickness).

e.g Cambium and cork cambium.

Periclinal - Parallel to the surface of plant organ.

Anticlinal - Right angles to the surface of plant organ.

Phases of Growth:-

In growing plants during the process of growth, the meristematic cells have to pass through three phases.

The meristems may be apical, intercalary or lateral.

Every cell responsible for growth must pass through the phases of growth.

The three phases of growth are;

1. Phase of cell division or formative phase.
2. Phase of cell enlargement or elongation.
3. Phase of cell maturation or differentiation

1. Phase of cell division or formative phase.-

i. It is first phase of growth.
ii. It occurs in meristematic region i.e. root tips and shoot tips.
iii. The meristematic cells divide by mitosis to form new cells.
iv. The cells divides constantly and multiply in number.
v. The addition of new cells results in slight increase in size.
(The harmones like cytokinins; auxins, etc. play important role in cell division of plants)
vi. The daughter cells are thin walled with prominent nucleus and dense cytoplasm completed into two phases i.e. karyokinesis (division of nucleus) and cytokinesis (division of cytoplasm).

2.

Phase of cell enlargement or Elongation phase –

i. It is second phase of growth.
ii. The phase of cell division is followed by cell enlargement phase.
iii. The new cells produced in first phase increase in size and volume i.e., enlargement.
iv. Enlargement of cell occurs more in the linear direction therefore, stem and root elongates during this phase, so also called as phase of elongation.
v. Enlargement takes place by synthesis of more protoplasm with large quantities of solutes and extension of cell wall.
vi. As cell has large quantities of solutes, large amount of water enters the cell due to osmotic effect (i.e. endosmosis) increasing its turgidity and volume.
vii. Extension of cell wall is followed by deposition of cell wall material i.e. cellulose.
viii. A large vacuole appears in the centre which pushes the cytoplasm to periphery.
ix. Thus, cell enlargement expresses itself as the visible sign of growth i.e. increase in size and weight of organ or plant occurs.

3. Phase of maturation or differentiation:
i. It is the final phase of growth.
ii. During this stage, cell mature and differentiates to obtain a permanent size.
iii. Cell differentiation is of various types as structural, physiological, biochemical, etc.
iv. During this phase, new cells undergo differentiation to form different tissues of mature plant organs.
v. The differentiation and maturation of different kinds of cells depends upon number of external, internal, genetic or hormonal factors.
vi. The cell assumes its final size, shape and structure during structural differentiation.
vii. Newly formed meristematic cells matures into xylem, phloem, parenchyma, sclerenchyma, etc.
viii. Physiological differentiation makes a cell specialized to perform a particular type of function like photosynthesis, translocation of water, etc.
ix. In this function region, the cell get differentiated into permanent tissue and secondary walls are laid down during maturation.
(Differentiation is local permanent change in structure, biochemistry or physiology of cell according its function and position).

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deposition of cellulose molecules due to which mor water is absorbed and turgidity increases. This phase also results in appearance of large vacuole.
(iii) Cell differentiation / maturation phase :- In this last phase of growth, the cells are mature and differentiated into permanent tissue.

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Measurement of growth :-

The rate of growth can be measured ~~in by different methods~~ by using different equipments, as follows :-

(1) Arc indicator :-

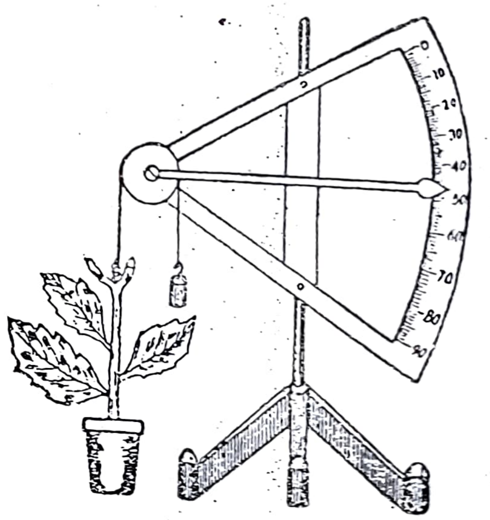


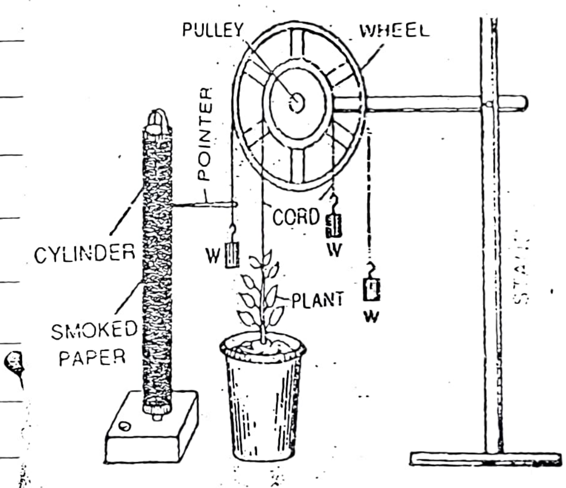
Fig. 19·3. An arc indicator.

In the arc indicator, a thread tied to the apex of stem is hung on a pulley and the other end of the thread is tied with a weight to keep it tight. The pully has a long pointer attached to it. The pointer slides over a graduated arc. The increase in the length of stem tip causes the weight tied to the thread to pull it. This results in moving the pully, & therefore, the pointer slides on the arc.

magnified

The growth is indicated in a magnified way. The magnification depends ~~on~~ upon the diameter of the pully and also on the length of the pointer. If the diameter of the pully is of 4 inches and the length of the pointer is of 20 inches, the magnification indicated on the arc is ten times.

(2) Pfeffer's automatic auxanometer :-



19'4. Pfeffer's auxanometer.

It consists of a revolving drum and ~~a revolving drum~~ two pulleys, one small & one larger. A thread tied to ~~small axis~~ stem apex is hung around the small pulley & its other ~~on~~ end is tied to a weight. Similarly, a thread is hung on large pulley, with both the ends tied with weights. An indicator is attached to the weight of the thread on one end to trace a line on the smoked paper pasted around the drum, which is kept in rotation (once every hour) by a clock work.

When growth takes place, the small pulley moves moving the other pulley which in turn moves the pointer to contineously make a scraching mark on the rotating smoked drum to record growth.

- With the help of radii of two pulleys and the rate of rotation of the drum the actual rate of growth can be calculated.

Factors affecting growth :-

Growth is affected by the factors which affect the activity of the protoplasm. A few imp. factors are discussed below :-

1) **Food supply** :- The supply of food is directly proportional to the rate of growth. With the deficient food supply to the growing region, the rate of growth decreases and ultimately stops. It affects the rate of growth because it provides growth material and potential energy to growing region.

2) **Water supply** :- The supply of water is also directly proportional to the rate of growth, because it is necessary for all metabolic activities of the

protoplasm & for increasing turgidity of the cell for cell enlargement.

3) Oxygen supply :- Oxygen increases growth because it helps in respiration & to convert potential energy into kinetic energy needed for vital activities of the plant including growth. O_2 also plays important role in G_1-stage of cell div^n.

4) Temperature :- Temperature also affects the growth directly or indirectly. Though growth occurs between 4°c to 45°C, optimum activity takes place at 28 to 33°C. The optimum temp. for growth of a plant is much dependent on the stages of development. Low temp. during nights reduces rate of respiration & high temp. during days increases photosynthesis & also the growth. Due to very low temp. (cold), plants are injured because of desiccation, chilling & freezing, while at temp. above 45°C, enzymes are inactivated. Both these conditions affect adversely.

5) Light :-
(a) Intensity of light :- High light intensity induce dwarfening ~~of~~ in the plant. Plants at top hills are short, whereas those of a ~~very~~ valley are tall. ~~ख़~~ Very weak light reduces photosynthesis & also rate of growth.
(b) Quality of light :- The overall growth of entire plant in full spectrum of visible light has been found to be better than the growth in any one of the different colors of light. The internode elongates most in blue violet. Expansion of leaves is least

in the green light.

(c) Duration of light :- The duration of light has pronounced effect on the growth of vegetative as well as reproductive structures. The duration of light is found to induce or suppress flowering.

6) Growth hormones :- Within last few years, it has been well-established that, the growth of plant is controlled by certain organic compounds present in a very minute quantity. These compounds are called as hormones or phyto-hormones or growth-promoting substances.

Avena curvature test (Went)

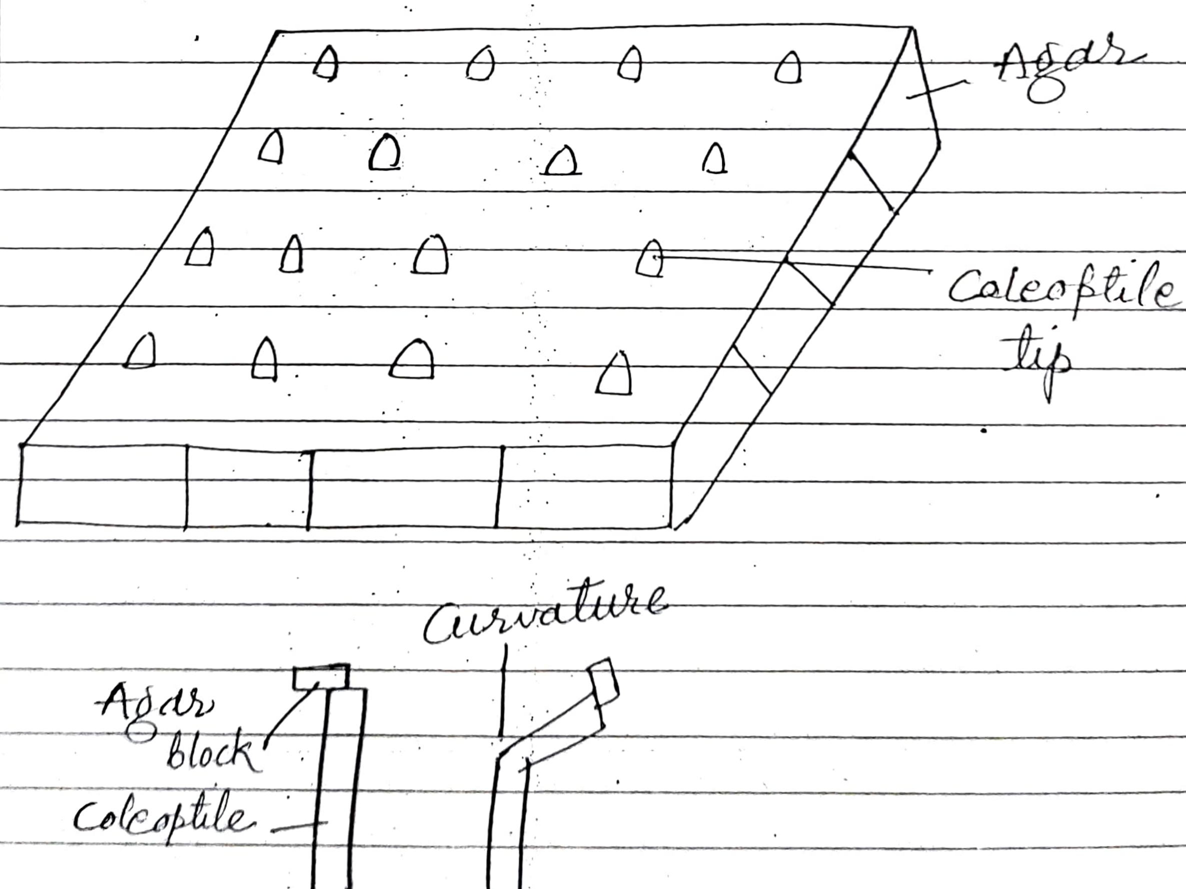


Fig. : Went's Experiment

* Plant growth regulators

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Certain substances affect the growth quite miraculously. In earlier literature, these were referred to as 'hormones'. Hormone is a Greek word derived from hormao which means to urge on or to stimulate. Thimann (1948) suggested to use the term phytohormones for hormones of plants. Phillips (1971) defined growth hormone as "Substances which are synthesized in particular cells & which are transferred to other cells where in extremely small quantities influence developmental process." The common hormones are auxins, gibberellins, cytokinines, ethylene, dormin, florigen, etc.

(1) Auxins :— (Gr. auxein = to grow)

Auxin is a group of hormones produced by the apices of stem & roots, which migrate from the apex to the zone of elongation. The auxins are essential for elongation process.

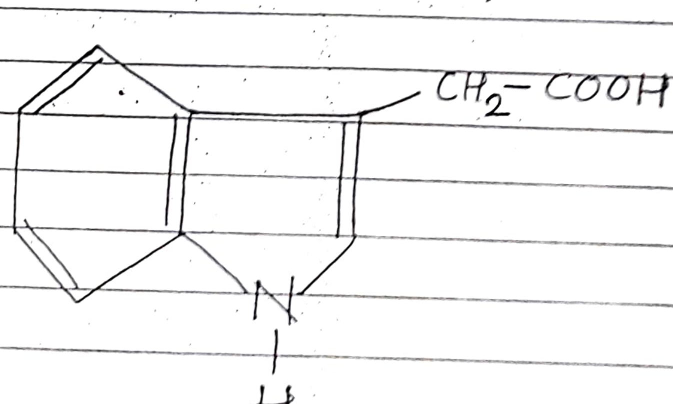
Most of the knowledge about auxins comes from the work on oat (Avena sativa). If the growing tip of oat coleoptile is removed, the remaining portion of coleoptile will show marked decrease in growth, which will ultimately stop. This means the growth is dependent on upper region. If the removed tip is placed on agar block for a period of several hours & then removed and the agar block now transferred to cut stem, it is observed that, the growth is resumed. This may be concluded that, the substance synthesized in the tip migrates downwards

in a grass or cereal

(in agar block) and is responsible for elongation of tip. The substance was denoted as auxin.

Went (1928) performed Avena curvature test. He placed several freshly cut coleoptile tips on agar blocks. After few hours, agar was cut into several pieces. He placed the agar block asymmetrically eccentrically (not in the centre) on the coleoptile cut portion for 2 hours in dark. The growth curvature occured & the coleoptile was bent on one side opposite to the agar block. It occured due to auxin diffusion from block to coleoptile resulting in elongation & growth on that side, as a result, coleoptile was bent. The experiment shows that, auxin is synthesized in coleoptile tip & is translocated downwards.

Chemical nature of auxins :-



Indole-3-acetic acid (IAA)

IAA is principle naturally occuring auxin of all higher plants. It also occurs in human urine. Many synthetic auxins are also being produced, some of them are Indole butyric acid (IBA), α & β-Naphthalene acetic acid (NAA), 2,4-Dichlorophenoxy acetic acid

(2,4-D), 2,4,5- Trichlorophenoxyacetic acid (2,4-T) & Indole propionic acid (IPA).

Practical Applications of auxins :-

(i) Germination :- IAA, IBA & NAA are mostly widely used for in soaking seeds for germination. In India, auxins are used widely to break the dormancy of seeds. But, at higher concentration & prolonged treatment, auxins retard & reduce germination.

(ii) Rooting :- Auxins are used to induce rooting. Roots induced by IBA showed increased number of vascular strands. If IBA is followed by with the supply of sugar or nitrogen, it induces still greater number of roots and higher number of strands.

(iii) Flowering :- Auxins accelerate the flowering in different plants. If 2,4-D & NAA are in dilute concentration are sprayed over a field of pineapple, the whole crop flowers with amazing uniformity. The use of auxin on wheat ~~(iv)~~ increases spikelet number, leaf number and weight & number of grains. In case of Gossypium hirsutum, the use of NAA & IBA increases the percentage of ball set.

(iv) Parthenocarpy :- In case of bhendi & brinjal, parthenocarpy was produced by NAA & IBA treatment. Treatment with NAA produced seedless fruits in cucumber & watermelon fruits. Now there are several examples.

(v) Fruit setting :- Improved fruit setting and increased yield have been produced by

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using auxins in plants belonging to Cucurbitaceae Solanaceae, Caricaceae, etc.

(vi) Prevention of premature drop of fruits :- The auxins 2,4-D, IAA, IBA are used to prevent premature drop of fruits in apple, pear, citrus, etc. Pre-harvest drop of sweet oranges can be controlled by using 2,4-D. & 2,4,5-T.

(vii) Tissue & organ culture :- The auxins are helpful in tissue & organ culture. Fast growth is reported in presence of auxins like IAA.

(viii) Weed control :- Auxins are selective weed-killers & are considerably used in the destruction of weeds in crop fields, rail-road sides, lawns & forests. Common weedicides of auxin in nature include 2,4-D, 2,4,5-T, NAA, etc. 2,4-D is selective weed-killer. It is highly-toxic to broad-leaved plants or dicots, while non-toxic to narrow-leaved plants or monocots. 2,4-D is economical, non-toxic to human beings & its residues disappear shortly from the soil.

(ix) Auxins as inhibitors :- Higher concentration of auxins inhibit the growth and exert toxic effect on the plants.

(2) Gibberellins :—

Gibberellins are second important hormones found in plants. It was first known by Konishi (1898) & discovered by Kurosava (1926). It was first extracted from the fungus Gibberella fusikuroi (Fusarium moniliforme), the causal organism of 'foolish seedling of rice' or commonly called bakanae disease of rice. The infected plants were usually taller, seedless & pale in color. These symptoms were produced due to a substance secreted by the fungus. Yabuta, Hayashi and Kannabe first isolated the active principle toxin from the fungus, which was called Gibberellin by them. Yabuta & Sumuki (1938), isolated Gibberelline A & B from the fungus, but soon after it was also isolated from the higher plants.

Chemical nature of Gibberellins :—

Gibberellins are cyclic diterpenes. Chemically, these are represented by molecular formula such as $C_{19}H_{24}O_6$ (GA_1), $C_{19}H_{26}O_6$ (GA_2), etc. They contain γ lactone ring on cyclohexane ring.

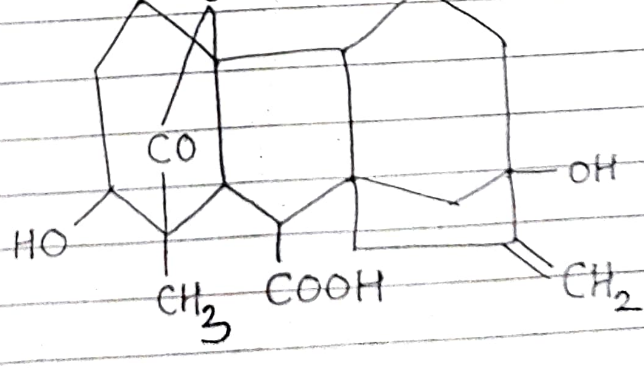


Fig: GA1

Now, more than 60 different types of Gibberellins are known & they are named as GA_1, GA_2, – upto GA_{60}. Largest number of Gibberellins (15 types) are reported from the fungus *Gibberella fujikuroi*. About 51 types are found in higher plants.

Practical applications of Gibberellins :– (GA) :

(i) **Germination** :– Gibberellins are widely used for germination. They accelerate germination of seeds in different plants, like *Morus indica*. GA increases the length of hypocotyl & cotyledonary leaf area of *Phaseolus aureus*.

(ii) **Rooting** :– Gibberellins have no effect on rooting. Gibberellins not only inhibit the root initiation, but also the stimulation of rooting caused by auxin is also counteracted.

(iii) **Leaf expansion** :– In pea, bean, tomato, pepper, cucumber, sweet corn & cabbage plants when treated with GA, leaves become broader & elongated. This results in an increase in photosynthetic area which heightens the plants.

(iv) **Flowering** :– GA induces flowering in long day plants and in plants requiring inductive cold period, in general. It also promotes the formation of male flowers by playing important role in development of androecium.

(v) **Parthenocarpy** :– GA induces parthenocarpic fruits in case of guava, brinjal, etc.

(vi) **Fruit setting** :– GA affects positively on fruit setting in grapes. An increased fruit sets, size, total yield & quality of sweet lime ~~too~~ is also reported.

(vii) Prevention of premature drop of fruits :-
The effect of GA on fruit drops is not clear, Though reduction in fruit drop in Citrus reticulata is reported.

(viii) Stem elongation :- The most important effect of GA is the stem elongation. i.e. GA induces cell elongation in several plants, such as pea, bean, tomato, pepper, sweet corn, cabbage, etc. In these plants, a significant elongation of internodes is reported.

(ix) Pollen germination :- GA treatment in certain Plant ~~sugarcane~~ induces pollen germination in vitro. These pollens could not germinate under normal conditions. GA also accelerates growth of pollen tube.

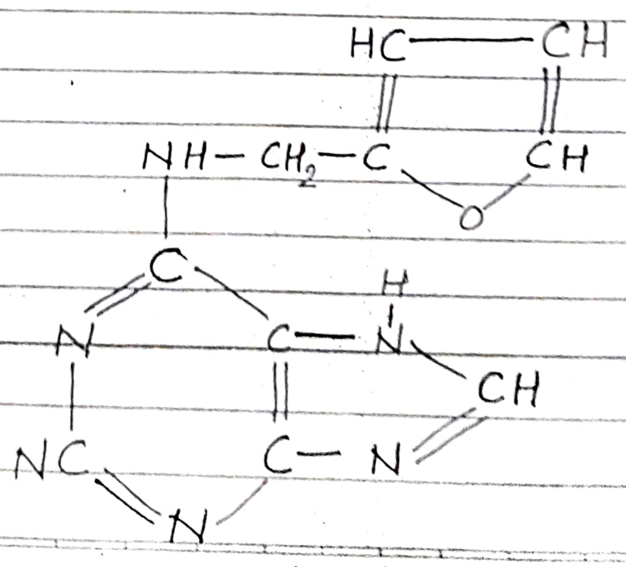
(x) Breaking of dormancy :- In temperate plants, buds become dormant in late summer & donot sprout even when exposed to sufficient moisture, temperature & oxygen. These require treatment with low temp. or long days or red light. GA overcomes such dormancy. Potato tubers can be made to germinate in winter by GA treatment.

(3) Cytokinins :-

Cautheret (1939), Nobecourt (1939) and White (1939) were the first to report the success of plant tissue culture. Skoog (1954) reported that a substance present in vascular tissue of Nicotiana tabacum was responsible for causing cell-division in the pith cells. Since the substance had specific effect on cytokinesis, it was named 'Kinetin'. Various terms such as Kinetenoid, phytokinin, phyto-cytomin have been used for Kinetin, but the term 'cytokinin' proposed by Letham (1963) has been widely accepted. Cytokinines are characterised by initiation of cell-division, delay of senescence, use in tissue culture and counteract apical dominance.

Chemical nature of cytokinin / Kinetin :-

Miller (1954) was the first to isolate kinetin. Kinetin has been found to contain C, H, N & O in the ratio - $C_{10}H_9N_5O$



Miller proposed that, the group comprises a furan nucleus on extra carbon present either as a side methyl on the furan ring or as a methylene radical between the furan and purine nuclei. Strong (1956) suggested that, kinetin was an adenine bearing a furfuryl substituent at 6 position.

Naturally occuring cytokinins :- Cytokinins have so far been extracted from coconut milk, tomato juice, fruits of pear & plum, cambial tissues of *Pinus radiata*, *Eucalypus regnans* & *Nicotiana tabacum*, immature fruits of maize, banana, etc, female gametophytes of *Ginkgo biloba*, seedlings of *Pisum sativum* & root exudates of sunflower. Letham (1963) obtained zeatin in pure crystalline form from immature corn grains.

Practical applications of cytokinins :-

Morphogenesis - Formation of organs

(i) Cell-division :- It is the most important property associated with cytokinins. On exogenous supply of cytokinin, a normal Vinca cell converts into a tumour cell. IAA alongwith cytokinin induced many mitotic divisions in tobacco pith tissues. It has been confirmed in many cases.

(ii) Cell enlargement :- Cytokinins help in cell enlargement in many plants. The effect can be doubled in combination with auxins.

(iii) Morphogenesis :- A dramatic response of cytokinins in formⁿ of organs is reported. In case of tobacco pith, a balanced level of IAA and kinetin produces callus & if the ratio of kinetin is raised, there is formation of buds, which may grow into a complete tobacco plant.

(iv) Breaking of dormancy :- Cytokinins are found effective in breaking dormancy of seeds and some other plant organs. Lactuca sativa requires red light for breaking its seed dormancy, but this effect was overpowered by application of kinetin, which acts here as a substitute to red light. Similar effects were reported in seeds of Tobacco, carpet grass, etc.

(v) Apical dominance :- Cytokinins counteract the usual apical dominance of bud & induce lateral bud formation.

(vi) Initiation of interfascicular cambium :- Kinetin can induce formation of interfascicular cambium. It was reported in pea stem.

(vii) Nucleic acid metabolism :- A quick increase in amount of RNA in onion root after kinetin treatment. In tobacco pith cells, increase in DNA has been reported.

(viii) Protein synthesis :- It is found that, the rate of protein synthesis increases on kinetin treatment. Cytokinines regulate translocation in protein synthesis.

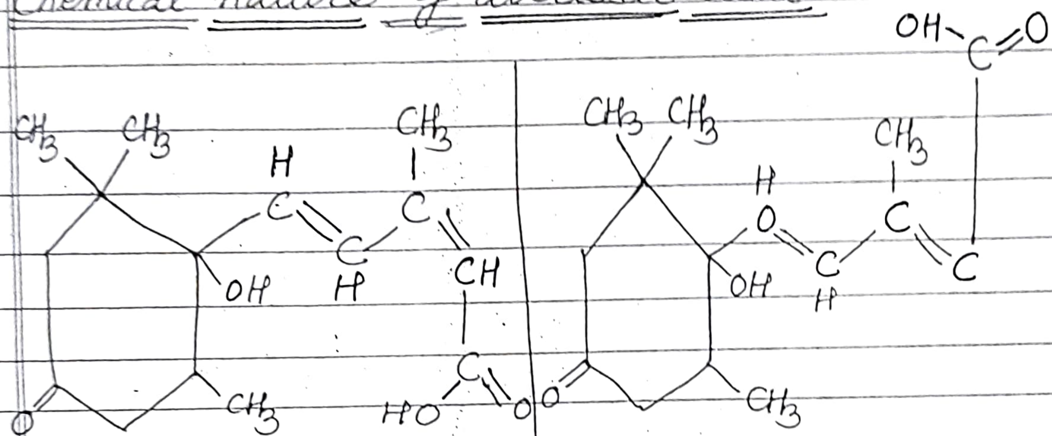
(ix) Cytokinins & Florigens :- Cytokinins are found to act as florigens (ie. induce flowering) in short day plants, such as Duckweeds.

Apical dominance :- Suppression of the emergence of lateral buds by the presence of lateral buds by the presence of shoot apex

(4) Abscissic acid (ABA) :-
(Stress harmone)

Certain plants have been found to contain a new type of hormone which acts as growth inhibitors. It has a wide range of physiological effect - inducing senescence & abscission, retardation & inhibition of growth. Abscissic acid is a naturally occuring hormone present in a wide variety of plants.

Chemical nature of abscissic acid :-



Cis - Abscissic acid | Trans - Abscissic acid

The 15 C atoms of ABA configure an aliphatic ring with one double bond, 2 methyl groups & an unsaturated chain with a terminal carboxyl group. Nearly all the naturally occuring ABA is in the cis-form. The biological activity of ABA have shown that, almost any change in the molecules results in loss of activity.

Role of Abscissic acid :-

(i) Bud dormancy :- ABA has been found to induce bud dormancy in certain plants. It is believed that bud dormancy is controlled through the changes in the levels of endogenous growth inhibitors (ABA), which is influenced by day length & chilling effects.

(ii) Senescence :- Senescence of leaf is promoted by ABA. Senescence is last developmental stage prior to death of an organ or of the whole organism.

(iii) Abscission :- It is believed that, cause of abscission is the presence of ~~to~~ growth inhibitor hormone (ABA).

(iv) Flower initiation :- In certain short day plants ABA induces flowering in long days. It inhibits flowering in long day plants.

(v) Release of ethylene :- ABA stimulates the release of ethylene.

(vi) Water stress :- When water stress is develops ABA reduces the stomatal aperture to reduce transpiration. Thus, it plays important role in draught resistance, desication & tolerance. It is also called stress hormone.

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senescence :- degradative changes finally leading to death of an organ or organism (Proteins, chlorophyll and nucleic acid become brokendown into simpler compounds like sugars, aminoacids which are exported out to other parts and leaf becomes chlorotic.

Abscission :- Falling of leaves, flowers and fruits (due to auxin production capacity decreases in old and damaged parts)

(5) Ethylene :- (The ripening hormone)

Ethylene is a gas & occurs in all plant organs like roots, stems, leaves, bulbs, tubers, fruits & seeds. Ethylene production varies from tissue to tissue within the organ, but is frequently located in peripheral tissues. It is also considered to be growth-inhibiting hormone like ABA. The ethylene formation is associated with the ripening process of fruits.

Structure of ethylene :-

$$H_2C = CH_2$$

The molecular formula of ethylene is C_2H_4. It has mol. wt. 28 & is lighter than air under physiological conditions.

Role of ethylene :-

(To contd.)

(i) **Abscission** :- Ethylene is principle accelerator of abscission, capable of promoting ~~agi~~ the ageing of leaves, petioles, flowers and fruits. It causes abscission through the enhancement of activity of cell-wall destroying enzymes.

(ii) **Ripening** :- Ripening and maturity of fruits are two basic properties of ~~these~~ this gas hormone. When applied as foliar spray, ethylene accelerates maturity & induces uniform ripening in pine apple & figs & induces fruiting in ornamental plants.

(iii) **Degreening of Citrus & banana fruits** :- Since green Citrus & banana fruits are not acceptable to market, their artificial degreening is required. Ethylene degreening is a common commercial practice in U.S.A., Japan, Israel, Australia & several other countries. Degreening does not occur during exposure to ethylene, but it does occur by exposing the ethylene treated fruits to air.

(iv) Chlorophyllase activity :- Ethylene remarkably increases the chlorophyllase activity. It may be the reason for degreening phenomenon.

(v) Wound response :- When plants are wounded, rapid ethylene formation takes place, which reduces the stress & helps the plant to withstand the infection.

(vi) Flower induction :- The ethylene ~~production~~ is commercially important hormone, in the induction of flowering in pineapple, mango, apple, etc.

(vii) Breaks Seed Dormancy :- Ethylene breaks the dormancy of seed & causes sprouting of potato tuber.

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* Seed Dormancy :-

Majority of the land plants pass thro' a phase of dormancy at some ~~phase~~ stage in the life cycle. In ~~hi~~ lower plants, dormancy is represented by resting spores & in higher plants, seed stage is important dormant phase. In certain plants, specialized resting organs such as tubers, rhizomes, ~~bulb~~ bulbs, etc. are formed. The dormant phase in plants is meant to pass over the unfavourable conditions for growth, such as low or high temperatures. Thus, it is the typical phase of life-cycle which shows special adaptation to adverse environmental conditions. "Dormancy is a state of suspended growth & metabolism".

Dormancy in plants is both a convenience and an inconvenience to humans. The temporary dormant period experienced by many cereal grains allows for their harvest, dry storage & ultimate use as food. Otherwise these grains would germinate & useless ~~for~~ to us. The ability of certain weed seeds to lie dormant for many years in soil has proven to be of great inconvenience. During ploughing, the dormancy of many ~~seeds~~ of these seeds will be broken, thereby allowing them to compete with any economic crop sown in that area.

Causes of seed dormancy :-

If all the conditions such as supply of oxygen, water and suitable temperature are favourable, the seed germinates immediately. But, many seeds do not germinate even under ideal conditions of Oxygen, water & temperature. Such seeds are said to exhibit dormancy. The causes of seed dormancy are as follows :-

(i) Dormancy due to seed coat :- A hard seed coat can cause dormancy in three ways

(a) seed coat impermeable to water : Seeds of many plants including leguminosae, Malvaceae, Solanaceae, etc. have hard seed coats. Such seed coats are impermeable to water.

(b) Seed coat impermeable to oxygen :- In some species, the hard seed coat is completely impermeable to oxygen. Such seeds would not germinate unless they have undergone the period of dormancy, during which the permeability of seed coat will gradually increase.

(c) Mechanically resistant seed coat :- In certain wild plants, the hard seed coat acts as a physical barrier to the expansion of embryo.

(ii) Dormancy due to immature embryos :- Some seeds are shed before the embryo is mature & not fit to grow. Such seeds require an 'after ripening period', during which period certain changes occur within the seed. It is believed that, there is some change of acidity, enzyme activity & respiratory rate or may be activation of production of some growth-promoting hormones or may be the inactivation of some germination-inhibitory substances within seeds. Once embryo development is complete, the seed then germinate without any special treatment.

(iii) Dormancy due to chemical inhibitors :- The seeds present inside the juicy fruits such as oranges & tomatoes do not germinate while in fruit plenty of liquid is present. It is due to presence of germination inhibitory substances such as Coumarins & para-ascorbic acids. These can be destroyed by chilling treatment.

(iv) Dormancy requiring for after ripening in dry storage :- At the time of harvesting, seeds of many plants are dormant, but do not require any special treatment to overcome dormancy. Simply keeping them under dry storage conditions at normal temp. for few weeks to several months overcomes dormancy. Many of common cereals such as barley, oat, wheat etc. show this type of dormancy.

(v) Dormancy requiring for chilling treatment :- Many seeds of temperate species show dormancy which is overcome by chilling. eg. seeds of apple, rose & peach will not germinate if kept under moist conditions at 20 °C, ~~for several weeks~~ but will germinate if kept under moist conditions at 0-5 °C for several weeks & then transferred to warmer conditions. Other examples include *Pinus*, *Prunus*, *Rosa*, *Thuja*, etc.

(vi) Dormancy due to light sensitivity :- Germination of many seeds is affected by light. Such seeds are called photoblastic. The seeds in which $germ^n$- is stimulated by light are called +vely photoblastic (eg: tomato, tobacco, etc), whereas those in which $germ^n$- is inhibited by light are called negatively photoblastic (eg.: *Nigella*, *Silene* etc).

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Methods of breaking seed dormancy :-

The methods employed for breaking seed dormancy vary from species to species depending upon the cause of the dormancy.

(1) **Scarification** :- Scarification is a treatment by which the hard seed coat is ruptured or weakened. Scarification may be of 2 types :-

(a) **Mechanical** – It includes threshing of the seeds by machine, rupturing the seeds with hammer, cutting the seed coat by scalpel, etc.

(b) **Chemical** – It includes keeping the seeds in strong acids or certain organic solvents.

In nature, the dormancy is broken by the slow decay of the seed coats.

(2) **Low Temperature (chilling)** :- In some cases, after-ripening of the seeds occurs rapidly at low Temperature (0-5°c). Under field conditions, this chilling requirement is normally met by the natural winter temperatures. That is why such seeds do not germinate in the autumn when they are shed & their germination is delayed untill the following spring.

(3) **Alternating Temperature** :- Seeds in which the embryos are in dormant stage, dormancy may be broken by exposing them alternately to low and high temperatures. Difference between the two extreme temperature must not be more than 10 – 20 °C.

(4) Seed stratification :- If The dormancy is due to inhibitory substances, the chilling of seeds is adopted by placing the seeds in different layers of soil. This is called stratification. The inhibitory substances get washed away as the seed lies in the ground.

(5) Light :— Seeds whose germination is affected by light are called photoblastic. The positively photo-blastic seeds overcome their dormancy when They are exposed To light. The germination of a comparitively small number of negatively photo-blastic seeds is inhibited by exposure to light.

(6) Pressure :- In This method, the dormancy of seeds is broken by exposing them to high atmospheric pressure. The dormancy due to impermeability of water and oxygen is broken by this method. Seeds of sweet clover (Meliotus alba) & alfalfa (Medicago sativa) showed improved germination after being subjected to hydraulic pressure of 2000 atm. at 18 °C.

★ Seed germination :-

An ovule after fertilization develops into a mature embryo inside the ovary itself. Protected by testa, it develops into a multi-cellular embryo with radicle (which develops into primary root afterwards) and plumule (which develops into primary shoot afterwards) It is provided with one cotyledon in case of monocots or two cotyledons in case of dicots, with stored food for embryo to utilize till it becomes capable of synthesizing its own food.

A mature seed in some cases can germinate immediately after the completion of its formation if proper conditions are given. In most cases it can germinate only after a certain period of rest or dormancy. Germination includes the stages through which an embryo passes to become an independent plant capable of supporting itself and synthesizing its own food.

For germination, two factors are necessary.

(a) Moisture which enters the seed by imbibition & helps to start biochemical activity including activation of enzymes.

(b) oxygen which is needed by seed for increasing the rate of respiration to provide more energy to the developing embryo.

Mechanism of seed germination :-

Germination of seed is the first step towards plant growth. In favourable conditions of environment, seed germinates.

The embryo ~~&~~ lies dormant in the seed, but when the seed is supplied with moisture, the embryo becomes active and tends to develop into a small seedling." The resumption of metabolic activity and growth by the seed tissue is called germination." In other words, "the process by which the dormant embryo wakes up & begins to grow is known as germination." The embryo grows by absorbing the food material stored up in the cotyledons, or the endosperm, when it is present. At first, the seed absorbs moisture & swells up considerably. The radicles elongates & comes out thro' the micropyle & gives ~~out~~ rise to the root. It's rate of growth is much faster than that of the plumule. As a result of swelling, the seed coat bursts and the cotyledons ~~are~~ partially or completely separate from each-other to give way to plumule which lies within. Prior to germination, several physiological processes occur within the seed. A rapid increase in respiration occurs. This is accompanied by the appearance of some hydrolytic enzymes that break down food materials stored in the seed to simpler molecules that can be utilized by the seedling until it can become photosynthetically efficient.

Types of germination :—

(1) Epigeal germination :- The type of germination in which the cotyledons come above the surface of soil is called epigeal germination. In this type of germination, the hypocotyl grows fastly & brings the cotyledons above the soil surface. When cotyledons

come above the soil surface, Turns green & photosynthetic. It is found in many dicot plants like tamarind, cucumber, cotton, castor, bean, sunflower, etc.

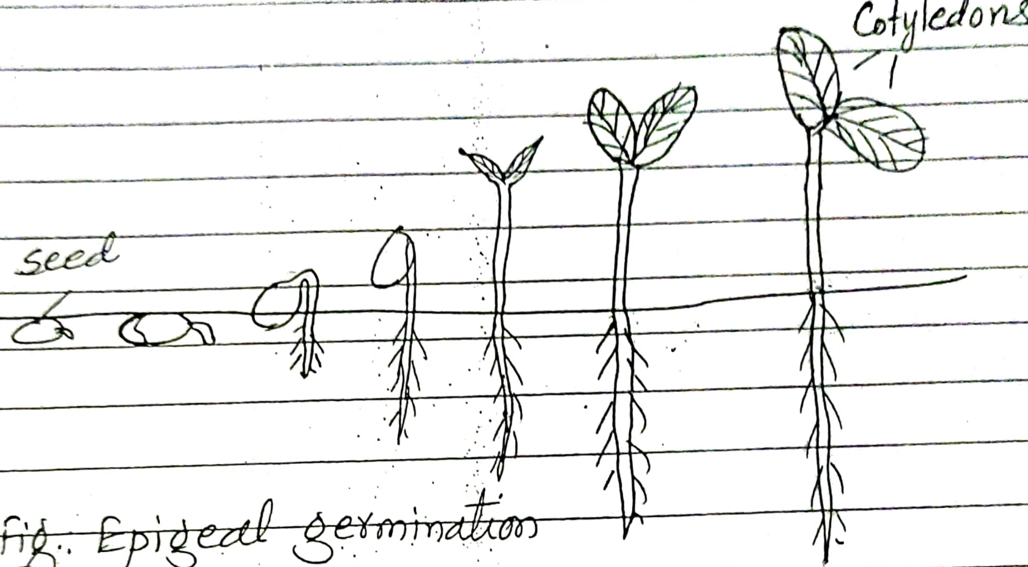

fig.: Epigeal germination

(2) Hypogeal germination :- The type of germination in which the cotyledons remain below the soil surface are called as hypogeal germination. In this type of germination, the epicotyl elongates and carries the plumule above soil surface. It is commonly found in the monocot plants like maize, coconut, etc. It is also found in some dicot plants like gram, ~~bean~~ pea, groundnut, mango, etc.

HYPo-below
geal-soil.

(3) Viviparous germination :- In this type of germination, the seeds germinate within the fruit, while the fruit is still attached to the mother plant. It occurs in several species of the plants of mangrove vegetation, such as Rhizophora, Sonneratia, Ceriops, Candelia, Avicennia, etc. The seeds in such plants do not

germinate in soil due to high salt contents and deficiency of oxygen in the marshy habitats. In such plants, the seed dormancy is absent. Instead, the embryo grows continuously without any hinderance inside the fruit, while it is still attached to the mother plant.

During this type of germination, the hypocotyl elongates & pushes the radicle out of the seed & fruit. Thereafter, the hypocotyl grows more vigorously & becomes club-like & sometimes attains a length of 50 cm or so, as in Rhizophora. The young green seedling comes out of the fruit showing the long hypocotyl & radicle. The cotyledons act as haustoria & suck food from the parent plant. When the seedling gains weight, it is detached from the fruit & falls down vertically like a dart (तीर). Now, the radicle penetrates into the mud. The lateral roots immediately develop on this seedling and it soon establishes as a plant in the muddy soil. The plumule remains above the water level and grows safely.

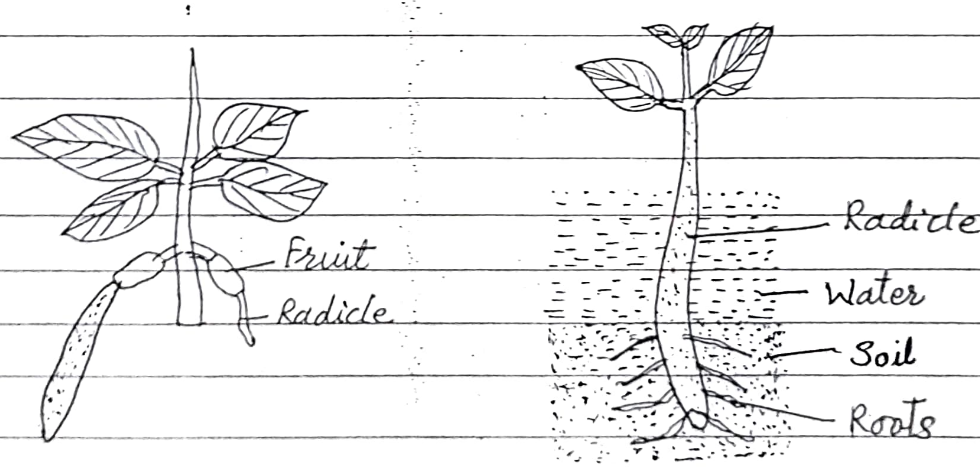

Fig. Viviparous germination

cotyledon - it is a part where reserve food material is stored.

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★ Physiology of flowering :

Flowering is an important phase of life-cycle, because the transition from the vegetative growth to reproductive phase involve various changes in the physiology of plant. Flowering is a decisive stage. It requires a definite period of vegetative growth. The period may vary from plant to plant. eg.: a fruiting tree requires several years to flower, while an annual herb flowers in a few months only. The physiological mechanism responsible for flowering has been found to be controlled by —
(i) Periodicity of light (photoperiodism), and
(ii) temperature (vernalization).

(1) Photoperiodism :-

It is found that, the length of daylight period ~~has been found~~ plays important role in flowering. Garner & Allard (1920) found that, a mutant variety of tobacco, Maryland mammoth flowered when the relative length of day was shorter than length of the dark period. This led to the discovery of photoperiodism. They used the term photoperiodism to designate the response of ~~an~~ organism to the relative length of day & night and photoperiod to designate the favourable length of day for each plant. Thus "photoperiodism is the response of plants to relative length of day and night."

On the basis of length of photoperiod requirements of plants, the plants are classified as
(i) Short-day plants,
(ii) Long-day plants. &
(iii) Day-neutral plants

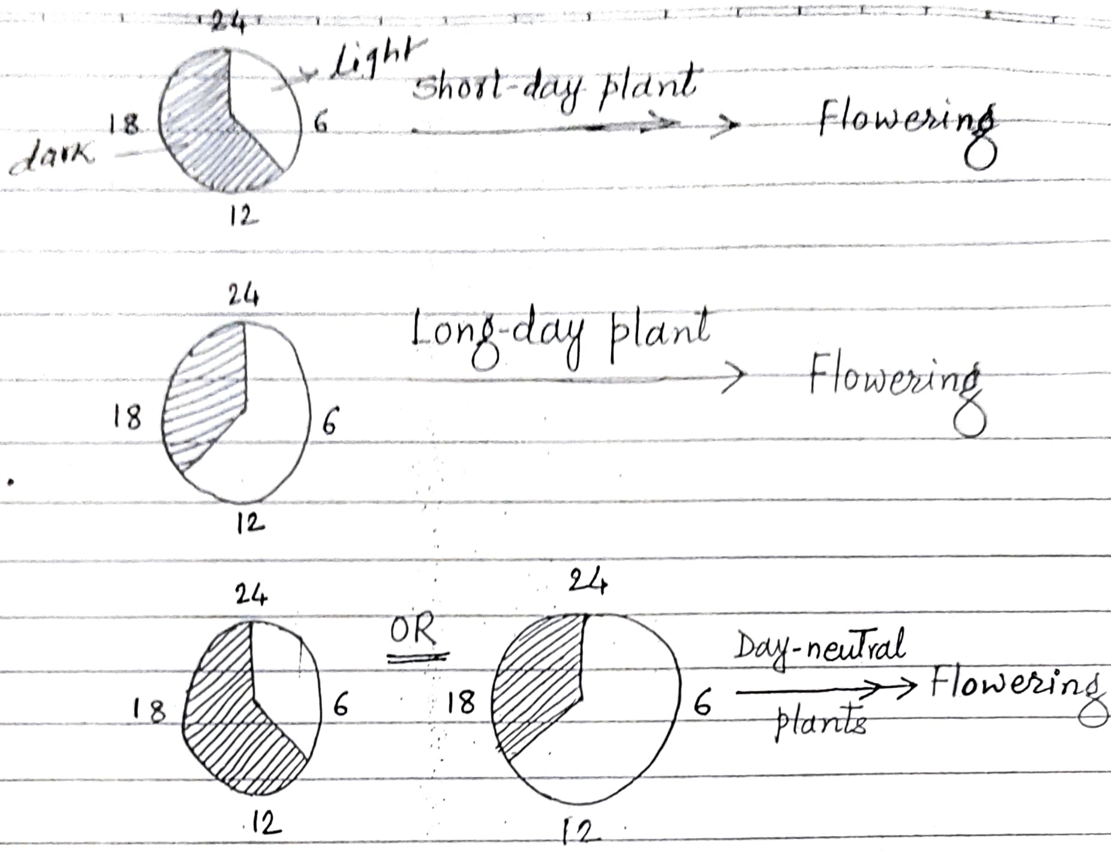

Fig. : The three categories of plants.

Critical photoperiod :- [illegible] light period above or below of which the plant never blooms

(i) **Short-day plants :- (Long night plants)**

For flowering of Short-day plants, the day length required is less than a critical length. Short-day plants may be more correctly called as long night plants as a certain minimum of uninterrupted dark period in 24 hours is necessary for their flowering. If dark period is less than a critical length, flowering will not occur. Short-day plants will not flower even if a flash of light or weak light is provided during a continuous dark period. These plants are ~~not~~ also not capable of flowering if short dark & short light periods are provided alternately. Hillman (1959) showed that, short-day plants are capable of flowering even if kept continuously in dark but provided with sucrose. This shows that, the short-day plants require light period only for ~~flowering~~ photosynthesis.

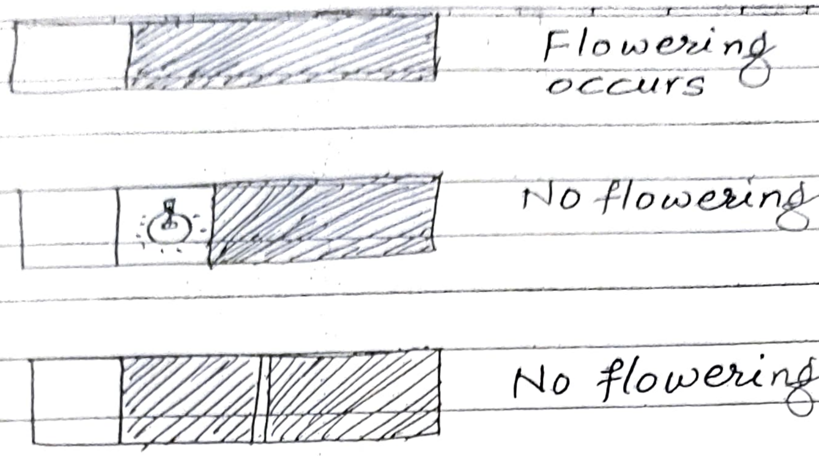

Fig.: Short-day plants

Some examples of a short-day plants are soybean, poinsettia, potato

(ii) Long-day plants :- (Short-night plants)

For flowering of long-day plants, there is requirement of a photoperiod more than a critical length, which may vary from 14 to 18 hours. The best flowering in long-day plants occurs in continuous light. For flowering, they require either no dark period or a very short dark period. A flash of light given to long day plants during long dark periods can induce flowering in them even during short day periods. Here, darkness has an inhibitory effect on flowering. The flowering in long-day plants is inhibited not because of the short light periods, but because of too long dark periods, and because of this, long day plants can also be called short-night plants.

Some examples of long-day plants are spinach, lettuce, radish, alfalfa, sugarbeet, maize, oat, wheat, etc.

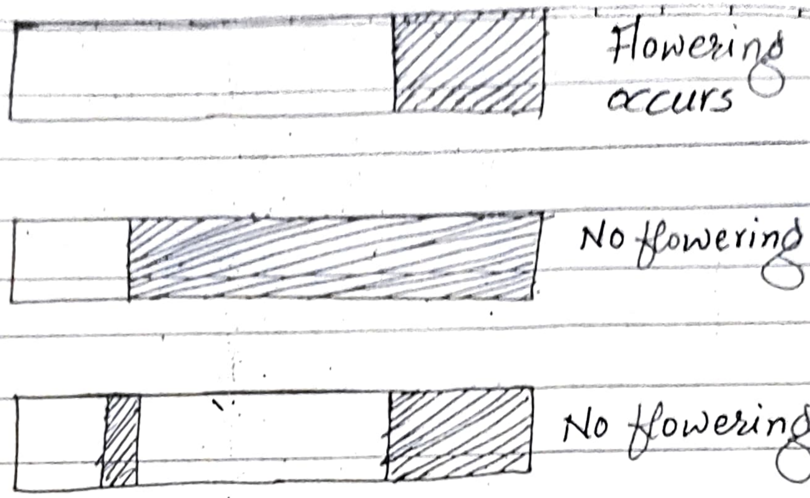

Fig : Long-day plants

(iii) Day-neutral plants :-

Flowering in day-neutral plants is not affected by length of the day. They can flower even if the light period provided is from few hours to continuous illumination.

Some examples of day-neutral plants are sunflower, Tomato, cucumber, pea, cotton, etc.

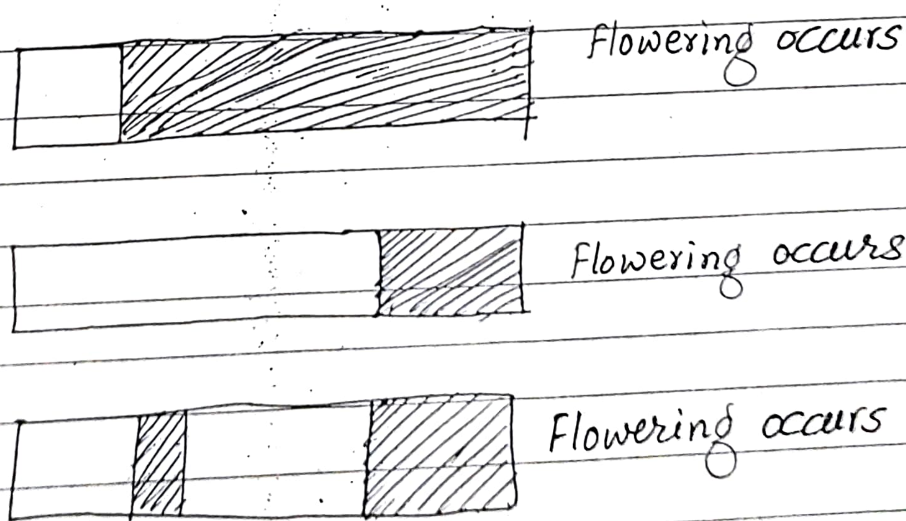

Fig : Day-neutral plants

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Vernalisation :-

In most of the plants, temperature has a profound effect on flowering. Some plants do not flower unless they are exposed to prolonged periods of cold temperatures. Biennials remain vegetative during the first season and after being exposed to the cold temperatures of winter, they flower in spring. Majority of the plants will not flow if they are not subjected to exposure and will grow vegetatively for an indefinite period. However, if they are subjected to cold treatment followed by correct photoperiod, they will flower. The term vernalisation has been coined to explain the effect of chilling treatment that prepares a plant to flower.

For vernalisation, the seeds are allowed to germinate for some time and then are given cold treatment by keeping them at 0 – 5 °C. The period of cold treatment varies from few days to many weeks from species to species. After cold treatment, seedlings are allowed to dry for some time & then sown. They should not be sown immediately after cold treatment.

The Russian Geneticist T.D. Lysenko (1928) first used the term vernalisation. Klippart (1857) studied the effect of temperature on flowering in two varieties of wheat, namely winter variety and spring variety. He noticed that, winter wheat variety may be converted ~~to~~ into (summer) spring variety if sprouted grains are treated with low temperature ~~0-7~~ (0 – 5 °C). Melchers (1939) suggested that, the flowering stimulus is in the form of hormone & called it as 'vernalin'.

Thus, vernalisation prepares the plant to flower.

whereas photoperiodic stimulus not only prepares the plant for flowering, but also induces it.

Vernalisation is defined as "the method of inducing early flowering in plants by pretreatment of their seeds at low temperatures."

Mechanism of vernalisation :-

The mechanism of vernalisation is explained by two theories, as follows :-

(1) Phasic development theory :-

This theory was proposed by Lysenko (1934). According to this theory, growth and development are two different phenomena. ie. thermophase and photophase. The plant requires thermophase & photophase for the ~~following~~ flowering.

(a) Thermophase :- It is the phase of vernalization. It is governed by temperature. It is also called Lysenko phase (or vernalisation stage). In order to produce a flower, a plant must pass through the desired thermophase, so as to enter the photophase.

(b) Photophase :- It is governed by light. It starts after completion of thermophase. Photophase has pronounced effect of relative day and night which accelerates flowering. During the development of flower, the act of vernalisation provides necessary thermophase which enables the plant to enter the photophase.

(2) Hormonal theory :-

This theory was proposed by Lang and Melchers (1947). Melchers grafted vernalised part on non-vernalised plant & observed that, the non-vernalised plant initiates flowering. This suggested that, the stimulus in the form of hormone causes flowering. **Melchers** named 'vernalin' to this hormone. This theory is also known as hormone precursor theory. Gregory & Purvis supported this theory after studying physiology of flowering in winter variety of Petkus Ryye in 1948.

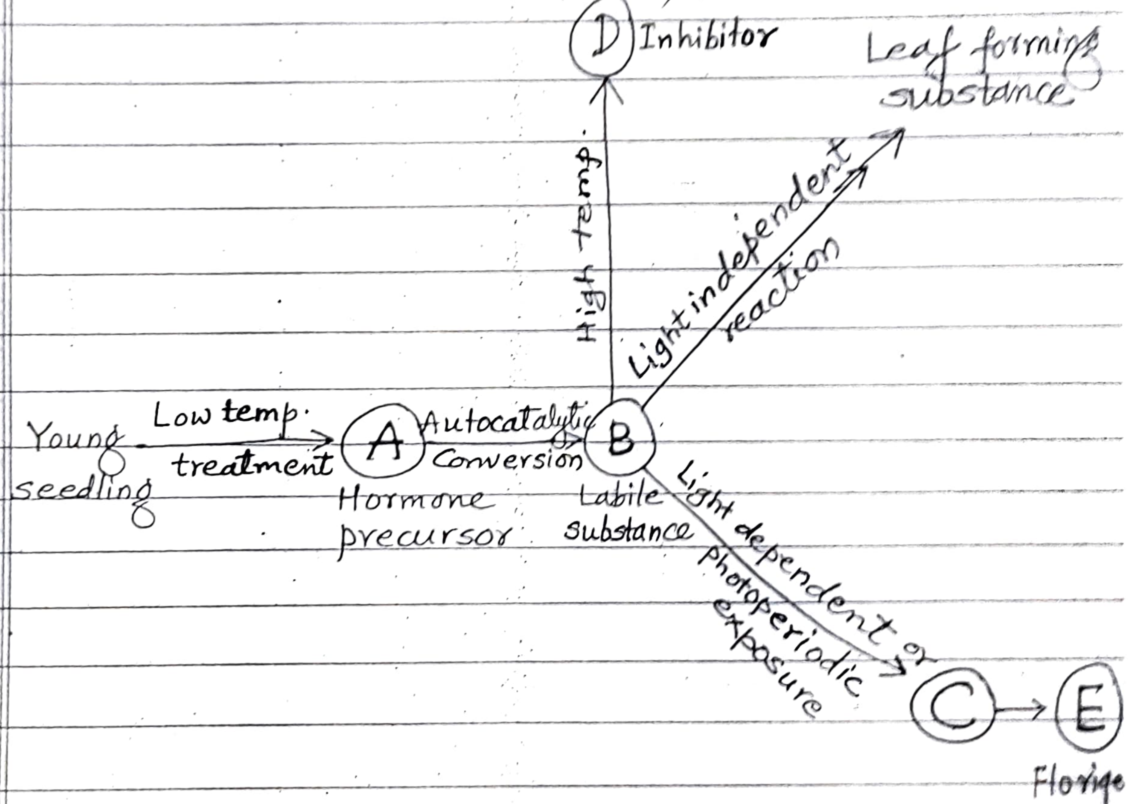

Fig: Schematic representation of hormonal theory of vernalisation.

Gregory & Purvis suggested that, in winter varieties of cereals, the hormone precursor 'A' is synthesized during early stages of growth in embryo cells. This requires low temperature treatment. This hormone precursor 'A' is translocated to growing region & accumulated gradually. The precursor 'A' is converted into another unknown substance 'B' which is thermolabile. The substance 'B' is labile because it can give rise to a leaf-producing substance as well as a spikelet (flower)-

Thermolabile - readily destroyed or deactivated by heat

labile -

-forming substance. The formation of leaf-forming substance from 'B' is not dependent on light. The formation of spikelet-forming substance from 'B' is dependent on light. In vernalised plant, if 'B' is exposed to appropriate photoperiod (normal temp.), it is converted into third unknown substance 'C'. The substance 'C' is then converted into flowering hormone 'florigen' (E). If plant is exposed to high temperature, 'B' is converted into another substance 'D' which inhibits flowering (Devernalisation).

Devernalisation :-

"The process of reversal of the effect of vernalisation is known as devernalisation." High temperature is the factor for vernalisation. Gregory & Purvis (1937), first demonstrated that, in Petkus winter rye, the effect of cold treatment may be reverted by high temperature. If vernalised plant is kept at high temperature, the effect of vernalisation is removed. The devernalised plant can be again revernalised by low temperature. The devernalisation is not possible in case of optimally vernalised plant. So, the cold treatment given must be below the optimum temperature. The heat treatment must be given immediately after the cold treatment. The time gap between the cold and heat treatment stabilises the effect of chilling treatment and prevents the subsequent devernalisation.

Importance of vernalisation :—

(i) The vernalisation reduces the vegetative period of development & induces early flowering.
(ii) It increases cold resistance in plants.
(iii) Winter variety of plants can be converted into spring variety by vernalisation. eg.: Russian wheat varieties. It helps to increase the yield of crop plants.
(iv) In Triticale, vernalisation can remove kernels ~~wrinkles~~ wrinkles.

Phytochrome

Def^n:- The pigment responsible for the photo-induction or inhibition of flowering in short day plants and stimulation of flowering in long day plants is called phytochrome. It is proteinaceous in nature.

- Phytochrome acts as photoreceptor molecule which absorbs light and showing its effects on various developmental processes of plant.
- Borthwick and Hendricks proposed that the light absorbing pigment (phytochrome) exists in two forms:-
  1) Phytochrome red (abbreviated as P_R) which is its inactive form and
  2) Phytochrome far red (P_{FR}) which is its active form.
- Both P_R and P_{FR} forms are interconvertible.
- The active form is responsible for developmental and morphogenetic processes.
- It is confirmed that red light induces photomorphogesis (Development of form and structure in plants which is affected by light other than that occuring for photosynthesis; or it is the process by which plants grow and develop in response to light signals.) and far red light reverses the red light induced responses.
- The P_R form can be converted into P_{FR} form in presence of red light (660-665 nm).
- Similarly, P_{FR} form can be converted into P_R form in presence of either far red light (730-735 nm) or darkness.
- The conversion of P_{FR} to P_R in under thermal control.

Red light (Day time)
670 nm

No response ← P_R (Non active form) ⇄ P_{FR} → Active → Response → Flowering.

730 nm (Far red zone)
Night

Interconversion of Phytochromes.

- phytochrome is found in green and red algae, bryophytes, gymnosperms and angiosperms. It has been detected from roots, stems, coleoptiles, cotyledons, petioles and blades of leaves, vegetative buds, etc.
- phytochrome is a conjugated protein and chemically it is made up of a water soluble protein and chromophore.
- Each phytochrome molecule is a dimer, containing two identical monomeric units.

× Photomorphogenesis

- Light is an imp factor on the lives of plants.
- In addition to being required for photosynthesis, light in required for many other physiological and morphological processes.
- These effects of light on plant morphology is called photomorphogenesis.

Ex 1) The effect of light on flowering of plant or responses of plants to duration of light.
2) Photosynthesis. 3) Germination of seed.

- ie The light mediated growth and development is called photomorphogenesis.

Cryptochrome

Photoreceptors

It is well known that light is a crucial environmental factor that has a fundamental role in plant growth and development from seed germination to fruiting.

- For this ~~purpose~~ process, plants contain versatile photoreceptor systems to sense variations in the light spectrum.
- Five main groups of photoreceptors have been found in higher plants i.e. cryptochromes, Phototropins, UVR8, zeitlupes and phytochromes, but last one is the most characterized.
- phytochromes play an important role in stress responses.

Cryptochromes

- cryptochromes are blue, ultraviolet-A photoreceptors.
- They were first reported from Arabidopsis and are also found in ferns and algae.
- They are flavoproteins.
- cryptochromes mediate a variety of light responses including circadian rythums in plants.
- Arabidopsis has two cryptochromes, CRY1 and CRY2, which mediate primarily blue light inhibition of hypocotyl elongation and photoperiodic control of floral initiation.
- cryptochromes also regulate several other light responses like stomata opening guard cell development, root development, seed dormancy, bacterial and viral pathogen responses, abiotic stress responses, etc.