# Plant Growth and Development

## INTRODUCTION

- The plants grow and develop from the seedling to the reproductive stage. There are many factors that help in this growth and development.
- The germination of the seed and the development of the plant help in the formation of a body organisation that produces roots, leaves, flower, fruits and seeds.

**Definition**

**Growth:** It is an irreversible permanent increase in size, mass of a cell, organ or whole organism.

## GROWTH

- It is an **irreversible permanent increase** in size, mass of a cell, organ or whole organism.
- Plants show indeterminate growth.
- Plants show growth due to the presence of meristematic cells in different parts of the plant.
- Meristematic cells keep on dividing and thus help in the growth of the plant. Some of the meristematic cells become permanent and later differentiate to form different tissue and organs.

**Gray Matter Alert!!!**

**Heteroblastic development:** It is the sudden change from juvenile to adult phase.

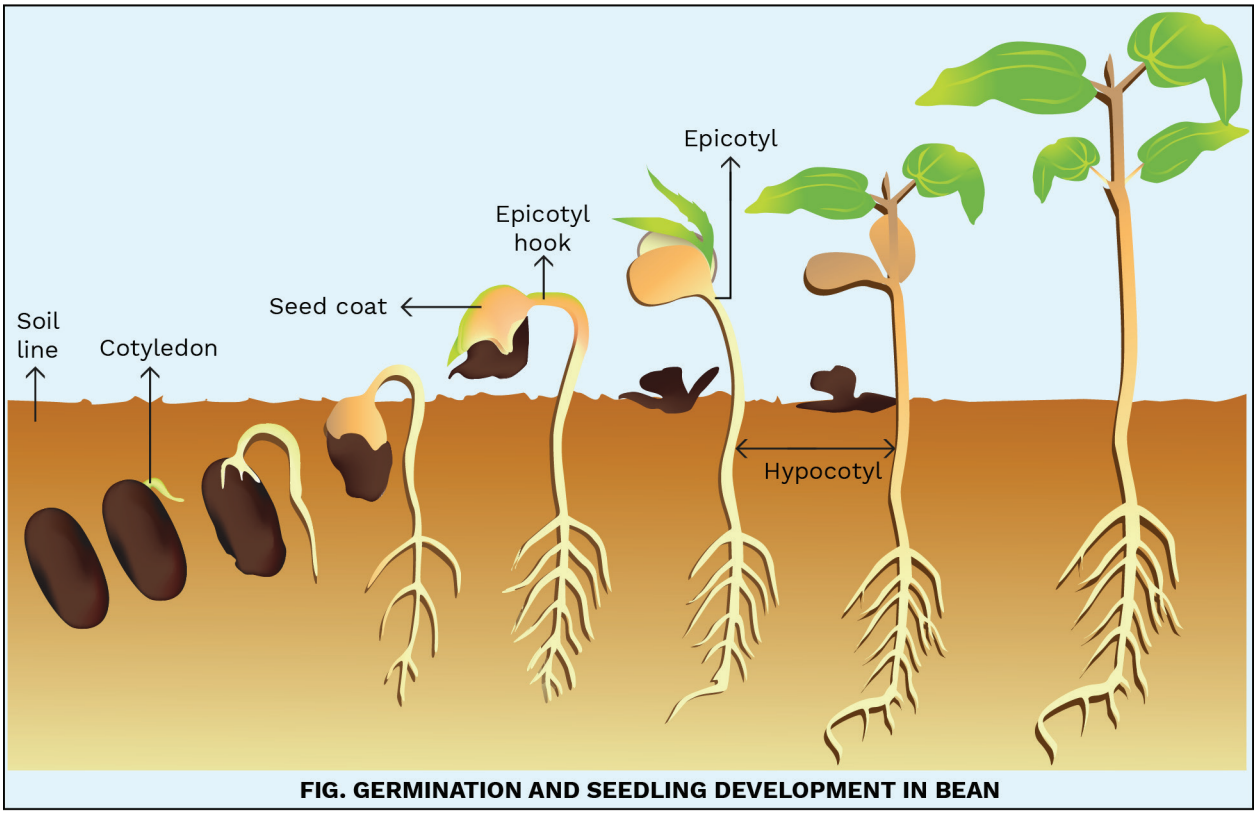



**FIG. GERMINATION AND SEEDLING DEVELOPMENT IN BEAN**

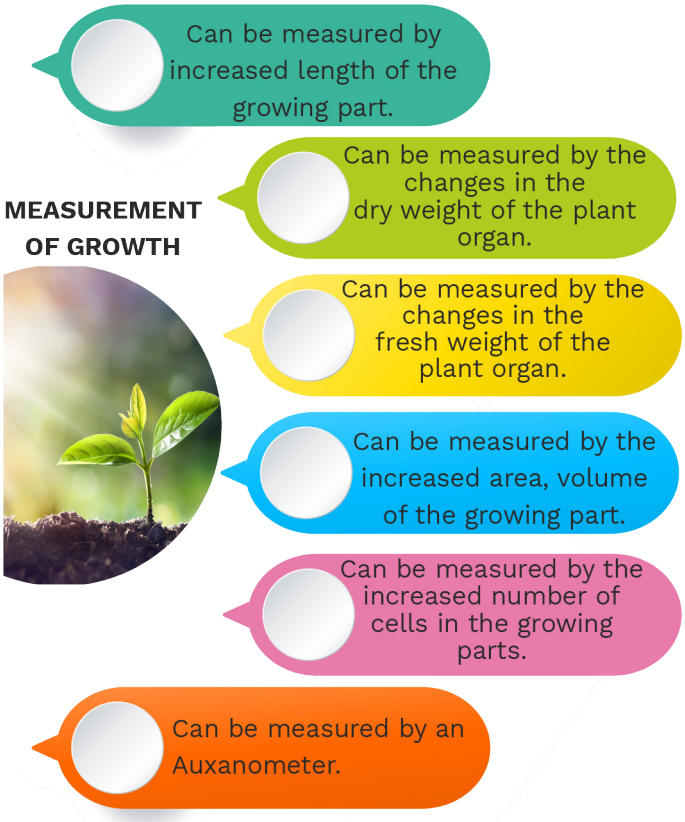
- In multicellular algae, every cell is capable of division, while in Bryophytes and Pteridophytes there is a single apical cell that divides and the plant grows. Higher plants have two zones-tunica and corpus which keep on dividing and thus the thallus grows in height.
- A group of cells on the sides of the apex divides by periclinal divisions and results in formation of protuberance, which gives rise to leaf primordium. New leaf primordia are being continuously initiated above the existing ones.
- A group of meristematic cells are present at the tip of the tissue. These cells divide actively and increase the length of the roots.
- Flower is a modified shoot. The vegetative apex of the plant changes into flowering apices and form flowers.

**Previous Year's Question**

**Assertion:** Plant growth as a whole is indefinite.
**Reason:** Plants retain the capacity of continuous growth throughout their life.

(1) Both Assertion and Reason are true and Reason is the correct explanation of assertion.
(2) The Assertion and Reason are true but Reason is not correct explanation of assertion.
(3) Assertion is true but, reason is false.
(4) Assertion is false but, reason is true.

**MEASUREMENT OF GROWTH**



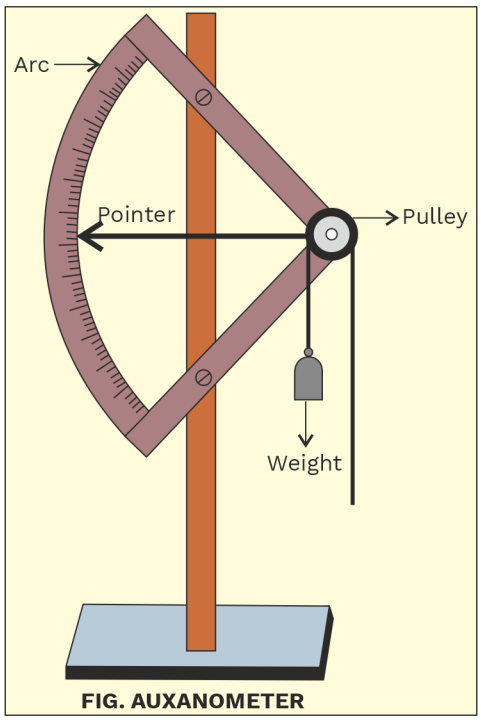
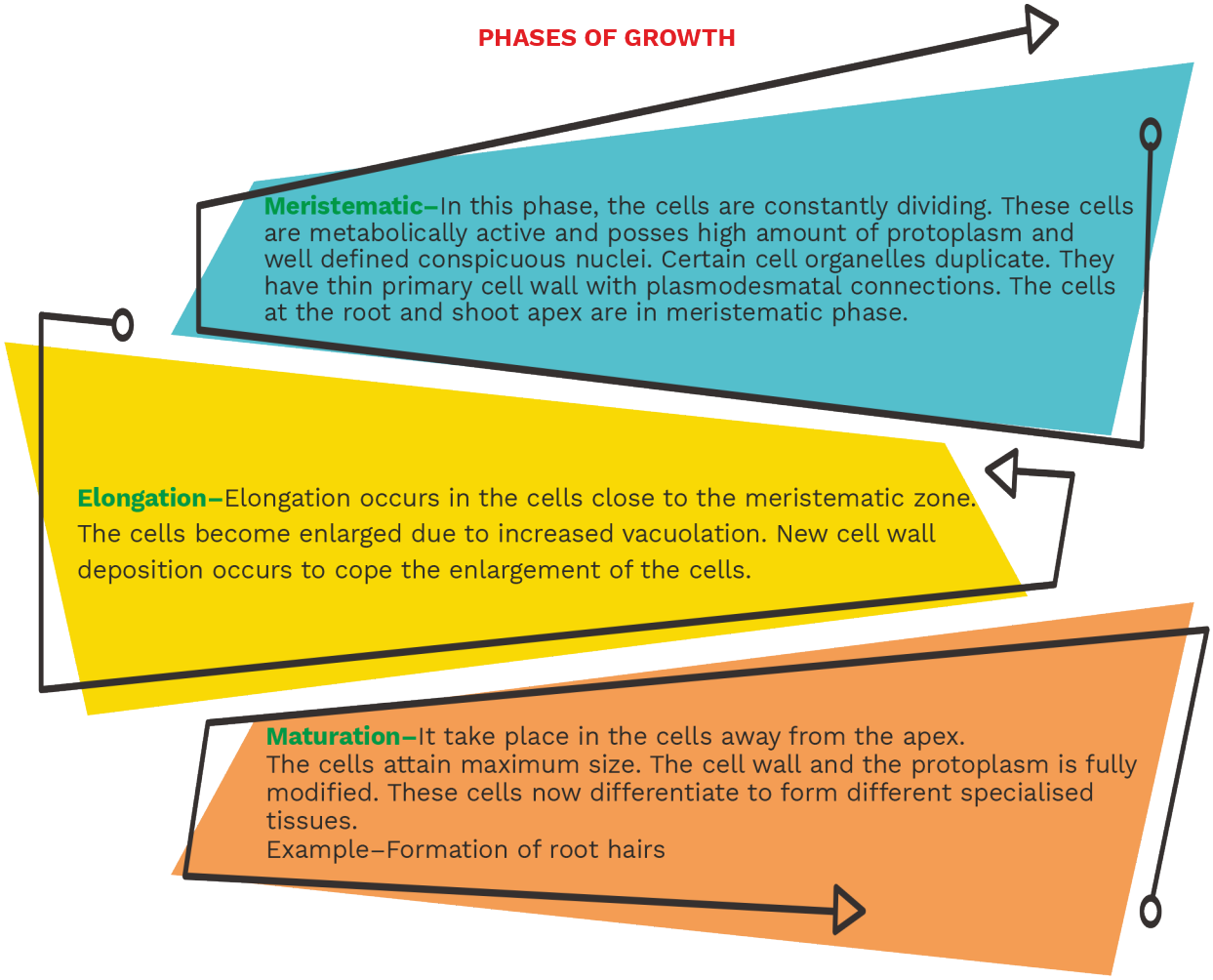



FIG. AUXANOMETER

## PHASES OF GROWTH



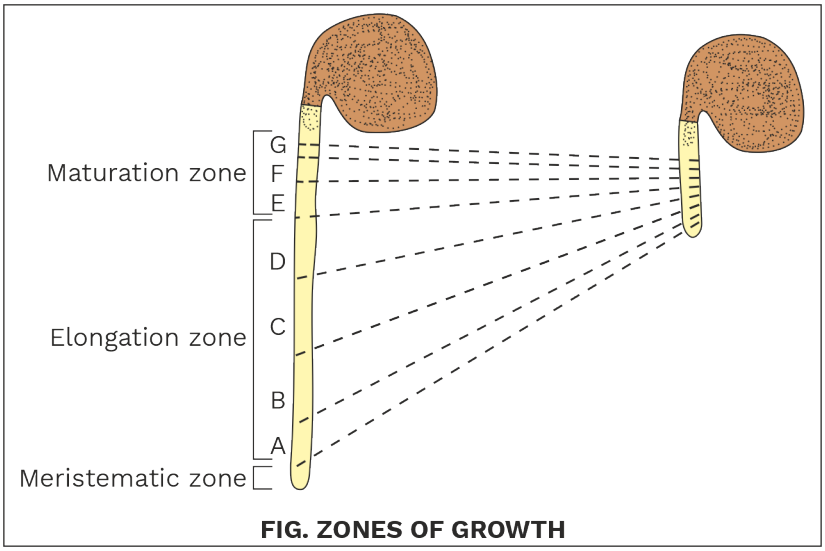
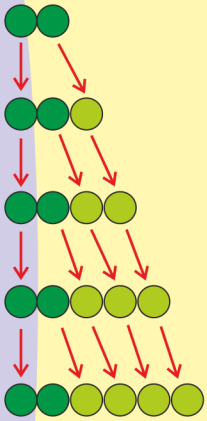




**FIG. ZONES OF GROWTH**

## GROWTH RATES

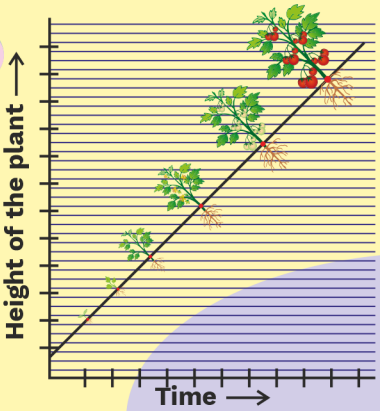
### Arithmetic Growth

- Meristematic cells divide by mitotic divisions to form two daughter cells.
- Only one daughter cell continues dividing, this cell remain meristematic. Other daughter cell becomes a permanent cell and differentiates



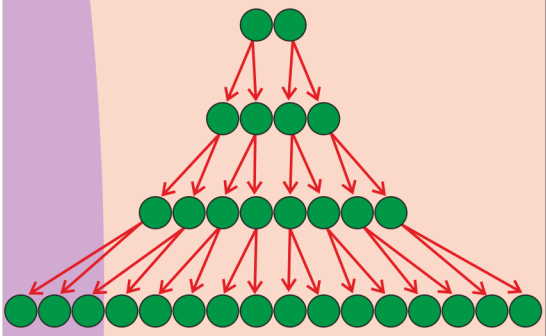
Cells capable of division

Cells that lose capability to divide

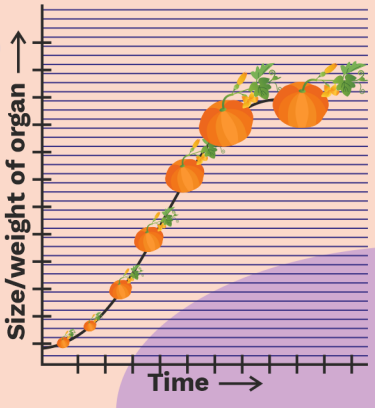



### Geometric Growth

- Meristematic cells divide by mitotic division to form two daughter cells.
- Both the daughter cells further divide and form new cells which keep on dividing.



Cells capable of division



## Arithmetic Growth

- The linear curve represents continuous growth occurring in the plant.
  There is a gradual increase in the size of the plant showing arithmetic growth.
  In this, the rate of growth is constant and the increase in growth occurs in arithmetic progression.
- Mathematically,
  $L_t = L_0 + rt$
  $L_t$ = length of plant at time 't'.
  $L_o$ = length of plant at time 0.
  r = growth rate
- Example–Growth of root and shoot apex.

## Geometric Growth

- The sigmoid shaped growth curve represents 3 phases-
  Lag phase–The rate of growth is slow.
  Log phase (Exponential phase) Growth rate becomes rapid. Growth reaches maximum.
  Stationary phase (Steady state)–Growth slows down and ultimately stops. The growth slows down due to limitations of resources.
- The exponential growth is represented by–
  $W_1 = W_0 e^{rt}$, $W_1$ = final size
  $W_0$ = initial size,
  r = growth rate, t = time of growth, e = base of natural logarithms
- Example–The growth of young leaf sheath of banana.

**Previous Year's Question**

In root, the region of fastest growth is
(1) root hair zone
(2) behind the root tip
(3) root tip
(4) before the root tip

**Previous Year's Question**

Typical growth curve in plants is
(1) stair-steps shaped
(2) parabolic
(3) sigmoid
(4) linear

- Quantitative comparisons between the growth of living system can be done in the following ways-
  - **Absolute growth-**Total growth per unit time is known as absolute growth.
  - **Relative growth rate-**The growth per unit time as percentage of initial size
    - Relative growth Rate

$$= \frac{\text{Growth per unit time}}{\text{Initial size}} \times 100$$

**DIFFERENTIATION, DEDIFFERENTIATION AND REDIFFERENTIATION**

- The meristematic cells in the plants which are present at different locations of the plant keep on dividing. Some of the meristematic cells become permanent and give rise to different tissues in the plants.
- **Differentiation** is the process of change in cell, tissue, organ during the embryological development which results in the appearance of different mature structures. The plant is differentiated into root and shoot. Shoot and root further differentiates.
- Example: The meristematic tissues divide and forms tissue which differentiates into vascular tissue – the xylem and the phloem. Xylem and phloem perform specialised function of water and food conduction.
- The process by which the differentiated cells despecialise and become undifferentiated and divide is known as **dedifferentiation.**
- Example: Cork Cambium and Interfasicular cambium are produced by dedifferentaition.
- **Redifferentiation** is the process by which the dedifferentiated cells mature and perform specific functions and thus become redifferentiated.

**Rack Your Brain**

What does the stationary phase of the sigmoid growth curve indicate?

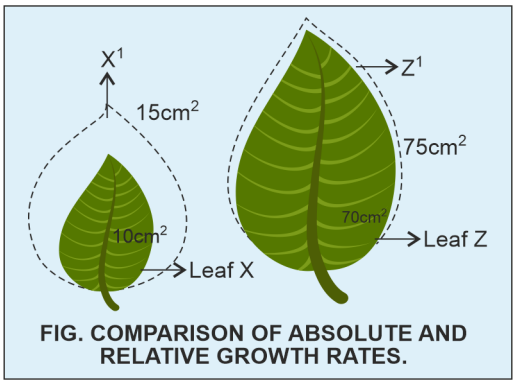



FIG. COMPARISON OF ABSOLUTE AND RELATIVE GROWTH RATES.

**Definition**

**Differentiation:** It is the process of change in cell, tissue, organ during the embryological development which results in the appearance of different structures.

**Previous Year's Question**

Hormones primarily connected with cell division is
(1) IAA
(2) NAA
(3) Cytokinin/Zeatin
(4) Gibberelic acid

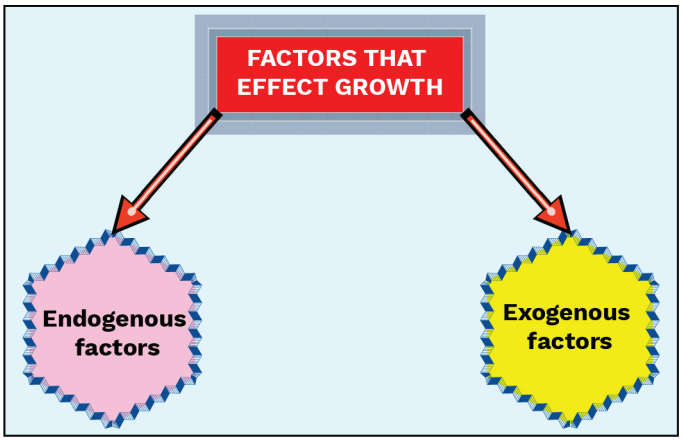
**Definition**

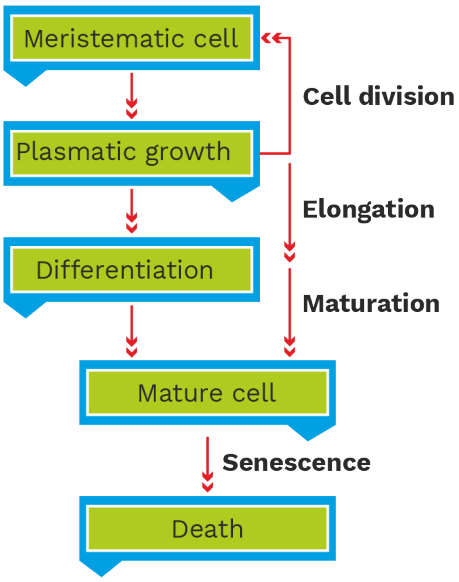
**Dedifferentiation:** The process by which the differentiated cells despecialise and become undifferentiated and divide.

- Example: The **cambium** layer formed between the xylem and phloem starts dividing in the dicots after the primary growth has taken place. The cambium forms the **secondary xylem** towards the inside and **secondary phloem** towards the outside. This leads to secondary growth in the dicots that leads to the increase in the girth of the plants.

**DEVELOPMENT**

- Development includes all the changes in a plant from the germination of seed to senescence.
- Plants during their growth and development show different responses to the environmental conditions and develop different structures. This ability is known as plasticity.
- **Example:**
  - **Heterophylly** is seen in the cotton, coriander and buttercup plants.
  - In cotton and coriander plants, the leaves in juvenile and adult plants are different morphologically.
  - In buttercup, the leaves submerged in water are morphologically different from the terrestrial leaves.



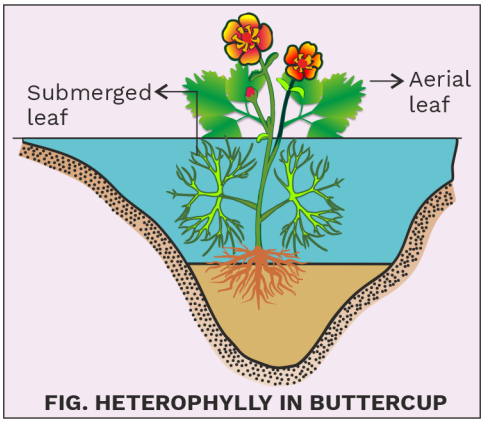




FIG. HETEROPHYLLY IN BUTTERCUP

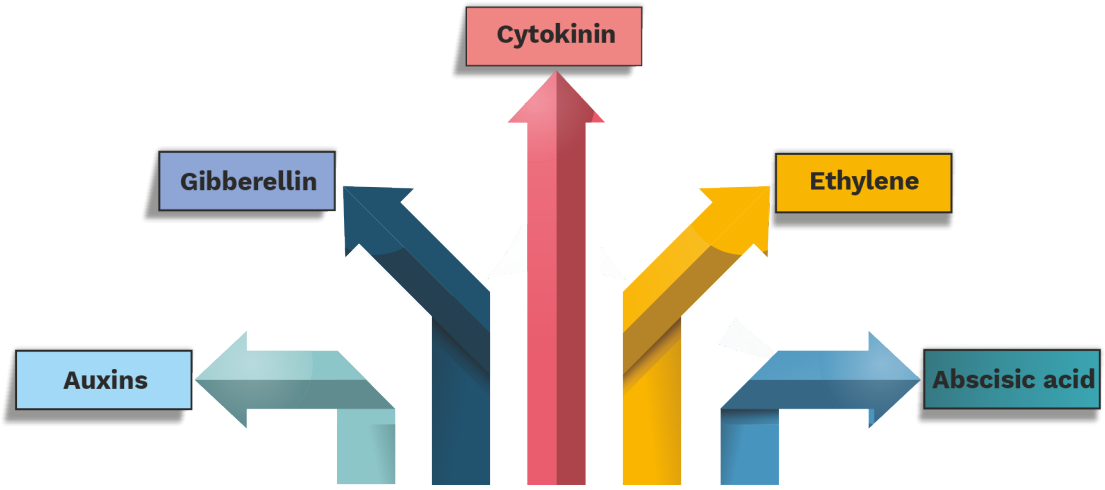
**Previous Year's Question**

Differentiation of shoot is controlled by

(1) high auxin : cytokinin ratio
(2) high cytokinin : auxin ratio
(3) high gibberellin : auxin ratio
(4) high gibberellin : cytokinin ratio

## CONDITIONS FOR GROWTH

- Growth of the plants is regulated by the plant growth regulators and the environmental cues.




PLANT GROWTH REGULATORS

## ENDOGENOUS GROWTH REGULATORS

- The chemicals which affect the growth and differentiation process are known as Growth Regulators.
- K.V. Thimann used the term phytohormone for hormones of plants.
- They are the following:
  - Auxins
  - Gibberellins
  - Cytokinin
  - Ethylene
  - Abscisic Acid
- **Ethylene** and **abscisic acid** are known as **plant growth inhibitor.**

**Definition**

**Phytohormone:** Chemicals which are synthesised by the plants that help in their physiological functioning.

## AUXIN

- The site of the synthesis of Auxin is mainly the meristematic tissue in developing leaves, flowers and fruits.
- Some natural auxins are **Indole Acetic Acid (IAA), Indole Butyric Acid (IBA).**

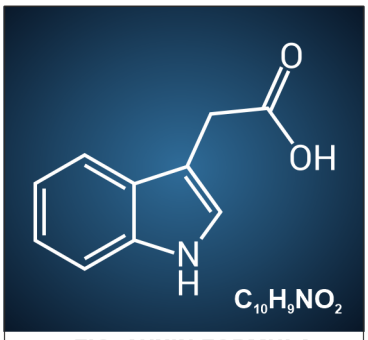



FIG. AUXIN FORMULA

- **2,4-Dichlorophenoxy acetic acid (2,4-D), 2, 4, 5-Trichlorophenoxyacetic acid (2, 4, 5-T), Naphthalene acetic acid (NAA) are synthetic.**

**Physiological Effects of Auxins**

**Root-Shoot Differentiation**

- In relatively **higher** concentrations, auxins promote **shoot** growth while in **lower** concentrations, **root** growth is promoted. It inhibits primary root growth but promotes secondary root growth.

**Cell Elongation**

- Auxins bring about cell elongation by increasing the osmotic solutes of the cell. Auxins cause phototrophic curvature of the shoot. **Auxin accumulates on the shady side** of the shoot and causes the **elongation of the cell** thus leading to **bending** of the shoot.

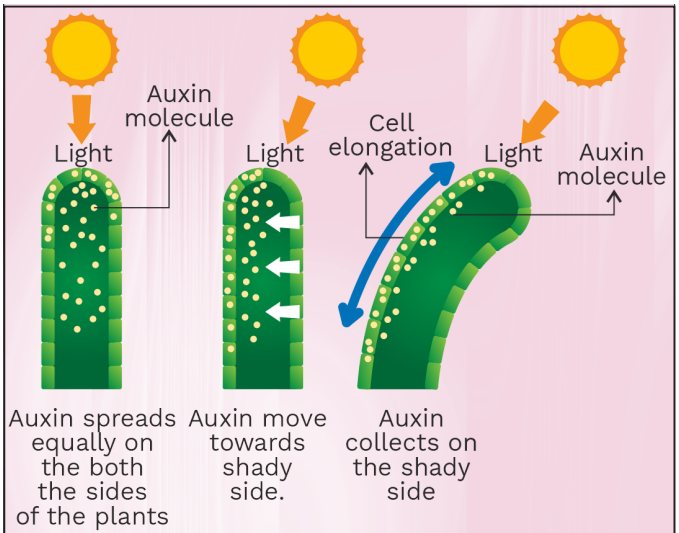



**FIG. EFFECT OF AUXIN ON THE GROWTH OF SHOOT TIP TOWARDS LIGHT**

**Apical Dominance**

- Auxin is responsible for the apical dominance in plants. **Lateral shoot** initiation is **not present.**

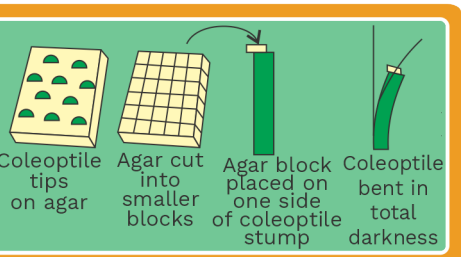
**Discovery of Auxins**

Charles Darwin experimented on the unilateral phototropic response in *Phalaris canariensis*. He found out that when seedlings are exposed to lateral light, something is transmitted from the upper tip to the lower part, causing the latter to bend".

**Boysen–Jensen** described that it is a chemical that is transmitted from the tip.

**Paal** said that this chemical moves down the coleoptiles, continually, on all sides and acts as correlative growth promoter.

**F.W. Went** conducted the Avena coleoptile experiment. He placed tip of the coleoptile over agar block. This block was placed over one side of a decapitated straight coleoptile stump. It caused curvature on other side, to which the agar block was placed. This proved auxin present in the agar block cause the bending.




**Kogl and Haagel-Smit** isolated auxin from human urine. They also isolated another auxin from human urine, called it by auxin a, auxin b and heteroauxin which was called Indole-3-acetic acid (IAA).

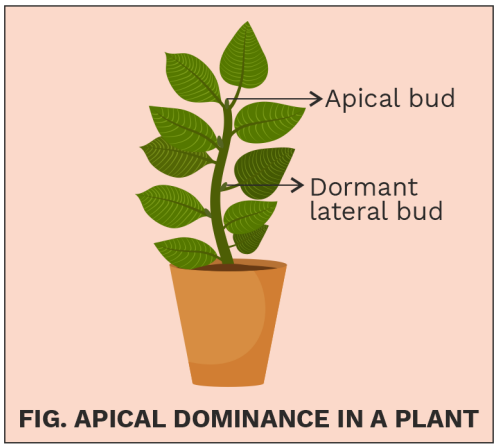


FIG. APICAL DOMINANCE IN A PLANT

**Biosynthesis of Auxin**

It has been experimentally shown that auxins are synthesised from Tryptophan.

**Transportation of Auxin**

Auxins are transported in one direction from apex to downward through phloem. In coleoptiles, stems, hypocotyls, petioles flower stalks and roots. Auxin movement is rapid basipetally. Specific carrier protein in the cell membrane is needed for its transport .

### Delay in Abscission

- Abscission of leaf, flower and fruit can be prevented by application of auxins. It ensures that there is no pre-harvest fruit drop.

### Parthenocarpy

- Application of auxins on the stigma of emasculated flower induces parthenocarpy e.g., **tomato.**

### Fruit Set

- Application of auxins in tomato, tobacco, fig, litchi, pepper causes the ripening of fruit and seed set. It increases fruit set.

### Callus Formation

- It is used to produce a mass of cells i.e., callus during tissue culture.

### Weedicide

- 2, 4–D and 2, 4, 5–T are herbicides with property of killing woody perennial weeds. They kill the weeds by **blocking the photosystem II.**

### Sex Expression

- In dioecious plants, female flowers are produced in genetically male plants like *Cannabis sativa*. In monoecious plants like cucumber, (*Cucumis sativus*), the female flower or female

**Previous Year's Question**

Highest auxin concentration occurs
(1) in growing tips
(2) in leaves
(3) at base of plant organs
(4) in xylem and phloem

**Previous Year's Question**

The growing plant is decapitated, then
(1) its growth stops
(2) leaves become yellow and fall down
(3) axillary buds are inactivated
(4) axillary buds are activated

part of flower tends to differentiate under higher auxin content, then to male flower.

### Initiation of Flowering

- Auxins help in flower initiation in **pineapple** and **litchi.**

### GIBBERELLINS

- It was found to be present in all parts of the plant.
- There are about 100 gibberellins isolated and reported. Gibberellic acid is denoted as $GA_3$.

### Physiological Effects of Gibberellins

#### Elongation of the internodes

- By increased cell extension and cell division gibberellins bring about **internode elongation.** The flowering axis can be induced in rosette plants like cauliflower. This is known as **bolting.** Thus, it is also known as a **bolting hormone.**

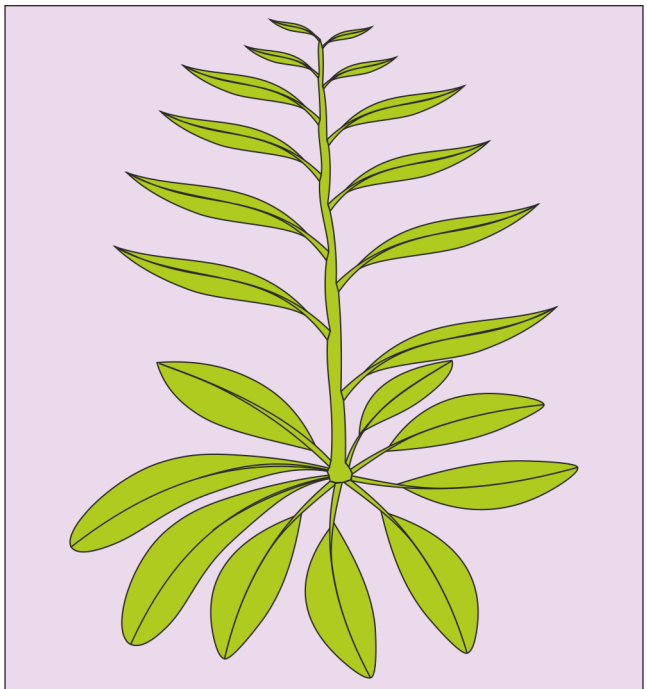
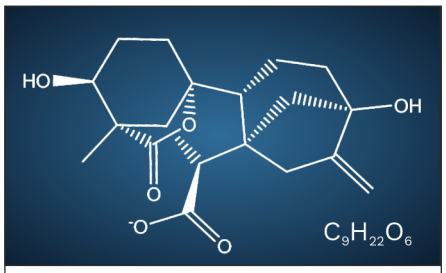


FIG. ROSETTE PLANT SHOWING BOLTING

**Rack Your Brain**

What is the reason for lateral growth of hedges due to pruning?




GIBBERELLIN FORMULA

**Discovery of Gibberellin**

Kurosawa found that rice plants infected with fungus *Gibberella fujikuroi* showed excessive elongation of stem, the disease was named "bakanae" or "foolish seedling".

The fungus free extract when applied to rice plant, had the capacity to produce the disease. It was concluded that *Gibberella fujikuroi* had produced the substance responsible for the abnormal growth.

Yabuta gave the name Gibberellin to it.

**Biosynthesis of Gibberellins**

Synthesis of Gibberellins takes place by the condensation of Isopentenyl Pyrophosphate.

**Transportation of Gibberellin**

It is transported in all directions in the plant. It moves through the xylem and phloem in the plants.

**Parthenocarpy**

- Parthenocarpic fruits can be induced in apple and peach.

**Seed Germination**

- Seed treated with Gibberellins germinate in dark otherwise require a brief exposure of light for germination.

**Dormancy**

- Gibberellic acid can break the dormancy of the seeds. GA can **substitute for cold treatment.**

**Sex Expression**

- Gibberellins acid help in **production of male flowers.**

**Hydrolytic Action of the enzyme alpha Amylase**

- Germinative seeds has a high content of gibberellins. It helps in the synthesis of alpha amylase in the aleurone layer of the endosperm which hydrolyses starch to form sugars which provides nutrition to the developing embryo.
- In $GA_3$ treated seeds without Aleurone layer, the amylolytic activity was found to be enhanced.

**CYTOKININS**

- Cytokinin is a phytohormone that is a growth promoter. It helps in various development.

**Physiological Effects of Cytokinin**

**Cell Division**

- Cytokinins promote **rapid cell division** and thus help in the development and growth of the plant.

**Callus Formation and shoot differentiation**

- It helps in the formation of callus and helps in differentiation of shoot.

**Cambial Activity**

- In Pea stem it stimulate the cambial activity.

**Previous Year's Question**

A few normal seedlings of tomato were kept in a dark room. After a few days they were found to have become white-coloured like albinos. Which of the following terms will you use to describe them?
(1) Mutated
(2) Embolised
(3) Etiolated
(4) Defoliated

**Rack Your Brain**

Which hormone would you suggest a farmer for removing the weeds from a crop field to save the space and nutrients for the main crop plant?

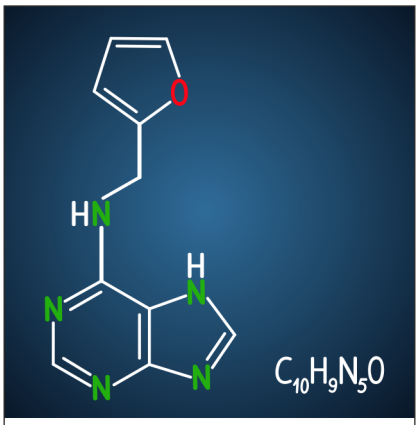



FIG. CYTOKININ FORMULA

**Lateral Growth**

**Cytokinin promotes the growth of lateral buds**

- The excision of root tip leads to **lateral growth** as it removes apical dominance caused by auxin.

FIG. LATERAL GROWTH IN A PLANT

**Seed Dormancy**

- It helps to overcome seed dormancy and can initiate germination in seeds of lettuce and tobacco, in dark also.

**Flowering Induction**

- Induces flowering in some plants like Duckweed.

**Chloroplast Development**

- Cytokinin help in the conversion of **etioplasts into chloroplast.** The chloroplast develops many grana and a large amount of chlorophyll which increases the rate of photosynthesis.

**Translocation of Solutes**

- Cytokinin help in the translocation of solutes in the plants.

**Cytokinin**

**Miller et al and Skoog–**The cells of tobacco pith kept on dividing when grown in very old DNA material or yeast. They autoclaved the DNA stored for a long the and isolated a substance and named it kinetin.

In higher plants substance showing cell division feature of kinetin had been isolated. It was named as Cytokinin.

**Biosynthesis**

Cytokinins are synthesised from adenosine monophosphate and isopentenyl pyrophosphate.

**Transport**

Transported via the xylem.

**Previous Year's Question**

Hormone primarily connected with cell division is
(1) IAA
(2) NAA
(3) cytokinin/zeatin
(4) gibberellic acid

**Previous Year's Question**

One of the commonly used plant growth hormone in tea plantations is
(1) ethylene (2) abscisic acid
(3) zeatin (4) IAA

## ETHYLENE

- **Gaseous hormone.**
- The spray of 2-chloroethylphosphonic acid (Ethephon) produces ethylene.

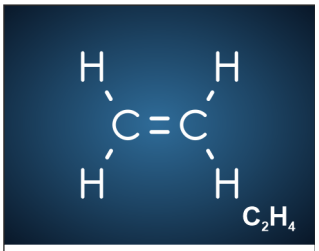


FIG. ETHYLENE FORMULA

### Physiological Effects of Ethylene

#### Ripening of Fruits

- It helps in ripening of fruit.
- During ripening, the fruits release ethylene which causes **respiratory climactic.** Respiratory climactic is the large increase in respiratory rate, during initiation of ripening.

#### Triple response

- It causes the following responses in etiolated seedling –
  - Inhibition of stem elongation
  - Radial swelling of the stem
  - Formation of seedling hook

#### Inter-nodal Elongation

- Ethylene enhances cell expansion of the internodal cells. It can be seen in deep water rice plants.

#### Plumule hook formation

- In etiolated dicotyledonous seedling, the plumule forms a hook that protects the apical tip from any injury while penetrating the soil.

#### Sex Expression

- Female flowers in cucumber are enhanced by ethylene.

#### Epinasty

- High ethylene levels show epinasty. (Condition when the growth of the upper side of a petiole of the leaf is faster than the lower side of the leaf.)

**Discovery**

**D.N. Nelyubov–**Showed that is gas Ethylene from coal gas inhibited stem elongated, stimulated radical swelling of stem, and horizontal growth of stems of the etiolated pea seedling.

**I.H. Cousins–**Ethylene might be a natural product of plant tissue
**R. Gane–**Showed that ethylene is natural product of ripening fruits.
**Burg and Thimann–**Established ethylene as a growth regulator.

**Pratt-Goeschi–**Established ethylene as natural plant growth hormone.

**Biosynthesis**

Ethylene is formed from methionine.

**Transport**

Through different organs of the plant.

### Flowering

- It brings about **synchronized flowering** and fruit set in **pineapple.**

### Root Hair Formation

- It helps in the formation of root and root hair.

### Breaking Dormancy of Seed and Buds

- Ethylene breaks dormancy and initiates germination in some cereals, fruit trees and potato tubers.

### Abscission

- Increased ethylene production during dry spell causes abscission of leaves, flower and fruits. More Ethylene production in waterlogged plants effect leaf senescence.
- The inhibition effect of ethylene may be seen in the case of arrested development of some buds, leaves and apical meristems.

### ABSCISIC ACID

- It is also known as stress hormone.

### Physiological Effects of Abscisic Acid

### Leaf Abscission

- When the auxin content is low, there is formation of abscission layer at the base of the petiole, which finally causes the leaf fall. ABA promotes leaf abscission.

### Fruit Abscission

- The **abscission zone** is formed at the base of pedicel, leading to fruit drop at various stages of development of fruit.
- During **high auxin content,** there is **less fruit drop.**

### Nucleic Acid Synthesis

- If a tissue or organ of a plant is treated with Abscisic acid, it causes a reduction in DNA synthesis and cell division.

**Rack Your Brain**

Which hormone at lower concentration causes root formation and at higher concentration inhibits root formation?

**Previous Year's Question**

Which one of the following pairs, is not correctly matched?
(1) Gibberellic acid – Leaf fall
(2) Cytokinin – Cell division
(3) IAA – Cell wall elongation
(4) Abscisic acid – Stomatal closure

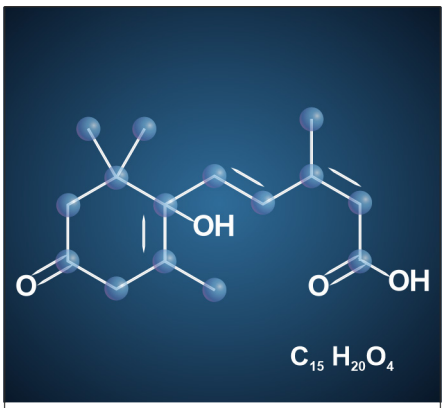



FIG. ABSCISIC ACID FORMULA

**Previous Year's Question**

ABA is involved in
(1) shoot elongation
(2) increased cell division
(3) dormancy of seeds
(4) root elongation

- ABA inhibit the $GA_3$ initiated α-amylase activity in aleurone system.

**Resting Buds**

The effect of dormancy can be induced in non-dormant seeds.

**Antagonistic Effect**

- **ABA and cytokinins are antagonistic in their effect.**

**Senescence**

- ABA (as well as ethylene) promotes senescence in leaves.

**Stomatal Closure**

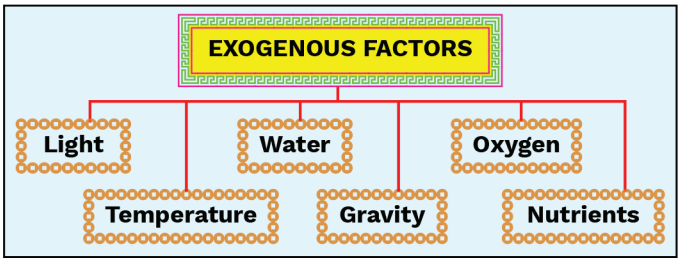
- ABA induces **stomatal closure.** It prevents the influx of $K^+$ into the guard cells.

**Water Stress**

- During dry conditions, the internal water deficit rises, also there is a rise in ABA content in the shoot. When leaf water potential decreases, ABA begins to accumulate. But, when the stress is relieved by watering, ABA is degraded. In drought conditions, ABA keeps transpiration and photosynthesis low.

**GROWTH RESPONSES TO EXOGENOUS FACTORS**

- The plants show certain movement with respect to the environmental factors.




- These growth movements can be temporary or permanent on the basis of the stimulus.
- They are of the following type-

**Discovery of Abscisic Acid**

F.T Addicott isolated a substance from young cotton fruits that was antagonistic to growth and named it Abscisic II

Eagles and Wareing- Isolated substance in birch leaves which inhibited growth and induced dormancy. They named it dormin. Later Comforth et al found it to beidentical to abscisic acid.

**Biosynthesis of Abscisic Acid**

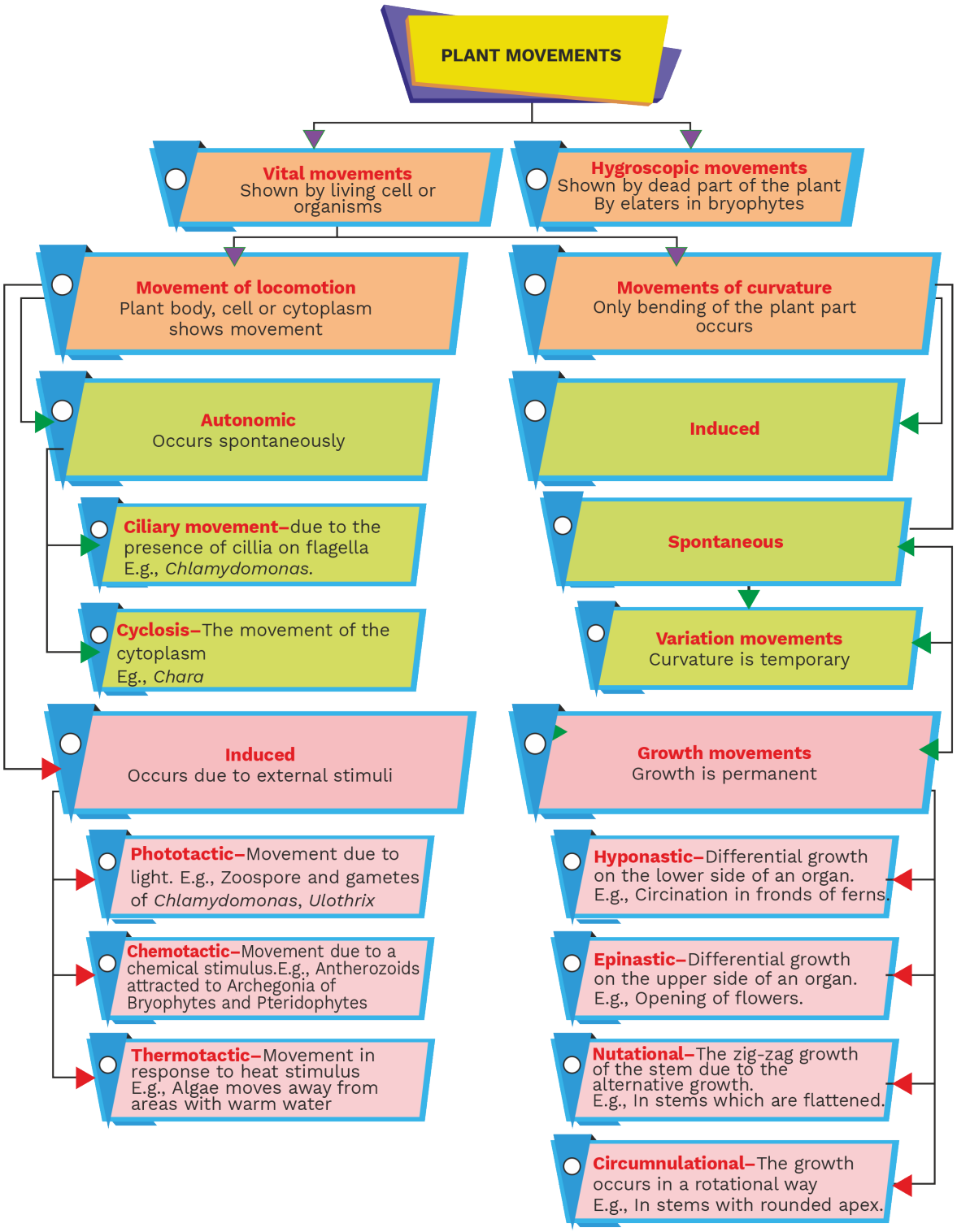
ABA is synthesised indirectly through carotenoid pathway as breakdown product of 40–C xanthophyll.

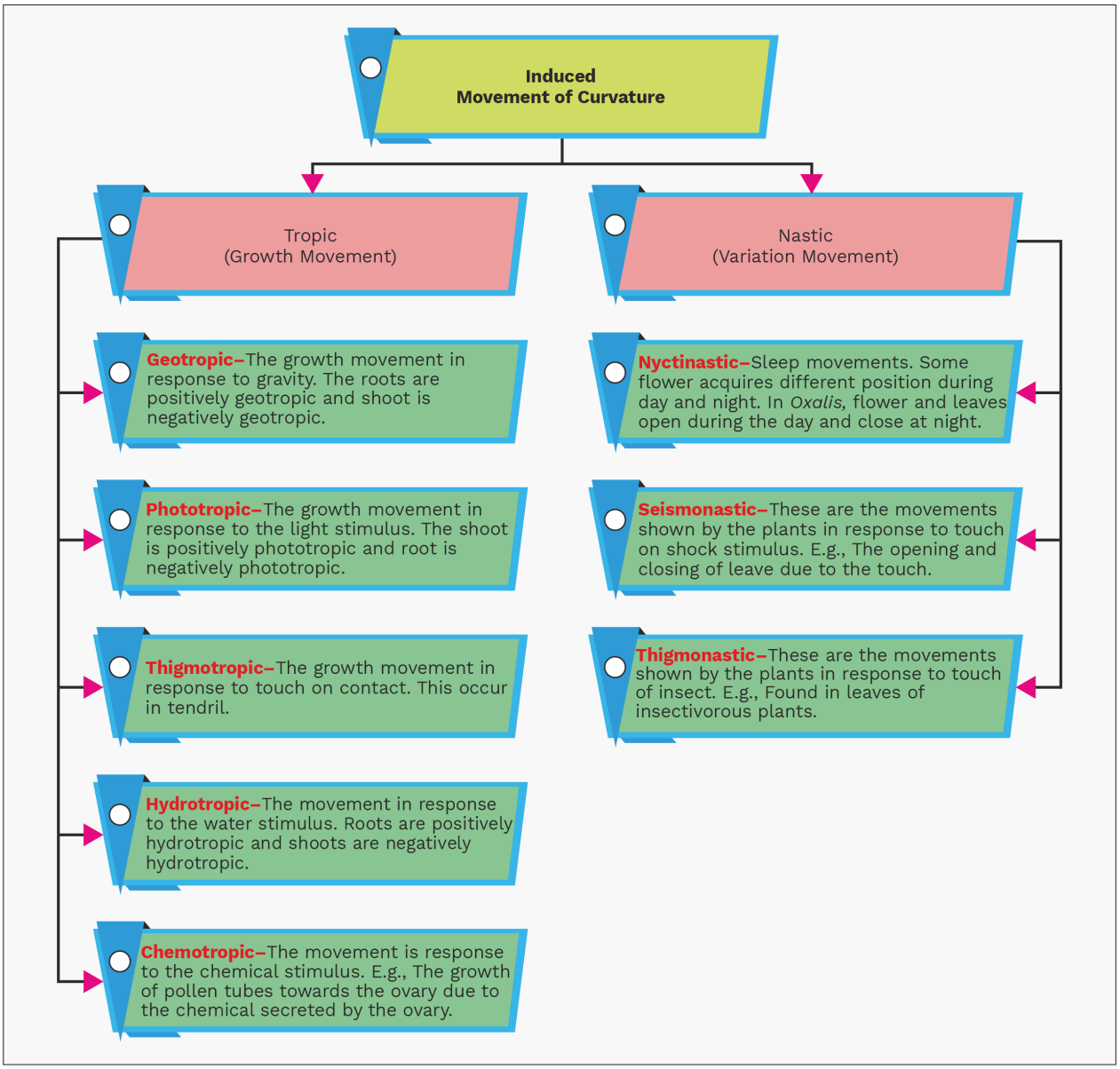
**Transport of Abscisic Acid**

In all directions in the plant.

**Previous Year's Question**

The twining of tendrils around a support is a good example of
(1) phototropism
(2) chemotropism
(3) nastic movements
(4) thigmotropism


PLANT MOVEMENTS
Vital movements
Shown by living cell or organisms
Hygroscopic movements
Shown by dead part of the plant
By elaters in bryophytes
Movement of locomotion
Plant body, cell or cytoplasm shows movement
Movements of curvature
Only bending of the plant part occurs
Autonomic
Occurs spontaneously
Induced
Ciliary movement–due to the presence of cillia on flagella
E.g., Chlamydomonas.
Spontaneous
Cyclosis–The movement of the cytoplasm
Eg., Chara
Variation movements
Curvature is temporary
Induced
Occurs due to external stimuli
Growth movements
Growth is permanent
Phototactic–Movement due to light. E.g., Zoospore and gametes of Chlamydomonas, Ulothrix
Hyponastic–Differential growth on the lower side of an organ.
E.g., Circination in fronds of ferns.
Chemotactic–Movement due to a chemical stimulus.E.g., Antherozoids attracted to Archegonia of Bryophytes and Pteridophytes
Epinastic–Differential growth on the upper side of an organ.
E.g., Opening of flowers.
Thermotactic–Movement in response to heat stimulus
E.g., Algae moves away from areas with warm water
Nutational–The zig-zag growth of the stem due to the alternative growth.
E.g., In stems which are flattened.
Circumnulational–The growth occurs in a rotational way
E.g., In stems with rounded apex.




**Rack Your Brain**

To increase the shelf value of tomatoes we keep them in the refrigerator. What causes its slow ripening?

**Rack Your Brain**

Name the hormone that acts antagonistic to ABA.

**PHOTOMORPHOGENESIS**

- The non-directional, non-periodic developmental strategy which a plant adopts, when growing in light, is termed Photomorphogenesis.
- They are of the following types-
  - Photoperiodism
  - Seed Germination

**PHOTOPERIODISM**

- Garner and Allard found that soybean (*Glycine max*), tobacco (*Nicotiana tabaccum*) and its Maryland Mammoth variety continued to grow vegetative during summer but bloomed in greenhouse.
- They concluded that length of daily light and dark periods is important in control of flowering.
- **The phenomenon where the day and light period in the plant results in flowering is termed as photoperiodism**.
- On the basis of this, plants were categorized into the following-
  - Short day plants(SDP)
  - Long day plants(LDP)
  - Day-neutral plants(DNS)

**Short Day Plant**

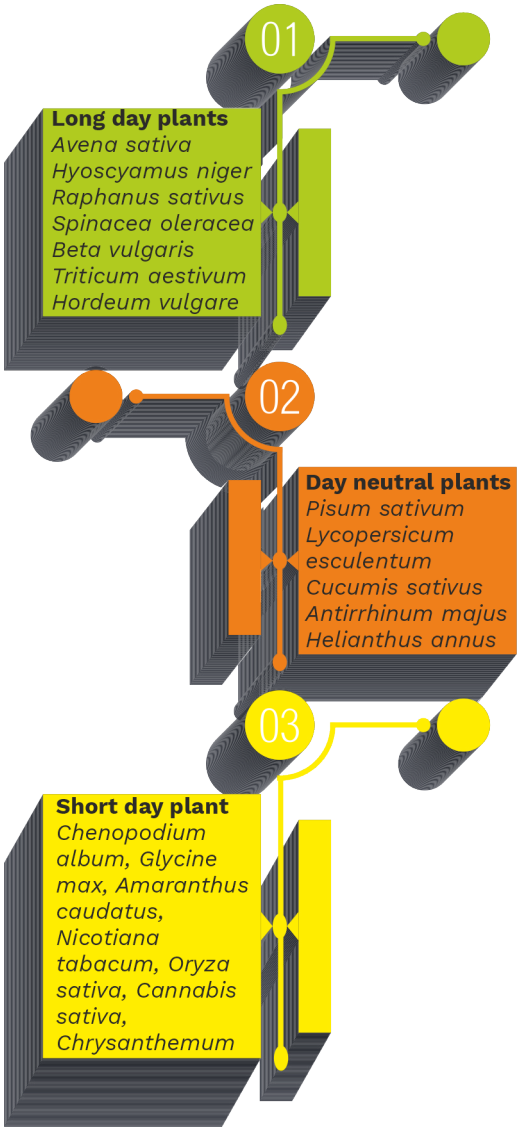
- In these plants, the dark period is critical and must be continuous. If this dark period is interrupted even with a brief exposure to red light, the short-day plant will not flower.
- Inhibitory effect of red light can be overcome by an exposure to far-red light.
- Continuous dark period initiates early flowering in short day plants.

**Long Day Plants (LDP)**

- These plants require a longer day light period i.e. of 14-16 hours for flowering.
- They also need short dark periods. Thus, also known as short night plants. In long day plants, the light period is critical.

**Previous Year's Question**

Which plant is a LDP?
(1) Tobacco
(2) *Glycine max*
(3) *Mirabilis jalapa*
(4) Spinach



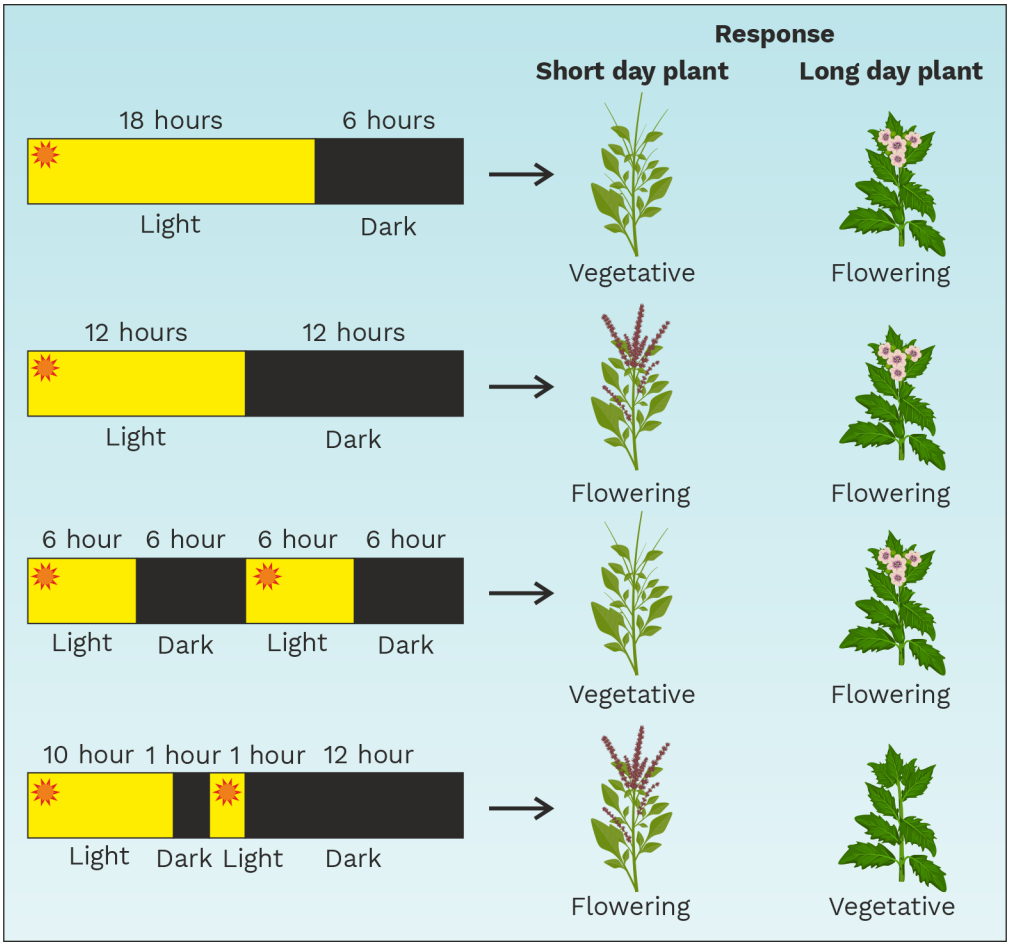
- A short exposure to a dark period or increased light period stimulates flowering in long day plants.

### Day Neutral Plants

- These plants flower in all photoperiods ranging from 5 hours to 24 hours of continuous light.
- Chailakhyan demonstrated that the stimulus for flower promotion is perceived by leaves.
- A hormone, **florigen,** is synthesised and transmitted to different parts of plant which cause flowering.

**Previous Year's Question**

The pineapple which under natural conditions is difficult to blossom has been made to produce fruits throughout the year by application of
(1) NAA, 2, 4-D
(2) Phenyl acetic acid
(3) Cytokinin
(4) IAA, IBA



## PHYTOCHROME

- An exposure to red light in the critical dark period inhibits flowering in short day plants but exposure to far red light can cause flowering.
- The increased light period of long day plants and the Interruption of dark period causes flowering in Long day plants.
- This is because of a **protein pigment Phytochrome.**
- Phytochrome exists in two forms
  - **Red light absorbing-$P_R$**
  - **Far red light absorbing-$P_{FR}$**
- When $P_R$ form absorbs red light in 660-665 μm, it changes to $R_{FR}$ form while $P_{FR}$ form absorbs far red light in 730-735 μm, it changes to $P_R$ forms.
- In dark, $P_{FR}$ form changes to $P_R$ form.

### Importance of Photoperiodism

- The knowledge of the phenomenon of photoperiodism has been of great importance in **hybridisation experiments** in plants.

## SEED GERMINATION AND DORMANCY

### Dormancy of Seed

- The seed of the plant germinates in favourable conditions and give rise to a new plant.
- Sometimes, in some plants the seed does not germinate even if favourable conditions are present and this is known as dormancy
- The dormancy is also seen in rhizome, bulb, tuber and corms.

### Causes of Dormancy

- **Seed coat impermeable to water-** The hard seed coat is impermeable to water and thus preventing germination.
- **Seed coat impermeable to Oxygen-** The seed coat of some plants is impermeable to Oxygen.
- **Mechanically resistant seed coat-** The seed coat of some plants prevents any expansion of the embryo and thus preventing germination.

**Previous Year's Question**

One set of the plant was grown at 12 hours day and 12 hours night period cycles and it flowered while in the other set night phase was interrupted by flash of light and it did not produce flower. Under which one of the following categories will you place this plant?
(1) Long day
(2) Darkness neutral
(3) Day-neutral
(4) Short day

**Rack Your Brain**

Which wavelengths are most effective in photoperiodism?

**Previous Year's Question**

Phytohormones are
(1) chemical regulating flowering
(2) chemical regulating secondary growth
(3) hormones regulating growth from seed to adulthood
(4) regulators synthesised by plants and influencing physiological processes

- **Need for after-ripening time-** In some plants, the seed is shed at a stage when the embryo is fully developed, but still, it does not germinate as the seed needs some after-ripening time.
- **Immaturity of the embryo-** In some, the embryo is not fully developed when the seed is shed and thus it does not germinate.
- **Low temperature requirement-** Some seeds require exposure to cold temperature for germination. The seeds remain dormant throughout the winter and germinate in spring.

**Ways to Overcome Dormancy**

- Woody plants need exposure to winter chill to overcome their dormancy.
- Ethylene, cytokinin, gibberellins are also effective in breaking seed dormancy in many cases.
- **Scarification-** In this process, the seed coat is weakened or ruptured by mechanical means or by thrashing the seeds, abrasion with sand, concentrated sulphuric acid for a limited duration. It is also carried out in cases where the testa is impervious to water.
- Seeds of some plants are stored at room temperature, for few weeks to several months to overcome dormancy. The storage is called after-ripening storage".
- Seeds some plants need exposure to light for seed germination.
- In some plants the seed requires a chilling temperature.

**VERNALIZATION**

- Term vernalization was given by **Trofim Denisovich Lysenko.**
- The **vegetative period** of the plant is **cut short** resulting in an early flowering due to **exposure to cold temperature conditions.**
- *Hyoscyamus niger* and certain perennials e.g., apples have a low temperature requirement for flowering.

**Previous Year's Question**

Which hormone breaks dormancy of potato tuber?
(1) Gibberellin
(2) IAA
(3) ABA
(4) Zeatin

**Previous Year's Question**

Period of suspended growth due to exogenous condition is termed as
(1) quiescence
(2) dormancy
(3) perennation
(4) hibernation

**Gray Matter Alert!!!**

**Vivipary:** The germination of the seed within the fruits while the seed is still attached to the fruit. Vivipary can be seen in *Rhizopus*, squash and coconut.

**Previous Year's Question**

Hormone responsible for plant and seed dormancy during drought is
(1) IBA
(2) NAA
(3) ABA
(4) Zeatin

- The effect of the cold stimulus on plant is not immediately visible. It is expressed only at a certain later stage in the form of flowering.
- In cereals like winter wheat, if planted in spring it would fail to flower. These varieties are planted in autumn and thus receive sufficient amount of cold temperature hence showing effective germination.
- But, if the winter variety is delayed in sowing, it remains vegetative.
- The spring varieties of plants are planted in spring and thus flower and produce garins before the end of the growing seasons.
- Vernalization has shown to induce flowering in biennials like Sugarbeet,cabbage and carrots. The vernalization is effective only germinating seeds have received cold temperature treatment for sufficient time.
- It has been suggested that in gibberellins probably through stem elongation tigger some reaction leading to flowering.

### Perception of the Cold Stimulus

- The cold stimulus is perceived by the apical meristems.

### Presence of a Floral Hormone

- It is believed that the perception of the cold stimulus results in the formation of a floral hormone **'Vernalin'** which is transmitted to other parts of the plant.

### Utility of Vernalization

- Vernalization shortens the vegetative period of the plants.
- Vernalization increases the cold resistance of the plants specially in countries which have severe winters.

**Rack Your Brain**

Certain plants only flower when exposed to low temperature for weeks. Name this phenomenon.

**Previous Year's Question**

If a tree flowers thrice in a year (Oct., Jan. and July) in Northern India, it is said to be

(1) photo and thermo-insensitive
(2) photo and thermo-sensitive
(3) photosensitive but thermo-insensitive
(4) thermosensitive but photo-insensitive

**Rack Your Brain**

Which organelle in leaves is the last to show evidence of death during senescence?

**Previous Year's Question**

Through their effect on plant growth regulators, what do the temperature and light control in the plants?

(1) Apical dominance
(2) Flowering
(3) Closure of stomata
(4) Fruit elongation

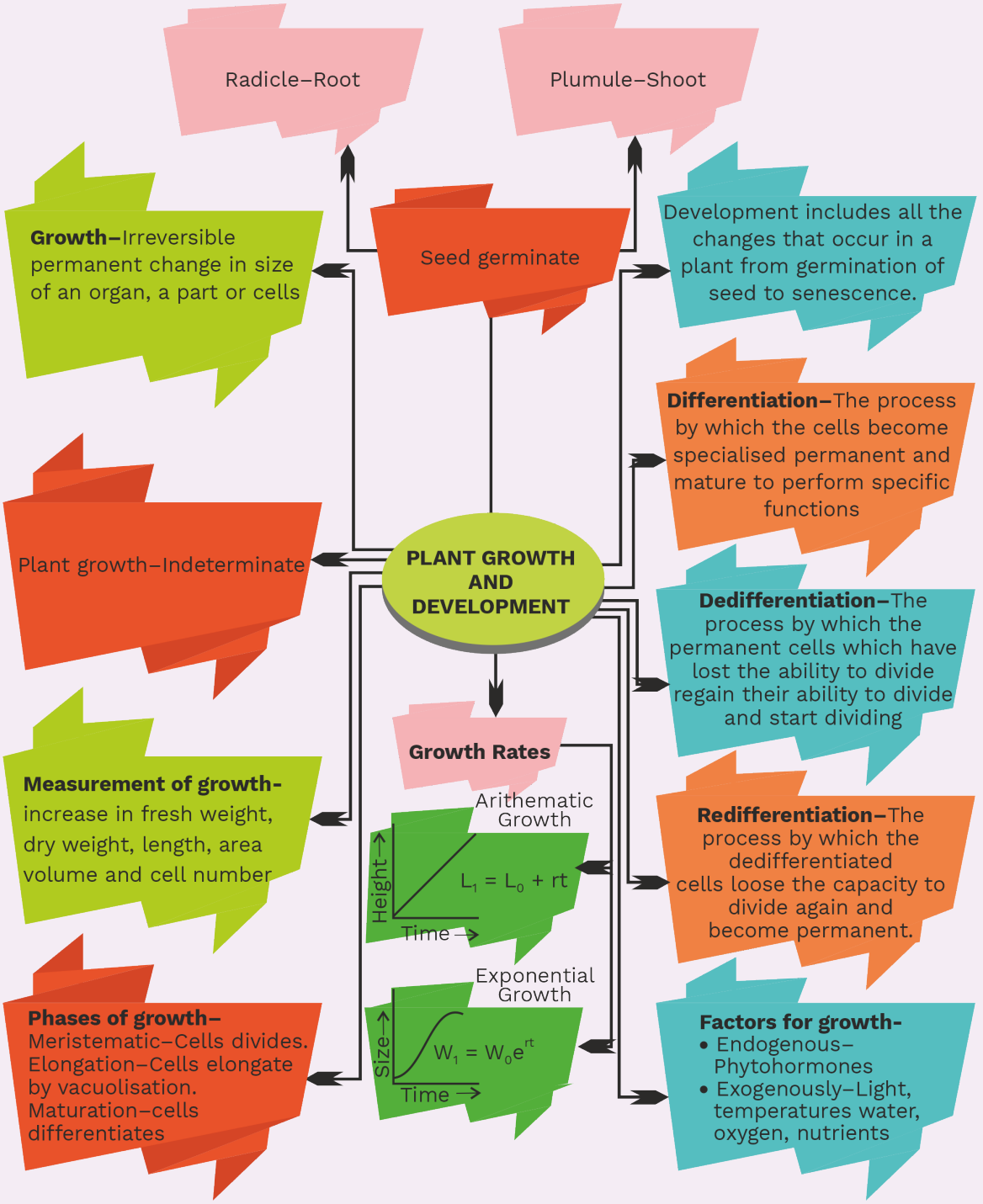
**SENESCENCE**

- Senescence consists of a number of events that are genetically programmed. The senescence may be a whole plant senescence or organ senescence which again may be sequential senescence or simultaneous senescence.

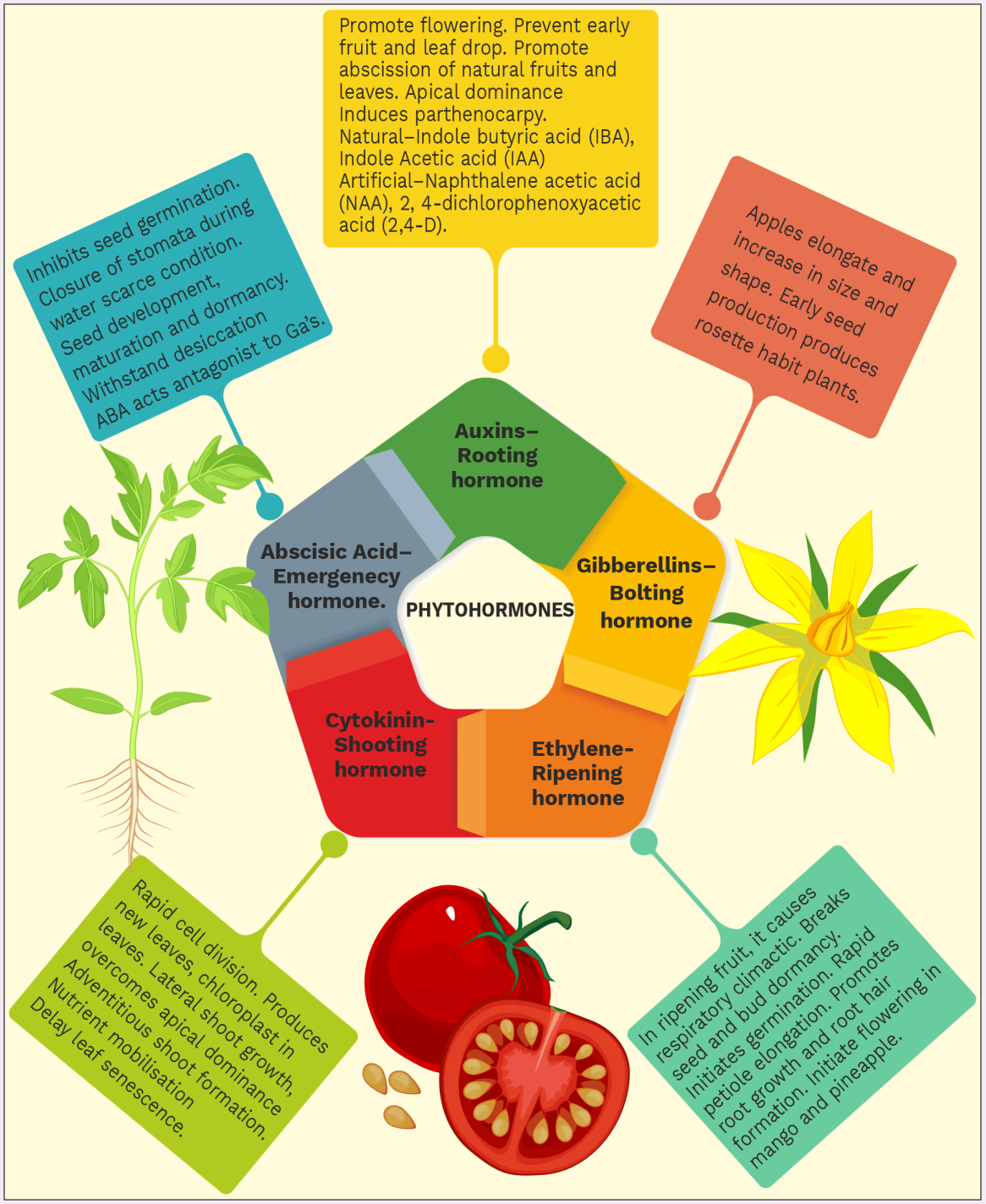
**Keywords**

- IAA – Indole acetic acid
- NAA – Naphthalene acetic acid
- ABA – Abscisic acid
- IBA – Indole-3 butyric acid
- 2,4-D – 2,4-dichlorophenoxy acetic acid
- PGR – Plant growth regulator

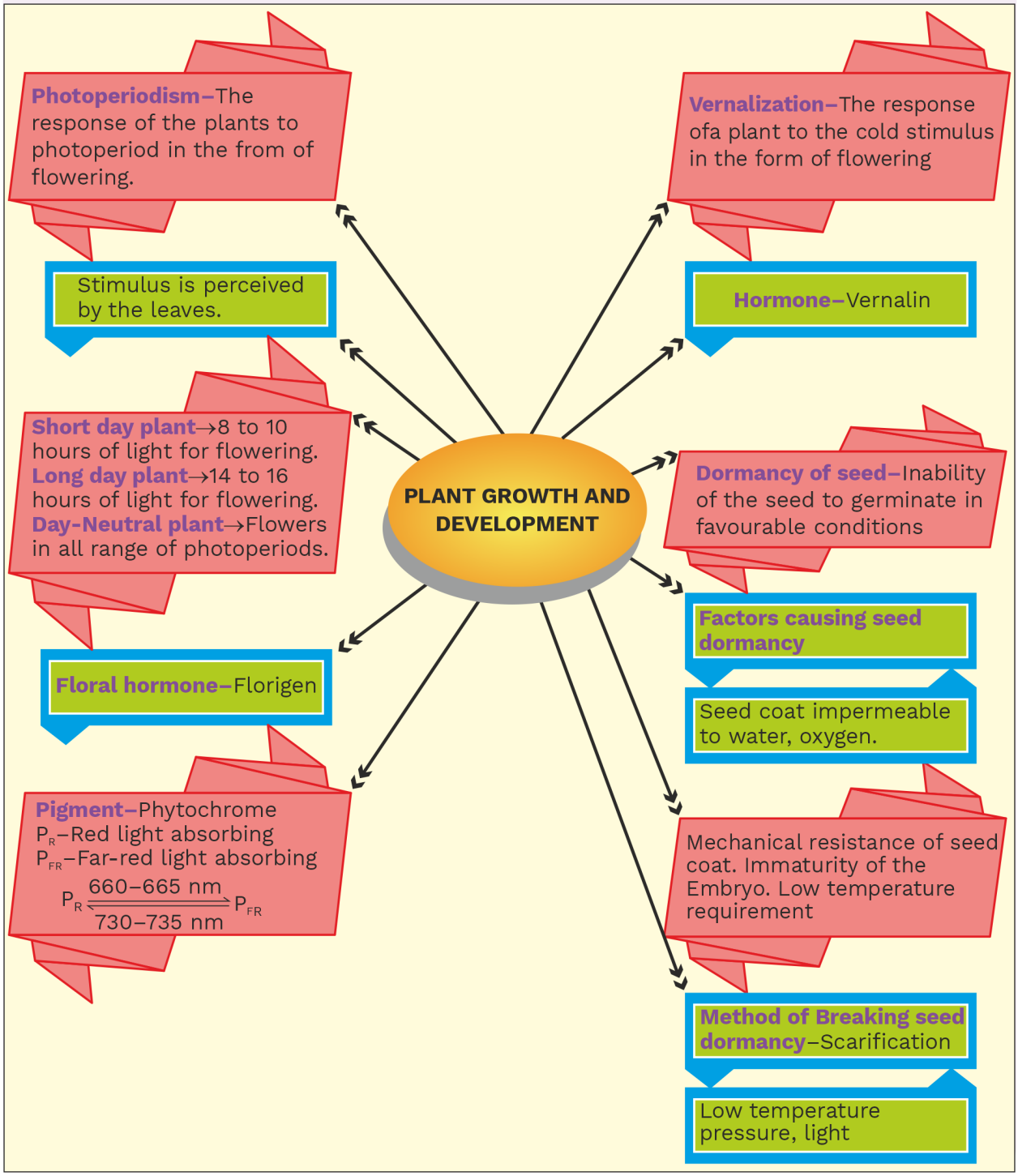
## Summary


Radicle–Root
Plumule–Shoot
Growth–Irreversible permanent change in size of an organ, a part or cells
Seed germinate
Development includes all the changes that occur in a plant from germination of seed to senescence.
Differentiation–The process by which the cells become specialised permanent and mature to perform specific functions
Plant growth–Indeterminate
PLANT GROWTH AND DEVELOPMENT
Dedifferentiation–The process by which the permanent cells which have lost the ability to divide regain their ability to divide and start dividing
Growth Rates
Measurement of growth- increase in fresh weight, dry weight, length, area volume and cell number
Arithematic Growth
Height
Time
$L_1 = L_0 + rt$
Redifferentiation–The process by which the dedifferentiated cells loose the capacity to divide again and become permanent.
Exponential Growth
Size
Time
$W_1 = W_0e^{rt}$
Phases of growth– Meristematic–Cells divides. Elongation–Cells elongate by vacuolisation. Maturation–cells differentiates
Factors for growth-
• Endogenous–Phytohormones
• Exogenously–Light, temperatures water, oxygen, nutrients

## Summary


Promote flowering. Prevent early fruit and leaf drop. Promote abscission of natural fruits and leaves. Apical dominance Induces parthenocarpy. Natural–Indole butyric acid (IBA), Indole Acetic acid (IAA) Artificial–Naphthalene acetic acid (NAA), 2, 4-dichlorophenoxyacetic acid (2,4-D).
Inhibits seed germination. Closure of stomata during water scarce condition. Seed development, maturation and dormancy. Withstand desiccation ABA acts antagonist to Ga's.
Apples elongate and increase in size and shape. Early seed production produces rosette habit plants.
Auxins– Rooting hormone
Gibberellins– Bolting hormone
Ethylene- Ripening hormone
Cytokinin- Shooting hormone
Abscisic Acid– Emergenecy hormone.
PHYTOHORMONES
Rapid cell division. Produces new leaves, chloroplast in leaves. Lateral shoot growth, overcomes apical dominance Adventitious shoot formation. Nutrient mobilisation Delay leaf senescence.
In ripening fruit, it causes respiratory climactic. Breaks seed and bud dormancy. Initiates germination. Rapid petiole elongation. Promotes root growth and root hair formation. Initiate flowering in mango and pineapple.

## Summary


PLANT GROWTH AND DEVELOPMENT
Photoperiodism–The response of the plants to photoperiod in the from of flowering.
Stimulus is perceived by the leaves.
Short day plant→8 to 10 hours of light for flowering.
Long day plant→14 to 16 hours of light for flowering.
Day-Neutral plant→Flowers in all range of photoperiods.
Floral hormone–Florigen
Pigment–Phytochrome
$P_R$–Red light absorbing
$P_{FR}$–Far-red light absorbing
$P_R \underset{730–735\ nm}{\overset{660–665\ nm}{\rightleftharpoons}} P_{FR}$
Vernalization–The response ofa plant to the cold stimulus in the form of flowering
Hormone–Vernalin
Dormancy of seed–Inability of the seed to germinate in favourable conditions
Factors causing seed dormancy
Seed coat impermeable to water, oxygen.
Mechanical resistance of seed coat. Immaturity of the Embryo. Low temperature requirement
Method of Breaking seed dormancy–Scarification
Low temperature pressure, light

**Solved Exercise**

**Q1** **The pineapple which under natural condition is difficult to blossom has been made to produce fruits throughout the year by application of**
**(1) NAA, 2, 4D**
**(2) Phenyl acetic acid**
**(3) Cytokinin**
**(4) IAA, IBA**

**A1** **(1)**
NAA and 2,4 D are synthetic auxins that promote flowering.

**Q2** **Abscisic acid controls**
**(1) cell division**
**(2) leaf fall and dormancy**
**(3) shoot elongation**
**(4) cell elongation and wall formation**

**A2** **(2)**
Abscisic forms abscission layer and causes leaf fall and causes dormancy.

**Q3** **Phototropic and geotropic movements are linked to**
**(1) gibberellins**
**(2) enzymes**
**(3) auxin**
**(4) cytokinins**

**A3** **(3)**
The presence of auxins at the tip of the shoot causes its growth towards light and formation of roots is linked with geotropism.

**Q4** **Which of the following movement is not related to auxin level?**
**(1) Bending of shoot towards light**
**(2) Movement of root towards soil**
**(3) Nyctinastic leaf movements**
**(4) Movement of sunflower head tracking the sun**

**A4** **(3)**
The movement of leaves is not related to the level of auxin.

**Q5** **Which of the following hormones can replace vernalisation?**
**(1) Auxin**
**(2) Cytokinin**
**(3) Gibberellins**
**(4) Ethylene**

**A5** **(3)**
Gibberellins can be sprayed to replace the cold treatment.

**Q6** **Leaf fall can be prevented with the help of**
**(1) abscisic acid**
**(2) auxins**
**(3) florigen**
**(4) cytokinins**

**A6** **(2)**
Auxins prevent premature leaf fall.

**Q7** **Mowing of grass lawn facilitates better maintenance because**
**(1) wounding stimulates regeneration**
**(2) removal of apical dominance and stimulation of intercalary meristem**
**(3) removal of apical dominance**
**(4) removal of apical dominance and promotion of lateral meristem**

**A7** **(4)**
Mowing grass lawn cut the apical tip and thus removes apical dominance and promotes lateral growth.

**Q8** **Which one increases in the absence of light?**
**(1) Uptake of minerals**
**(2) Uptake of water**
**(3) Elongation of internodes**
**(4) Ascent of sap**

**A8** **(3)**
Absence of light causes elongation of internodes.

**Q9** **Coconut milk factor is**
**(1) an auxin**
**(2) a gibberellin**
**(3) abscisic acid**
**(4) cytokinin**

**A9** **(4)**
Coconut milk contains cytokinin in it.

**Q10** **Which one of the following growth regulators is known as 'stress hormone'?**
**(1) Abscisic acid**
**(2) Ethylene**
**(3) GA 3**
**(4) Indole acetic acid**

**A10** **(1)**
Abscisic acid is known as stress hormone as it helps the plant to overcome stress conditions like drought.