Plant growth regulators
(Plant hormones)

In plants, many behavioral patterns and functions are controlled by hormones. These are "chemical messengers" influencing many patterns of plant development.

- Plant hormones – a natural substance (produced by plant) that acts to control plant activities. Chemical messengers.

- Are produced in one part of a plant and then transported to other parts, where they initiate a response.
- They are stored in regions where stimulus are and then released for transport through either phloem or mesophyll when the appropriate stimulus occurs.

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 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

Classification

- **Natural hormone**: Produced by some tissues in the plant. Also called **Endogenous** hormones. e.g. IAA.
- **Synthetic hormone:** Produced artificially and similar to natural hormone in physiological activity. Also called **Exogenous** hormones. e.g. 2,4-D, NAA etc.

On the Basis of Nature of Function

- **Growth promoting hormones/Growth promoter:**

  Increase the growth of plant.

- e.g. Auxins. Gibberellins, Cytokinins etc.

- **Growth inhibiting hormones/Growth retardant:** Inhibit the growth of plant.

- e.g. ABA, Ethylene.

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.

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

1. **Natural Auxins**—which are almost continuously produced by some tissues in the plant Also known as endogenous growth substances. e.g. IAA (Indole Acetic Acid)

Synthetic Auxins

- 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

Natural Auxins:

1. Indole-3-acetic acid (IAA)
2. Indole-3-butyric acid (IBA)
3. Indole-3-acetonitrile (IAN)
4. Indole-3-acetaldehyde (IAc)
5. Ethylindoleacetate
6. Indole-3-pyruvic acid (IpyA)
7. Indole-3-ethanol (IEtOH)

Cut off the tips of Avena coleoptile

Placed on agar block

Auxin diffuses into agar block

Placed the agar block Asymmetrically On cut coleoptile stump

Coleoptile showed typical curvature

Avena curvature test

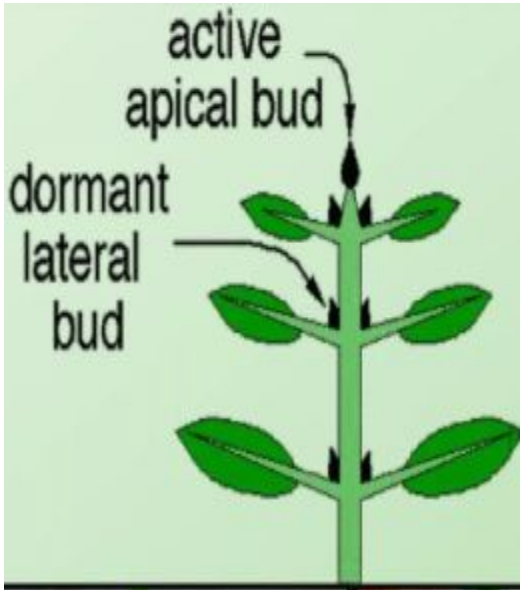
Effects of different Auxin on Plant Growth and Development

➢ **Cell Elongation and Cell Division**

- Causes growth in coleoptiles and stem due to elongation of **already existing cells.**
- The main causes of cell elongation-
  - By increasing the osmotic content, permeability of cell to water, wall synthesis.
  - By reducing wall pressure.
  - By inducing the synthesis of RNA & protein which in turn lead to an increase in cell wall plasticity & extension.
- Auxin also induces / promotes cell division within the cambial region.

➢ Apical Dominance

- Apical or terminal buds of many vascular plants are very active while the lateral buds remain inactive.
- Removal of apical buds promotes lateral buds to grow.
- Apical dominance is due to much higher auxin content in the apical buds than lateral buds.



➢ Phototropism

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

➢ Root initiation

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

Prevention of Abscission

Natural auxins have controlling influence on the abscission of leaves , fruits etc..

Auxin in Agriculture

- Both natural and synthetic auxins are used in agriculture, horticulture home gardening, and plant science for the promotion of rooting, fruit setting, fruit thinning, and fruit-drop control.
- Other auxin (2,4 D) like compounds are used as selective weed killers.
- Pretreatment of seeds with IAA, is very effective in increased the percentage of germination and in the total yield of the crop plants.

➢ 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**

➢ 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.

➢ 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

- 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**

- Gibberellic Acid
- Have a regulatory function
- Are produced in the shoot apex primarily in the leaf primordial (leaf bud) and root system
- Stimulates stem growth dramatically
- Stimulates cell division, cell elongation (or both) and controls enzyme secretions. Ex: dwarf cultivars can be treated with GA and grow to normal heights – indicates dwarf species lack normal levels of GA
- Involved in overcoming dormancy in seeds and buds.
- GA translocates easily in the plant (able to move freely) in both directions – because produced in not only shoot apex but also in the root structure.
- Used commercially in:
  - Increasing fruit size of seedless grapes
  - Stimulating seed germination & seedling growth

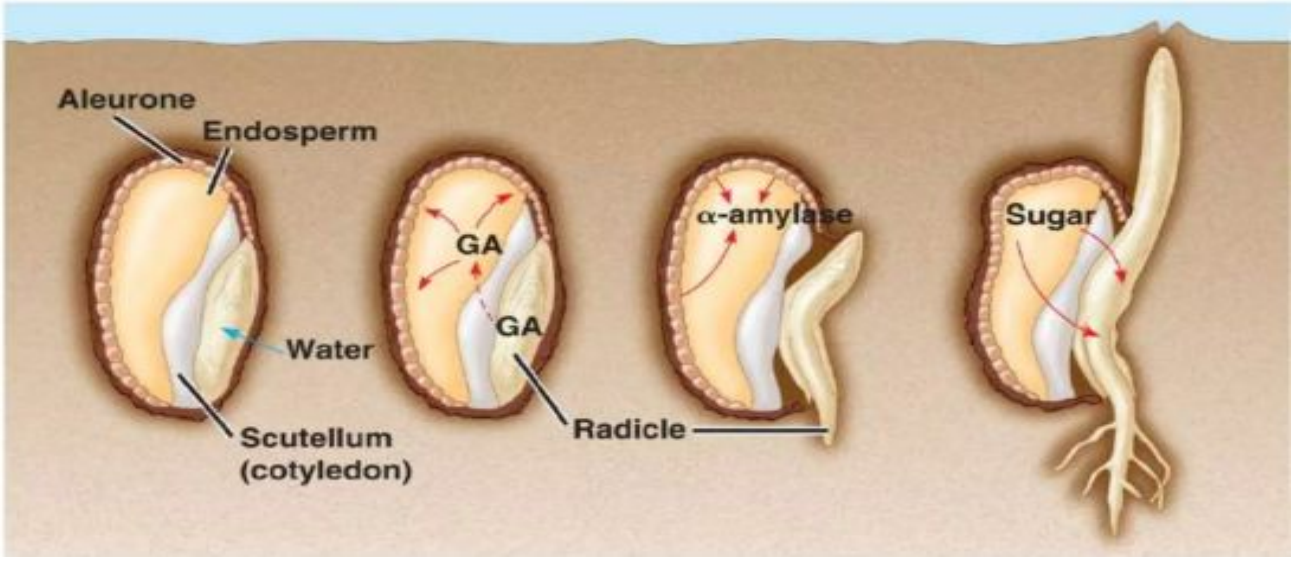
- Promoting male flowers in cucumbers for seed production.
- Overcoming cold requirements – for some seed, application of GA foregoes the cold requirements (some seed require to be frozen or placed in the refrigerator for a period of time before they will germinate).
- **Auxin** and **Gibberellins** 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).**

Stem Elongation

Gibberellin regulates their height due to internode elongation. At the cellular level, gibberellin leads to encouragement in cell growth and elongation in the stems and between nodes (Bolting).

Gibberllins induces flowering, parthenocarpy, senescence, or the natural death of leaves and other plant parts., leaf expansion, trichome development, pollen maturation.

Seed Germination (or break seed dormancy)



CYTOKININS

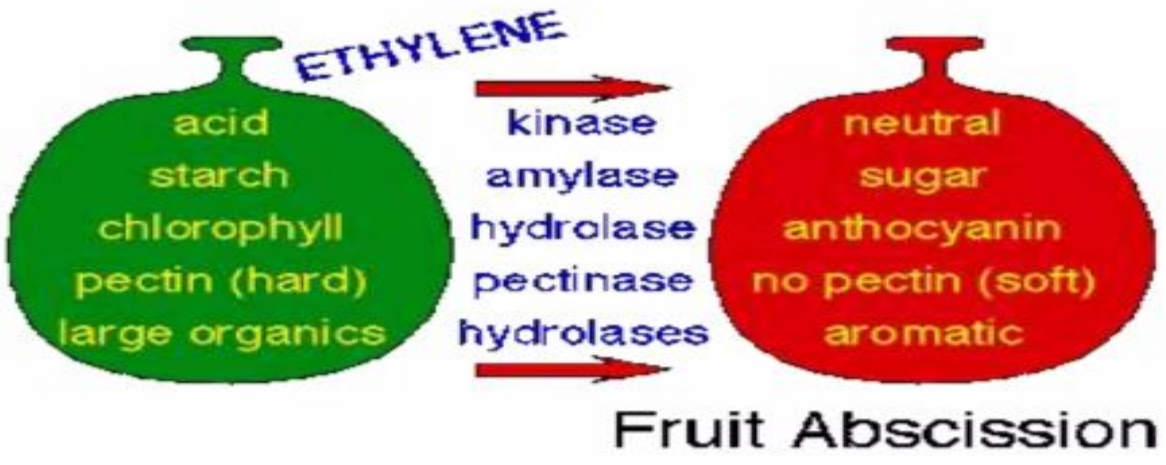
- Promotes cell division
- Found in all tissues with considerable cell division.
  - Ex: embryos (seeds) and germinating seeds, young developing fruits
- Roots supply cytokinins upward to the shoots.
- Interact with auxins to influence differentiation of tissues (may be used to stimulate bud formation).
- As roots begin to grow actively in the spring, they produce large amounts of cytokinins that are transported to the shoot, where they cause the dormant buds to become active and expand.
- Tissue cultures use cytokinins to induce shoot development
- Cytokinins may slow or prevent leaf senescence (leaf ageing or leaf fall).

CYTOKININ IN AGRICULTURE

- Helps in promoting cell division and growth of the plant.
- When applied to cotton seedlings, led to 5-10 % increase even in drought conditions.
- Plays a major role in plant pathogenesis by inducing resistance against certain disease-causing bacteria.

ETHYLENE ($CH_2=CH_2$)

- ✓ Growth retardant.
- ✓ Ethylene promotes ripening
- ➢ Gaseous hormone
- ➢ Produced in the actively growing meristems of the plant, in senescing ripening or ageing fruits, in senescing (ageing or dying) flowers, in germinating seeds and in certain plant tissues as a response to bending, wounding or bruising.
- ➢ Ethylene as a gas, diffuses readily throughout the plant.



Ethylene in commercial field

1. Fruit Ripening:

   Kerosene lamps and hay were previously used for stimulating colour development and ripening of some fleshy fruits, e.g., Banana, Mango, Apple, and Tomato. The effect is due to ethylene. Ethylene lamps are now specifically used for this purpose.

2. Feminising Effect:

   External supply of very small quantity of ethylene increases the number of female flowers and hence fruits in Cucumber.

3. Sprouting of Storage Organs:

   Rhizomes, corms, tubers, seeds (e.g., Peanut) and other storage organs can be made to sprout early by exposing them to ethylene.

4. Thinning:

   Excess flowers and young fruits are thinned with the help of ethylene, e.g., Cotton, Cherry, and Walnut. It allows better growth of remaining fruits.

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ABSCISSIC ACID (ABA)

- ✓ Growth retardant.
- ✓ Induce stomata closing.
- ✓ Inhibition of bud growth and shoot formation.
- Abscisic Acid (ABA)
  - ➢ Widespread in plant body – moves readily through plant
  - ➢ ABA appears to be synthesized (made) by the leaves.
  - ➢ Interacts with other hormones in the plant, counteracting the growth – promoting the effects of auxins & gibberellins.

- Involved with leaf and fruit abscission (fall), onset of dormancy in seeds and onset of dormancy (rest period) in perennial flowers and shrubs
- ABA is effective in inducing closure of stomata in leaves, indicating a role in the stress physiology in plants. (ex: increases in ABA following water, heat and high salinity stress to the plant)