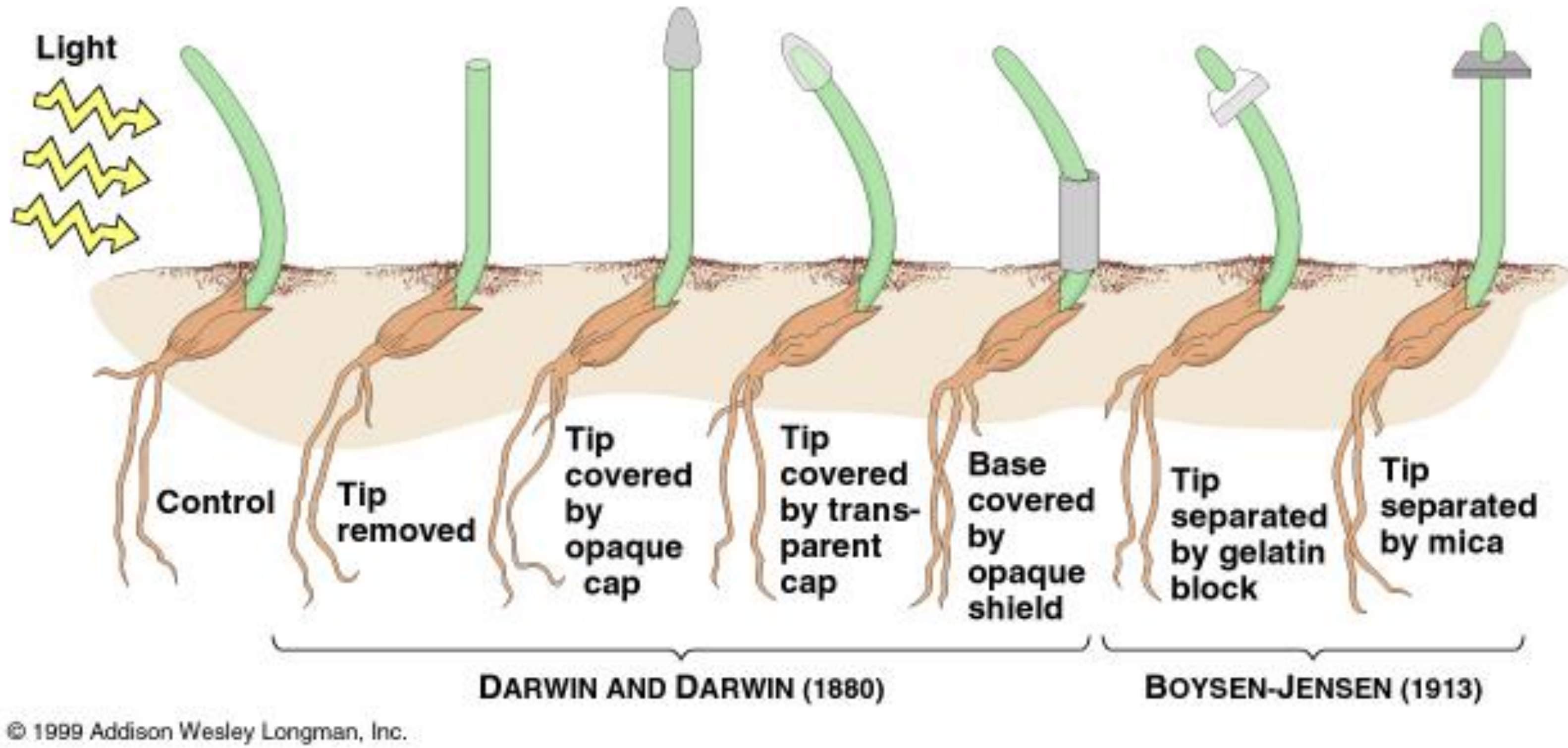
Plant Growth Regulators

Plant Growth Regulators - control growth, development and movement

EARLY EXPERIMENTS ON PHOTROPISM SHOWED THAT A STIMULUS (LIGHT) RELEASED CHEMICALS THAT INFLUENCED GROWTH

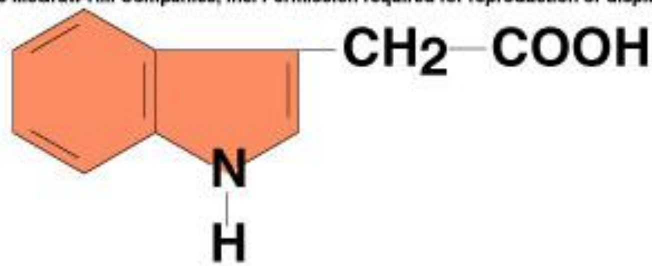


Results on growth of coleoptiles of canary grass and oats suggested that the reception of light in the tip of the shoot stimulated a bending toward light source.

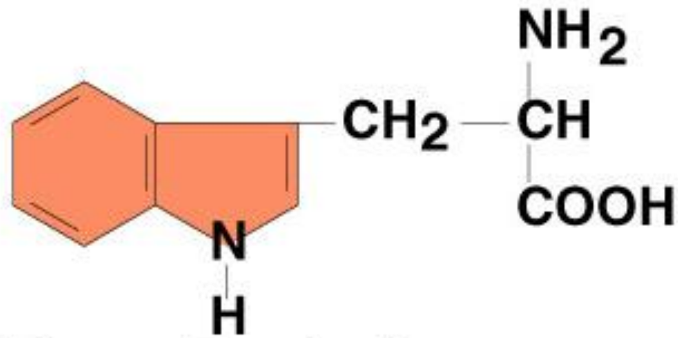
General plant hormones

- **Auxins** (cell elongation)
- **Gibberellins** (cell elongation + cell division - translated into growth)
- **Cytokinins** (cell division + inhibits senescence)
- **Abscisic acid** (abscission of leaves and fruits + dormancy induction of buds and seeds)
- **Ethylene** (promotes senescence, epinasty, and fruit ripening)

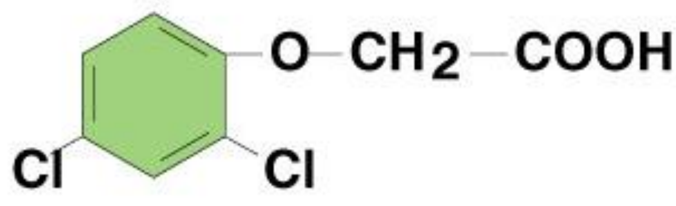
Auxins



(a) IAA (Indoleacetic acid)

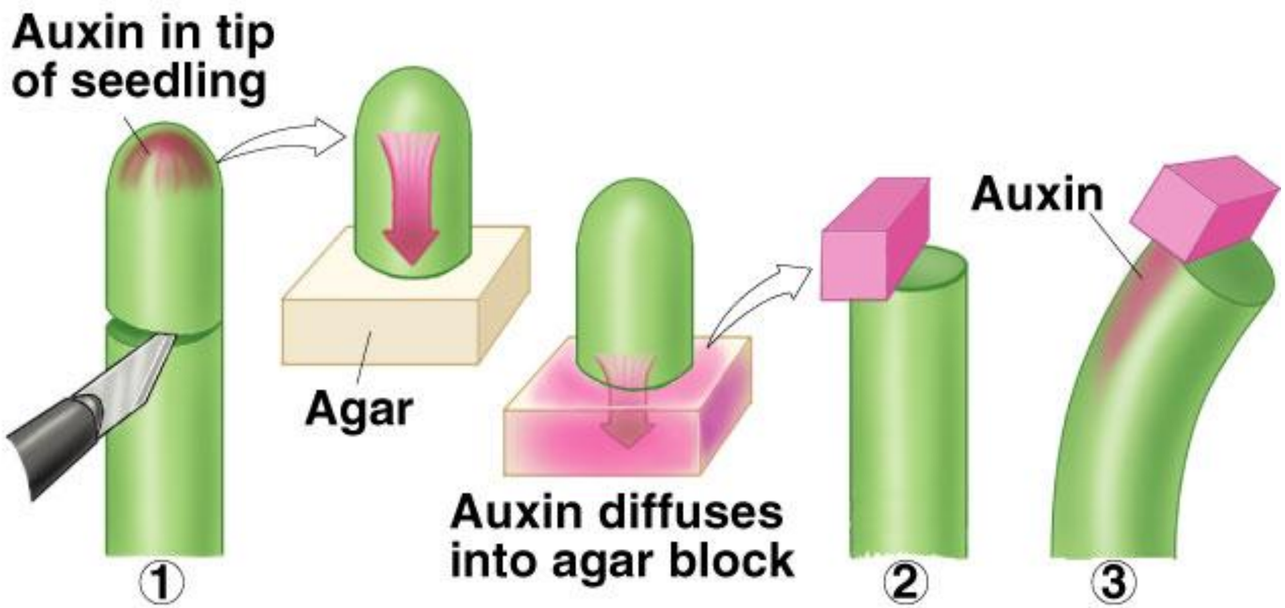


(b) Tryptophan

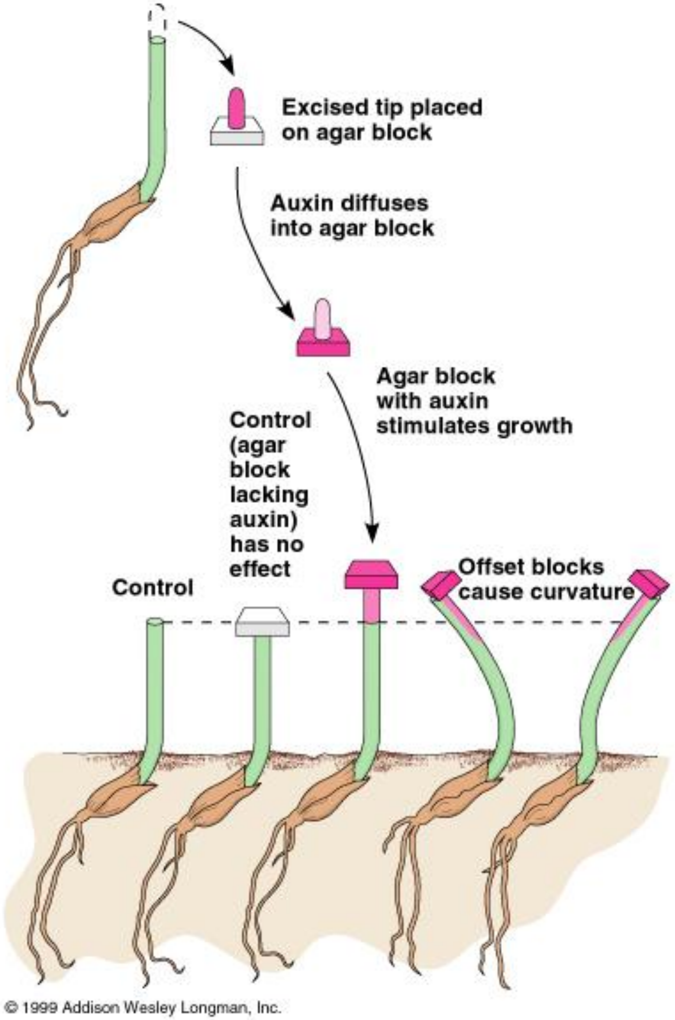


(c) Dichlorophenoxyacetic acid (2,4-D)

- Auxin increases the plasticity of plant cell walls and is involved in stem elongation.
- Arpad Paál (1919) - Asymmetrical placement of cut tips on coleoptiles resulted in a bending of the coleoptile away from the side onto which the tips were placed (response mimicked the response seen in phototropism).
- Frits Went (1926) determined auxin enhanced cell elongation.

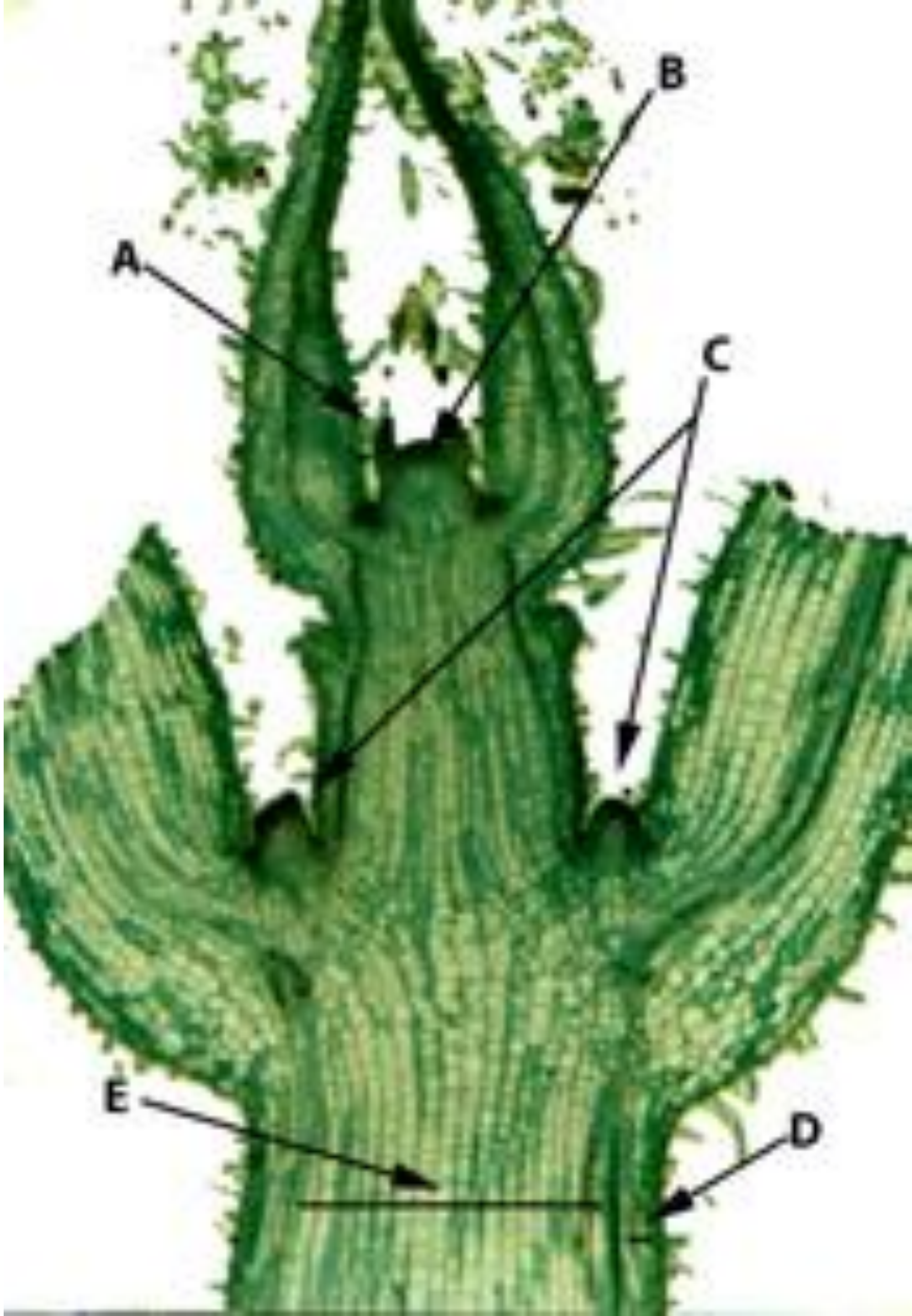


Demonstration of transported chemical

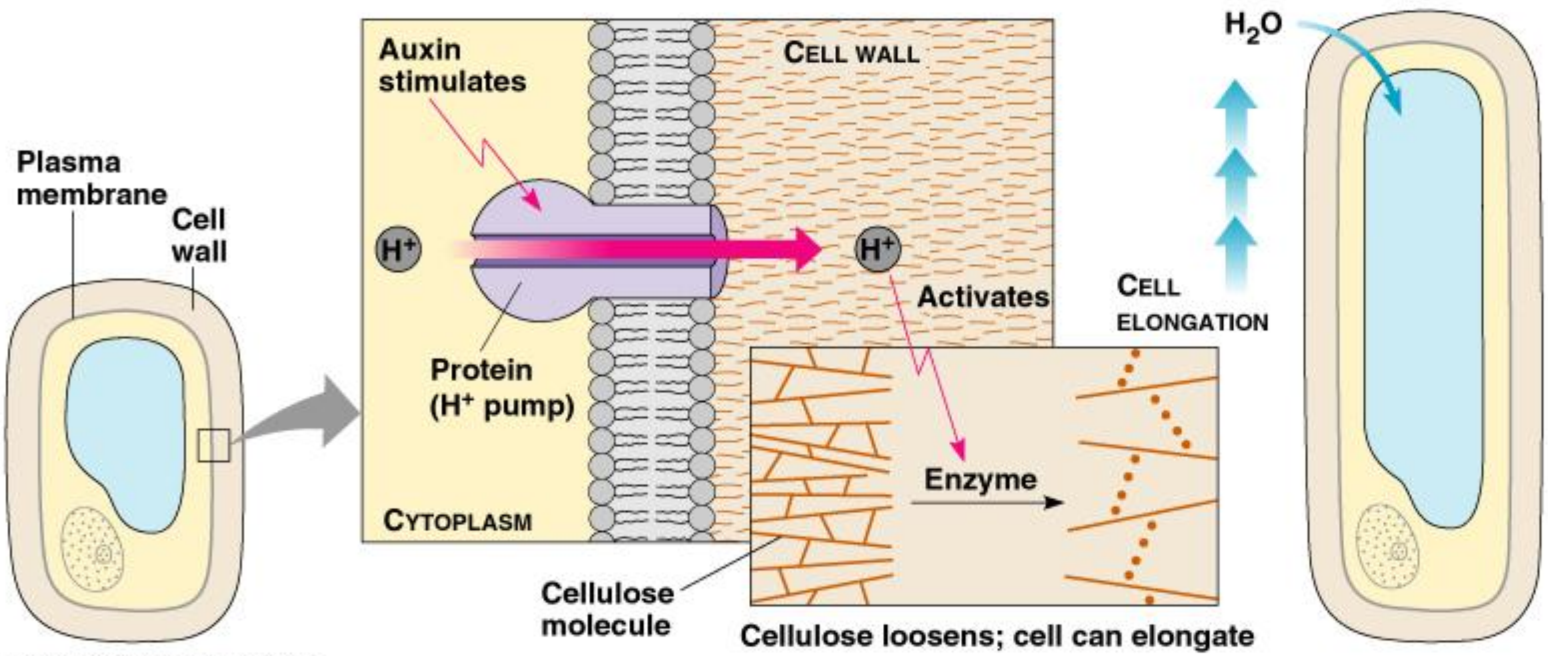


Auxins

- Stem elongation
- Produced in tips of stems ("B" in photo)
- Migrate from cell to cell in stems



Loosening of cell wall



Phototropism – ability to bend towards light

- Auxins - responsible for plants bending towards light.

- Auxins - move down shaded side of the stem and cause cells to elongate

Gravitropism (geotropism) – plant response to gravity

- Auxins – responsible for plant response to gravity

- Auxins – move to lowest side and cause stem tissue to elongate – stem curves upwards

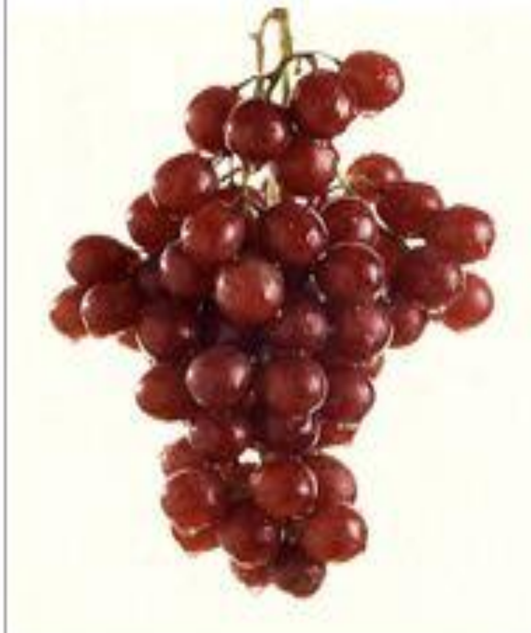
Auxin

- Synthetic auxins
  - widely used in agriculture and horticulture
    - prevent leaf abscission
    - prevent fruit drop
    - promote flowering and fruiting
    - control weeds
- Agent Orange - 1:1 ratio of 2,4-D and 2,4,5-T used to defoliate trees in Vietnam War.
    - Dioxin usually contaminates 2,4,5-T, which is linked to miscarriages, birth defects,leukemia, and other types of cancer.

Additional responses to auxin

- abscission - loss of leaves
- Callus tissue production
- flower initiation
- fruit development
- apical dominance

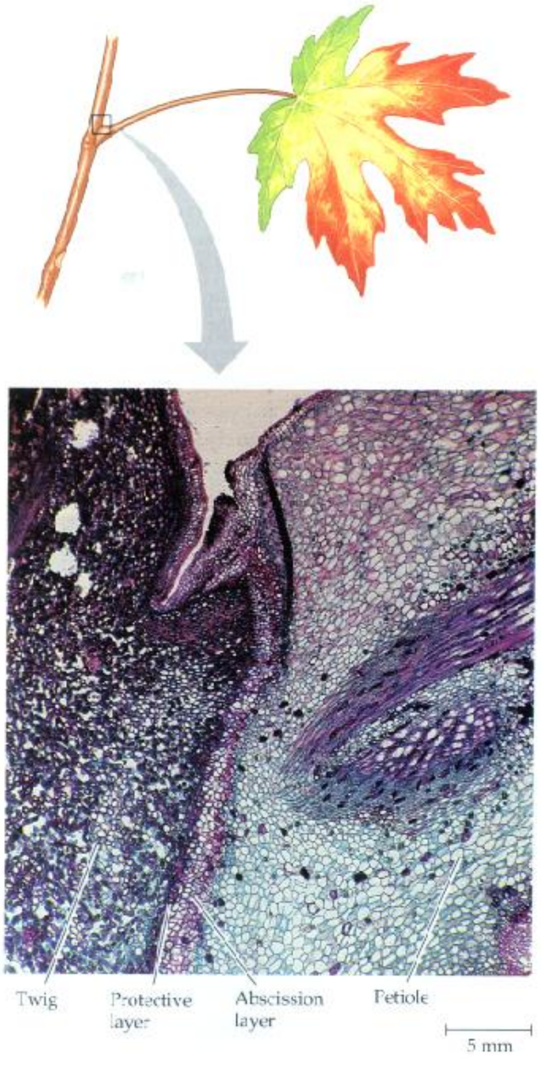
1	Cell divisions and enlargement Eg. cambial growth in diameter	.IAA + GA
2	Tissue culture	Shoot multiplications (IBA and BAP),callus Growth (2,4,-D), root multiplication IAA and IBA (1-2 mg)
3	Breaking dormancy and Apical dominance	NAA
4	Shortening internode	Apple trees (NAA) (dwarf branch-fruit)
5	Rooting of cuttings	(10-1000 ppm - NAA, IAA, phenyl acetic acid)
6	Prevent lodging	NAA- develop woody and erect stem
7	Prevent abscission	Premature leaf, fruit, flower fall (NAA, IAA and 2,4-D)
8	Parthenocarpic fruit	Grapes, banana, orange - (IAA)
9	Flower initiations	Pine apple -uniform flowering - fruit ripening (NAA). Delay flowering (2,4-D)
10	Weed eradications	2,4,D and auxin compounds

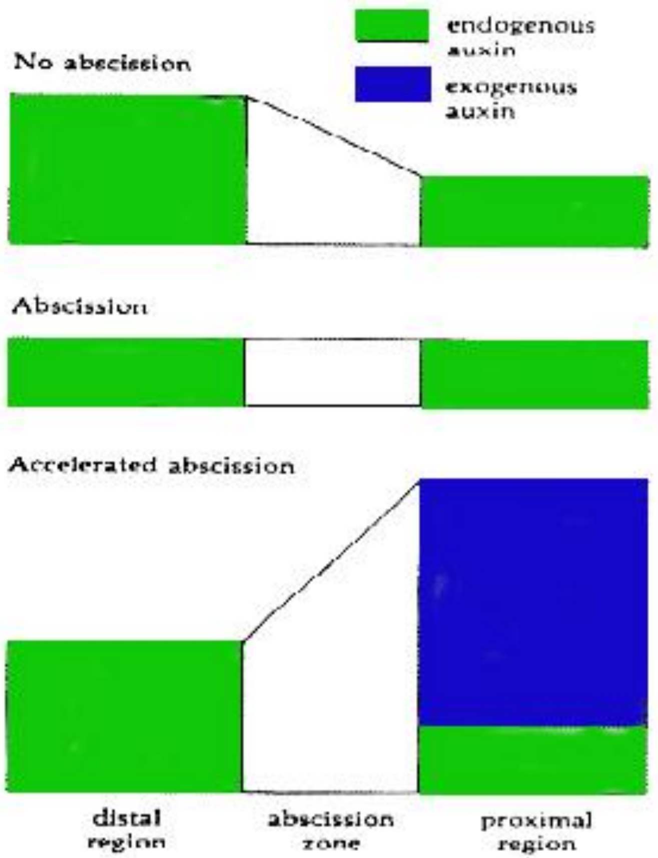


Preventing fruit abscission

Tissue culture: Callus growth and Shoot multiplication

Control of abscission by auxin

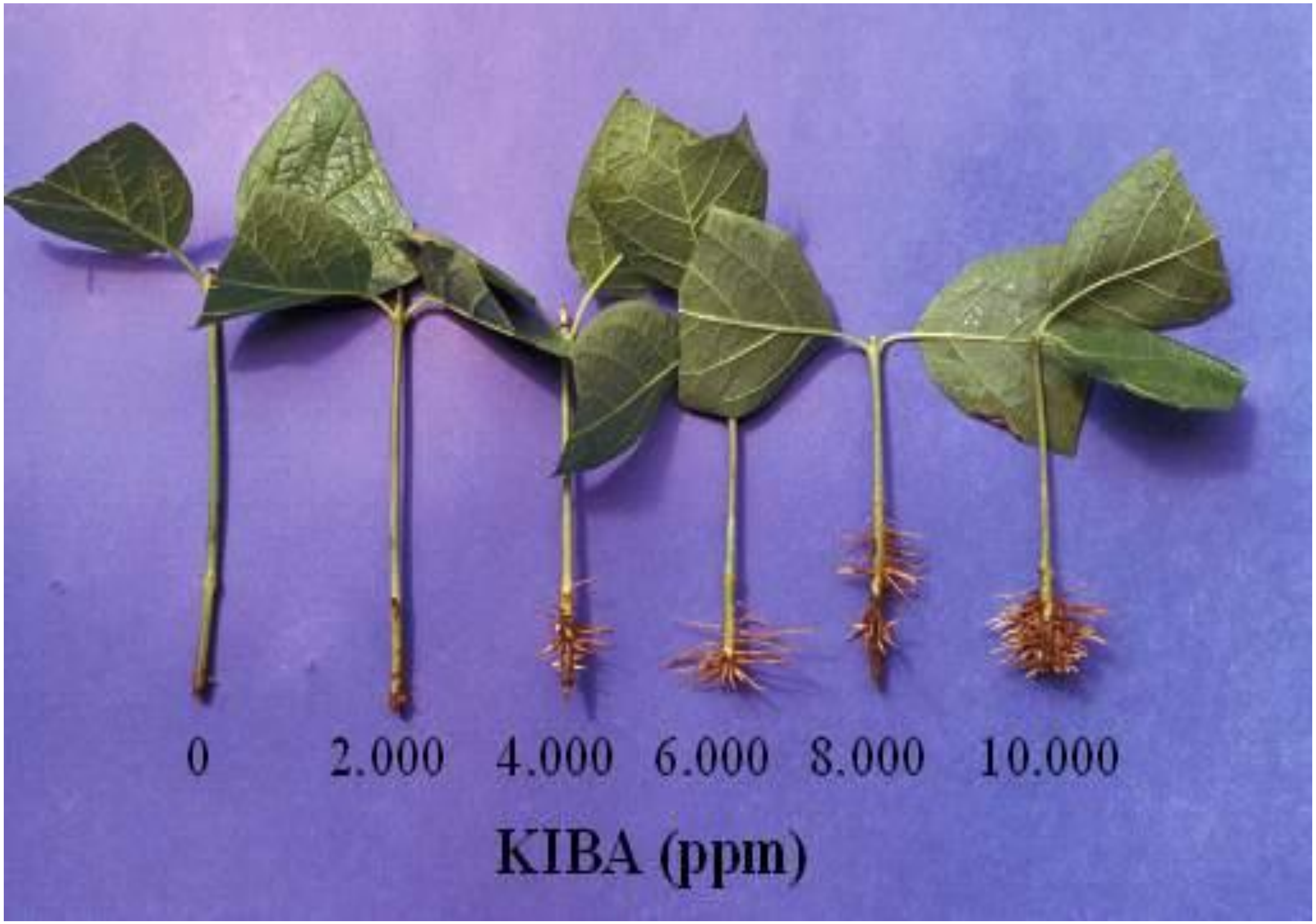




Relationships between auxin gradient across abscission zone and abscission.

Root development

- Auxins encourage root development in cuttings
- Some plants produce plenty of auxins to make rooting cuttings easy
- Other plants need synthetic auxins such as IBA

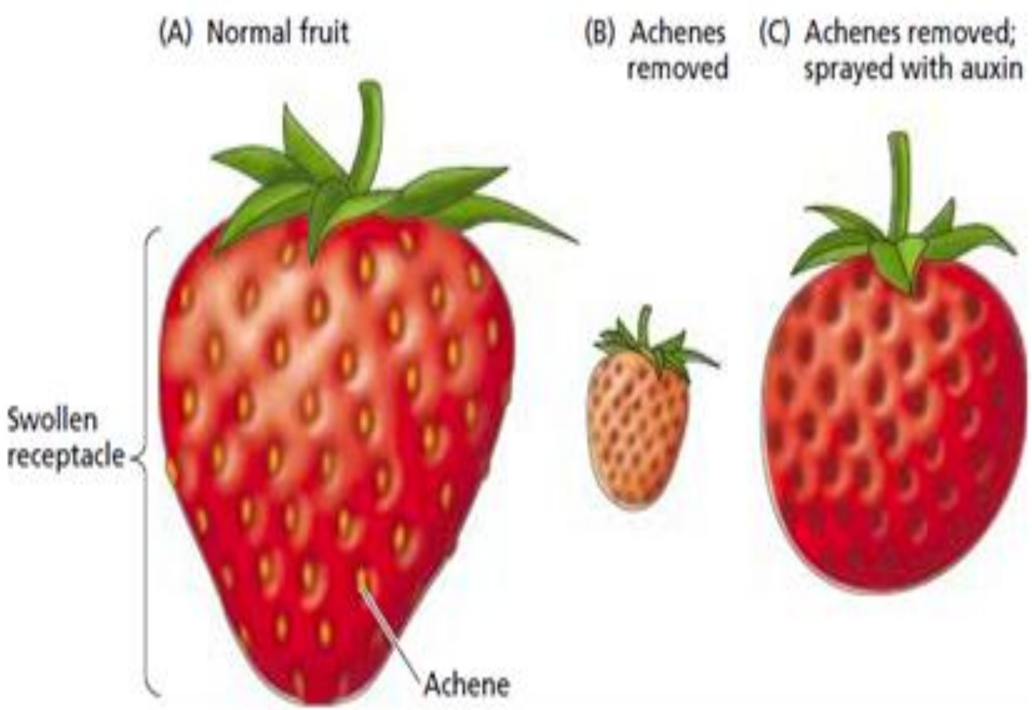

0
2.000
4.000
6.000
8.000
10.000
KIBA (ppm)

Apical Dominance

- Lateral branch growth are inhibited near the shoot apex, but less so farther from the tip.
- Apical dominance is disrupted in some plants by removing the shoot tip, causing the plant to become bushy.

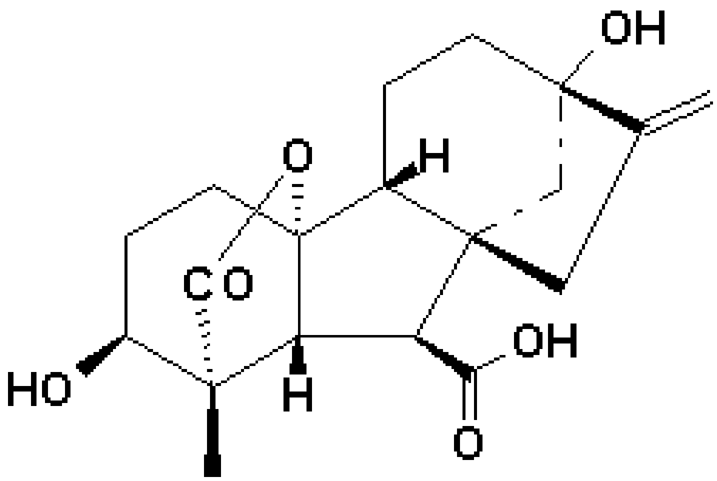
Pinching

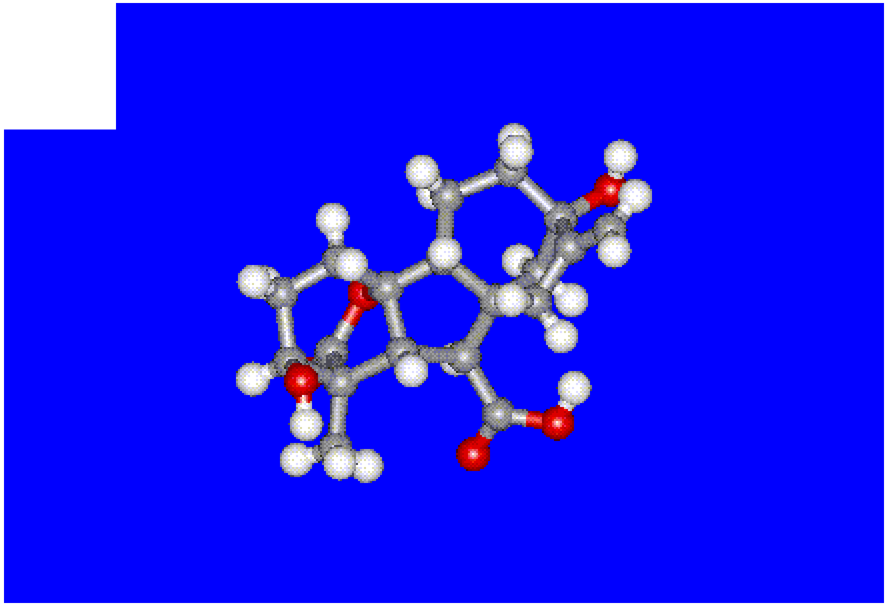
- Pinching = removing the terminal bud
- Pinching - stops flow of auxins down the stem and allows side shoots to develop
- Produces bushy, well-branched crops



- Above describes the effect of auxin on strawberry development. The achenes produce auxin. When removed the strawberry does not develop (Raven, 1992).

Gibberellin





Discovered in association with In 1930's, bakanae or foolish seedling disease of rice (*Gibberella fujikuroi)*

- In 1930's, Ewiti Kurosawa and colleagues were studying plants suffering from bakanae, or "foolish seedling" disease in rice.
- Disease caused by fungus called, *Gibberella fujikuroi*, which was stimulating cell elongation and division.
- Compound secreted by fungus could cause bakanae disease in uninfected plants. Kurosawa named this compound gibberellin.
  - *Gibberella fujikuroi* also causes stalk rot in corn, sorghum and other plants.
  - Secondary metabolites produced by the fungus include mycotoxins, like fumonisin, which when ingested by horses can cause equine leukoencephalomalacia - necrotic brain or crazy horse or hole in the head disease.
  - Fumonisin is considered to be a carcinogen.

Gibberellins

- Gibberellins are named after the fungus *Gibberella fujikuroi* which causes rice plants to grow abnormally tall.
  - synthesized in apical portions of stems and roots
  - important effects on stem elongation
  - in some cases, hastens seed germination

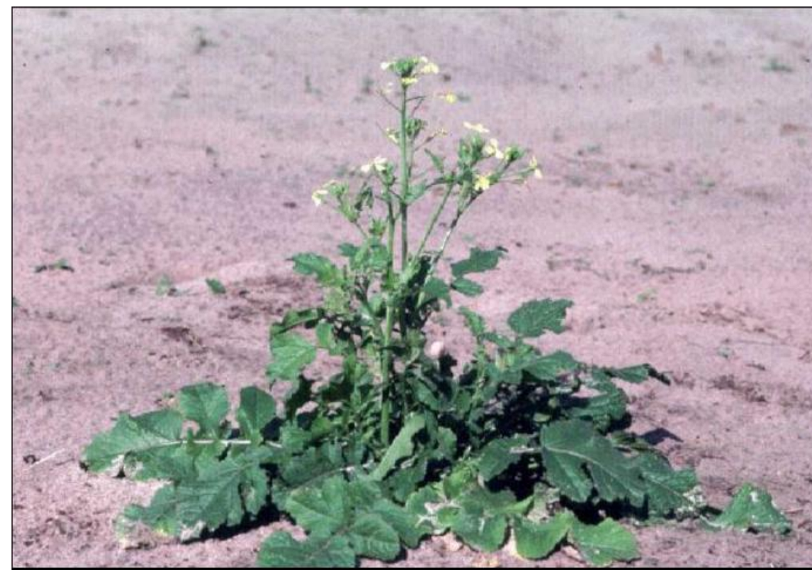
Effects of Gibberellins

- Cell elongation.
  - GA induces cellular division and cellular elongation; auxin induces cellular elongation alone.
  - GA-stimulated elongation does not involve the cell wall acidification characteristic of auxin-induced elongation
  - Breaking of dormancy in buds and seeds.
  - Seed Germination - Especially in cereal grasses, like barley. Not necessarily as critical in dicot seeds.
  - sex determination
- Promotion of flowering.
- Transport is non-polar, bidirectional producing general responses.

Wild Radish – Rosette & Bolt

A FLOWERING ANNUAL

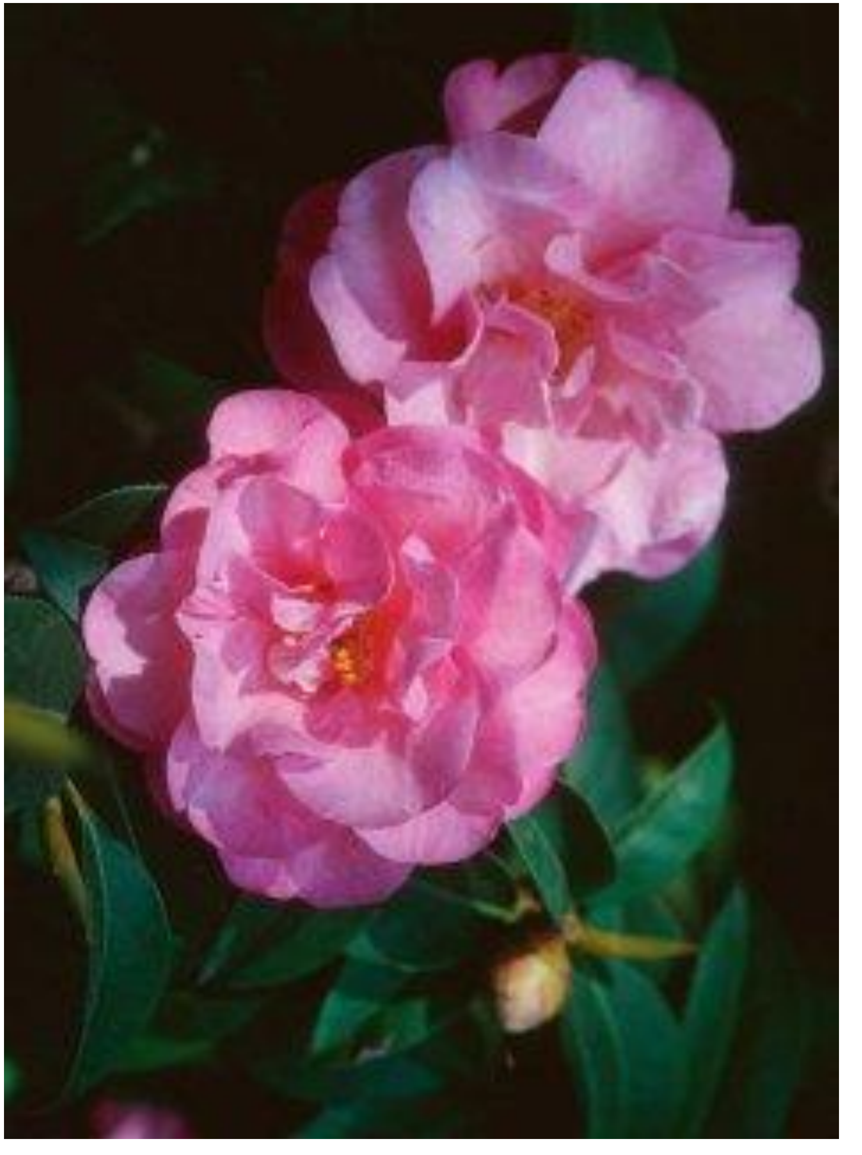
YEAR ONE



YEAR ONE

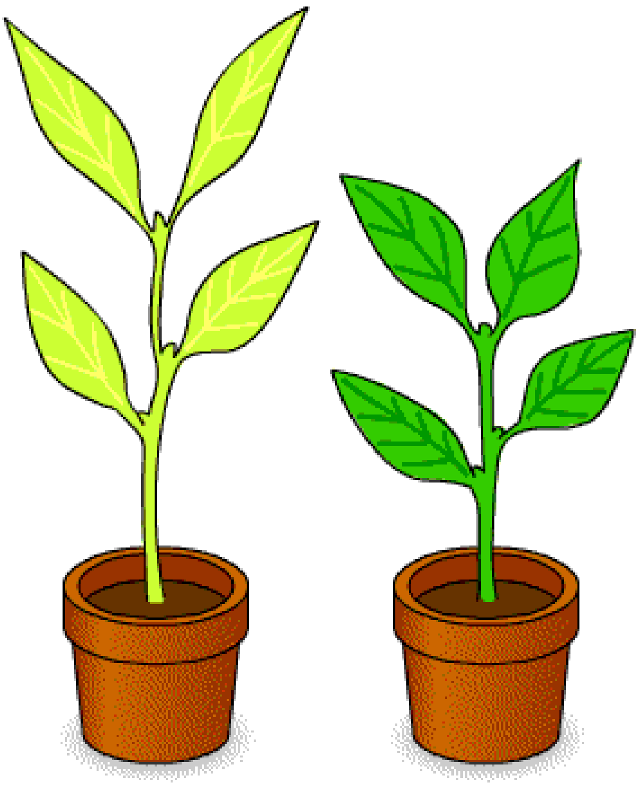
Gibberellins

- Cell elongation and cell division
- Stimulate development of flowers (as in “gibbing” camelias)
- Cause internodes to stretch
- Produced in stem and root apical meristems, seed embryos, young leaves

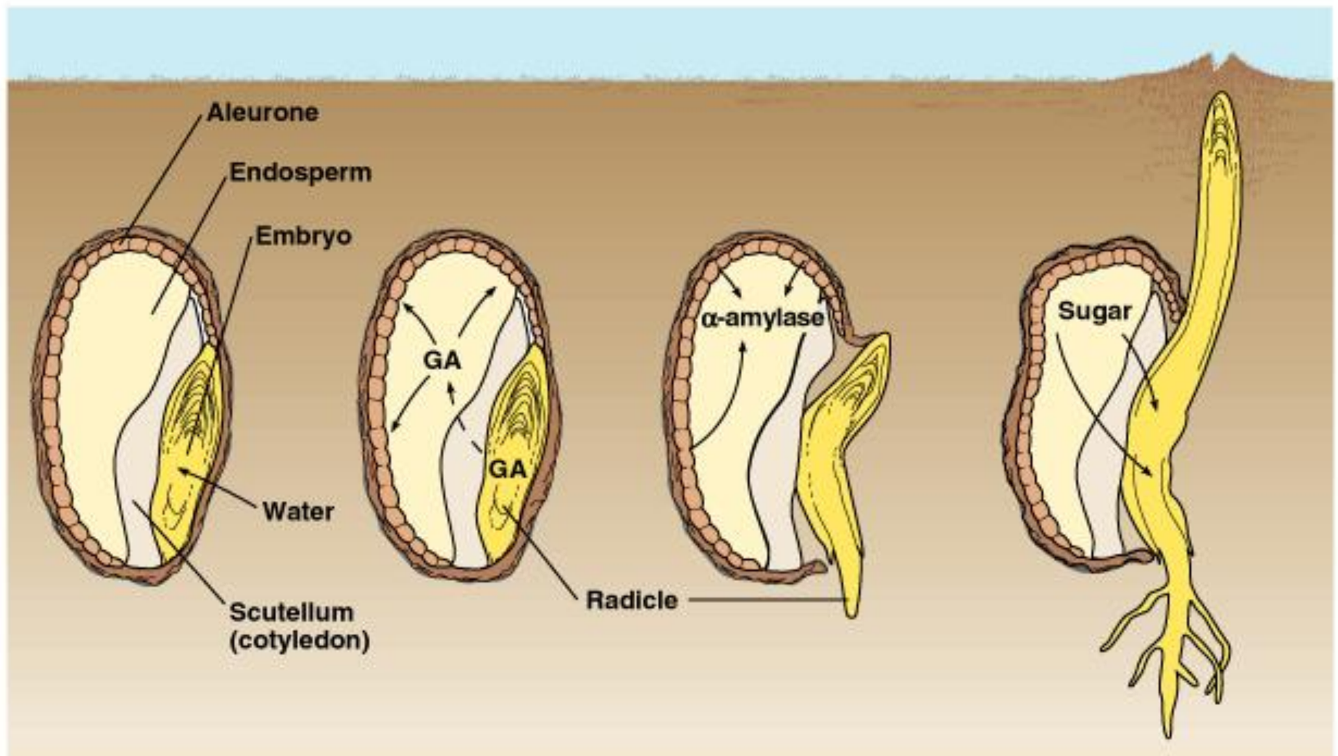


Internode Elongation

- Gibberellins cause internodes to stretch in relation to light intensity.
- High light intensity = no stretch
- Low light intensity = long internodes. Leaves are raised to capture light



Mobilization of reserves



Gibberellins and Fruit Size

- Fruit Formation - "Thompson Seedless" grapes grown in California are treated with GA to increase size and decrease packing.

Dwarf Tall

High yielding semi-dwarf rice has reduced endogenous gibberellin

Fewer flowers and larger fruit

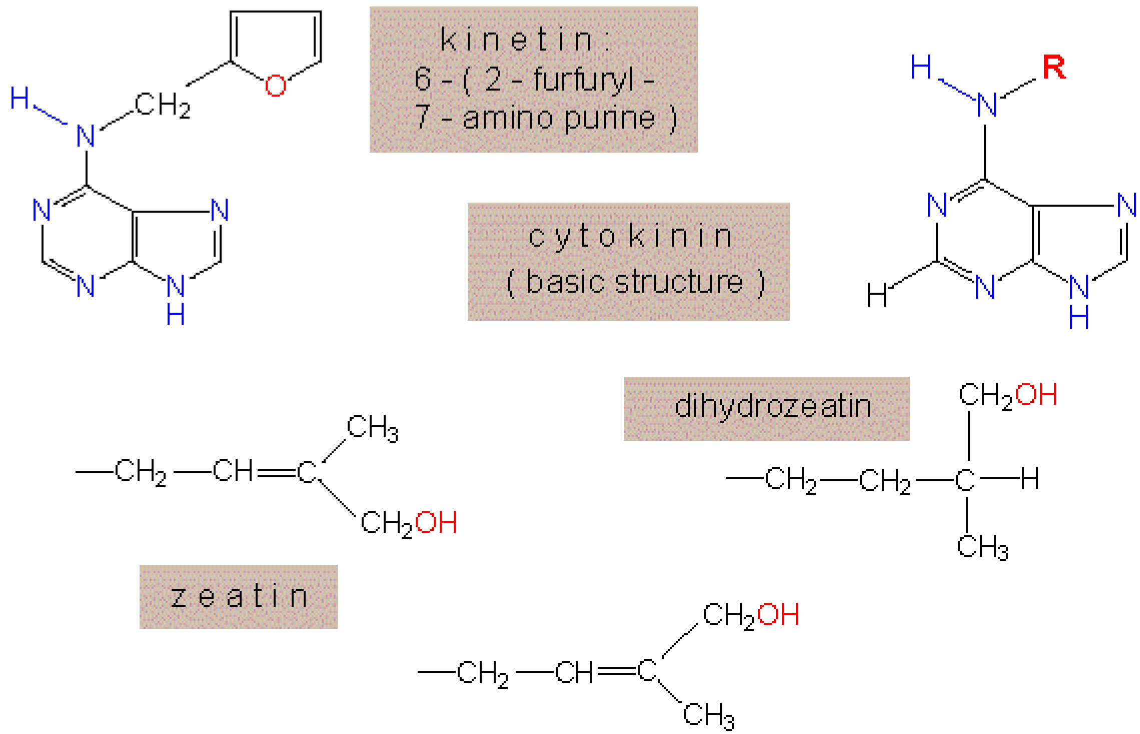
Delayed fruit harvest

Increased fruit size

GAs are used commercially to increase fruit size in table grapes and to regulate citrus flowering and rind maturation

The effects of paclobutrazol, an inhibitor of gibberellin biosynthesis, on shoot growth and flowering of poinsettia

Cytokinins


kinetin :
6 - (2 - furfuryl -
7 - amino purine)
cytokinin
(basic structure)
dihydrozeatin
zeatin
R

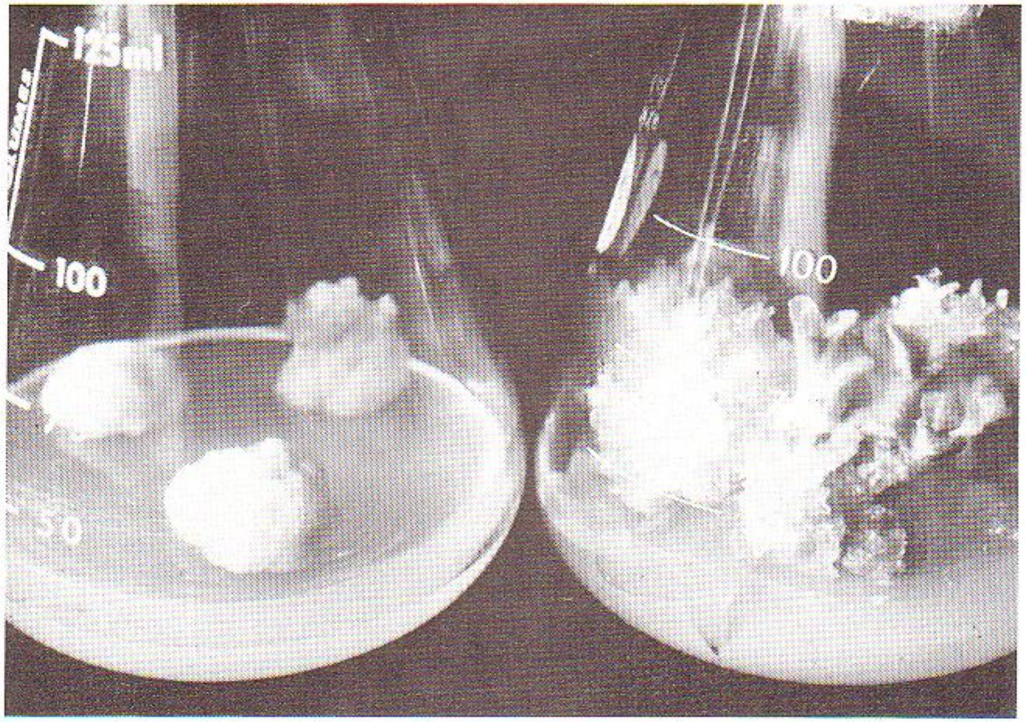
Discovery of cytokinins

- Gottlieb Haberlandt in 1913 reported an unknown compound that stimulated cellular division.
- In the 1940s, Johannes van Overbeek, noted that plant embryos grew faster when they were supplied with coconut milk (liquid endosperm), which is rich in nucleic acids.
- In the 1950s, Folke Skoog and Carlos Miller studying the influence of auxin on the growth of tobacco in tissue culture. When auxin was added to artificial medium, the cells enlarged but did not divide. Miller took herring-sperm DNA. Miller knew of Overbeek's work, and decided to add this to the culture medium, the tobacco cells started dividing. He repeated this experiment with fresh herring-sperm DNA, but the results were not repeated. Only old DNA seemed to work. Miller later discovered that adding the purine base of DNA (adenine) would cause the cells to divide.
- Adenine or adenine-like compounds induce cell division in plant tissue culture. Miller, Skoog and their coworkers isolated the growth facto responsible for cellular division from a DNA preparation calling it kinetin which belongs to a class of compounds called cytokinins.
- In 1964, the first naturally occurring cytokinin was isolated from corn called zeatin. Zeatin and zeatin riboside are found in coconut milk. All cytokinins (artificial or natural) are chemically similar to adenine.
- Cytokinins move nonpolarly in xylem, phloem, and parenchyma cells.
- Cytokinins are found in angiosperms, gymnosperms, mosses, and ferns. In angiosperms, cytokinins are produced in the roots, seeds, fruits, and young leaves

Function of cytokinins

- Promotes cell division.
- Morphogenesis.
- Delay of senescence.
- Mobilization.
- Lateral bud development.

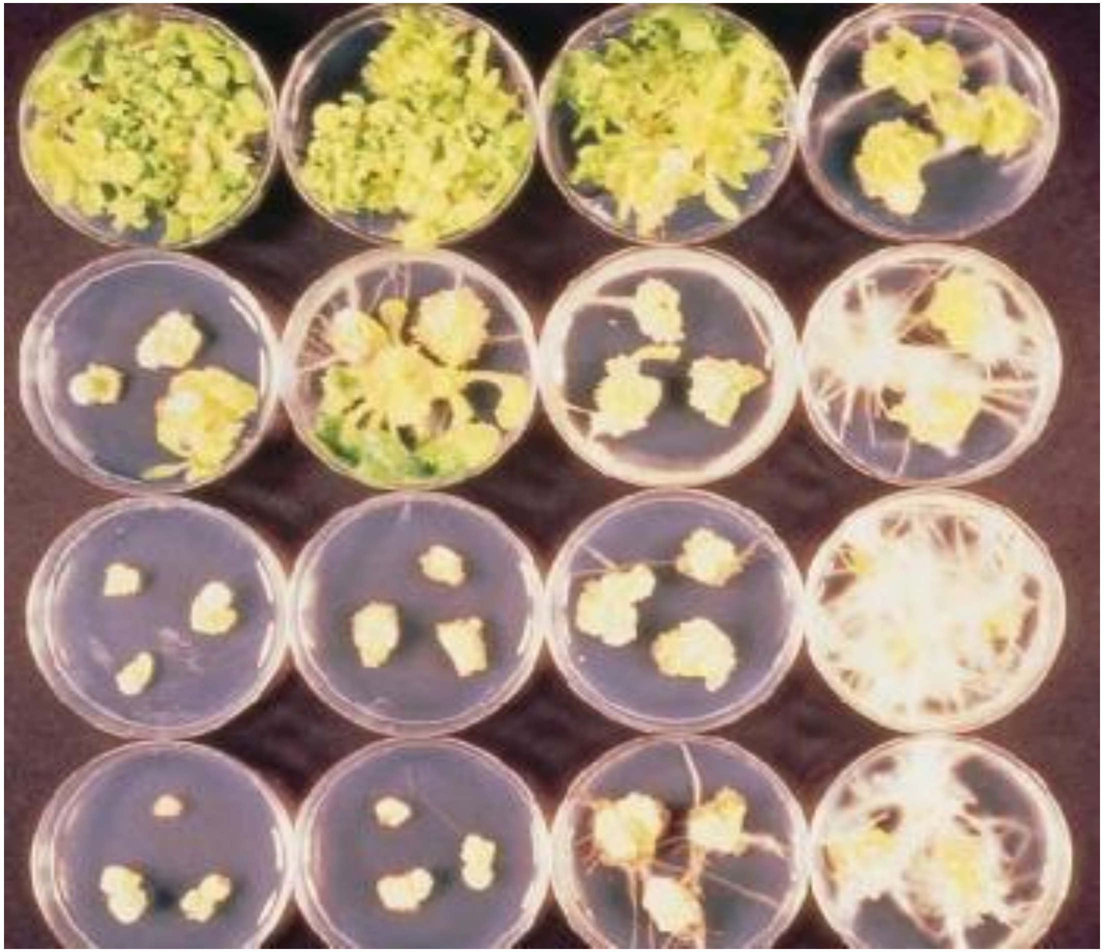
Interaction of cytokinin and auxin in tobacco callus (undifferentiated plant cells) tissue



Tissue cultures of tobacco (*Nicotiana tabacum*) callus. By altering cytokinin-to-auxin ratio, tobacco stem pith tissue may be maintained in culture as undifferentiated callus (left) or induced to differentiate and bud into plantlets (right).

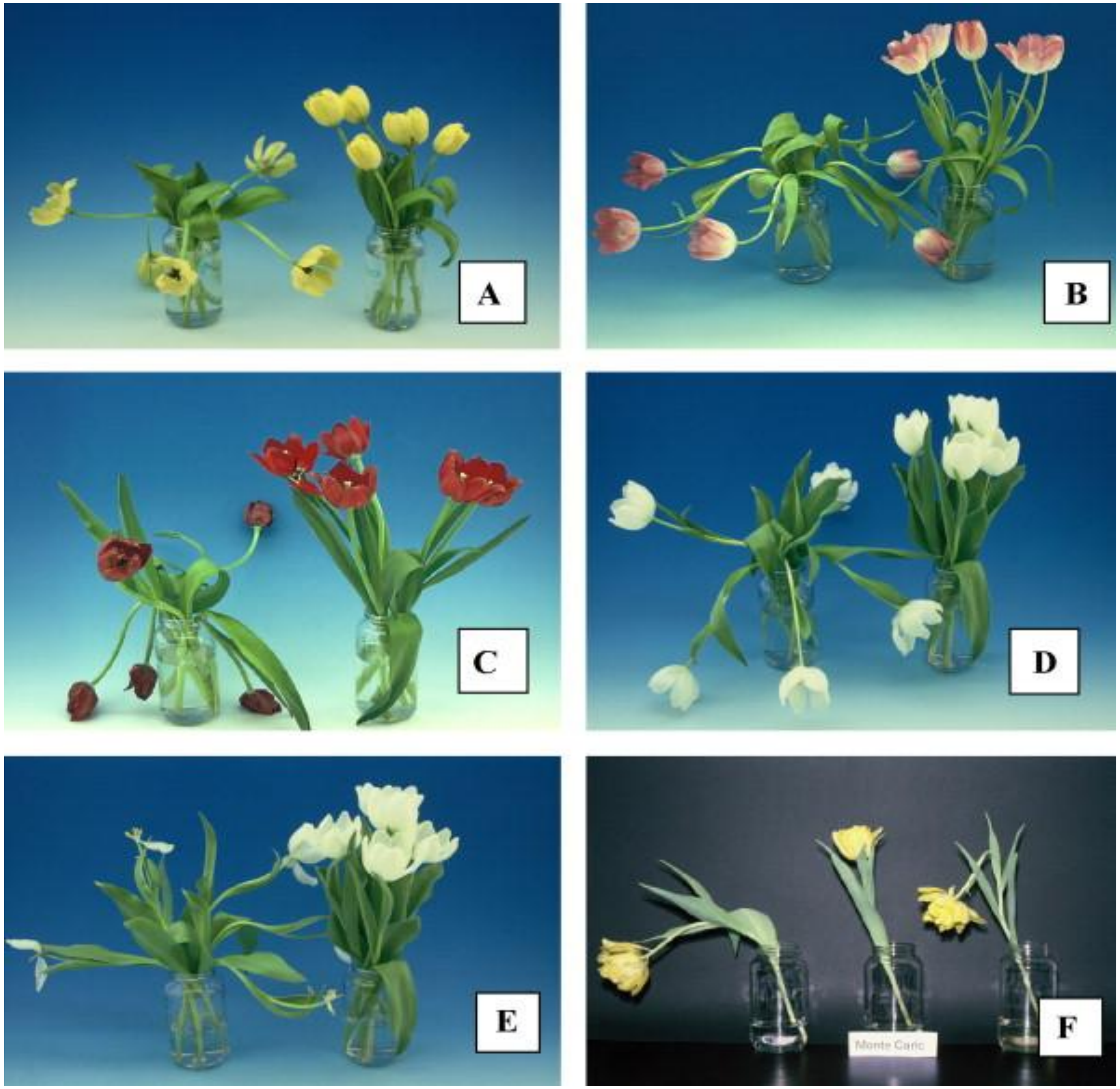
From work of F. Skoog and C.O. Miller. Photo by F.H. Witham.

- ❖Organogenesis: Cytokinins and auxin affect organogenesis
- ❖High cytokinin/auxin ratios favor the formation of shoots
- ❖Low cytokinin/auxin ratios favor the formation of roots.



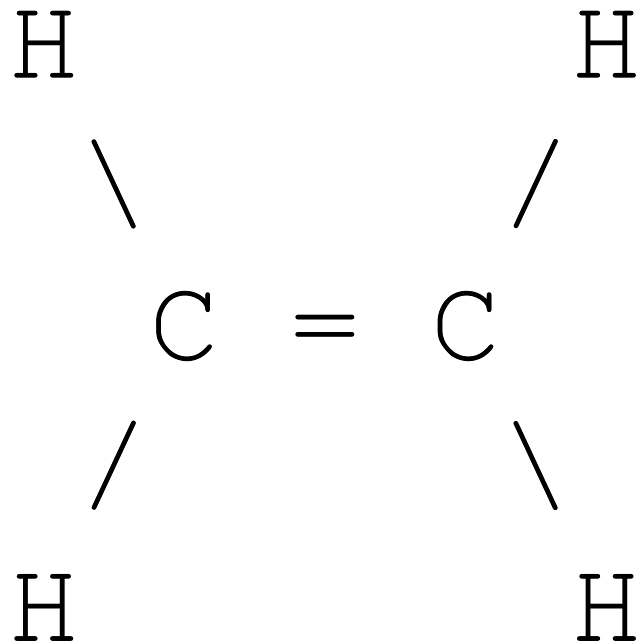
Tobacco leaf explants cultured on media with varying concentrations of an auxin (α-naphthaleneacetic acid; NAA) and a cytokinin (6-benzylaminopurine; BAP). Concentrations of NAA are from left to right, 0, 0.01 µM, 0.1 µM, 1.0 µM; concentrations of BAP are from bottom to top 0, 0.01 µM, 0.1 µM, 1.0 µM. At low auxin to cytokinin ratios shoot development predominates, whereas at high ratios profuse root initiation occurs. At intermediate ratios, callus is often the result.

Leaf segments of control (left, middle) and transgenic line (right) during after postharvest stress treatment.



The flowers in the vase on the left side are the controls, and on the right side the flowers had been pulse-treated, for 6 h, with a mixture of GA_3, BA, and calcium ions.

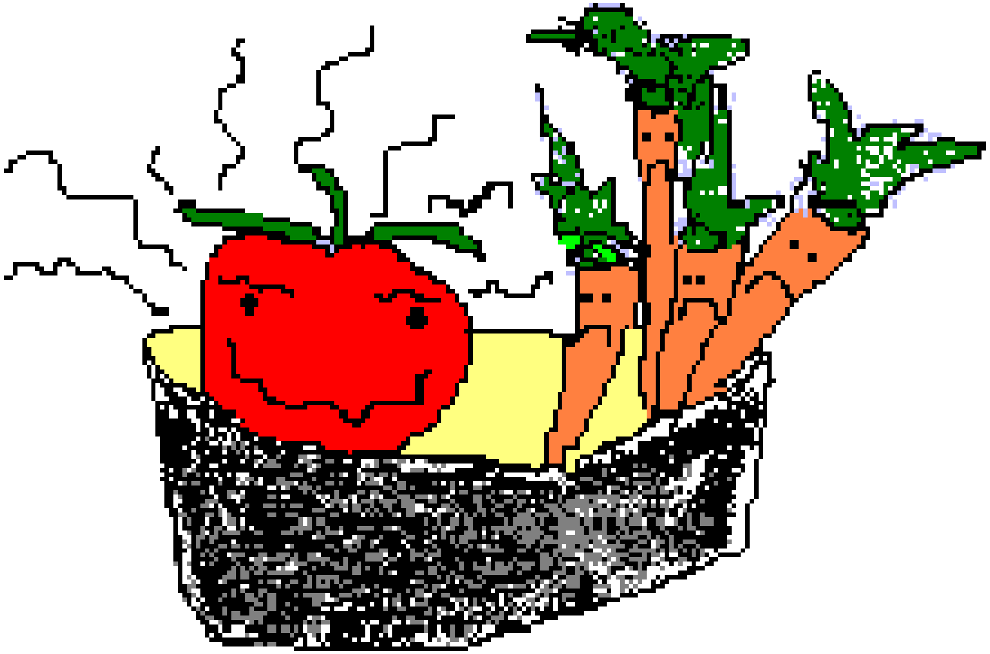
Ethylene



Discovery of ethylene

- In the 1800s, it was recognized that street lights that burned gas, could cause neighboring plants to develop short, thick stems and cause the leaves to fall off. In 1901, Dimitry Neljubow identified that a byproduct of gas combustion was ethylene gas and that this gas could affect plant growth.
- In R. Gane showed that this same gas was naturally produced by plants and that it caused faster ripening of many fruits.
- Synthesis of ethylene is inhibited by carbon dioxide and requires oxygen.

Ethylene Gas



- Colorless gas
- Produced in nodes of stems, ripening fruits, dying leaves

Ethylene Effects

- Dormancy
- Flowering (pineapple)
- Sex determination
- Fruit ripening

Functions of ethylene

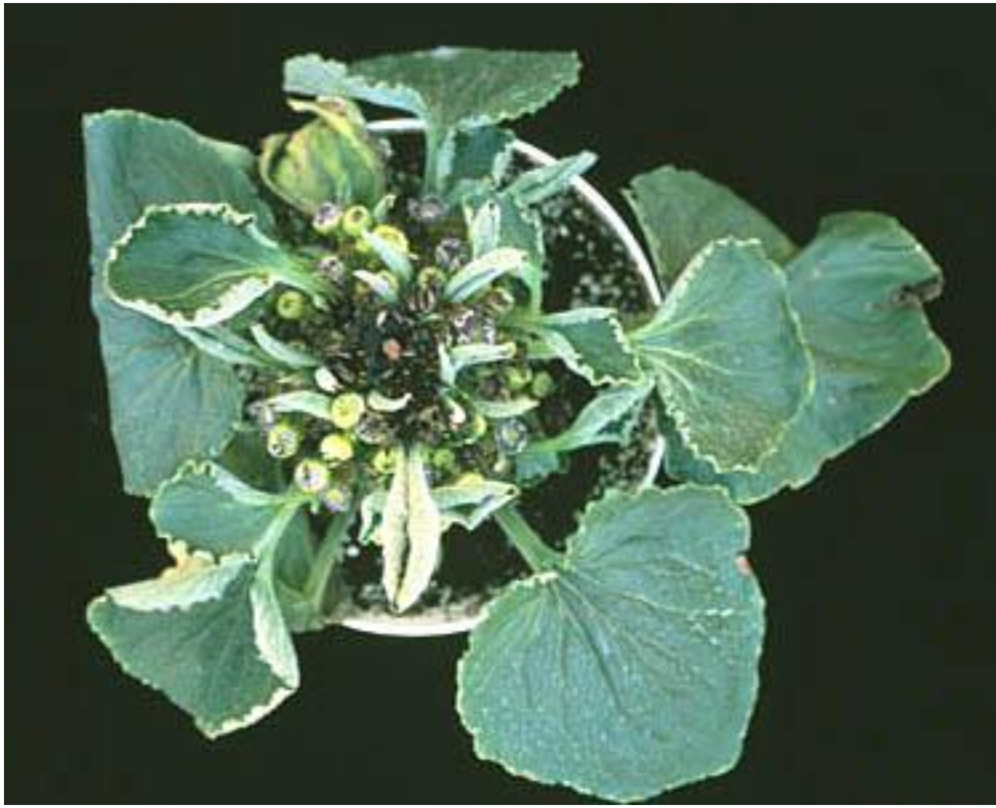
- Gaseous in form and rapidly diffusing.
- Gas produced by one plant will affect nearby plants.
- Fruit ripening.
- Epinasty – downward curvature of leaves.
- Encourages senescence and abscission.
- Initiation of stem elongation and bud development.
- Flowering - Ethylene inhibits flowering in most species, but promotes it in a few plants such as pineapple, bromeliads, and mango.
- Sex Expression - Cucumber buds treated with ethylene become carpellate (female) flowers, whereas those treated with gibberellins become staminate (male) flowers.

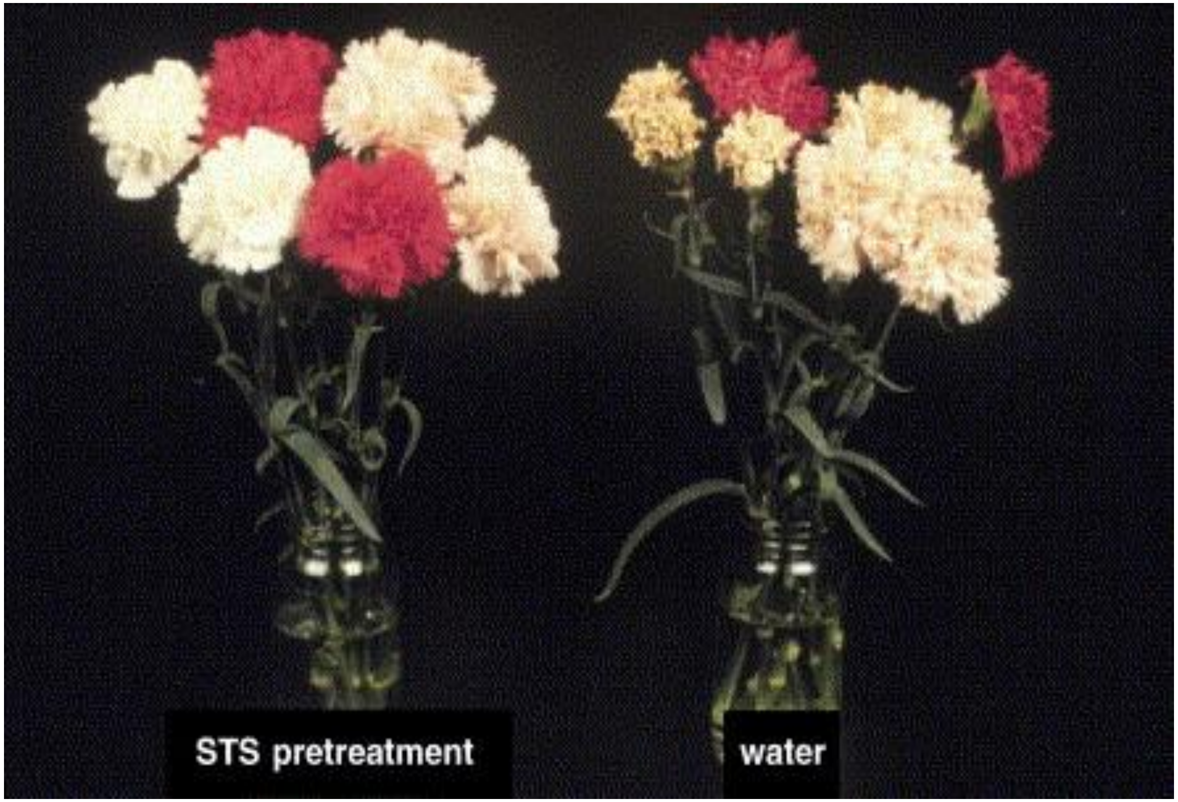

200 ml
±5%
150
100
50

DEGREENED

Ethylene exposure

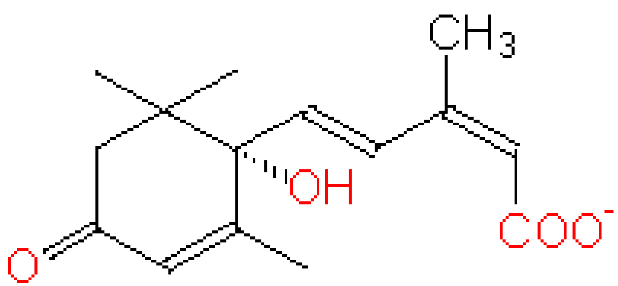
- Thickens stems
- Breaks down chlorophyll
- Weakens cell membranes
- Softens cell walls



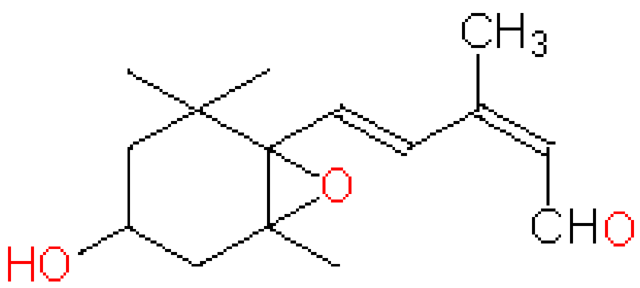


- Different varieties of carnation treated overnight with 0.2 mM STS solution. Photograph was taken after 10 days of vase life. Note that cultivar Chinera (pink colored), with reduced sensitivity to ethylene, benefits less from the STS pretreatment.

Abscisic acid



abscisic acid (ABA)



xanthoxine

❖In 1940s, scientists started searching for hormones that would inhibit growth and development, what Hemberg called dormins.

❖In the early 1960s, Philip Wareing confirmed that application of a dormin to a bud would induce dormancy.

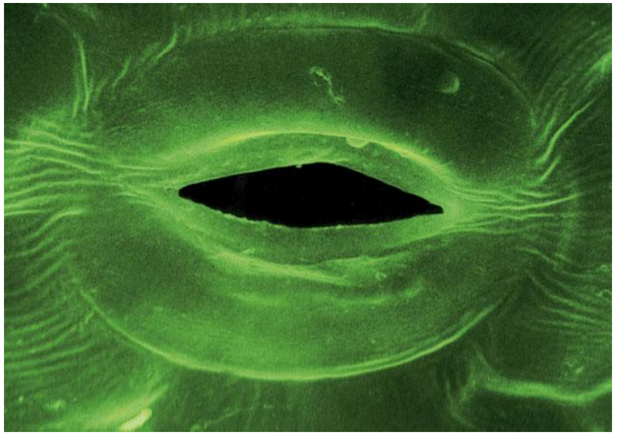
❖F.T. Addicott discovered that this substance stimulated abscission of cotton fruit. he named this substance abscisin. (Subsequent research showed that ethylene and not abscisin controls abscission).

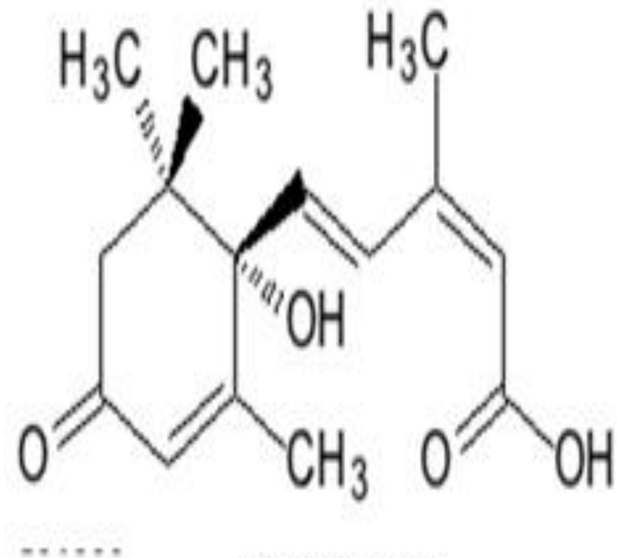
❖Abscisin is made from carotenoids and moves nonpolarly through plant tissue.

Functions of abscisic acid

- General growth inhibitor.
- Bud and seed dormancy.
- Overcoming apical dominance
- Causes stomatal closure.
- Produced in response to stress.

- Abscisic acid is produced chiefly in mature green leaves and in fruits.
  - suppresses bud growth and promotes leaf senescence
  - also plays important role in controlling stomatal opening and closing

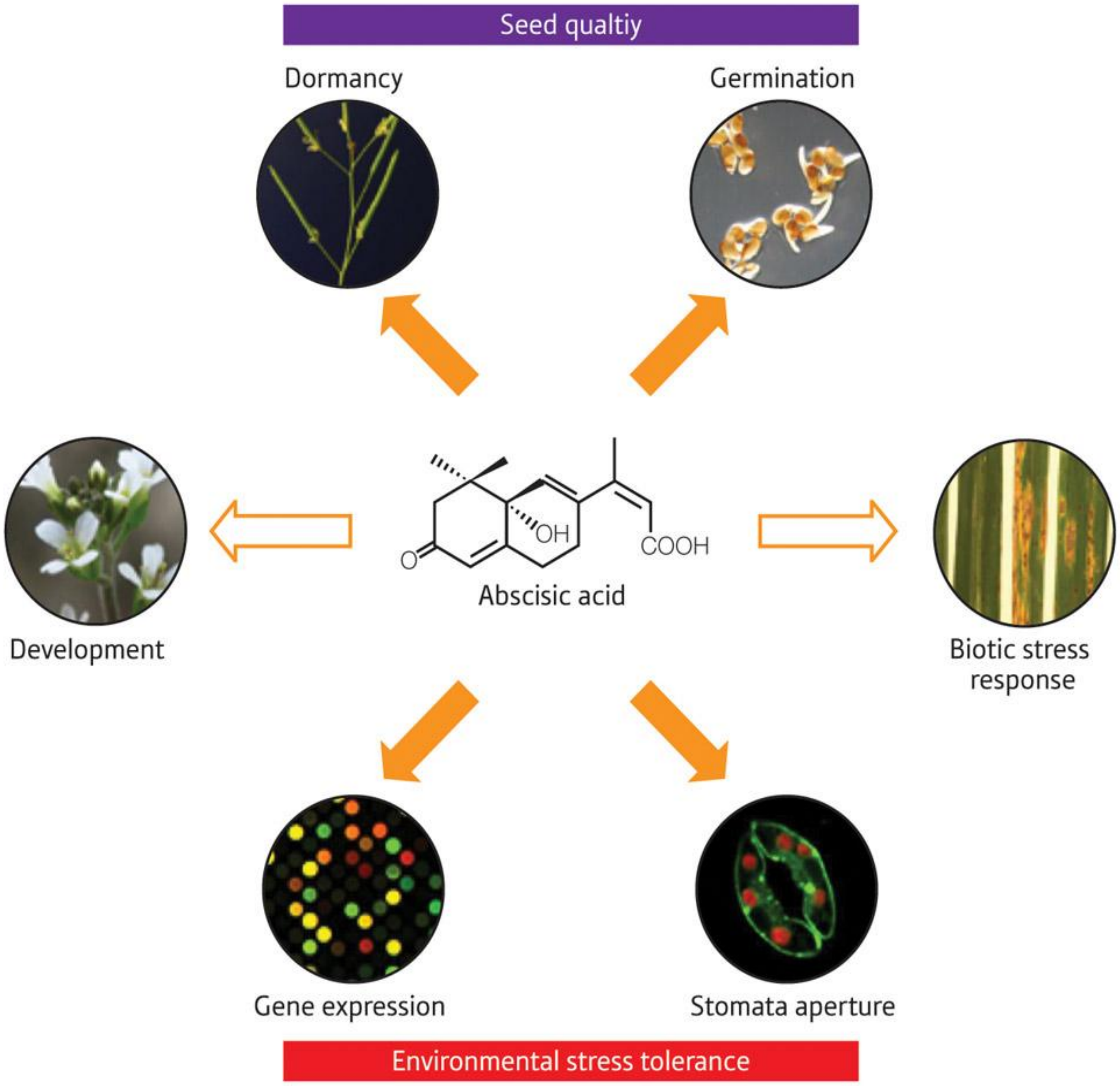




Abscisic acid

Salt treatmet

- transgenic *Arabidopsis* overexpressing *ABA2* with elevated ABA levels promote delay of seed germination and tolerance to salt.


Seed qualtiy
Dormancy
Germination
Development
OH
O
COOH
Abscisic acid
Biotic stress response
Gene expression
Stomata aperture
Environmental stress tolerance

Growth Inhibitors

Growth Retardants

- Widely used in the greenhouse industry
- Inhibit action of gibberellins on stem elongation

Goal of Synthetic Growth Retardants:

- Compact plants
- More attractive
- Greener
- Easier to transport
- Flowering NOT affected

Other New Hormons

- Brassinosteroids
- Brassinolids was isolates from the pollen of the rapeseed plant in 1979

- Jasmonates
- Are represented by jasmonic acid and methyl jasmonate.

- Salysilic acid