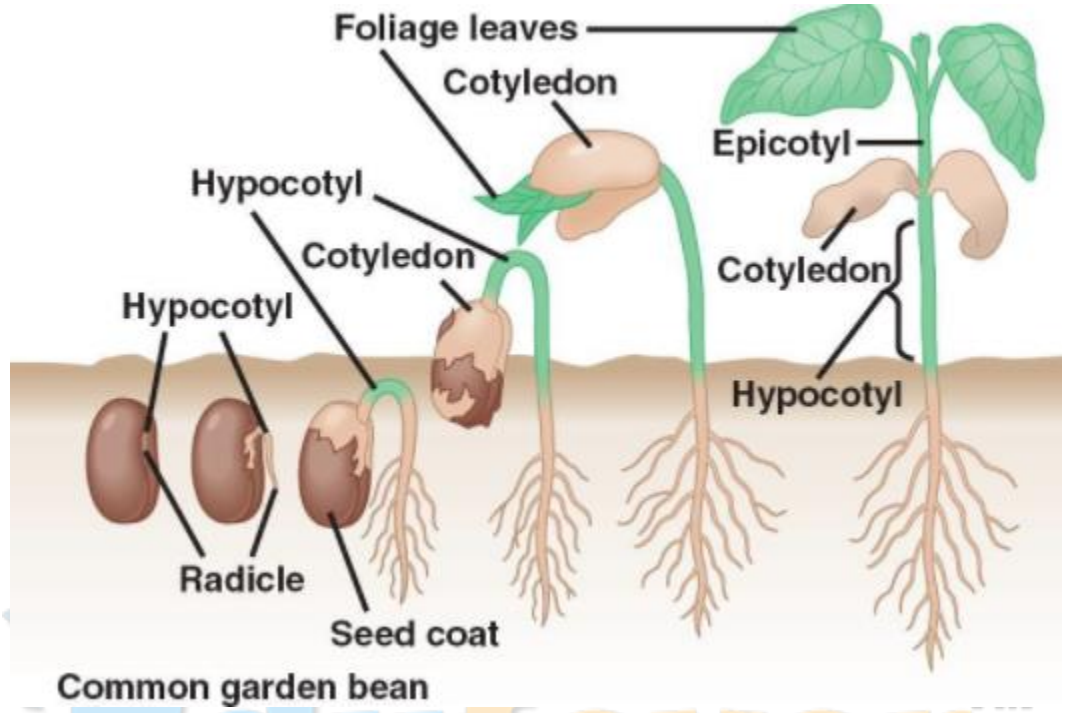
PLANT GROWTH AND DEVELOPMENT

All cells of the plant develop from the zygote. The development of a mature plant from the zygote follow a precise and highly ordered succession of events. It is actually the sum total of growth and differentiation. A complex body organization is formed during this process. The body produces roots, leaves, branches, flowers and seeds and after that the plant dies.



15.1 Growth: An irreversible permanent increase in size of an organ or its parts or even of an individual.

One of the most fundamental characteristics of living things is their ability to grow and develop.

A mature plant consists of numerous cell types because all the cells do not grow and develop in the same way.

Growth is characteristic of living things. During growth several metabolic processes occurs like **catabolism and anabolism**.

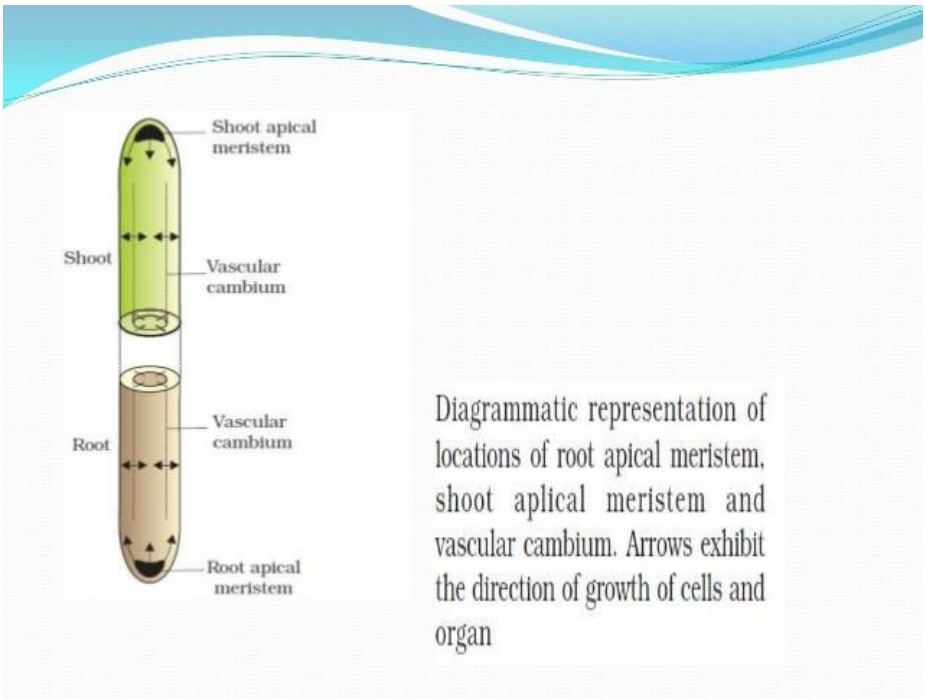
15.1.1 Plant growth is generally indeterminate: In plants growth occurs by cell division and cell enlargement. Plants retain their capacity for unlimited growth throughout their life. This ability is due to the presence of meristems at certain locations in their body. Meristems are the actively dividing cells. The new cells produced by the meristems soon lose their capacity to divide and enter into the G_0 phase of the cell cycle and make up the plant body. This type of growth wherein new cells are always being added to the plant body by the activity of meristems is called **open form of growth**. As a result of open growth, plants are always growing and forming new organs to replace the older and senescent ones.

Growth in plants may be of two types-**Primary growth and secondary growth**.

Primary growth-The increase in length of axis by growth is called the primary growth. It takes place by the activity of the apical meristem and intercalary meristem. As a result of primary growth, length is increased.

Secondary Growth: The increase in growth or thickness of the axis by growth is called secondary growth or secondary thickening. It takes place by the activity of lateral meristem. Vascular cambium and cork cambium are

the lateral meristem. Secondary growth brings about an increase in width of stem and root. As a result of growth, the dry weight is increased. In plants growth is not limited, where as in animals, growth is limited.



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

15.1.2 Growth is measurable: Growth is an increase in the quantity of protoplasm. Increase in the amount of protoplasm is difficult to measure directly, one generally measures some quantity which is more or less proportional to it. To measure growth different parameters can be used, like increase in fresh weight, dry weight, length, area, volume, cell number etc.

One single maize root apical meristem can give rise to more than 17,500 new cells per hour, where as cells in a water melon fruit may increase in size by up to 3,50,000 times.

15.1.3 Phases of growth: The period of plant growth is divided into three stages.

- **Meristematic phase**
- **Phase of elongation**
- **Phase of maturation.**

Meristematic phase: During this phase, the cells in the growing region undergo mitotic division to form numerous cells. These cells are iso-diametric with prominent, large and conspicuous nucleus and rich protoplasm without vacuoles. They have thin cellulosic cell wall with many plasmodesmata. In higher plants, the meristematic phase takes place in meristems at root apex and shoot apex.

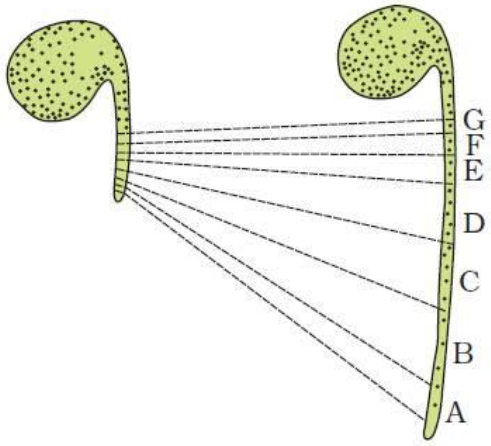
Phase of elongation: It is the dominant phase in growth of plants. During this phase, the newly formed cells absorb more water. As a result, the turgidity and the amount of protoplasm increase. Vacuoles appear at the centre. The cell walls become more thickened. Due to these events, the cells enlarge. Enlargement of cells takes place in all directions.

Rapid growth occurs during the phase of elongation.

Phase of maturation: During this phase, the enlarged cells become differentiated to perform specific functions.

The matured cells gradually get differentiated into permanent tissues by attaining their maximum size in terms of wall thickening and protoplasmic modifications.

The time interval from the meristematic phase to maturation phase is called **Grand period of growth.**



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

15.1.4 Growth rates: The expression of increased growth per unit time is called growth rate. The expression of growth rate mathematically is called arithmetic growth and geometrically is called geometrical growth.

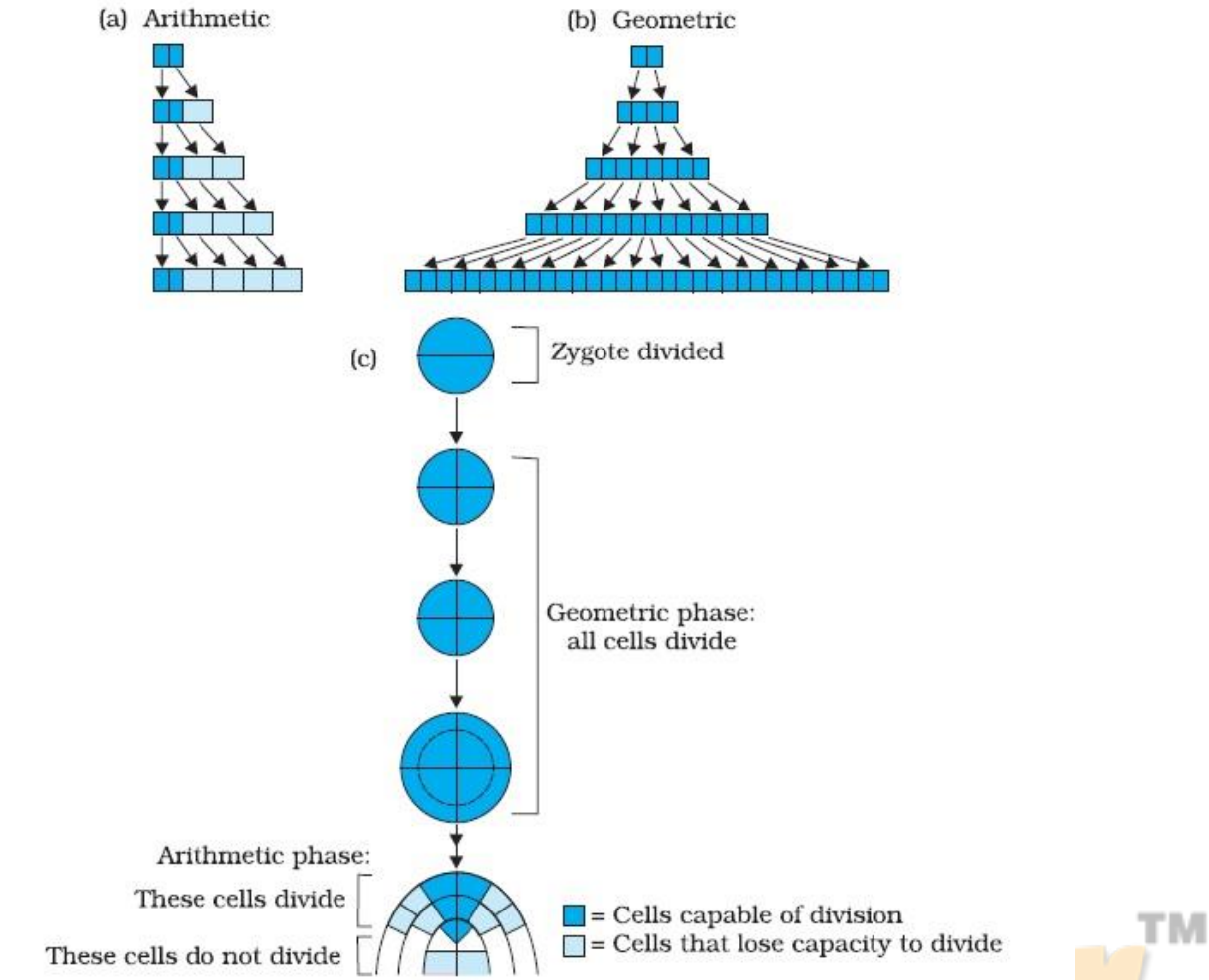


Figure15.4 Diagrammatic representation of : (a) Arithmetic (b) Geometric growth and (c) Stages during embryo development showing geometric and arithematic phases

In arithmetic growth, only one daughter cell continues to divide by mitotic division while the other daughter cell differentiates and mature. The arithmetic growth is simply expressed by a root elongation at a constant rate.

On plotting the length of the organ against time, a linear curve is obtained.

Mathematically it is expressed as:

$L_t = L_0 + r_t$

L_t-length at time t

L0=length at time zero

r=growth rate/ elongation per unit time

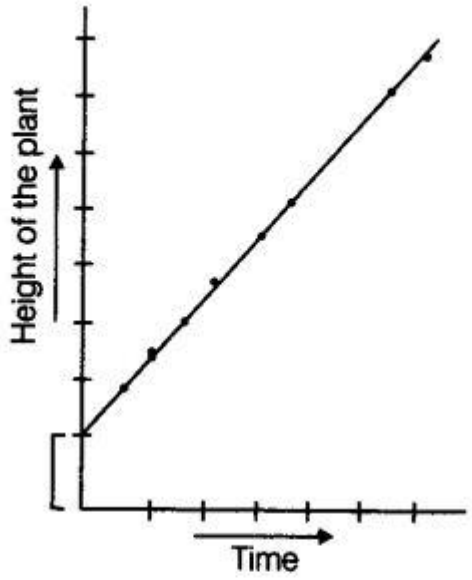


Fig. 15.5 Constant linear growth, a plot of length L against time t

$$L_t = L_0 + rt$$

where L_t = Length at time 't'

L_0 = Length at time 'zero'

and r = Growth rate/elongation per unit time.

Growth may not be sustained at a high rate throughout the life of cell or tissue or organ or organism. When the parameter of growth (weight, volume, size etc.) of a plant organ is measured and is plotted against time, and S shaped curve is obtained. This is called **growth curve or sigmoid curve or S curve**.

In Geometric growth every cell divides with all daughter cells growing and dividing again.

In geometric growth, the sigmoid curve consists of 3 parts-Lag phase, Exponential or log phase and stationary phase.

Lag phase-During this phase, the rate of plant growth is generally slow. It is due to the utilization of reserve food materials.

Exponential phase or Log phase - During this phase, the rate of growth increases rapidly. The rate of growth is exponential and reaches the maximum value. Here both the daughter cells following mitotic cell division retain the ability to divide and continue to do so. The limited nutrient supply slows down the growth and leads to a stationary phase.

Stationary phase: During this phase, the ratio of growth again slows down due to the limitation of nutrients. A sigmoid curve is exhibited by numerous annual plants and individual parts of both annual and perennial plants.

The exponential growth can be expressed a as

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

W_1=final size

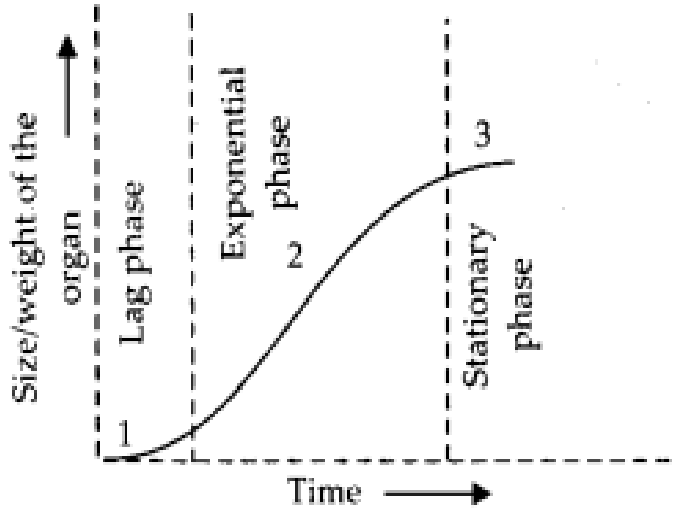
W_0 = initial size

r = growth rate

t = time of growth

e = base of natural logarithm

Efficiency index is the ability of a plant to produce a new plant material. So the final size of W1 depends on the initial size W_0



Quantitative comparison between the growths of living systems can be made in 2 ways- absolute growth rate and relative growth rate.

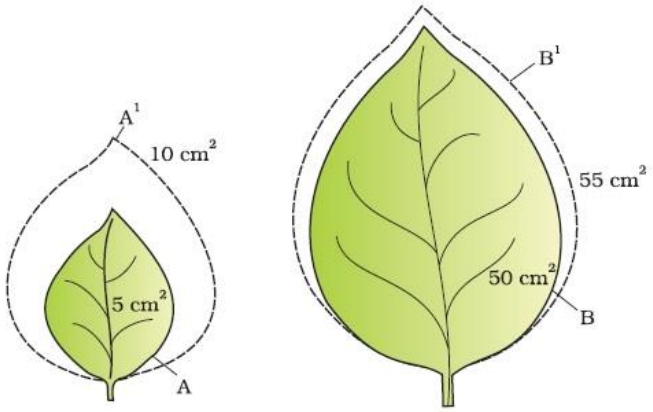
Absolute growth rate-It is the measurement and comparison of total growth per unit time.

Relative growth rate- It is the growth of the given systems per unit time expressed on a common basis.

E.g.: per unit initial parameter.

Two leaves A and B .They are of different size of area .They show exact absolute increase in the area in a given time. One of them has much higher relative growth rate.

Leaves A and B have grown by 5 cm^2 in one day. The initial size of leaf A was 5cm^2 and that of B was 50 cm^2. Even though their absolute growth is the same, relative growth rate is faster in leaf A.



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.

15.1.5 Conditions for growth:

1. Supply of nutrient, oxygen, water, sustainable temperature and light are necessary for proper growth.

2. Environmental signals like force of gravity and light etc. determine the directions of root growth and shoot growth and affect certain stages of growth.

3. Nutrients provide necessary material for the synthesis of protoplasm and act as a source of energy.

4. Water maintains turgidity of growing cell which helps in extension of growth.

5. Water provides medium for enzymatic reactions needed for growth.

6. Oxygen helps in releasing metabolic energy necessary for growth activities.

7. Temperature has thermotonic effect on growth. Optimum temperature for proper growth is 28 degree centigrade to 30 degree centigrade. Temperature above 45 degree centigrade results in the protoplasm of meristematic cells becoming coagulated and damaged. So, it inhibits proper growth.

8. During the initial stages of growth, light is not necessary. But light is required for further growth and photosynthesis. Light has a stimulating effect on plant growth. In the absence of light, growth is decreased in certain plants. This is called **etiolation**.

9. The presence of high concentration of salts, the deficiency of mineral nutrients, and stress factors negatively affect the rate of plant growth.

15.2 Differentiation, Dedifferentiation and Redifferentiation:

The cells that arise from various meristems like root apical meristem, shoot apical meristem, and cambium eventually differentiate and mature to perform special functions. The process of specialization of cells that leads to their maturation is called **differentiation.**

During differentiation, cells undergo different structural changes in their cells and protoplasm.

E.g. For the formation of tracheary element in phloem, the cells will be losing their protoplasm. They develop a very strong, elastic, lignocellulosic secondary wall. Some of the living and differentiated cells in plants can regain the capacity of cell division under certain conditions and is called **dedifferentiation.**

Eg- formation of certain meristems.

All interfascicular cambium, cork cambium, and wound meristems are derived from parenchyma cells.

Callus formed from a parenchyma tissue in a culture medium is an example for dedifferentiated cells.

The dedifferentiated cells or tissues can divide and produce new cells once again. They again lose their capacity to divide and mature to perform specific functions. This phenomenon is called **redifferentiation.**

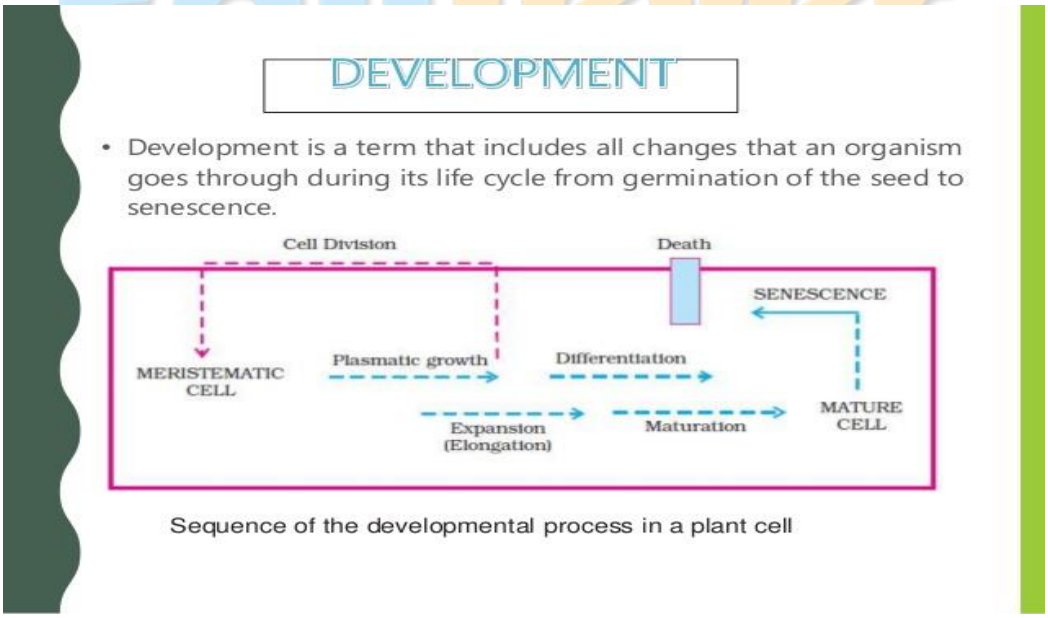
E.g.: Secondary xylem and secondary phloem from interfascicular cambium, secondary cortex and cork from cork cambium.

Growth in plants is of open form. The cells arising from the same meristem have different structures at maturity. The final structure of a cell or tissue arising from the same meristem is determined by the location of the cells.

E.g.: The cells positioned away from the root apical meristem differentiate as root cap cells, while those pushed to the periphery mature as epidermis.

15.3 Development: All changes from germination of the seed to senescence (ageing) constitute the development of a plant. The important aspects of growth are cell division and differentiation.

Growth is a quantitative phenomenon whereas development is a qualitative phenomenon. The sum of growth and differentiation is called development.



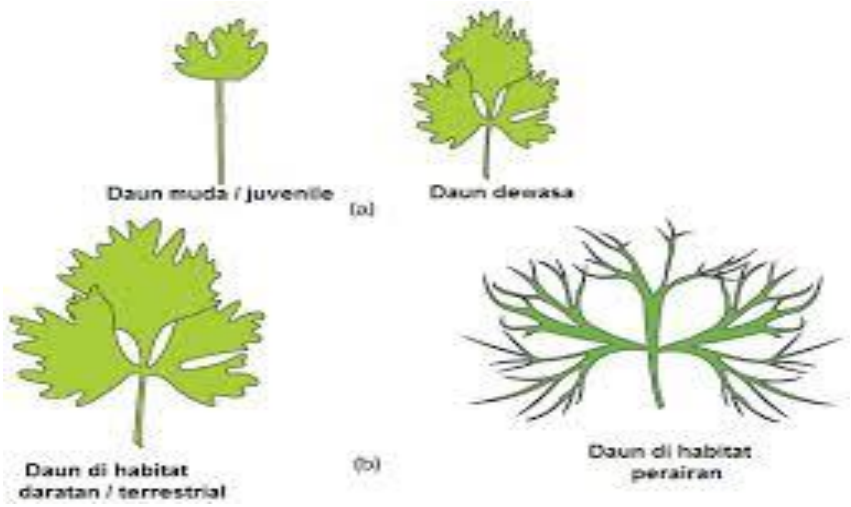
Sequence of the developmental process in a plant cell

Plasticity is seen in plants in response to environment or phases of life to form different kinds of plant structures.

E.g.: Heterophilly (occurrence of more than two types of leaves on the same plant) in larkspur, cotton, coriander etc.

In these heterophyllous plants, the leaves of the juvenile plant are different in shape than those in adult plants (developmental heterophilly).

In some aquatic plants like butter cup (*Rannunculus flabellari* and *Rannunculus aquatilis*) and *Limnophylla heterophylla* the shapes of leaves produced in the air are different. In these plants, the aerial and floating leaves are generally broad while submerged leaves are ribbon shaped, linear and dissected (environmental heterophilly).



In plants, development is under the control of intrinsic and extrinsic factors. The intrinsic factors or internal factors include intracellular or genetic factors and intracellular factors -chemicals like plant growth regulators. Extrinsic factors include light, temperature, water, Oxygen, nutrition etc.

15.4: Plant growth regulators:

15.4.1 Characteristics:

In plants, certain chemical substances occurring in minute quantities regulate growth and differentiation. These chemical substances are **called plant growth regulators or phytohormones or plant hormones or plant growth substances**. They are influenced by the genetic makeup and environment. They play an important role in the growth and differentiation of plants.

Plant hormones are organic compounds which are capable of influencing physiological activities leading to promotion, inhibition and modification of growth. The growth regulators have a positive effect or a negative effect in the growth of a plant. If it has a positive effect on a process it can promote it and has a negative effect it causes inhibition of the process.

Based on the functions, the PGRs can be divided into 2 groups-**growth promoting hormones and growth inhibiting hormones.**

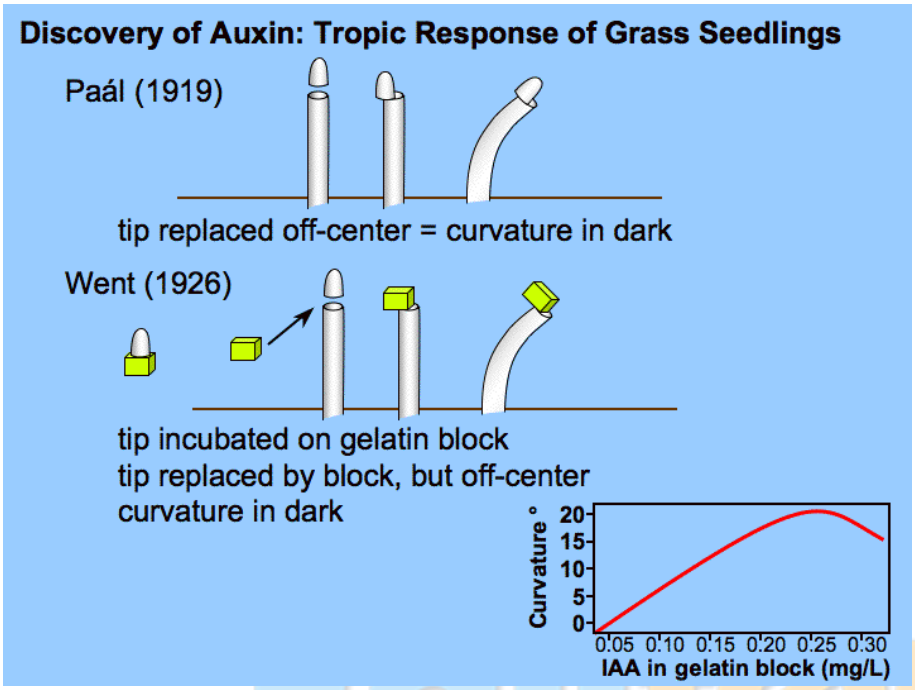
Growth promoting hormones- The Plant Growth Regulators are involved in various growth promoting activities - cell division, cell enlargement pattern formation, tropic growth, flowering, fruiting, seed formation etc. - **Auxins, Gibberellins and Cytokinins.**

Growth inhibiting hormones- These Plant Growth Regulators are involved in various growth inhibiting activities like dormancy and abscission (shedding of leaves, flowers and fruits) .They also play important role in plant responses to wounds and stresses of biotic and abiotic origin. **ABA (abscisic acid) belongs to this group**.

Gaseous PGR – Ethylene, could fit either of the groups, but it largely inhibits growth activities.

15.4.2 The Discovery of Plant Growth Regulators:

The first indication of the existence of PGR came from the work of Charles Darwin and his son Francis Darwin while working on canary grass (*Phalaris canariensis*) demonstrated the bending of grass coleoptiles towards unilateral source of light (phototropism). After conducting many experiments, it was found that the site of transmittable influence was the tip of the coleoptiles which caused the bending of the entire coleoptiles.



Later the experiments conducted in different laboratories, resulted in the discovery of the first PGR called Auxin.

In 1928 F.W Went isolated auxin from coleoptiles' tips of Oats (*Avena sativa*) He cut off the tip of the *Avena sativa* coleoptiles and so the remaining portion of the coleoptiles do not possess auxin to elongate. Then he placed the excised tip of coleoptiles on a cube of agar. Auxin diffused into the cube.

The coleoptiles tip was removed and the agar block containing auxin was placed on one side of another decapitated coleoptiles tip.

Auxin moved down the coleoptiles directly below it, and caused greater elongation of cells along that side of the coleoptiles than on the opposite side. Thus curvature was caused. It was by differential growth rates on the two sides. From this experiment, F.W Went proved that the substance always moved from the apex towards the base of the coleoptiles. Agar blocks containing auxin (diffused substance) when placed on decapitated coleoptiles could induce the action of the apex. F.W.Went named this substance as auxin and concluded that no growth can occur without auxin.

Kogl and Haagen Smith in 1931 isolated first naturally occurring auxin from human urine.

E.Kurosawa discovered gibberellins.

Skoog and Miller identified and crystallized kinetin (cytokinin).

During mid 1960's 3 independent researches purified and studied the chemical characterization of 3 different kinds of plant growth inhibitors-**inhibitor B, Abscission II, and dormin. Later all the three were proved to be chemically identical and named it as ABA (Abscisic acid).**

Cousins identified the gaseous hormone Ethylene by reporting the release of volatile substance from ripened oranges that increased the rate of ripening of stored unripened bananas.

15.4.3 Physiological Effects of Plant Growth Regulators:

15.4.3.1 Auxins: Indole derivative.

Auxins are of two types-Natural auxin and Synthetic auxin.

Natural auxins- It occur naturally and includes IAA (Indole Acetic Acid), IBA (Indole Butyric Acid), IPA (Indole 3 Pyruvic Acid). IAA, IBA, IPA have been isolated from plants. Of these IAA is found in all plants and fungi.

Synthetic auxins-The synthetic compounds which function as auxins are called synthetic auxins.

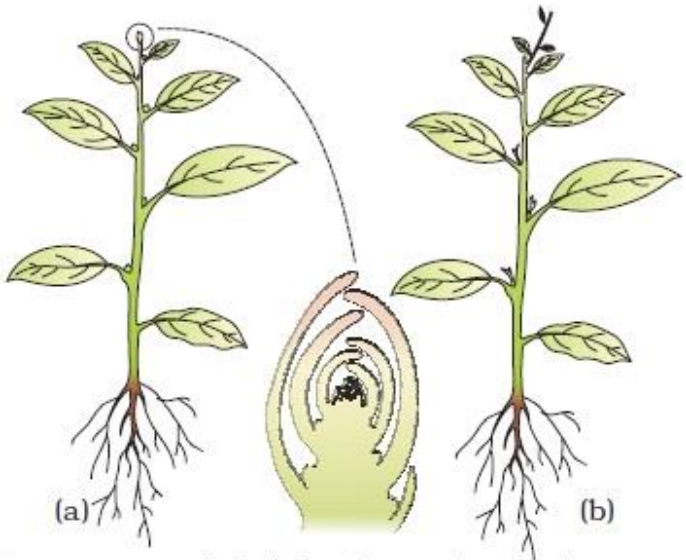
Some of them are NAA (Naphthalene acetic Acid), 2-4 D (2,4, Dichlorophenoxy Acetic Acid), 2,4,5 T(2,4,5,-Trichlorophenoxy Acetic Acid) and PAA (Phenyl Acetic Acid).

Auxins plays an important role in agriculture and horticulture.

The important applications of auxins are:

Plant propagation

- Promotes apical dominance- It is the phenomenon by which the presence of auxins in the shoot apex inhibits the growth of lateral buds and promote the growth of apical buds. Decapitation promotes the growth of lateral buds. This aspect is employed in tea plantation and in gardening for hedge making.



Apical dominance in plants :
(a) A plant with apical bud intact
(b) A plant with apical bud removed
Note the growth of lateral buds into branches after decapitation.

- Promotes abscission of mature leaves and prevents abscission of immature leaves. At the time of shedding, they stop producing auxin. NAA is used to control pre-harvest fruit drop.
- Initiates rooting from stem cuttings. Hence used in vegetative propagation of plants.
- Auxin normally inhibit flowering in all plants except in pine apple and litchi.
- Induce parthenocarpy in tomato.
- 2, 4, D is an inducer selective weedicide to remove broad leaved weeds.
- Auxins controls differentiation of xylem and helps in cell division. Hence used in tissue culture along with cytokinins.
  Bioassay - (To determine the activity of a substance) for Auxins are *Avena* curvature test and Root growth inhibition test.

15.4.3.2 Gibberellins: Terpene derivative.

These are known as Gibberellic acid (GA).

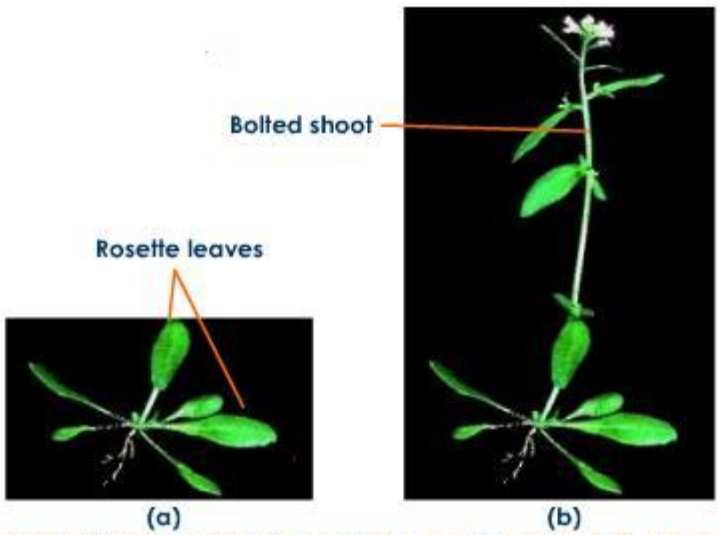
GA were first isolated by Yabuta and Samuki in 1939 from an ascomycetous fungus, *Gibberella fujikuroi* which causes **foolish seedling disease or bakanae disease in rice seedlings.** This fungus is now known as ***Gibberella monoliforme***. The affected plants have a tendency to appear taller, paler, thinner and without seeds. The highest level of Gibberellins is detected in seeds.

There are more than 100 GAs and are named as GA1, GA2, GA3, etc.

GA3 is the first discovered GA and the most intensively studied Gibberellic acid.

Gibberellins are produced in fungi and also in plants.

- Promotes cell elongation especially of intermodal cells and causes elongation of axis. Hence used to promote production of grapes with long stalks.
- Promote the production of large apples with definite shape.
- Promote bolting (Internodal elongation prior to flowering) in cabbage, carrot, Beet root etc.



Showing bolting in a 'rosette' plant (cabbage) induced by the application of gibberellin.
a() an untreated plant (b)Treated plant showing bolting.
Note the elongated internodes and flowering.

- Increase sugar yield by increasing length of the stem of sugar cane.
- It induces parthenocarpy in Pome fruits such as apple and pear.
- It controls flowering in long day plants. Gibberellins can be applied as a substitute for long day requirements in long day plants.
- Sex expression –It controls sex expression in certain species. Generally it promotes the production of male flowers.
- Gibberellin stimulates the production of male flowers in genetically female plants of *Cannabis*.
- Seed Germination- it induces germination of positively photoblastic seeds of lettuce and tobacco in complete darkness.
- Genetic dwarfism- it is caused by the mutation of a single gene which may cause a block in the metabolic pathway leading to gibberellins synthesis. Gibberellin treatment on genetically dwarf varieties of pea, maize etc. cause them to grow tall by the elongation of internodes. Dwarfism is due to the deficiency of gibberellins. It has no effect on roots.
- Increase rate of malting (conversion of starch into maltose sugar in brewing by increasing production of enzyme alpha amylase).
- Break seed dormancy and promote seed germination.
- It delays senescence and so used to extent the market period of fruits by keeping the fruits on the trees.
- Spraying of gibberellins on juvenile conifers hastens its maturity period and promote early seed production.

Bioassay for Gibberellins are Dwarf pea test, Dwarf Corn test and Barley endosperm bioassay.

15.4.3.3 Cytokinins:

Cytokinesis promoting plant hormone are called cytokinins or kinins.

The **term Cytokinin was proposed by Letham** in 1964.There are about 18 different types of cytokinins identified. Chemically cytokinins are the derivatives of adenine.

The first discovered cytokinin is kinetin. It was a modified form of adenine, a purine (6 furfuryl amino purine). **It was first isolated by Miller and Skoog from the autoclaved herring sperm DNA (fish DNA) in 1955. Kinetin does not occur naturally in plants.**

In 1964 **Lethom** isolated the first naturally occurring cytokinins called zeatin from corn kernels and coconut milk.

Functions and applications:

- Promote cell division. It cannot act alone. Cytokinin is considered as the true cell division factor. It plays a vital role in the morphogenesis (Organ formation) of plants. It is used in tissue culture experiments. In tissue culture, cytokinin in association with auxin promotes cell division in the parenchyma cells. None of these two hormones in itself can promote mitosis.
- Cell enlargement and cell differentiation- The kinetin-auxin interaction controls cell differentiation of shoot and root meristems. If both are present in equal quantities, cells divide but do not differentiate. The proportion of these two hormones controls organ formation in callus. **If more cytokinin is present than auxin, shoot buds develop from a callus, and if more auxin is present than cytokinin, roots develop.**
- Overcome apical dominance- Auxin promotes the growth of apical bud, whereas cytokinin promotes the growth of lateral buds. Thus two hormones can act antagonistically in the control of apical dominance.

- Delays senescence. Thus retards ageing of plant organs or plants by mobilization of resources and controlling protein synthesis.
- The leaves dipped in cytokinins stay green longer than control leaves. The effect of cytokinin in retarding ageing is called **Richmond Lang Effect.**
- Breaking dormancy- They induce the breaking of seed dormancy, and also promote seed germination.
- Delay leaf senescence- Cytokinins promote nutrient mobilization which helps in the delay of leaf senescence.

Bioassay-Chlorophyll preservation test, Excised cell enlargement test, and Germination and differentiation test.

15.4.3.4 Ethylene -It is a simple gaseous growth inhibiting PGR. It is synthesized in large amounts by tissues undergoing senescence, and by ripening fruits. High concentration of auxins stimulate ethylene production. It is produced in plants from the amino acid **methionine.**

Maximum ethylene formation takes place during the ripening of fruits. Ethylene stimulates the activity of the cellulase enzyme, and there by the cellulose is broken down. As a result the tissues become softened. Ethylene is a natural product of metabolism in plants.

Functions and uses-

- Ethylene promotes horizontal growth of seedling, swelling of axis and apical hook formation in dicot seedling (Triple response). Triple response test is the bioassay of ethylene.
- Ethylene promotes elongation of internode and leaf petiole in deep water paddy plants so as to keep the shoot tips above water level.
- Induce flowering in pineapple and litchi.
- Promote sprouting of bulbs in Potato, Ginger and *Amorphophallus*.
- Promotes development of roots and root hair hence increases surface area for absorption.
- Initiate germination of pea nut seeds.

Ethylene is the most widely sued PGR in agriculture –in the form of **Ethephone and Ethrel**. Ethephone is used as aqueous foliar spray. It is easily absorbed by the leaves and slowly released as ethylene within the plant.

Applications:

- Used to promote ripening of tomato and apple fruits.
- To increase cucumber yield by increasing production of female flowers.
- To accelerate abscission of flowers and fruits (thinning). In cotton, Cherry, Walnut etc.
- Ethelyne is used in rubber tapping to increase the flow of latex.

15.4.3.5 Abscisic acid:

Abscisic acid is a naturally occurring plant growth inhibitor and an inhibitor of plant metabolism.

It is weakly acidic in nature. It was first isolated by **Addicot** in 1963 from cotton fruits. ABA is called dormin because it causes bud dormancy. It is isolated from different parts of higher plants. It is synthesized in leaves and then translocated to stem tips through phloem. It interacts with other growth regulators.

Functions and use-

- It inhibits seed germination
- Inhibits growth of excised embryos
- Stimulation of closing of stomata during severe drought and hence called as stress hormone.
- It inhibits mitosis in vascular cambium
- It acts as an antagonist to gibberellins.
- It regulates dormancy of buds, tubers, and seeds by inhibiting the growth processes. As ABA inhibits gibberellins stimulated growth in plants, it is called antigibberellins.ABA act as an antagonist to GA3. Dormant seeds germinate when ABA is overcome by gibberellins.

15.5 Photoperiodism-The response of the plant to the relative length of day and night for flowering is called photoperiodism.

The term photoperiodism was first used by Garner and Allard. They first demonstrated photoperiodism in *Nicotiana tobacum* (Maryland Mammoth variety of tobacco).

A day length or daily duration of light is referred to as a photoperiod or critical duration. Continuous 12 hours of day length is called critical day duration and the continuous 12 hours darkness is called **critical dark duration.**

According to the photoperiodic responses Garner and Allard classified the flowering plants into 3 groups.

- **Short day plants**
- **Long day plants**
- **Day neutrals**

1. Short day plants-Produce flowers when exposed to duration of light lesser than the critical duration. They need long night than the critical dark period for flowering. Also called as **long night plants.**

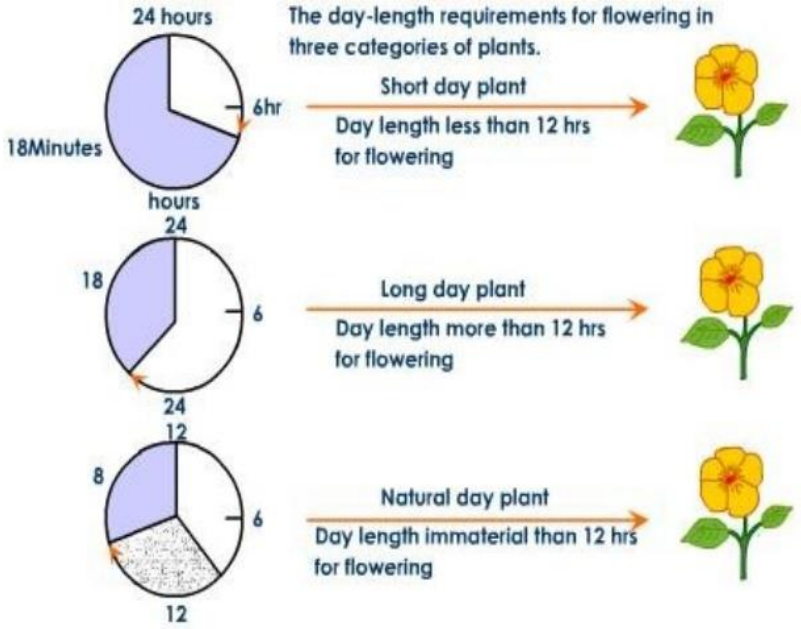
E.g.: Cosmos, Dahlia, Rice, Sugar cane, potato etc.

2. Long Day plants-These plant produce flowers when exposed to duration of light greater than critical day duration. These plants require a short night than the critical dark period. So they are also known as short night plants.

E.g.: Wheat, Barley, Sugar beet, Cabbage, Spinach, Radish etc.

3. Day Neutrals- Produce flowers irrespective of the light period. After completing the vegetative phase starts the flowering. They are also called as **Inter mediated day plants or Photoneutral plants.**

E.g.: Sunflower, Tomato, Corn, Pea, Cotton etc.



Long short day plants –These are short day plants but must be exposed to long days during early period of growth for subsequent flowering. E.g.: *Bryophyllum*.

Short long day plants- These are long day plants, they require short days for floral initiation and long day for blossoming.

E.g.: Certain varieties of wheat and rye.

In 1936 **Chailakhyan** suggested that a flowering hormone is synthesized in the leaves soon after perceiving the required favourable photoperiod and this flowering hormone is named as **florigen.**

15.6 Vernalisation-The low temperature treatment (0 to 5 degree centigrade) for flowering is called vernalisation. Also called as Chilling treatment or Yarovization. The term was first used by Lysenko.

The low temperature treatment was first realized by **Klippart** while working on wheat varieties. Vernalisation stimulus is perceived by the embryo of seed, especially plumule tips.

Natural vernalisation is observed in plants like Wheat, Barley and Rye and also in biennial monocarpic plants like cabbage, Carrot, Sugar beet etc.

Vernalisation is due to a hormone called vernalin by G.Melchers. Vernalin is now identified as Gibberellin. Vernalin may be considered as the precursor of florigen.

If vernalised seedlings or seeds are subjected to higher temperature like 35 to 40 degree centigrade the plants that develop from such treatment fail to flower. Such a nullifying effect by higher temperature is called devernalisation.

FAST TRACK REVISION:

Growth is an irreversible increase in mass, volume, or weight of an organism accompanied by increase in dry weight.

Plants show limited and unlimited growth, parts of the plant like fruits and leaves show limited growth where as stem and root show unlimited growth.

The rate of growth can be measured by plotting growth against time.

Growth curve or sigmoid growth curve is S shaped curve showing three phases namely lag phase, log and stationary phase.

Cells in their life cycle shows three phases-cell division phase, cell enlargement phase and cell maturation phase.

Development is the sum total of growth and differentiation.

Growth is controlled by internal factors like hormones, which can both promote and inhibit growth.

Plant hormones are Auxins, Gibberellins, Cytokinins, Ethylene and Abscisic acid.

The response of the plants to the relative length of day and night is called photoperiodism.

Promotion of flowering in biennial plants by cold treatment is called vernalisation.