PLANT GROWTH REGULATORS

- 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'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.	1) Vitamins are used in the same part without being transported.
2) Plant hormones are physiologically active.	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

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.

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

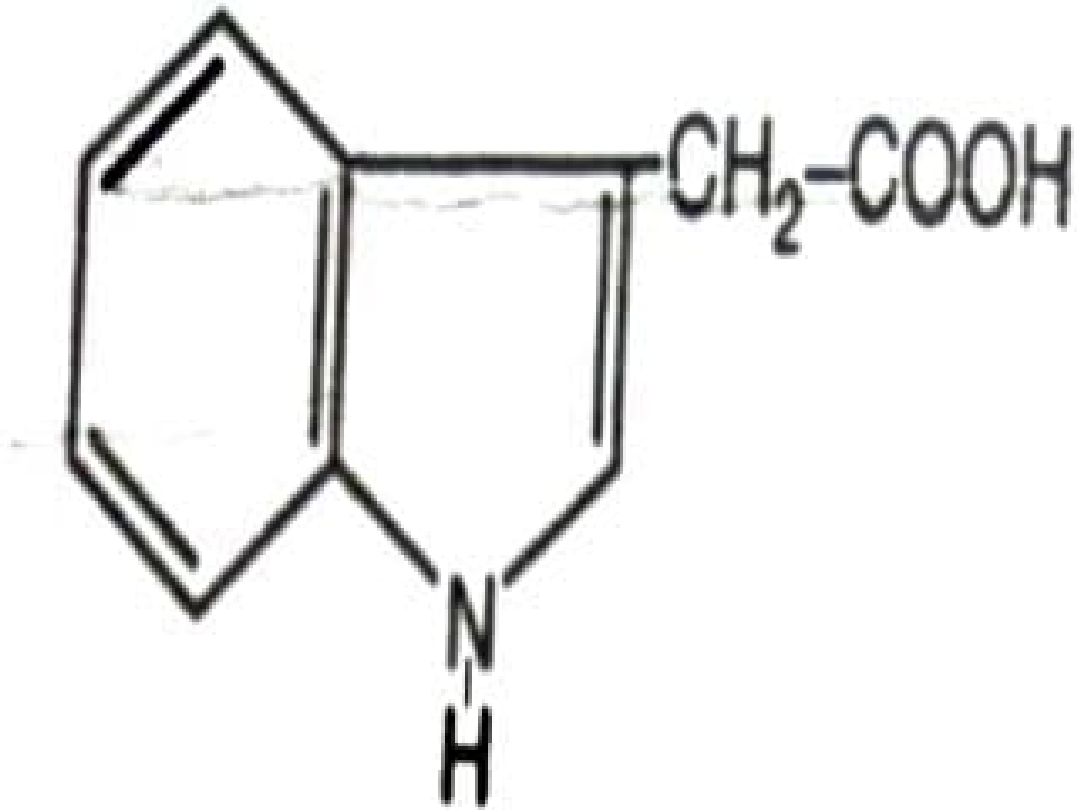
- The idea of existence of auxin was proposed by **Charles Darwin** (1880) in his book **"The Power of Movements in Plants".**
- Coleoptiles of Canary grass (*Phallaris canariensis*) to unilateral light and observed it to bend towards light.
- He covered the coleoptiles tip with tin foil or cut it off 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

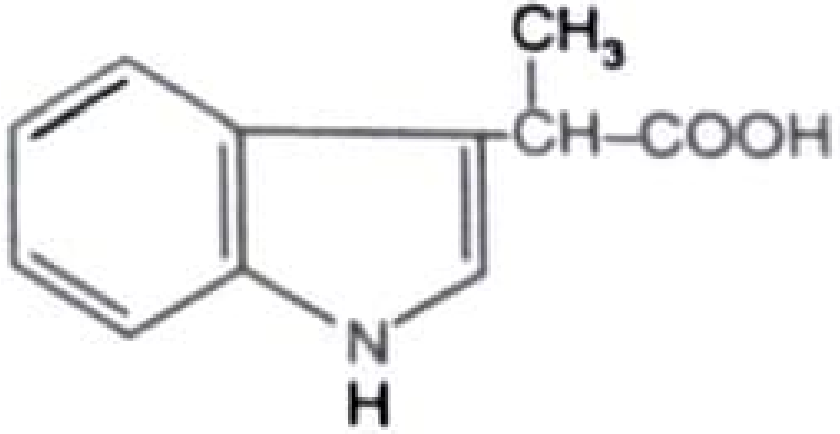
1. Natural Auxins—which are almost continuously produced by some tissues in the plant Also known as endogenous growth substances. e.g. IAA (Indole Acetic Acid)



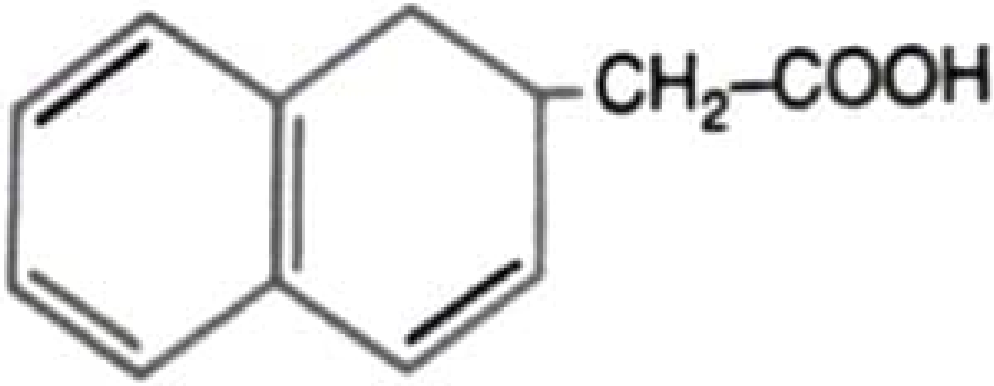
Synthetic Auxins

- 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) etc.

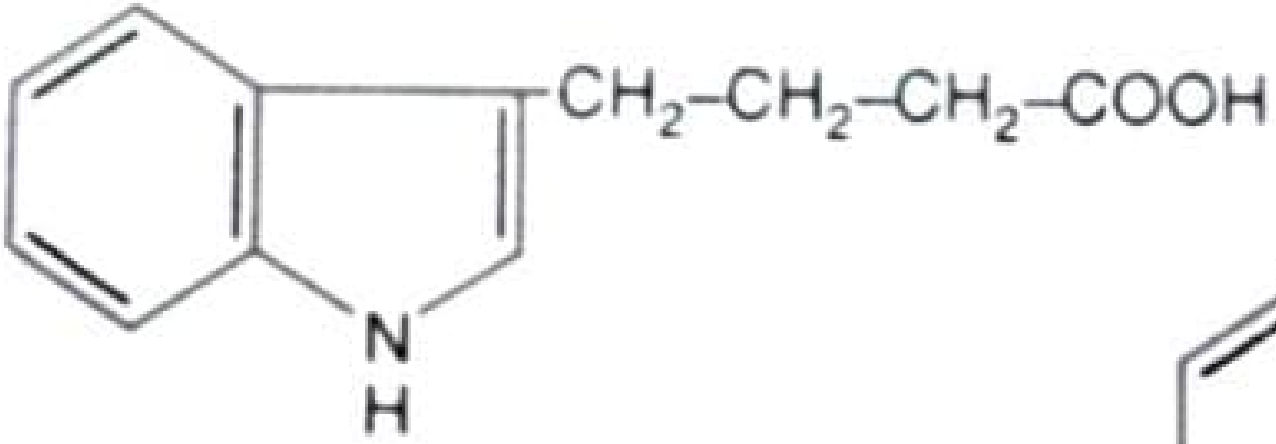
Structure of Auxins



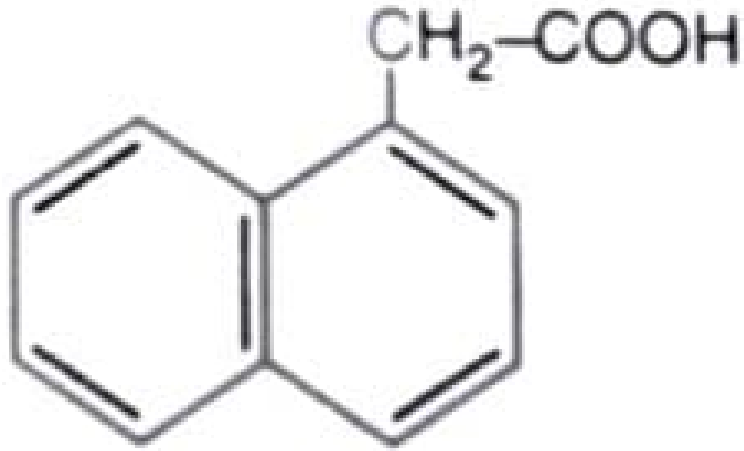
α-Indole propionic acid
(IPA)



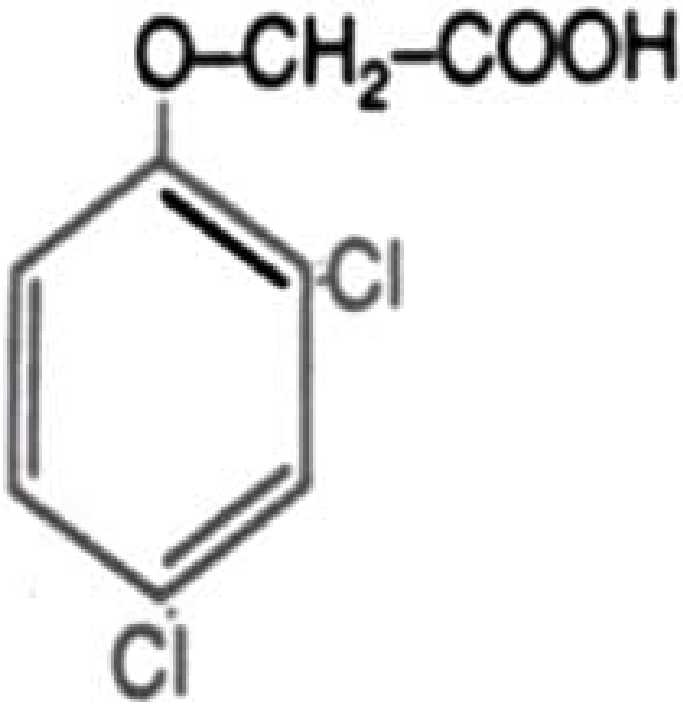
β-NAA



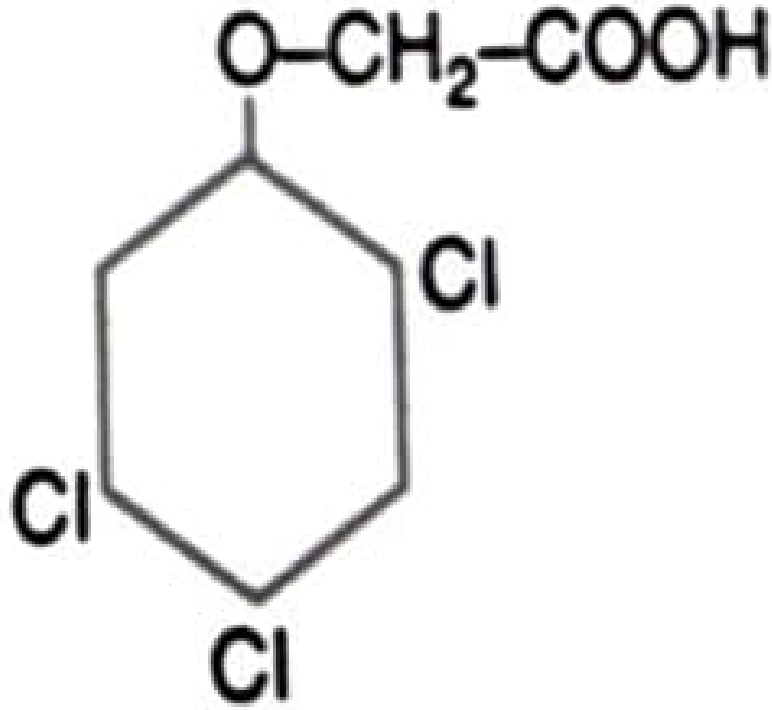
α-Indolebutyric acid
(IBA)



α-NAA



2,4-Dichlorophenoxy acetic acid (2,4 D)



2,4,5 Trichlorophenoxy acetic acid (2,4,5 T)

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.

➢ 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 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.(development of fruit with out fertilization or seed.

➢ 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.

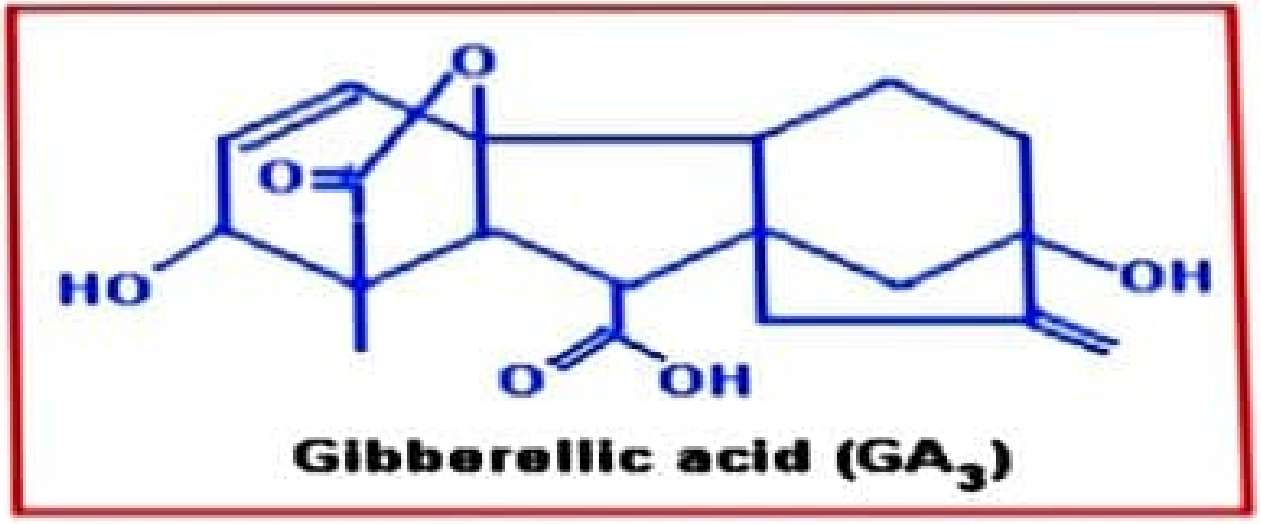
GIBBERELLINS

- 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} available.
- The most commonly occurring gibberellins is **GA_1**

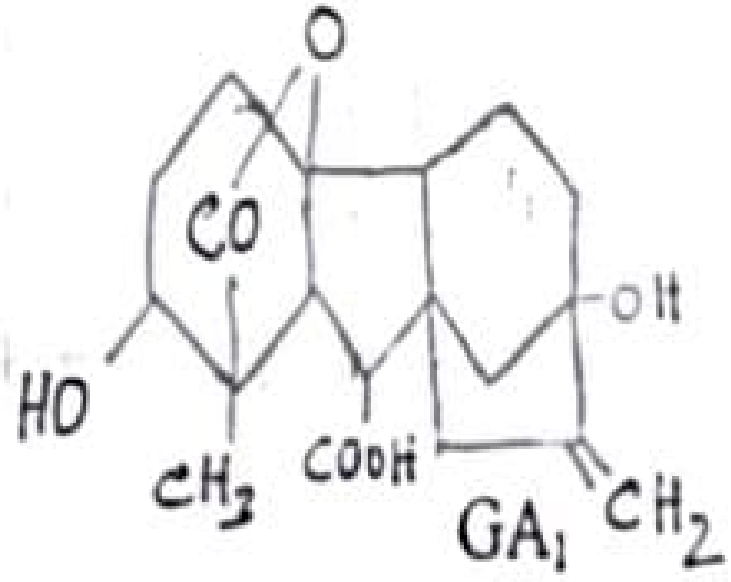
- Gibberellic Acid
- Have a regulatory function
- Are produced in the shoot apex primarily in the leaf primordial (leaf bud) and root system
- Stimulates stem growth dramatically

- 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

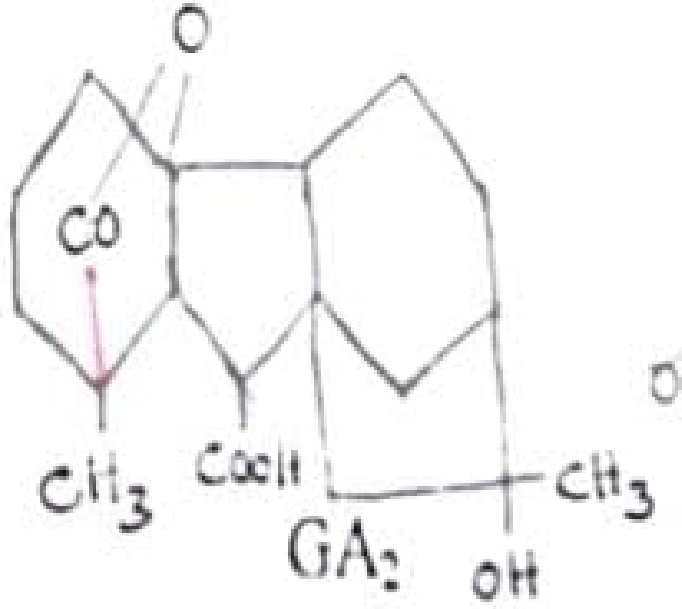
- Promoting male flowers in cucumbers for seed production.
- Overcoming cold requirements – for some seed, application of GA foregoes the cold requirements (some seed require to be frozen or placed in the refrigerator for a period of time before they will germinate).



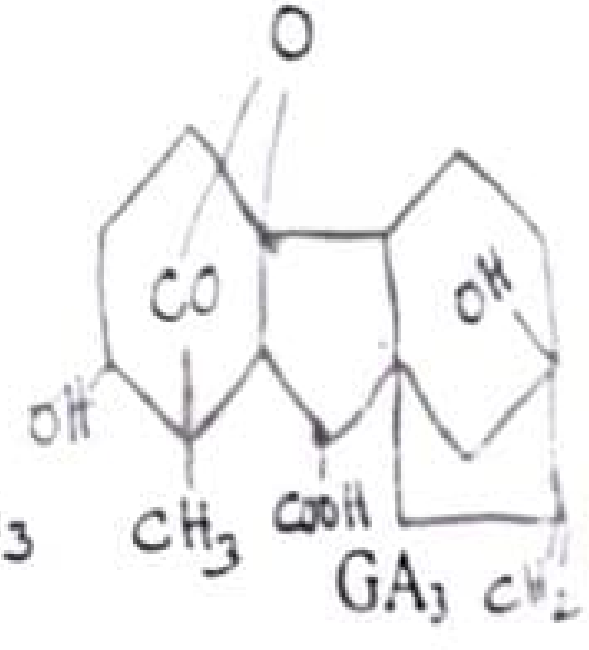
Gibberellic acid (GA_3)



$(C_{19}H_{24}O_6)$



$(C_{19}H_{26}O_6)$



$(C_{19}H_{22}O_6)$

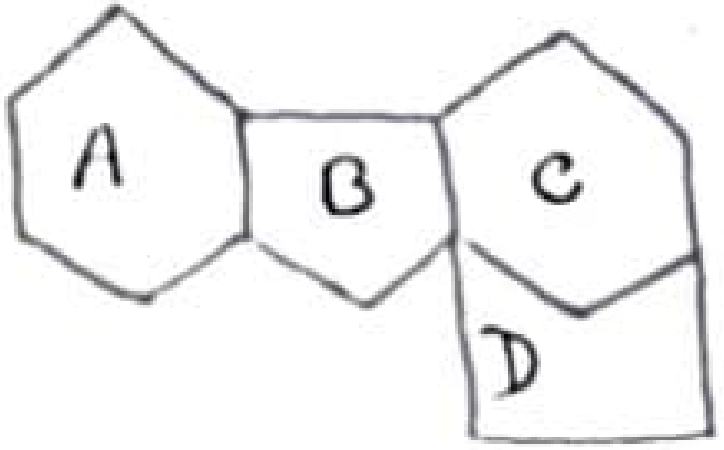


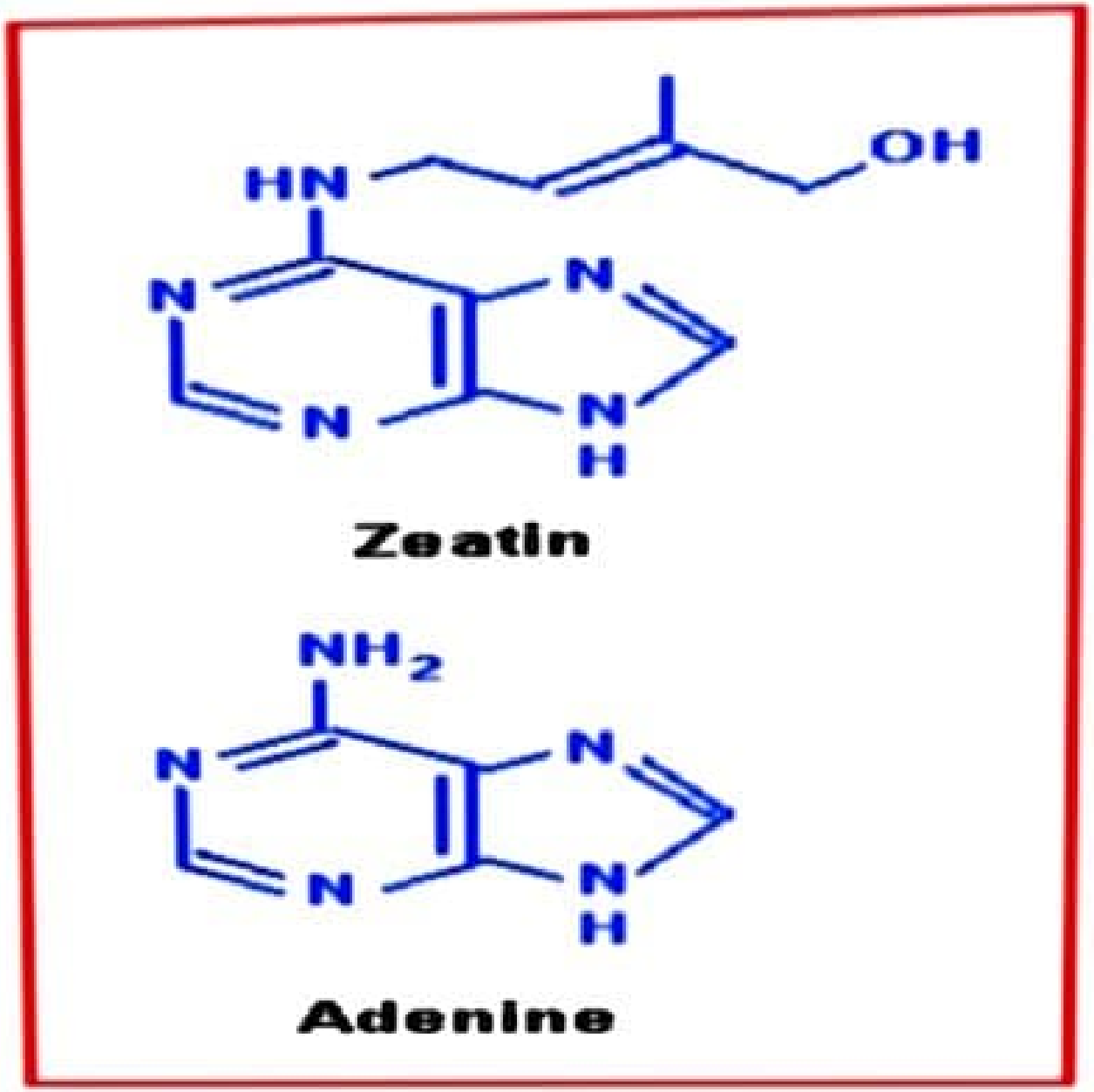
Fig. Gibben Ring

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).

- **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**).

- 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).


HN
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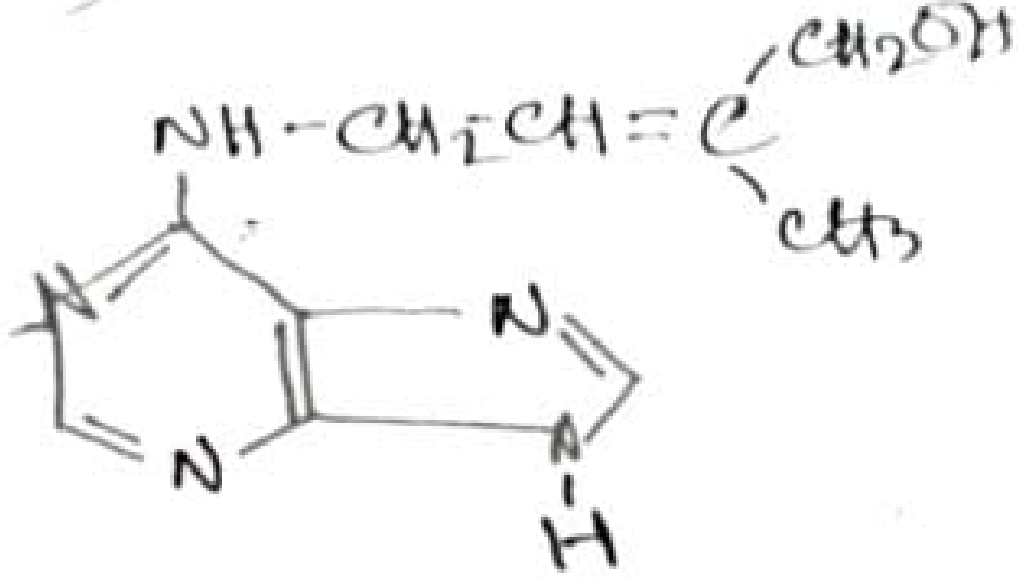
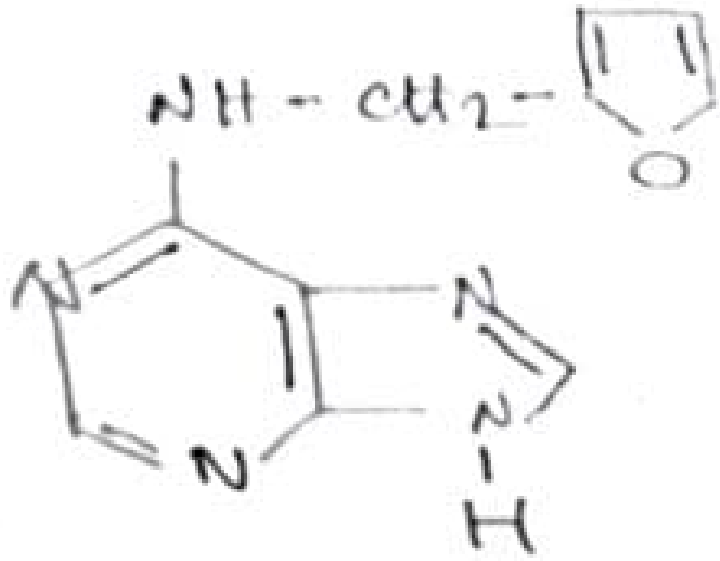


Zeatin
(Natural)

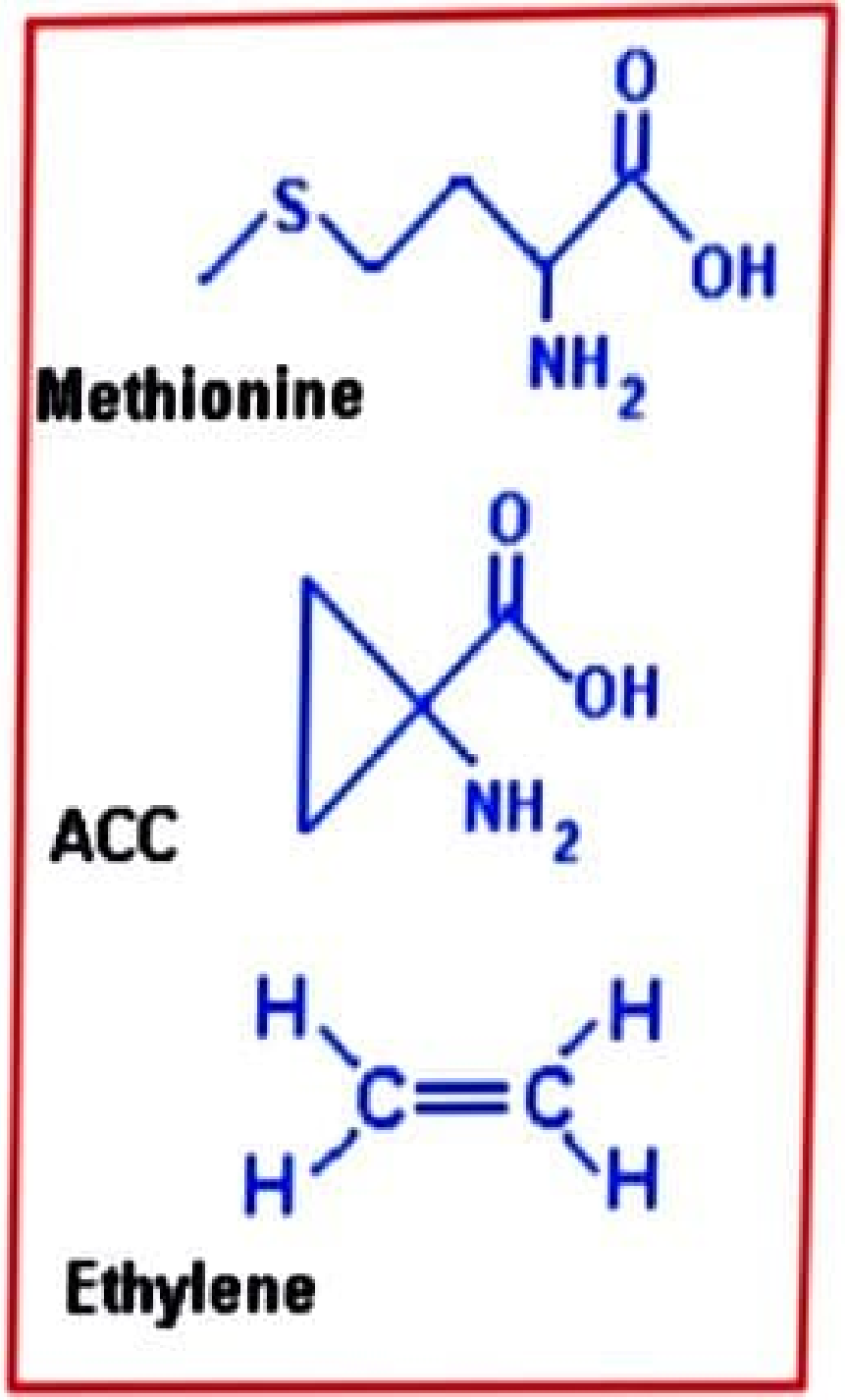


Kinetine
(Natural)

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.

- ✓ May promote leaf senescing and abscission (leaf fall).
- ✓ Increases female flowers in cucumbers (economically - will increase fruit production).
- ✓ Degreening of oranges, lemons and grapefruit – ethylene gas breaks down chlorophyll and lets colors show through.

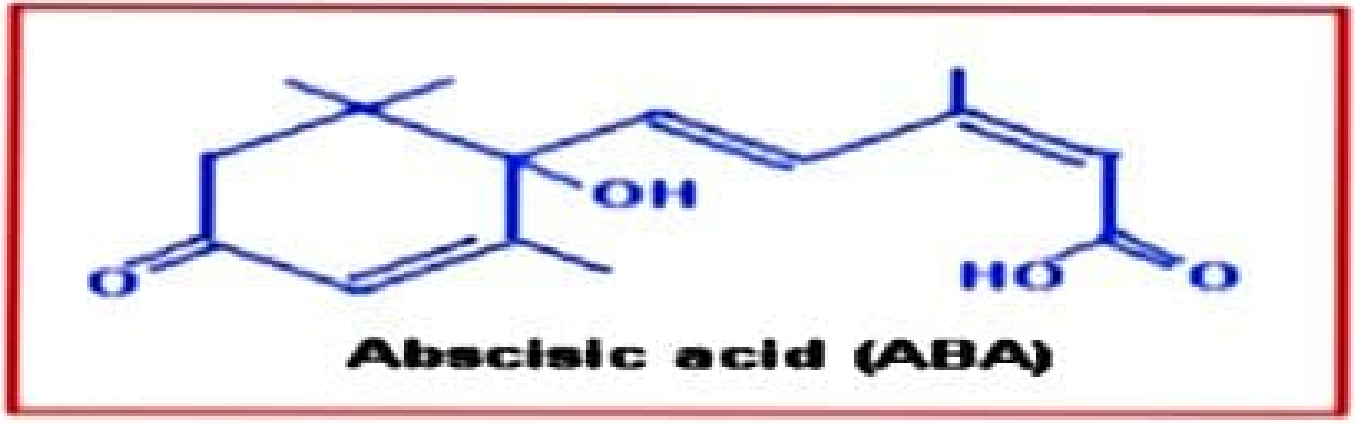


ABSCISSIC ACID (ABA)

- ✓ 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)



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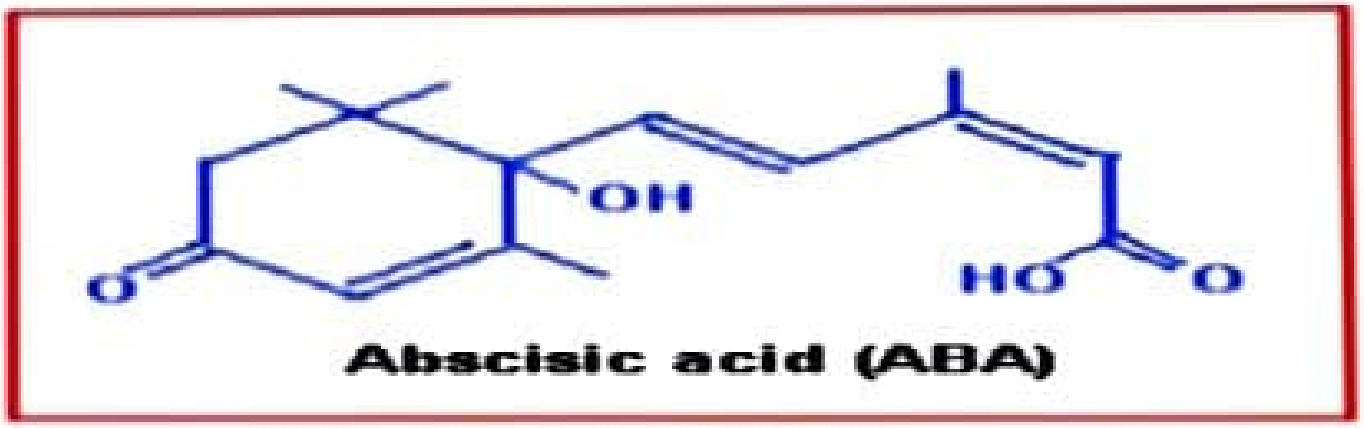

Abscisic acid (ABA)