PLANT GROWTH AND DEVELOPMENT

Growth:

- It is an irreversible change in the size or volume of cell organ or whole organism.
- According to **Thinman**, It is a irreversible positive change in size and volume of living being usually accompanied by an increase in dry weight or fresh weight.

Parameters of Growth:

- Growth occurs in plants due to various anabolic and catabolic complex reactions.

Various parameters of growth are as follows:

(1) Vegetative and Reproductive growth:

(a) Vegetative growth: Vegetative parts of higher plants are root, stem and leaves. Root and stem show unlimited growth while leaves show limited growth. The growth of these organs are known as vegetative growth.

(b) Reproductive growth: In this phase, reproductive organs develop in plants.

(2) Types of growth:

On the basis of types of growth, the organs of higher plants can be classified into two categories.

(a) Organs showing limited growth **e.g. leaves, flower, fruit.**

(b) Organs showing unlimited growth **e.g. Roots, Stem.**

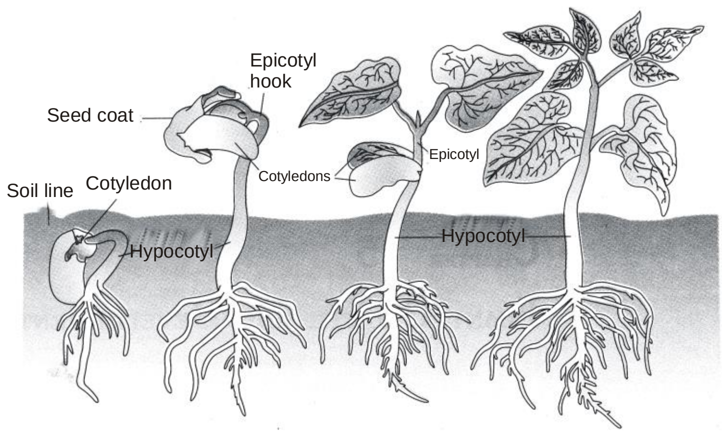


Fig : Germination and seedling development bean

- **Plant Growth Generally is indeterminate:** Plant growth is unique because plants retain the capacity for unlimited growth throughout their life. This ability of the plants is due to the presence of meristems at certain locations in their body. The cells of such meristems have the capacity to divide and self-perpetuate. The product, however, soon loses the capacity to divide and such cells make up the plant body. This form of growth wherein new cells are always being added to the plant body by the activity of the meristem is called the open form of growth.Root apical meristem and the shoot apical meristem both are responsible for the primary growth of the plants and principally contribute to the elongation of the plants along their axis. In dicotyledonous plants and gymnosperms, the lateral meristems, vascular cambium and cork-cambium appear later in life. These are the meristems that cause the increase in the girth of the organs in which they are active. This is known as secondary growth of the plant.

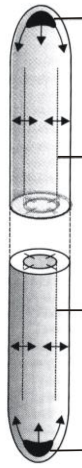


Fig. Diagrammatic representation of locations of root apical meristem, shoot apical meristem and vascular cambium. Arrows exhibit the direction of growth of cells and organ

- Meristems do not active for long time in the organs of limited growth whereas meristems active for long time in case of organs of unlimited growth.
- On the basis of position in plants, Meristems are of three types

  (1) Apical meristem

  (2) Intercalary meristem

  (3) Lateral meristem

Phases of Growth:

It has three phases

(1) Phase of cell formation (Meristematic phase): The constantly dividing cells, both at the root apex and the shoot apex, represent the meristematic phase of growth. The cells in this region are rich in protoplasm, possess large conspicuous nuclei. Their cell walls are primary in nature, thin and cellulosic with abundant plasmodesmatal connections.

(2) Phase of cell elongation: The cells proximal (just next, away from the tip) to the meristematic zone represent the phase of elongation. Increased vacuolation, cell enlargement and new cell wall deposition are the characteristics of the cells in this phase.

(3) Phase of cell maturation: Further away from the apex, i.e., more proximal to the phase of elongation, lies the portion of axis which is undergoing the phase of maturation. The cells of this zone, attain their maximal size in terms of wall thickening and protoplasmic modifications.

Growth Rates:

- Enhancement in growth per unit time is called growth rate. It is due to **arithmetic or geometric growth**.

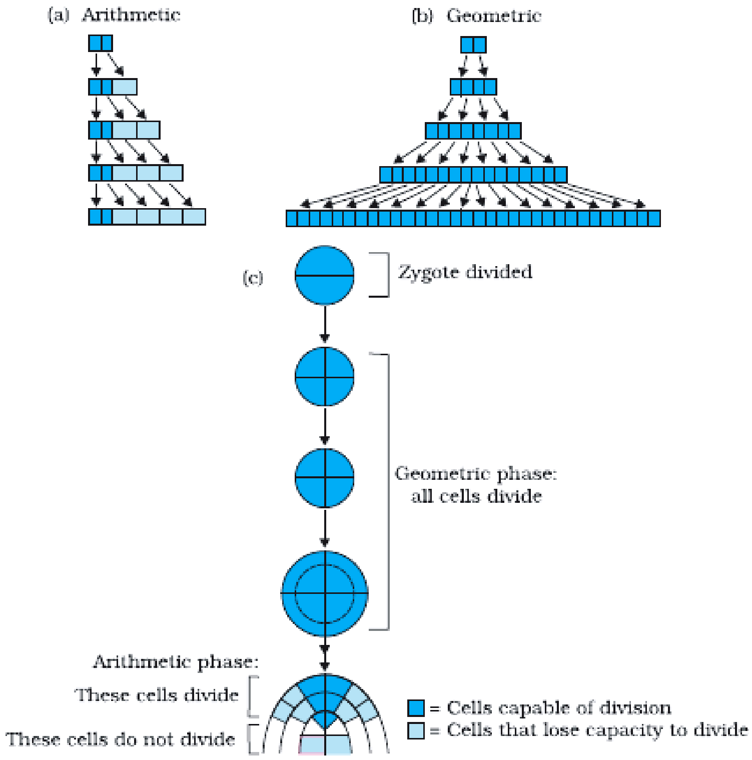


Fig. Diagrammatic representation of (a) Arithmetic (b) Geometric growth and (c) Stages during embryo development showing geometric and arithematic phases

1. Arithmetic Growth:

Growth takes place in arithmetic manner–1, 2, 3, 4, 5, 6. **e.g. Root and shoot.**
Mathematically it can be expressed by the following equation.

$$L_t = L_0 + rt$$

L_0 = length at the beginning, L_t = length after time t. r = growth rate.

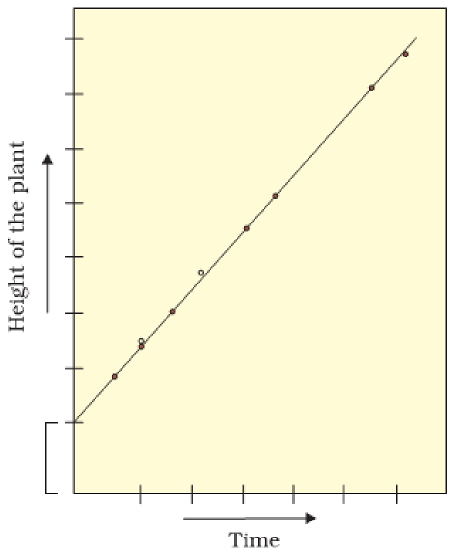


Figure : Constant linear growth, a plot of length L against time t

2. Geometric Growth:

- Growth occurs in geometric manner – 2, 4, 8, 16, 32. e.g. unicellular organisms show it in nutrient rich medium, here every cell divides.

Law of compound Interest (Exponential Growth):

- Growth depends upon three factors– initial size (W_0), rate of growth (r) and the time interval for which the rate of growth can be retained. It looks like depositing money in a bank. The money will grow at compound interest. It can be expressed by the following equation.

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

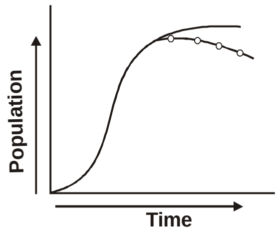


Fig : Growth of a population of unicellular organisms.

- W_0 is initial size, W_1 is the final size, r is growth rate, t is time of growth, e is the base of natural logarithms.

The magnitude of r or rate of growth called **efficiency index** by **Blackman**.

Growth curve :

It includes four steps

(i) Lag phase : Growth starts at a slower rate in this phase of formation of cells.

(ii) Log phase or exponential phase: The growth rate increases rapidly and reaches to the maximum.

(iii) Decline phase or Deaccelerating phase: In this phase the rate of growth gradually declines because metabolic processes become slow.

(iv) Stationary or steady phase: As the cells enlarge, they gradually acquire permanent shapes and forms. It is called stationary phase. All the four steps are collectively called **'grand period of growth' & it shows S-shaped growth curve.**

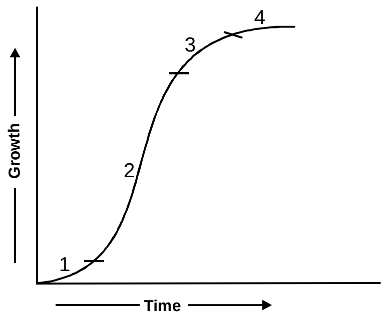


Fig:- Growth curve
1 **Lag phase** 2 **Log phase**
3 **Decelerating phase** 4 **Stationary phase**

- Quantitative comparisons between growths of various systems can be made by measuring their absolute and relative growth rates.

Absolute Growth rate: The total growth per unit time. It is usually S-shaped

Relative Growth rate: It is growth per unit time per unit initial parameter of growth.

Relative Growth rate $= \dfrac{\text{Growth in Given Time Period}}{\text{Measurement at Start of Time Period}}$

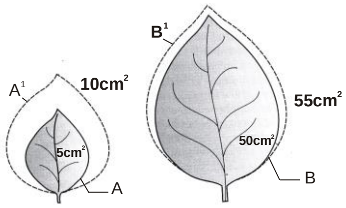


fig: Diagrammatic comparison of absolute and relative growth rates. Both leaves A and B have increased their area by 5 cm^2 in a given time to produce A^1, B^1 leaves.

Factor affecting growth:

(1) Nutrients **(2) Water** **(3) Temperature**

(4) Light **(5) CO_2** **(6) O_2**

(7) Minerals & Hormones.

DIFFERENTIATION, DEDIFFERENTIATION AND REDIFFERENTIATION

- The cells derived from root apical and shoot-apical meristems and cambium differentiate and mature to perform specific functions. This act leading to maturation is termed as **differentiation**. During differentiation, cells undergo few to major structural changes both in their cell walls and protoplasm. For example, to form a tracheary element, the cells would lose their protoplasm. They also develops a very strong, elastic, lignocellulosic secondary cell walls, to carry water to long distances even under extreme tension.

- The living differentiated cells, that by now have lost the capacity to divide can regain the capacity of division under certain conditions. This phenomenon is termed as **dedifferentiation.** For example, formation of meristems – interfascicular cambium and cork cambium from fully differentiated parenchyma cells.
- While doing so, such meristems/tissues are able to divide and produce cells that once again lose the capacity to divide but mature to perform specific functions, i.e., get **redifferentiated.**
- **Differentiation in plants is open**, because cells/tissues arising out of the same meristem have different structures at maturity. The final structure at maturity of a cell/tissue is also determined by the location of the cell within. For example, cells positioned away from root apical meristems differentiate as root-cap cells, while those pushed to the periphery mature as epidermis.

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

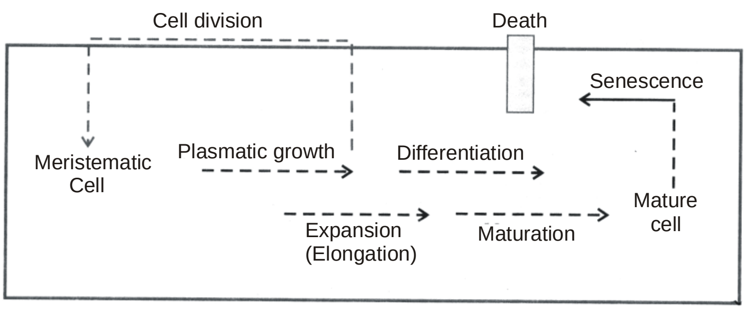


Fig : Sequence of the developmental process in a plant cell

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

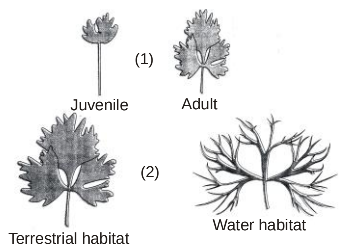


Fig : Heterophylly in (1) Larkspur (2) buttercup

Plant growth regulators (PGR) or Growth hormones:

- These are organic substances, which control the growth and one or more physiological reactions of plants in low concentration. They are transported from synthesizing part to active part.
- PGR are broadly classified in to two groups–**Plant growth promoters, Plant growth inhibitors**.

Plant growth promoters involve auxins, gibberellins and cytokinins whereas plant growth inhibitors involve abscisic acid. Ethylene is largely plant growth inhibitor but is also involved in some growth promotion activities.

(A) Auxin:

- Auxins (to grow) are organic substances having an unsaturated ring structure and capable of promoting cell elongation (especially of shoots) at a concentration of less than 100 ppm.
- **Charls Darwin and Francis Darwin** firstly reported the presence of growth hormone in the coleoptile tip of **canary grass (*Phalaris canariensis*)** when he described the effect of light and gravity, in his book **"Power of movements in plants"**. He found that coleoptile tip of canary grass bend towards light.
- According to **Boysen-Jenson (1913)** if coleoptile tip is decapitated then it does not show phototropic curvature.
- **F. W. went (1928)** worked on coleoptile of ***Avena sativa* (Oat)**. He demonstrated the presence of a substance which could diffuse into agar blocks. Agar blocks containing the diffused substance when placed on decapitated coleoptiles could induce the action of tip. He also made the important finding that substance always moved from the tip towards the base of the coleoptile. He called this substance auxin.

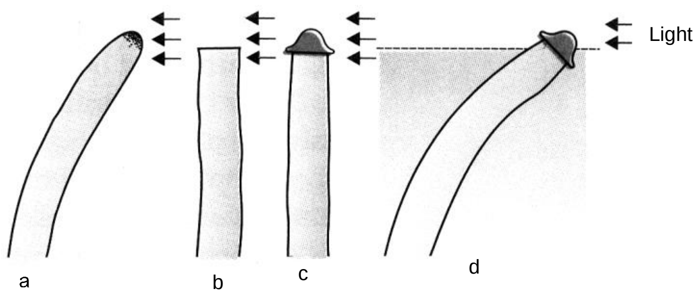
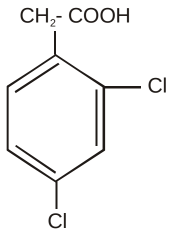


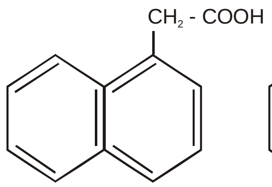
Fig : Experiment used to demonstrate that tip of the coleoptile is the source of auxin. Arrows in indicate direction of light

- **Kogl, Haagen & smith (1931)** isolated an active substance from urine of pellagra patient which was called as **Auxin-a (Auxenotriolic acid, $C_{18}H_{32}O_5$). Latter on they isolated another substance from corn germ oil called Auxin-b or Auxinolinic acid ($C_{18}H_{30}O_4$).**
- **Kogl, Erxleben and Haagen, smith (1931**) isolated another active substance from human urine and named it **heteroauxin (Indole-3-acetic acid or IAA, $C_{10}H_9O_2N$) by Thimann**.
- **Indole-3-acetic acid** or **IAA**, is a **natural auxin.**

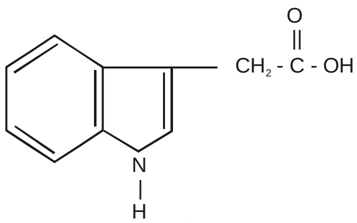
  Other **synthetic auxins** are - **IBA (Indole-3-Butyric acid), 2, 4-D (2, 4 Dichlorophenoxy acetic acid), & β-NAA (Napthalene acetic acid)**



2,4 dichlorophenoxyacetic acid = 2, 4 - D



Napthalene acetic acid = NAA



Indole acetic acid =IAA

Bioassay of Auxins:

- Testing of a biological activity like growth response of a substance by the use of living material like plant or plant part is called bioassay. It can be conformed by following test:

  (A) Avena curvature test

  (B) Cress root inhibition test

Physiological effects and Practical applications of Auxins:

(1) Apical dominance: In vascular plants, apical bud suppresses the growth of axillary buds or vegetative buds. It is called apical dominance it is caused by IAA. Removal of shoot tips (decapitation) usually results in the growth of lateral buds. It is widely applied in tea plantations, hedge-making.

(2) Cell elongation: The most important role of auxin to stimulate the elongation of cells in shoots. It is caused by solubilisation of carbohydrates, loosening of wall microfibrils, synthesis of more wall materials, increased membrane permeability and respiration.

(3) Cell division: Auxin stimulates the cell division. The rate of cell division in cambium is controlled by IAA along with its seasonal activity. Callus formation during grafting and injury is due to IAA. **Auxin also controls the xylem differentiation.**

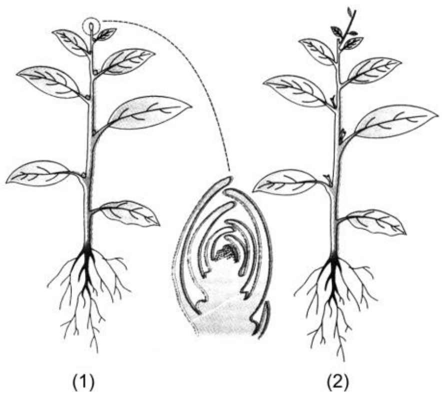


Fig : Apical dominance in plants (1) A plant with apical bud intact (2) A plant with apical bud removed note the growth of lateral buds into branches after decapitation.

(4) Prevention of Abscission: When the concentration of auxin becomes low in the leaves and fruits. Abscission layer is formed. **E.g. Apple, Pear, Citrus, Orange etc.** By the auxin spray the premature fall of leaves and fruits can be prevented. Auxin promotes the abscission of older mature leaves & fruits.

(5) Eradication of weeds: Weeds are unwanted plants growing crop field along with crop. The 2, 4 D and 2, 4, 5-T destroy the broad leaved weeds found growing along with narrow leaved crop plants (monocots) whereas Dalapon or 2, 2 Dichloropropionic acid destroy the narrow leaved weeds (grasses) found growing along with broad leaved crop plants.

(6) Preventation of lodging: In various cereal plants like Rice, Oat, the stem of plant show excessive elongation but the Internodes of these plants are weak and delicate so they fall down during immaure stage. It can be prevented by the use of **NAAM (Naphthalene Acetamide).** By the use of NAAM strength of internodes can be maintained in plant.

(7) Parthenocarpy: Formation of fruits without seeds is called parthenocarpy. Auxins **(like IAA, IBA, NAA)** spray over ovary walls get modified to fruit wall these auxins induce parthenocarpy in various plants. **e.g. Citrus, Tomato, Guava, Brinjal, etc.**

(8) Shortening of Internodes: Two types of branches are found in Apple and pear. Fruits develop only dwarf branches or spurs. More spurs can be formed by the use of **α-NAA** in these plants. Thus the production of fruits can be increased.

(9) Sweetening of fruits: Various auxins like **Malic hydrazide, IBA, 2,4-D** induce the sweetness in fruits usually they induced the conversion of starch into sugars. **e.g. Sugarcane.**

(10) Initiation of Roots: Usually auxins inhibit the root growth but it induces formation of new root initials. This property of auxin is used. If the basal part of the graft is dipped in Auxin **(NAA or IBA)** and then planted in soil then rooting occurs rapidly.

(11)Flowering: Usually auxins do not promote flowering but in pineapples, it initiates flowering.

(B) Gibberellins:

- The effect of gibberellins had been observed over a century ago. Japanese farmers noted some plants in rice fields were taller, thinner than the normal plants and named this disease as **'Bakanae disease' (Foolish seedling disease).**
- **Kurosawa (1926)** discovered that the causal organism was a fungus called ***Gibberella fujikuroi*** (the perfect stage of ***Fusarium monaliforme*****).**
- **Yabuta and Sumiki (1938)** isolated this substance in crystalline form and named it as Gibberellin.

There are more than 100 gibberellins reported from widely different organism such as fungi and higher plants. They are denoted as GA_1, GA_2, GA_3 and so on. All GAs are acidic.

The higher concentration of gibberellins is found in leaves, young seeds and embryo. The most common Gibberellin is **GA_3 ($C_{19}H_{22}O_6$).**

- Biosynthesis of Gibberellin takes place through **mevalonic acid pathway** & **kaurene** is its precursor.

Bioassay of Gibberellins:

(1) Dwarf Pea test.

(2) Barley Endosperm test

Physiological effects and Practical application of Gibberellins:

(1) Internodal growth: Gibberellin stimulates the elongation of Internodes in stem. Therefore the length of stem increases.

- This ability is used to increase the length of grapes stalks.
- Gibberellins causes fruits like apple to elongate and improve its shape. They also delay the senesence. Thus, the fruits can be left on the tree longer so as to extend the market period.
- Sugarcane stores carbohydrate as sugar in their stems. Spraying sugarcane crop with gibberellins increases the length of the stem, thus increasing the yield by as much as 20 tonnes per acre.

(2) Seed germination: Gibberellins stimulate the production of hydrolytic enzymes α-amylase, lipases, ribonucleases and proteases. The enzymes solubilise the reserve food of the seed. The same is transferred to embryo axis for its growth. Some of the light sensitive seeds germinate with the treatment of GA even in complete darkness. **e.g. *Lactuca sativa* and *Nicotiana***

(3) Breaking of seed dormancy

(4) Parthenocarpy: Gibberellins have been found to be 500 times more effective than auxins in inducing parthenocarpy **e.g. Tomato, Pear, apple, etc.**

(5) Flowering in LDP: Gibberellins induce flowering in long day plants in the presence of dim light. By the application of GA biennial plants can makes flower in first year of growth, so behave as annuals. **e.g. Henbane.**

(6) Elongation of genetically dwarf plants: GA induces the elongation in genetically dwarf plants therefore they grow as normal tall plant. **e.g. dwarf pea and maize plants.**

(7) Maleness: Gibberellins initiate the development of male reproductive organs in some plants like Cucumis, Cannabis.

(8) Bolting: By GA treatment the rosette habit can be changed to vine habit. This is due to the excessive elongation of internodes (Bolting effect). eg. Beet, cabbage

(9) Substitution of cold treatment: Low temperature requirement or vernalization in some plants can be replaced by gibberellins.

(10) GA_3 is used to speed up the malting process in brewing industry.

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

(C) Cytokinins:

- It was firstly isolated by **Miller** (1955) from **Herring sperm DNA** and named it **kinetin**.
- **Letham** (1963) isolated first natural occuring cytokinin from the immature seeds of corn (*Zea mays*), He named this compound as **Zeatin. Kinetin is 6 furfuryl aminopurine.**The **term cytokinin** used by **Letham**.

  Cytokinin is synthesized by mevalonic acid pathway in roots**.**
- F.skoog and his co-worker observed that from the internodal segments of tobacco stems, tha callus (a mass of undifferentiated cells) proliferated only if, in addition to auxin the nutrients medium was supplemented with one of the following: extracts of vascular tissue, yeast extract, coconut milk or DNA.
- **Skoog and Miller** latter identified and crystallised the cytokinesis promoting active substancethat they termed kinetin.

Bioassay of cytokinins:

(1) Tobacco Pith Culture

(2) Retardation of Leaf Senescence

Physiological effects and practical applications of cytokinin:

(1) Cell division: Cytokinin initiates cell division along with auxin. It is believed that the posterior half part of cytokinin is made up of adenine which is responsible for the expression of this effect.Natural cytokinins are synthesised in the regions where rapid cell division occurs. For example root apices, developing shoot buds, young fruits etc.

(2) Delay senescence: They promote nutrient mobilisation which helps in the delay of leaf senescence. According to **Richmand & Lang** (1957) cytokinins delay the loss of chlorophyll and destruction of proteins. It is called **Richmond-Lang effect.**

(3) Counteraction of Apical dominance: Exogenous application of cytokinin promote the growth of lateral buds. Thus the cytokinins reverse the auxin induced inhibition of lateral buds and counteract the apical dominance.

(4) Morphogenesis or Differentiation of organs: Cytokinin is essential for morphogenesis or differentiation of tissues and organs. It helps to produce new leaves, chloroplasts in leaves, lateral shoot growth and adventitious shoot formation. Kinetin-auxin interaction controls the morphogenetic differentiation of shoot and root meristems.

Cyt (low) + Auxin (high) $\rightarrow$ Root, Cyt (high) Auxin (low) $\rightarrow$ Shoot.

(5) Breaking of seed dormancy: Cytokinins overcome seed dormancy of various types.

(6) Other effects:

(i) Induced flowering in SDP	**(ii) Biosynthesis of lignin**	**(iii) Retards abscission**
(iv) Induce femaleness	**(v) Seedling growth**	**(vi) Tissue Culture**

(D) Ethylene:

- It is a gaseous plant hormone that is effective in concentration of **0.01-10.00ppm.**
- Russian scientist **Neljubow** (1901) firstly described the growth regulating properties of Ethylene gas.
- **Denny** (1924) observed that ethylene gas helps in inducing fruit ripening.
- **Gane** (1930) observed that ethylene is natural gaseous growth hormone.
- **Crocker** et al (1935) recognised ethylene as a plant hormone.
- **Bery & Theman** (1962) established that ethylene is a endogenous hormone which controls the fruit ripening.
- Ethylene regulates so many physiological processes, so it is one of the most widely used PGR in agriculture. The most widely used compound as source of ethylene is ethephon.

Practical application and physiological effects of Ethylene:

(1) **Ripening of fruit:** Ethylene play an improtant role in the ripening of various fruits. Example-Banana, Apple, Watermelon etc. Those fruits which produce ethylene during ripening are called climacteric fruits.

(2) Influences of ethylene on plants include horizontal growth of seedlings, swelling of the axis and apical hook formation in dicot seedlings.

(3) Ethylene promotes senescence and abscission of plant organs especially of leaves and flowers.

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

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

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

(7) Ethephon hastens fruit ripening in tomatoes and apples and accelerates abscission in flowers and fruits (thinning of cotton, cherry, walnut).

(8) **Isodiametric growth:** It promotes transverse growth but inhibits longitudinal growth in plants.

(9) **Sex modification:** Exogenous application of ethylene can change the sex in plants. i.e. induction of female flowers in male plants of cucumber and hence increases the yield.

(10) **Root growth:** Ethylene induces origin of root from graft, formation of lateral roots and formation of root hairs. Thus helping the plants to increase their absorption surface.

(11) **Graviperception:** It reduces senstivity to gravity.

(12) **Epinasty:** It promotes downward bending of leaves.

(E) Abscisic acid:

- In plants, certain substances inhibit their growth. These chemical substances are called growth inhibitor.

  Carns & Adicott (1965) isolated a substance from **cotton fruits** and named it **abscissin II**.
- **Wayering (1964)** and **Robinson (1964)** seperated a substance from **leaves of Acer** which inhibited seed germination and growth of buds. It was called **Dormin**. Inhibitor B was also identied by a independent researcher. But later it was found that Dormin, Inhibitor B and Abscisin II are a similar chemical. Later on it was named **Abscisic acid (ABA).**
- It counteracts the influence of growth promoting hormones (auxin, gibberellins and cytokinins) & induces
  dormancy and helps overcomes conditions of stress. It acts as a general plant growth inhibitor and an inhibitor of plant metabolism.

Role of Abscisic acid:

(1) It inhibits seed germination.

(2) It induces abscission in flowers and fruits.

(3) It stimulates dormancy in seeds and buds.

(4) It inhibits synthesis of RNA.

(5) It induces senescence in leaves and branches.

(6) It promotes stomatal closure and increases as the tolerance of plants to various kinds of stresses. Therefore, it is also called the stress hormone.

- Other growth inhibitors includes-**Malic hydrazide, Morphactins, Para- ascorbic acid, Coumaric acid or Cinemic acid.**

Photoperiodism:

- The effect of day length (Photoperiod) on the growth and development of plants, especially flowering, is called photoperiodism.
- It was firstly studied by **Garner and Allard (1920) in 'Maryland Mammoth' variety of Tobacco.**
- On the basis of photoperiodic response, plants can be classified into following catagories.

  (i) **Long Day Plants (LDP):** These plants perform flowering by receiving long photoperiod (above the critical period) **e.g. Spinach, Radish, Lettuce, Wheat, Oat, Henbane.**

  (ii) **Short Day Plants (SDP):** Flowering occurs below the critical period of day length **e.g. Xanthium (Colcklebur), Chrysanthemum, Cosmos, Aster, Rice, Sugarcane, Strawberry, Potato, Tobacco, Soyabean varieties.**

  (iii) **Day Neutral or indeterminate Plants (DNP) :** Flowering is not affected by photoperiod or day length. **e.g. Maize, Cotton, Tomato, Black Pepper, Cucumber, Sunflower.**

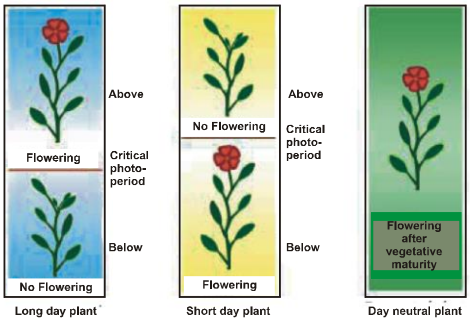


Fig : Photoperiodism : Long day, short day and day neutral plants

- Short day plants require a continuous critical dark period for flowering therefore they are also called long night plants. If the SDP plant is exposed to even a flash of light before achieving a critical dark period, flowering is prevented.
- **Photoperiodic Perception:** Fully developed leaves receive photoperiodic stimulus. The latter is perceived by **phytochrome** in the leaves.
- Phytochrome discovered by **Borthwick & Hendricks and the term Phytochrome** coined by **Butler.**

Role of Phytochrome in flowering:

$$\mathbf{Pr}_{660} \underset{\textbf{Far-red light}}{\overset{\textbf{Red light}}{\rightleftharpoons}} \mathbf{Pfr}_{730}$$

- Pr_{660} stimulates flowering in SDP whereas Pfr_{730} initiates flowering in LDP.

Resonate the Concept

- It is believed that **florigen** hormone **(discovered by Chailakyan)** is synthesized in the leaves after receiving photoperiodic stimulus. It is transmitted to growing point where flowering occurs.

Vernalisation (Yarovisation):

- The effect of low temperature **(0º–4ºC)** to bring early flowering is called vernalisation. The latter described by **Lysenko (1938)**. There are plants for which flowering is either quantitatively or qualitatively dependent on exposure to low temperature. This phenomenon is termed **vernalisation**. It prevents precocious reproductive development late in the growing season, and enables the plant to have sufficient time to reach maturity. Vernalisation refers specially to the promotion of flowering by a period of low temperature. Some important food plants, wheat, barley, rye have two kinds of varieties: winter and spring varieties. The 'spring' variety are normally planted in the spring and come to flower and produce grain before the end of the growing season. Winter varieties, however, if planted in spring would normally fail to flower or produce mature grain within a span of a flowering season. Hence, they are planted in autumn. They germinate, and over winter come out as small seedlings, resume growth in the spring, and are harvested usually around mid-summer. Another example of vernalisation is seen in biennial plants. Biennials are monocarpic plants that normally flower and die in the second season. Sugerbeet, cabbages, carrots are some of the common biennials. Subjecting the growing of a biennial plant to a cold treatment stimulates a subsequent photoperiodic flowering response.
- The stimulus of low temperature is received by embryo tip, shoot tip & other meristematic areas.

Requirements of Vernalisation:

(a) Meristematic cells **(b)** O_2

(c) Supply of continuous low temperature for few days to weeks **(d)** Proper hydration

- Seeds before giving cold treatment are soaked in water for some time and then dried and given cold treatment.
- **Melchers** stated that the stimulus of flowering is developed in the meristematic cells. Actually hormone **vernalin** is synthesized after cold treatment, it is supposed to be composed of gibberellin and anthesin. It is responsible for inducing flowering.

Devernalisation:

- The effect of vernalization is replaced due to unfavourable photoperiods, reduced water supply or high temperature (above 25ºC). It is also performed by Gibberellin.

Abscission:

- Shedding of leaves, flowers and fruits by a plant is called abscission. When auxin level decreases, Abscisic acid becomes activated and promotes formation of abscission layer at the point of attachment. The middle lamella between the cells is digested by cellulase and pectinase to make this region weak. A layer of suberised cells called protective layer is formed below it. The organ is then easily detached from the plant whenever there is rain or wind.

Senescence:

- It involves degenerative changes in the plant parts /plant that are ultimately responsible for the death of plant parts / plant. It occurs between reproductive maturity and death.
- During senescence, anthocyanin accumulates, protein synthesis decreases and protein breakdown, DNA degenerates. RNA contents and dry weight decrease. Cytokinin can delay senescence.

Seed Dormancy:

- It is the condition in which viable seed is unable to germinate even in the presence of favourable environmental conditions.
- **Quiescence**–Viable seed fails to germinate due to absence of favourble external environmental conditions.

Causes of Seed Dormancy:

(i) Tough seed coat **e.g. *Capsella.***

(ii) Seed coat is impermeable to water **(e.g. Legumes)** or gases **(e.g. Apple)** or chemicals **(e.g. *Xanthium*)**

(iii) Immature embryo at the time of shedding of seed

(iv) Presence of inhibitors **e.g. ferulic acid in tomato juice;** ABA, phenolic compounds, coumarins.

(v) Absence of growth hormones

(vi) Reqssuirement of chilling treatment

Breaking of Dormancy

(i) Scarification **(ii)** Impaction **(iii)** Stratification

(iv) Pressure **(v)** light **(vi)** Alternate temperature

Seed Germination:

- It involves sprouting of seed and resumption of growth of the embryo to form a young plant. It is regulated by two types of factors.

(a) External Factors: **(i)** water **(ii)** Oxygen **(iii)** Temperature **(iv)** Light **(v)** pH

(b) Internal Factors: It involves internal factors like viability of seeds, dormancy, availability of food, maturity of embryo at the time of shedding of seeds.

Types of Seed Germination:

1. **Hypogeal germination:** Cotyledons remain in soil due to rapid elongation of epicotyl e.g**. Pea, Gram.**
2. **Epigeal germination:** Cotyledons comeout of soil due to rapid elongation of hypocotyl. **e.g. Castor.**

Resonate the Concept

(1) Natural auxins (IAA) show polar transport from shoot apex to base **(basipetal movement).**

(2) Most common cytokinin, is **IPA (Isopentenyl adenine)** which has been isolated from ***Pseudomonas tumefaciens*.**

(3) **Agent orange** contains **2, 4-D, 2, 4, 5-T.** The former is a weedicide and used during Vietnam-American war as defoliant of forest tree.

(4) GA_4 and GA_7 are commerically used as **pomalin** with cytokinin (BAP) to increase size of apple fruits.

(5) The commerical product for providing ethylene is **Ethephon (2-chloroethyl phosphonic acid).**

(6) **Antigibberellins - e.g. Cycocel , phosphon-D.**

(7) The precursor of Auxin is **Tryptophan** amino acid. **Zn^{++}** is essential for the synthesis of Auxin.