15 Plant Growth and Development

GROWTH :

* It is a 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 show limited growth

Ex: leaves, flower, fruit.

(b) Organs show unlimited growth

Ex: Roots, Stem.

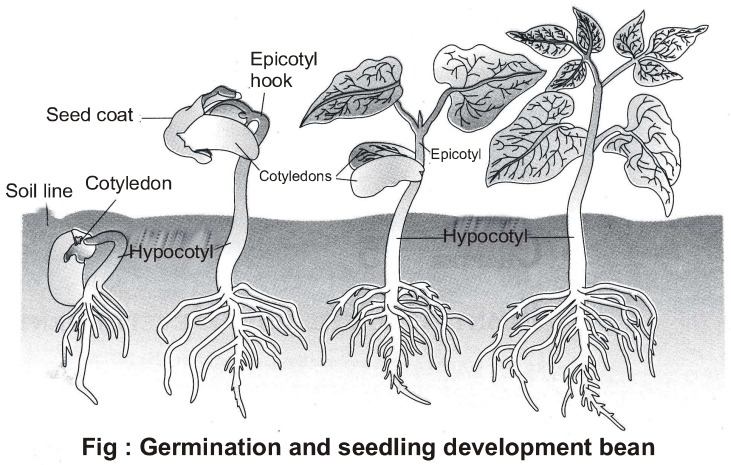


Fig : Germination and seedling development bean

* **Plant Growth Generally is indeterminate :** Plant growth is unique because plants retain the capacity for unlimited growth throughut their life. This ability of the plants in 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. Root apical meristem and the shoot apical meristem both are responsible for the primary growth of the palnts and principally contribute to the elongation of the plants along their axis and 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.

* Meristem 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.

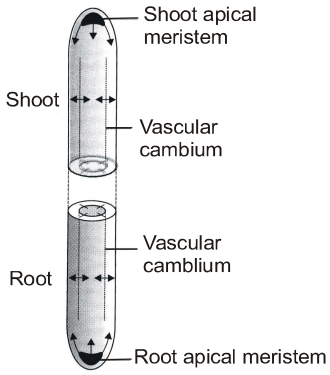


Fig : Diagrammatic representation of locations of root apical meristem, shoot apical meristem and vascular cambium. Arrows exhibit the direction of growth of cells and organ

* 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

(2) Phase of cell elongation

(3) Phase of cell maturation.

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. It is also called exponential phase.

(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.**

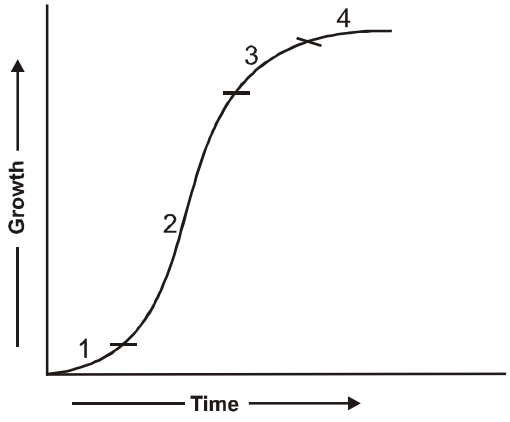


Fig:- Growth curve
1 Lag phase 2 Log phase
3 Decelerating phase 4 Stationary phase

Growth Rates :

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

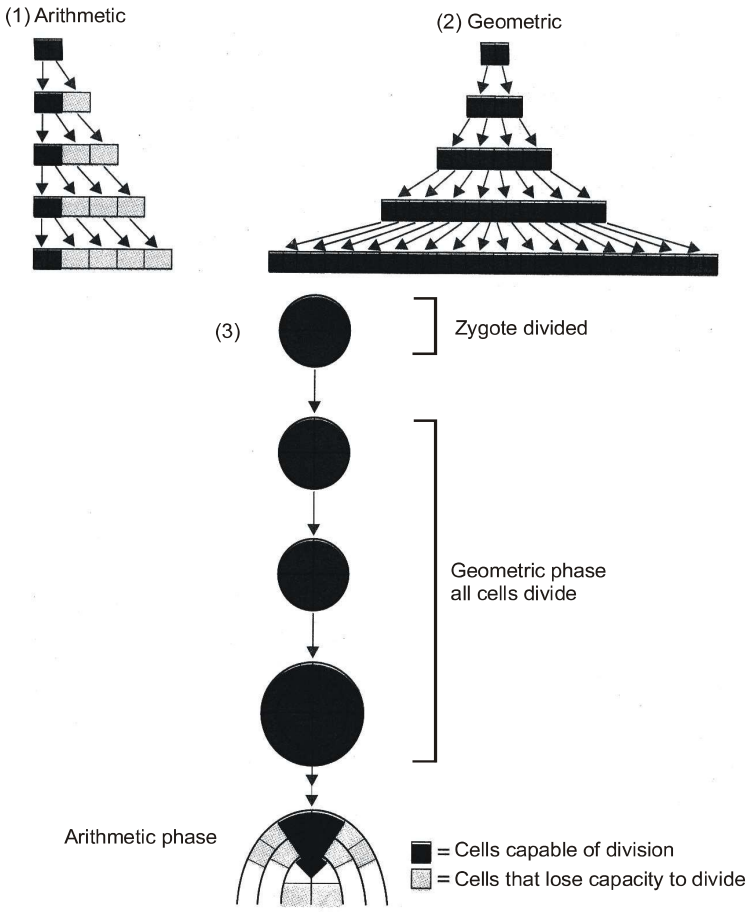


Fig : Diagrammatic representation of (1) Arithmetic (2) Geometric growth and (3) Stages during embryo development showing geometric and arithematic phases

Arithmetic Growth :

Growth takes place in arithmetic manner–1, 2, 3, 4, 5, 6. **Ex : 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.

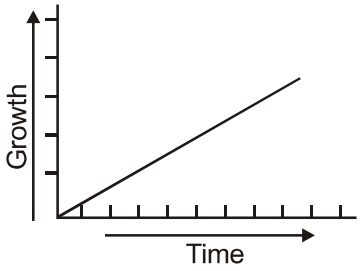


Fig : Arithmetic growth– Growth curve

Geometric Growth :

* Growth occurs in geometric manner–2, 4, 8, 16, 32. Ex : 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 is look like depositing money in a bank. The money will grow at compound interest. It can be expressed by the following equation.

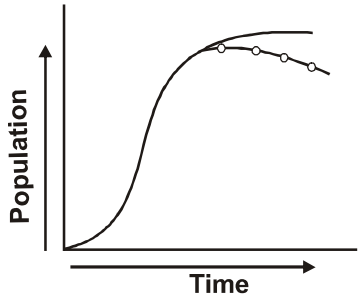


Fig : Growth of a population of unicellular organisms.

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

* 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**.
* Quantitative comparisons between growth 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 growth.

  Relative Growth rate

$$= \frac{\text{Growth in Given Time Period}}{\text{Measurement at Start of Time Period}}$$

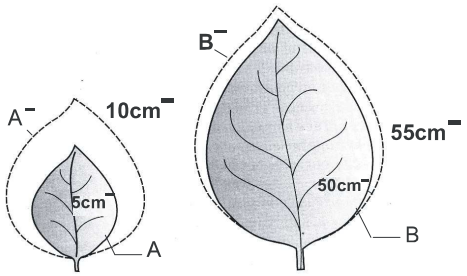


fig: Diagrammatic comparison of absolute and relative growth rates. Both leaves A and B have increased their area by 5 cm in a given time to produce A, B leaves.

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.

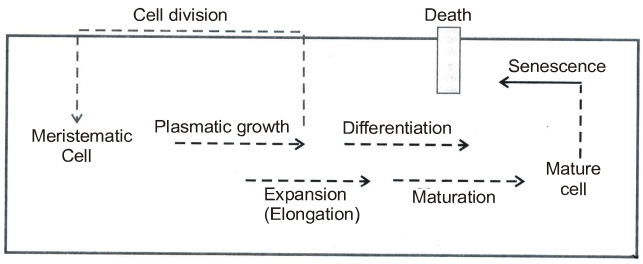


Fig : Sequence of the developmental process in a plant cell

* 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 shaper 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 hetrophyllous devlopment due to environment. This phenomenon of heterophylly is an example of plasticity.

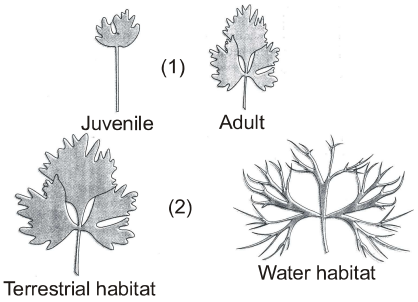


Fig : Heterophylly in (1) Larkspur (2) buttercup

Measurement of Growth :

(1) Direct method : The length of growing organ (like stem and root) is directly measured by means of a scale at a particular interval of time to find out the change in growth.

(2) Archauxenometer

(3) Peffer's auxanometer

(4) Crescograph

Factor affecting growth :

(1) Nutrients **(2) Water**

(3) Temperature **(4) Light**

(5) CO_2 **(6) O_2**

(7) Minerals & Hormones.

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 than 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.

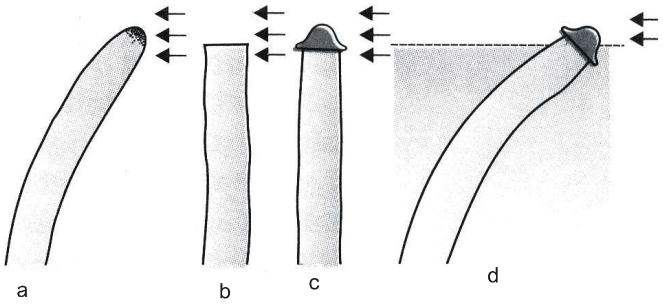
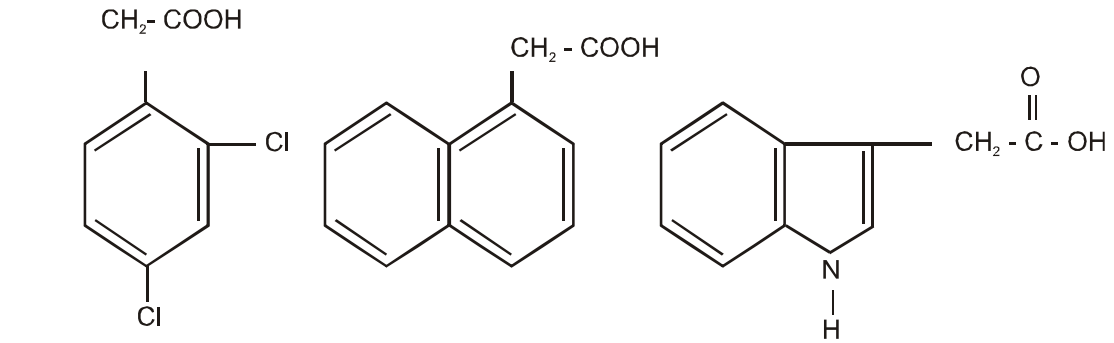


Fig : Experiment used to demonstrate that tip of the coleoptile is the source of auxin. Arrows in indicate direction of light

* **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

Nepthalene acetic acid = NAA

Inodle 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

(i) Avena curvature test

(ii) 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 Apical bud results in the rapid growth of lateral buds.

(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.

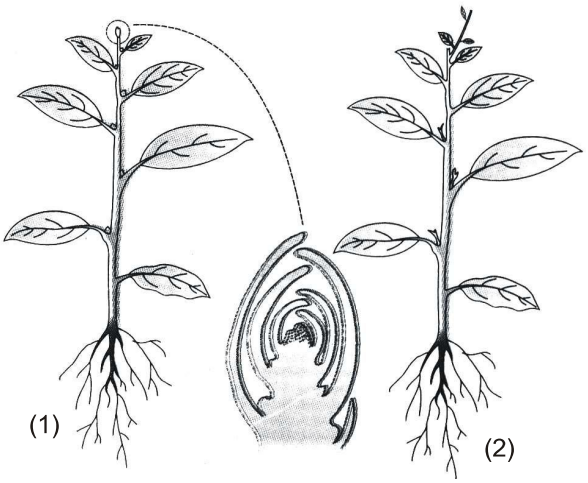


Fig : Apical dominance in plants
(1) A plant with apical bud intact
(2) A plant with apical bud removed note the growth of lateral buds into branches after decapitation.

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

(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 with out 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. **Ex : 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. **Ex : 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.

(B) Gibberellins :

* The effect of gibberellins had been observed over a century ago. Japanes 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.

  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 GIBBERLLINS :

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

(2) Seed germination : Gibberellins stimulate the production of m–RNAs and then 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.

Ex : Lectuca sativa and Nicotiana

(3) Breaking of dormancy : Application of GA stimulate germination of dormant organs like buds, seeds and potato tubers.

(4) Parthenocarpy : Gibberellins have been found to be 500 times more effective than auxins in inducing parthenocarpy **Ex : 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.

Ex : Henbane.

(6) Elongation of genetically dwarf plants : GA induces the elongation in genetically dwarf plants therefore they grow as normal tall plant.

Ex : 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).

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

(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**.**

Bioassay of cytokinins :

(1) Tobacco Pith Culture

(2) Retardation of Leaf Senescence

(3) Excised radish cotyledon Expansion.

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.

(2) **Delay senescence :** Application of cytokinins delay the 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) **Differentiation of organs :** Kinetin-auxin interaction controls the morphogenetic differentiation of shoot and root meristems.

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

(6) **Morphogenesis :** Cytokinin is essential for morphogenesis or differentiation of tissues and organs.

(7) **Other effects :**

(i) Induced flowering in SDP

(ii) Biosynthesis of lignin

(iii) Mobilization of food material

(iv) Retards abscission

(v) Induce femaleness

(vi) Seedling growth

(vii) 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.

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

(3) **Sex modification :** Exogenous application of Ethylene can change the sex in plants. i.e. induction of female flowers in male plants of cucumber.

(4) **Abscission :** It induces the Abscission of leaves, buds, flowers and fruits.

(5) **Root growth :** Ethylene induces origin of root from graft, formation of lateral roots and formation of root hairs.

(6) **Dormancy :** Germination in many seeds is stimulated by ethylene.

(7) **Flowering :** It induces profuse flowering in pine apple as auxin.

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

(9) **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 **abscisin 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**. But later it was found that Dormin and Abscisin 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.

ROLE OF ABSCISIC ACID :

(1) It inhibits seed germination.
(2) It induces abscission in leaves, 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.

* Other growth inhibitors includes-**Malic hydrazide, Morphactins, Para- ascorbic acid, Coumeric 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) **Ex: Spinach, Radish, Lettuce, Wheat, oat, Henbane.**

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

(iii) Day Neutral or indeterminate plants (DNP) : Flowering is not affected by photo period or day length.

Ex: Maize, Cotton, Tomato, Black Pepper, Cucumber, sunflower.

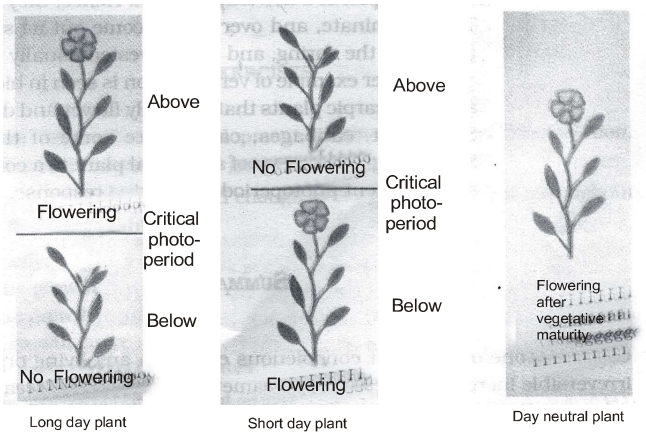


Fig : Photoperiodism : Long day, short day and day neutral plants

* Short day plants require a continuous critical dark period for flowering there fore 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 :

$$Pr_{660}\ (\text{blue}) \underset{\text{Far-red light}}{\overset{\text{Red light}}{\rightleftharpoons}} Pfr_{730}\ (\text{yellow green})$$

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

POINT OF REMEMBER

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)**. It is required by a number of temperate plants like Henbane, Cabbage, Winter Wheat, Chrysanthemum.
* 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.

Types of senescence :

(i) Whole plant senescence: Ex: monocarpic plants (annuals, biennials and perennials like Bamboos and sago Palm).

(ii) Organ senescence : It involves three types

(1) Shoot senescence : Ex: perennial herbs (Ginger, Banana, Urtica, Narcissus, Gladiolus)

(2) Sequential / Progressive senescence : Ex: mango, Eucalyptus.

(3) Simultaneous / Synchronous senescence Ex: Dalbergia, Mulberry, Maple, Poplar.

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 **Ex: Capsella.**

(ii) Seed coat is impermeable to water **(Ex: Legumes)** or gases **(Ex: apple)** or chemicals **(Ex: Xanthium)**

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

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

(v) Absence of growth hormones

(vi) Requirement 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 ramain in soil due to rapid elongation of epicotyl **Ex: Pea, Gram.**
2. **Epigeal germination :** Cotyledons comeout of soil due to rapid elongation of hypocotyl. **Ex: Castor.**

READ & DIGEST

(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.

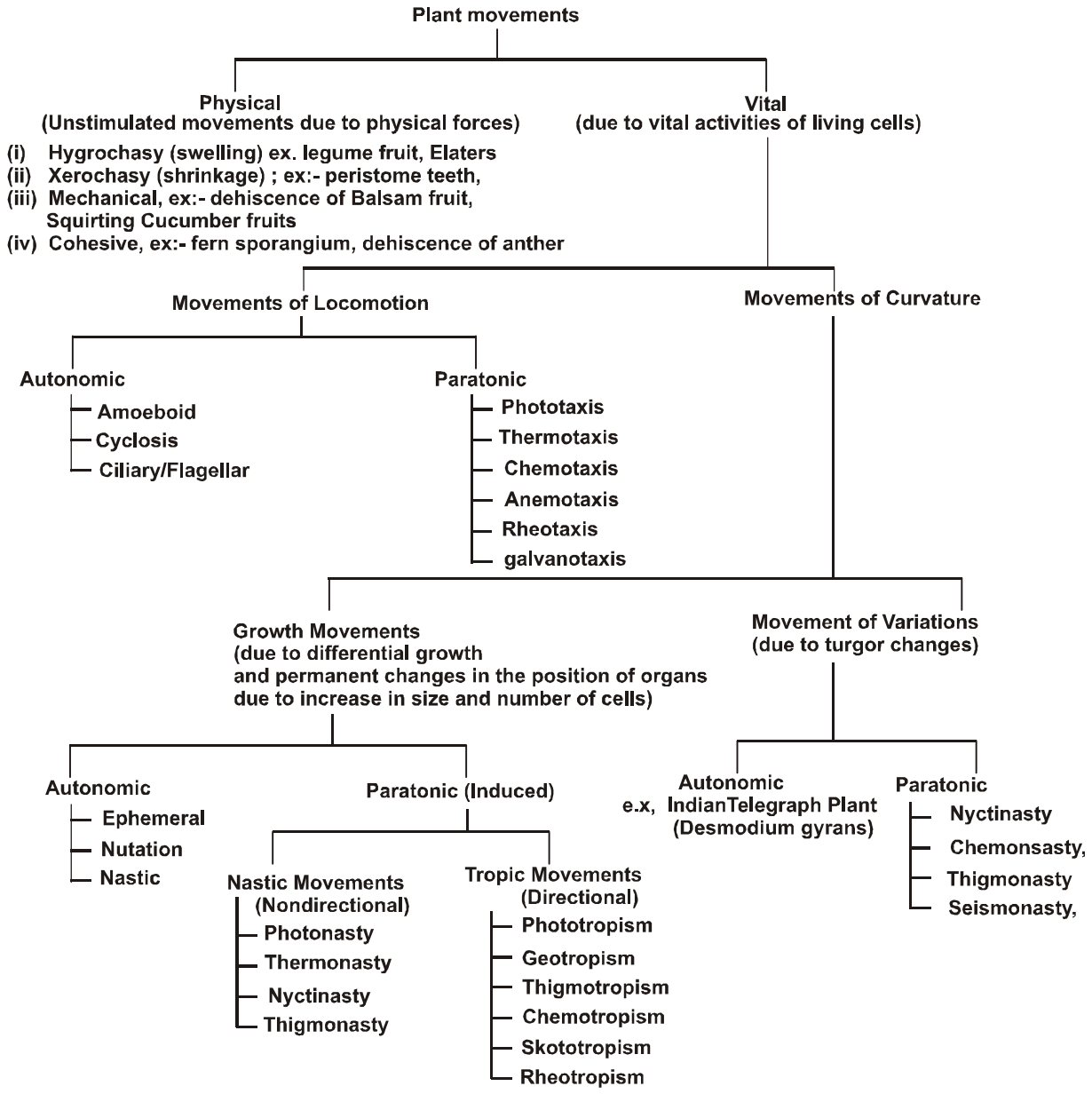
(4) GA_4 and GA_7 are commerically used as **pomalin** with cytokinin (BAP) to increase size of apple fruits.

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

(6) **Antigibberellins - Ex: Cycocel , phosphon-D.**

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

PLANT MOVEMENTS :



* Any changes in external or internal environment which produce a response in the plant is called **stimulus**.

  Reaction produces in a plant through stimulus is called **response**.

* The minimum time required for a stimulus to becomes effective is termed as **presentation time.**

* The duration between the application of stimulus and production of visible response is called **reaction time or latent time.**

* Living being show some change in their position either due to change in environment or due to some endogenous causes such changes are called movements.

TYPES OF PLANT MOVEMENTS :

(I) Physical

(II) Vital

(II) Vital movements :

These occur due to vital activities of living cells. They are of two types

(1) Movement of Locomotion

(2) Movement of curvature

(1) Movement of Locomotion :

It is a type of movement in which whole plant body or organ moves from one place to another, They are of two types.

(A) Autonomic movement : it occurs due to internal stimuli it is of following types.

(i) Ciliary movement : These movement are due to presence of cilia or flagella. **Ex: Zoospores of algae.**

(ii) Amoeboid movement : These movements are due to formation of pseudopodia. **Ex: Slime molds.**

(iii) Cyclosis or Protoplasmic movement : These are protoplasmic streaming movement and are of two types.

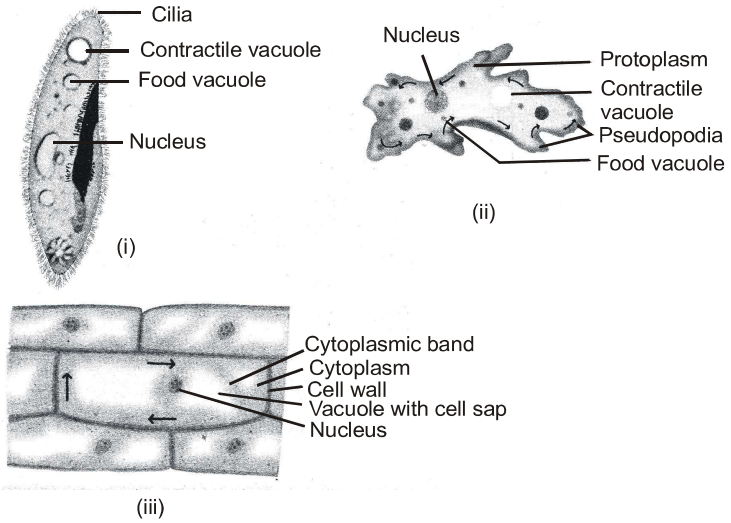


Fig : Protoplasmic movements (i) ciliary (ii) amoeboid (iii) cyclosis

(a) Rotation : Protoplasm moves around a single central vacuole either in clockwise or anticlockwise direction. **Ex: Hydrilla, Chara.**

(b) Circulation : Cytoplasm moves around a number of vacuoles present in the cell in various directions.

Ex: Staminal hairs in Tradescantia.

(iv) Excretory movement : Apical part of blue green algae **(Oscillotoria)** moves like a pendulum to right left. It occurs due to excretory substances.

(B) Induced movement of locomotion :

They occurs due to external stimuli They are of following types.

(i) **Phototaxis :** It occurs due to light stimulus, **Ex:** some algae like **chlamydomonas** moves from darkness to light and show positive phototactic movement.

(ii) **Thermotaxis :** It occurs due to temperature. **Ex: Thermal algae.**

(iii) **Chemotaxis :** It occurs due to to chemicals **Ex: Male gametes in Bryophytes and pteridophytes** are attracted towards mucilaginous substances present at mouth of archegonial neck and perform movement.

(iv) **Rheotaxis :** It occurs in response to water currents. **Ex: Aquatic angiosperms.**

(v) **Galvanotaxis :** It occurs in response to stimulus of electric current. **Ex: Some bacteria and some members of volvocales.**

(2) Movement of curvature :

In this type of movement organs of plants show curvature. They are of two types.

(I) Movement of growth

(II) Movement of turgor variations

(I) Movement of growth : They cause due to unequal growth in different parts of organs. They may be

(A) Autonomic movement of curvature: They occurs due to internal stimuli. They are of following types.

(1) Nutation movement : Uneven growth on two surface hence coiling takes place usually cylindrical organs show nutation movement.

Ex: stem climbers in Cucurbitaceae.

(2) Circumnutation movement : Stem of twiners coiled around object due to unequal growth.

Ex: tendrils of lablab.

(3) Epinasty movement : When growth takes place more on upper suface the organ show curvature down wards. It is known as epinasty.

Ex : Opening of floral buds.

(4) Hyponasty movement : When growth takes place more on lower surface the organ bends up wards. It is called Hyponasty.

Ex : Uncoiling of leaf of fern.

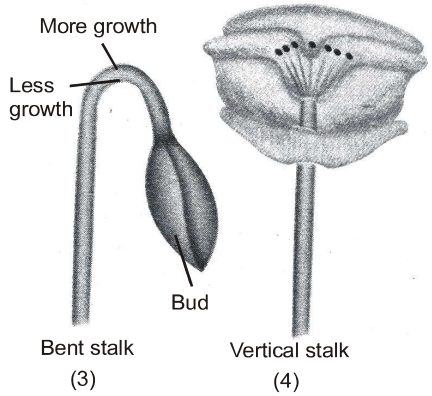


Fig : Nastic movements in plants (3) epinasty and (4)hyponasty

(B) Induced curvature movements : They occur due to some external stimulus. These may be unidirectional or diffused.

(1) Phototropism : Due to light stimulus, stem moves to wards light and is called as positive phototropic. Root moves away from light and is called negative phototropic.

(2) Geotropism : They occur in response to gravitational force main stem grows away from gravity and show negative geotropism. Roots grows towards the centre of earth in response of gravitational force and show positive geotropism. When the organ grows at an intermediate angle (between 0° to 90° or between 90° to 180°) it is said to be plageotropic.

Ex: Lateral roots, leaves. clinostate is used to demonstrate the geotropic curvature.

(3) Chemotropism : These movements takes place due to stimulus of chemical substances.

Ex: fungal hyphae and pollen tube.

(4) Hydrotropism : They occur due to stimulus of water.

Ex: Root are positive hydrotropic. They always move towards water.

(5) Thigmotropism : Movement occur due to contact stimulus.

Ex: Tendrils & Weak climbers.

(II) Movement of turgor variation : They occur in response to diffused stimulus. They are of following types.

(1) Autonomic movement of variation : It occurs in **Indian telegraph plant (Desmodium gyrans)** in which trifoliate leaves are found. During day time the two lateral leaflets move up and down due to variation in turgidity.

(2) Paratonic movement of variation : They are non directional movement in which response is determined by the structure of responsive organ. They are of following types

(i) Nyctinasty : The diurnal movement of leaves and petals of flowers of some plants are called nyctinasty or sleep movements. When flowers and leaves open due to effect of light. It is called **photonasty.**

Ex: Acacia, Oxalis. Opening & Closing of flowers due to temperature is called **thermonasty**.

Ex : Tulip, Crocus.

(ii) Thigmonasty : It occurs in response of the touch stimulus. **Ex : Drosera.**

(iii) Seismonasty : This movement is best exhibited by sensitive plant **Mimosa pudica (Touch me not plant).** In this plant leaves are bipinnately compound with a swollen pulvinus at the base of leaf and pulvinules at base of pinnae or leaf lets. If terminal pinnae or leaf let is touched a shock or touch, stimulus passes down ward in the form of hormone. It resulted in to loss of turgor of the cells of lower half of pulvinus. So leaf becomes drooping. When the effect of hormone is lost.The cells of lower half of pulvinus become turgid and leaf attains its normal position.

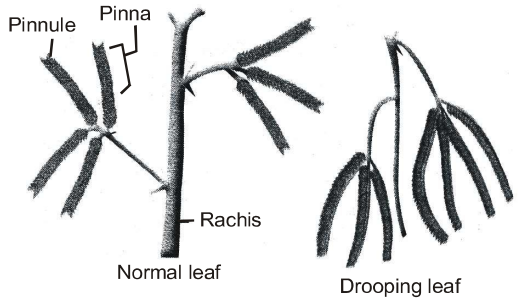


Fig : (iii) Seismonasty