

LE CITOCHININE

1913 Haberlandt

il tessuto vascolare contiene una sostanza in grado di stimolare la divisione cellulare (tubero patata/ferita)

1930 White

radici pomodoro



crescono in terreno minimo

fusti



non crescono

**quando il fusto
radica**



**cresce il fusto
cresce la radice**

un fattore prodotto dalla radice regola la crescita del fusto

ricerca del fattore che regola la divisione cellulare

succo pomodoro
latte di cocco



stimolo
divisione



zeatina
(solo nel 1974)

'50 Skoog

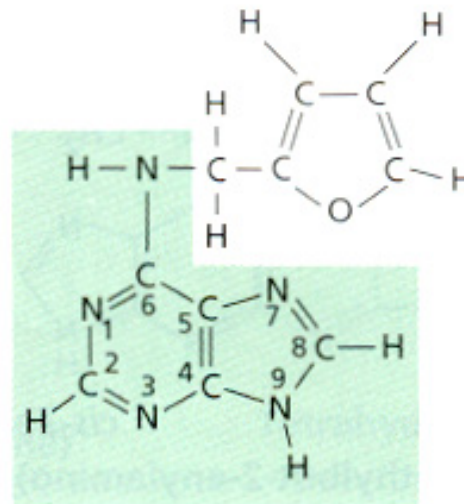
Ricerca fattori in grado di
stimolare la divisione in calli di
tabacco

adenina → + stimolo

DNA
autoclavato → ++++ stimolo



chinetina
(6-furfuril-aminopurina)



Kinetin

esiste nelle piante una sostanza simile alla chinetina?

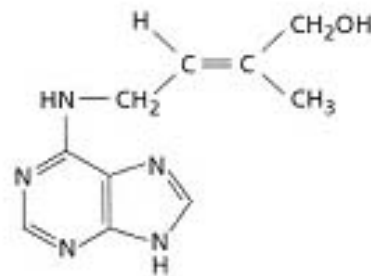
1973

identificazione dell'endosperma di mais della zeatina
(stimola divisione insieme ad auxina)

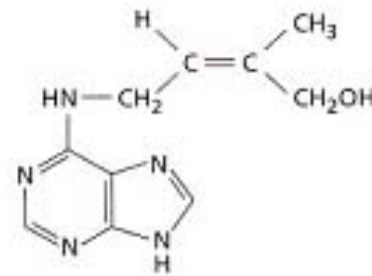
simile alla
chinetina

configurazione
cis/trans

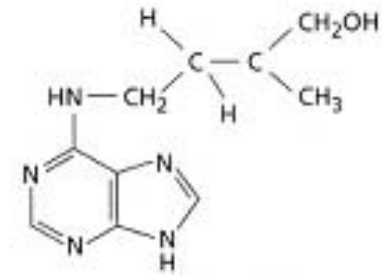
trans = forma
attiva



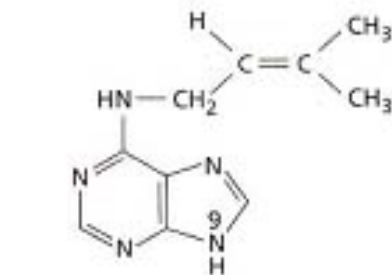
trans-Zeatin
6-(4-Hydroxy-3-methylbut-2-enylamino)purine



cis-Zeatin



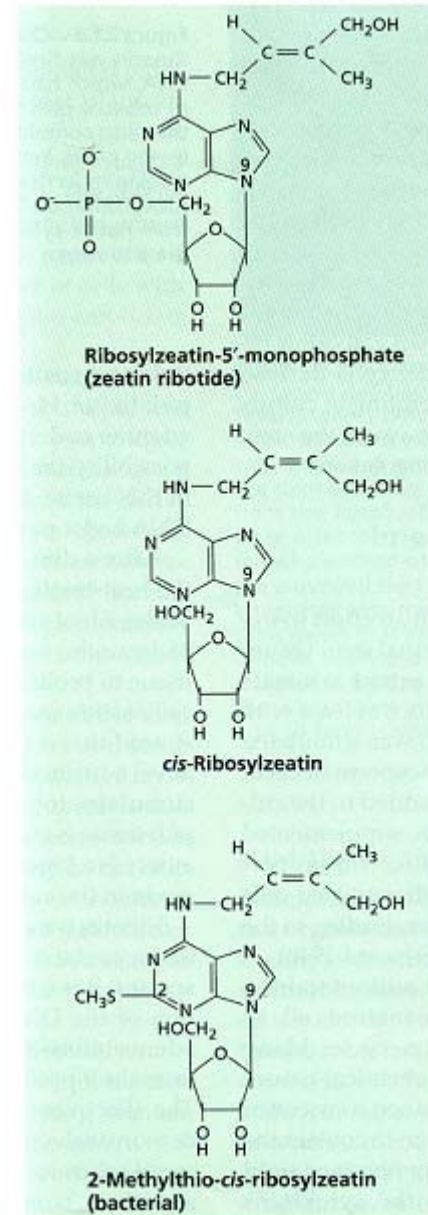
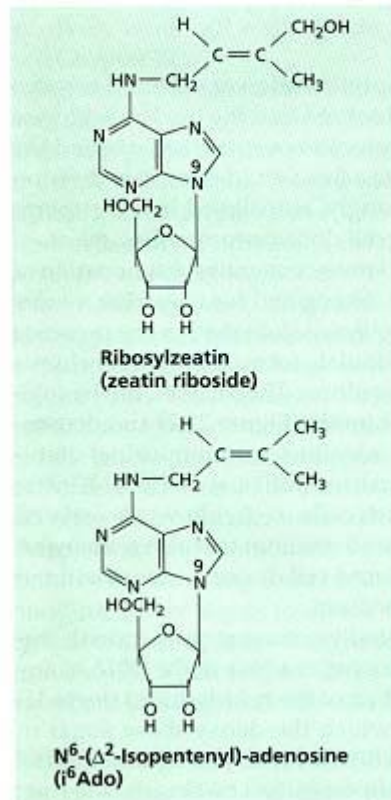
Dihydrozeatin



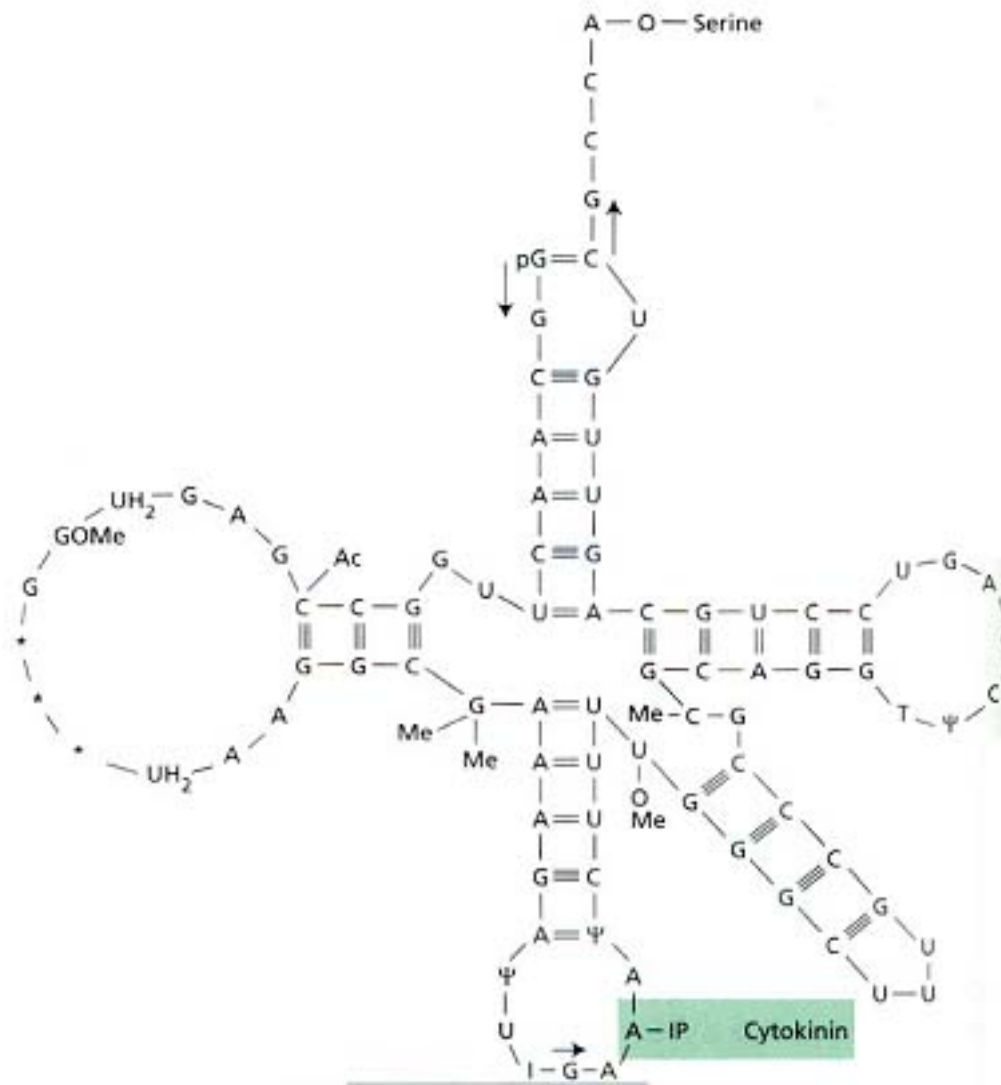
N⁶-(Δ²-Isopentenyl)-adenine
(i⁶Ade)

esistono citochinine coniugate

ribosidi



ribotide



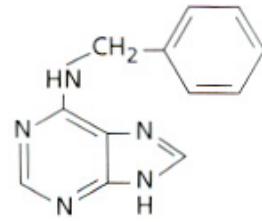
preniltransferasi



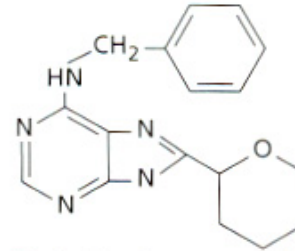
aggiunge gruppi isopentenilici
all'adenina

alcuni composti sintetici possono riprodurre gli effetti delle citochinine

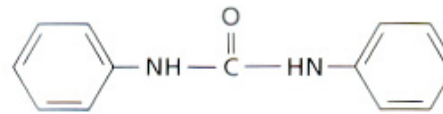
(A) Synthetic compounds active as cytokinins



Benzyladenine
(benzylaminopurine)
(BAP)

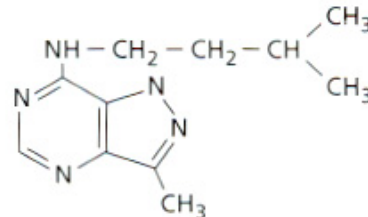


Tetrahydropyranylbenzyladenine



***N,N'*-Diphenylurea** (nonamino
purine with weak activity)

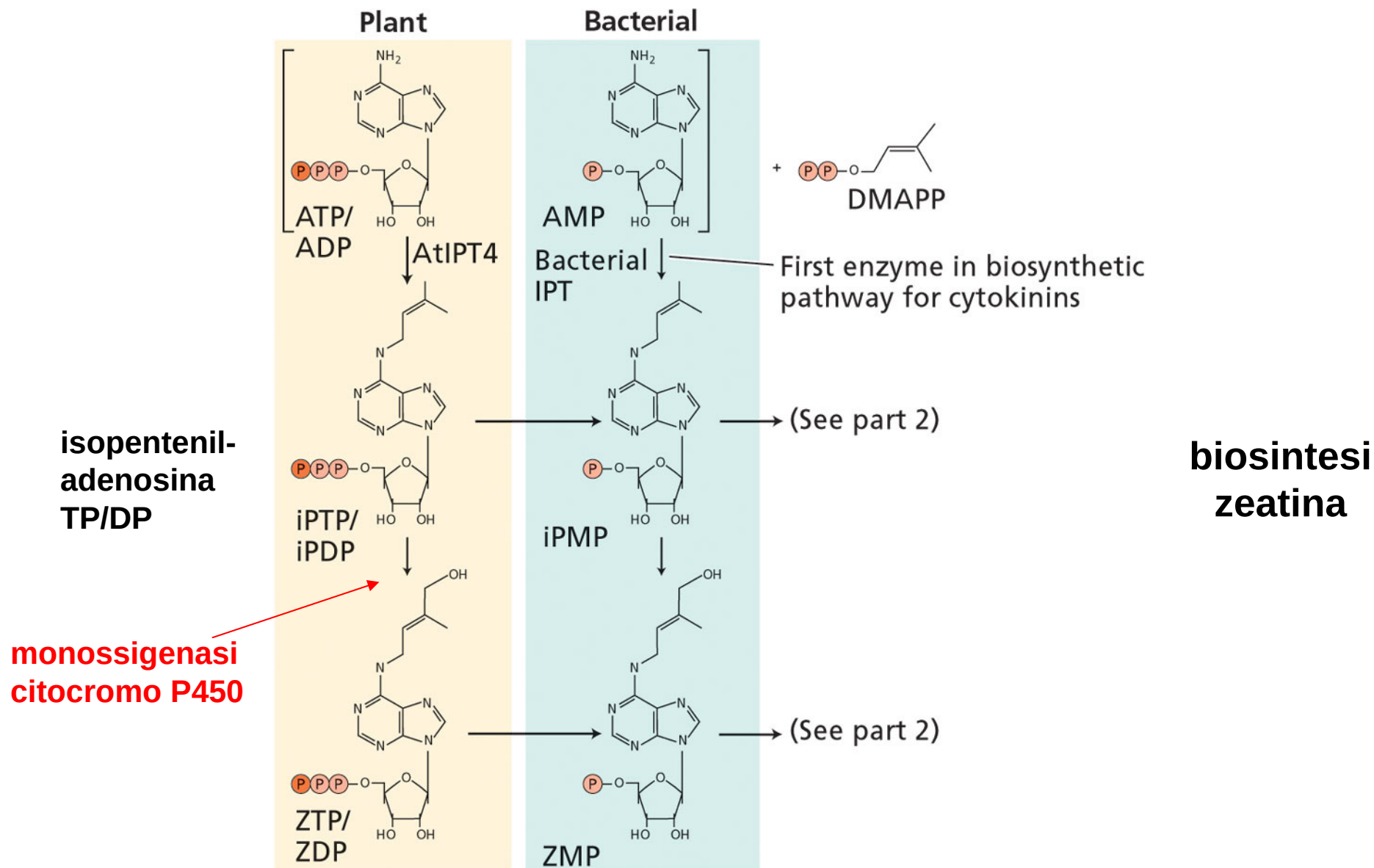
(B) Cytokinin antagonist (note modified purine ring)



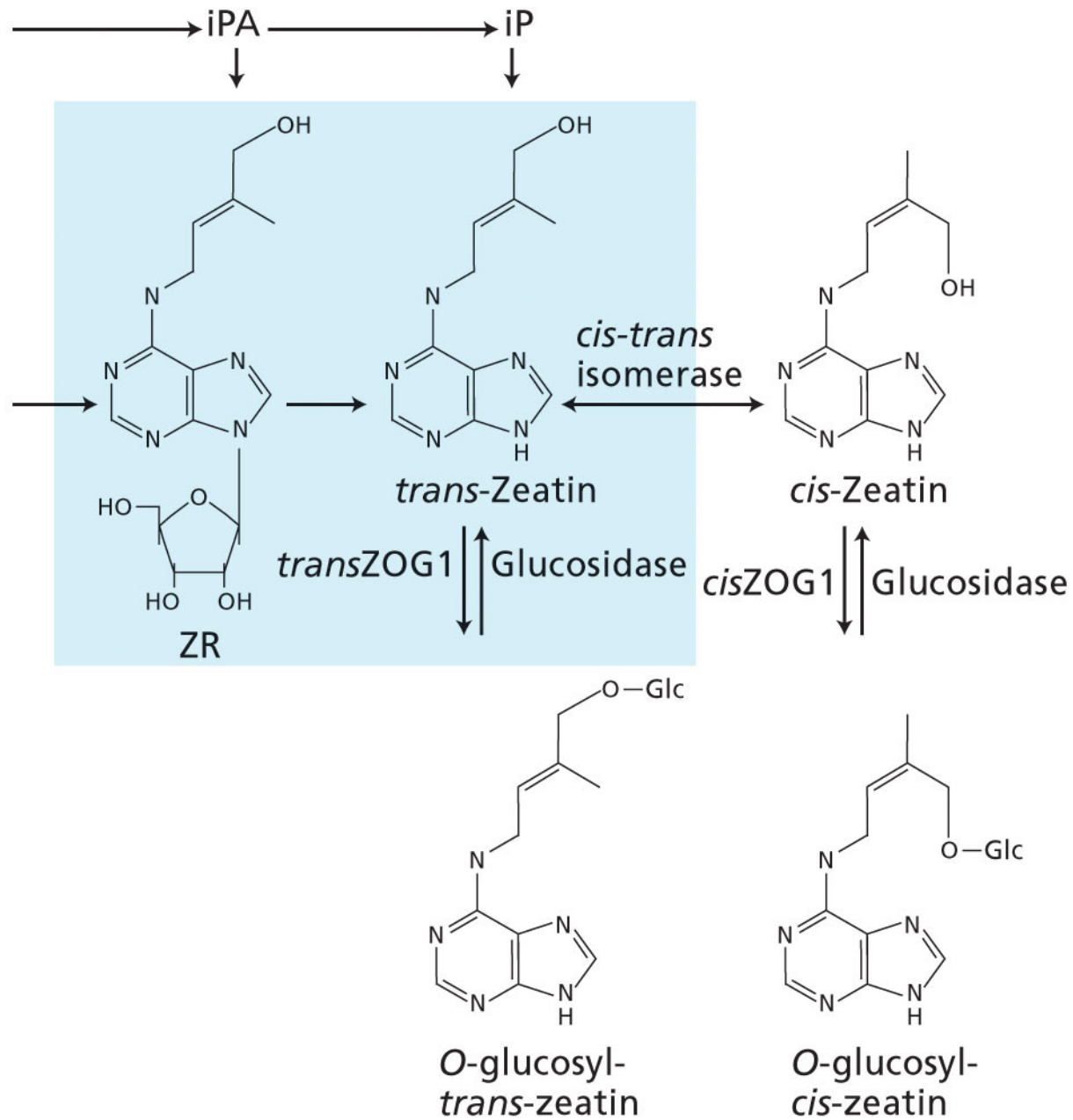
3-Methyl-7-(3-methylbutylamino)pyrazolo[4,3-d]pyrimidine

antagonista

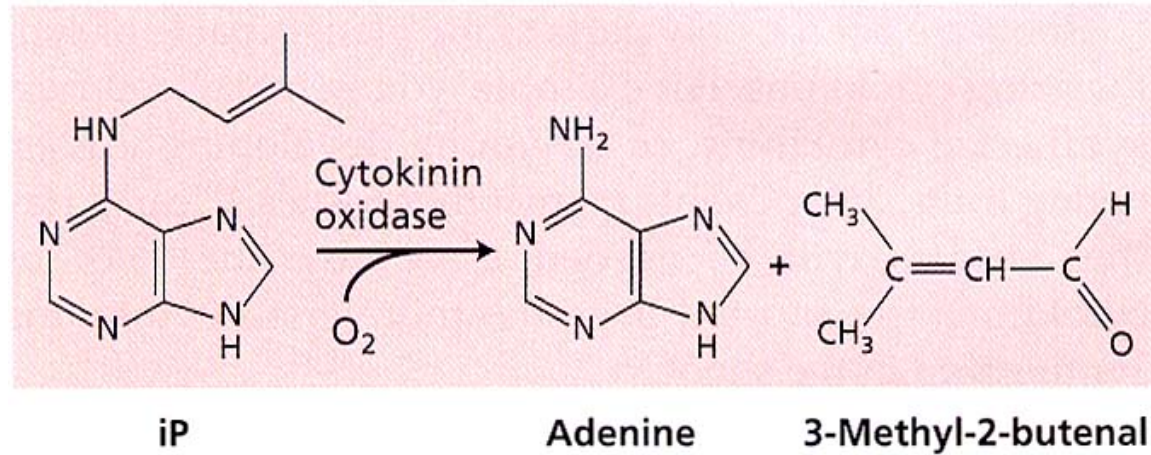




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degradazione citochinine



gene citochinina ossidasi



indotto da citochinine

Il principale sito di sintesi delle citochinine è la radice

meristema apicale radice



zeatina riboside

xilema



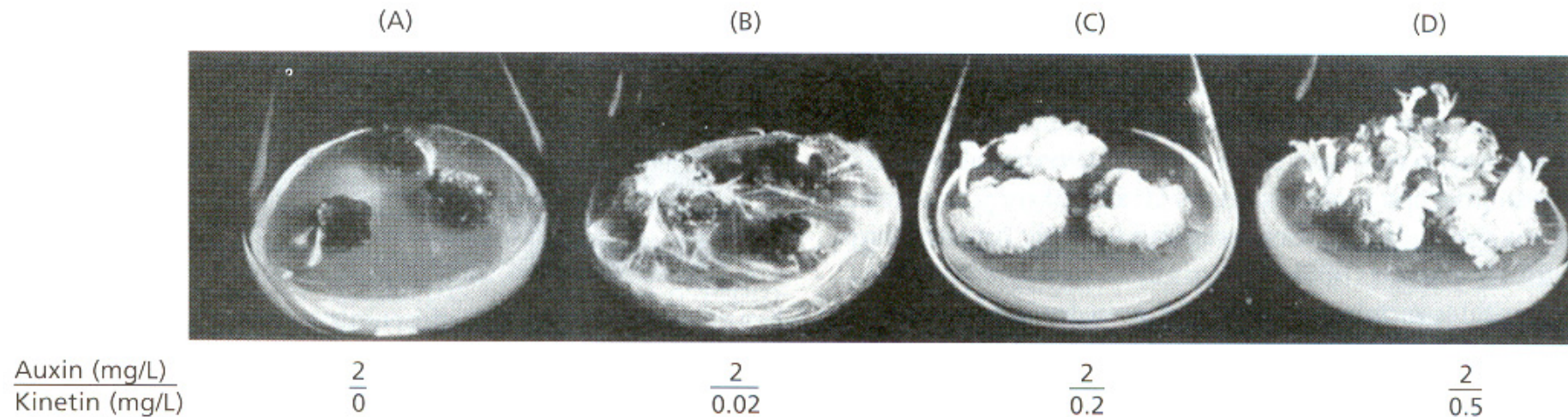
**foglie
semi**

glucosidi

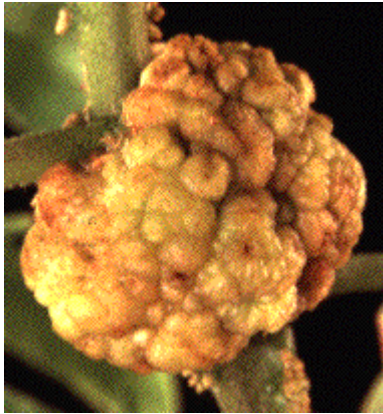
**In Arabidopsis i geni IPT sono espressi in molti tessuti.
Esistono anche altri siti di sintesi?**

RUOLO BIOLOGICO CITOCHININE

**il rapporto auxina:citochinina regola la morfogenesi
in tessuti in coltura**

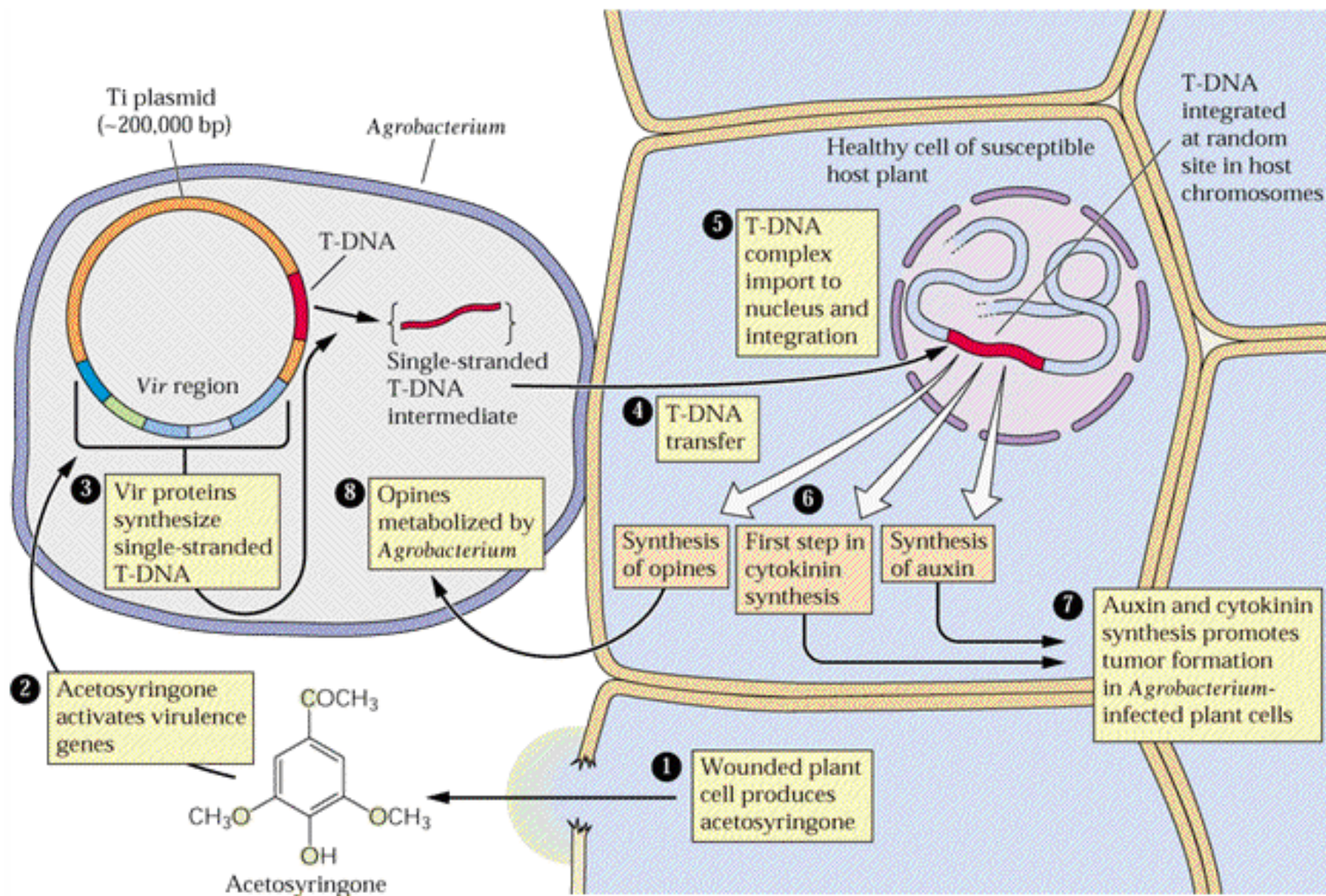


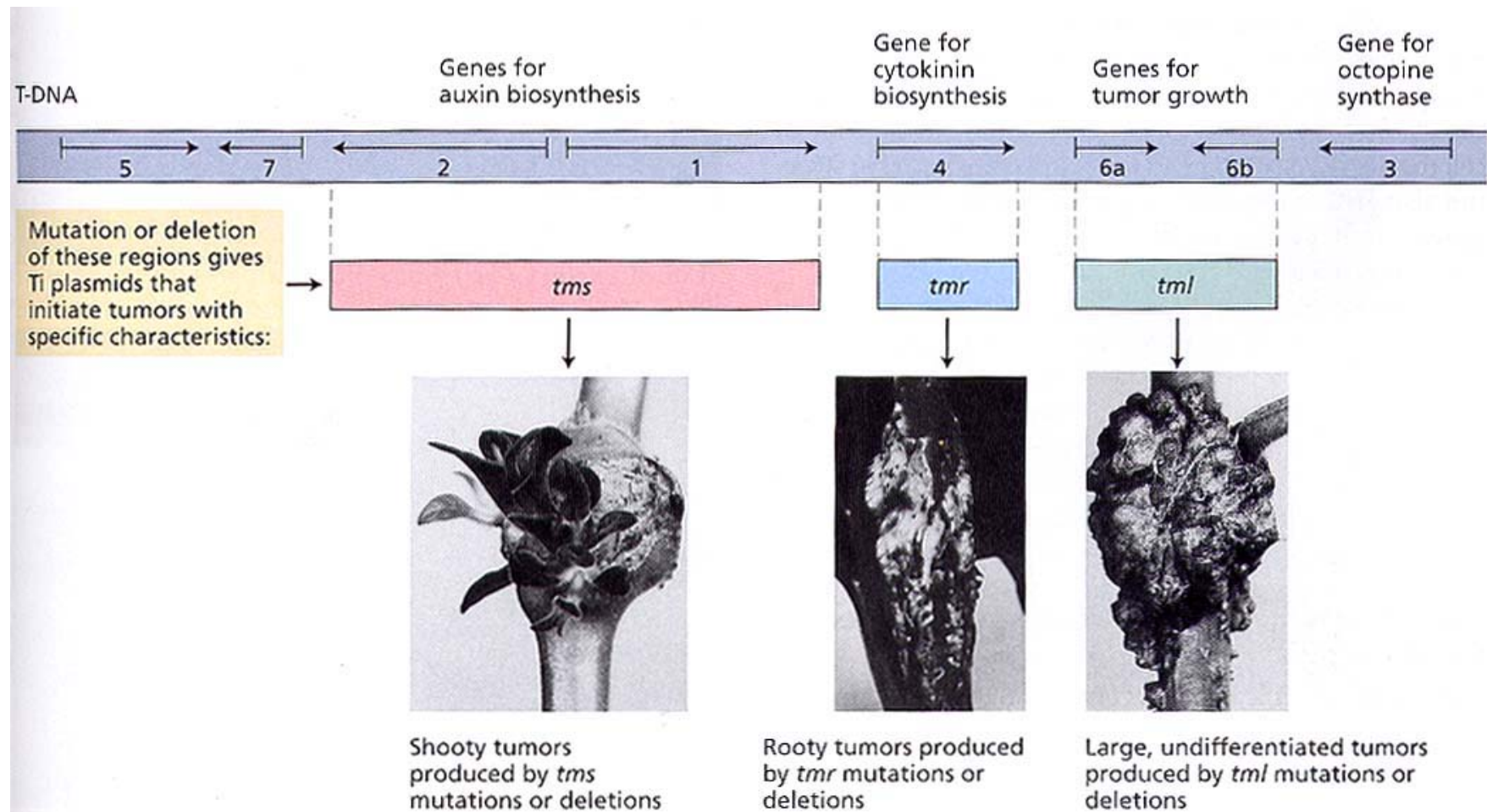
- A) no divisione cellulare
- B) formazione radici
- C) sviluppo callo indifferenziato
- D) formazione germogli



galla a corona

Agrobacterium tumefaciens





analisi piante che overproducono citochinine

ipt (*Agrobacterium tumefaciens*)

CALLI

ipt



germogli

**promotore gene indotto
da auxina
+ ipt**



piantina intera

pianta ipt

gli apici generano più foglie

+ clorofilla

apici avventizi dai piccioli

ritardata senescenza

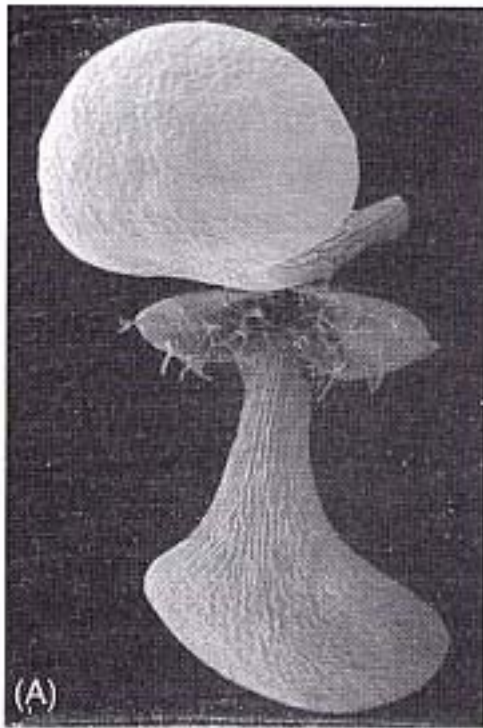
ridotta dominanza apicale

**ridotta capacità di produrre radici
avventizie da fusti recisi**

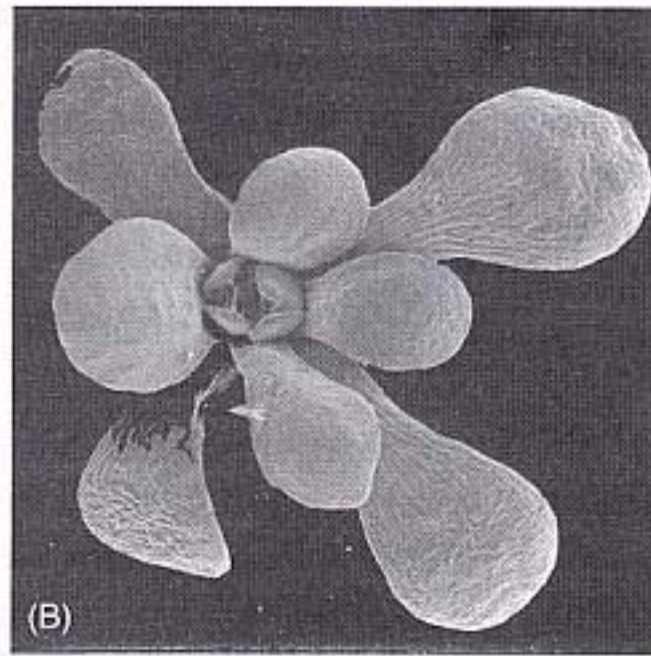
analisi mutanti con morfologia alterata



il mutante *amp1* di *Arabidopsis* ha alti livelli di zeatina



wt



amp1

le citochinine regolano la divisione cellulare

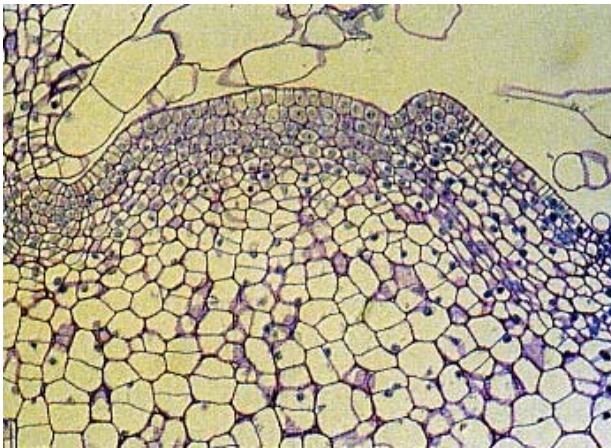
**stimolo divisione cellulare
nei fusti**

**piante tabacco overesprimenti la
citochinina ossidasi**

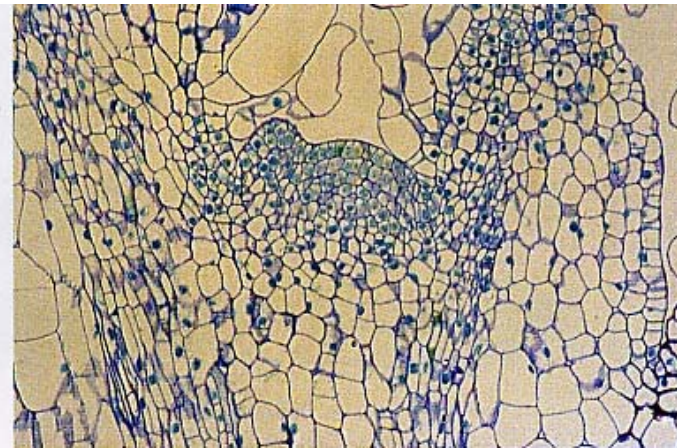


C AtCKX1 AtCKX2

**le piante AtCKX hanno una ridotta attività del
meristema apicale**



C



AtCKX

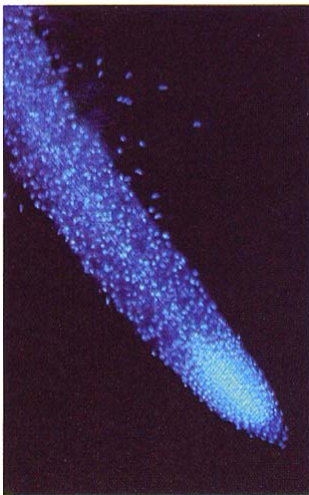
inibizione divisione cellulare nelle radici



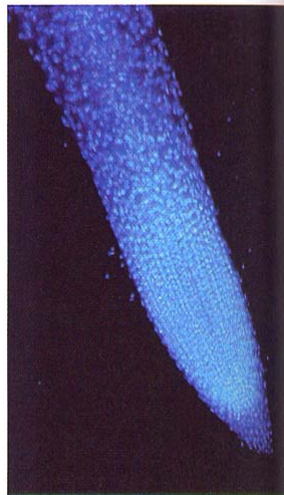
C

AtCKX

(A)



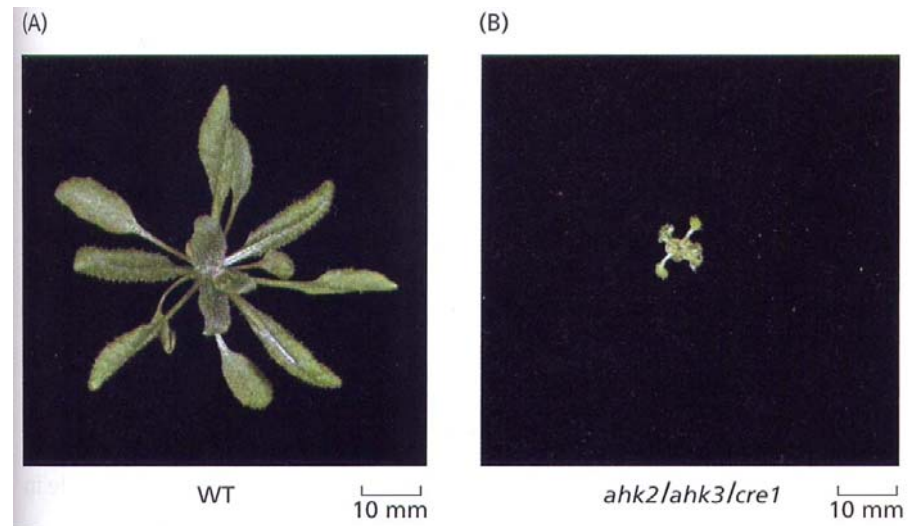
(B)



**sonda fluorescente che
colora i nuclei**

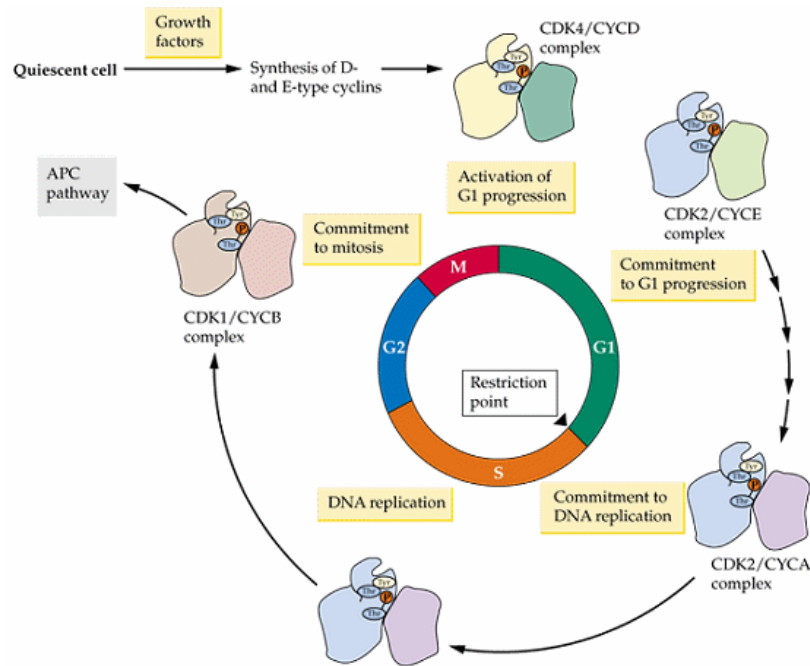
**aumento dimensioni
meristema apicale della
radice**

Mutante recettori citochinine





le citochinine regolano componenti del ciclo cellulare



CDK
Cyclin dependent
protein kinase

Cdc2
(inattiva)

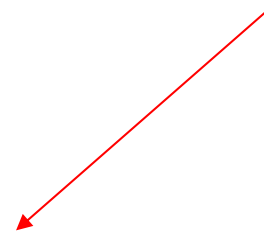
← **auxina**

Cdc25

← **citochinine**

↓
Cdc2
(attiva)

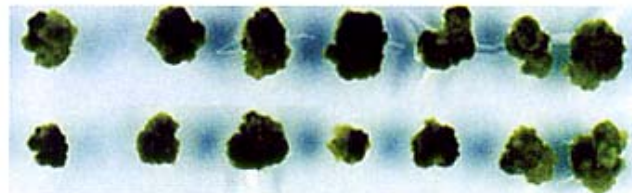
cytokinine



CYCD3

regola il passaggio dalla fase G1 alla fase S

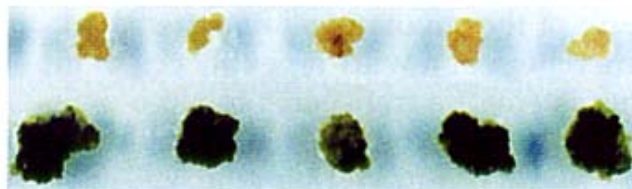
Auxin + cytokinin



wild type

CYCD3
overexpressor

Auxin

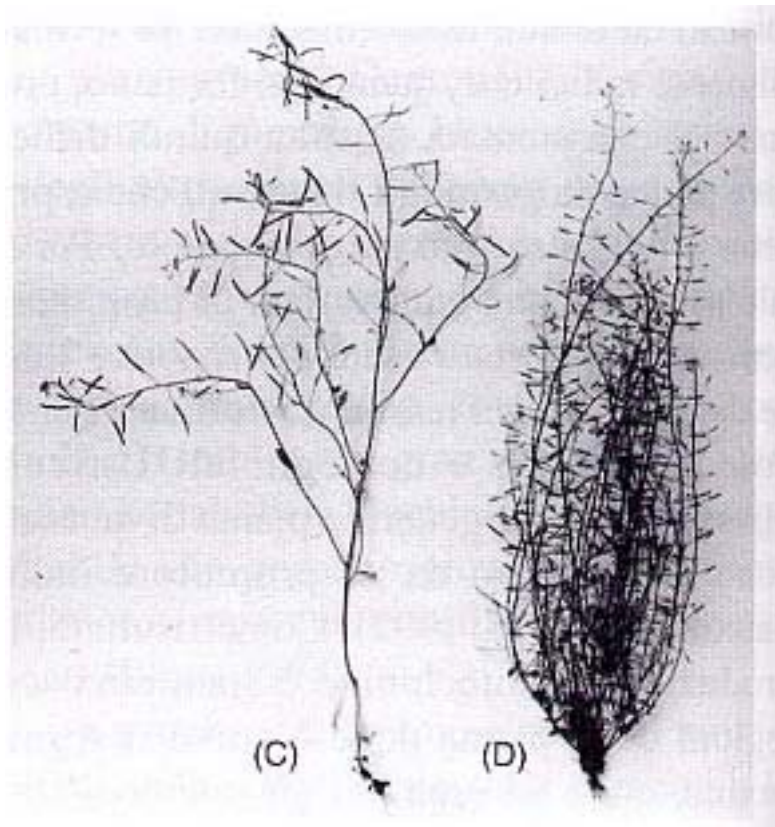


wild type

CYCD3
overexpressor

le citochinine promuovono la crescita delle gemme laterali

le piante *amp1* hanno una ridotta dominanza apicale



**Abete infettato da
*Corynebacterium fascians***

Whitches' broom

le citochinine ritardano la senescenza fogliare

applicazione citochinine

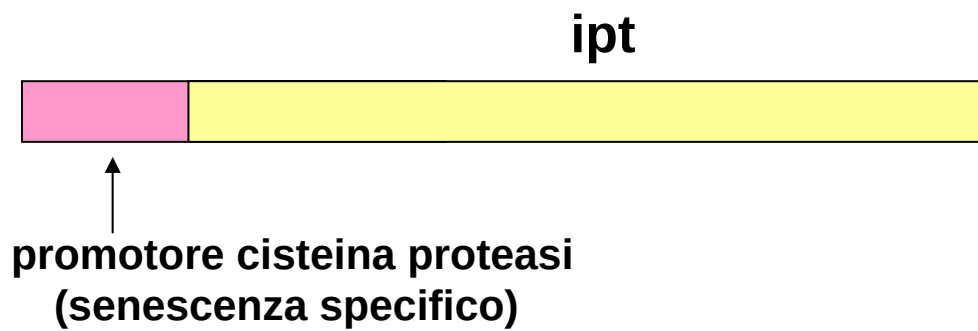


ritardo senescenza



ipt

C



Control
lettuce
plants

Lettuce plants
expressing the *ipt*
gene at the time
of senescence



l'overproduzione di citochinine determinano i tumori genetici

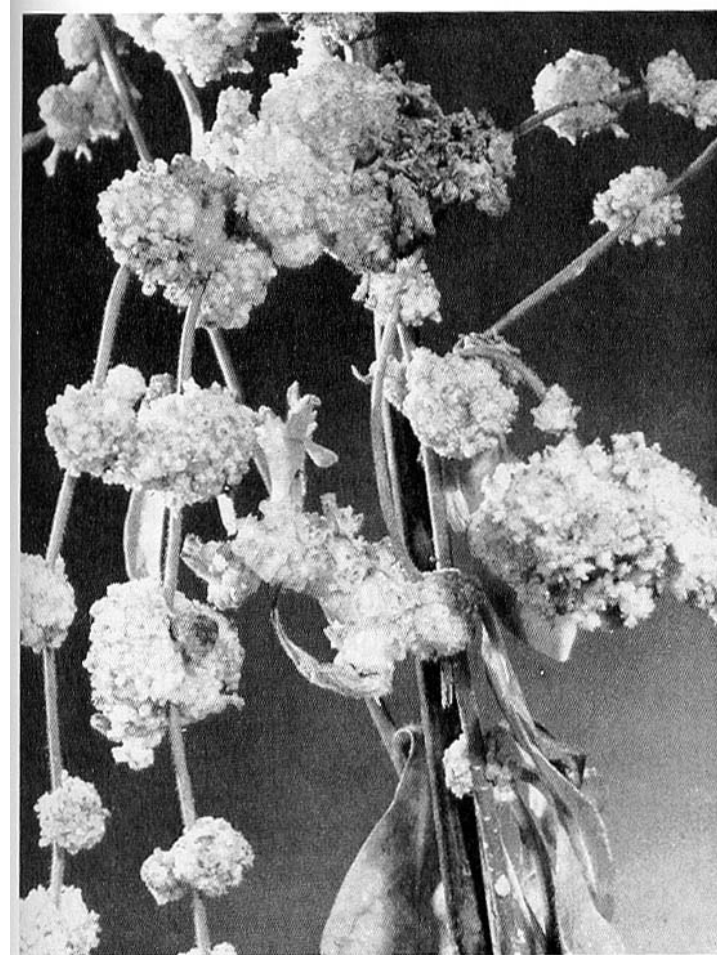
Nicotiana

ibridi interspecie

300 ibridi

90% fenotipo normale

10% tumori genetici

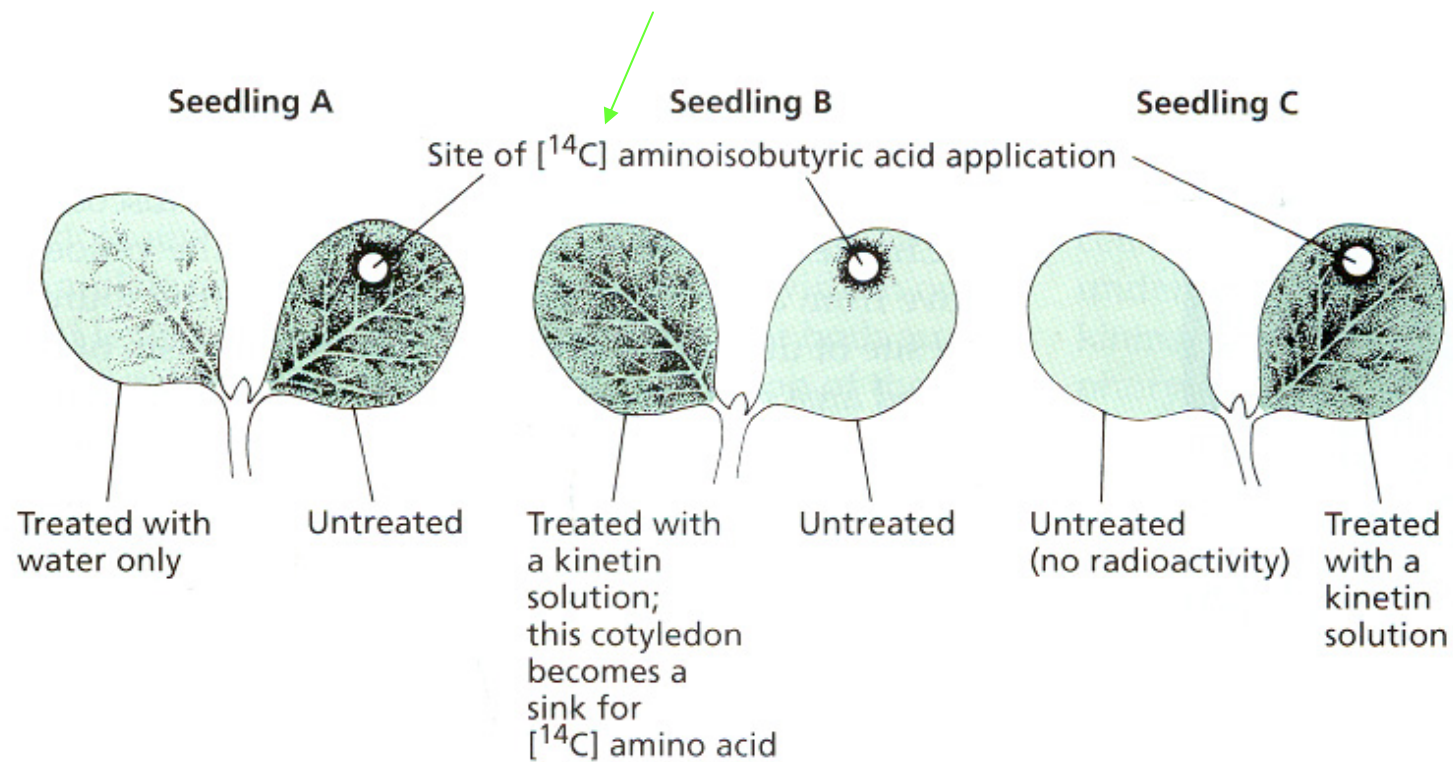


Nicotiana langsdorfii

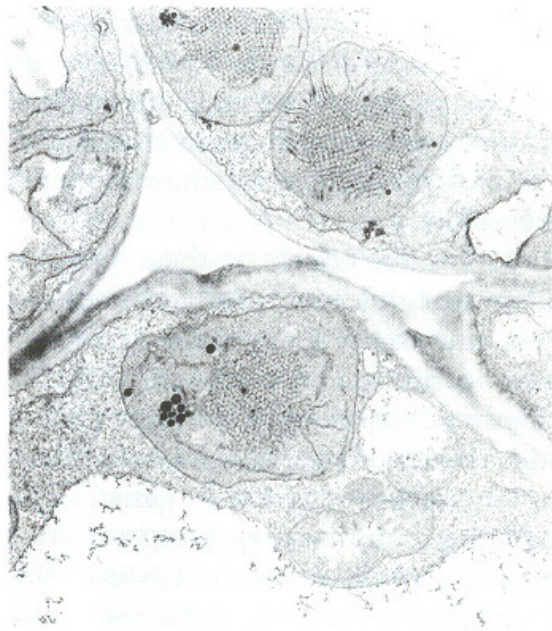
x

Nicotiana glauca

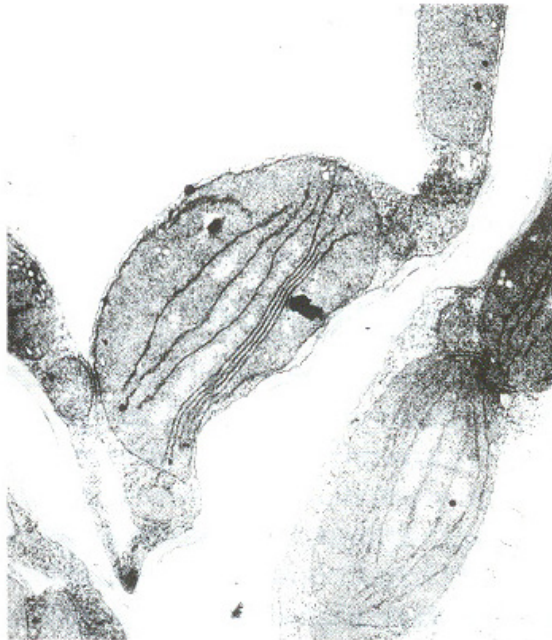
le citochinine promuovono la mobilitazione dei nutrienti



le citochinine promuovono la maturazione dei cloroplasti



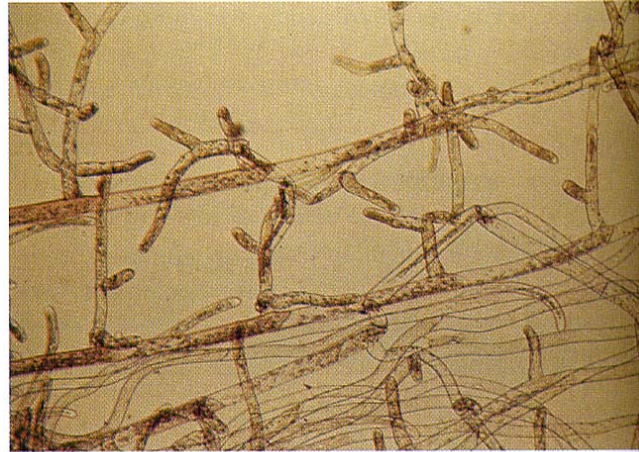
(D) Chloroplasts of dark-grown seedlings without cytokinin



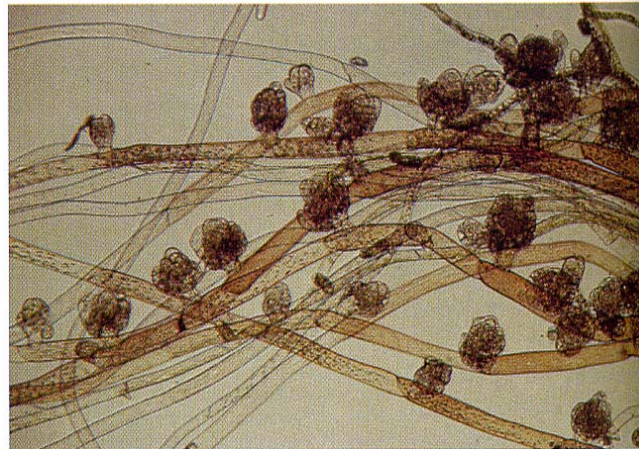
(E) Chloroplasts of dark-grown seedlings with cytokinin,
showing thylakoid formation

formazione delle gemme in alcune briofite

**citochinine
(buio)**



(B)

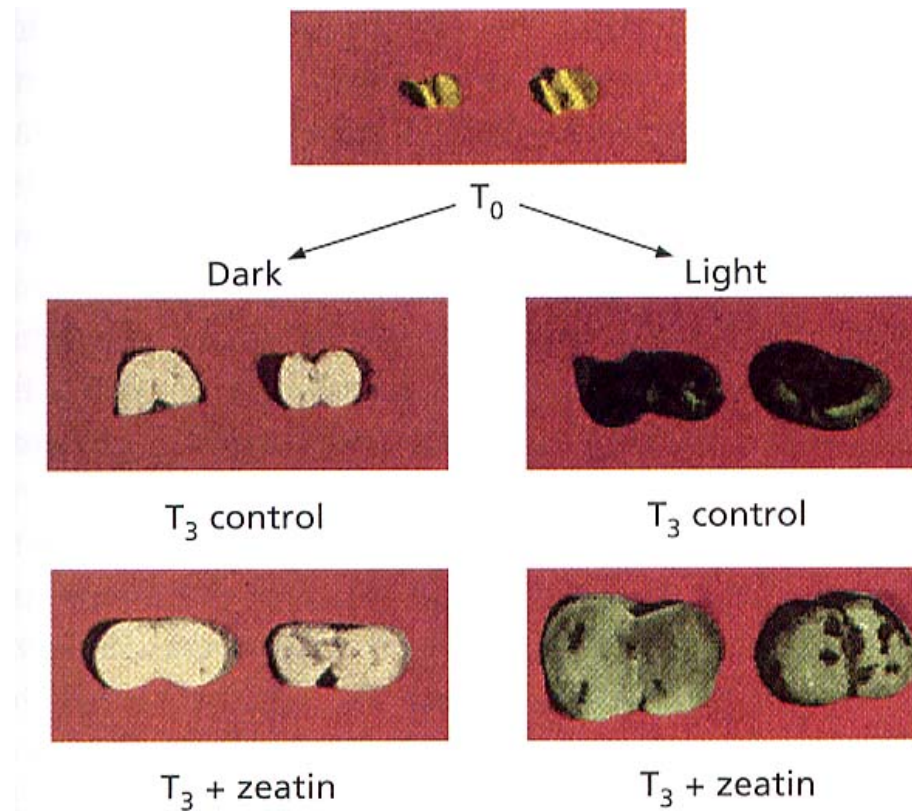


buio

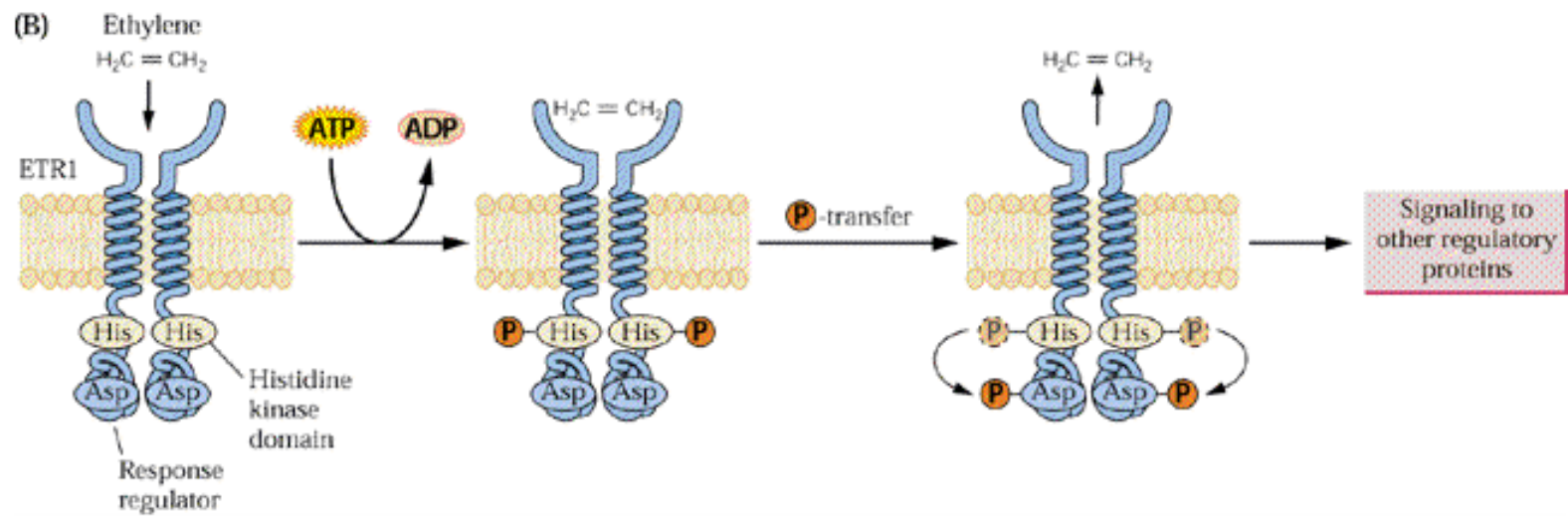
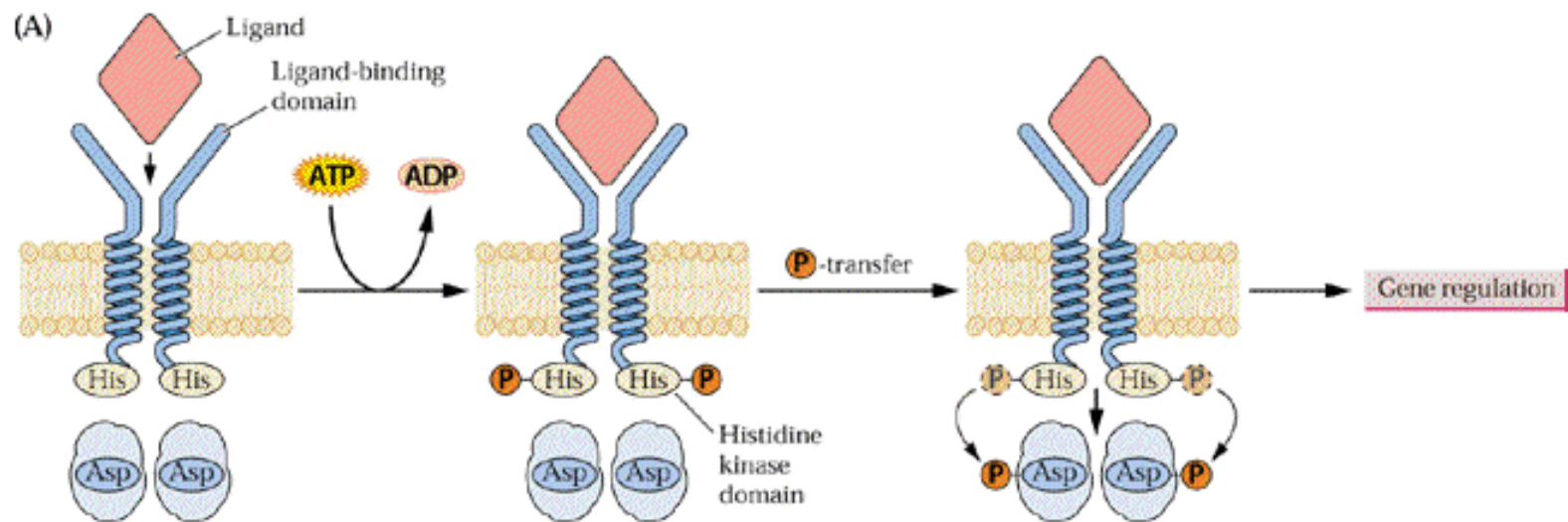
luce

Funaria hygrometrica

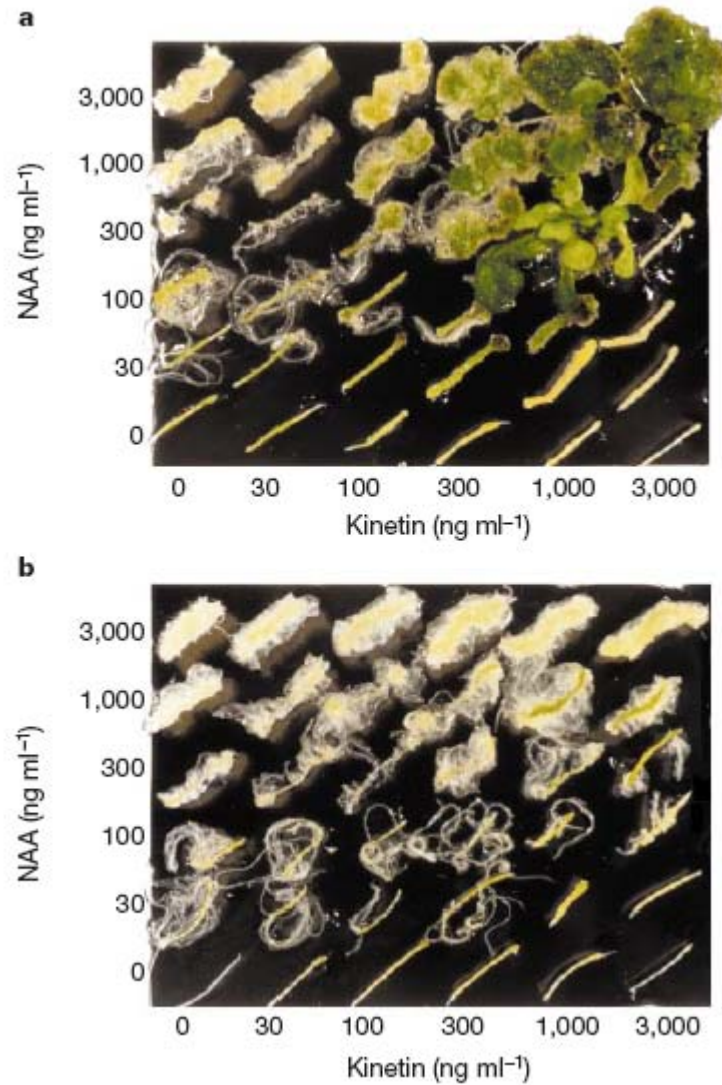
cotiledoni luce → espansione cellulare



**le citochinine promuovono l'espansione dei
cotiledoni anche al buio**

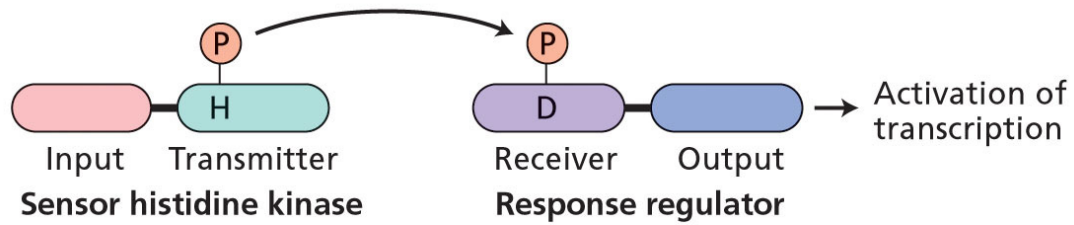


identificazione CRE1

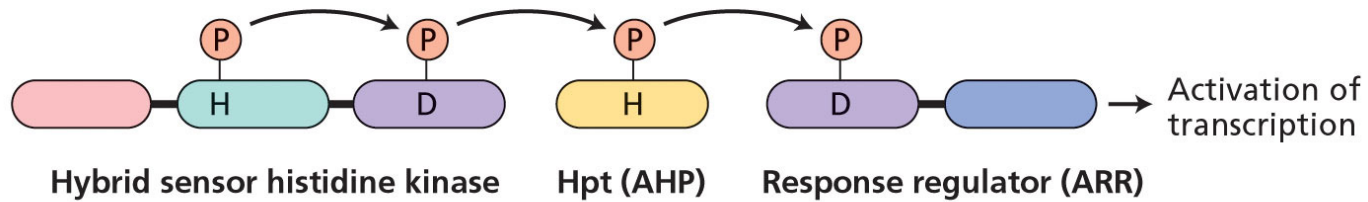


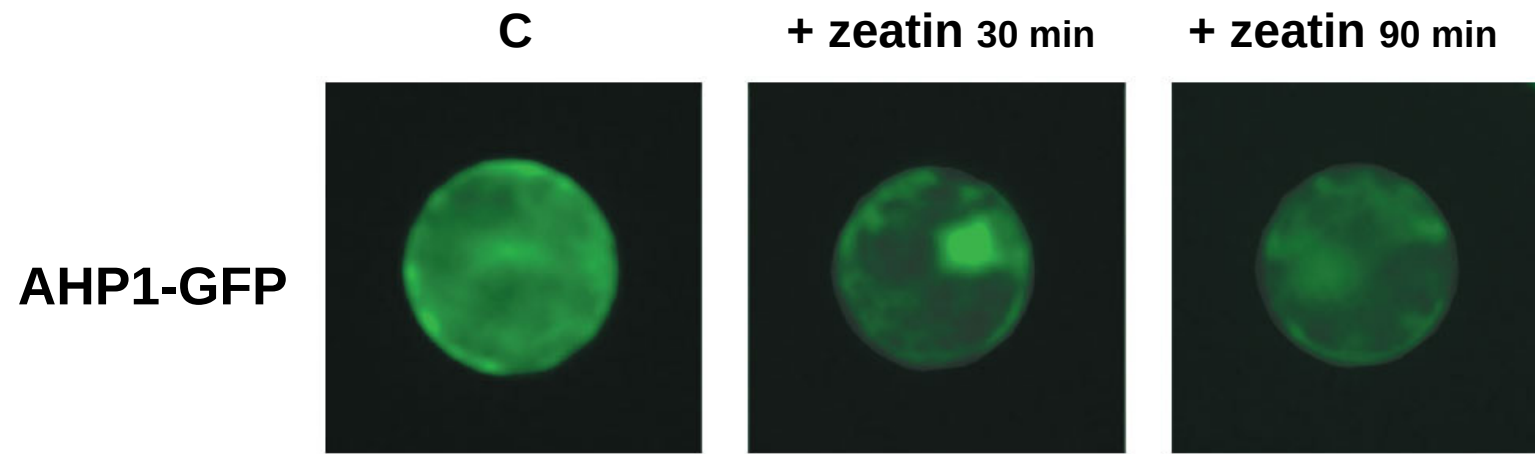
**successivamente
sono stati
identificati altri
due recettori,
AHK2 e AHK3**

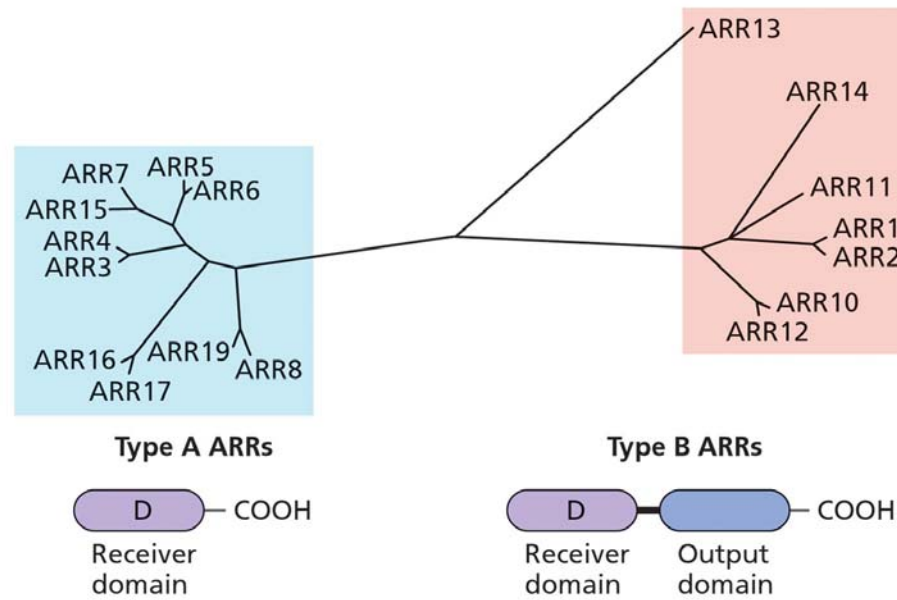
Simple two-component signaling system



Phosphorelay two-component signaling system







PLANT PHYSIOLOGY, Third Edition, Figure 21.23 © 2002 Sinauer Associates, Inc.

1. Cytokinin binds to CRE1, which is likely to occur as a dimer. Cytokinin binds to an extracellular portion of CRE1 called the CHASE domain. Two other hybrid sensor kinases (AHK2 and AHK3) containing a CHASE domain are also likely to act as cytokinin receptors in *Arabidopsis*.

2. Cytokinin binding to these receptors activates their histidine kinase activity. The phosphate is transferred to an aspartate residue (D) on the fused receiver domains.

3. The phosphate is then transferred to a conserved histidine present in an AHP protein.

4. Phosphorylation causes the AHP protein to move into the nucleus, where it transfers the phosphate to an aspartate residue located within the receiver domain of a type-B ARR.

5. The phosphorylation of the type-B ARR activates the output domain to induce transcription of genes encoding type-A ARRs.

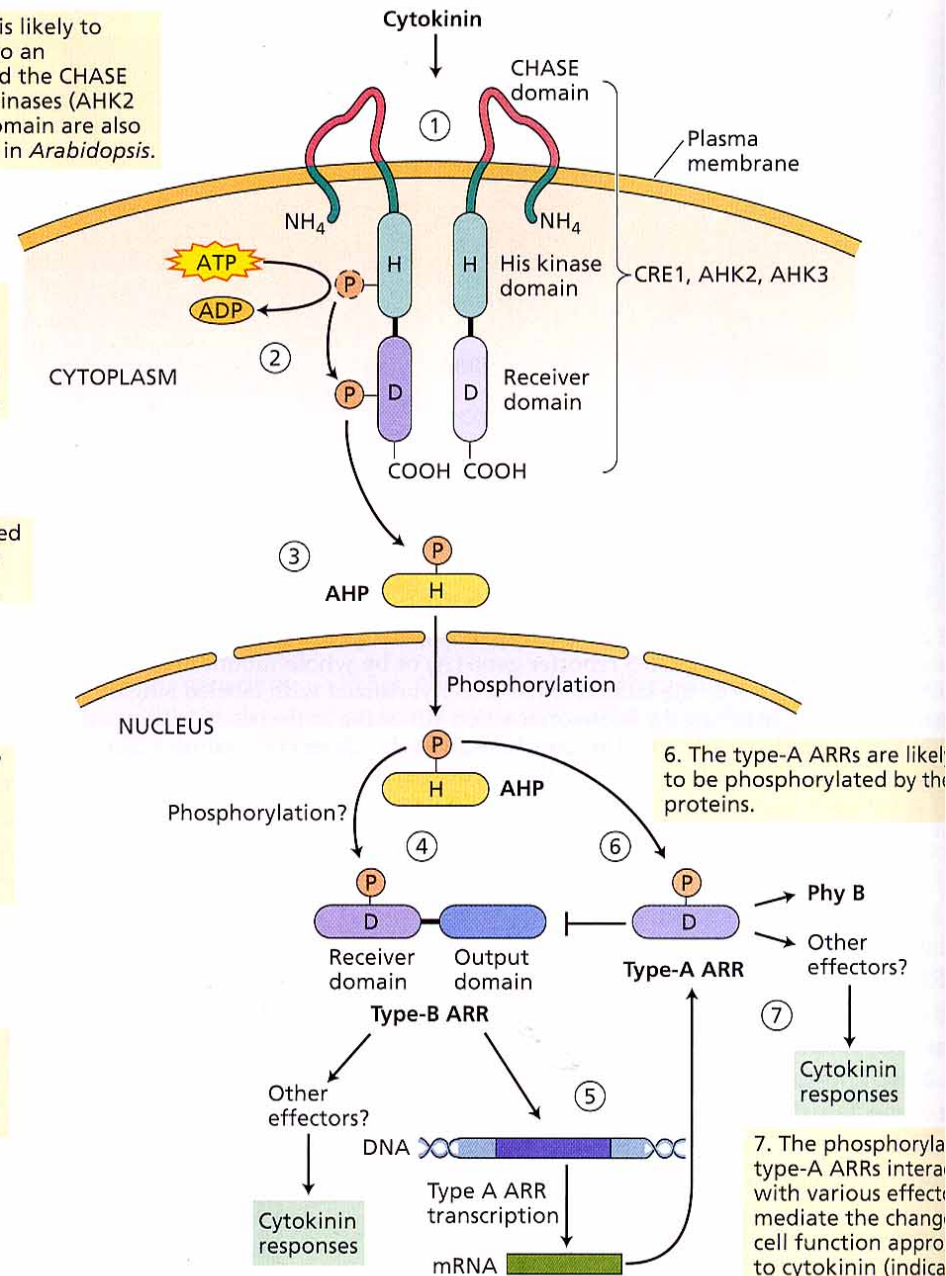


FIGURE 21.27 Model of cytokinin signaling. The near future should see significant refinement of this model, the tools are now in hand to analyze the interactions among these elements.