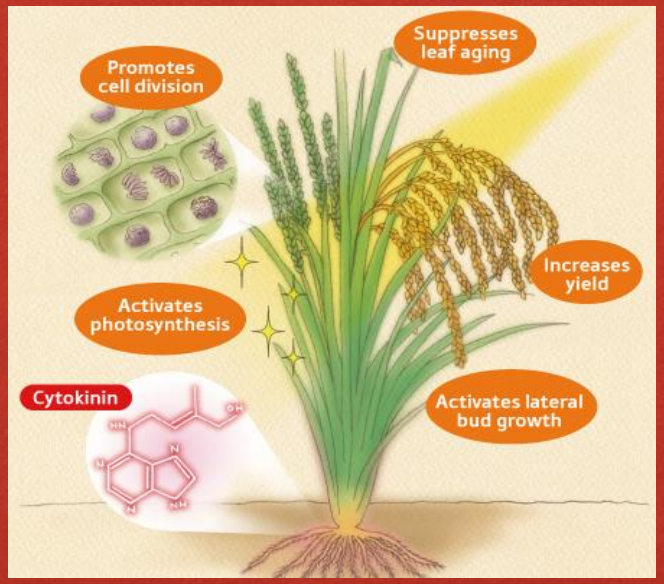
Lecture 5

Plant Hormones



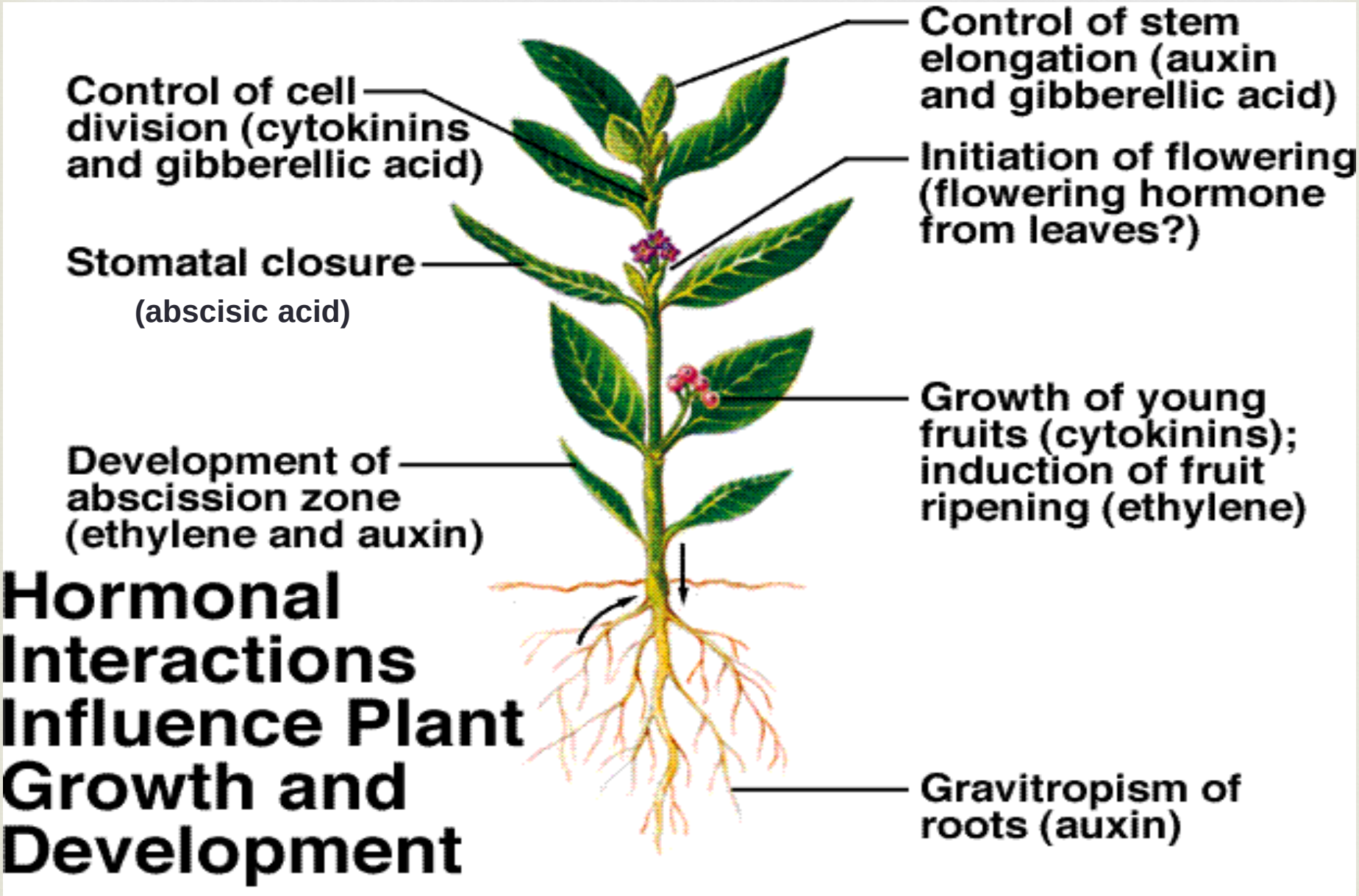
SUBTOPICS

- Definition
- Characteristics
- Classification
- Plant Hormones Actions

Definition

- They are various organic compounds other than nutrients produced by plants that control or regulate germination, growth, metabolism, or other physiological activities.
- Also called phytohormone and recently called growth bioregulators.

Plant Hormones & Growth



Definition

- Plant hormones, which are active in very low concentrations, are produced in certain parts of the plants and are usually transported to other parts where they elicit specific biochemical, physiological, or morphological responses.
- They are also active in tissues where they are produced.

Definition

- Each plant hormone evokes many different responses. Also, the effects of different hormones overlap and may be stimulatory or inhibitory.
- The commonly recognized classes of plant hormones are the auxins, gibberellins, cytokinins, abscisic acid, and ethylene.
- Some evidence suggests that flower initiation is controlled by hypothetical hormones called florigens, but these substances remain to be identified.
- A number of natural or synthetic substances such as brassin, morphactin, and other growth regulators not considered to be hormones nevertheless influence plant growth and development.

Definition

- Each hormone performs its specific functions; however, nearly all of the measurable responses of plants to heredity or environment are controlled by interaction between two or more hormones.
- Such interactions may occur at various levels, including
  a. The synthesis of hormones,
  b. Hormone receptors, and second messengers,
  c. Ultimate hormone action.
- Furthermore, hormonal interactions may be cooperative, antagonistic, or in balance.

Definition

- Plant hormones (or plant growth regulators, or PGRs) are internally secreted chemicals in plants that are used for regulating the plants' growth.
- According to a standard definition, plant hormones are:

Signal molecules produced at specific locations, that occur in very low concentrations, and cause altered processes in target cells at other locations.

Characteristics

- The concentration of hormones required for the plant response is very low(10^{-6} to 10^{-5}M), comparing with the requirement of mineral and vitamin for plants.
- The synthesis of plant hormones is more diffuse and not always localized.

Classification

Classes of Plant Hormones :

- It is accepted that there are two major classes of plant hormones:

Class	Action	Examples
Promoters-	Cause faster growth	Auxins Cytokinins(cks) Gibberellins (gas) Brassinosteroids
Inhibitors-	Reduce growth	Ethylene Abscisic acid (ABA) Jasmonic acid

What do hormones control in plants?

- Roots and shoots growth
- Seed germination
- Leaf fall
- Disease resistance
- Fruit formation and ripening
- Flowering time
- Bud formation
- Anything related to plant growth!

Table 11.1 Plant Hormones (1 of 2)

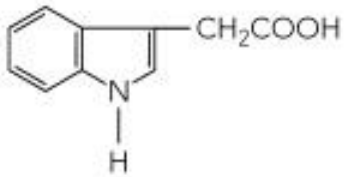
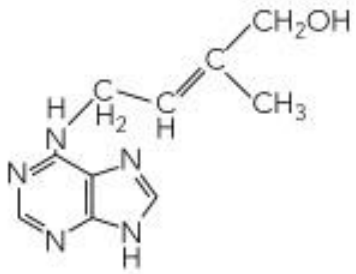
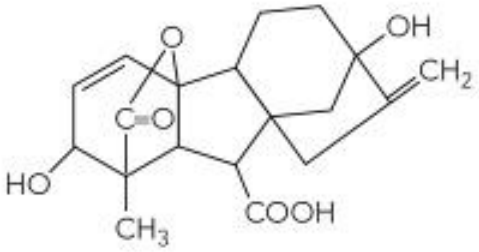
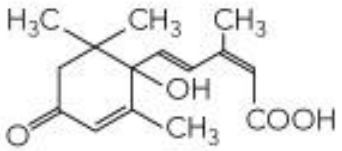
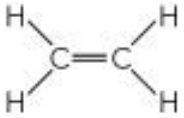
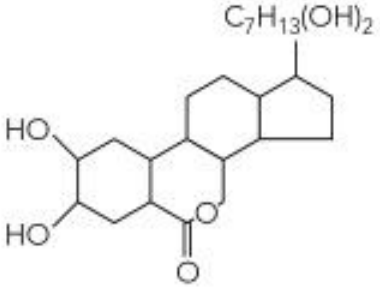
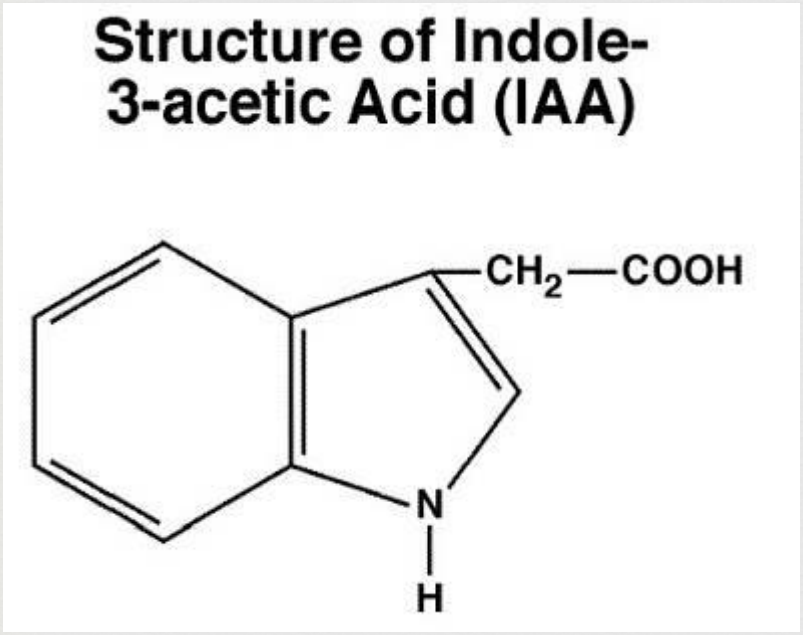
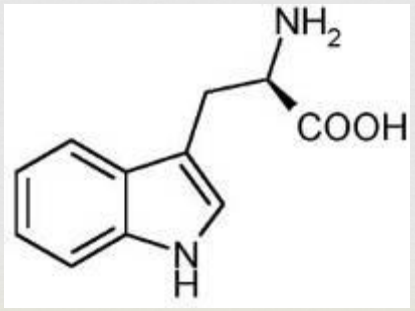
Hormone		Where synthesized in plants	Major functions
Auxins (Example shown: IAA)		Embryos, meristems, buds, young leaves	Stimulates stem and root growth; promotes cell differentiation in tissue culture and in procambium; regulates development of fruit; apical dominance; causes phototropism and gravitropism
Cytokinins (Example shown: zeatin)		Roots	Promotes root growth and differentiation; stimulates cell division and growth in tissue culture; stimulates germination; retards aging
Gibberellins (Example shown: GA_3)		Meristems, young leaves, embryos	Promotes seed germination and bud growth; promotes stem elongation and leaf growth; stimulates flowering and fruit development

Table 11.1 Plant Hormones (2 of 2)

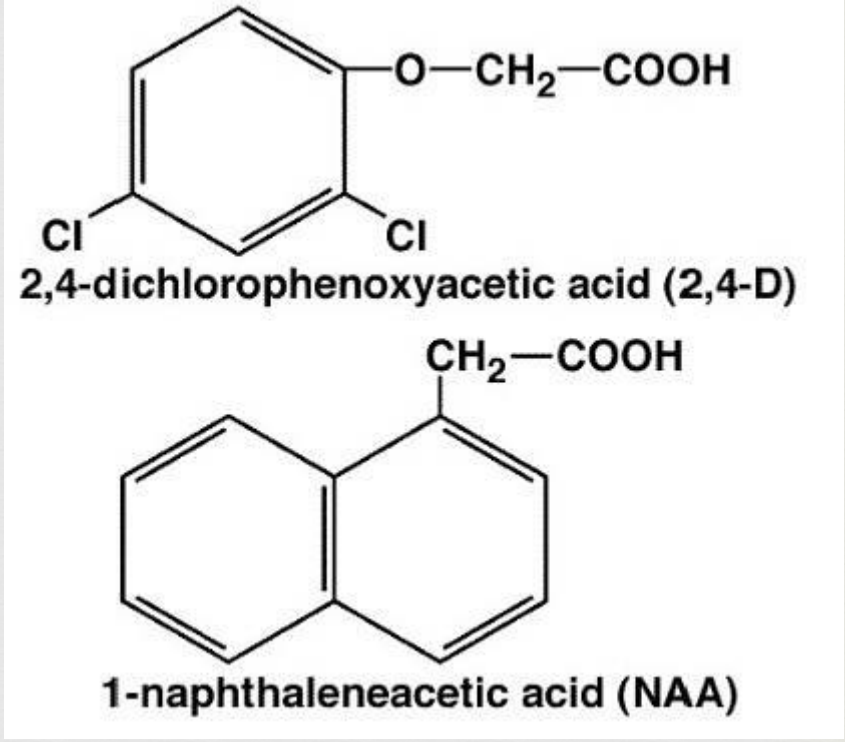
Hormone		Where synthesized in plants	Major functions
Abscisic acid (ABA)		Leaves, stems, roots, fruits	Inhibits growth; closes stomata during water stress; promotes dormancy
Ethylene		Ripening fruits, aging leaves and flowers	Promotes ripening of some fruits and thickening of stems and roots
Brassinosteroids (Example shown: brassinolide)		Seeds, fruits, shoots, leaves, and flower buds	Auxin-like effects; inhibits root growth; retards leaf abscission; promotes xylem differentiation

Auxins





tryptophan

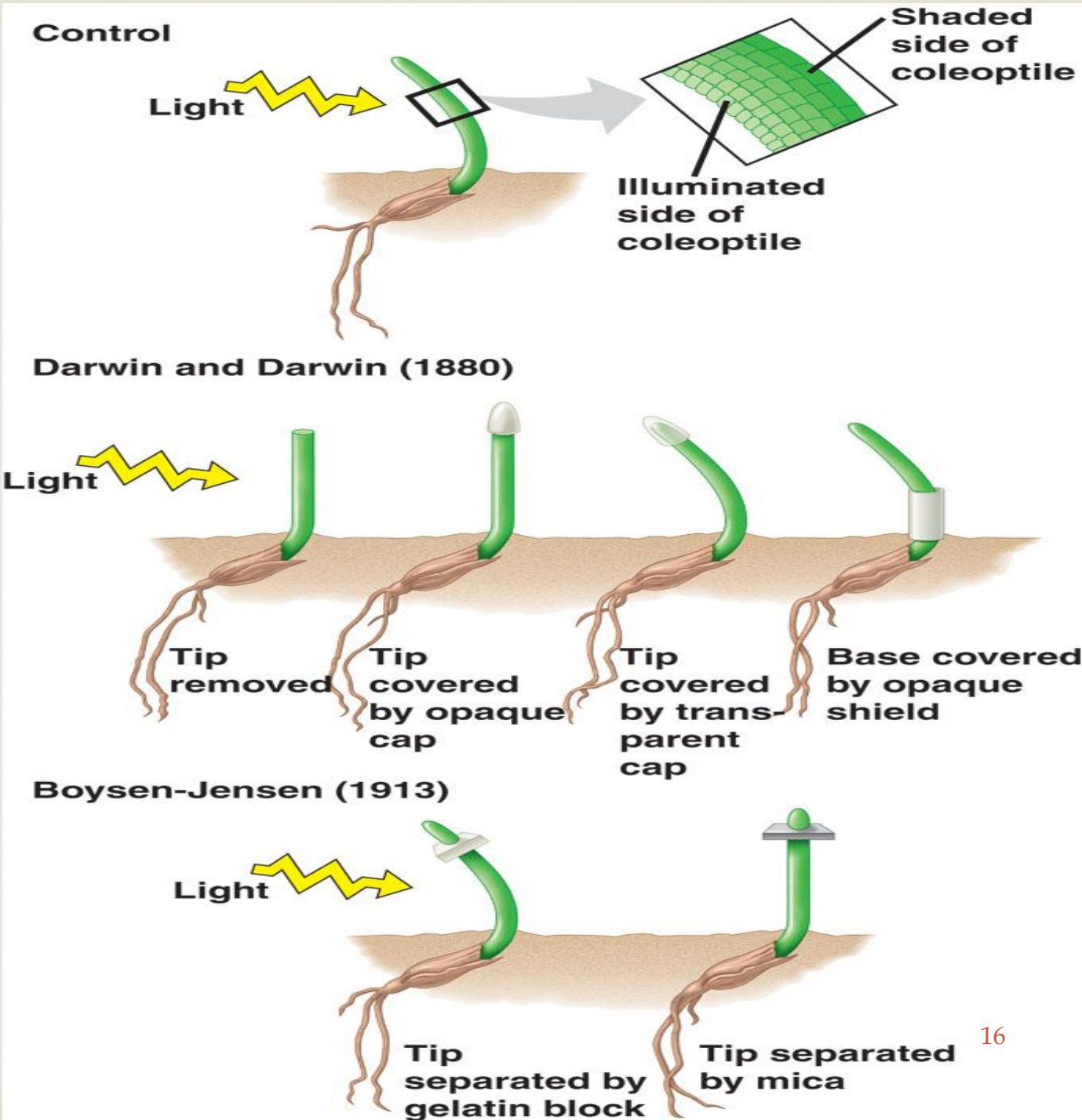


Auxins

Introduction:

- Auxin is a general name for a group of hormones that are involved with growth responses (i.e., elongate cells, stimulate cell division in callus).
- Not surprisingly, the term "auxin" is derived from the Greek word "to increase or grow".
- This was the first group of plant hormones discovered.

Discovery of Auxins:



Auxins

Site

- Auxin is made in actively growing tissue which includes young leaves, fruits, and especially the shoot apex.
- Made in cytosol of cells .

Auxins

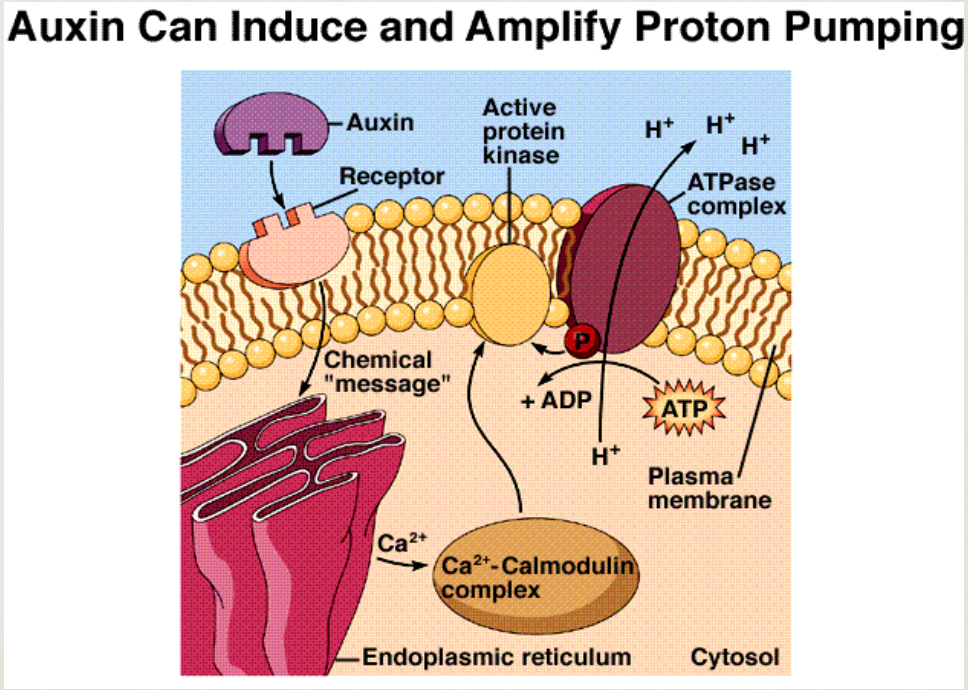
Transport :

- Basipetal (or Polar) Transport Auxin is transported in a basipetal (towards the base, base-seeking) direction.
- In other words, auxin moves from the shoot tip towards the roots and from the root tip towards the shoot.

Auxin Actions

1. Cellular Elongation:

- Auxin can induce and amplify proton pumping.
- Acidified cell walls have increased elasticity which lead to cell elongation.



Auxin Actions

2. Cell differentiation

Auxin promotes differentiation of vascular tissue (i.e., xylem & phloem):

- Auxin and sugar -----> Vascular tissue
- Auxin and low sugar (1.5 - 2.5%) -----> Xylem
- Auxin and high sugar (4%) ------->- Phloem
- Auxin and moderate levels of sugar (2.5 - 3.0%) ----->- Xylem & Phloem

Auxin Actions

3. Ethylene production

- IAA apparently stimulates the production of ethylene.

4. Inhibition of root growth

- [IAA] > 10^{-6} M inhibit root elongation.
- However, very low [IAA] (>10^{-8} M) favor root elongation.

5. Stimulate root initiation (lateral roots, adventitious roots)

- Roots always form at the basal end of cutting

Auxin Actions

Formation of adventitious roots

Auxin Actions

6. Flowering

- Although most plants don't initiate the production of flowers after auxin treatment, pineapple and its relatives (Bromeliaceae) do.
- Once flowers are initiated, in many species, IAA promotes the formation of female flowers.

Auxin Actions

7. Parthenocarpic fruit development

- Pollination of the flowers of angiosperms initiates the formation of seeds.
- As the seeds mature, they release auxin to the surrounding flower parts, which develop into the fruit that covers the seeds.
- Some commercial growers deliberately initiate fruit development by applying auxin to the flowers. Not only does this ensure that all the flowers will "set" fruit, but it also maximizes the likelihood that all the fruits will be ready for harvest at the same time.

Auxin Actions

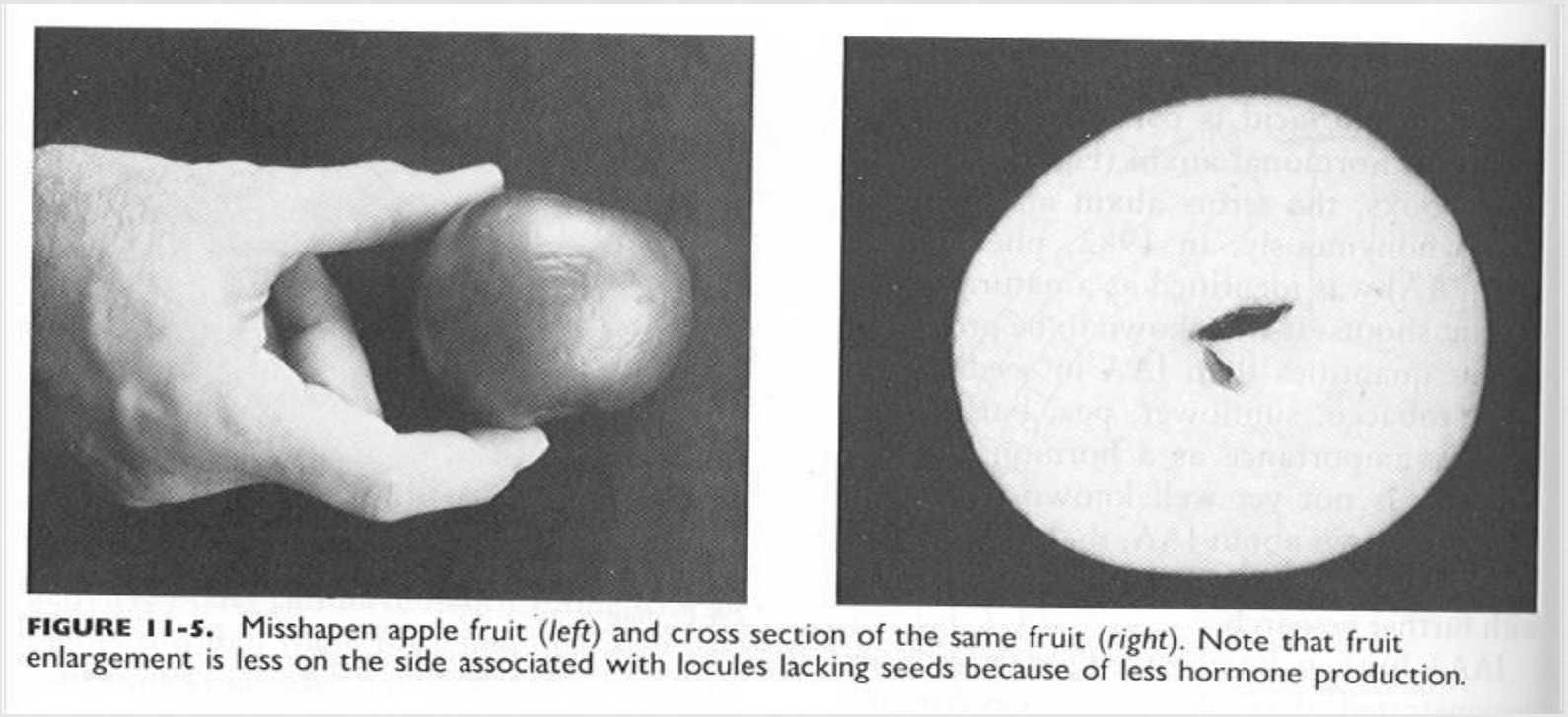


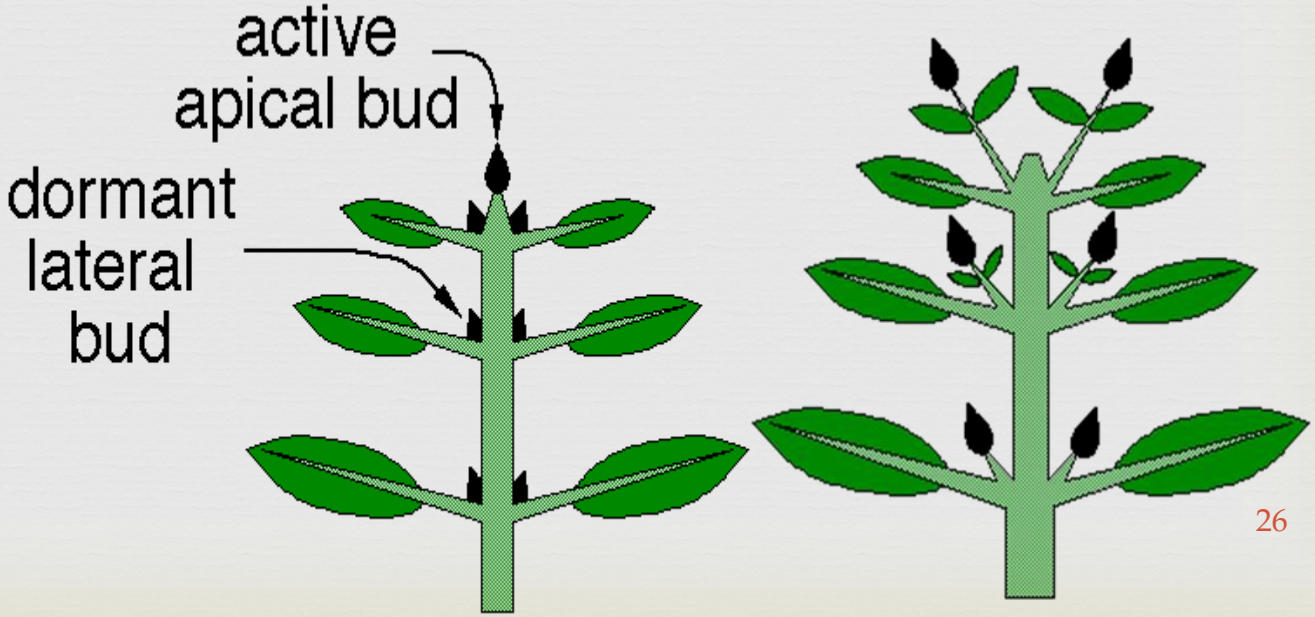
FIGURE 11-5. Misshapen apple fruit (*left*) and cross section of the same fruit (*right*). Note that fruit enlargement is less on the side associated with locules lacking seeds because of less hormone production.

Auxin produced by seeds promotes ovary tissue growth

Auxin Actions

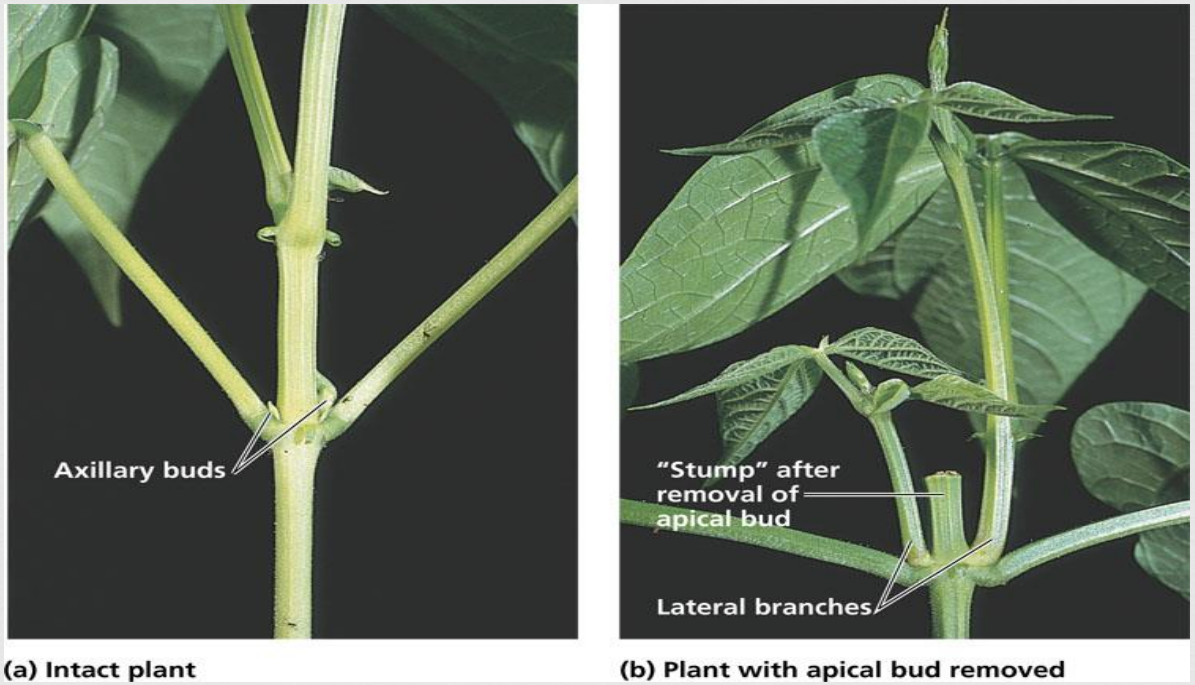
8- Apical Dominance

- 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.



Auxin Actions

8- Apical Dominance



Plant b has apical bud removed so axillary buds grow

Auxin Actions

10- Tropic responses

Such as gravitropism and phototropism

A-Phototropism

- is a growth movement induced by a light stimulus

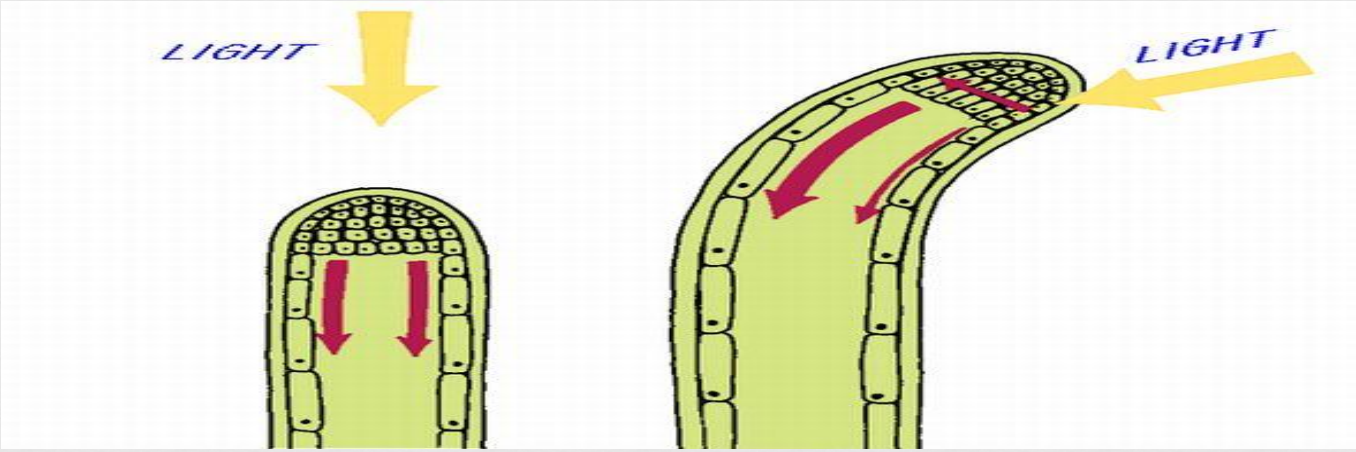
Auxin Actions

Phototropism

- Sunlight breaks down auxin
- Plant stems indirect sunlight will have the least amount of auxin
- Area of the plant that is more shaded will have more auxin
- More cell growth on shaded side
- Plant bends towards light

Auxin Actions

Phototropism



- Light directly over the plant
- Auxins are in equal quantity
- Cell elongation is equal on all sides of the cell

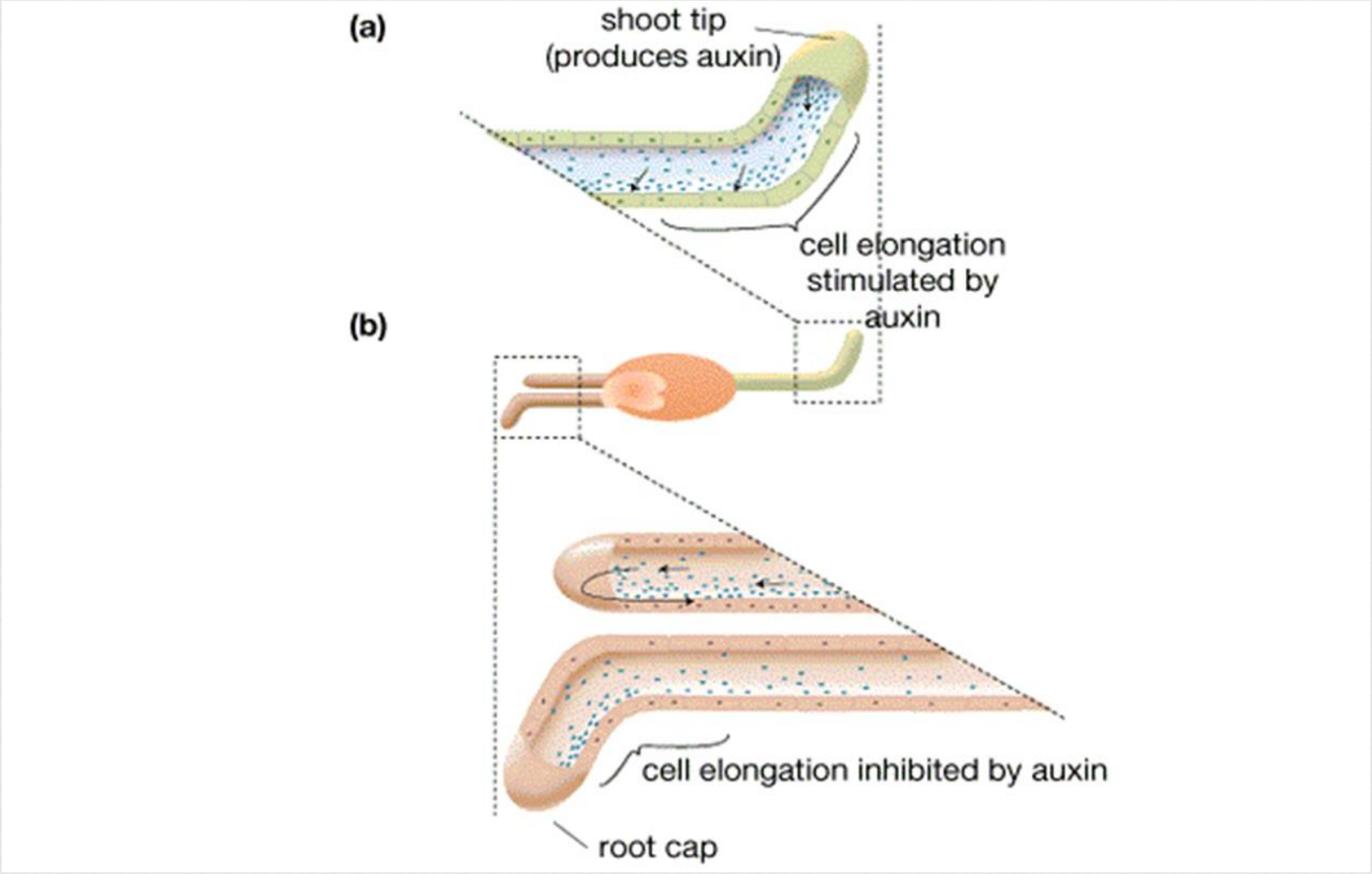
- Greater light on the right side of the plant
- Auxin quantity becomes greater on the left cell
- Auxins trigger cell elongation on the left side
- Plant 'stretches' to the light

Auxin Actions

Geotropism or Gravitropism

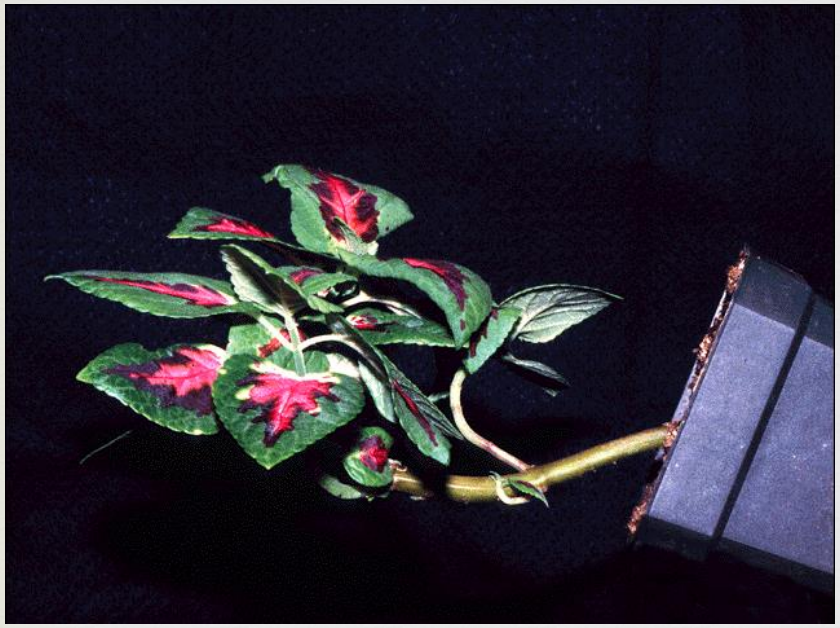
- The plant stem that was once upright is on its side
- The auxin are settle on the bottom side of the stem
- More auxin accumulate on the stems bottom side
- More cell growth occurs on bottom side
- Plant bends upward
- A growth response to gravity which causes roots to grow downward and shoots to grow upward

Auxin Actions



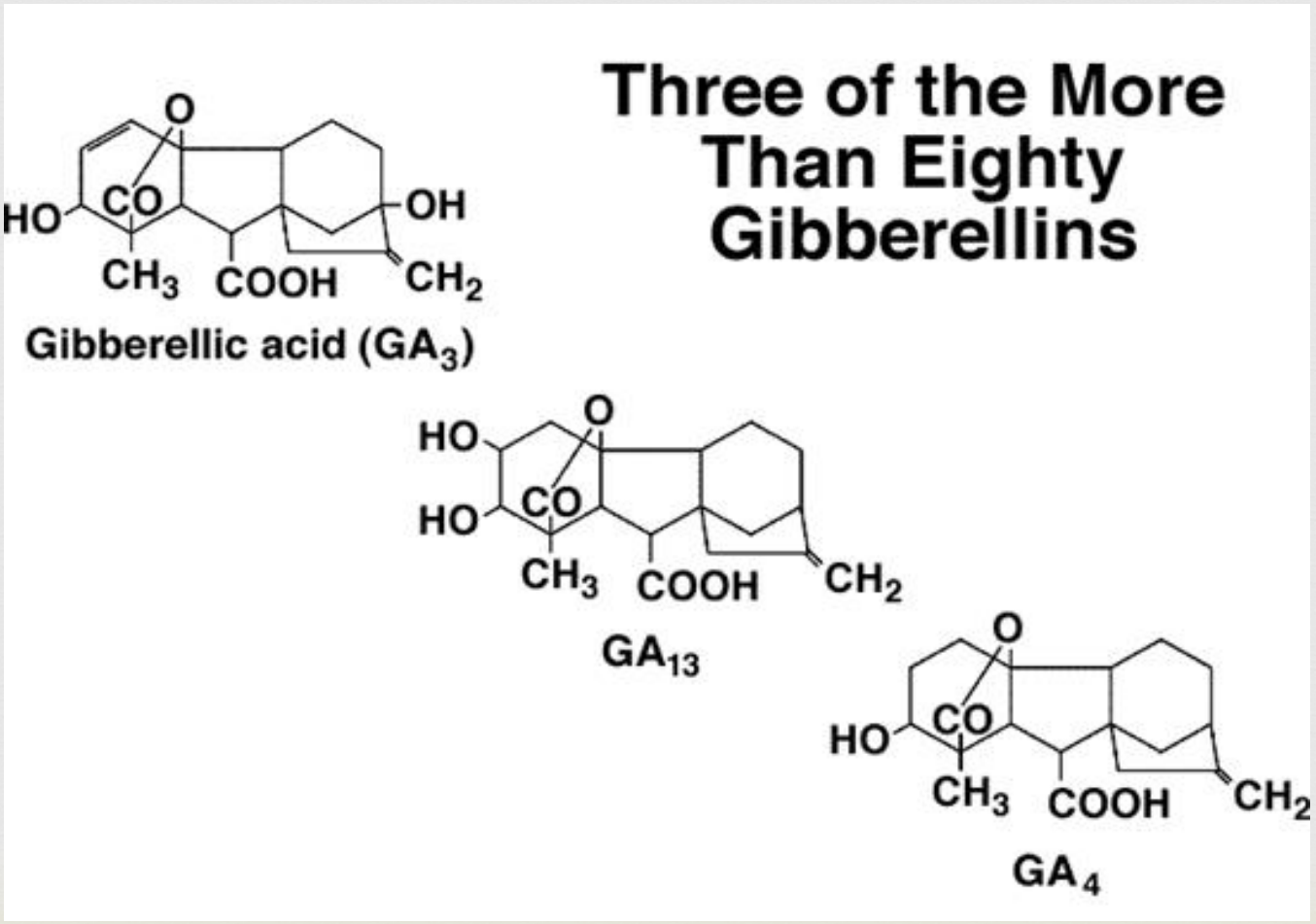
Gravitropism

Auxin Actions



Gravitropism

Gibberellins



Gibberellins

- Gibberellins are plant hormones that promote growth, seed germination and leaf expansion.
- They occur at low concentrations in vegetative tissues but at higher concentrations in germinating seeds.
- Induce cell elongation and cell division.
- Important for plant growth and development through flowering and/or seed germination.

Gibberellins

Site :

- Young leaves, roots, and developing seeds (developing endosperm) and fruits.

Transport :

- Made in the tissue in which it is used
- Transport occurs through xylem, phloem, or cell-to-cell.
- Phloem seems to be most important transport route
- Transport is not polar, as it is for auxin.

Gibberellins Actions

1- Promotes stem elongation

- When applied to intact plants, GA usually causes an increase, unlike auxin.
- It overcomes dwarfism in mutants that have a mutation in the GA synthesis pathway.

  dwarf = short;

  wild type = tall ;

  dwarf + GA = tall.

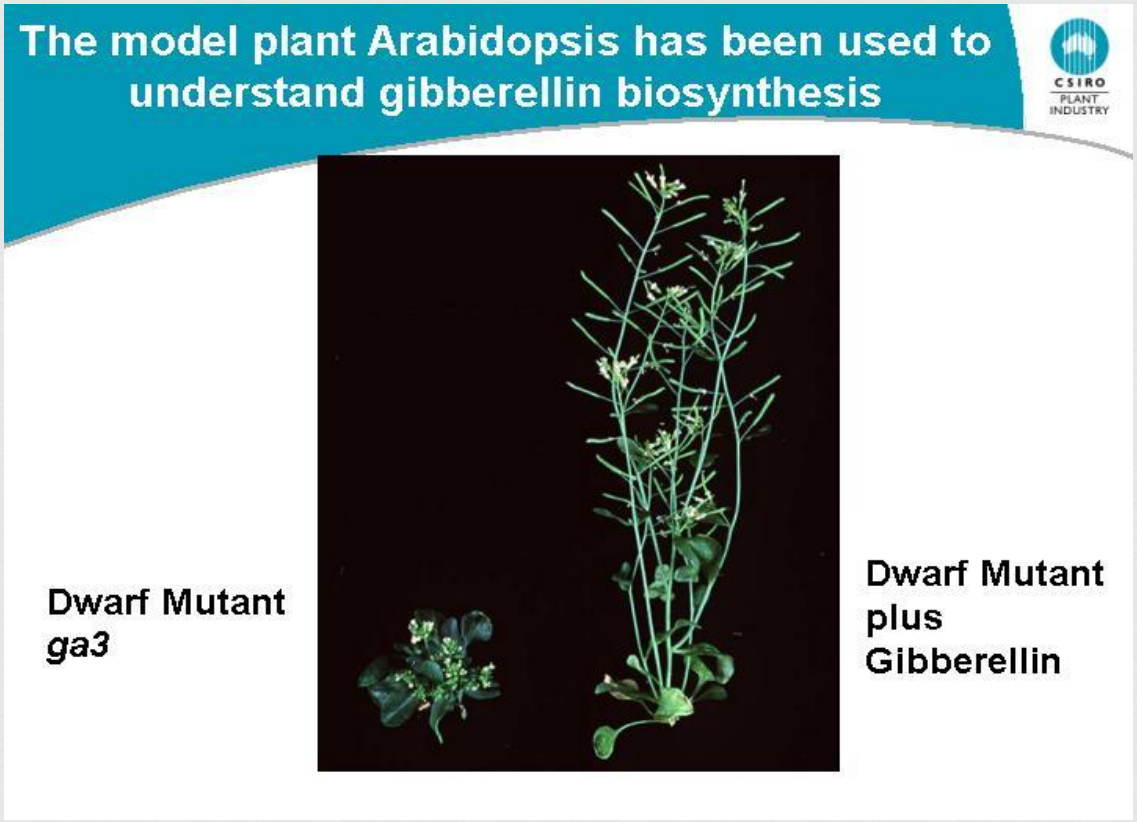
- Thus, GA application:

  (1) stimulates elongation; and

  (2) acts on intact plants.

Gibberellins Actions

1- Promotes stem elongation



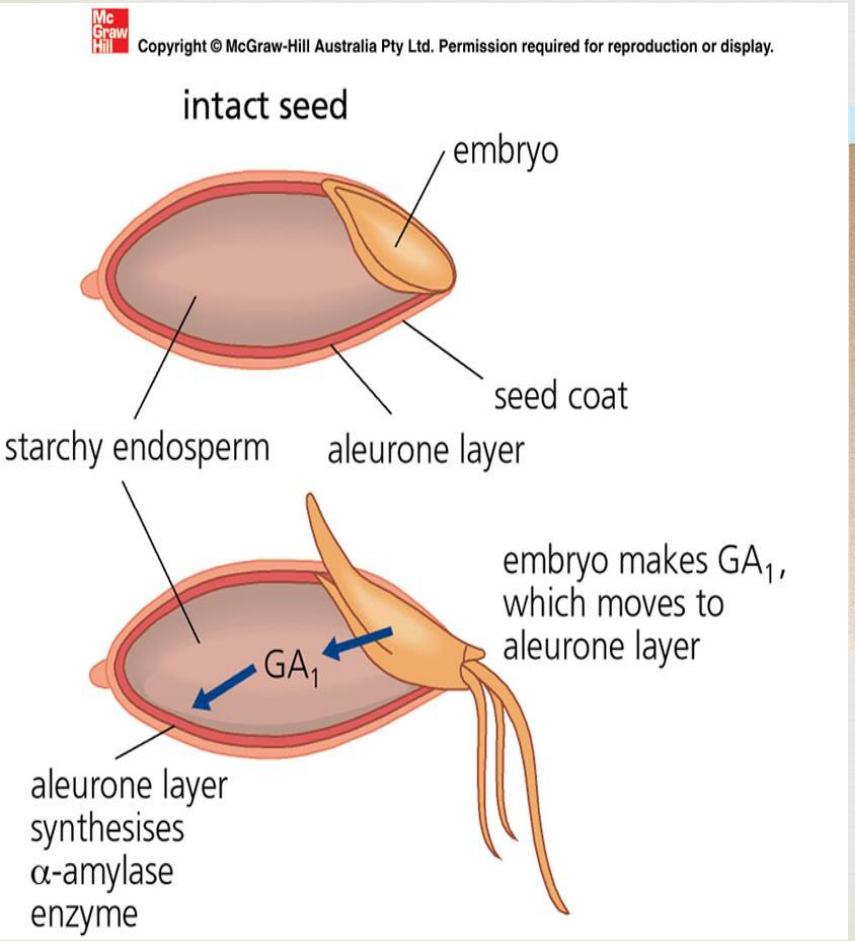
Gibberellins Actions

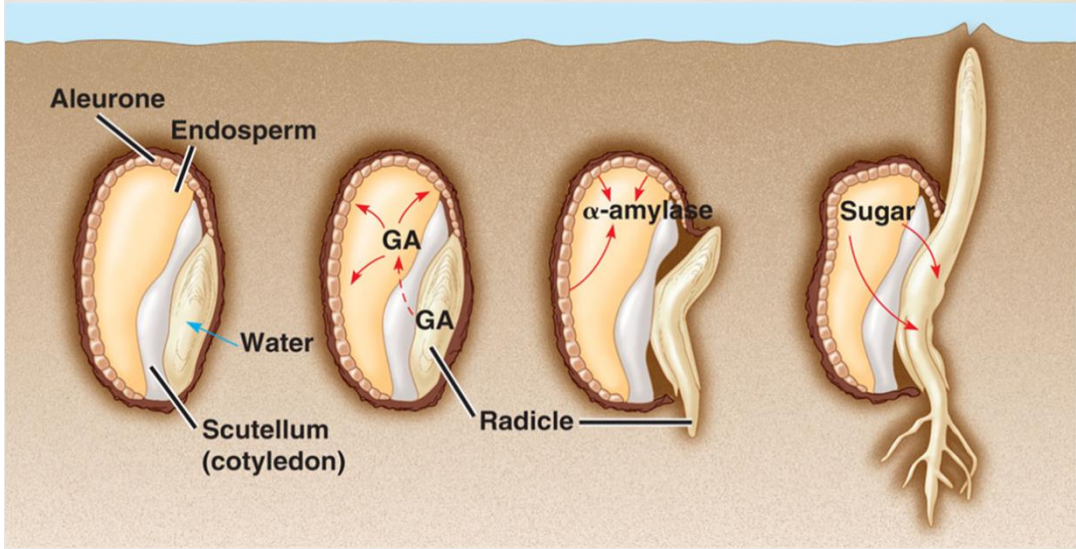
2- Overcomes dormancy in seeds

- Gibberellins also have a fundamental role in breaking seed dormancy and stimulating germination.
- The endosperm of many seeds contains protein and carbohydrate reserves upon which a developing embryo relies for energy and nutrition.
- These reserves must be mobilised and transported to the embryo.
- A range of hydrolytic and proteolytic enzymes break down endosperm starches and proteins into smaller, more easily transported molecules, such as sugars and amino acids.

Gibberellins Actions

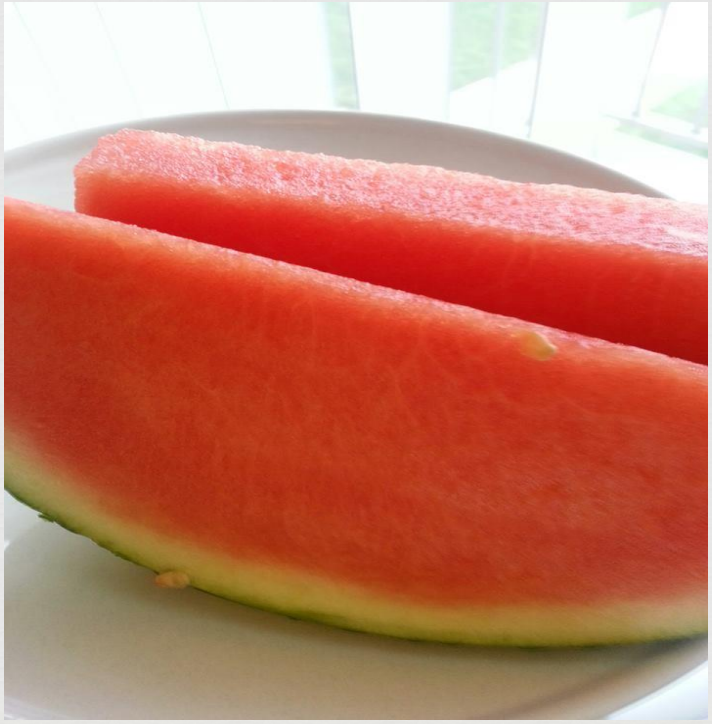
2- Overcomes dormancy in seeds





Gibberellins Actions

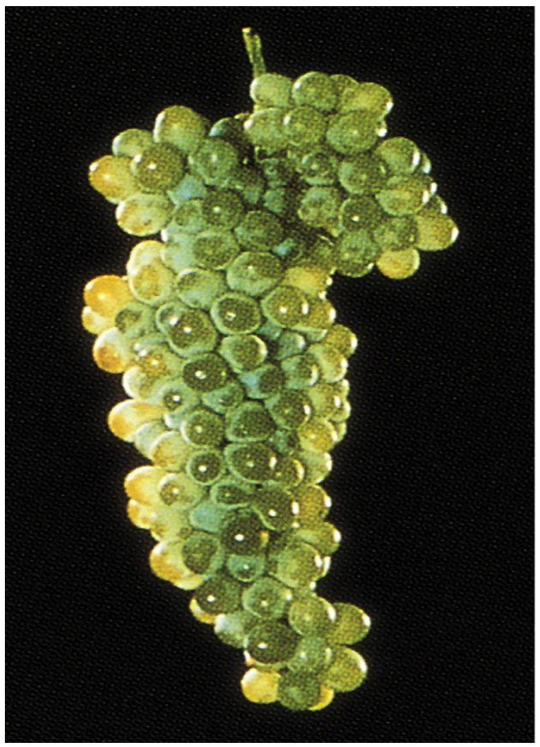
3- Involved in parthenocarpic fruit development

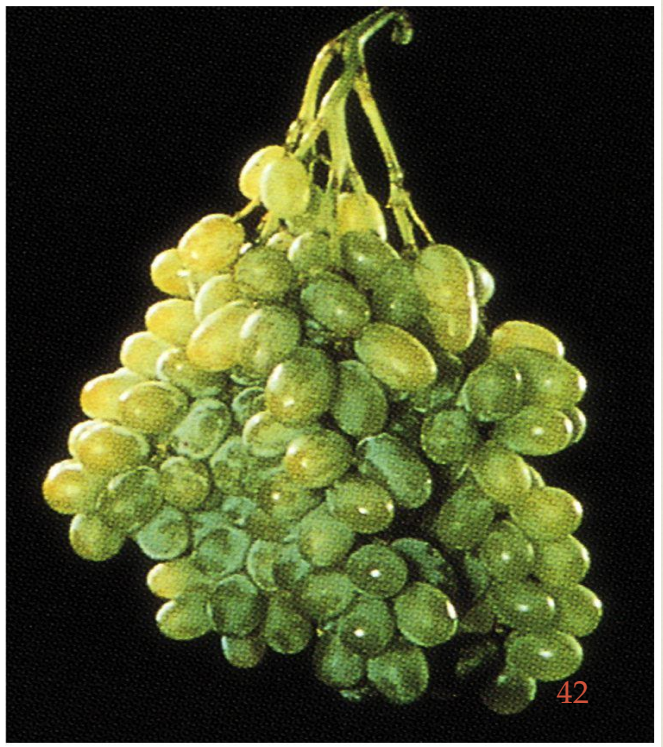


Gibberellins Actions

4- GA can induce fruit enlargement

External application of gibberellins can also enlarge fruit size in grapes





Gibberellins Actions

5- Promotes cell division & elongation

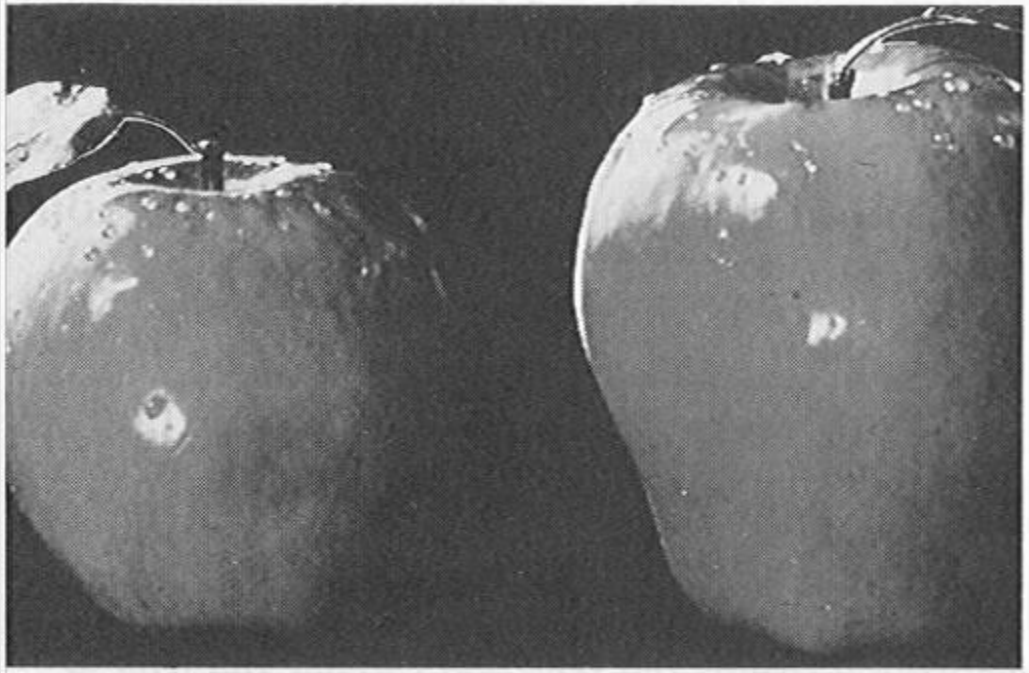
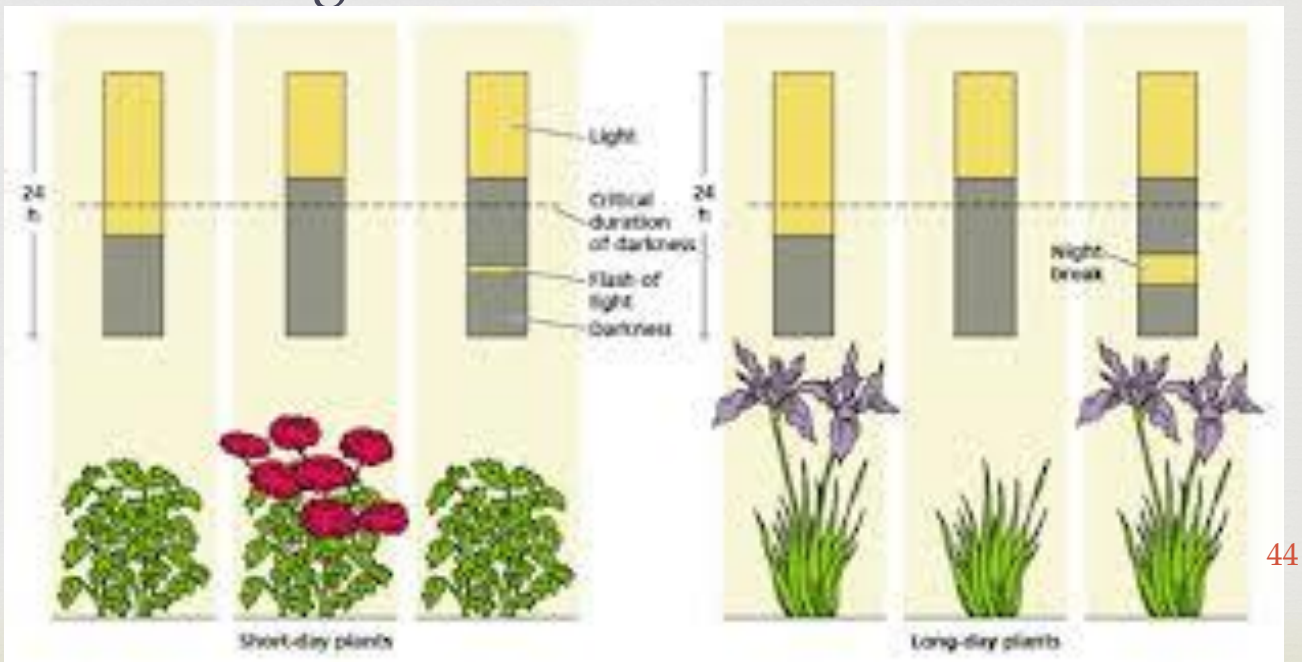


FIGURE 12-11. 'Red Delicious' apples untreated (*left*) and treated with a combination of benzyladenine, a cytokinin, and $GA_4 + GA_7$ (*right*). Note the elongated, almost pointed shape. *Courtesy of Abbott Laboratories, Chicago, IL.*

Gibberellins Actions

6- Flowering

- GA stimulates bolting in Long Day plants and can substitute for long days or cold treatments that are necessary for flowering.

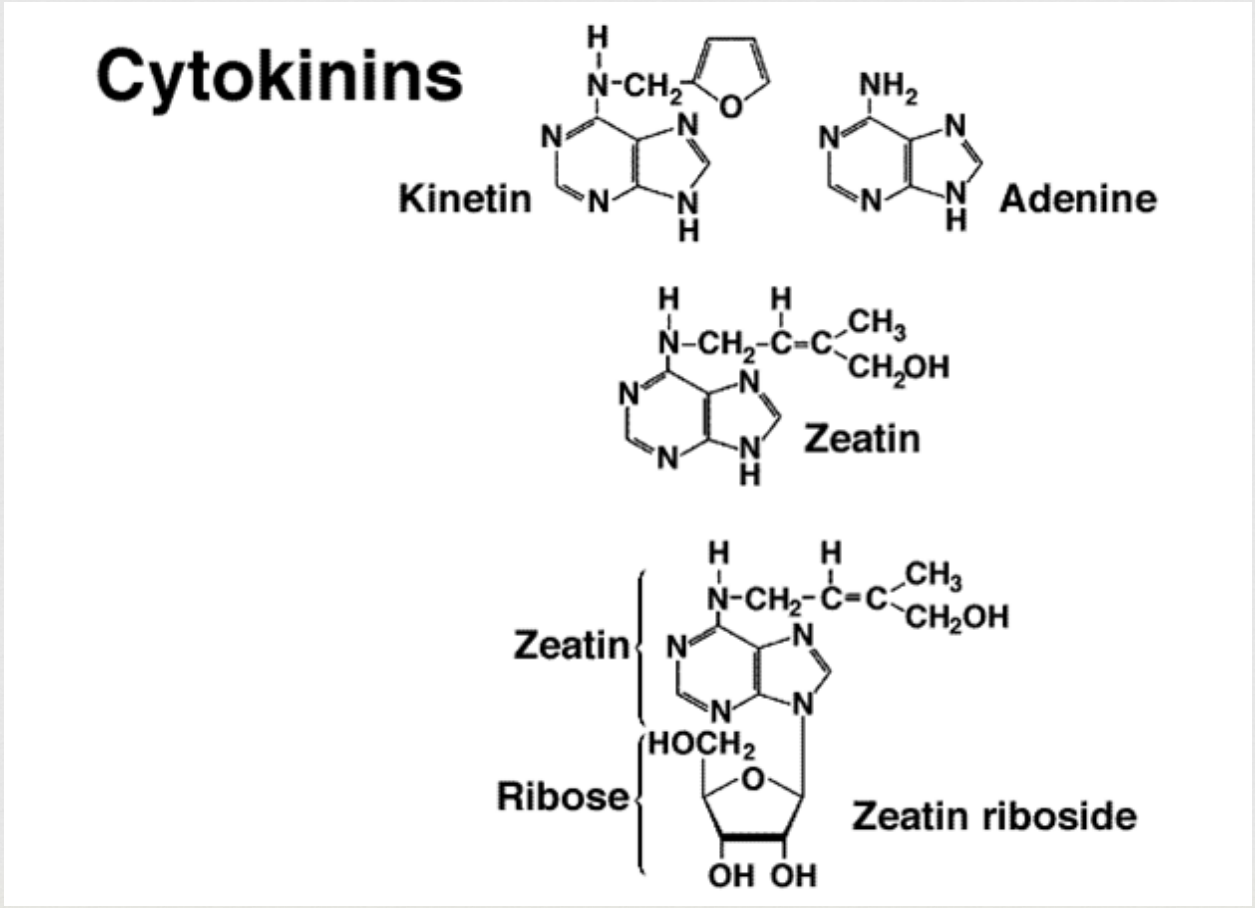


Gibberellins Actions

7-Sex expression

- In plants with separate male and female flowers, GA application can determine sex.
- For example, in cucumber and spinach, GA treatment increases the proportion of male flowers.
- In maize, GA treatment causes female flower development.

Cytokinins


Cytokinins
Kinetin
Adenine
Zeatin
Zeatin
Ribose
Zeatin riboside

Cytokinins

- Cytokinins are hormones that stimulate cell division, or cytokinesis
- These hormones may also be involved in controlling leaf senescence and the growth of lateral branches
- The most active, naturally-occurring cytokinin is zeatin.
- Cytokinins occur in most plants including mosses, ferns, conifers, algae and diatoms

Cytokinins

Site:

- Synthesized primarily in the meristematic region of the roots.
- This is known in part because roots can be cultured (grown in Artificial medium in a flask) without added cytokinin, but stem cells cannot.
- Cytokinins are also produced in developing embryos .

Cytokinins

Transport:

- Via xylem (transpiration stream).
- Zeatin ribosides are the main transport form; converted to the free base or glucosides in the leaves.
- Some cytokinin also moves in the phloem.

Cytokinins Actions

1- Control morphogenesis

In plant tissue cultures, cytokinin is required for the growth of a callus (an undifferentiated, tumor-like mass of cells):

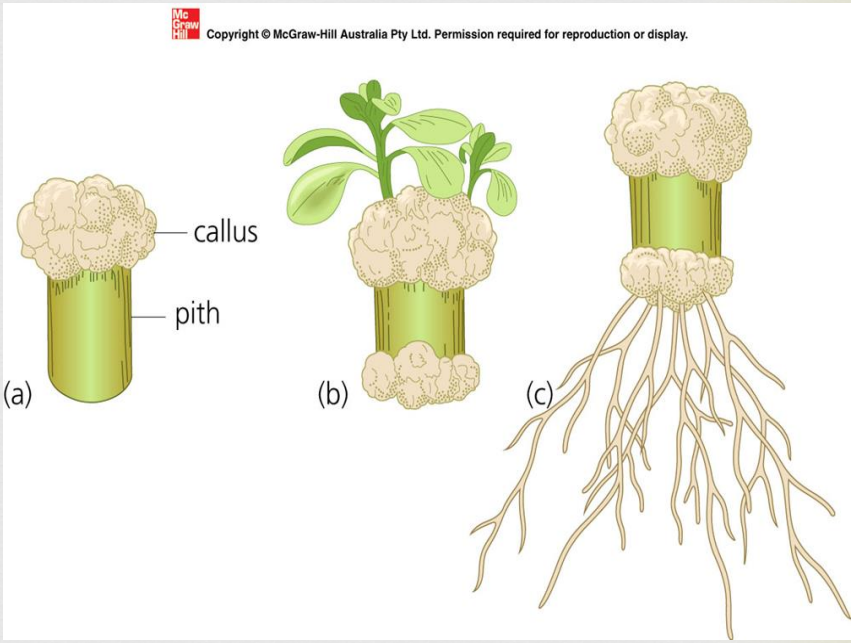
The Medium	The callus differentiation
callus + auxin + no cytokinin	little growth of callus
callus + auxin + cytokinin	callus grows well, undifferentiated

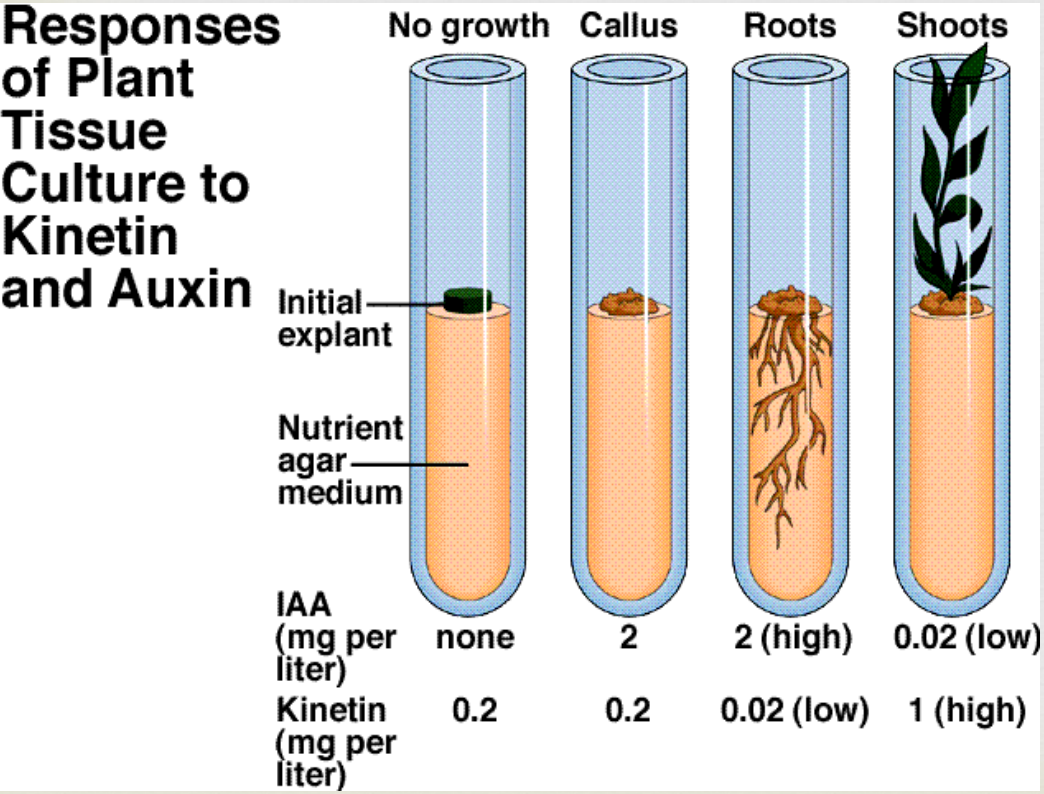
Ratio of cytokinin and auxin are important in determining the fate of the callus:

The concentration	The callus differentiation
callus + low [cytokinin/auxin]	callus grows well, forms roots
callus + high [cytokinin/auxin]	callus grows well, forms meristem & shoots

Cytokinins Actions

1- Control morphogenesis





Cytokinins Actions

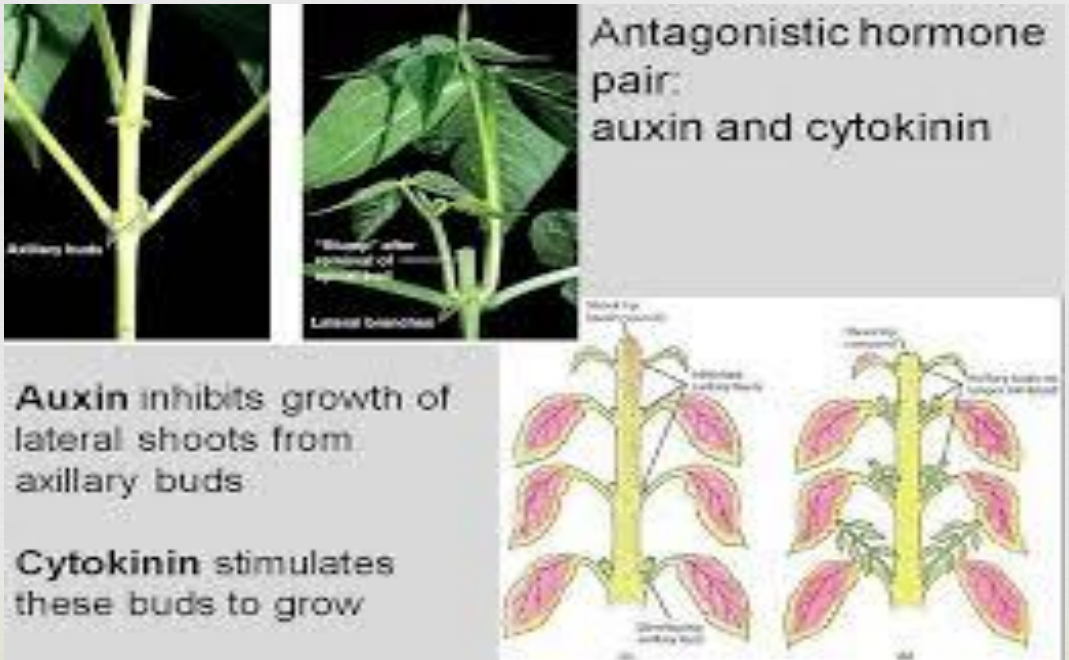
2- Regulates the cell cycle/cell division

- (hence, the name "cytokinins) –especially by controlling the transition from G2 ⟶ mitosis.
- This effect is moderated by cyclin-dependent protein kinases (CDK's) and their subunits, cyclins.

Cytokinins Actions

3- Bud development

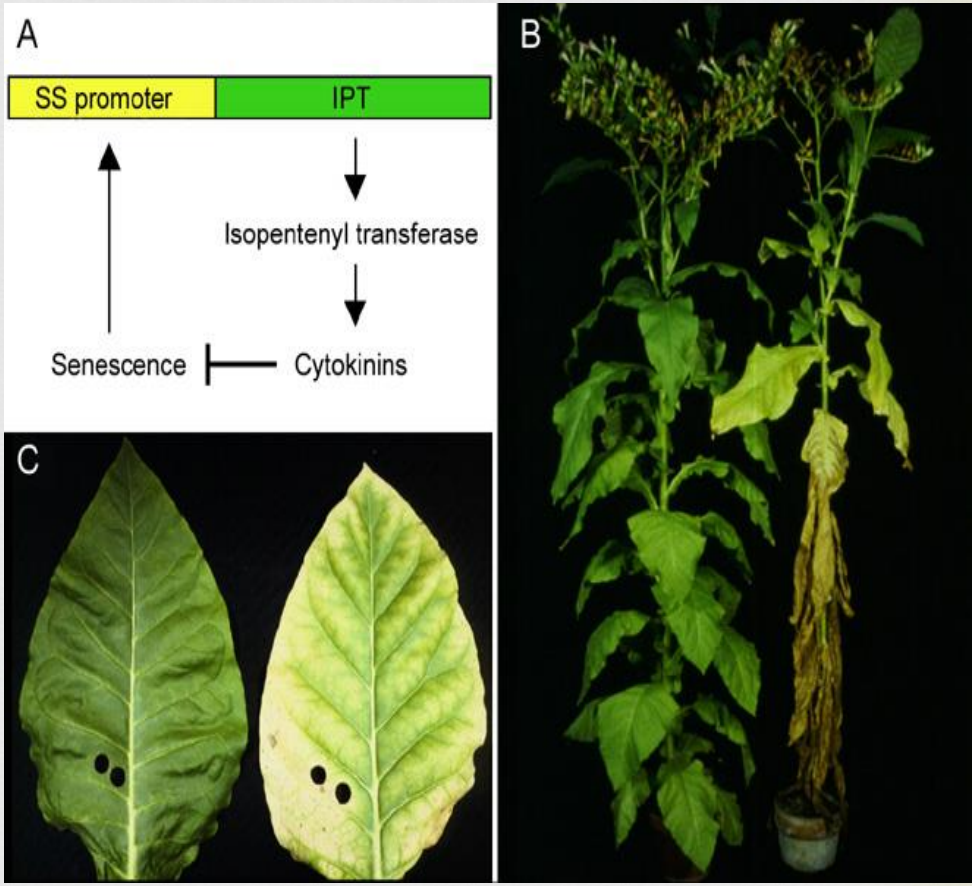
- Direct application of cytokinin promotes the growth of axillary buds
- Exogenous cytokinin and auxin are thus antagonistic in their effects on axillary bud growth



Cytokinins Actions

4- Delay senescence

- Senescence is the programmed aging process that occurs in plants.
- Loss of chlorophyll, RNA, protein and lipids.
- Cytokinin application to an intact leaf markedly reduces the extent and rate of chlorophyll and protein degradation and leaf drop.



Cytokinins Actions

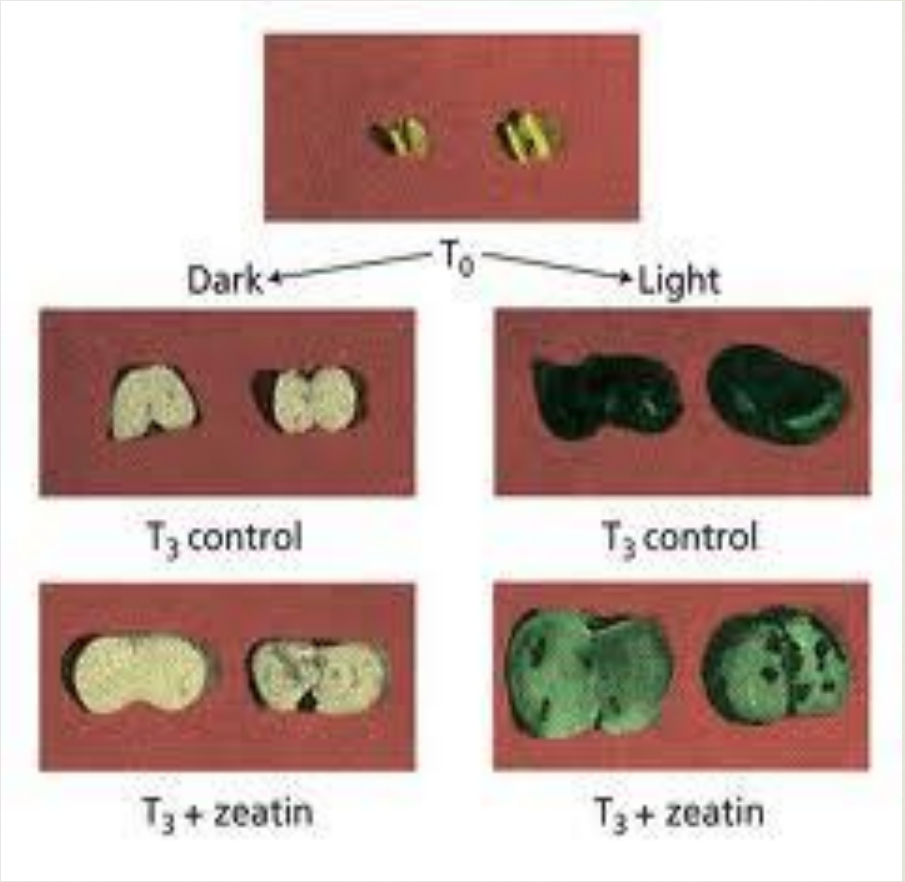
5- Greening

- Cytokinins promotes the light-induced formation of chlorophyll and conversion of etioplasts to chloroplasts (greening process).

Cytokinins Actions

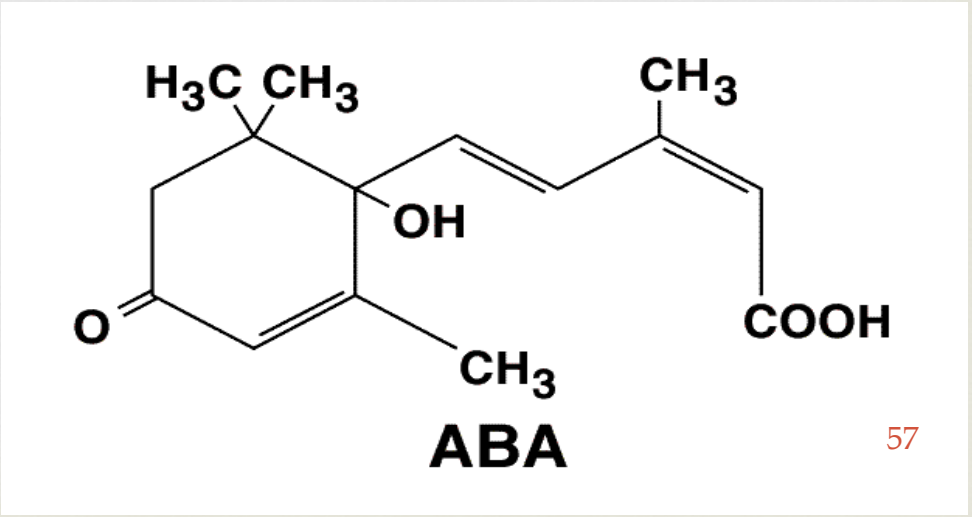
6. Promote cell expansion

- Cytokinins stimulate the expansion of cotyledons.
- The mechanism is associated with increased plasticity of the cell wall, not associated with acidification.



Abscisic acid

- Inhibits growth
- Promotes dormancy
- Closes stomata
- Produced in response to stress.



Abscisic acid

Sites :

- Plastids
- Most tissues, especially leaves and seeds

Transport :

- Xylem and phloem (greater amounts)

Abscisic acid Actions

1- ABA—drought resistance

- Abscisic acid is the key internal signal that facilitates drought resistance in plants
- Under water stress conditions, ABA accumulates in leaves and causes stomata to close rapidly, reducing transpiration and preventing further water loss.
- ABA causes the opening of efflux K^+ channels in guard cell plasma membranes, leading to a huge loss of this ion from the cytoplasm.
- The simultaneous osmotic loss of water leads to a decrease in guard cell turgor, with consequent closure of stomata.

Abscisic acid Actions

2- ABA—freezing resistance

- Elevated ABA levels are associated with increased freezing resistance.
- ABA appears to mediate a plant's response to environmental stresses, such as freezing, by regulating gene expression.
- Certain genes are switched on by ABA while others are switched off.

Abscisic acid Actions

3- ABA—Seed Dormancy

- ABA plays a major role in seed dormancy
- During seed maturation, ABA levels increase dramatically.
- This inhibits germination and turns on the production of proteins that enable the embryo to survive dehydration during seed maturation
- As dormancy can only be broken by specific environmental cues, it ensures that a seed will germinate only under suitable conditions of moisture, light and temperature
- The breaking of dormancy is associated with a decline in the level of ABA

Abscisic acid Actions

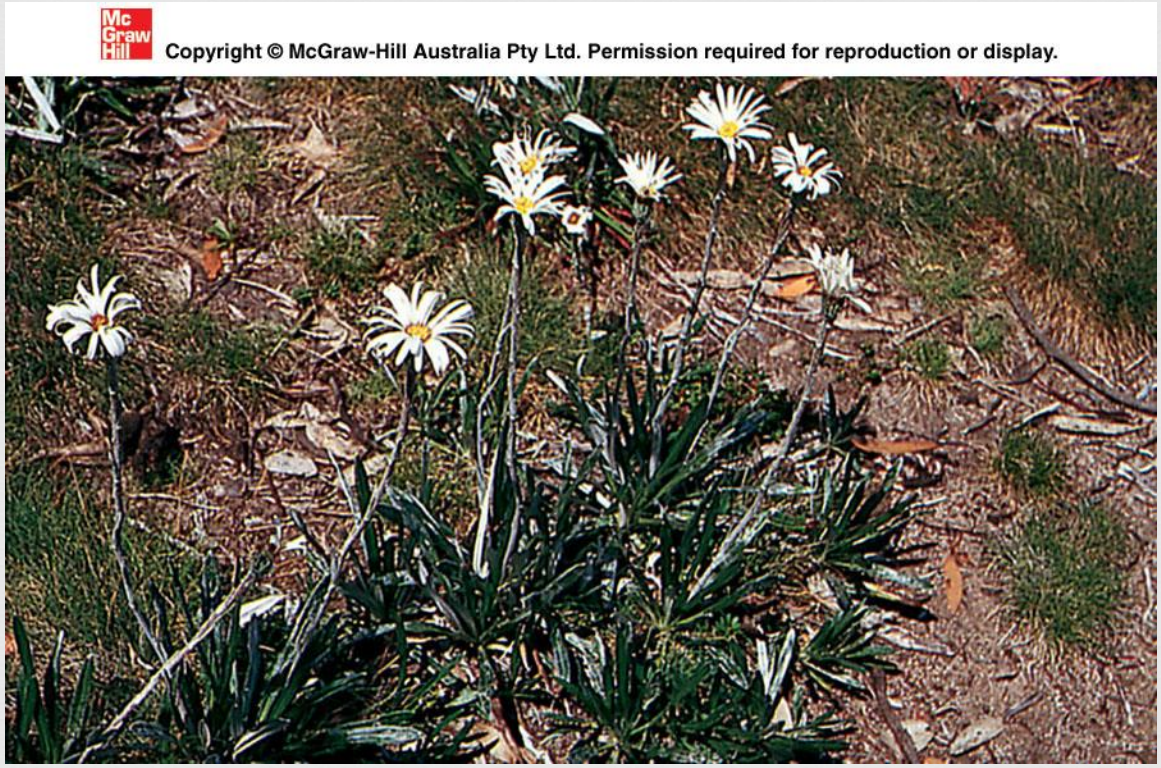
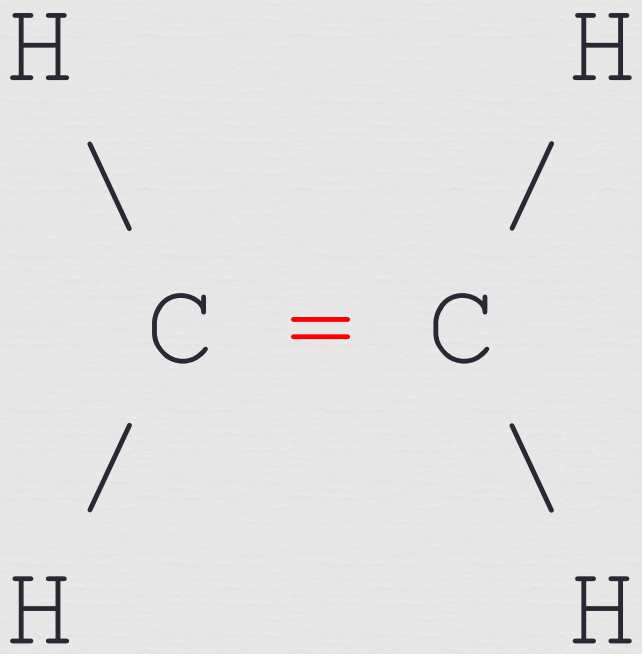


Fig. 17.15: *Celmisia aseriifolia* (snow daisy)

Ethylene



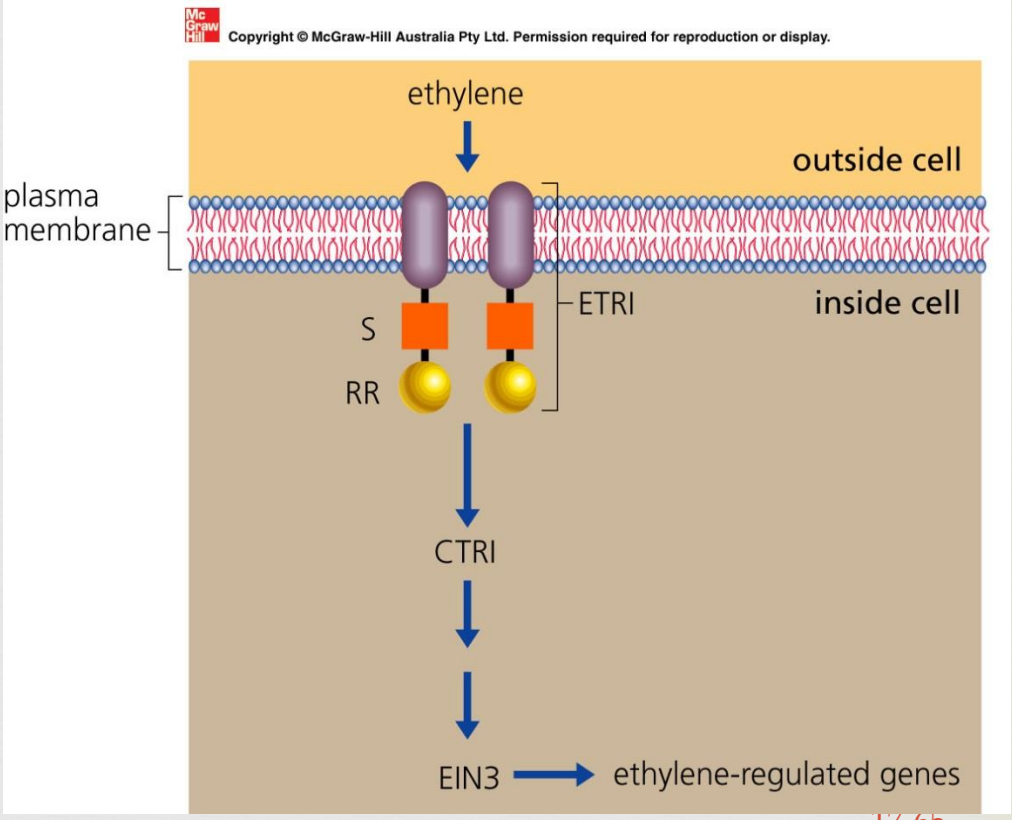
Ethylene

- Ethylene is the only gaseous plant hormone (C_2H_4)
- It is produced naturally by higher plants and is able to diffuse readily, via intercellular spaces, throughout the entire plant body
- Ethylene is involved primarily in plant responses to environmental stresses such as flooding and drought, and in response to infection, wounding and mechanical pressure
- It also influences a wide range of developmental processes, including shoot elongation, flowering, seed germination, fruit ripening and leaf abscission and senescence

Ethylene Action

1- Ethylene—signal transduction

- Several transmembrane proteins have been identified that bind to ethylene at the cell surface and function as signal transducers.



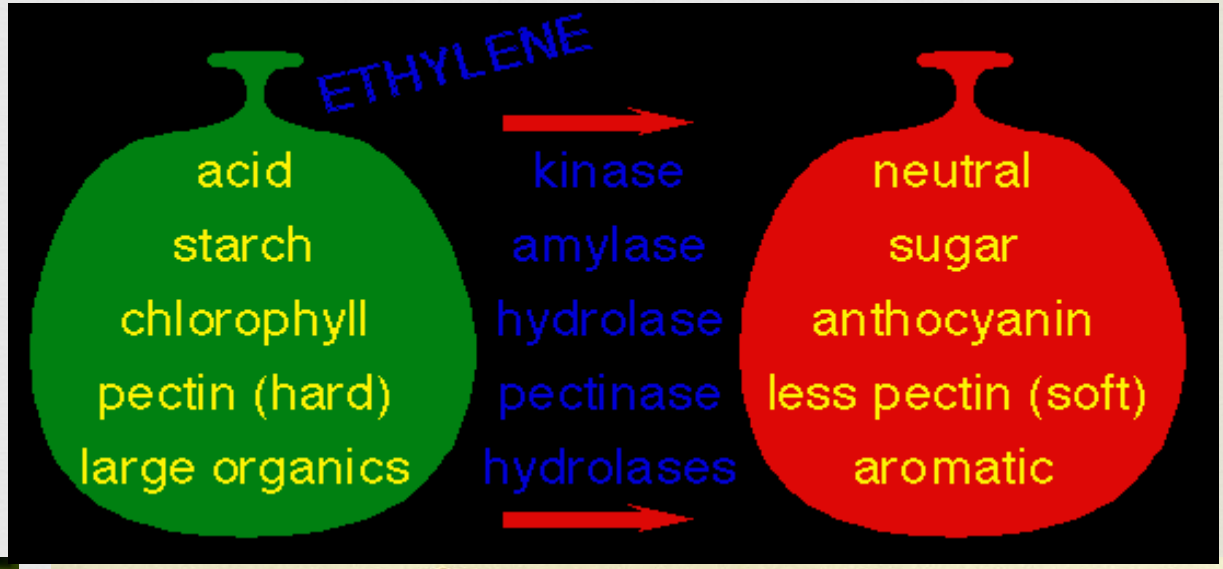
Ethylene Action

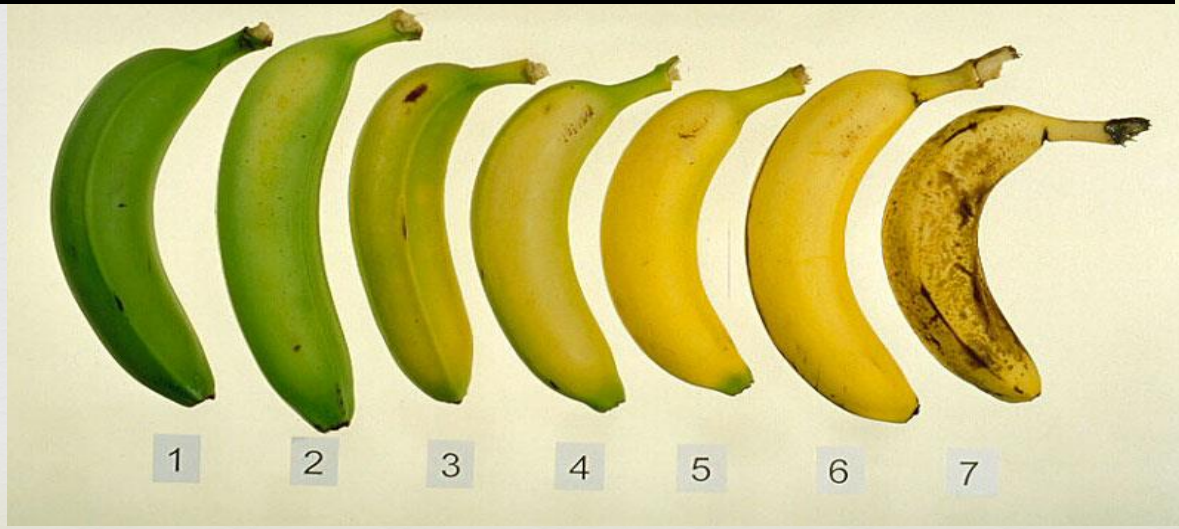
2- Ethylene—fruit ripening

- Under natural conditions, fruits undergo a series of changes, including changes in colour, declines in organic acid content and increases in sugar content
- In many fruits, these metabolic processes often coincide with a period of increased respiration, the respiratory *climacteric*
- During the climacteric there is also a dramatic increase in ethylene production
- Ethylene can initiate the climacteric in a number of fruits and is used commercially to ripen tomatoes, avocados, melons, kiwi fruit and bananas

Ethylene Action

2- Ethylene – fruit ripening

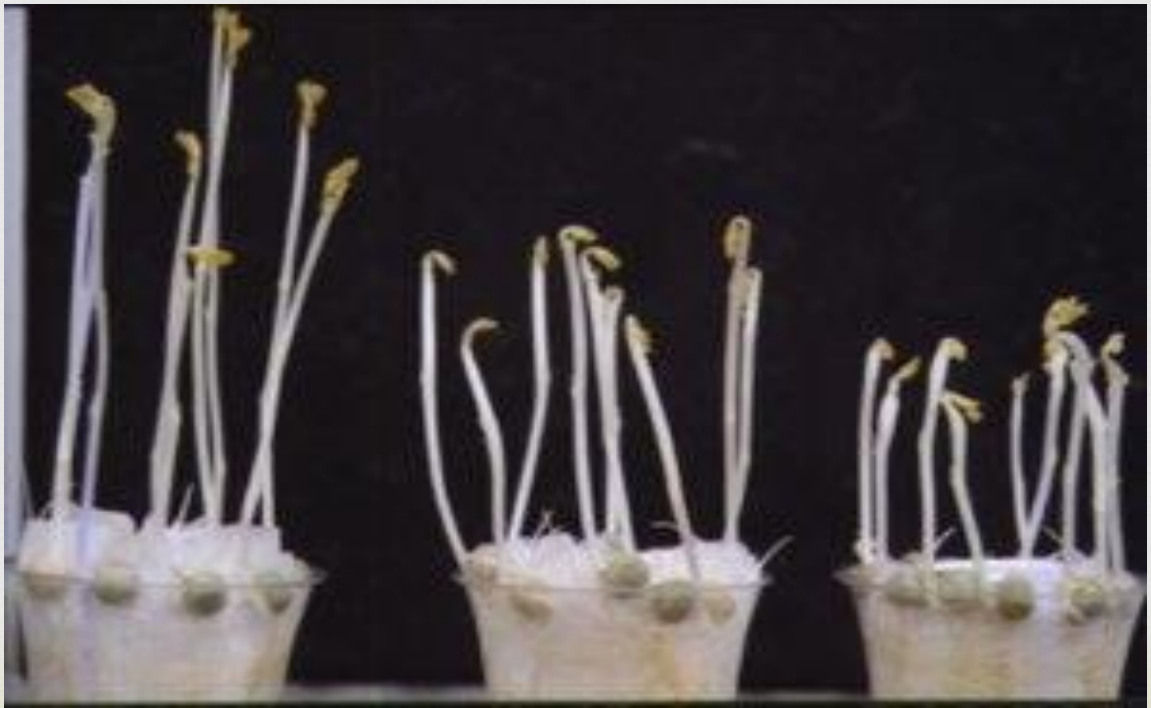




Ethylene Action

3- Ethylene – Shoot Growth

- Applied ethylene has the capacity to influence shoot growth
- Application of ethylene to dark-grown seedlings can cause reduced elongation of the stem, bending of the stem and swelling of the epicotyl or hypocotyl.



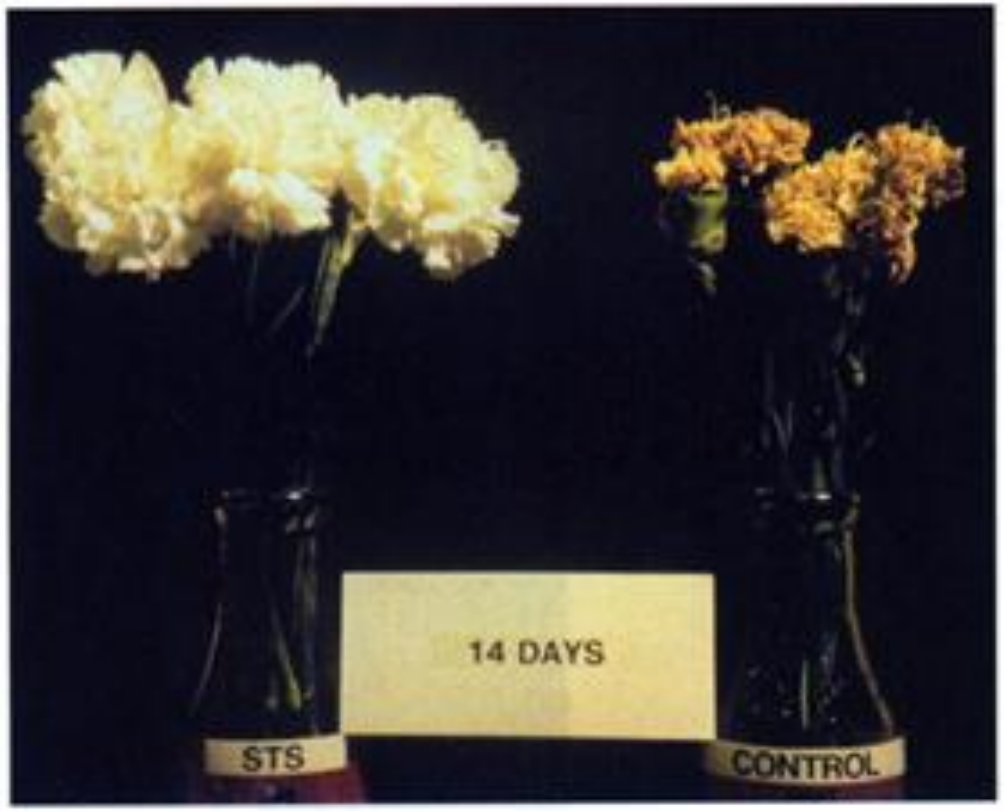
Ethylene Action

4- Ethylene—flowering

- The ability of ethylene to affect flowering in pineapples has important commercial applications.
- Ethylene also promotes flower senescence (ageing) in plants such as petunias, carnations and peas.

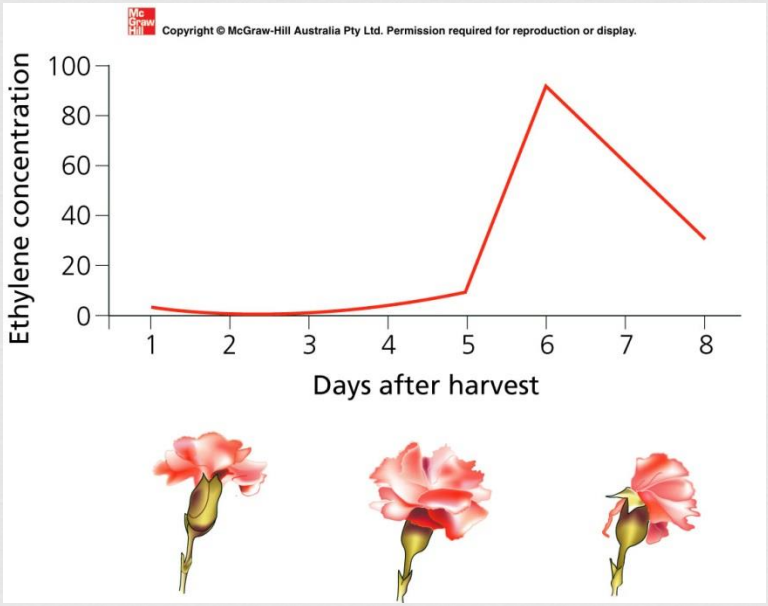
Ethylene Action

4- Ethylene – flowering



Ethylene Action

(a)



(b)

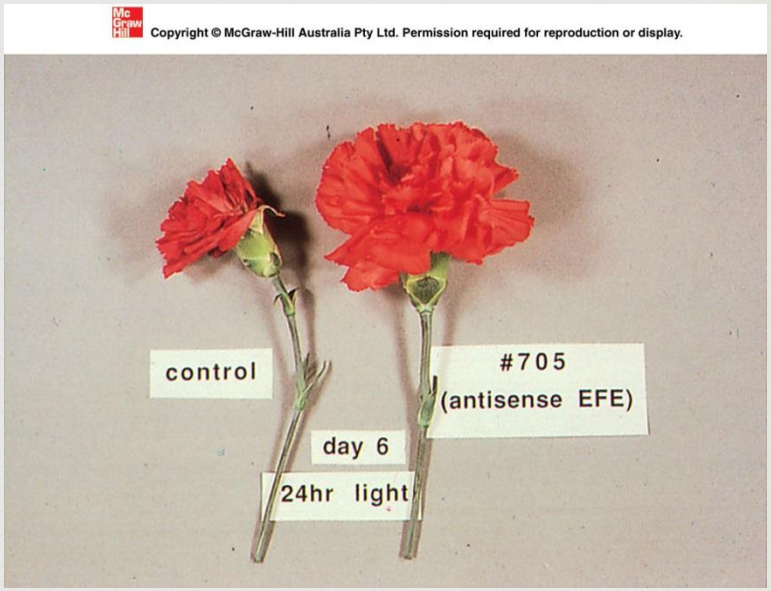


Fig. 17.19: Senescence in carnations

Ethylene Action

5- Thigmomorphogenesis

- The change in growth form in response to a mechanical stimulation such as touch.

Brassinosteroids

- Brassinosteroids (BRs) are plant steroid hormones that have a similar structure to animal steroid hormones
- They have multiple developmental effects on plants, including :

promotion of cell elongation, cell division and xylem differentiation, and delaying of leaf abscission

Brassinosteroids

- BR-deficient mutants exhibit dramatic growth defects, including dwarfism, reduced apical dominance and male fertility, as well as delayed senescence and flowering
- Brassinosteroids switch on specific genes by inactivating a protein that otherwise indirectly blocks transcription of those genes

Brassinosteroids

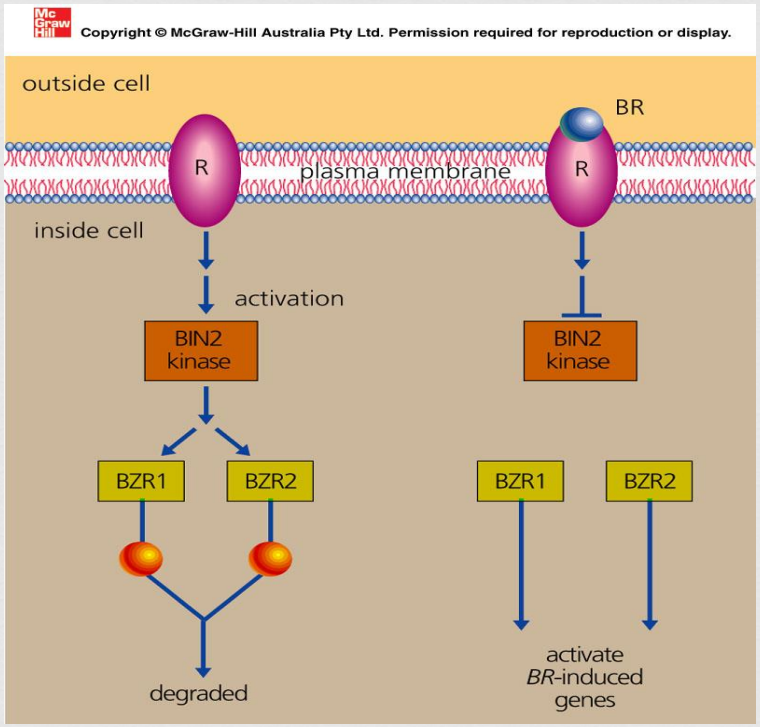


Fig. 17.20: Signal transduction chain for the response to brassinosteroids