Growth Regulators

SEC : UNIT 4

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GROWTH

Growth

- Irreversible change in Mass, i.e. increase in size, volume and weight of any part of plant's body.
- It means quantitative increase in plant body.
- e.g. Cell division ⟶ Cell enlargement.

Development

- Irreversible change in state.
- It means the qualitative change in plant body.
- e.g. Seed ⟶ Seedling ⟶ Vegetative maturation ⟶ Flowering.

Growth is a continuous process
Development is phase to phase process.

- Plant's growth and development are under the control of two sets of internal factors.
- Nutritional factors such as the supply of carbohydrates, proteins, fats and others constitute the raw materials required for growth.
- Proper utilization of these raw materials is under the control of certain ***"chemical messengers"*** which can be classified into hormones and vitamins.

Hormone	Vitamin
1) The site of synthesis is different from the site of action. 2) Plant hormones are physiologically active.	1) Vitamins are used in the same part without being transported. 2) Vitamins by themselves are not physiologically active. They act as co-factor of enzyme.

- The term Hormone is derived from a Greek root '*hormao*' which means 'to stimulate' (Beylis and Starling, 1902).

- Thimann (1948) suggested using the term '**Phytohormone**' for Hormones of plant.

- Phytohormones are organic substances produced naturally by the plants which in minute/low concentration
  - ✓ increase,
  - ✓ decrease
  - ✓ modify the growth and development.
- *Also termed as*
  - ✓ growth hormones
  - ✓ growth promoting substances
  - ✓ growth substances
  - ✓ growth regulators
  - ✓ growth factors etc.

Plant Growth Regulators

- Plant Growth regulators (PGR) refers to natural or synthetic substances influence the growth and development.
- IAA (Auxin)- Both natural and synthetic.
- IBA (Auxin) - Always synthetic.

- All plant hormone are plant growth regulators but,
- All plant growth regulator are not plant hormones

Plant hormones are

Signal molecules produced at specific locations, that occur in very low concentrations, and cause altered processes in target cells at other locations within plants

Plant growth regulators – include plant hormones (natural & synthetic), but also include non-nutrient chemicals not found naturally in plants that when applied to plants, influence their growth and development.

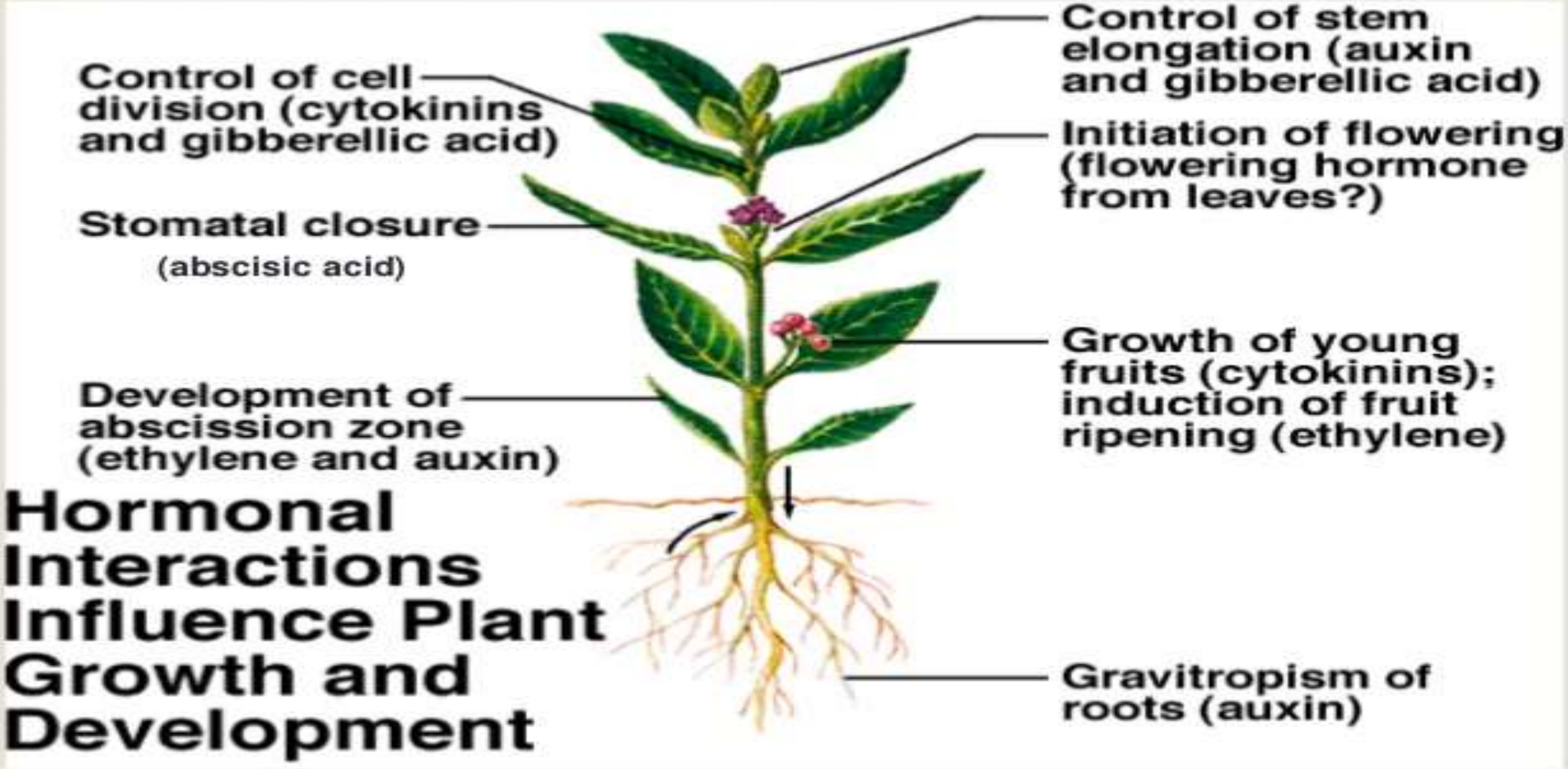
– 5 recognized groups of natural plant hormones and growth regulators.

- 1. Auxins
- 2. Gibberellins
- 3. Cytokinins
- 4. Ethylene
- 5. Abscisic acid

5 groups of natural plant hormones

- Each plant hormone evokes many different responses. Also, the effects of different hormones overlap and may be stimulatory or inhibitory.
- The commonly recognized classes of plant hormones are the auxins, gibberellins, cytokinins, abscisic acid, and ethylene.
- Some evidence suggests that flower initiation is controlled by hypothetical hormones called florigens, but these substances remain to be identified.
- A number of natural or synthetic substances such as brassin, morphactin, and other growth regulators not considered to be hormones nevertheless influence plant growth and development.

Plant Hormones & Growth



Hormonal Interactions Influence Plant Growth and Development

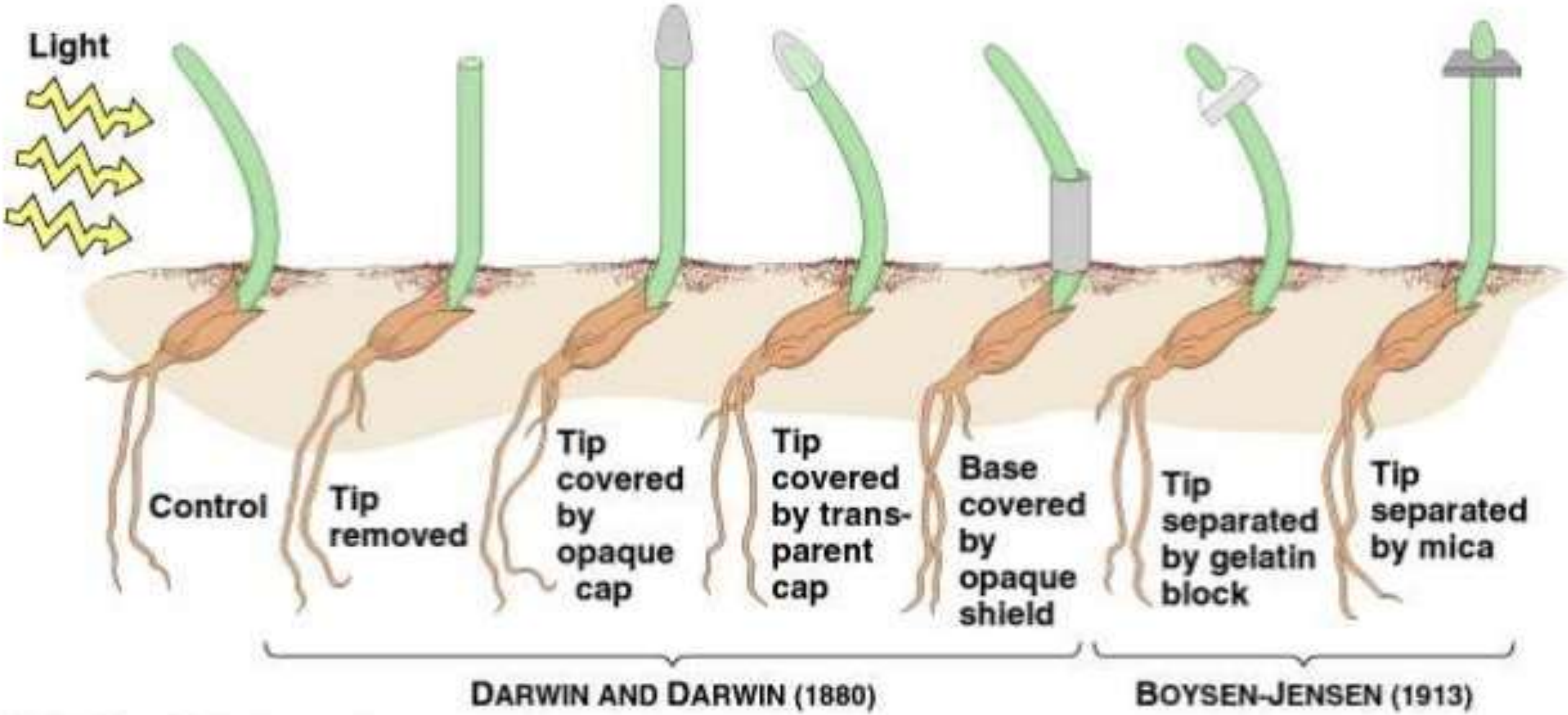
Discovery of Auxins

- The idea of existence of auxin was proposed by **Charles Darwin** (1880) in his book **"The Power of Movements in Plants".**
- Coleoptiles of Canary grass (*Phallaris canariensis*) to unilateral light and observed it to bend towards light.
- He covered the coleoptiles tip with tin foil or cut it off and observed that coleoptiles did not bend towards unilateral light.
- Concluded - some stimulus is transmitted from upper to the lower part which induced bending of the coleoptiles.

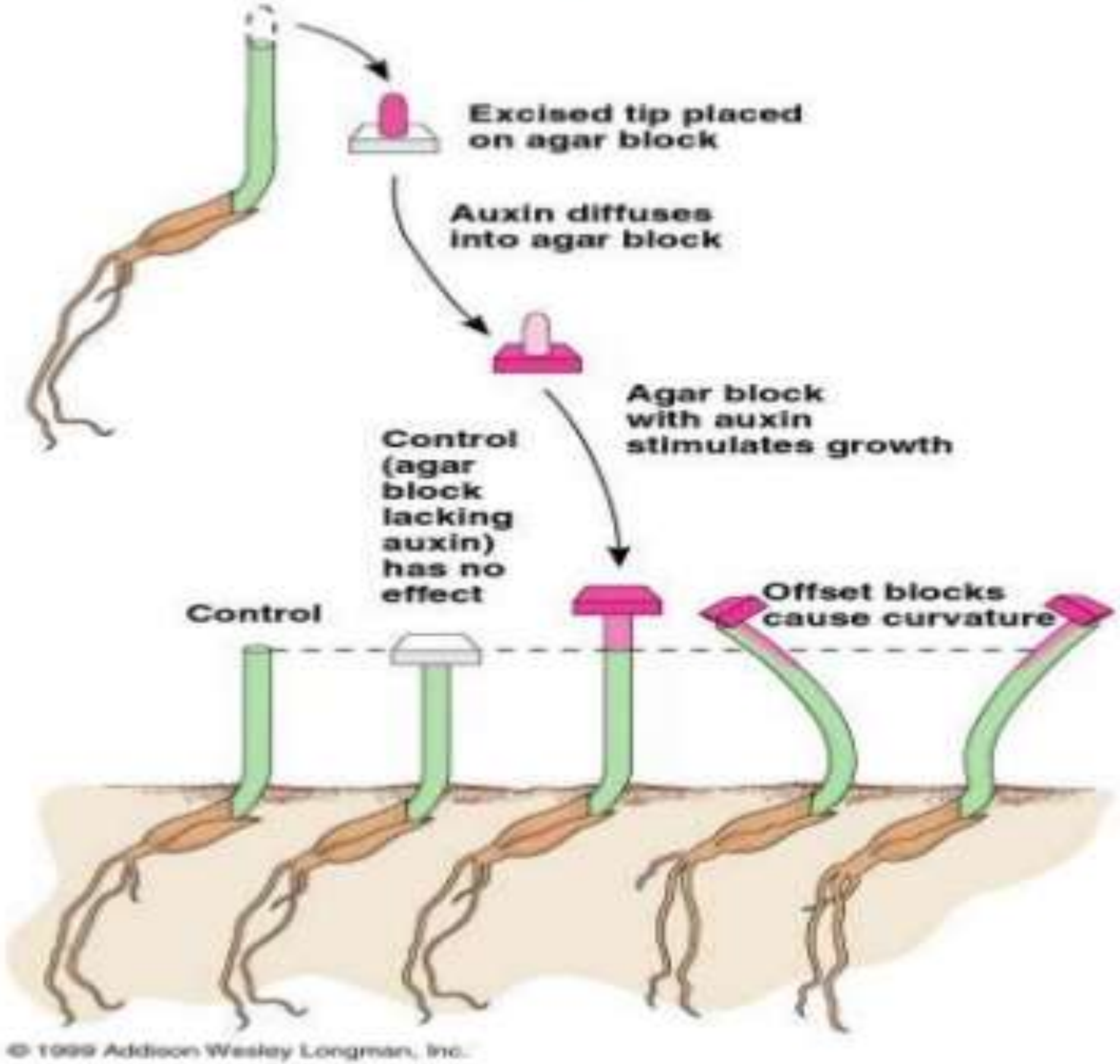
AUXINS

- Derived from the Greek word "auxein" means- "to grow/increase".
- Auxins may be defined as growth promoting substances which promote growth along the vertical axis when applied in low concentration to the shoot of the plant.

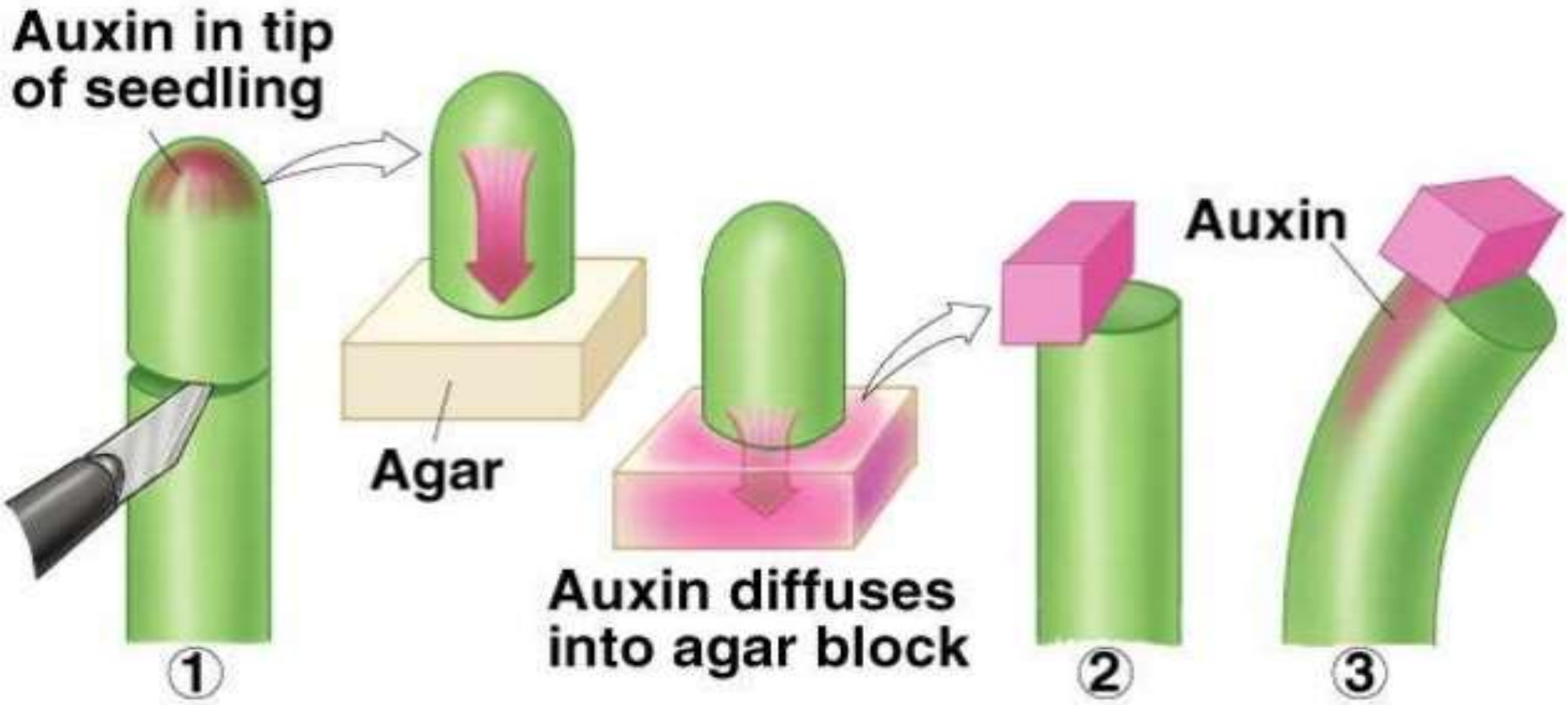
Discovery of Auxins



Discovery of Auxins



Discovery of Auxins



Auxins

Site

- Auxin is made in actively growing tissue which includes young leaves, fruits, and especially the shoot apex.
- Made in cytosol of cells .

Auxins

Transport :

- Basipetal (or Polar) Transport Auxin is transported in a basipetal (towards the base, base-seeking) direction.
- In other words, auxin moves from the shoot tip towards the roots and from the root tip towards the shoot.

4 18

Occurrence and Distribution of Auxins

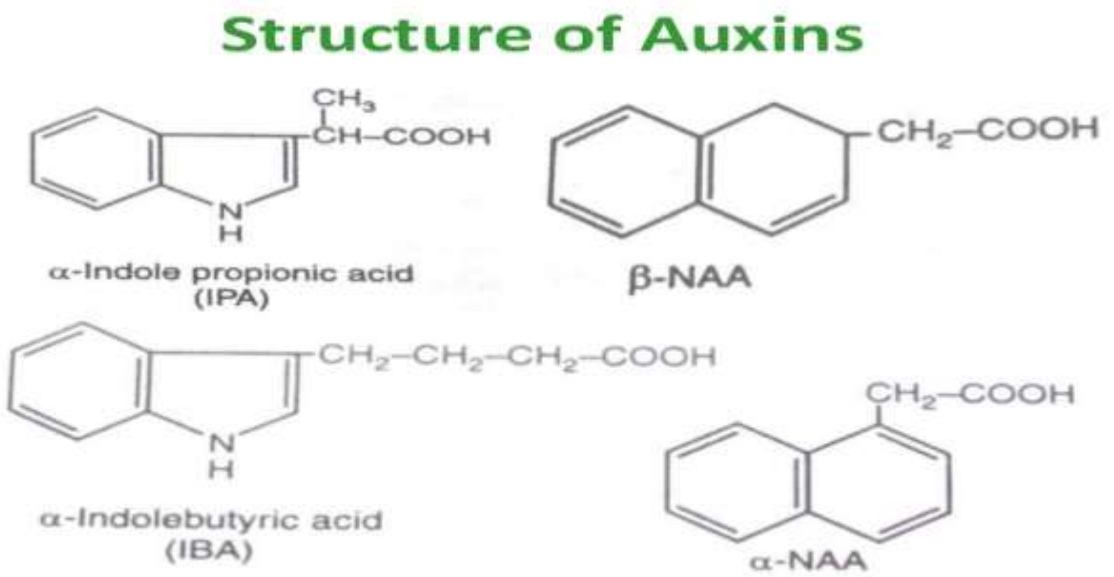
- Occurs universally in all plants.
- Where there is active growth there is auxin production.
- Growing meristem and enlarging organs produces auxin.
- Shoot apex produces much auxin than root apex.
- Apical bud synthesizes more auxin than lateral buds.
- Developing seeds contain more auxin than matured seeds.
- Apical bud synthesizes six times more auxin than expanding leaves.

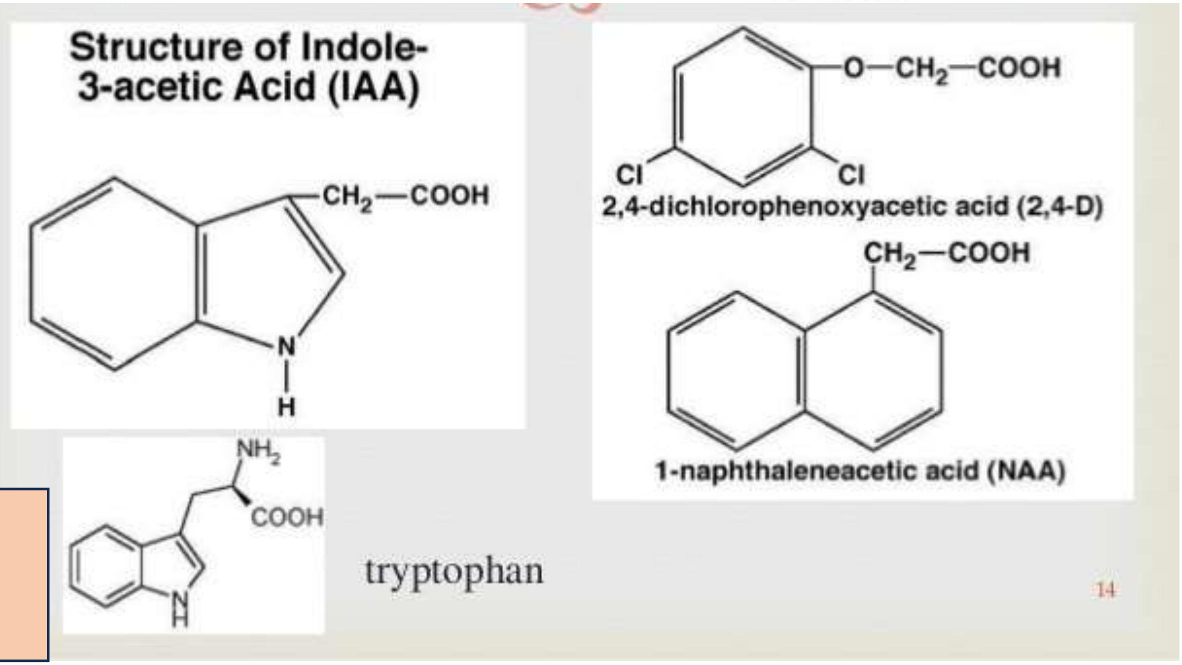
Structure of Auxins

Synthetic Auxins—produced artificially and similar to natural in their physiological activity.

- IPA (Indole Propionic Acid)
- IBA (Indole Butyric Acid)
- NAA (Napthalene Acetic Acid)
- 2,4-D (2,4 – Dichlorophenoxy acetic acid)
- 2,4,5-T (2,4,5 – Trichlorophenoxy acetic acid)

etc.





Auxin (IAA) synthesized from the precursor Tryptophan (an amino acid)

Physiological role of auxin

Cell Elongation and longitudinal growth:

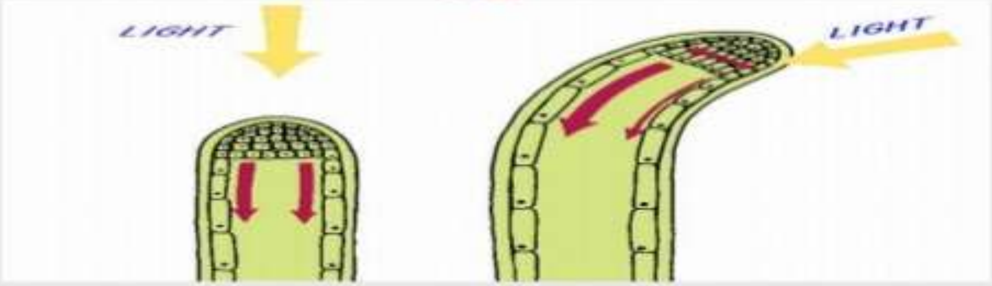
- The primary and chief function of auxin in plants is to stimulate the cell elongation in shoot.
- Auxins induce enzymatic or non-enzymatic deformation or loosening of cell wall by breaking the cross links between the cell wall components. This results in increased plasticity with decreased elasticity of the cell wall. The bonds are reformed after the cellular elongation.

Apical Dominance:

- The influence of apical bud in suppressing the growth of lateral buds is called apical dominance. If the terminal bud is intact and growing, the lateral buds remain suppressed, particularly in long and sparsely branched vascular plants. Removal of apical bud results in the fast growth of the lateral buds causing the plant bushy.
- The reason is that, the auxin is synthesized in the apical meristem from where it is translocated downwards causing inhibition of growth of lateral buds.

Auxin Actions

Phototropism



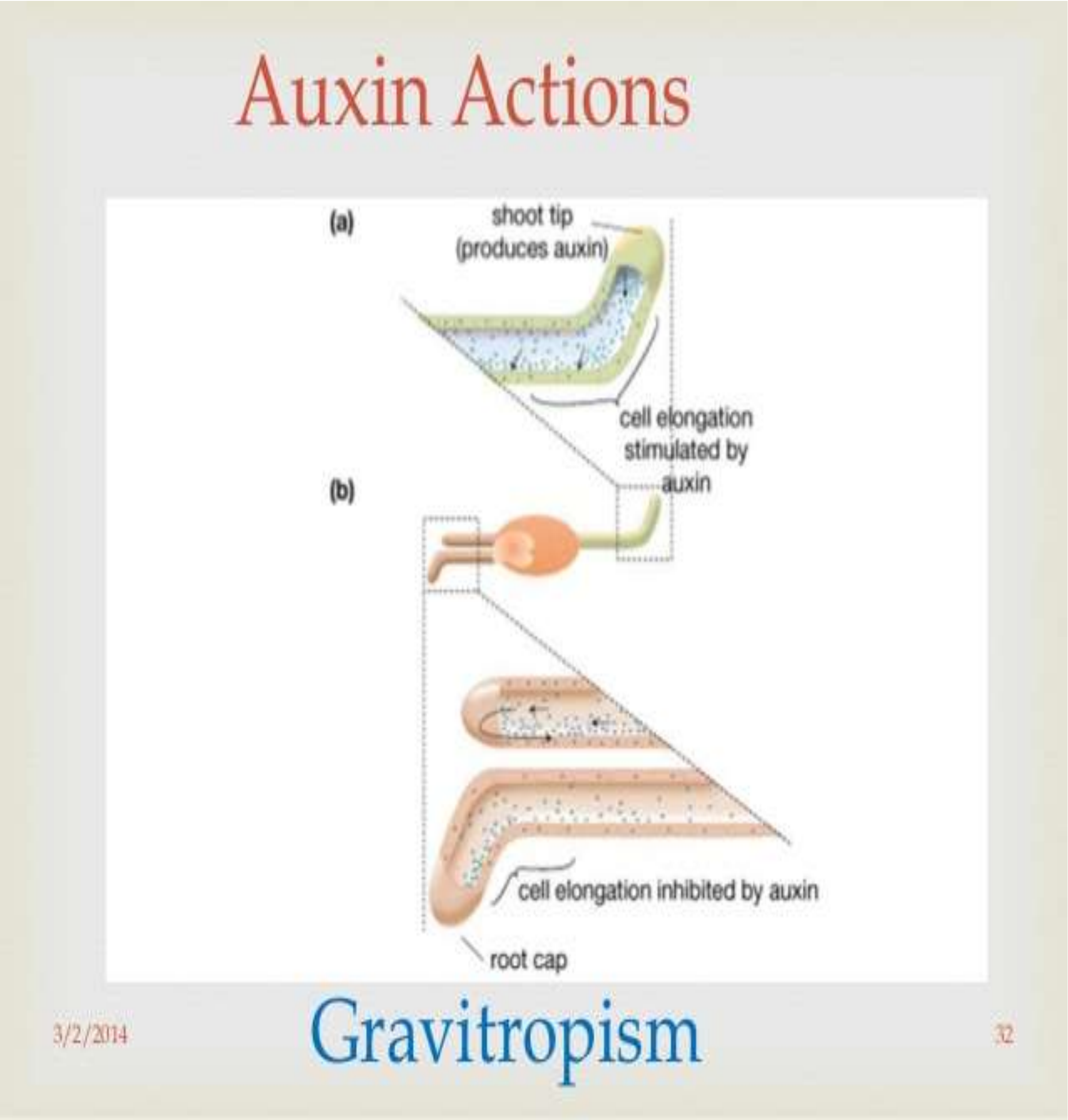
- Light directly over the plant
- Auxins are in equal quantity
- Cell elongation is equal on all sides of the cell

- Greater light on the right side of the plant
- Auxin quantity becomes greater on the left cell
- Auxins trigger cell elongation on the left side
- Plant 'stretches' to the light

➢ Phototropism

- Plant bend towards unilateral light.
- This is due to higher concentration of auxin on the shaded side.

Plant growth movements: Auxin regulates phototropism, geotropism and other developmental changes. The uneven distribution of auxin, due to environmental cues, such as unidirectional light or gravity force, results in uneven growth of plant tissue.



Effects of different Auxin on Plant Growth and Development

- **Geotropism**

- Movement of a plant's organ in response to gravity is known as geotropism/ gravitropism.
- Stem and roots accumulate IAA on the lower side in response to gravity.
- Increased auxin concentration on the lower side in stems causes those cells to grow more than cells on the upper side.
  - stem bends up against the force of gravity
    - **negative gravitropism**
- Upper side of roots grow more rapidly than the lower side.
  - roots ultimately grow downward
    - **positive gravitropism**

Root growth and root initiation:

Auxins always inhibit root growth at higher concentrations. At low concentrations, they promote root growth. The conc. of auxin which is inhibitory to root growth causes initiation of adventitious roots from the nodes or basal regions of stem.

Root initiation

- Application of IAA to cut end of a stem promotes root formation.

Control or Prevention of Abscission

- Abscission does not occur when auxin content is high on distal end and low in the proximal end of abscission zone.

Parthenocarpy

- Auxin induces Parthenocarpy.

Effects of different Auxin on Plant Growth and Development

Callus Formation

Undifferentiated mass of parenchymatous tissue is known as callus.

- Application of IAA causes cells to elongate & adventitious root.

Sex Expression

- Auxin induced the changing of sex ratio of flowers towards femaleness, i.e. increase the number of female flowers.

Use of Auxins in Agriculture

➢ Rooting of Cuttings

- Application of NAA (in Mango) and IBA (in Guava) in stem cutting causes 100% success in vegetative propagation.

➢ Seedless Fruit Production (Parthenocarpy)

- In case of Banana, Grapes, Strawberry, Brinjal, Grapes – Application of IAA, IBA, and NAA show 100% success.

➢ Promotion of Flowering

- Application NAA causes uniform flowering in Pineapple leading to development of uniform sized fruits.
- 2, 4 -D is also used to increase the femaleness in monoecious Cucurbits.

➢ Prevention of Premature Dropping of Fruits

- In case of Apple and Cotton - NAA
- In case of Citrus fruits – 2,4–D/ 2,4,5-T

➢ Germination

- IAA, IBA, is most widely used in soaking seeds for germination.

Fruit Setting

- 2, 4, 5-T is used for improved fruit setting in berries.

Thinning of Flower, Fruit and Leaves

- 2, 4-D is used for defoliation of Cotton plant before boll harvesting.
- NAA is used for fruit thinning in Apple.

Prevention of Lodging in Cereals

- 30-40% Yield loss in traditional tall varieties. Alpha naphthalene acetamide is used to prevent lodging in cereals.

Weedicide

- 2, 4-D, MCPA (Methyl Chloro-Phenoxy Acetic Acid) are weed killer.
- 2,4-D is highly toxic to broad leaved plants or dicotyledons.

Tissue Culture

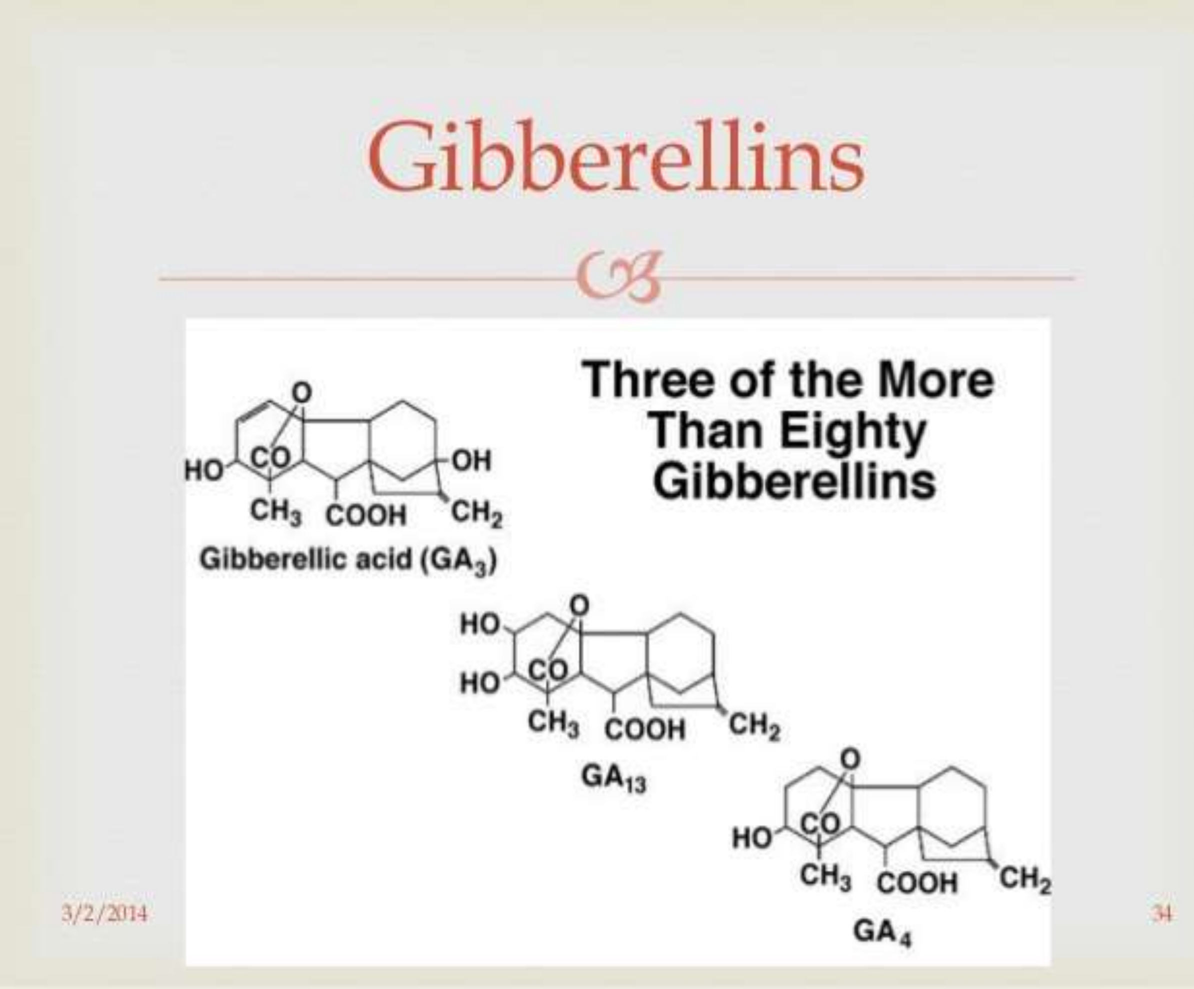
- Auxin along with cytokinin shows successful callus formation, root-shoot differentiation etc.

Gibberellins

- Also known as Gibberellic acid or GA
- Growth promoting chemicals
- Stimulate stem growth through cell elongation and cell division
- Commercial supplies obtained from the fungus Gibberella fujikuroi

GIBBERELLINS

- Discovered by Kurosawa, a Japanese Plant Pathologist in 1928.
- Rice plants infected by the fungus *Gibberella fujikuroi* (Synonym: *Fusarium moniliforme*) showed excessive stem elongation.
- Symptom is called *'Bakane'* diseases.
- Chemical was extracted & purified and named as Gibberellic Acid (GA).
- Now 80 different Gibberellins are available- GA_1 to GA_{80} is available.
- The most commonly occurring gibberellins is **GA_3**.



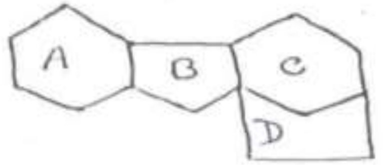


Fig. Gibben Ring (consists of 4 rings)

Gibberellins

- Gibberellins are plant hormones that promote growth, seed germination and leaf expansion.
- They occur at low concentrations in vegetative tissues but at higher concentrations in germinating seeds.
- Induce cell elongation and cell division.
- Important for plant growth and development through flowering and/or seed germination.

Role of GA

Gibberellins

Site :

- Young leaves, roots, and developing seeds (developing endosperm) and fruits.

Transport :

- Made in the tissue in which it is used
- Transport occurs through xylem, phloem, or cell-to-cell.
- Phloem seems to be most important transport route
- Transport is not polar, as it is for auxin.

Gibberellins Actions

1- Promotes stem elongation

- When applied to intact plants, GA usually causes an increase, unlike auxin.
- It overcomes dwarfism in mutants that have a mutation in the GA synthesis pathway.

  dwarf = short;

  wild type = tall ;

  dwarf + GA = tall.

- Thus, GA application:

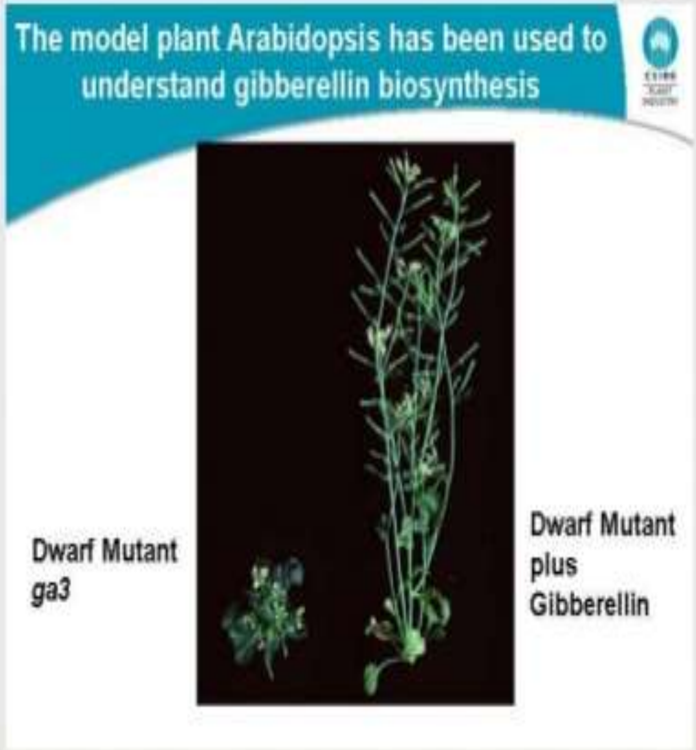
  (1) stimulates elongation; and

  (2) acts on intact plants.

Role of GA

Gibberellins Actions

1- Promotes stem elongation



Role of GA

Gibberellins Actions

5- Promotes cell division & elongation

FIGURE 12-11. 'Red Delicious' apples untreated (*left*) and treated with a combination of benzyladenine, a cytokinin, and $GA_4 + GA_7$ (*right*). Note the elongated, almost pointed shape. *Courtesy of Abbott Laboratories, Chicago, IL.*

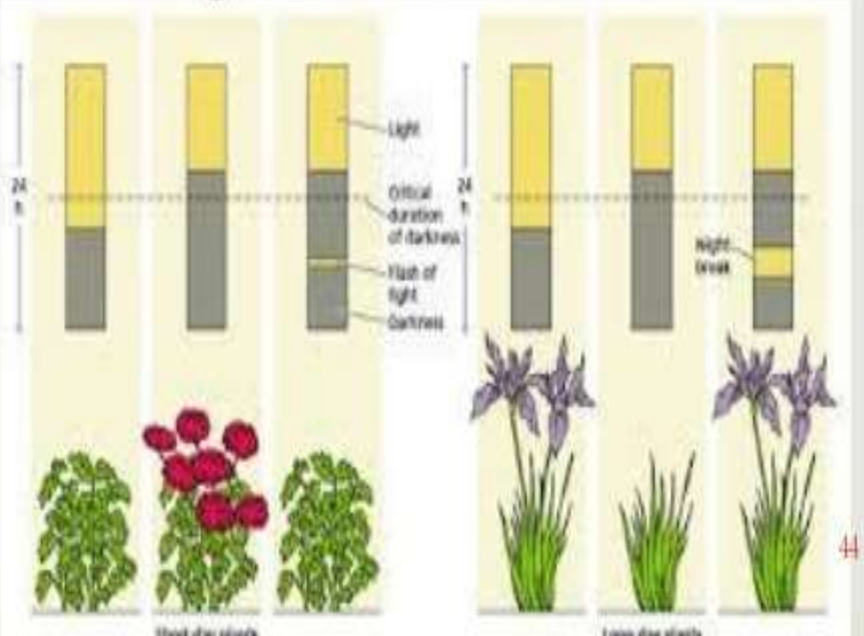
Role of GA

In Plants having rosette pattern of growth (Such as cabbage, henbane etc.), GA induce stem elongation before flowering.

This effect is called bolting effect.

6- Flowering

- GA stimulates bolting in Long Day plants and can substitute for long days or cold treatments that are necessary for flowering.



Role of GA

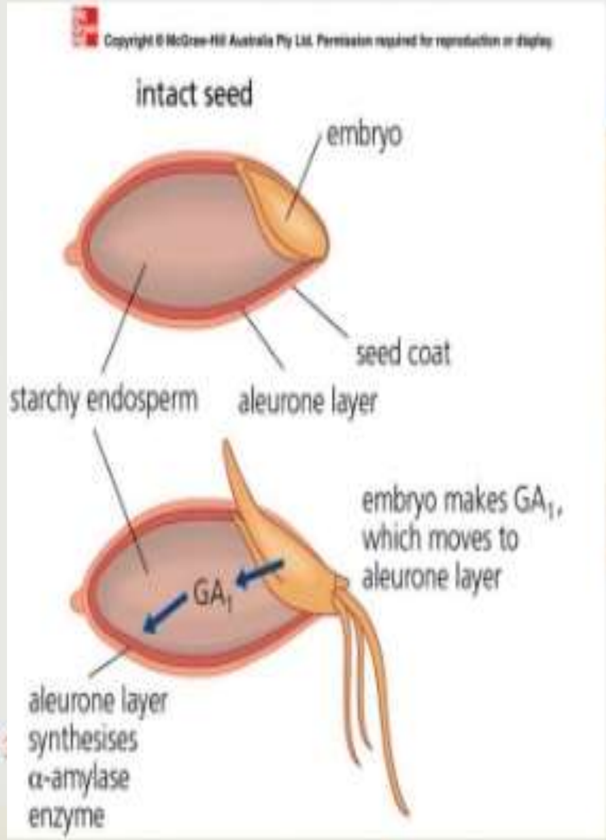
Gibberellins Actions

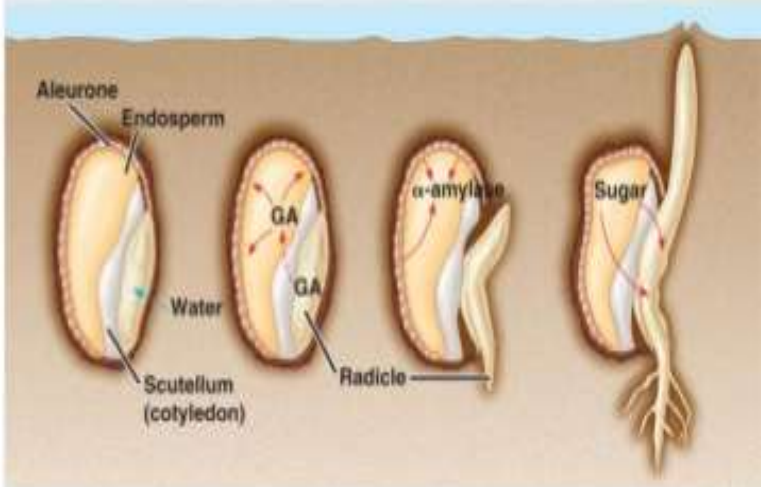
2- Overcomes dormancy in seeds

- Gibberellins also have a fundamental role in breaking seed dormancy and stimulating germination.
- The endosperm of many seeds contains protein and carbohydrate reserves upon which a developing embryo relies for energy and nutrition.
- These reserves must be mobilised and transported to the embryo.
- A range of hydrolytic and proteolytic enzymes break down endosperm starches and proteins into smaller, more easily transported molecules, such as sugars and amino acids.

Gibberellins Actions

2- Overcomes dormancy in seeds





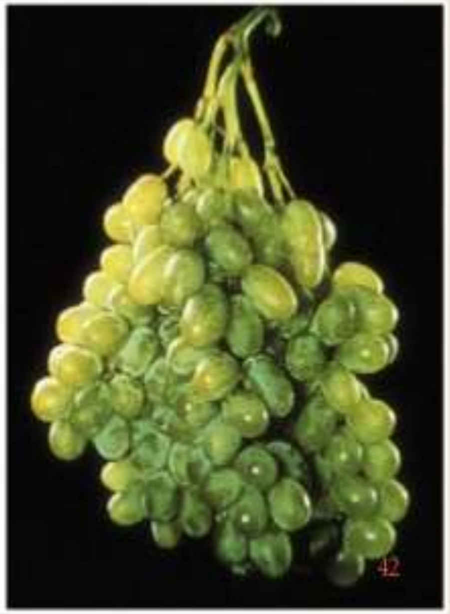
Gibberellins Actions

3- Involved in parthenocarpic fruit development

Gibberellins Actions

4- GA can induce fruit enlargement

External application of gibberellins can also enlarge fruit size in grapes



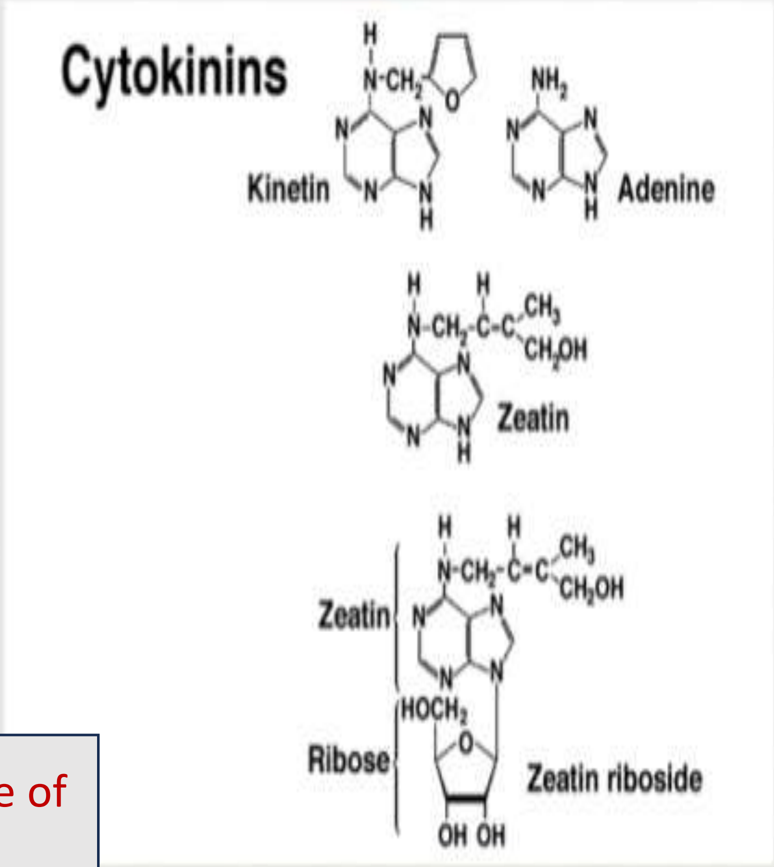
Cytokinins

- Promote cell division and delay leaf aging
- Used as a growth promoter in tissue culture
- Slows the process of senescence (biological aging) by preventing the breakdown of chlorophyll in leaves

CYTOKININS

- **Auxin** and **Gibberellins** increase growth *mainly* by increasing cell elongation.
- Growth involves another important process namely **Cell division.**
- Developing embryo shows active cell division.
- Liquid endosperm of coconut called **Coconut Water / Milk** contain cell division causing factors (**Kinetine**).
- Similarly the developing endosperm of maize contain such factors **(Zeatin).**

Cytokinins



Structure of CK

Cytokinins

Site:

- Synthesized primarily in the meristematic region of the roots.
- This is known in part because roots can be cultured (grown in Artificial medium in a flask) without added cytokinin, but stem cells cannot.
- Cytokinins are also produced in developing embryos .

Site of synthesis

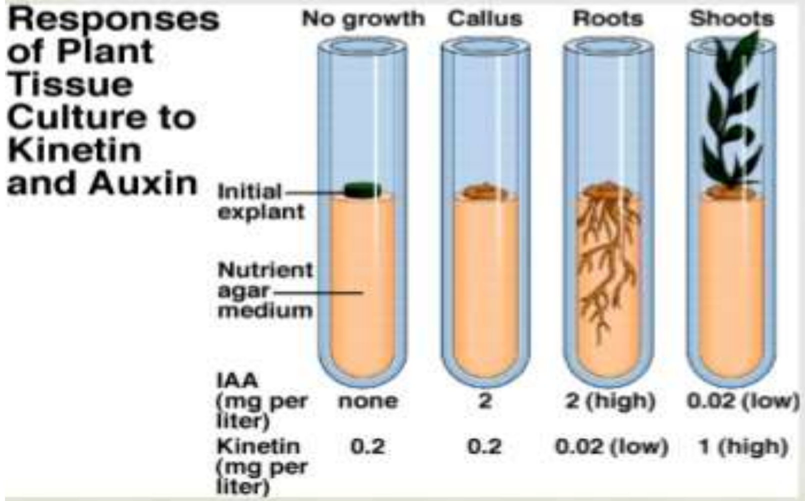
Cytokinins

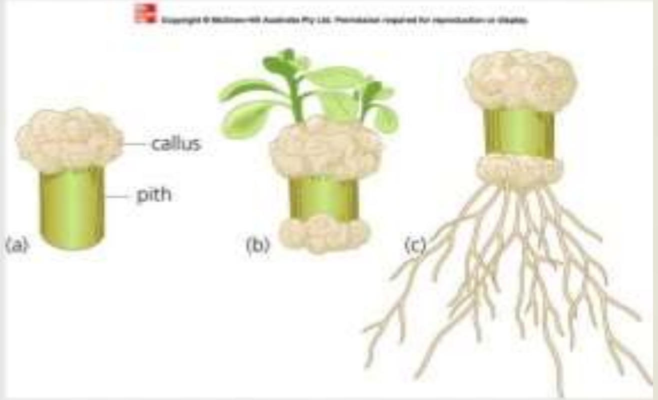
Transport:

- Via xylem (transpiration stream).
- Zeatin ribosides are the main transport form; converted to the free base or glucosides in the leaves.
- Some cytokinin also moves in the phloem.

Cytokinins Actions

1- Control morphogenesis





Ratio of cytokinin and auxin are important in determining the fate of the callus:

The concentration	The callus differentiation
callus + low [cytokinin/auxin]	callus grows well, forms roots
callus + high [cytokinin/auxin]	callus grows well, forms meristem & shoots

Cytokinins Actions

2- Regulates the cell cycle/cell division

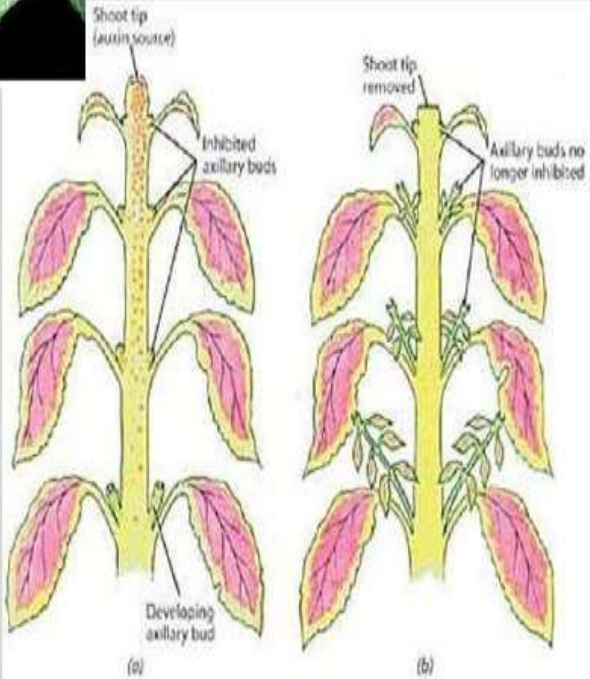
- (hence, the name "cytokinins) –especially by controlling the transition from G2 ⟶ mitosis.
- This effect is moderated by cyclin-dependent protein kinases (CDK's) and their subunits, cyclins.

CK

Antagonistic hormone pair:
auxin and cytokinin

Auxin inhibits growth of lateral shoots from axillary buds

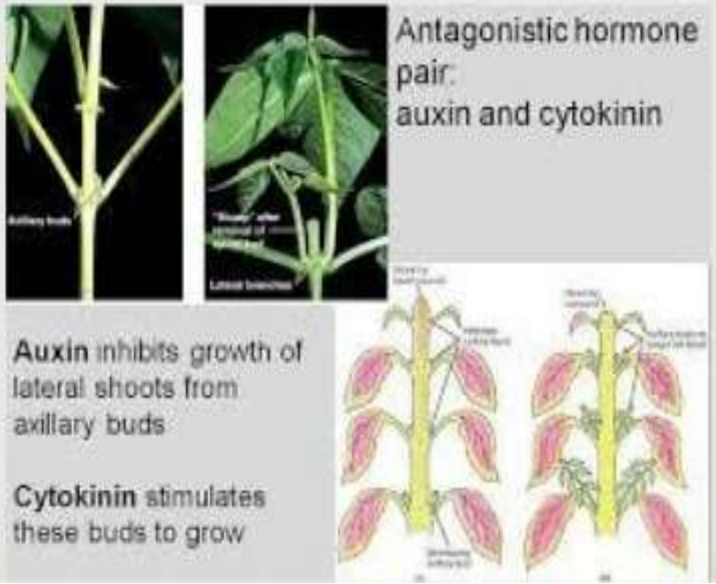
Cytokinin stimulates these buds to grow



Cytokinins Actions

3- Bud development

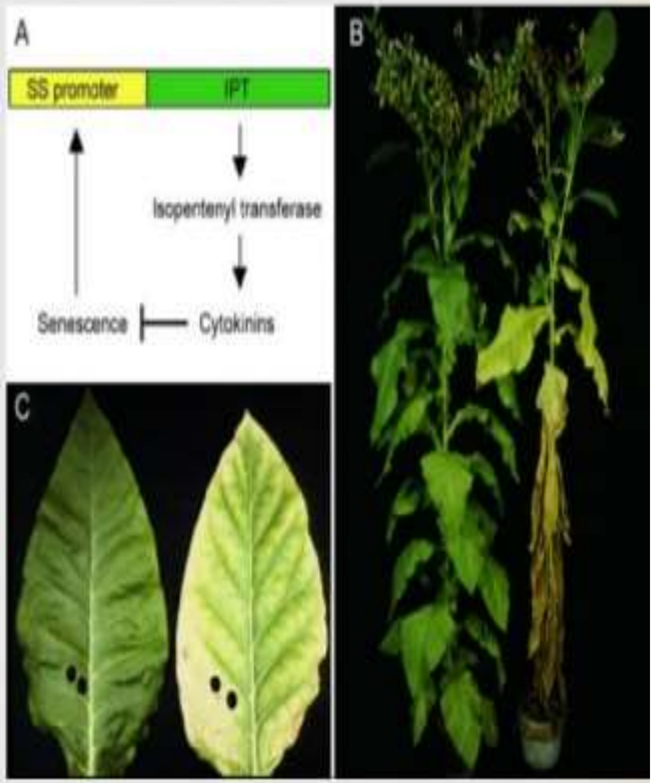
- Direct application of cytokinin promotes the growth of axillary buds
- Exogenous cytokinin and auxin are thus antagonistic in their effects on axillary bud growth



Cytokinins Actions

4- Delay senescence

- Senescence is the programmed aging process that occurs in plants.
- Loss of chlorophyll, RNA, protein and lipids.
- Cytokinin application to an intact leaf markedly reduces the extent and rate of chlorophyll and protein degradation and leaf drop.



Role of CK

Cytokinins Actions

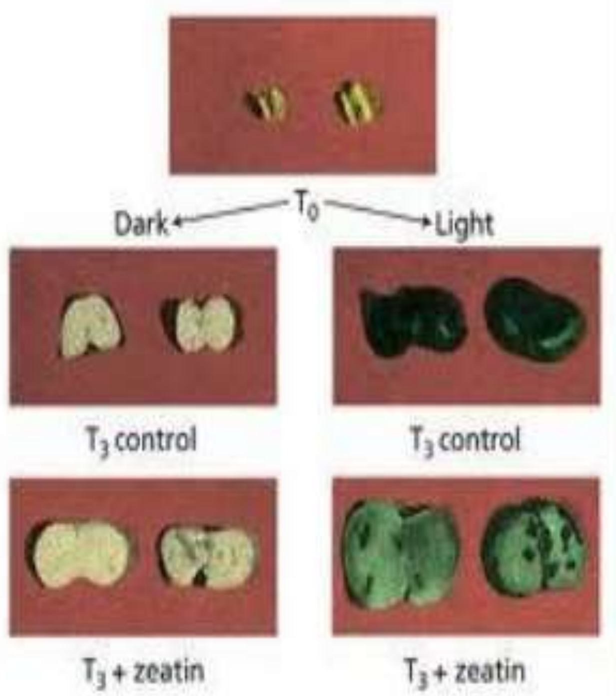
5- Greening

- Cytokinins promotes the light-induced formation of chlorophyll and conversion of etioplasts to chloroplasts (greening process).

Cytokinins Actions

6. Promote cell expansion

- Cytokinins stimulate the expansion of cotyledons.
- The mechanism is associated with increased plasticity of the cell wall, not associated with acidification.



FUNCTION OF CYTOKININ

A list of some of the known physiological effects caused by cytokinins are listed below

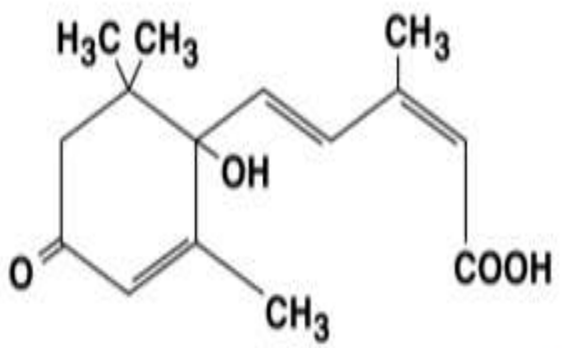
- Stimulates cell division.
- Stimulates morphogenesis (shoot initiation/bud formation) in tissue culture.
- Stimulates the growth of lateral buds-release of apical dominance.
- Stimulates leaf expansion resulting from cell enlargement.
- Cytokinins can slow down the aging of some plant organs.
- Slow deterioration of leaves on intact plant.

Abscisic acid (ABA)

- Only natural plant growth inhibitor
- Growth inhibitor that closes the stomates of plants under water stress
- Counteracts the effects of auxins and gibberellins
- Cycocel and B-Nine are two synthetic ABA type growth inhibitors commonly used

Abscisic acid

- Inhibits growth
- Promotes dormancy
- Closes stomata
- Produced in response to stress.



ABA

ABA

Abscisic acid

Sites :

- Plastids
- Most tissues, especially leaves and seeds

Transport :

- Xylem and phloem (greater amounts)

ABA

Abscisic acid Actions

1- ABA – drought resistance

- Abscisic acid is the key internal signal that facilitates drought resistance in plants
- Under water stress conditions, ABA accumulates in leaves and causes stomata to close rapidly, reducing transpiration and preventing further water loss.
- ABA causes the opening of efflux K^+ channels in guard cell plasma membranes, leading to a huge loss of this ion from the cytoplasm.
- The simultaneous osmotic loss of water leads to a decrease in guard cell turgor, with consequent closure of stomata.

Abscisic acid Actions

2- ABA – freezing resistance

- Elevated ABA levels are associated with increased freezing resistance.
- ABA appears to mediate a plant's response to environmental stresses, such as freezing, by regulating gene expression.
- Certain genes are switched on by ABA while others are switched off.

Abscisic acid Actions

3- ABA – Seed Dormancy

- ABA plays a major role in seed dormancy
- During seed maturation, ABA levels increase dramatically.
- This inhibits germination and turns on the production of proteins that enable the embryo to survive dehydration during seed maturation
- As dormancy can only be broken by specific environmental cues, it ensures that a seed will germinate only under suitable conditions of moisture, light and temperature
- The breaking of dormancy is associated with a decline in the level of ABA

ABSCISIC ACID (ABA)

ABA is one of the hormone plant. Also called as abscisic II & dormin

Function: inhibit growth, promote seed dormancy & inhibit early germination, promote stomatal closure during drought stress.

ABA also promotes abscission of leaves and fruits

ABA inhibits stem elongation probably by its inhibitory effect on gibberellic acid

ABA

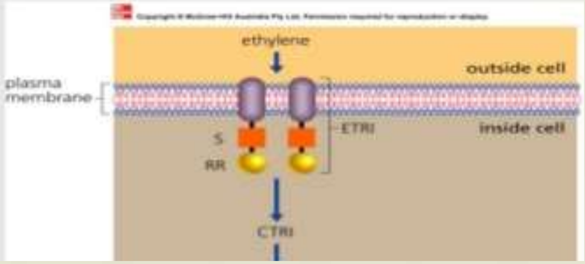
Ethylene

- Gas that forms in tissue undergoing stress
- Important in the fruit-ripening process and early petal drop of flowers

Ethylene Action

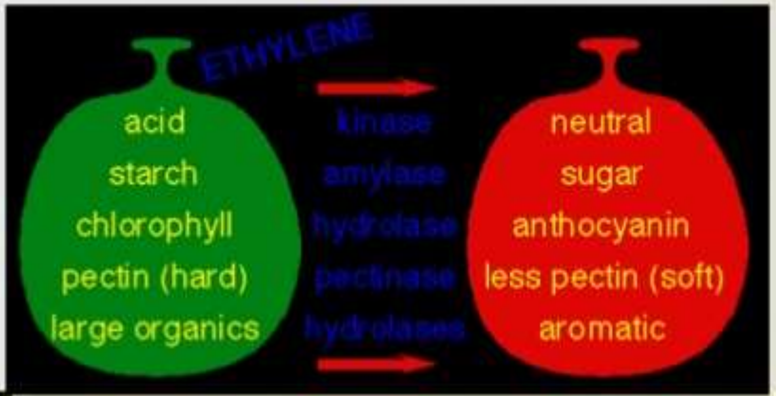
1- Ethylene – signal transduction

- Several transmembrane proteins have been identified that bind to ethylene at the cell surface and function as signal transducers.



Ethylene Action

2- Ethylene – fruit ripening



Ethylene Action

2- Ethylene – fruit ripening

- Under natural conditions, fruits undergo a series of changes, including changes in colour, declines in organic acid content and increases in sugar content
- In many fruits, these metabolic processes often coincide with a period of increased respiration, the respiratory *climacteric*
- During the climacteric there is also a dramatic increase in ethylene production
- Ethylene can initiate the climacteric in a number of fruits and is used commercially to ripen tomatoes, avocados, melons, kiwi fruit and bananas