PLANT GROWTH REGULATORS

THE FOLLOWING POWERPOINT PRESENTATION IS BASED, IN PART, ON MATERIAL ACCESSED ON THE INTERNET (4-12-06)

- http://styx.nsci.plu.edu/~dhansen/hormones2.ppt#257,2,Processes in growth
- http://www.coe.unt.edu/ubms/documents/classnotes/Spring2006/Plant%20Sensory%20Systems%201720_Chapter_40_2005.ppt

Plant Growth Regulators
AKA Plant Hormones

Plant Growth Regulators - control growth, development and movement

PLANT GROWTH REGULATORS (PLANT HORMONES)

- Internal and external signals that regulate plant growth are mediated, at least in part, by plant growth-regulating substances, or hormones (from the Greek word *hormaein*, meaning "to excite").
- Plant hormones differ from animal hormones in that:
  - No evidence that the fundamental actions of plant and animal hormones are the same.
  - Unlike animal hormones, plant hormones are not made in tissues specialized for hormone production. (e.g., sex hormones made in the gonads, human growth hormone - pituitary gland)
  - Unlike animal hormones, plant hormones do not have definite target areas (e.g., auxins can stimulate adventitious root development in a cut shoot, or shoot elongation or apical dominance, or differentiation of vascular tissue, etc.).

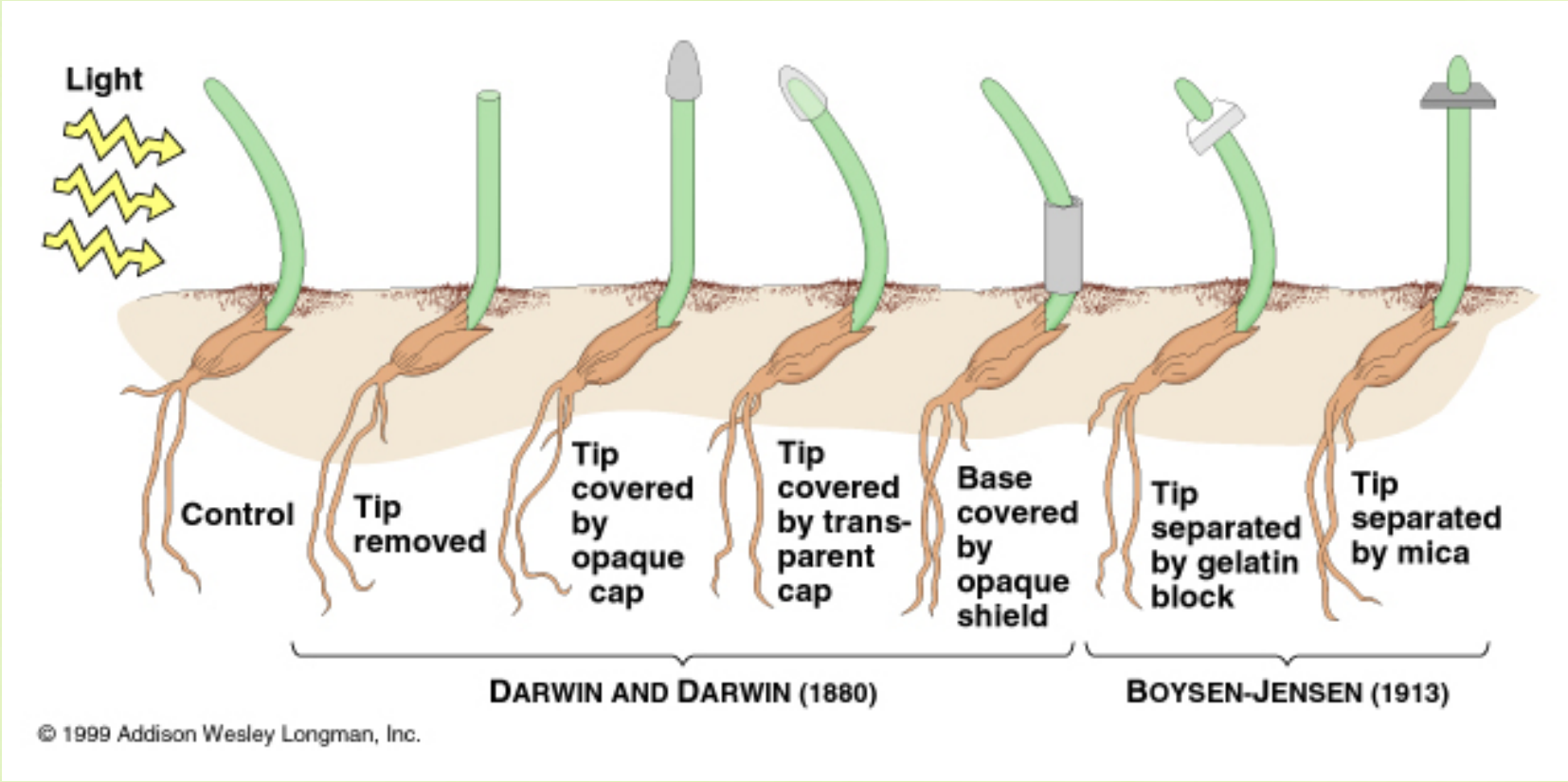
PLANT GROWTH REGULATORS

- PLANT GROWTH REGULATORS ARE NECESSARY FOR, BUT DO NOT CONTROL, MANY ASPECTS OF PLANT GROWTH AND DEVELOPMENT. - BETTER NAME IS GROWTH REGULATOR.
- THE EFFECT ON PLANT PHYSIOLOGY IS DEPENDENT ON THE AMOUNT OF HORMONE PRESENT AND TISSUE SENSITIVITY TO THE PLANT GROWTH REGULATOR
- substances produced in small quantities by a plant, and then transported elsewhere for use
  - have capacity to stimulate and/or inhibit physiological processes
- at least five major plant hormones or plant growth regulators:
  - auxins, cytokinins, gibberellins, ethylene and abscisic acid

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)

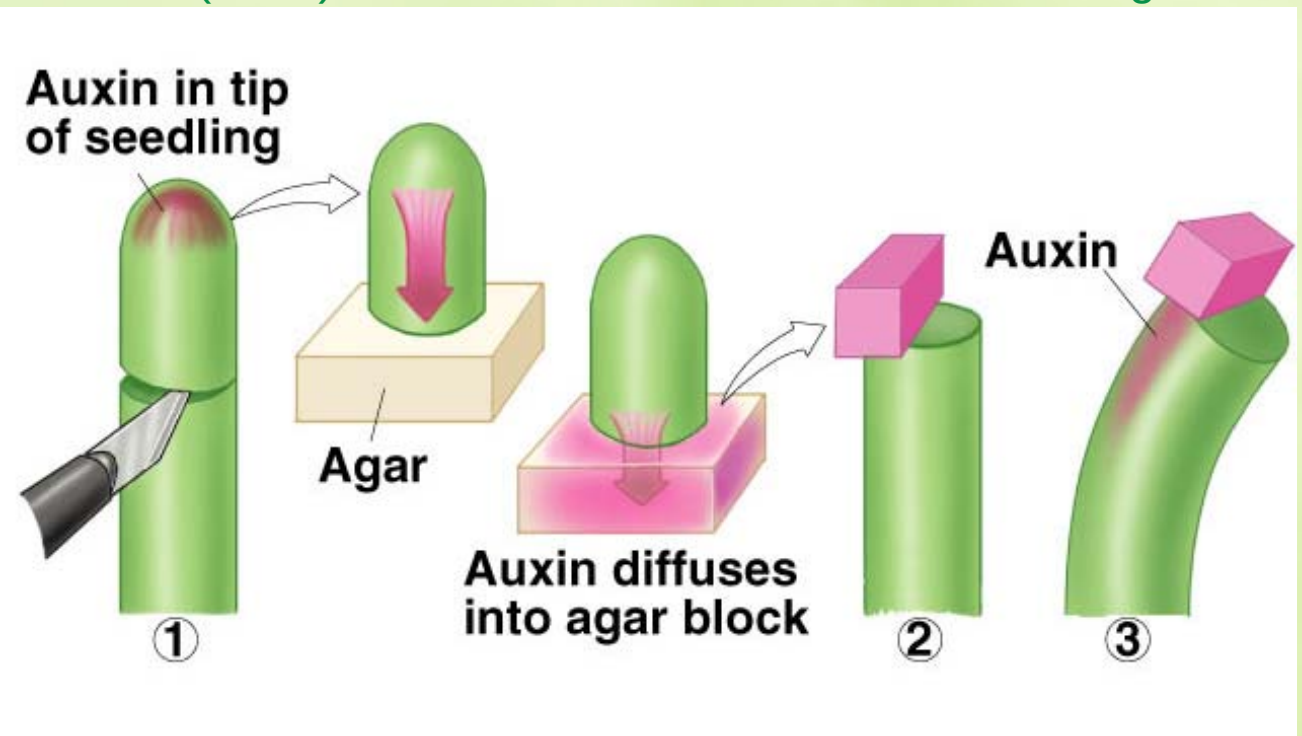
EARLY EXPERIMENTS ON PHOTROPISM SHOWED THAT A STIMULUS (LIGHT) RELEASED CHEMICALS THAT INFLUENCED GROWTH



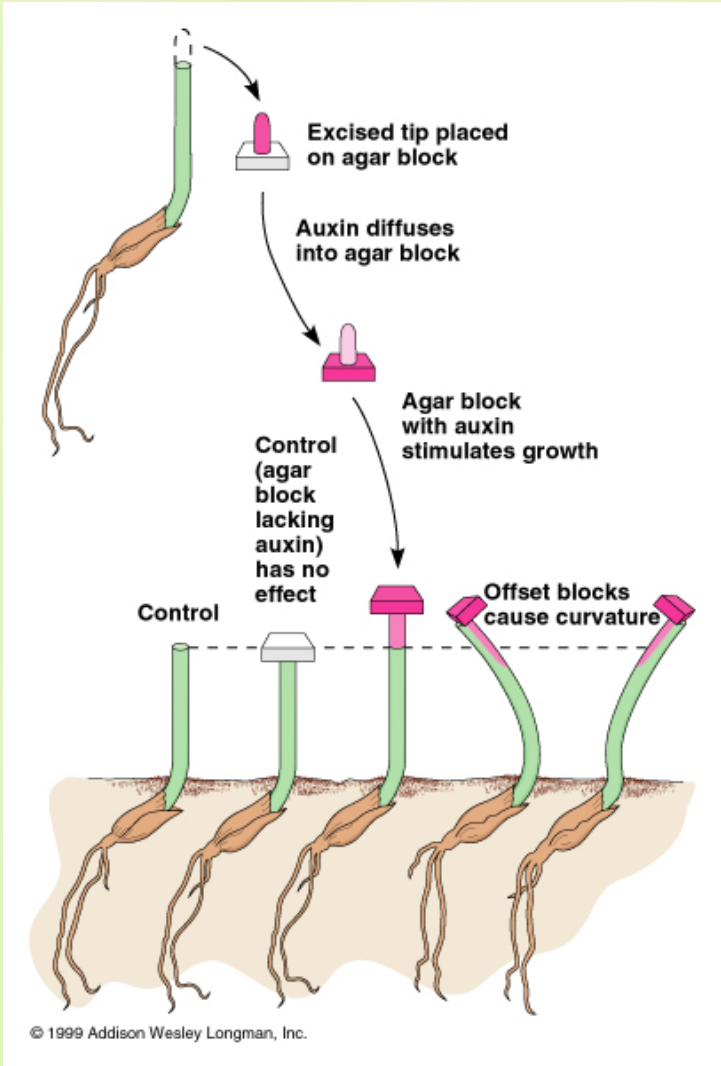
Results on growth of coleoptiles of canary grass and oats suggested that the reception of light in the tip of the shoot stimulated a bending toward light source.

Auxin

- 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.



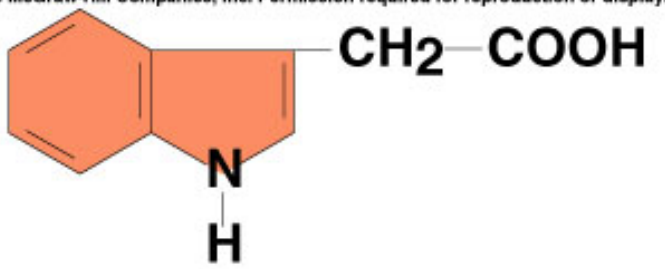
Demonstration of transported chemical



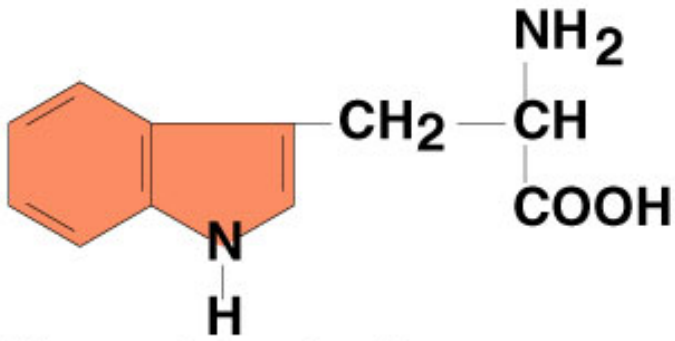
Auxin

- Discovered as substance associated with phototropic response.
- Occurs in very low concentrations.
  - Isolated from human urine, (40mg 33 $gals^{-1}$)
  - In coleoptiles (1g 20,000 $tons^{-1}$)
- Differential response depending on dose.

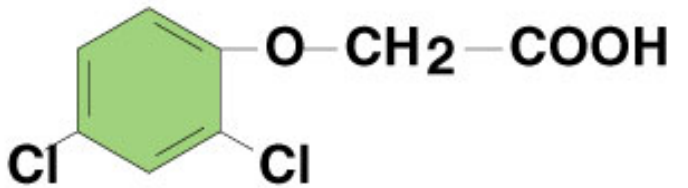
Auxins



(a) IAA (Indoleacetic acid)



(b) Tryptophan

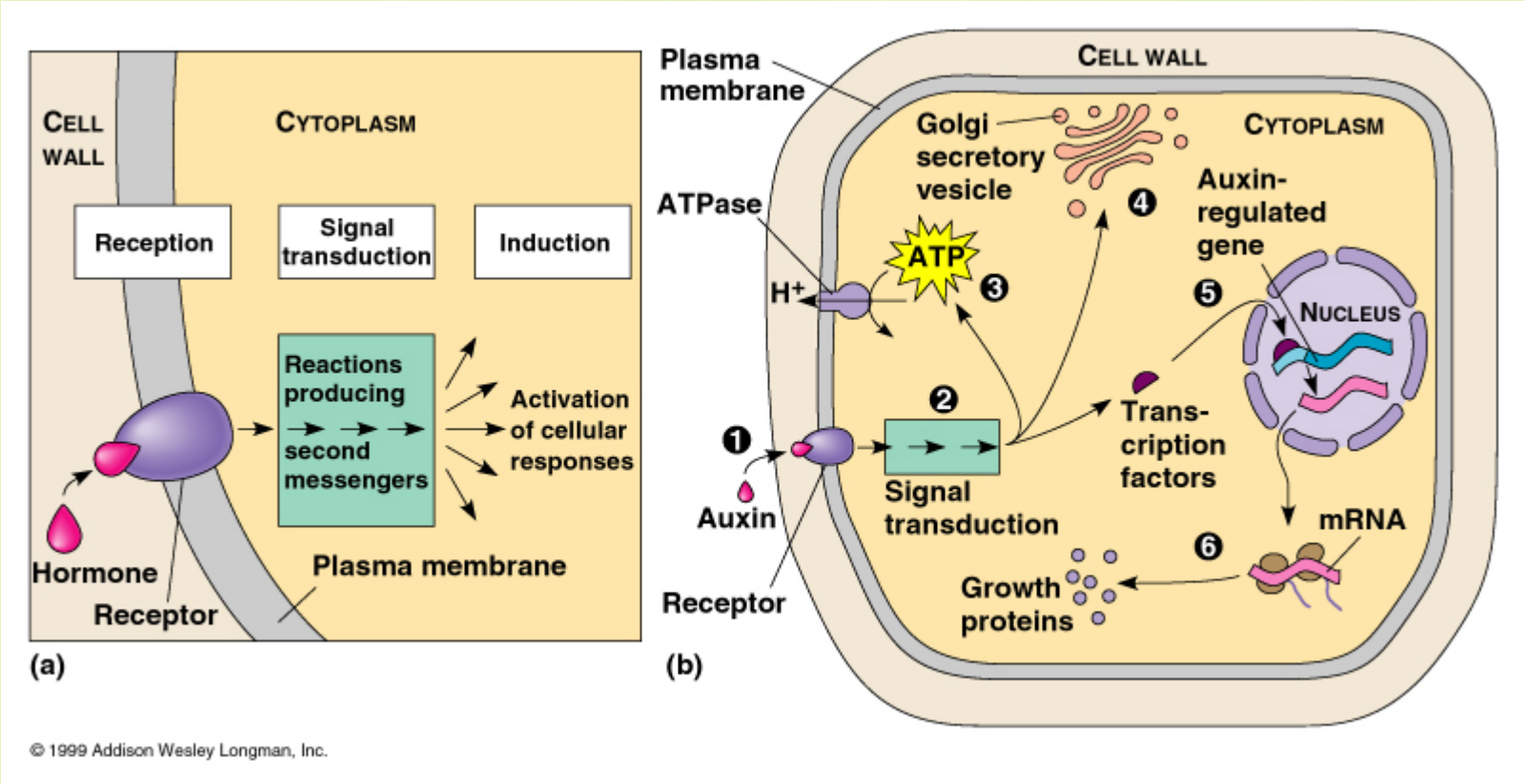


(c) Dichlorophenoxyacetic acid (2,4-D)

Auxin

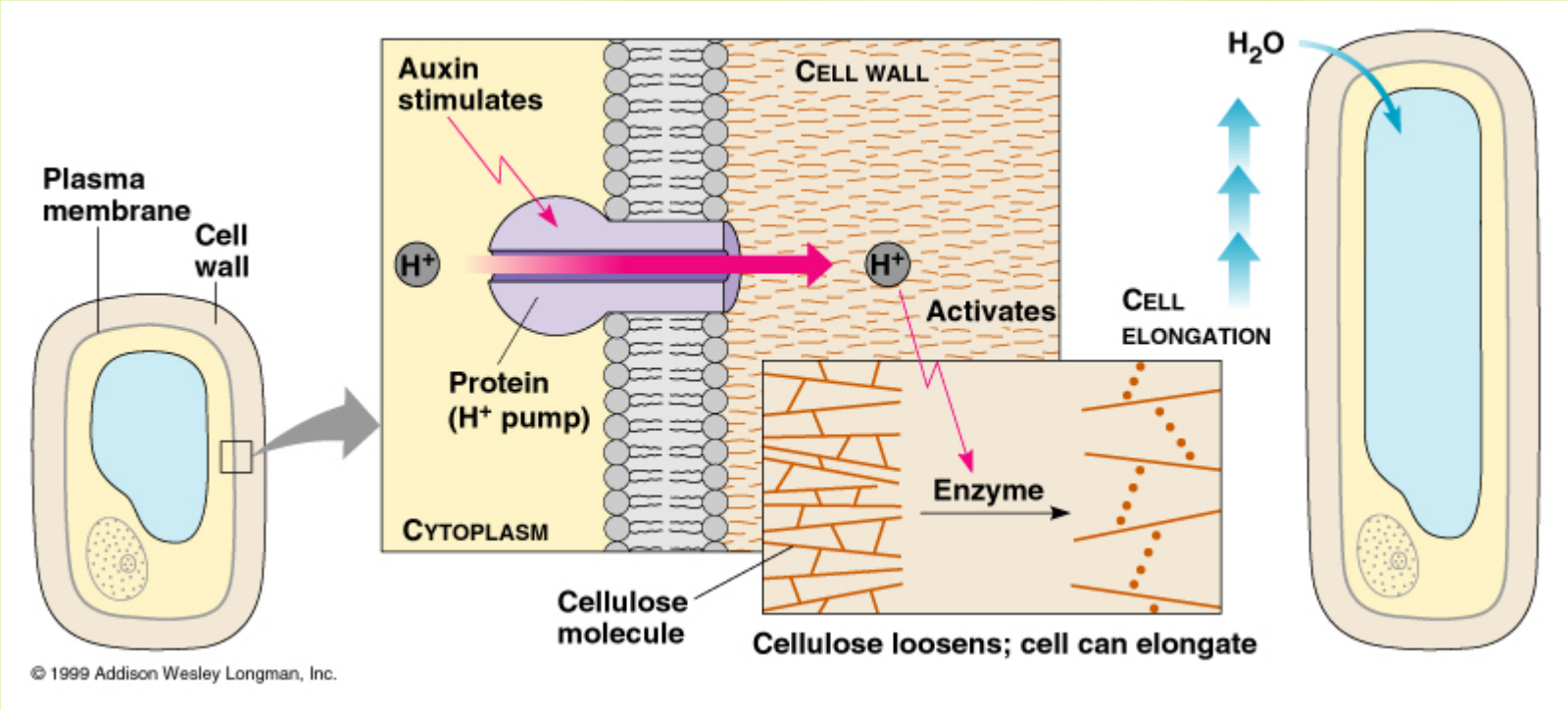
- Auxin promotes activity of the vascular cambium and vascular tissues.
  - plays key role in fruit development
- **Cell Elongation: Acid growth hypothesis**
  - auxin works by causing responsive cells to actively transport hydrogen ions from the cytoplasm into the cell wall space

Signal-transduction pathways in plants

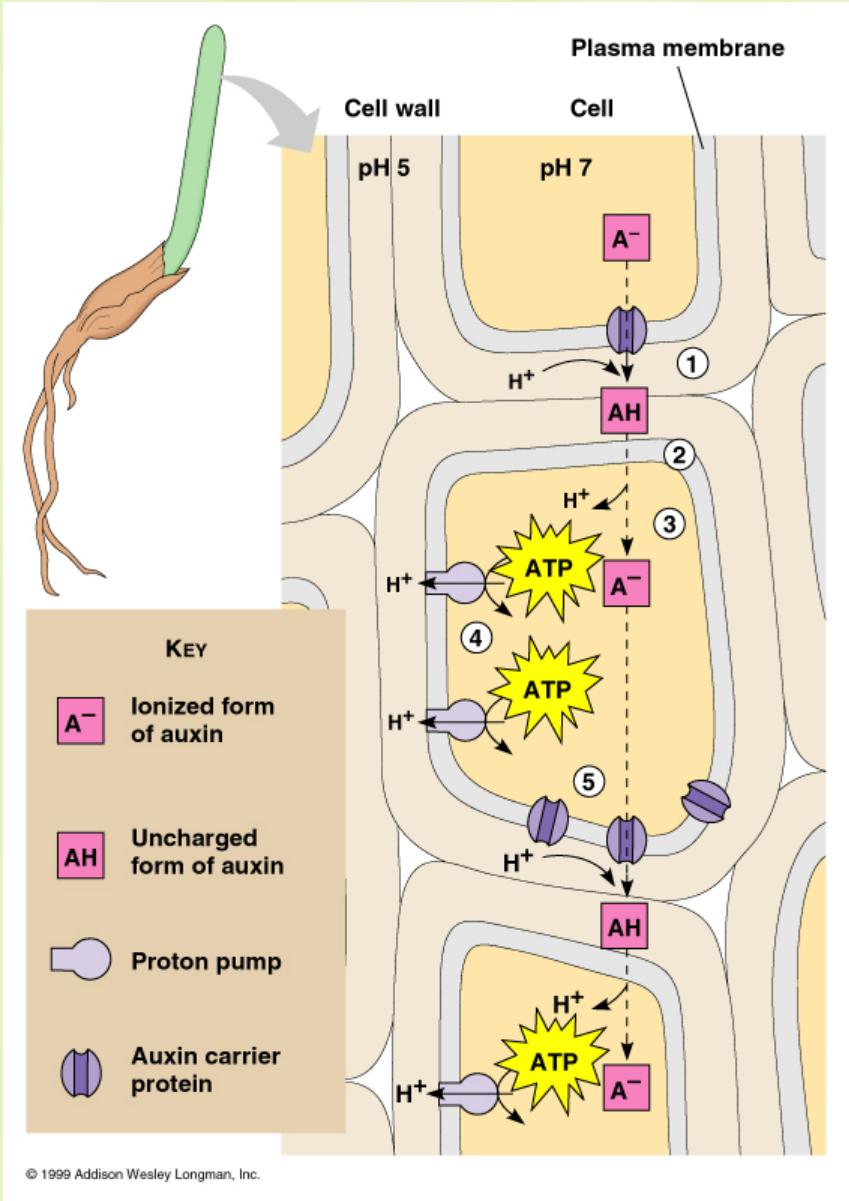


Auxin interacts with calcium ions which in turn calmodulin, a protein, which regulates many processes in plants, animals, and microbes.

Loosening of cell wall



Polar transport of Auxin



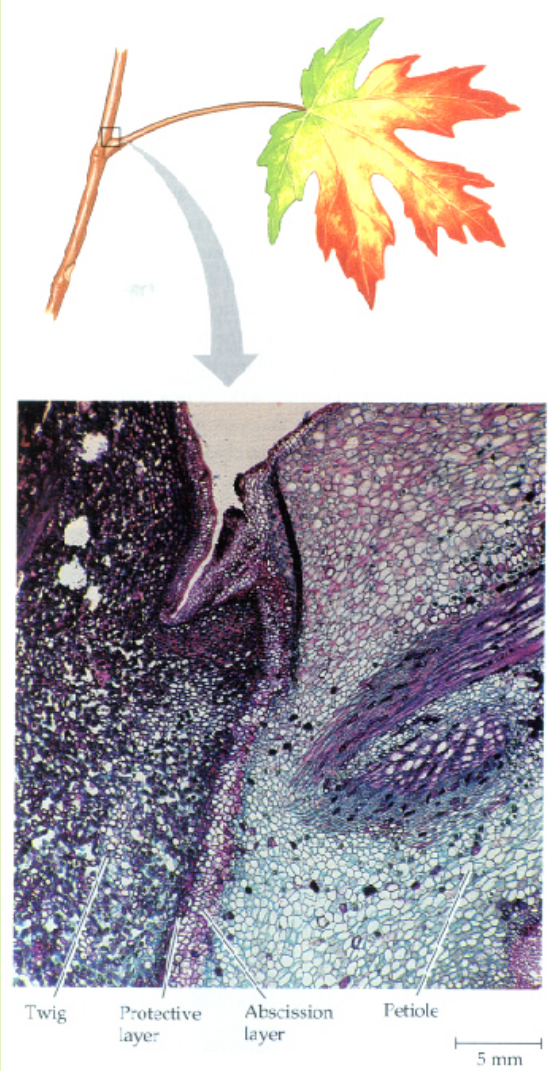
Auxin

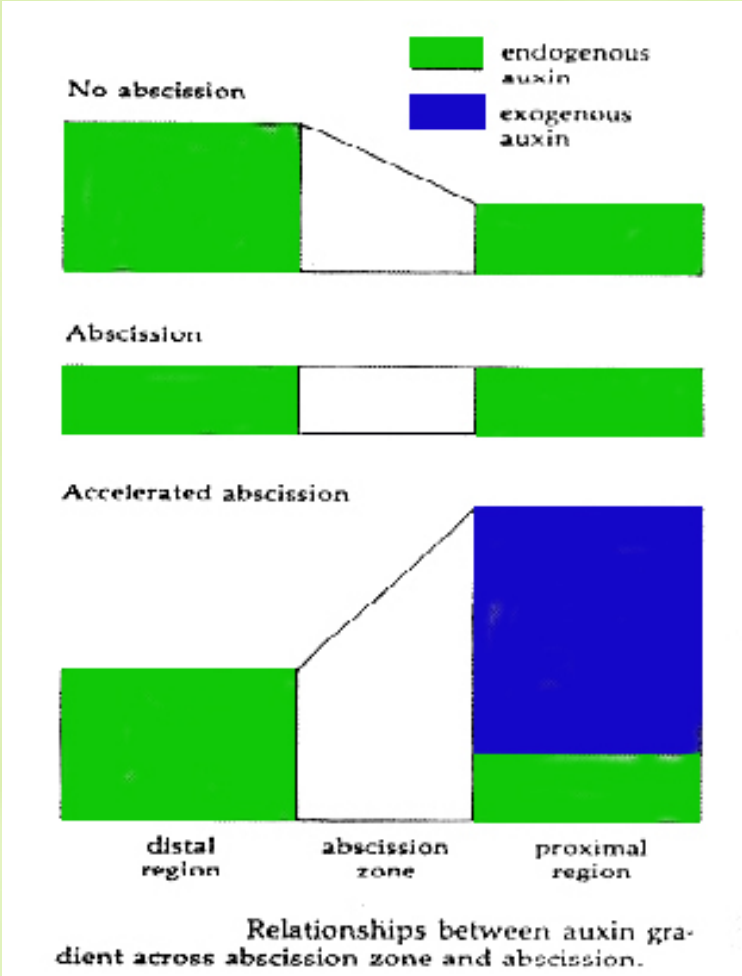
- Synthetic auxins
  - ❖widely used in agriculture and horticulture
    - ❖prevent leaf abscission
    - ❖prevent fruit drop
    - ❖promote flowering and fruiting
    - ❖control weeds
  - ❖Agent Orange - 1:1 ratio of 2,4-D and 2,4,5-T used to defoliate trees in Vietnam War.
    - ❖Dioxin usually contaminates 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
- flower initiation
- sex determination
- fruit development
- apical dominance

Control of abscission by auxin



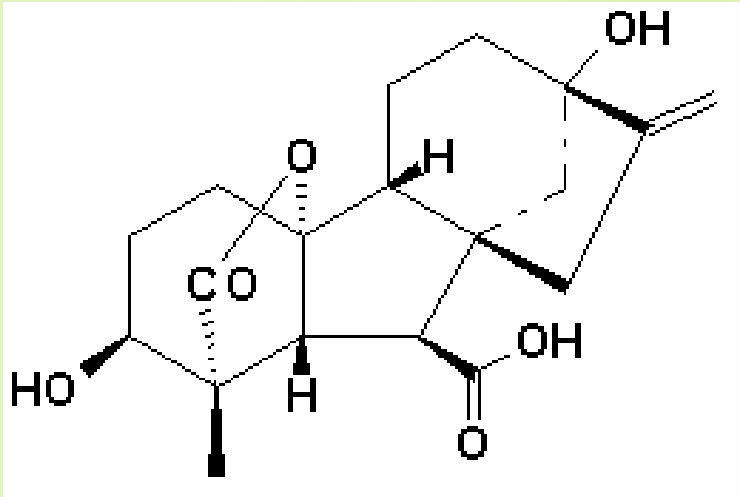


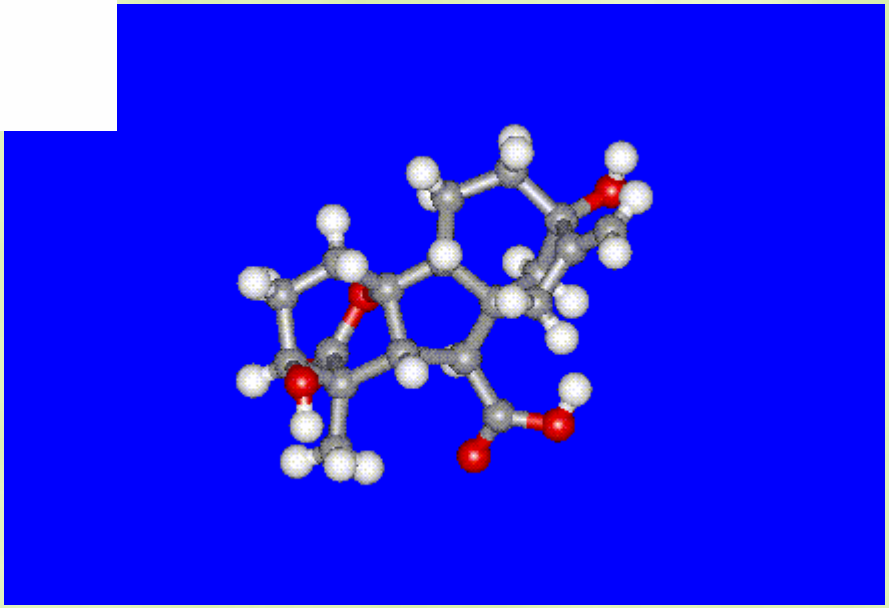
Relationships between auxin gradient across abscission zone and abscission.

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.

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.

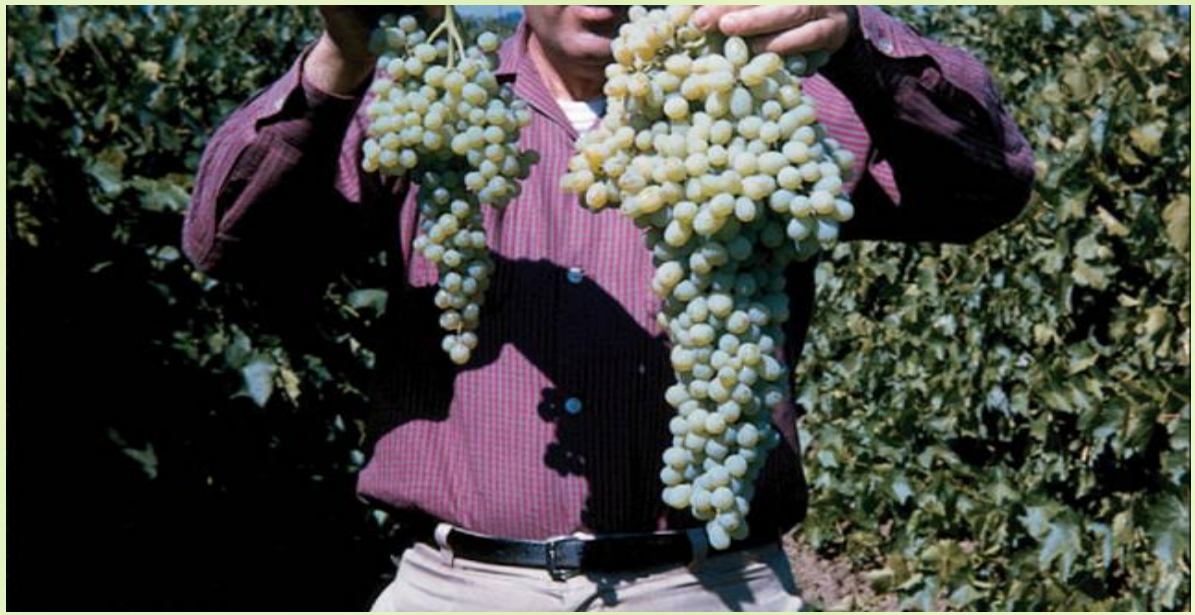
Gibberellins

- 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.
- Promotion of flowering.
- Transport is non-polar, bidirectional producing general responses.

Gibberellins and Fruit Size

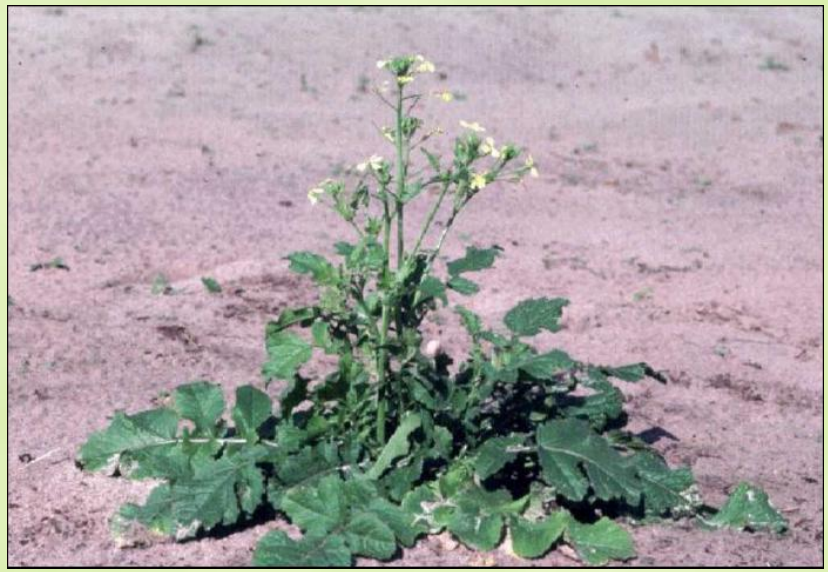


- Fruit Formation - "Thompson Seedless" grapes grown in California are treated with GA to increase size and decrease packing.

Wild Radish – Rosette & Bolt

A FLOWERING ANNUAL

YEAR ONE



YEAR ONE

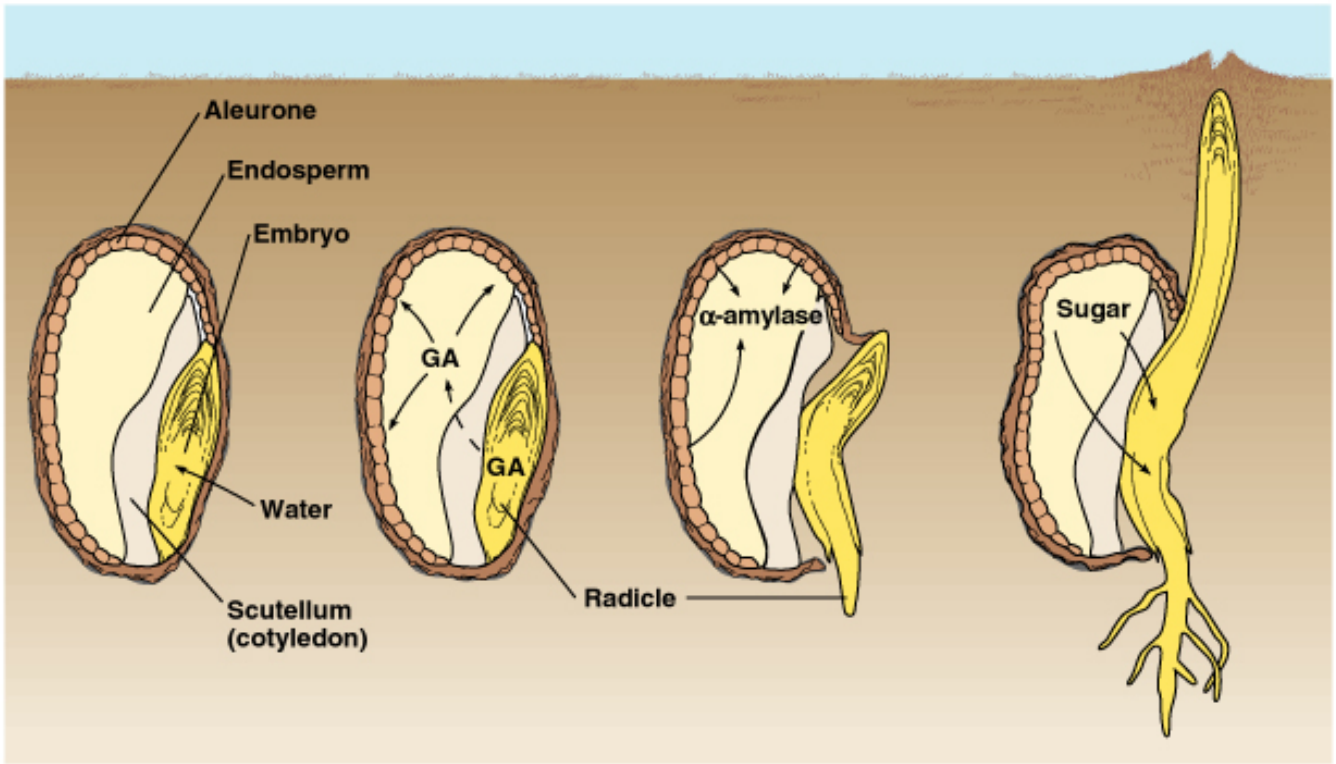
Common Mullen – Rosette & Bolt

A FLOWERING BIENNIAL

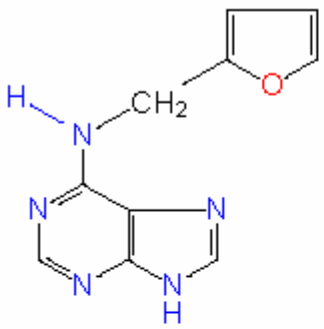
YEAR ONE

YEAR TWO

Mobilization of reserves

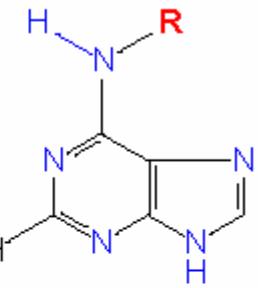


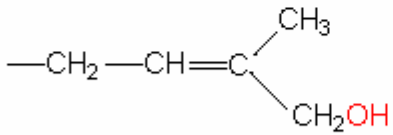
Cytokinins



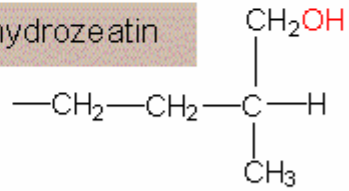
kinetin :
6 - (2 - furfuryl -
7 - amino purine)

cytokinin
(basic structure)

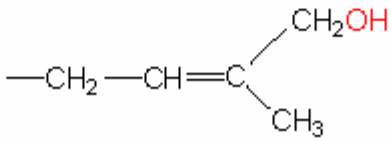




dihydrozeatin



zeatin



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

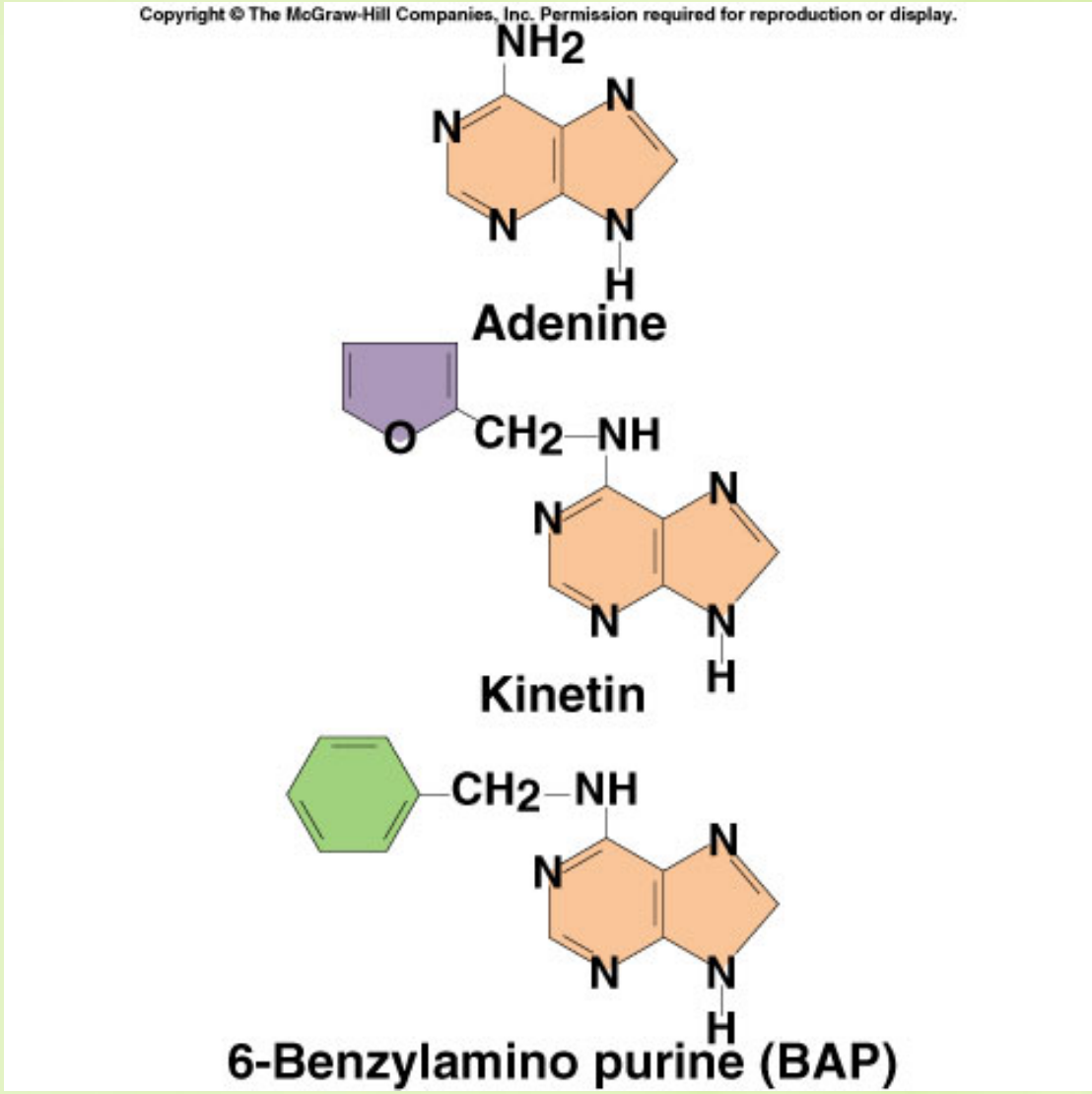
Function of cytokinins

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

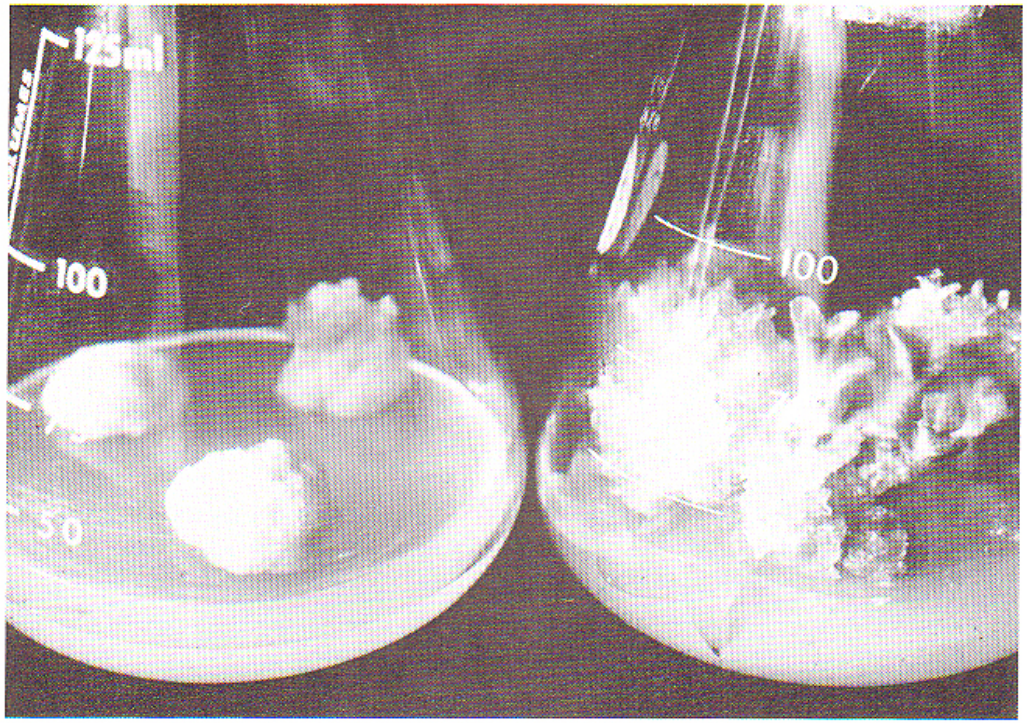
Cytokinins

- Cytokinins, in combination with auxin, stimulate cell division and differentiation.
  - most cytokinin produced in root apical meristems and transported throughout plant
    - inhibit formation of lateral roots
      - auxins promote their formation

Cytokinins



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

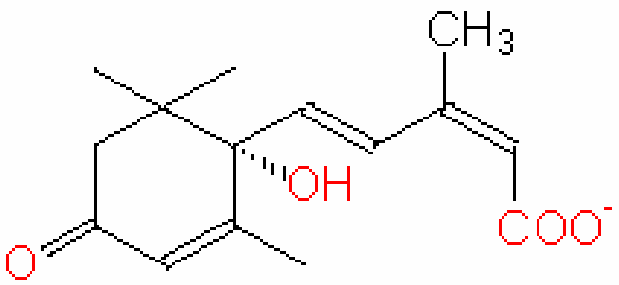


Tissue cultures of tobacco (*Nicotiana tabacum*) callus. By altering cytokinin-to-auxin ratio, tobacco stem pith tissue may be maintained in culture as undifferentiated callus (left) or induced to differentiate and bud into plantlets (right).

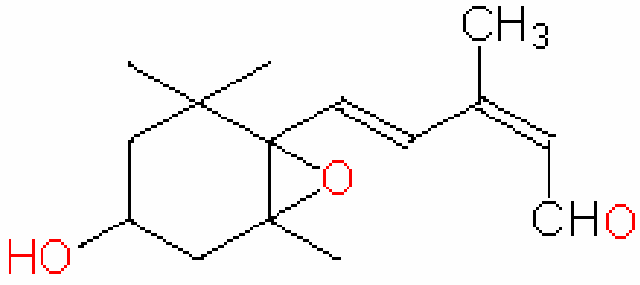
From work of F. Skoog and C.O. Miller. Photo by F.H. Witham.

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

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).

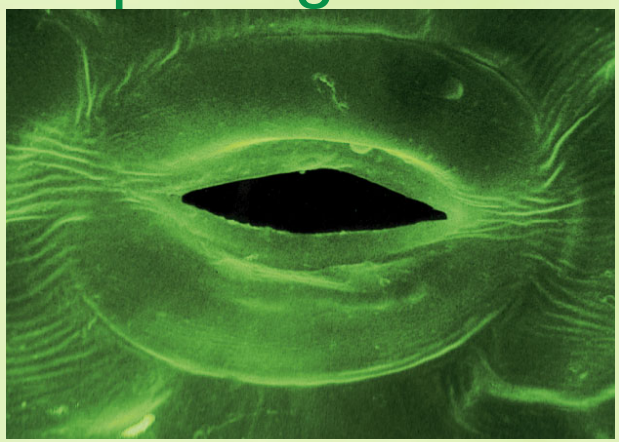
❖Abscisin is made from carotenoids and moves nonpolarly through plant tissue.

Functions of abscisic acid

- General growth inhibitor.
- Causes stomatal closure.
- Produced in response to stress.

Abscisic Acid

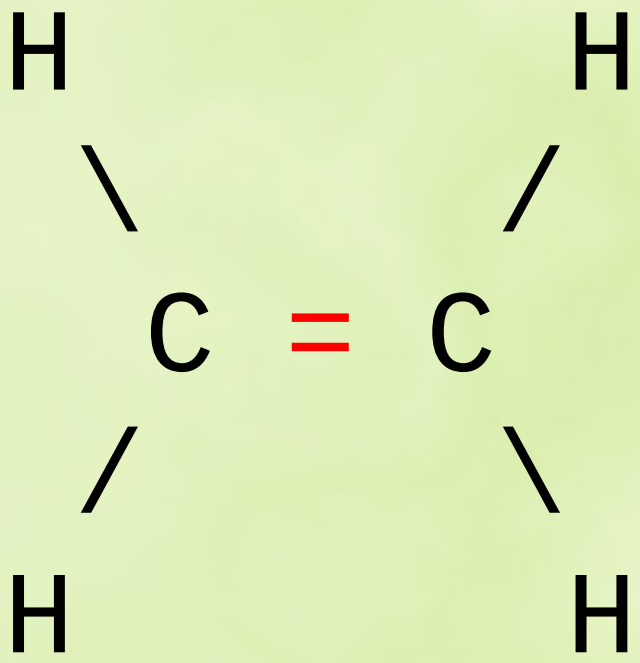
- Abscisic acid is produced chiefly in mature green leaves and in fruits.
  - suppresses bud growth and promotes leaf senescence
  - also plays important role in controlling stomatal opening and closing



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



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.

HOW PLANTS RESPOND TO ENVIRONMENTAL STIMULI

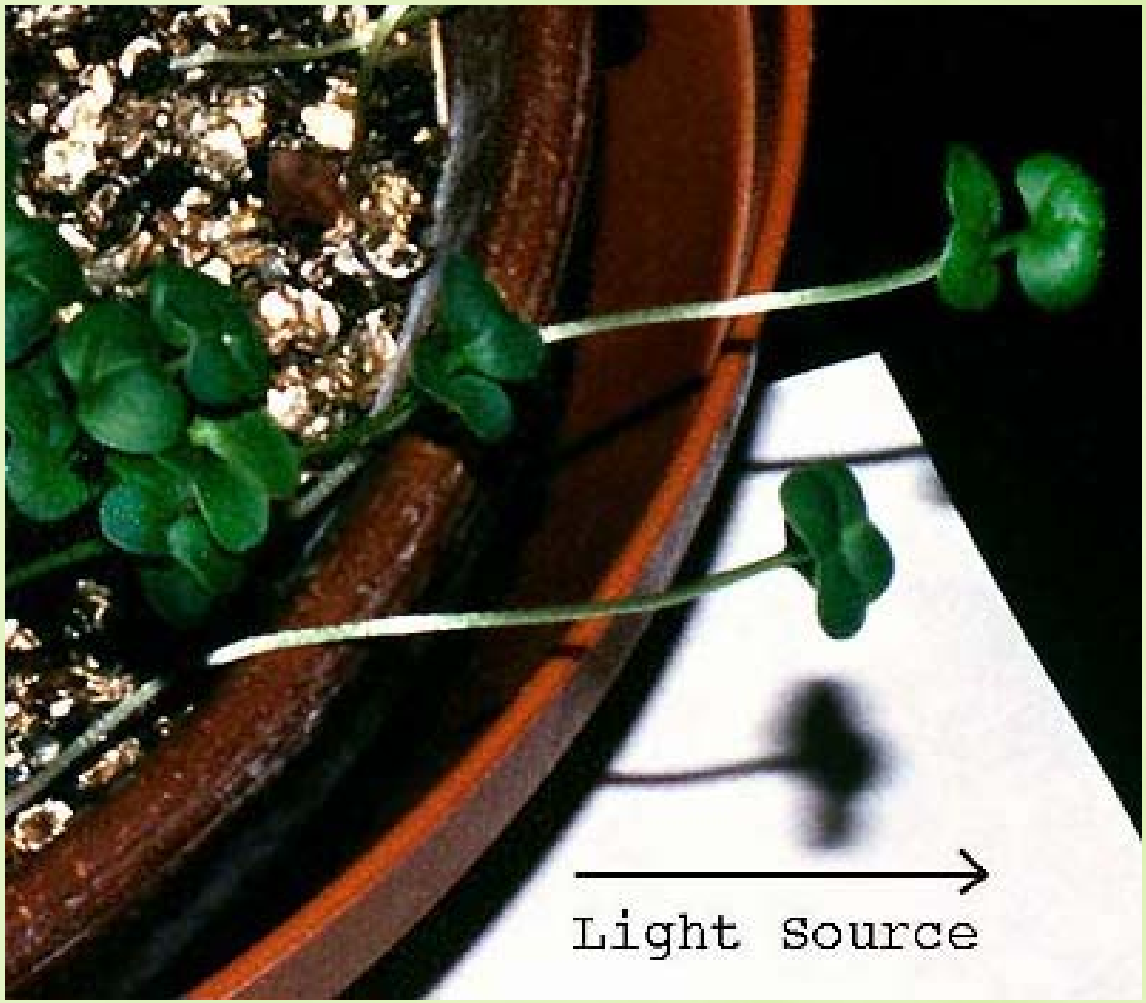
- **Tropisms - plant growth toward or away from a stimulus such as light or gravity.**

- **Nastic Movements - response to environmental stimuli that are independent of the direction of the stimulus. Pre-determined response.**

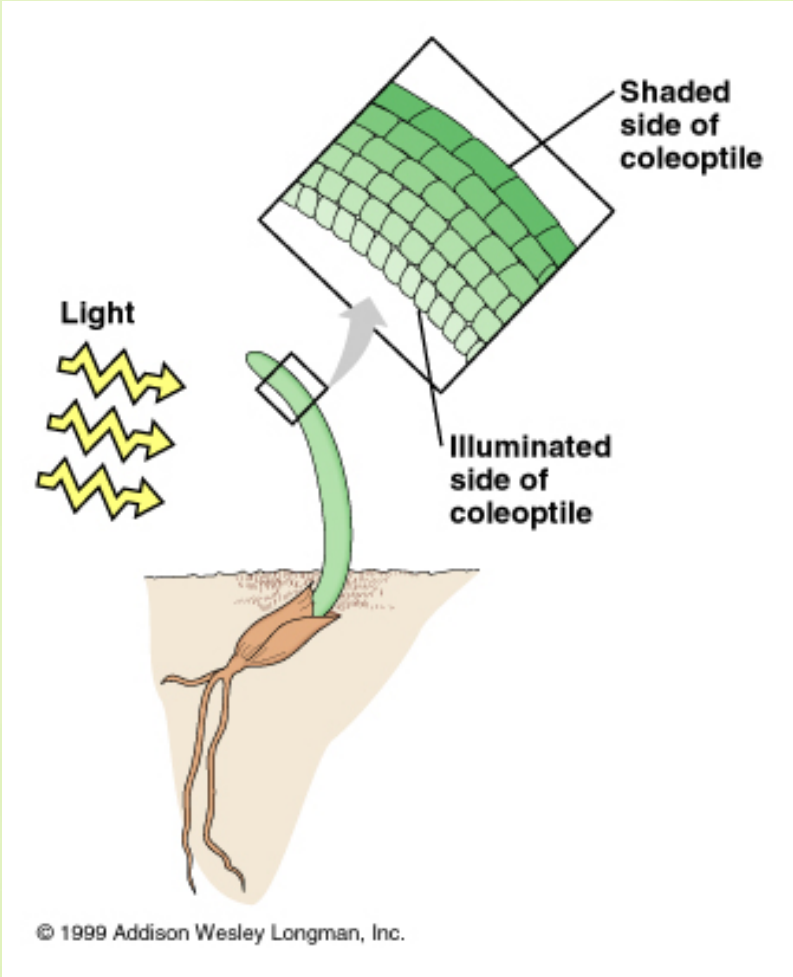
Tropic responses

Directional movements by growth in response to a directional stimulus

Phototropism

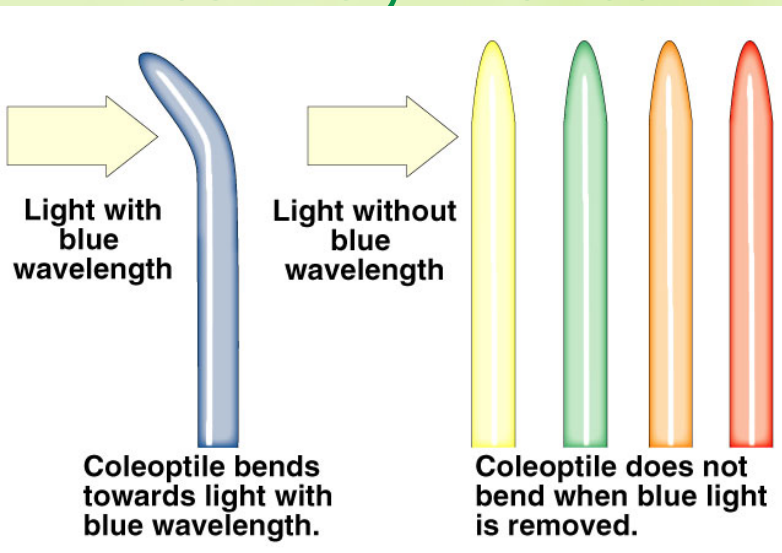


Growth movement



Phototropisms

- Phototropic responses involve bending of growing stems toward light sources.
  - Individual leaves may also display phototrophic responses.
    - auxin most likely involved



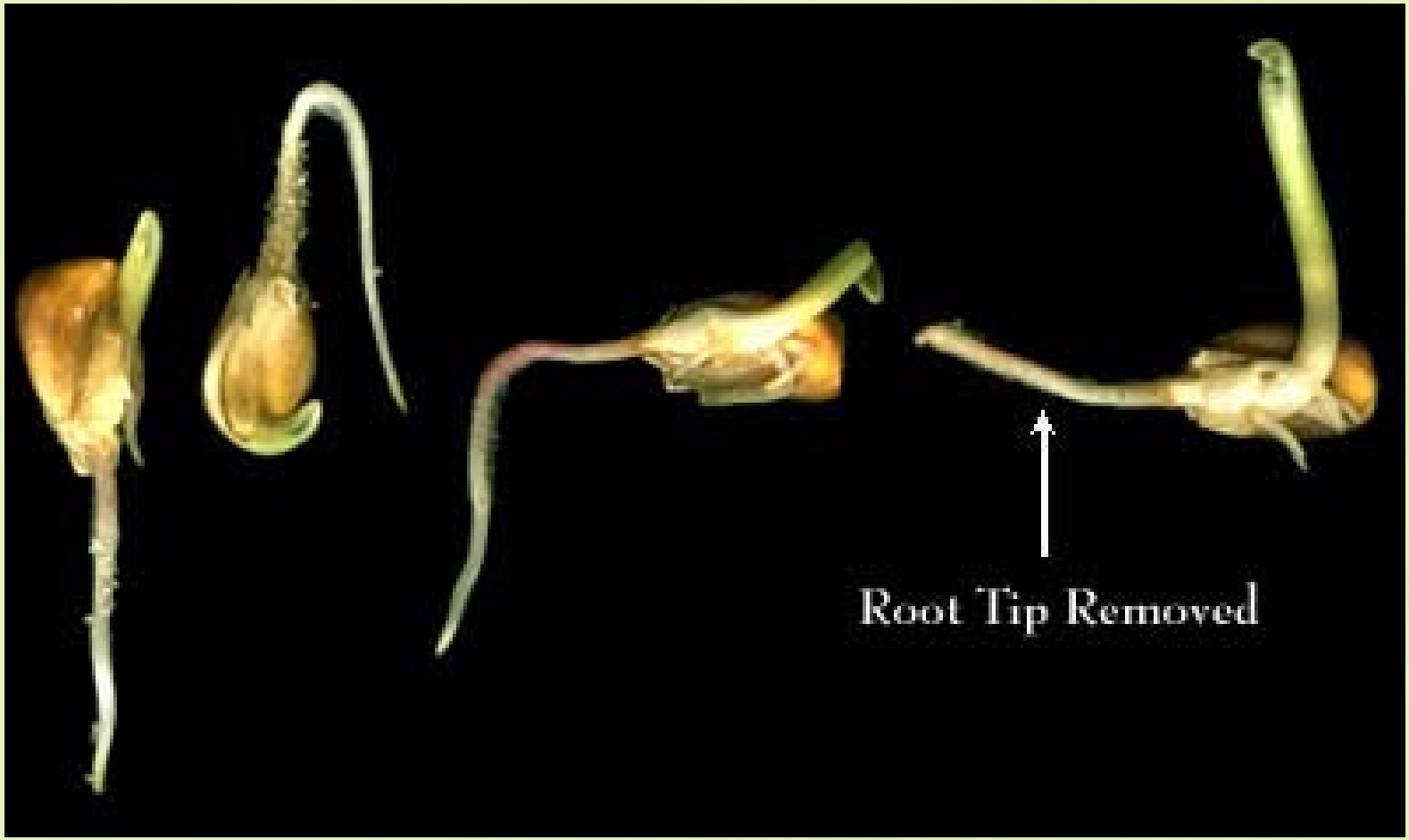
Plants Respond to Gravity

- Gravitropism is the response of a plant to the earth's gravitational field.
  - present at germination
    - auxins play primary role
  - Four steps
    - gravity perceived by cell
    - signal formed that perceives gravity
    - signal transduced intra- and intercellularly
    - differential cell elongation

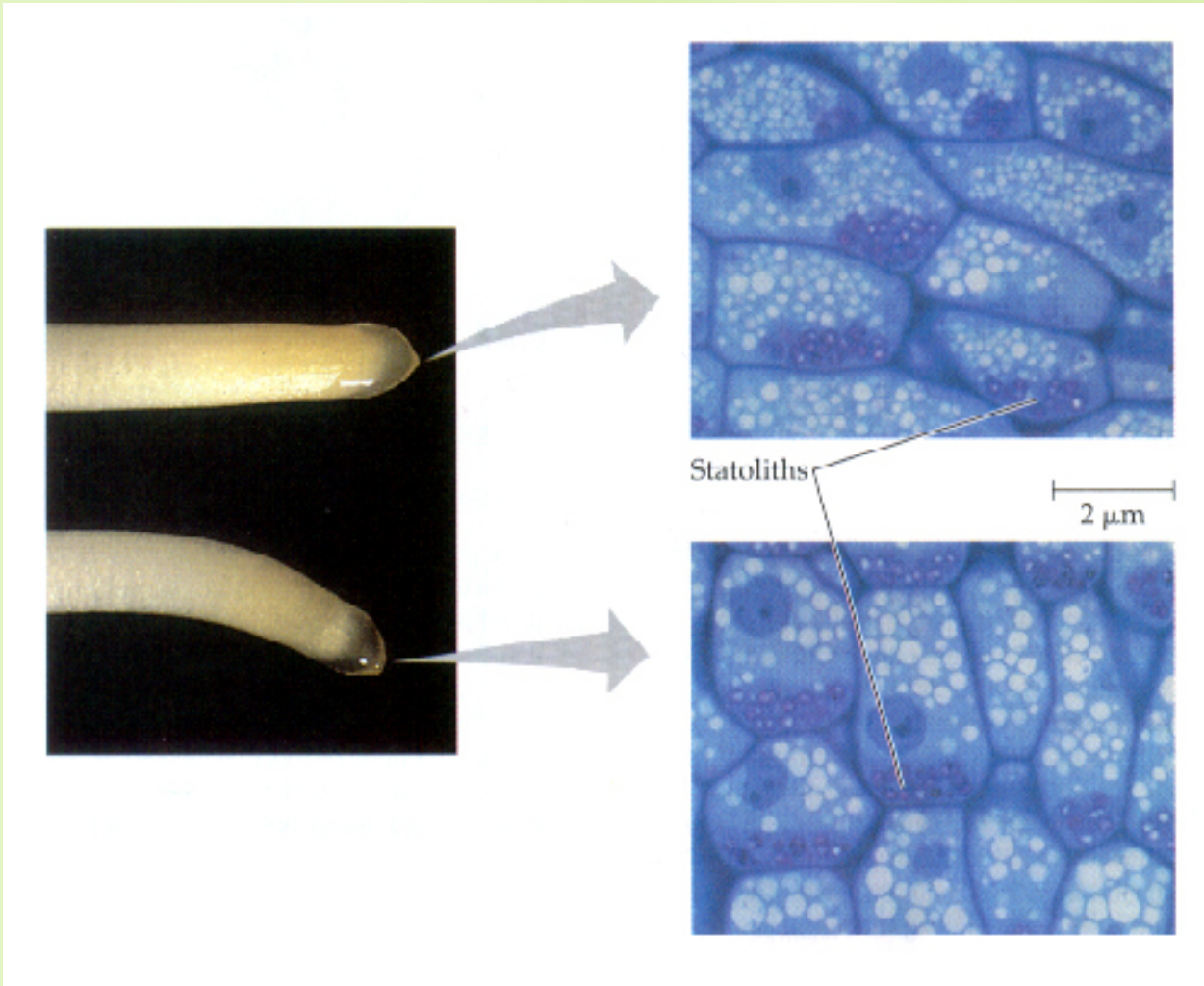
Gravitropism

- 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 oriented horizontally grow more rapidly than the lower side
  - roots ultimately grow downward
    - positive gravitropism

Gravitropism = Geotropism



Statoliths



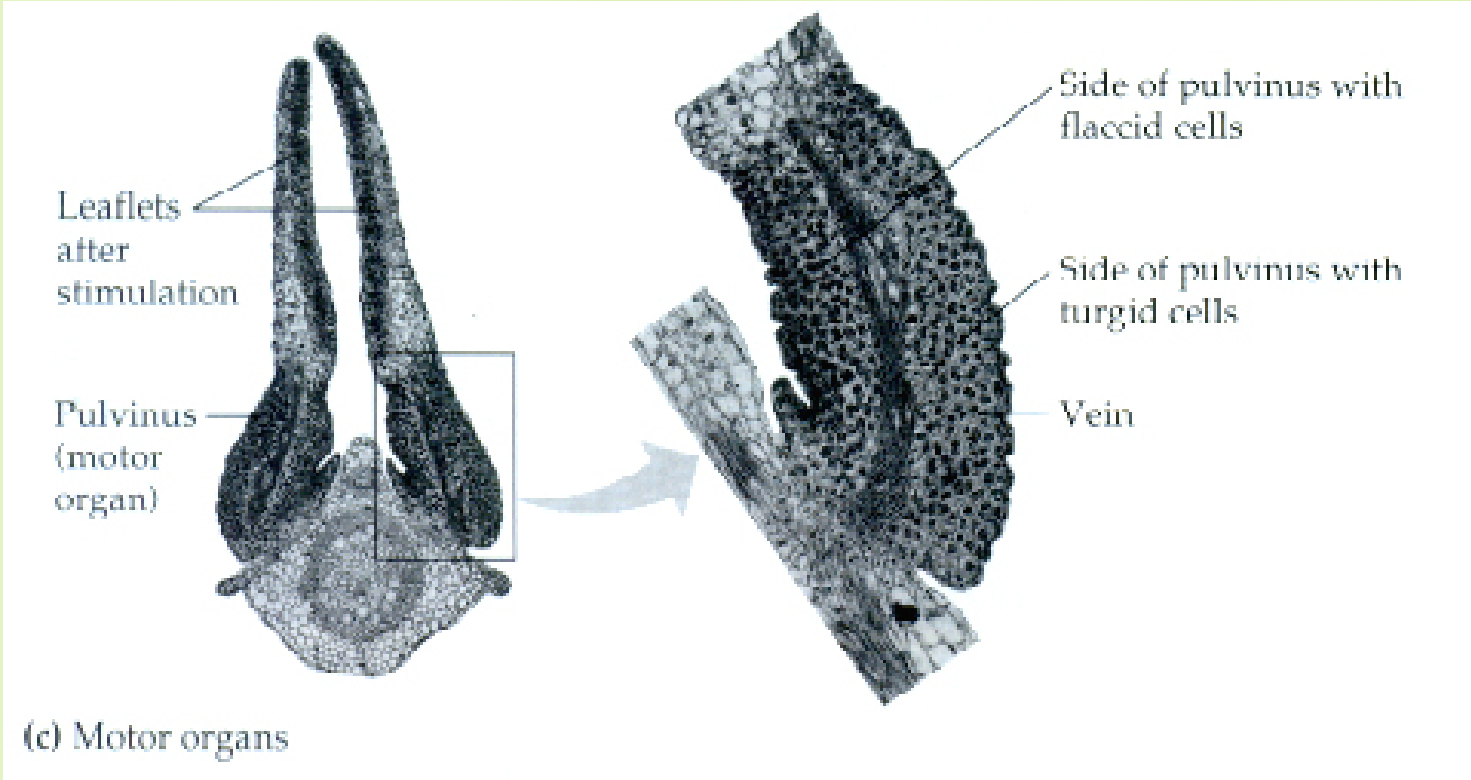
Plants Respond to Touch

- Thigmotropism is directional growth response to contact with an object.
  - tendrils

Thigmotropism

SEISMONASTY - a nastic response resulting from contact or mechanical shaking *Mimosa pudica* L. (sensitive plant)

Pulvinus of *Mimosa pudica*



Plants Response to Light

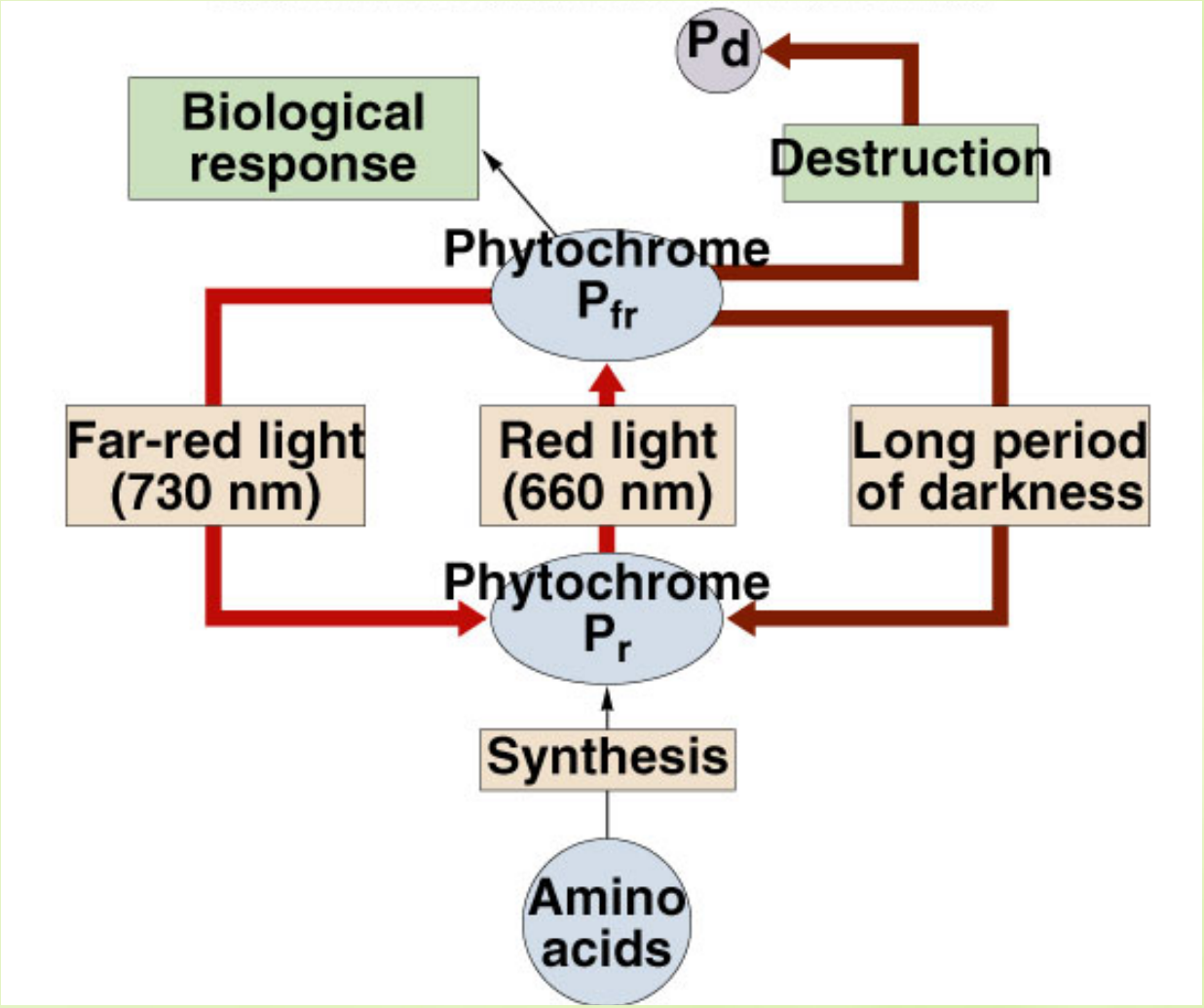
- Photomorphogenesis
  - nondirectional, light-mediated changes in plant growth and development
    - red light changes the shape of phytochrome and can trigger photomorphogenesis
    - Stems go from etiolated (in dark or Pfr) to unetiolated (in light with Pr).
- Photoperiodism
  - Regulates when seeds of lettue and some weeds. Presence of Pr inhibits germination, while its conversion to Pfr in red light induces germination

    Red light ===> germination
    Far-red light ===> no germination
    Red ===> far-red ===> red ===> germination
    Red ===> far-red ===> red ===> far-red ===> no germination

    Those seeds not buried deep in the ground get exposed to red light, and this signals germination.

  - Regulates when plants flower; either in the Spring or later in the Summer and Fall.

How Phytochrome Works



NYCTINASTY

- **sleep movements**
- **prayer plant - lower leaves during the day and raises leaves at night**
- **shamrock (*Oxalis*)**
- **legumes**

Credit:(http://employees.csbsju.edu/ssaupe/biol327/Lab/movie/movies.htm)

Circadian Clocks

- Circadian clocks are endogenous timekeepers that keep plant responses synchronized with the environment.
  - circadian rhythm characteristics
    - must continue to run in absence of external inputs
    - must be about 24 hours in duration
    - can be reset or entrained (to determine or modify the phase or period of <circadian rhythms *entrained* by a light cycle>)
    - can compensate for temperature differences