

CYTOKININS

Physiological Roles

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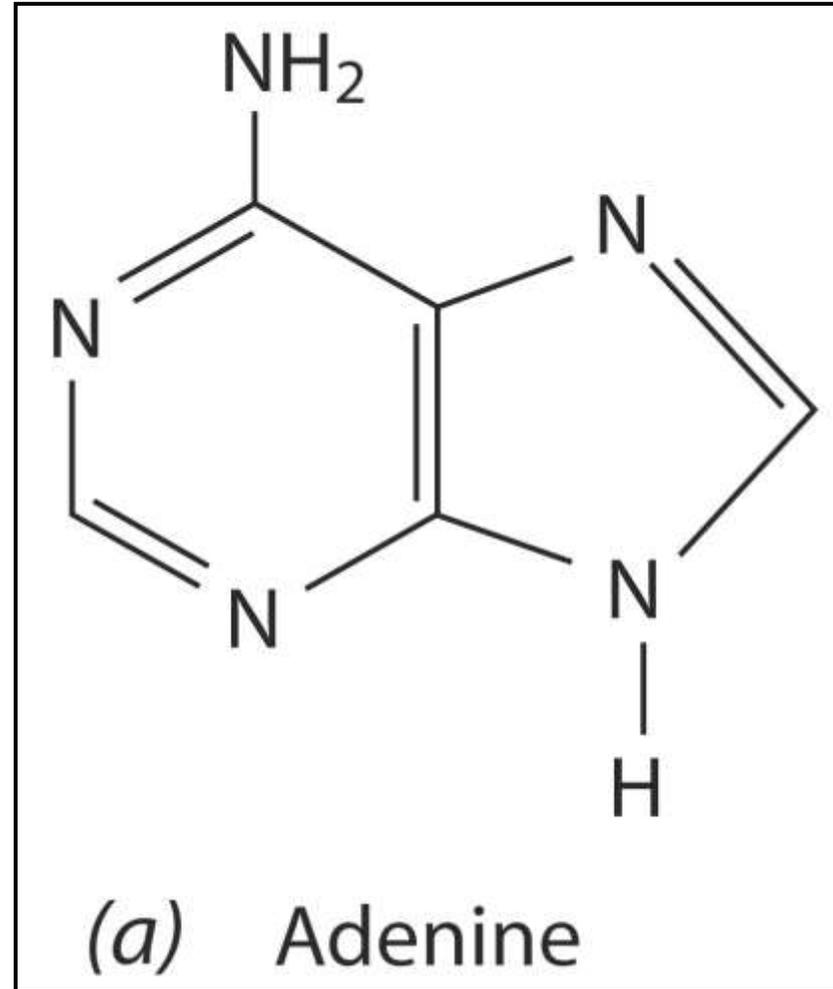
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CYTOKININS

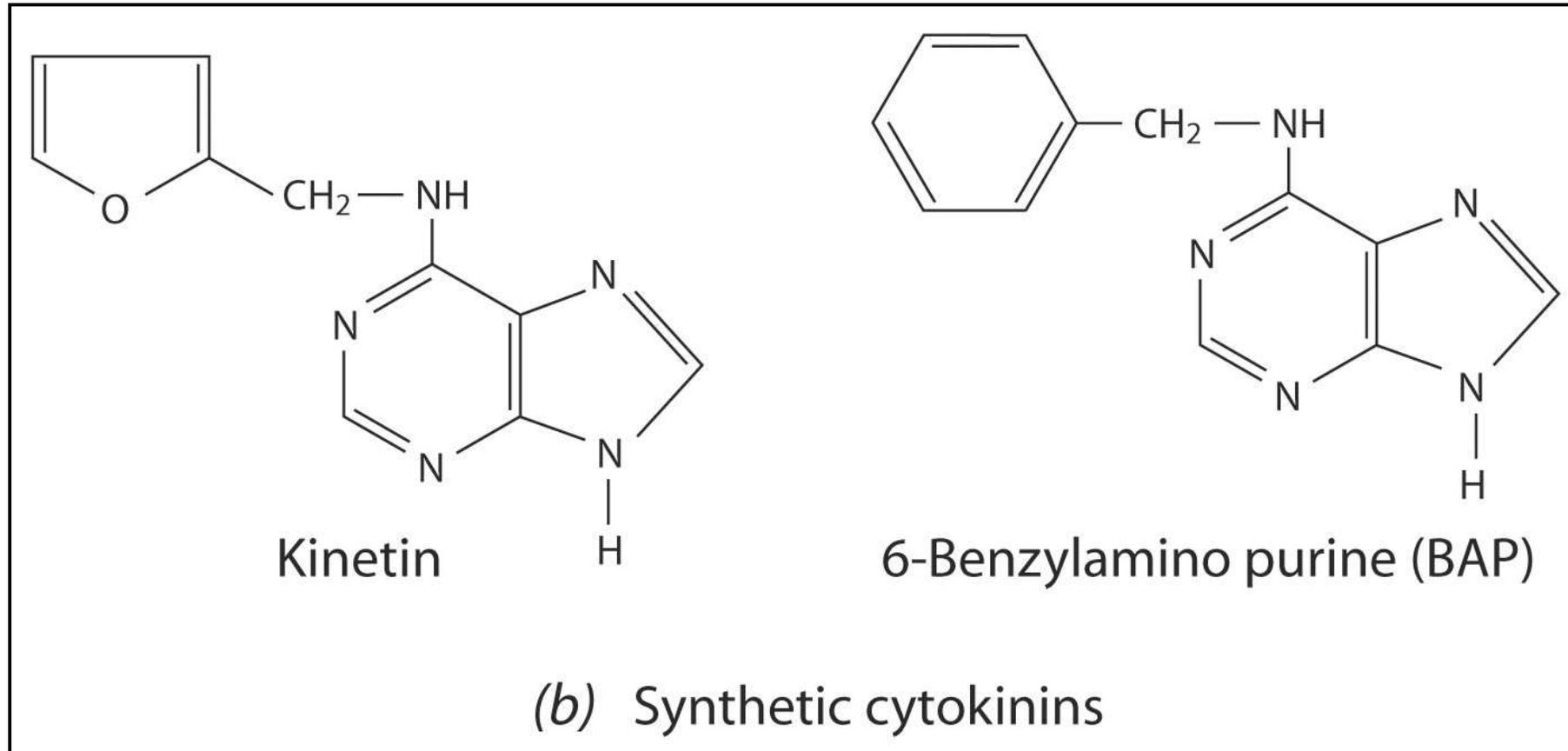
Cytokinins (CK) are a class of plant growth substances (plant hormones) active in promoting cell division, and are also involved in cell growth, differentiation, and other physiological processes.

There are two kinds of cytokinins:

All cytokinins have basic Adenine ring structure



There are synthetic cytokinins derived from diphenylurea (DPU) that are structurally unrelated to the adenine type cytokinins.



♣ Adenin cytokinins

Examples: kinetin, zeatin, benzyl adenine (same as 6-Benzylaminopurine).

All natural cytokinins are derivatives of the base adenine. The DNA base adenine is a structural analogue of cytokinins and have low cytokinin bioactivity.

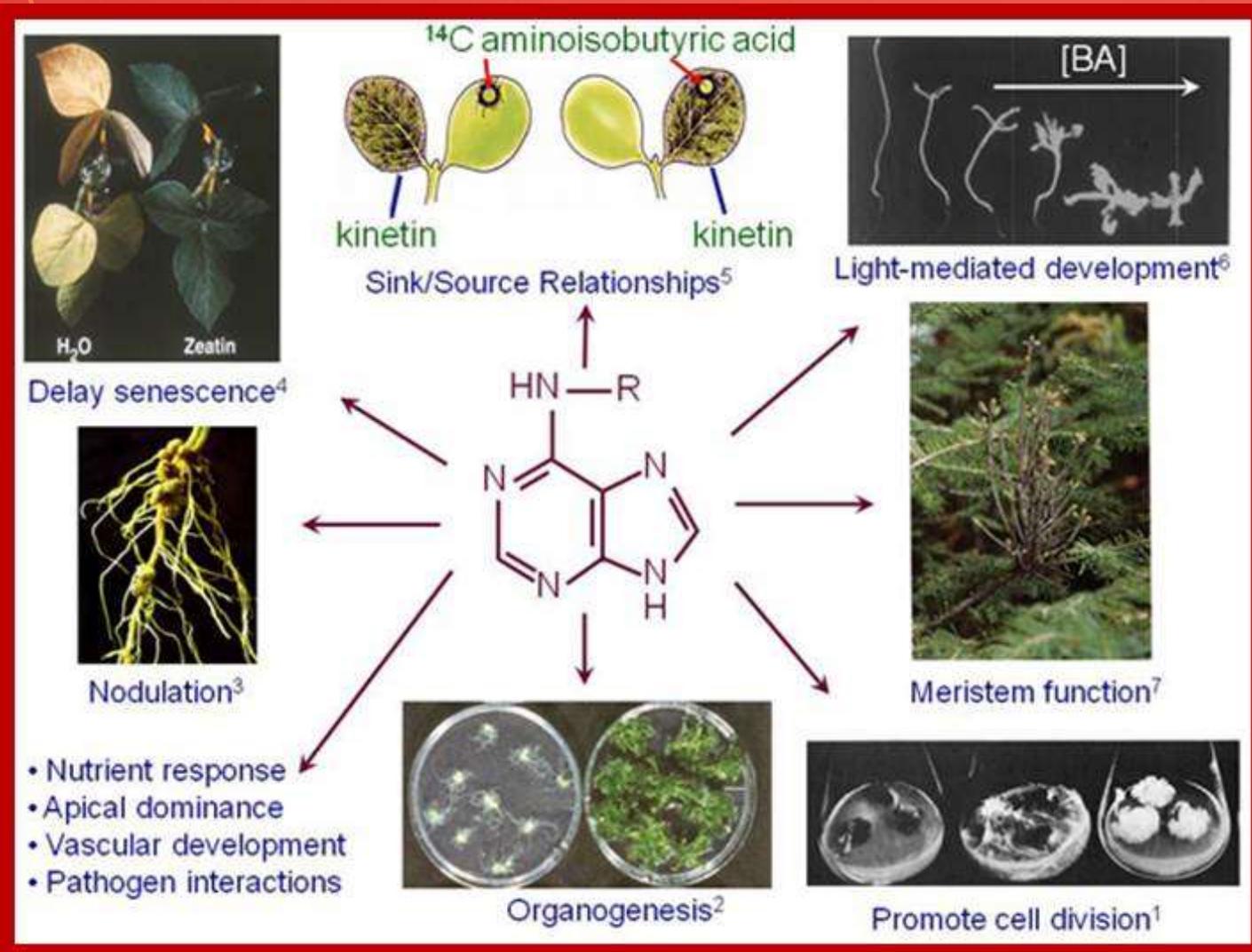
♣ Phenylurea cytokinins

Some synthetic cytokinins are substituted phenylureas .

Example: N, N'-diphenylurea

Although their chemical compositions differ, there is a structural correlation between adenine cytokinins and urea cytokinin, and both show similar biological activities.

MAIN FUNCTIONS OF CYTOKININS



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1. Cell Division

- Stimulate

2. Apical Dominance

- Inhibit

3. Leaf Senescence

- Inhibit

4. Nutrient Mobilization

- Stimulate

5. Bud Dormancy

- Reverse

6. Seed Germination

- Stimulate

DISCOVERY

CYTOKININS

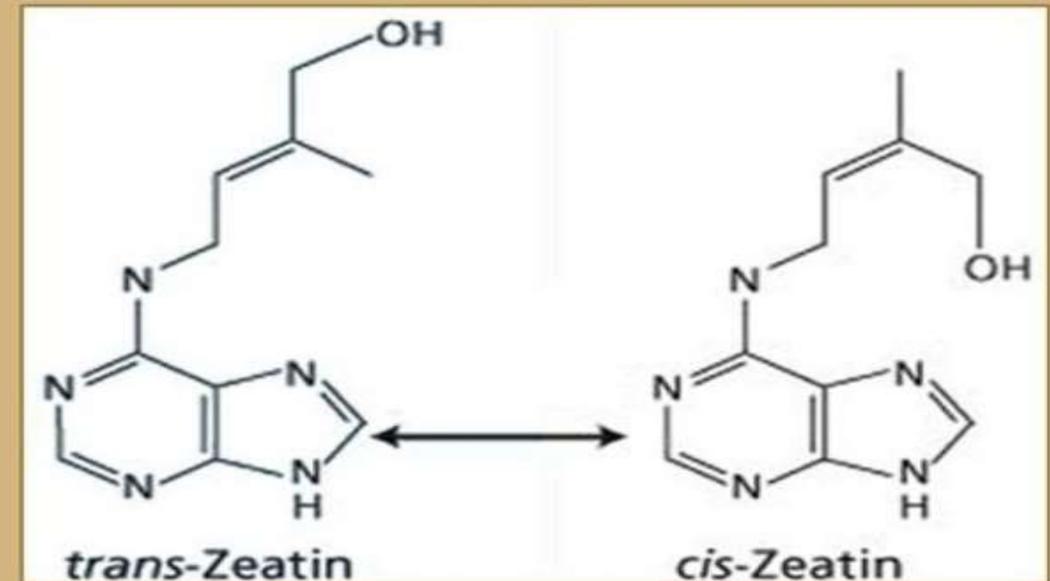


- Haberlandt (1913) – compound in phloem stimulates cell division
- Van Overbeek (1941) – coconut milk (endosperm) also has the ability to stimulate cell division
- Jablonski & Skoog (1954) – compounds in vascular tissues promote cell division

DISCOVERY

CYTOKININS

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



Distribution

- ✚ Distribution Cytokinins have been detected in a wide variety of plants; from unicellular **yeasts, algae** to multi cellular **higher plants**.
- ✚ Particularly in higher plants, cytokinins are found in **root tips, xylem, young leaves; endosperms of developing fruits, germinating seeds and tumour tissues**.
- ✚ Today there are more than 200 natural and synthetic cytokinins combined.

Occurrence

- Cytokinins have been found in almost all higher plants as well as mosses, fungi, bacteria,
- Cytokinins are found in actively growing tissues where cell division takes place (root tip, shoot tip, expanding leaf, developing endosperm – e.g. Liquid endosperm of coconut, immature maize endosperm.
- Today there are more than 200 natural and synthetic cytokinins combined.
- However it is not known whether they are synthesized in these tissues or transported to these tissues from other sites of synthesis. Root tips are the probable sites of cytokinin synthesis.
- The balance of cytokinins and auxins acting together causes development of organs like shoots and roots

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).

Site of Synthesis

- Occurs in root tips and developing seeds

Biosynthesis

- Cytokinins occur in free form or in tRNA
- The major site of biosynthesis of free cytokinins is root tip and distribute via xylem – also produced in developing buds, developing seeds.
- tRNA-cyto are formed in every living cell in cytoplasm, chloroplast and mitochondria

THE BIOLOGICAL ROLES OF CYTOKININS

Cytokinins Regulate Cell Division in Shoots and Roots



FIGURE: Tobacco plants overexpressing the gene for **cytokinin oxidase**. The plant on the left is wild type. The two plants on the right are overexpressing two different constructs of the *Arabidopsis* gene for cytokinin oxidase: *AtCKX1* and *AtCKX2*. Shoot growth is strongly inhibited in the transgenic plants. (From Werner et al. 2001.)

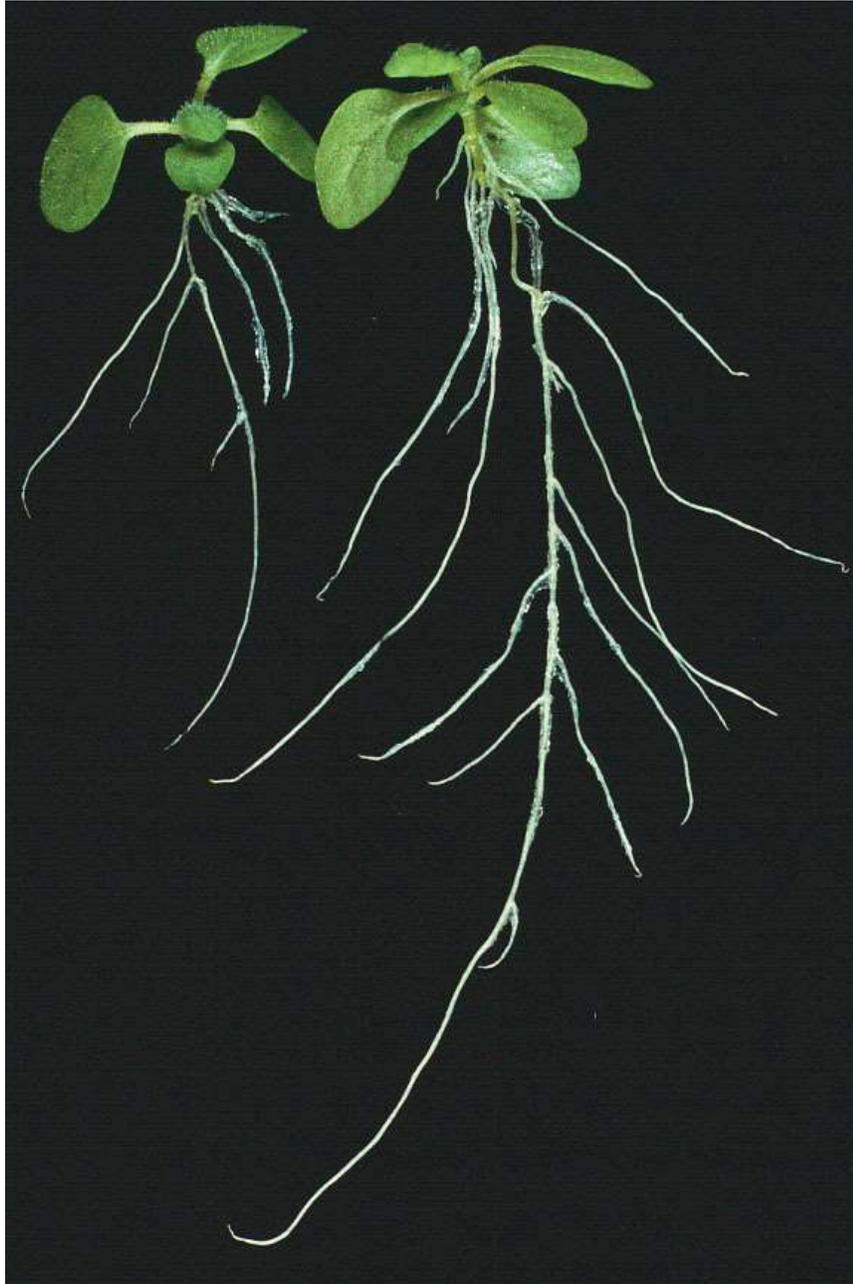
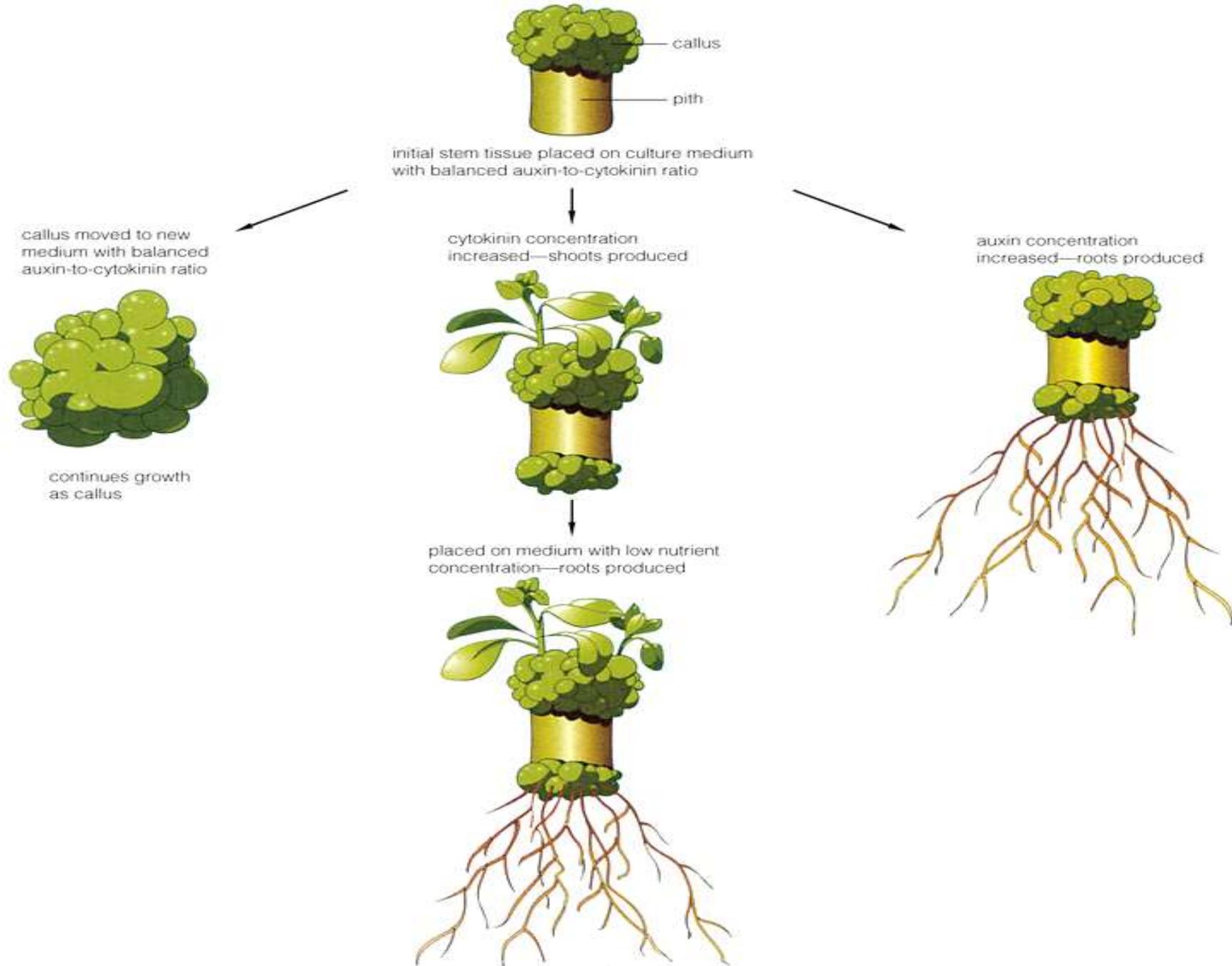


FIGURE 21.10 Cytokinin suppresses the growth of roots. The cytokinin-deficient *AtCKX1* roots (right) are larger than those of the wild-type tobacco plant (left). (From Werner et al. 2001.)



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CELL DIFFERENTIATION

CYTOKININ FUNCTION

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



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):

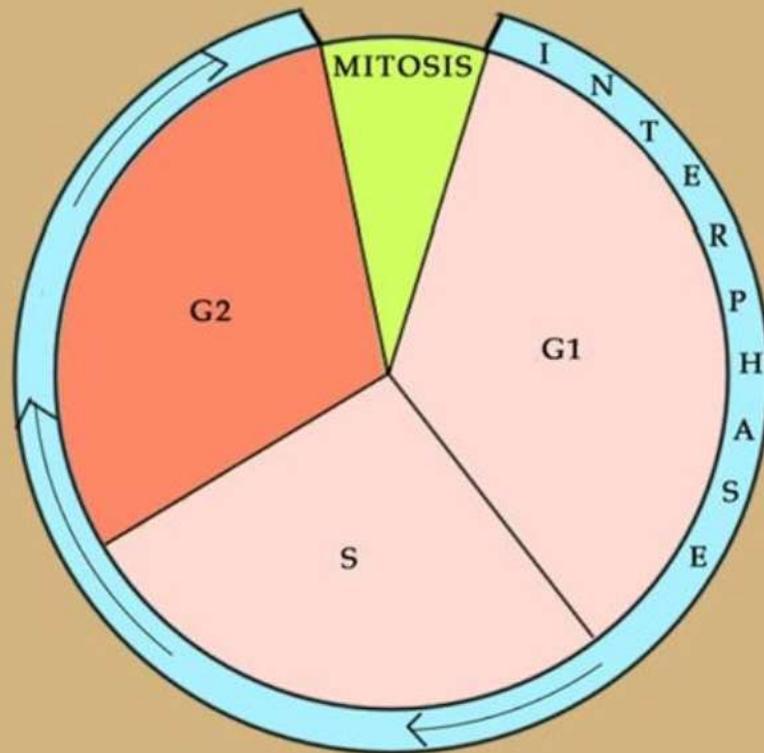
The Medium	The callus differentiation
callus + auxin + no cytokinin	little growth of callus
callus + auxin + cytokinin	callus grows well, undifferentiated

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

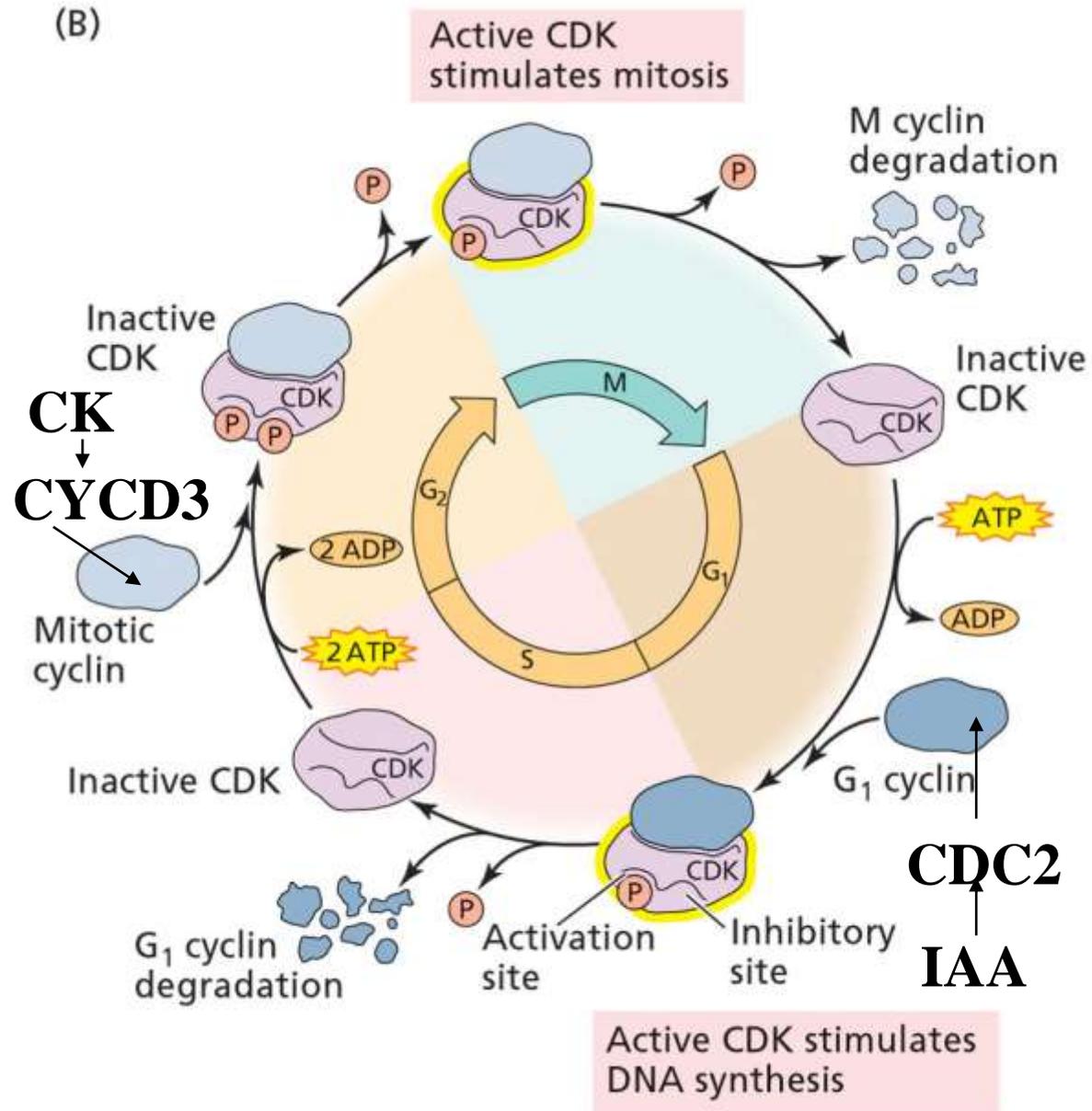
The concentration	The callus differentiation
callus + low [cytokinin/auxin]	callus grows well, forms roots
callus + high [cytokinin/auxin]	callus grows well, forms meristem & shoots

CELL DIVISION

CYTOKININ FUNCTION



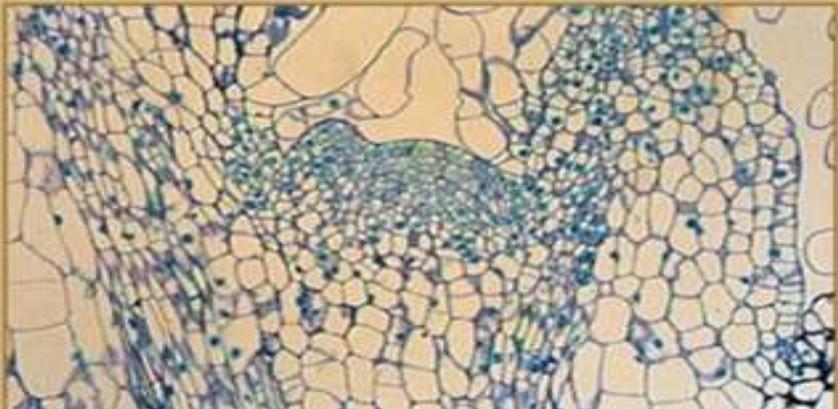
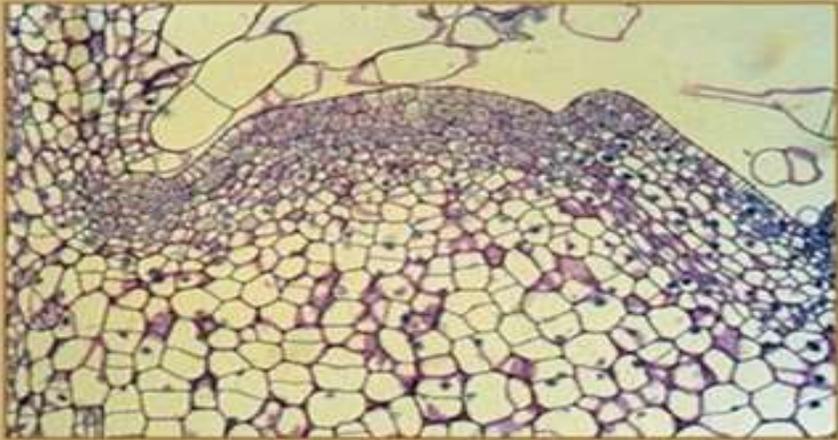
- Auxin and cytokinins influence the activity of:
 - **Cyclin-dependant protein kinases (CDKs) and cyclins**
 - Both are proteins that regulate transitions between **G1 to S** and **G2 to mitosis** stages in the cell cycle
 - Auxin stimulates the production of CDKs and cyclins
 - Cytokinins activate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



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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

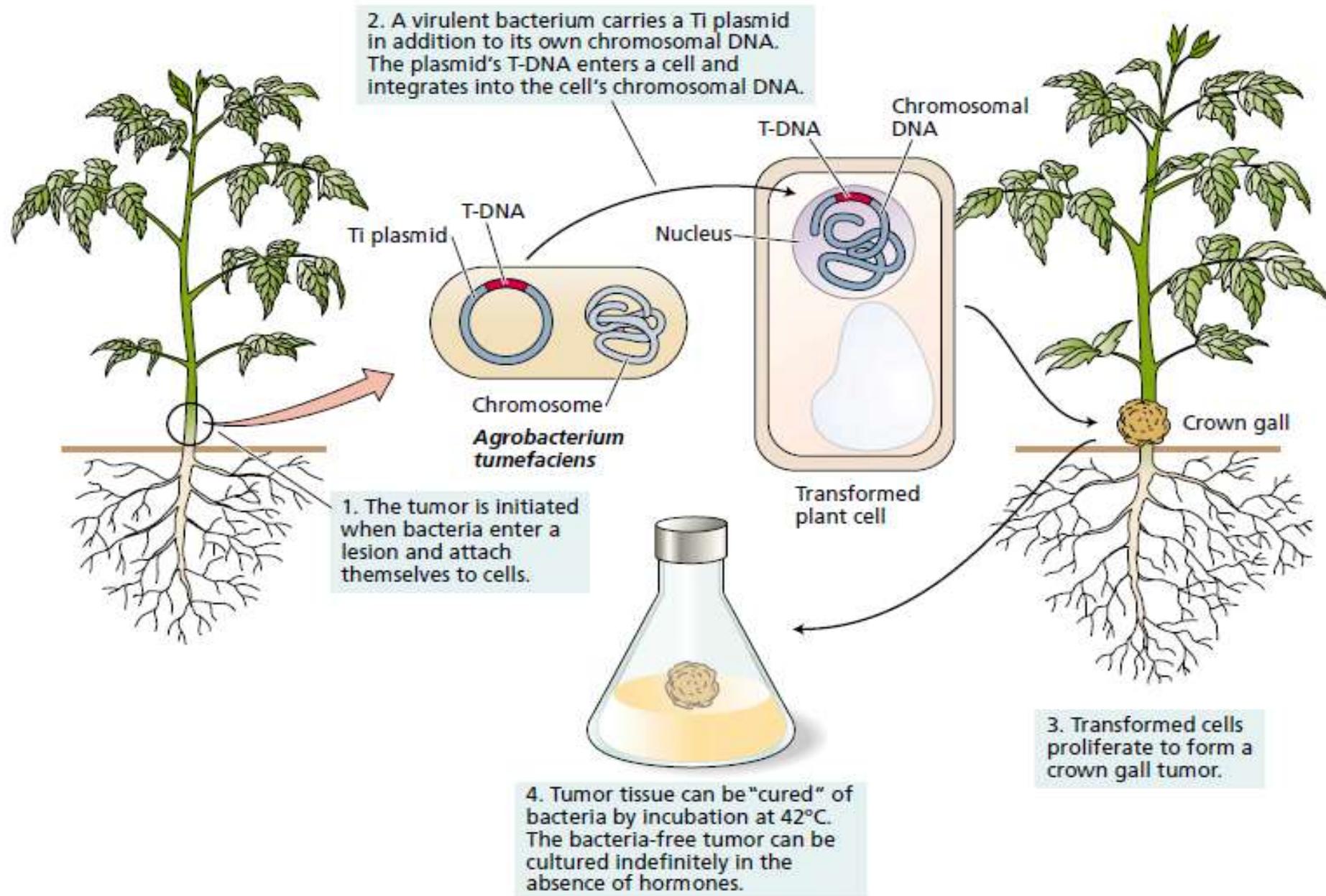
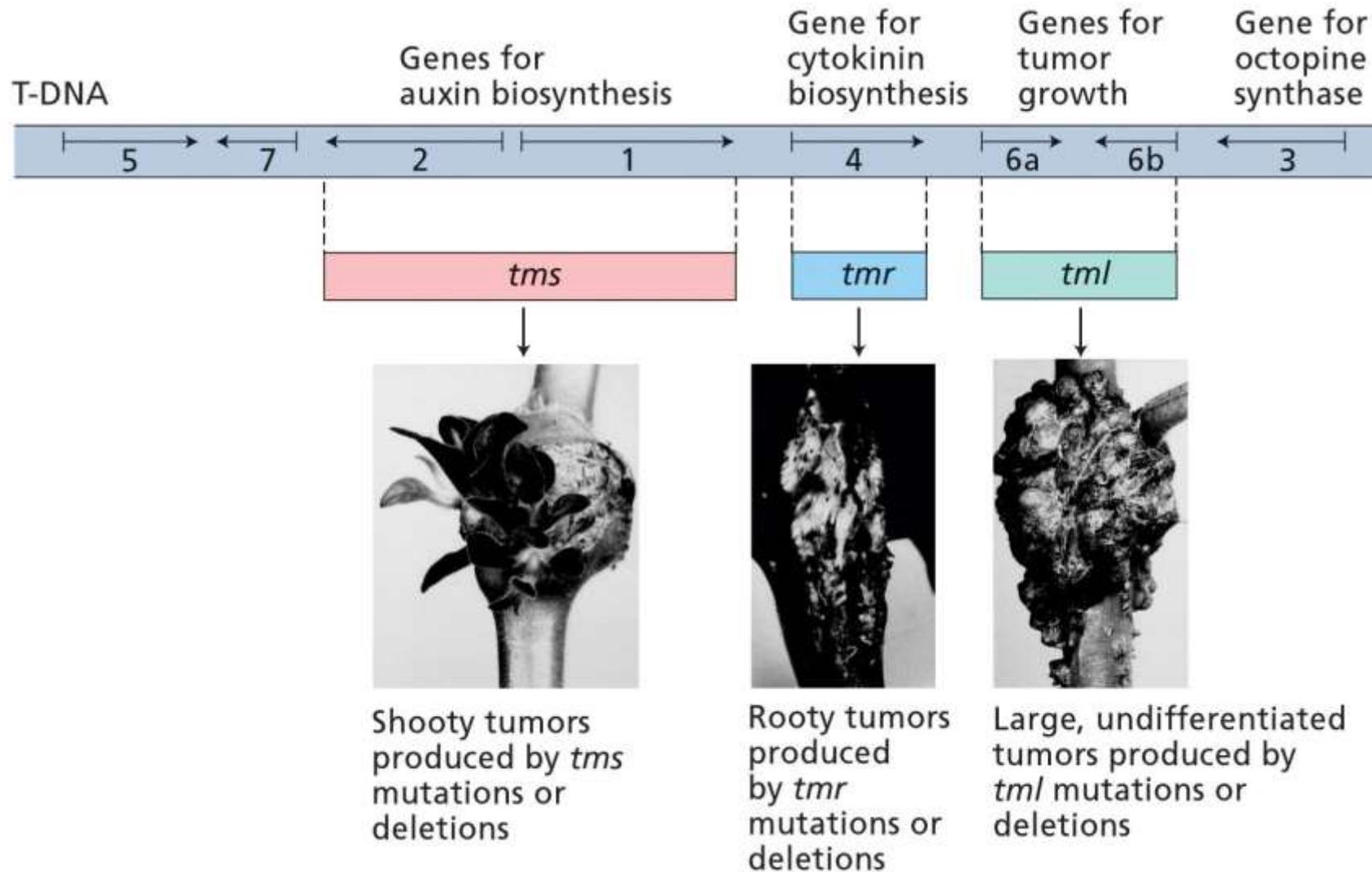


FIGURE 21.4 Tumor induction by *Agrobacterium tumefaciens*. (After Chilton 1983.)



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FIGURE 21.14 Map of the T-DNA from an *Agrobacterium* Ti plasmid, showing the effects of T-DNA mutations on crown gall tumor morphology. Genes 1 and 2 encode the two enzymes involved in auxin biosynthesis; gene 4 encodes a

cytokinin biosynthesis enzyme. Mutations in these genes produce the phenotypes illustrated. (From Morris 1986, courtesy of R. Morris.)

Cytokinins Delay Leaf Senescence



Plant expressing *ipt* gene remains green and photosynthetic

Age-matched control: advanced senescence, no photosynthesis

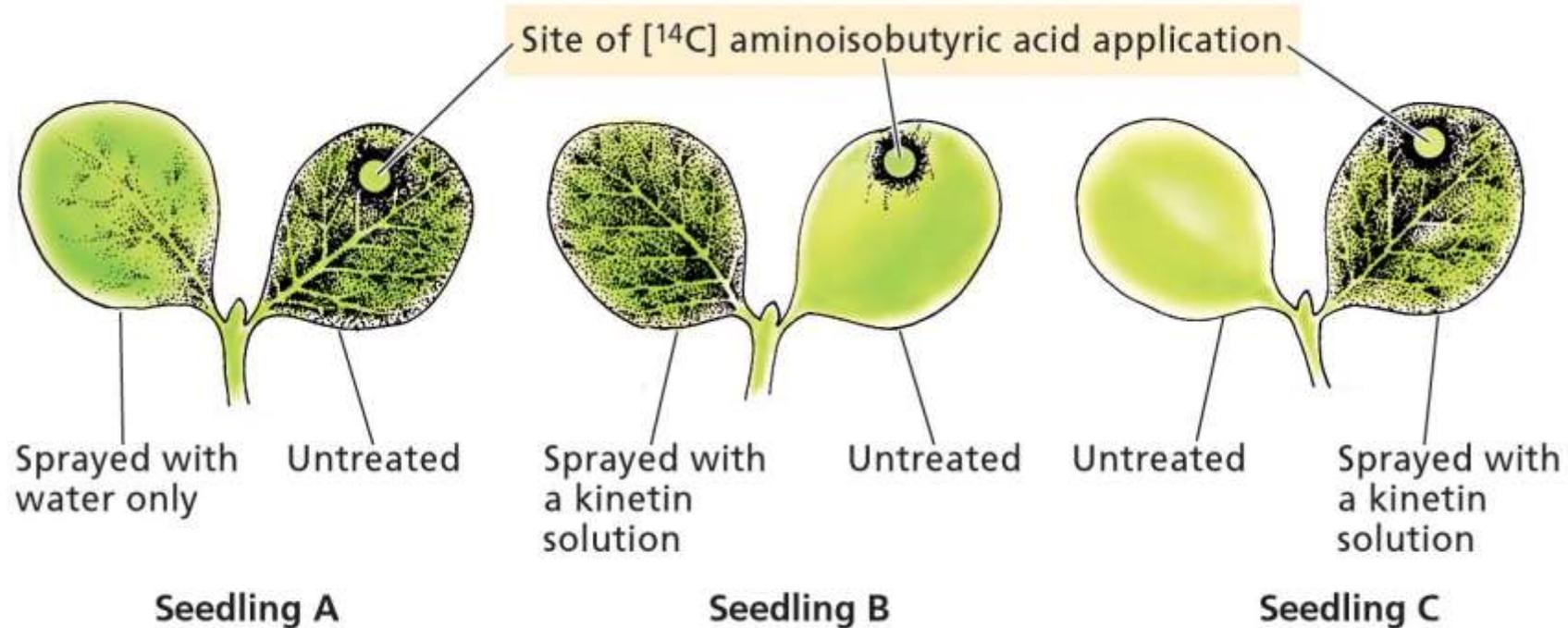
LEAF SENESCENCE

CYTOKININ FUNCTION



- Cytokinin delays leaf senescence
 - Delay the degradation of chloroplasts
 - May increase the growing season for agricultural purposes.
- Delayed leaf senescence help plants recover from environmental stresses
 - Drought (Rivero et al. 2007)
 - Flooding (Zhang et al. 2000) (Hyunh et al. 2005)

Cytokinins Promote Movement of Nutrients



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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

OTHER FUNCTIONS

-  **Promote Chloroplast maturation: Promotes the conversion of etioplasts into chloroplasts via stimulation of chlorophyll synthesis - Etiolated leaves treated with cytokinins develop chloroplast
May enhance stomatal opening in some species.**
-  **Involved in releasing seed dormancy Delay of senescence**
-  **Promote nutrient metabolism in some species**

Anticytokinins

The compounds recently been synthesized are structurally related to cytokinins , but act as cytokinin antagonists or anticytokinins in certain plant bioassays.

Example...7-alkylamino-3-methylpyrazolo [4,3-d] pyrimidine

Such cytokinin antagonists regulate plant development and the biosynthesis of specific products and in adjustment to environment. Might be used to study plant cell genetics because they prevent mitosis or cytokinesis.

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Thanks