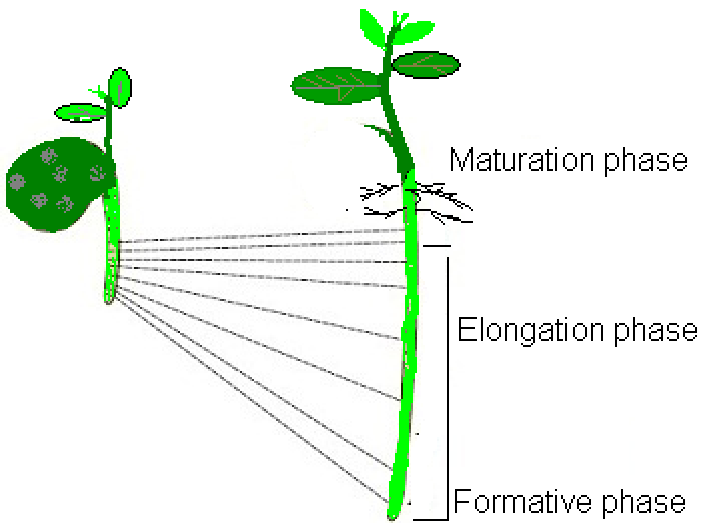
Address :
#1,C.V.R Complex (Big Bazaar Back side),
Singaravelu St,
T.Nagar, Chennai - 17 .
Mobile no: 733 888 4137 , 733 888 4136
www.spiroacademy.com , info@spiroacademy.com

PLANT GROWTH AND MOVEMENT

- Growth is a process in which there is increase in the size by cell division and enlargement accompanied by the formation of new cellular material. It results in the irreversible increase in size, length area or volume accompanied by increase in dry weight. In living beings, growth is internal or intrinsic in contrast to extrinsic growth observed in some non-living objects. Irreversible increase in size, mass or volume of living beings is an external manifestation of growth. Further growth is a quantitative phenomenon which can be measured in relation to time.
- Development can be defined as a process in which there is a sequence of qualitative changes, towards a higher or more complex state. It includes all the changes an organism undergoes from the time of birth till death. In development plant shows a regular sequence of seed germination, growth, differentiation, maturation, seed formation and senescence.

CHARACTERISTICS OF GROWTH

- Primary growth is formation of primary permanent tissues and organs. It is caused by activity of apical and intercalary meristems.
- Secondary growth is increase in girth. It occurs by two types of lateral meristems, vascular cambium and cork cambium.
- Unlimited growth is growth that continues throughout life as it occurs in case of root and stem. Limited growth is that growth which stops after some time, e.g. leaves, flowers, fruits
- In higher plants the growth involves three steps or phases
  - Phase of cell division
  - Phase of cell enlargement
  - Phase of cell maturation



GROWTH RATES

The expression of increased growth per unit time is called growth rate.

Growth rate shows two types of increase

- Arithmeticgrowth : It is a type of growth in which the rate of growth is constant and increase in growth occurs in arithmetic progression 2,4,6,8 etc. Here after mitosis, only one daughter cell continuous to divide. Other take part in differentiation and maturation i.e. root elongating at constant rate. Here a linear curve is obtained with value

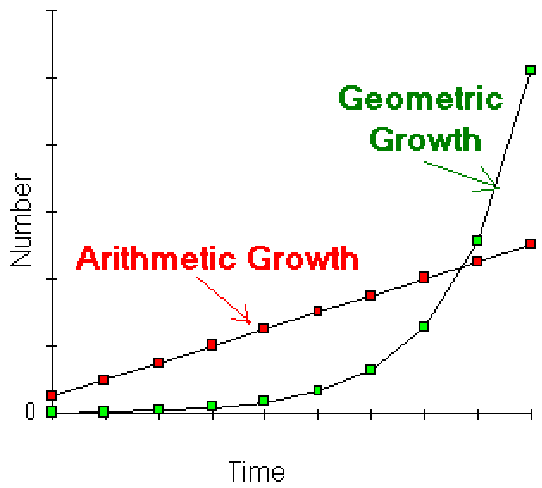
$$L_t = L_o + rt$$

L_t : Length at time t

L_o = Length at time 'zero'

R : growth rate

- Geometric growth: It is quite common in unicellular organisms when growth in nutrient rich medium. Here every cell divides. The daughter grow and divide. The granddaughter repeat the process and so on. Number of cells is initially small so that initial growth is slow. Later on, there is rapid growth at exponential rate. An embryo log or exponential growth. An embryo initially shows geometrical growth in cells, but later it passes into arithmetic phase



GROWTH CURVE

- The exponential growth curve can be represented by equation

$$W_t = W_o e^{rt}$$

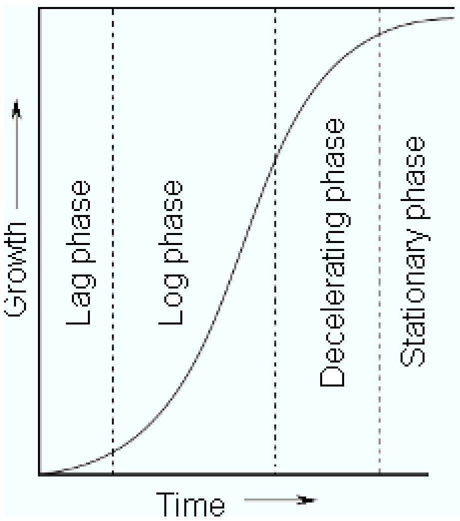
W_t : Final size

W_o : Initial size at beginning of the time period

r : growth rate

t : time of growth

- V.H. Blackman (1919) suggested 'r' might be used as a measure of the ability of a plant to produce new plant material and called it efficiency index
- The rate of growth is not uniform for a cell, organ or an organism. If the growth rates of a plant are plotted against time on a paper, a sigmoid growth curve or S-shaped growth curve is obtained. It consists of lag phase or slow phase, log phase or exponential growth phase, rate becomes more rapid and senescence phase or declining phase. A steady phase or stationary phase(limited growth) occurs at the end.



MEASUREMENT OF GROWTH

- Growth is measured with the help of auxometer, horizontal microscope and crescograph (developed by Sir J.C.Bose)
- Growth can be measured by measuring increase in weight area and volume in fresh and dry form. In yeast and bacteria, increase in length, number of cells can be taken into account.
- In arc auxometer, when growth occurs, stem increases in length. Due to pressure of weight wheel rotates gradually. This leads to movement of indicator on arc scale. This reading on graduated arc provides information about the rate of growth.

FACTOR INFLUENCING GROWTH AND DEVELOPMENT

1. LIGHT
   It controls photosynthesis, transpiration, pigment formation, tissue differentiation seed germination, etc. Ultraviolet ray are inhibitory. They induce rosette formation. Red light promotes growth but plant organs are soft. Blue light produce normal slightly less growth. Low light intensity increases intermodal length and leaf size. High light intensity decreases their size but allows more Certain seed germinate only in the presence of light, eg. Viscumalba. Seeds of lettuce and tobacco require red light for their

germination. Certain other seeds e.g. onion cannot grow in the presence of light. Light induces tissue differentiation in plants. Light induced tissue differentiation is called photo-morphogenesis. It involves photoreceptor pigment system called phytochrome. This can be observed by growing seedlings in dark. The seedlings are pale and weak. The phenomenon is etiolation and seedlings known as etiolated seedlings.

Etiolated seedlings have:

(i) Pale colour
(ii) Long internodes
(iii) Subterminal hook
(iv) Small pale leaver
(v) No mechanical tissue
(vi) Small and few roots

2. TEMPERATURE

Minimum, optimum and maximum temperature for plant growth are 2^O -5^O C. 20^O -30^O C., 40^O -50^OC. Lower temperature inactivates enzymes. It increase density of protoplasm. There is little absorption of water from soil. Internal water can be frozen. Chilling and freezing injury may occur. Cold storage or refrigerator is due to inhibition of growth of plant organs, reduced metabolic activity influences seed germination, growth and seasonal development of plants. Some plants require low temperature treatment for their growth and flowering. The phenomenon is called vernalisation.

High temperature of 45^OC and above reduces growth due to excessive transpiration, denaturation of enzymes and coagulation of protoplasm. Its effect is externally visible as leaf scorch, heat canker and desiccation.

3. WATER

Optimum hydration is essential for cell elongation, cell turgidity and functioning of metabolic machinery. Growth is reduced even in slight deficiency of water. It however, promotes differentiation. Water stress completely stops growth.

4. OXYGEN

It is required for release of energy during respiration. Energy is needed for anabolic activities of growth

5. SOIL

It provides minerals, some growth stimulants and water

6. CARBON DIOXIDE

Essential for photosynthesis and hence nutrition. However, in higher concentration carbon dioxide inhibits growth

7. HERIDITARY POTENTIALITY

Growth and differentiation is genetically determined

8. GRAVITY

It determines the direction of root and shoot growth.

9. STRESS
   Stress factors like excess or deficiency of salts, low or high temperature, excess and deficiency of water have a detrimental effect on growth.
10. NUTRITION
    It provides raw material for growth and differentiation as well as source of energy.
11. GROWTH REGULATORS

DIFFERENTIATION, DEDIFFERENTIATION, REDIFFERENTIATION

- Differentiation: It is the permanent qualitative changes in structure, chemistry and physiology of cell wall and protoplasm of cells, their tissues and organs. It is caused by repression of some genes.
- Dedifferentiation: It is the process of despecialisation of differentiated living cells so that they regain the capacity to divide and for new cells. A dedifferentiated tissue can act as meristem e.g.interfasicular vascular cambium, cork cambium, wound cambium. In culture experiments, parenchyma cells dedifferentiate to produce a mass of dividing cells called callus.
- Redifferentiation : Structural, chemical and physiological specialization of cells derived from dedifferentiation. It is similar to differentiation of cells and tissues formed by primary meristems. Secondary phloem, secondary xylem, cork, secondary cortex are some of the tissues formed through redifferentiation.

PHOTOPERIODISM

- Photoperiodism is the effect of duration of light and darkness on the growth, development and behavior of organisms. It is especially connected with flowering of plants, formation of underground storage organs, leaf fall etc. the effect of photoperiods on flowering was discovered by Garner and Allard (1920)incase of maryland of mammoth variety of Tobacco on the basis of their response to photoperiods.
  Plants are of the following types
  1. Long Day plants (LDP)
     Plants flowers after receiving light above a critical length e.g. wheat oat, sugarbeet, spinach, radish, lettuce, poppy.
  2. Short Day Plants (SDP)
     Plants flower only when they receive light below a critical length e.g. tobacco, potato, Xanthium, rice, dahlia, chrysanthemum, soya bean
  3. Day Neutral Plants (DNP)
     Photoperiods have no impact on these plants which come to flower after completing their vegetative growth e.g. tomato, maize, cotton, sunflower, cucumber
  4. Short-long Day Plants (SLDP)

Short photoperiod for initiation of lower and long photoperiods for blossoming e.g. Campanula medium, Trifoliumrepens.

5. Long-short Day Plants (LSDP)
   Long photoperiods for initiation of flowering and short photo photoperiod for blossoming e.g. Bryophyllum, cestrum

- Day Neutral Plants are more common in tropical areas. They can be made to flower throughout year. In subtropical and temperate areas short day plants flower during autumn and spring while long day plants flower during summer.
- Critical day length is that continuous duration of light which must always be exceed in short day light.
- Critical dark period is that continuous duration of darkness. Long day plants do not require any continuous dark period. They are, therefore, called short night plants (SNP). Short day plants are known as long night plants (LNO)
- The phenomenon of perceiving appropriate light periods and obtaining the stimulus of flowering is known as photoperiodic induction. Photoperiodic induction requires
  (i) A minimum vegetative growth
  (ii) A minimum number of appropriate photoperiod
  (iii) Photoreceptor pigment called phytochrome

$$\text{Bluish phytochrome P660} \underset{\text{light 730 nm}}{\overset{\text{light 660 nm}}{\rightleftharpoons}} \text{yellowish green 730}$$

  (iv) Fully developed leaves which receive the stimulus of light

VERNALISATION

- Vernalisation means ability of low temperature treatment to convert cereal into spring cereal
- Site of vernalisation is apical meristem or all the meistematic cells. E.g. shoot, tip, embryo tips, root apex
- As a result of vernalization, a flowering hormone called vernaline is formed but vernaline has never been isolated.
- Once a plant is vernalized, it can be devernalized by exposing the plant to temperature of 30^{O}C or above. For establishing vernalization, plant should be kept at 20^{O}C for 4-5 days

CONDITIONS NECESSARY FOR VERNALISATION

- Temperature : 1 – 6^{O}C is the optimum temperature
- Duration : 1 to 1.5 months low temperature treatment is necessary
- Oxygen : As vernalisation is aerobic process, so it requires O_2
- Water : Proper hydration is necessary

IMORTANCE OF VERNALISATION

- Crop can be grown earlier
- Plants can be grown in such regions where normally they do not grow
- Yield of the plant is increased
- Resistance to cold and frost is increased
- Resistance to fungal disease

SENESCENCE

It is the process of ageing which is caused by increased entropy, cellular breakdown, reduced homeostasis, increased metabolic failure and errors of replication as well as transcription

1. Whole plant senescence
   Monocarpic plants begin to undergo senescence along with fruit ripening. Eg. Bamboos and sago palm
2. Shoot senescence
   Certain perennial herbs produce annual aerial shoots for photosynthesis, bearing of flowers and fruits. With maturity of fruits, the aerial shoot undergo senescence underground parts perennate. Eg. Ginger, Narcissus, banana
3. Sequential / progressive senescence
   Polycarpic evergreen perennial plants show progressive senescence of older leaves, lateral organs and branches, flower, fruit bearing shoots as new growth occurs near the tip eg. Mango, eucalyptus
4. Simultaneous/ Synchronous leaf senescence.
   In perennial polycarpic deciduous plant all the leaves undergo senescence and are shed simultaneously in a particular season, commonly autumn E.g. Elm, maple, mulberry

GROWTH REGULATORS

(a) Characteristics
- Plant growth regulators are small, simple molecules secreted in minute quantities that influence various physiological functions in plants. They are of diverse chemical composition, as given below
  (i) Indole compounds : Indole-3-acetic acid (IAA)
  (ii) Adenine derivatives : Kinetin, N^6 – furfuryl amino purine
  (iii) Derivatives of carotenoids : Abscisic acid (ABA)
  (iv) Gases : Ethylene

(b) Classification
- Plant growth regulators are grouped into two categories based on the nature of their action
  (i) Plant growth promoters e.g. Auxins, cytokinins, Gibberellins
  They promotes growth activities like cell division, cell enlargement, flowering, fruiting and seed formation, tropic growth movement etc.

(ii) Plant growth inhibitors e.g. Abscisic acid
They play an important role in plant response to wounds and stress of biotic and a biotic origin
They are involved in growth inhibiting activities such as dormancy, abscission etc.

AUXIN

(a) Discovery
- Charles Darwin and his son Francis Darwin observe that the coleoptiles of canary grass responded to unilateral illumination by growing towards the light source (phototropic curve)
- After a series of experiments, it was concluded that tip of the coleoptiles is the site of production of a substance, that caused the bending of coleoptiles.
- F.W. Went isolated auxin from the tips of coleoptiles of oat seedlings

(b) Isolation
- The word auxin is derived from Greek word 'auxein' meaning to grow
- It was first isolated from human urine
- Indole-3-acetic acid (IAA) and Indole butyric acid have been isolated from plants
- Naphthalene acetic acid (NAA) and 2,4 dichlorophenoxy acetic acid (2,4-D) are synthetic auxins

(c) Physiological effects
- Auxins control growth of plant cells.
- They also control cell division in vascular cambium and xylem differentiation
- They are responsible for apical dominance in plants
- They prevent the formation of abscission layer and there by prevent premature fall of leaves, flowers, fruit etc

(d) Application / Use
- Auxin are used to initiate rooting in stem cuttings.
- They are used to induce parthenocarpic fruits in tomatoes.
- 2, 4 D is used as a weedicide/ herbicide to kill dicotyledonous weeds
- They promote flowering in pineapples and litchi
- Auxins are used to prevent the premature fall of leaves, flowers, fruits etc

GIBBERELLINS

(a) Discovery
- The 'Bakan' (foolish seedlings) disease in rice seedling was caused by a fungus Gibberellafujikuroi
- EE. Kurosawa found that the symptoms of the disease could be developed in uninfected seedling by treating them with sterile filtrate of the fungus
- The active principle was later identified to the gibberellin acid.

(b) Isolation

- There are more than hundred gibberellins reported from various higher plants and fungi.
- They are denoted as GA_1, GA_2, GA_3 and so on
- GA_3 is the most intensively studied form of GAS

(c) Physiological effects

- They cause elongation of the internodes
- They promote bolting in rosette plants like cabbage, beet root etc
- GA_3 initiates synthesis of hydrolases to digest and mobilize the reserve food materials of the seed to the developing embryo and thus it breaks seed dormancy

(d) Applications/ Uses

- Gibberellins are used to increase the length of grape stalks
- They causes the fruits like apple to elongate and improve shape
- They delay senescence and hence the fruits can be left on the trees for longer period; this increases/ extend the market period
- GA_3 is used to speed up malting process in brewing industry
- By increasing the length of internodes in sugarcane, GA_3 increases the yield of sugar cane by about 20 tonnes/acre.
- Spraying juvenile conifers with GA_3 hastens their maturity and leads to early seed production.

CYTOKININS

(a) Discovery

- Skoog and his co-workers observed that tobacco callus could proliferate only if the medium contains in addition to auxin, the extracts from yeast, coconut milk or DNA.
- Skoog and miller later identified and crystallized the cytokinesis – promoting substance and called it kinetin

(b) Isolation

- Cytokinins were discovered as kinetic from the autoclaved herring sperm DNA.
- Kinetin does not occur naturally in plants and search for natural substances with cytokinin – like activities led to the isolation of zeatin from corn-kernels and later a cytokinin from coconut milk
- Later several naturally –occuringcytokinins and synthetic compounds with cell division – promoting activity have been identified.
- Natural cytokinins are synthesized in plants in regions where rapid cell division occurs e.g. root apices, shoot buds, young fruits et

(c) Physiological effects

- Cytokinins help in the growth of lateral buds into branches and help to overcome apical dominance
- They also promote adventitious shoot formation as they help to produce new leaves and chloroplasts in leaves
- They promote nutrient mobilization and help to delay senescence

(d) Applications
- They are used to make the lateral buds grow into branches
- They are used to delay leaf senescence

ABSCISIC ACID (ABA)

(a) Discovery
- There independent researchers reported three kinds of growth inhibitors:
  (i) Inhibitor – B
  (ii) Abscisin II
  (iii) Dormin
- Later all of them were found to be chemically similar and named abscisic acid

(b) Isolation
- It was discovered from its role in regulating abscission and dormancy

(c) Physiological effects
- It plays an important role in seed development and inducing seed dormancy, by this it helps the seed to withstand desiccation and other unfavourable factors.
- It stimulates the closure of stomata under conditions of intense solar radiation and water stress
- It increases tolerance of plants to various stress and hence called as stress hormone
- ABA stimulates the formation of abscission layer and abscission of leaves flowers and fruits

(d) Application
- Seeds are treated with ABA to remain dormant during storage

ETHYLENE

(a) Discovery
Cousins confirmed that ripened organs released a volatile substance that fastened the ripening of the stored banana ; later this volatile substance was identified as ethylene

(b) Isolation
- Ethylene is synthesized in large quantities by the tissues of ripening fruits and senescing organs

(c) Physiological effect
- It promotes horizontal growth of seedlings and swelling on the axis.
- It induces apical kook formation (called epinasty) in dicot seedlings
- It promotes senescence and abscission of leaves and flowers
- It promotes root growth and root hair formation, thereby increasing the absorptive area.
- It promotes rapid elongation of internodes and petioles of deep water rice plants and helps the leaves to be above water level

(d) Applications

- Ethephon is the compound used to supply ethylene, it is an aqueous solution that is readily absorbed and transported within the plant and it releases ethylene slowly.
- It hastens fruit ripening in tomatoes and apple
- It promotes the production of female flowers on a monoecious plant
- It accelerates abscission of flower and fruits in cotton, cherry, walnut etc
- It is used to initiate flowering and for synchronizing fruit set in pineapples
- It breaks seed and bud dormancy and initiates germination in peanut seeds and sprouting of potato tubers

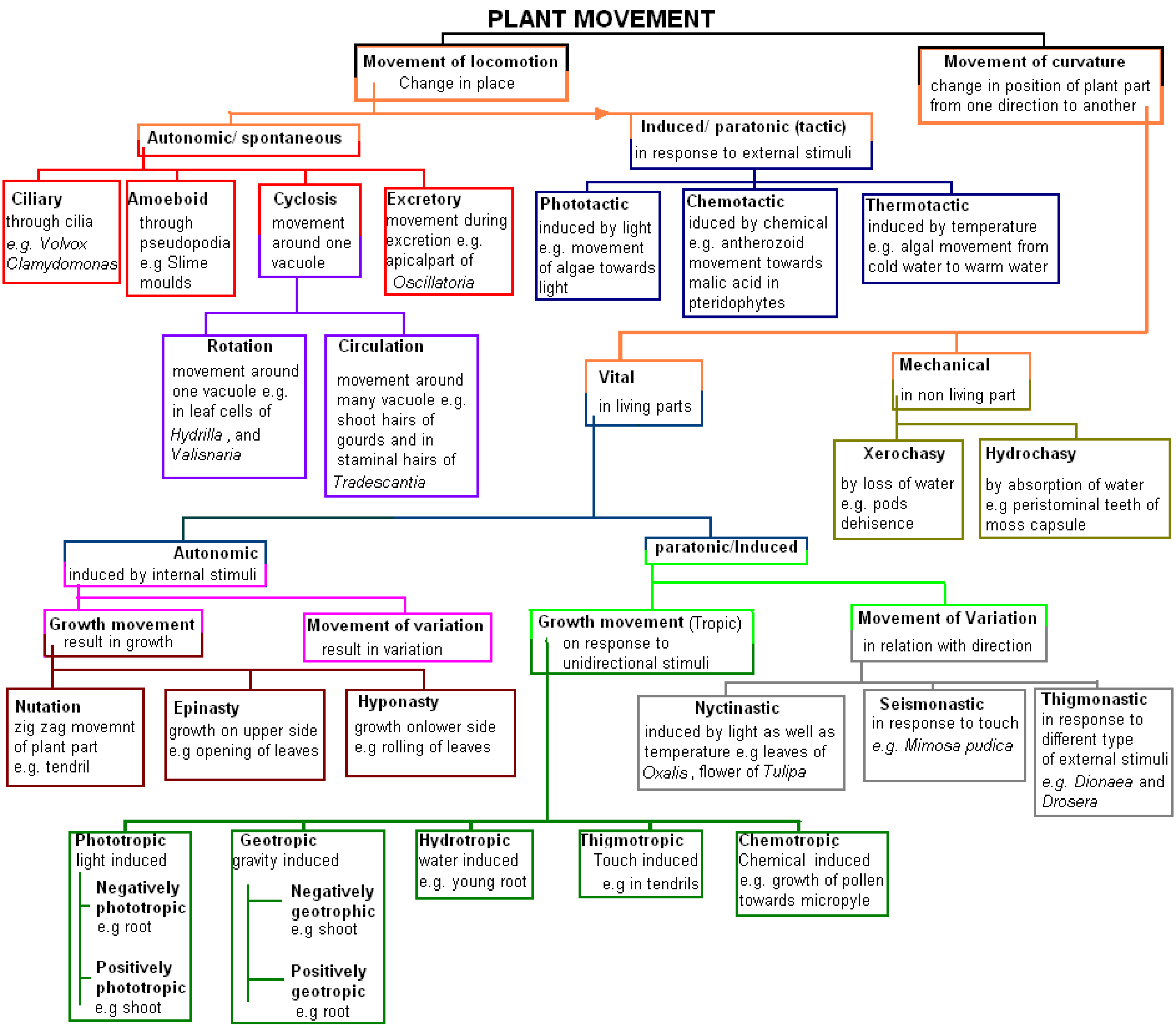
PLANT MOVEMENT

Plants have the capacity of changing their position in response to external (environment) or internal stimuli, which are known as plant movement.

The specific region or site where the stimulus is received for changing the position called perception site or region. The minimum period for which stimulus should be given for inducing plant movement is called presentation time

Summary of movement flow chart on next page

PLANT GROWTH AND MOVEMENT



Address :
#1,C.V.R Complex (Big Bazaar Back side),
Singaravelu St,
T.Nagar, Chennai - 17 .
Mobile no: 733 888 4137 , 733 888 4136
www.spiroacademy.com , info@spiroacademy.com