

# CYTOKININS

- Cytokinins
  - Discovery
  - Chemical Structure
  - Biosynthesis
  - Transport
  - Signaling
  - Functions

# DISCOVERY

## CYTOKININS



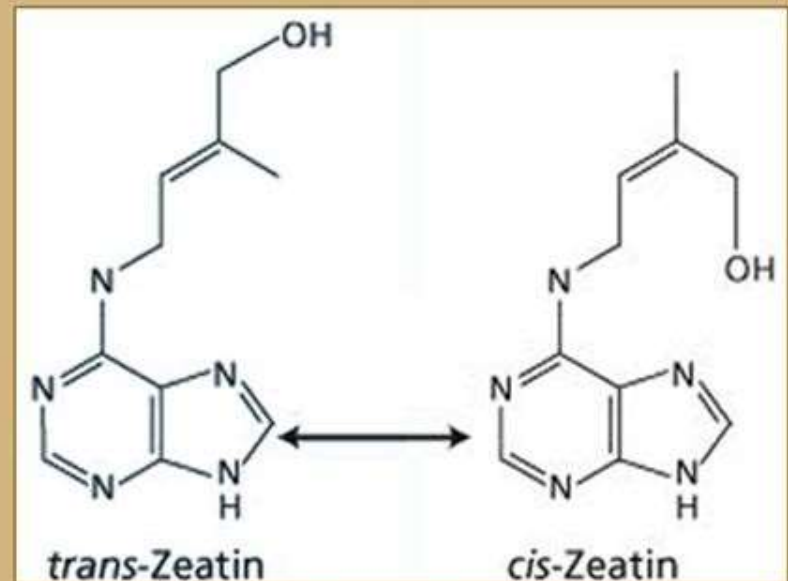
- Haberlandt (1913) – compound in phloem stimulates cell division
- Van Overbeek (1941) – coconut milk (endosperm) also has the ability to stimulate cell division
- Jablonski & Skoog (1954) – compounds in vascular tissues promote cell division



# DISCOVERY

## CYTOKININS

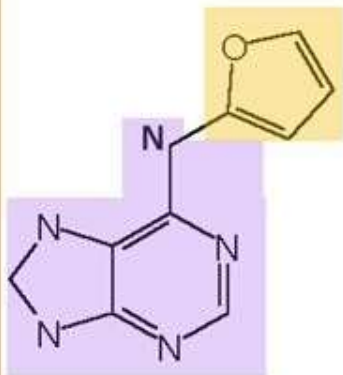
- Miller (1955) – first cytokinin isolated from herring sperm, named **kinetin**
- Miller (1961) – first naturally occurring cytokinin found in plants, later called **zeatin**



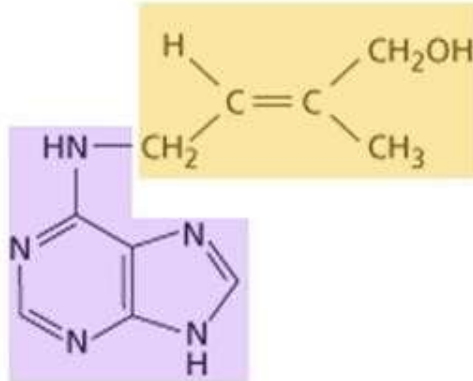
# CHEMICAL STRUCTURE

## CYTOKININS

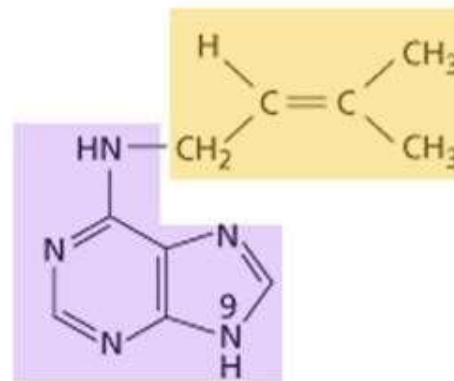
- Adenine structure (amino purine ring)
- N<sup>6</sup> Side chain
  - Degree of unsaturation
  - Number of carbons in side chain



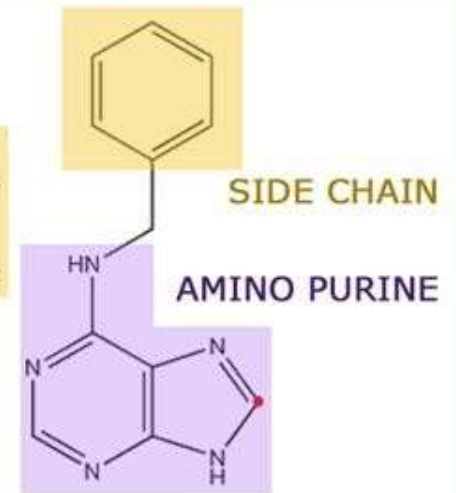
**Kinetin**



**trans-Zeatin**



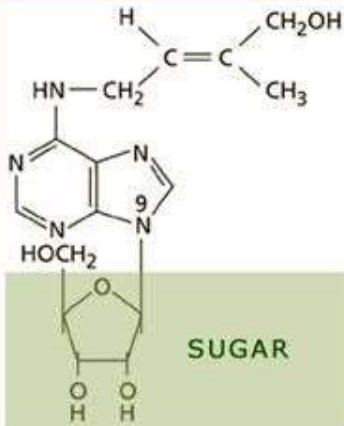
**N<sup>6</sup>-(Δ<sup>2</sup>-Isopentenyl)-adenine  
(i<sup>6</sup>Ade)**



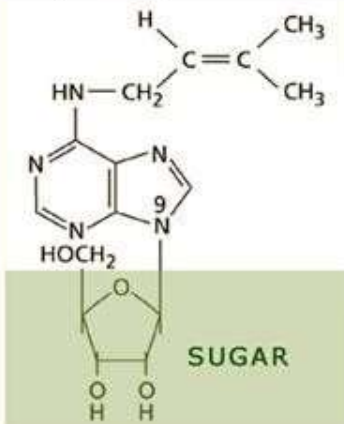
**Benzyladenine**

# CHEMICAL STRUCTURE

## CYTOKININS



Ribosylzeatin (zeatin riboside)



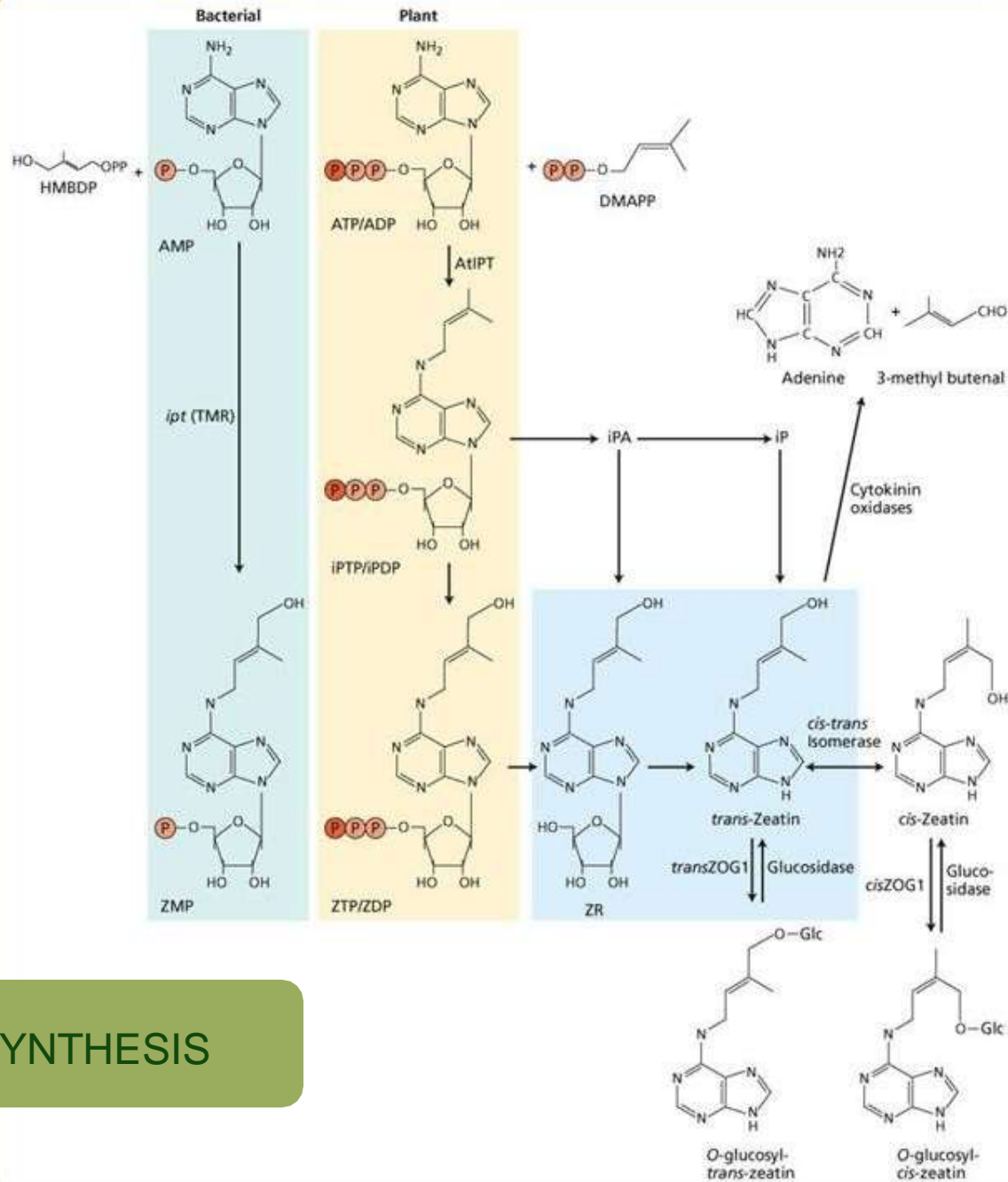
N<sup>6</sup>-(Δ<sup>2</sup>-Isopentenyl) adenosine ([9R]iP)

- Free base forms are most hormonally active (Yamada et al. 2001)
- May have sugars attached to make molecule more inactive and useful for transport
  - Ribosides
  - Ribotides
  - Glycosides

# BIOSYNTHESIS

## CYTOKININS

- Biosynthesis started by the IPT (isopentenyl transferase) enzyme
- Major pathway
  - Figure 21.6
- Other pathway
  - tRNA biosynthesis



# BIOSYNTHESIS

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## CYTOKININS

- tRNA breakdown not the major pathway for cytokinin synthesis

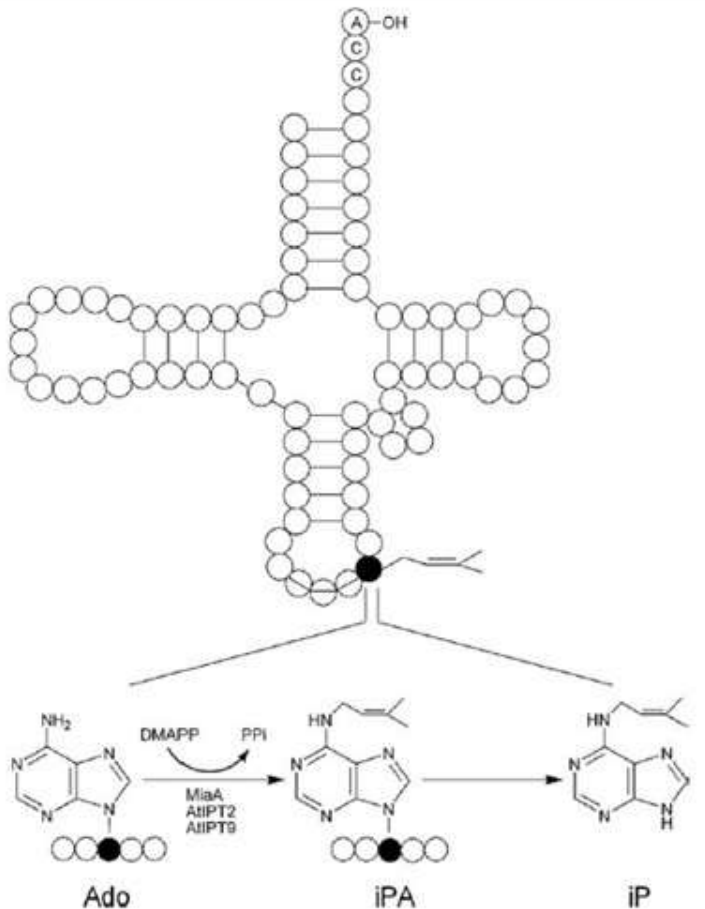


FIG. 1. Indirect synthetic pathway of cytokinins.

# BIOSYNTHESIS

## CYTOKININS

- Generated mostly in the **root apical meristems** but also found in:
  - Root cap cells
  - Ovules
  - Phloem cells
  - Leaf axils
  - Tips of young inflorescences
  - Fruit
  - Seeds

# BIOSYNTHESIS

## CYTOKININS

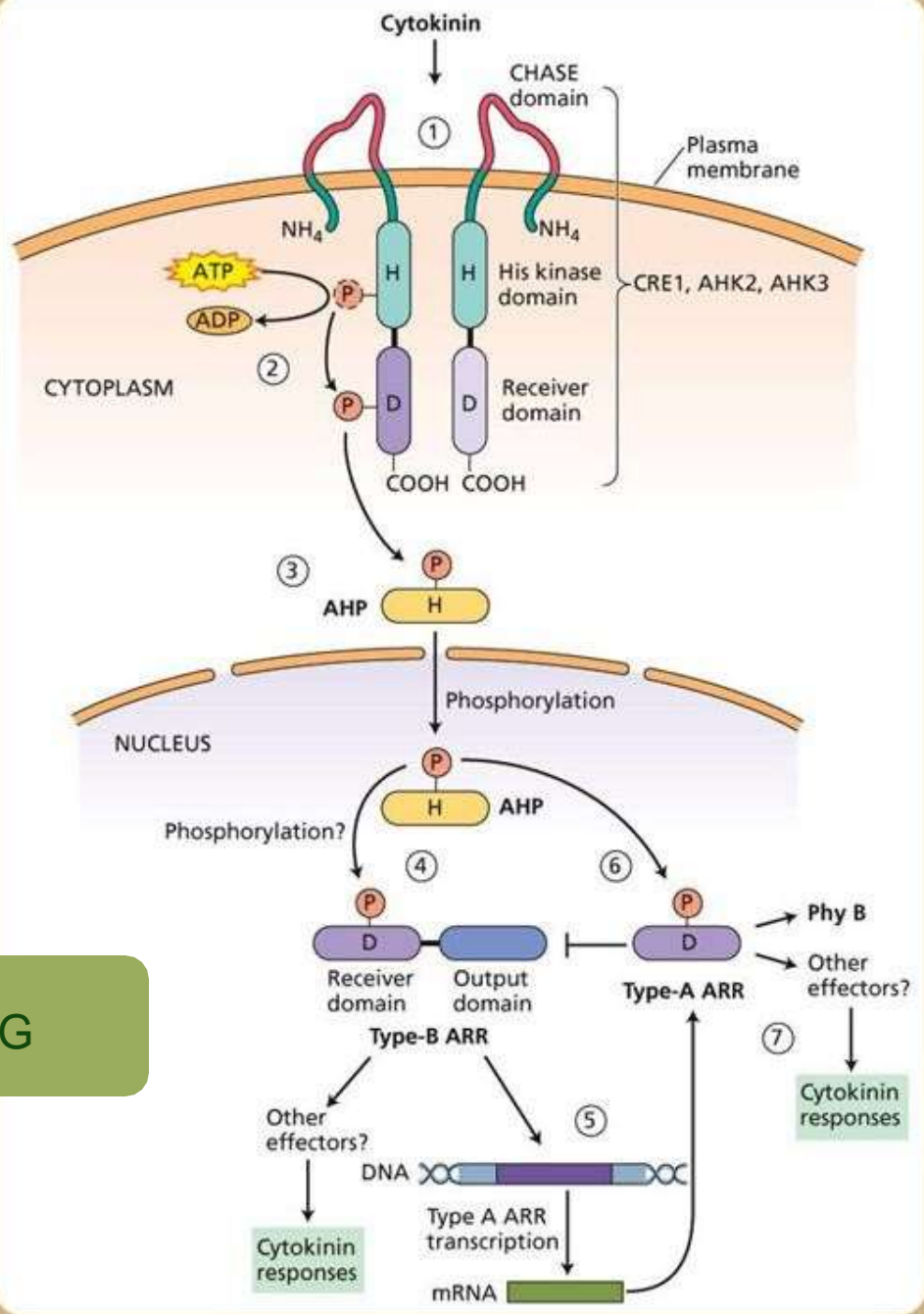


- Other organisms make cytokinins to influence the plant for their own benefit
  - Bacteria
  - Fungi
  - Insects
  - Nematodes

# TRANSPORT

## CYTOKININS

- Cytokinins move up the plant through the xylem
- By contrast, auxin moves from top down.
- Some signal in the shoot can also induce cytokinin transport from the root (Beveridge 2000).



SIGNALING

# SIGNALING

## CYTKININS

- Cytokinin changes the structure of the His Kinase domain
  - Phosphate moves from the kinase domain to the receiver domain
  - Phosphate moves onto AHP
  - AHP moves from cytoplasm into nucleus
  - Phosphate on AHP moves onto receiver domain of the response regulator
  - Change in structure of the receiver domain affects the output domain
  - Output domain then signals transcription → cytokinin responses

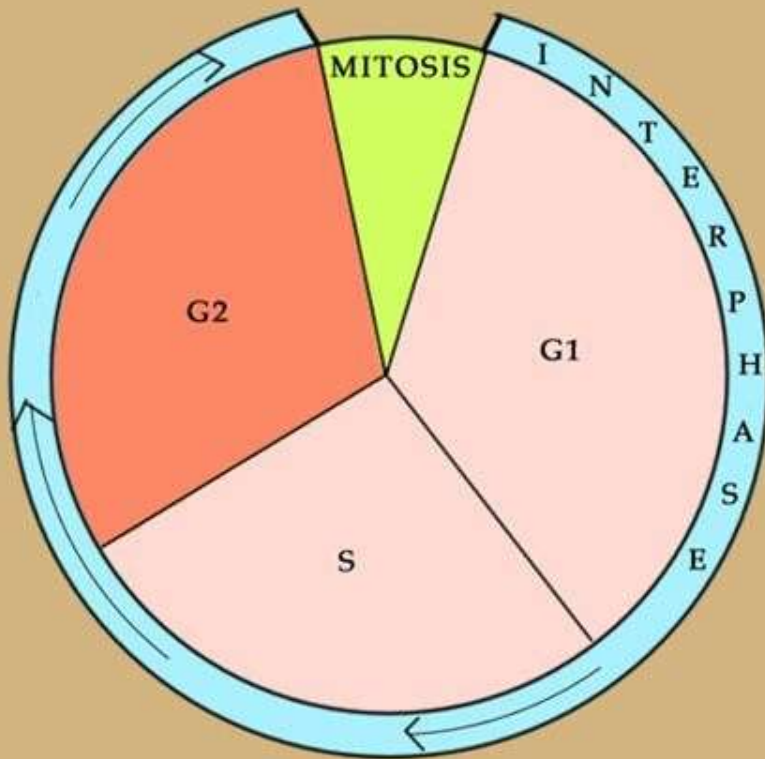
# FUNCTIONS

## CYTOKININS

- **FUNCTIONS**
  - Cell division
  - Root and shoot meristems
  - Cell differentiation
  - Leaf senescence
  - Inflorescence growth
  - Nutrient mobilization
  - Cotyledon expansion
  - Apical dominance
  - Seedling morphology

# CELL DIVISION

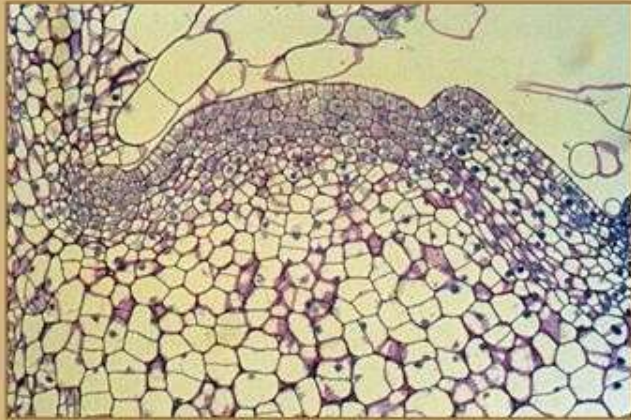
## CYTOKININ FUNCTION



- Auxin and cytokinins influence the activity of:
  - **Cyclin-dependant protein kinases (CDKs) and cyclins**
    - Both are proteins that regulate transitions between **G1 to S** and **G2 to mitosis** stages in the cell cycle
  - Auxin stimulates the production of CDKs and cyclins
  - Cytokinins activate CDKs and cyclins through phosphorylation and allow transition between stages

# ROOT AND SHOOT MERISTEMS

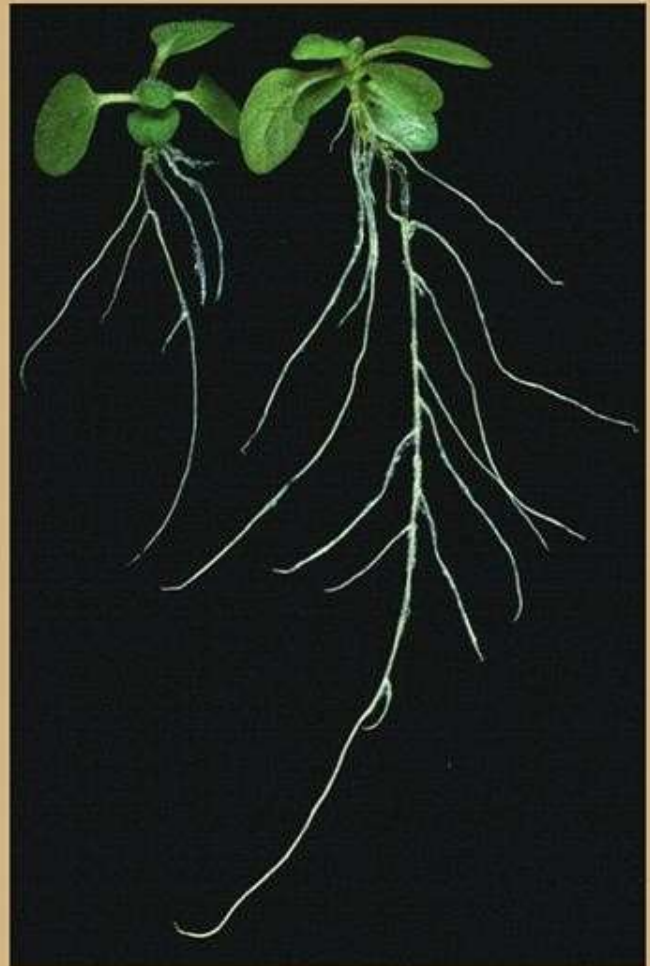
## CYTOKININ FUNCTION



- Optimal levels of cytokinins are needed for normal cell division
  - Root: cytokinin overabundance inhibits cell division
  - Shoot: cytokinins promote cell division
- Cytokinin oxidase dictates meristemic cytokinin concentrations
  - Mutants can either overproduce or underproduce this enzyme

# ROOT AND SHOOT MERISTEMS

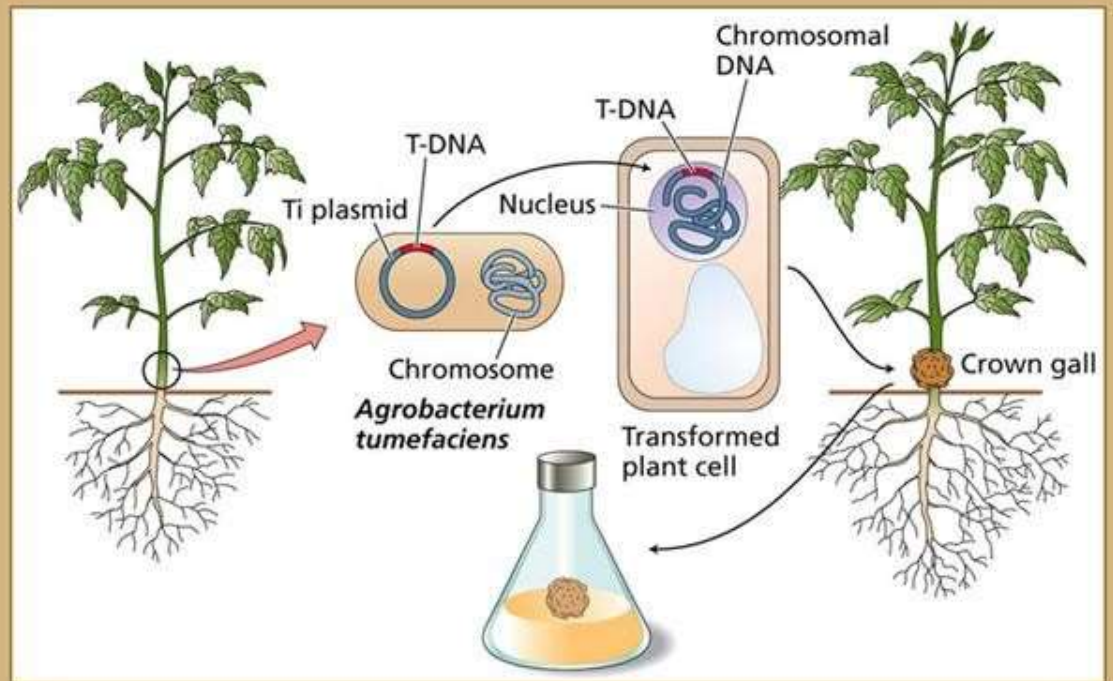
## CYTOKININ FUNCTION



# CELL DIFFERENTIATION

## CYTOKININ FUNCTION

Bacteria: *Agrobacterium tumefaciens*



# CELL DIFFERENTIATION

## CYTOKININ FUNCTION

- Auxin:cytokinin affects cell differentiation in callus tissue
- More auxin → roots
- More cytokinin → shoots
- Skoog and Miller (1965)



# LEAF SENESCENCE

## CYTOKININ FUNCTION



- Cytokinin delays leaf senescence
  - Delay the degradation of chloroplasts
  - May increase the growing season for agricultural purposes.

# LEAF SENESCENCE

## CYTOKININ FUNCTION



- Delayed leaf senescence help plants recover from environmental stresses
  - Drought (Rivero et al. 2007)
  - Flooding (Zhang et al. 2000) (Hyunh et al. 2005)

# INFLORESCENCE GROWTH

## CYTOKININ FUNCTION

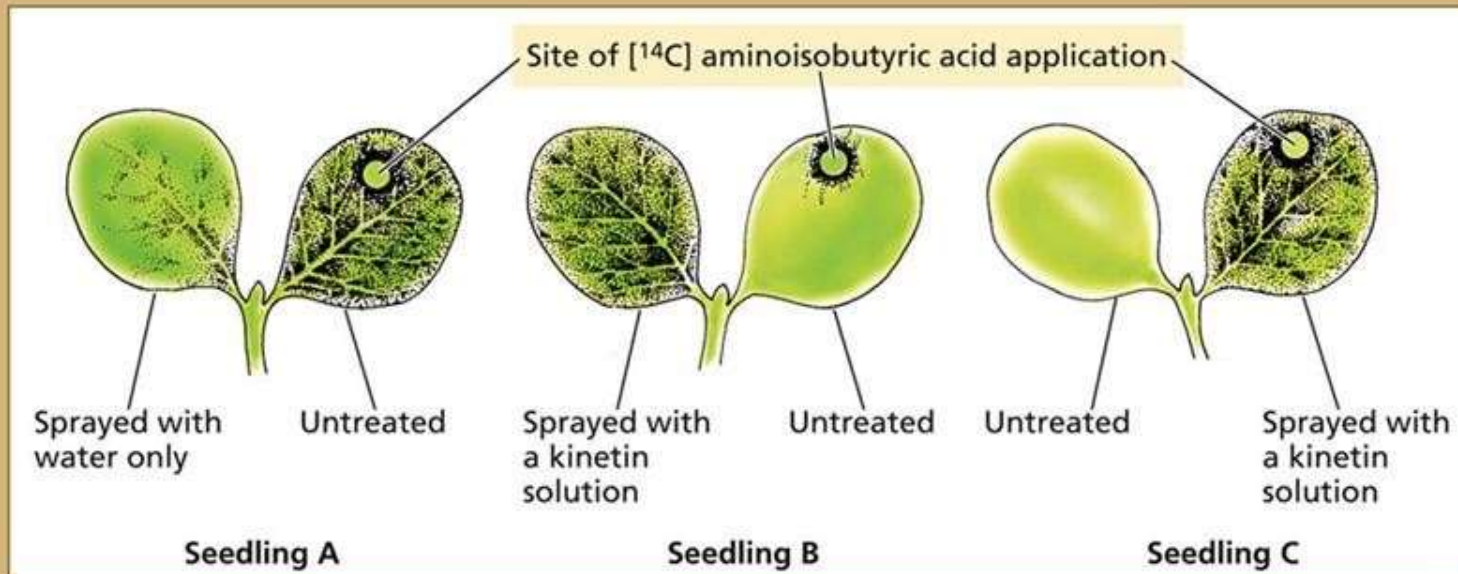


- Cytokinins induce division in inflorescence tips
  - Leads to more flowering which yields more fruit
- “Cytokinin Oxidase Regulates Rice Grain Production” (Ashikari et al. 2005)
  - Plants in this study have lower levels of cytokinin oxidase. The plants then produce more fruit.

# CYTOKININ-INDUCED NUTRIENT MOBILIZATION

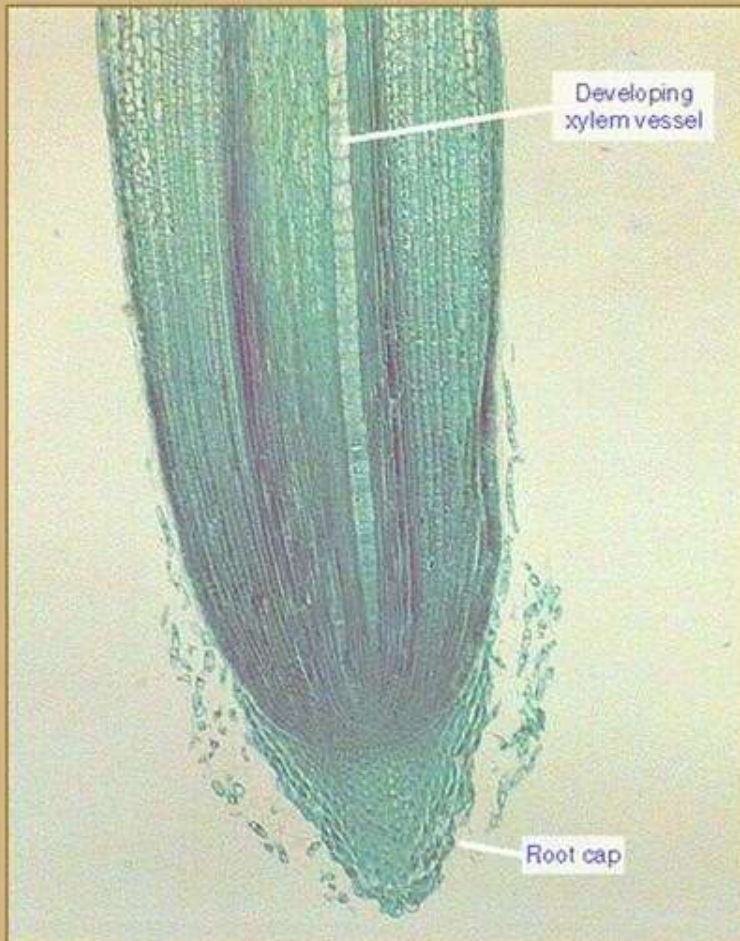
## CYTOKININ FUNCTION

- Causes a new source-sink relationship in the growing parts in the plant
- If a plant needs more nutrients to grow, cytokinins accumulate in the root zone to stimulate growth.
  - Nitrogen is often the limiting nutrient most sought after



# COTYLEDON EXPANSION

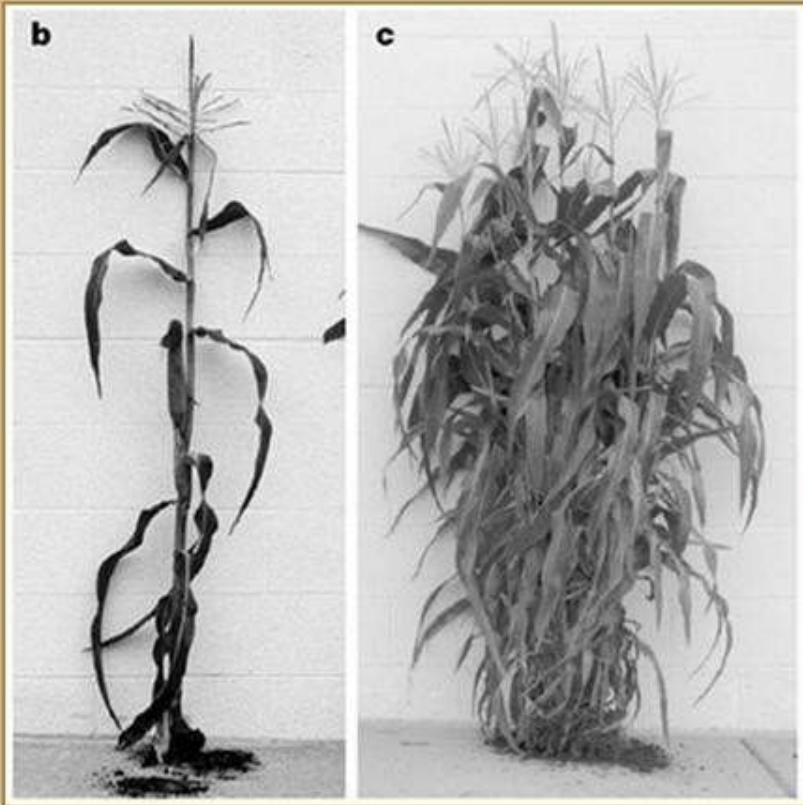
## CYTOKININ FUNCTION



- Promotes expansion in cotyledons
- Extends the cell wall
- Differs from auxin expansion
  - Unlike auxin, no proton extrusion through the cell wall happens

# APICAL DOMINANCE

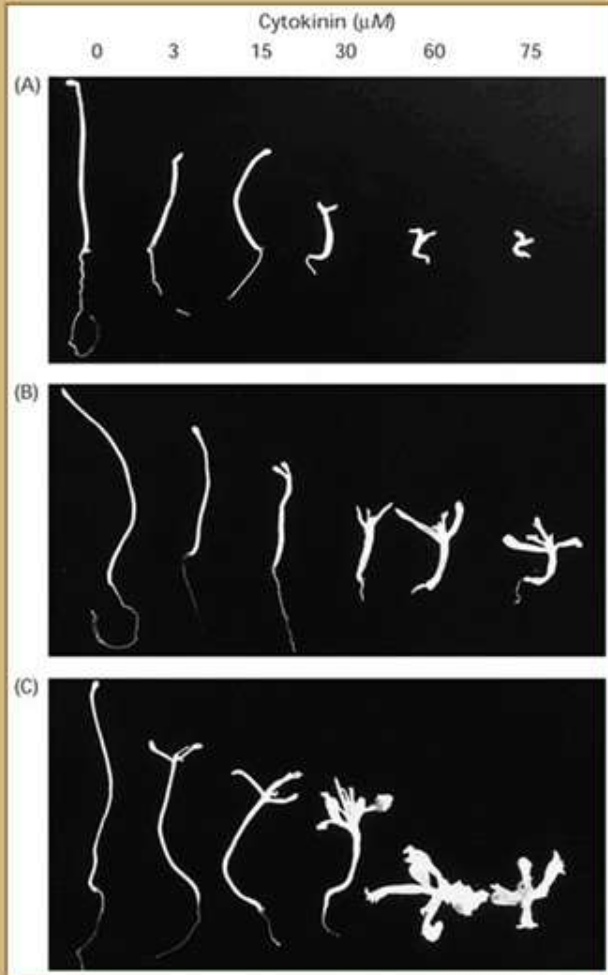
## CYTOKININ FUNCTION



- Antagonistic hormone interaction between cytokinin and auxin
  - Cytokinin stimulates growth in auxiliary buds
    - Inhibits shoot elongation
  - Auxin restrains growth in auxiliary buds
    - Causes shoot to lengthen.
    - Mutants that overproduce cytokinins in lateral meristems are bushy.

# SEEDLING MORPHOLOGY

## CYTOKININ FUNCTION



- Etiolated leaves treated with cytokinins produce more active/productive chloroplasts upon illumination
- Dark-germinated seedlings treated with cytokinins
  - Shortened hypocotyls
  - Expanded cotyledons
  - Partial development of etioplasts into chloroplasts

# REFERENCES

## CYTOKININS

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