Plant Hormones:

Plant hormones are a group of naturally occurring, organic substances which influence physiological processes at low concentrations. The processes influenced consist mainly of growth, differentiation and development, though other processes, such as stomatal movement, may also be affected.

Exposing a plant tissue to a hormone has been compared to putting a dime in a vending machine. You may get your morning newspaper, a candy bar, or a record on the jukebox. It depends not so much on the dime as on the machine in which you put it. Similarly, the effects of plant hormones depend largely on the target tissues and the chemical environment in which these tissues find themselves.

Auxin

Nature: Indole-3-acetic acid (IAA) is the main auxin in most plants.

Sites of Biosynthesis: IAA is synthesized from tryptophan or indole primarily in leaf primordia and young leaves, and in developing seeds.

Transport: IAA transport is cell to cell. Transport to the root probably also involves the phloem.

Effects:

- Cell enlargement - auxin stimulates cell enlargement and stem growth.
- Cell division - auxin stimulates cell division in the cambium and, in combination with cytokinin, in tissue culture.
- Vascular tissue differentiation - auxin stimulates differentiation of phloem and xylem.
- Root initiation - auxin stimulates root initiation on stem cuttings, and also the development of branch roots and the differentiation of roots in tissue culture.

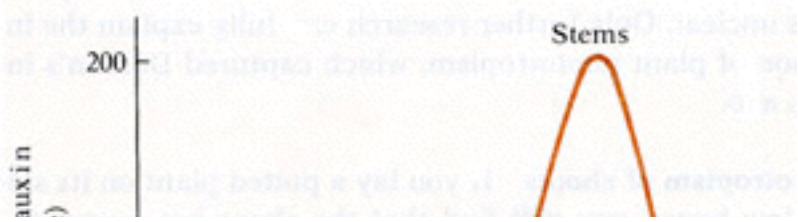
- Tropistic responses - auxin mediates the tropistic (bending) response of shoots and roots to gravity and light.
- Apical dominance - the auxin supply from the apical bud represses the growth of lateral buds.
- Delayed leaf senescence.
- Leaf and fruit abscission - auxin may inhibit or promote (via ethylene) leaf and fruit abscission depending on the timing and position of the source.
- Delayed fruit ripening.

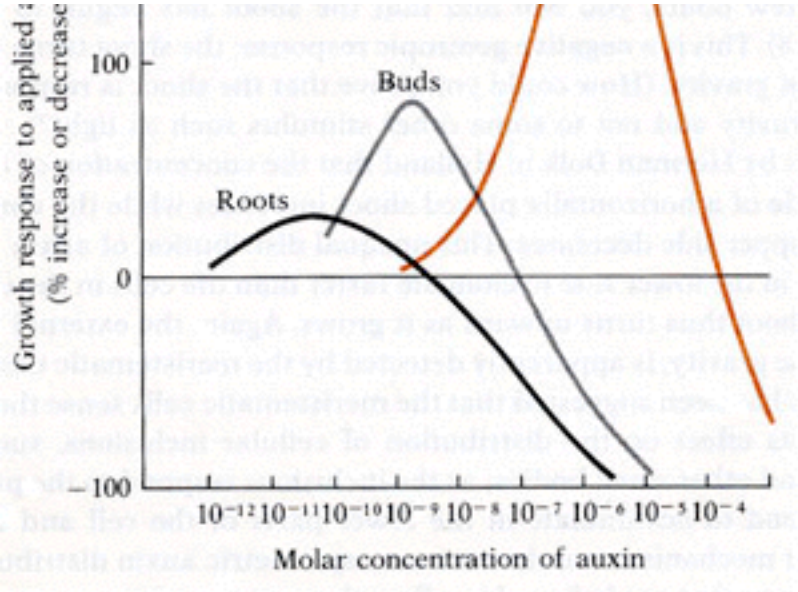
In several systems (e.g., root growth) auxin, particularly at high concentrations, is inhibitory. Almost invariably this has been shown to be mediated by auxin-produced ethylene. If the ethylene synthesis is prevented by various ethylene synthesis inhibitors, then auxin is no longer inhibitory.

Commercial uses:

The uses of synthetic auxins in horticulture can be traced directly to the natural roles of IAA in the plant. In general, compounds such as a-naphthalene acetic acid (NAA) are used because they resemble IAA in action but are resistant to degradation by plant enzymes. Auxins are used for a variety of agricultural purposes, including:

- Promotion of rooting of cuttings (e.g., Rootone). The base of the cutting is dipped in a powder containing NAA or indolebutyric acid (IBA) prior to planting.
- Induction of flowering in pineapple (actually caused by the auxin-induced production of ethylene). NAA is generally employed as the auxin.
- Increased fruit set and induction of the pericarp in the absence of fertilization.
- Prevention of preharvest fruit drop.
- Auxin type herbicides (e.g., 2-4-D).





Different Sensitivities of Roots, Buds, and Stems to Auxins. Roots are much more sensitive than stems; a concentration of auxin that produces maximal growth of roots is not sufficient to maintain even normal zgrowth of stems. Buds exhibit a sensitivity to auxin intermediate between roots and stems. (The line at 0 represents normal growth; values above the line indicate increases and values below the line decreases.)

Gibberellins (GAs)

Nature: The most widely available compound is GA3, or gibberellic acid, which is a fungal product. The most important GA in plants is GA1, which is the GA primarily responsible for stem elongation.

Sites of Biosynthesis: GAs are synthesized from mevalonic acid in young tissues of the shoot (exact location uncertain) and developing seed.

Transport: GAs are probably transported in the phloem and xylem.

Effects:

- Stem growth - GA1 causes hyperelongation of stems by stimulating both cell division and cell elongation. This produces tall, as opposed to dwarf, plants.
- Bolting in long day plants - GAs cause stem elongation in response to long days.

- Induction of seed germination - GAs can cause seed germination in some seeds that normally require cold (stratification) or light to induce germination.
- Enzyme production during germination - GA stimulates the production of numerous enzymes, notably a-amylase, in germinating cereal grains.

Commercial uses:

Commercially, gibberellins are produced by fungal cultures, and it is the purified natural products that are applied to plants. Generally, gibberellic acid (GA3) is used, because this is the only gibberellin obtainable in commercial quantities, although an expensive mixture of GA4 and GA7 is now commercially available for specific purposes. Gibberellins are used for the following purposes:

- Enhanced production of seedless grapes. Bigger, more uniform bunches with larger fruit are produced. Among other effects, the gibberellin causes lengthening of the peduncle (stalk) attaching each grape to the cluster, thus permitting larger grapes to form. Virtually all the grapes that go to market are now treated with gibberellin.
- Treatment of oranges to prevent rind senescence, to permit longer storage on the tree, and thus to extend the marketing period.
- Enhancement of flower bud formation and improvement of fruit quality in cherries.
- Improvement of fruit setting in apples and pears, particularly under weather conditions poor for setting.
- To substitute for a chilling requirement in instances such as:
    1. flower induction for seed production (radish).
    2. increased elongation (celery, rhubarb).
    3. earlier flower production (artichokes).
- The production of hybrid cucumber seed. Most high-producing cucumbers are F1 hybrids. GA sprays induce the production of male flowers on cucumber plants that normally produce only female flowers. The seed from neighboring all-female plants of a different strain is then exclusively hybrid.
- Increased malt production. The addition of GA to germinating barley

during beer production enhances a-amylase production so that more malt is produced more quickly. As the malt is the raw material for fermentation, a greater production of beer is made possible by this technique.

- Increased sugarcane yield: GA promotes the elongation of sugarcane stalks with no change in the sugar concentration, so that the net yield of sugar is increased.

Cytokinins (CKs)

Nature: CKs are adenine derivatives characterized by an ability to induce cell division in tissue culture (in the presence of auxin). The most common cytokinin base in plants is zeatin.

Sites of Biosynthesis: CK biosynthesis is through the biochemical modification of adenine. It occurs in root tips and developing seeds.

Transport: CK transport is via the xylem from roots to shoots.

Effects:

- Cell division - applications of CKs induce cell division in tissue culture in the presence of auxin. The presence of CKs in tissues with actively dividing cells (e.g., fruits, shoot tips) indicates that CKs may naturally perform this function in the plant.
- Morphogenesis - in tissue culture, CKs promote shoot initiation.
- Growth of lateral buds - CK applications can cause the release of lateral buds from apical dominance.
- Leaf expansion - resulting solely from cell enlargement. This is probably the mechanism by which the total leaf area is adjusted to compensate for the extent of root growth, as the amount of CKs reaching the shoot will reflect the extent of the root system.
- CKs delay leaf senescence.
- CKs may enhance stomatal opening in some species.
- Chloroplast development - the application of CK leads to an accumulation of chlorophyll and promotes the conversion of

leukoplasts into chloroplasts.

Mode of action: The action of CKs is still poorly understood and insufficient evidence exists to conclusively identify any biochemical point of action.

Commercial uses:

The major use for cytokinins derives from their ability to delay senescence and maintain greenness. The artificial, highly active cytokinin, benzyladenine, is the main compound used. The treatment of holly for festive decorations enables its harvest many weeks prior to use.
Post-harvest sprays or dips are now available to prolong the storage life of green vegetables such as asparagus, broccoli, and celery.

Ethylene

Nature: The gas ethylene (C_2H_4) is synthesized from methionine in many tissues in response to stress. It does not seem to be essential for normal vegetative growth. It is the only hydrocarbon with a pronounced effect on plants.

Sites of Biosynthesis: Ethylene is synthesized by most tissues in response to stress. In particular, it is synthesized in tissues undergoing senescence or ripening.

Transport:Being a gas, ethylene moves by diffusion from its site of synthesis.

Effects:

- Release from dormancy.
- Shoot and root growth and differentiation.
- Adventitious root formation.
- Leaf and fruit abscission.
- Flower induction in some plants.
- Induction of femaleness in dioecious flowers.
- Flower opening.

- Flower and leaf senescence.
- Fruit ripening.

Commercial uses:

Ethylene enjoys a wide variety of uses, but its gaseous nature precludes its use in nonenclosed spaces. Ethylene itself can be used to enhance the ripening of fruits such as bananas in storage following their shipment in an unripe condition; this is of great benefit, since the green bananas are rugged and do not bruise or spoil easily. The tender ripe bananas can then be carried safely to market from the nearby warehouse. Recently, an ethylene-producing liquid chemical, 2-chloroethylphosphonic acid (commercially called Ethrel or Ethephon) has been introduced into commerce. This compound is sprayed onto the plant at a slightly acid pH. When it enters the cells and encounters the cytoplasm at about neutral pH, it breaks down to release gaseous ethylene. Numerous commercial applications for this compound have appeared, mostly in relation to the natural effects of ethylene:

- The most important commercial use involves enhancing latex flow in rubber trees in Southeast Asia. When a rubber tree is "tapped," the latex flows for a certain period before the cut seals and the flow stops. Ethephon delays the healing of the cut so that the latex flow continues for a longer period, thus yielding more latex with less tapping.
- Enhancement of uniform fruit ripening and coloration. This has been shown to be of particular value in field tomatoes picked at a single time by machine.
- Acceleration of fruit abscission for mechanical harvesting. This provides a potential area of use in a wide variety of fruits such as grapes, cherries, and citrus.
- Promotion of female flower production in cucurbits (cucumber, squash, melon) so as to increase the number of fruits produced per plant.
- Promotion of flower initiation and controlled ripening in pineapples.

Abscisic Acid (ABA)

Nature: The name abscisic acid is rather unfortunate. The first name given was "abscisin II" because it was thought to control the abscission of cotton bolls. At almost the same time another group named it "dormin" for a purported role in bud dormancy. By a compromise the name abscisic acid was coined. It now appears to have little role in either abscission or bud dormancy, but we are stuck with this name. As a result of the original association with abscission and dormancy, ABA has become thought of as an inhibitor. While exogenous applications can inhibit growth in the plant, ABA appears to act as much as a promoter (e.g., storage protein synthesis in seeds) as an inhibitor, and a more open attitude towards its overall role in plant development is warranted.

Sites of Biosynthesis: ABA is synthesized from mevalonic acid in roots and mature leaves, particularly in response to water stress. Seeds are also rich in ABA which may be imported from the leaves or synthesized.

Transport: ABA is exported from roots in the xylem and from leaves in the phloem. There is some evidence that ABA may circulate to the roots in the phloem and then return to the shoots in the xylem.

Effects:

- Stomatal closure - water shortage brings about an increase in ABA which leads to stomatal closure.
- ABA inhibits shoot growth (but has less effect on, or may promote, root growth). This may represent a response to water stress.
- ABA induces storage protein synthesis in seeds.
- ABA counteracts the effect of gibberellin on a-amylase synthesis in germinating cereal grains.
- ABA affects the induction and maintenance of some aspects of dormancy in seeds. It does not, however, appear to be the controlling factor in "true dormancy" or "rest," which is dormancy that needs to be broken by low temperature or light.