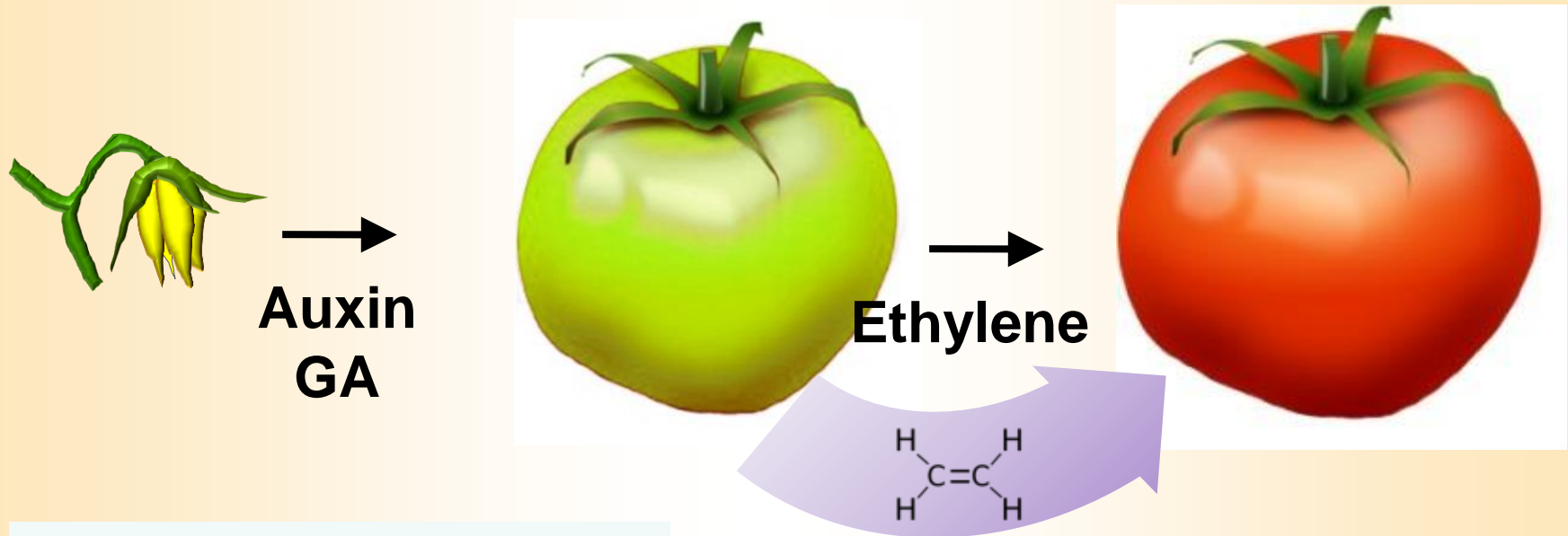


# Fruit ripening is induced by ethylene



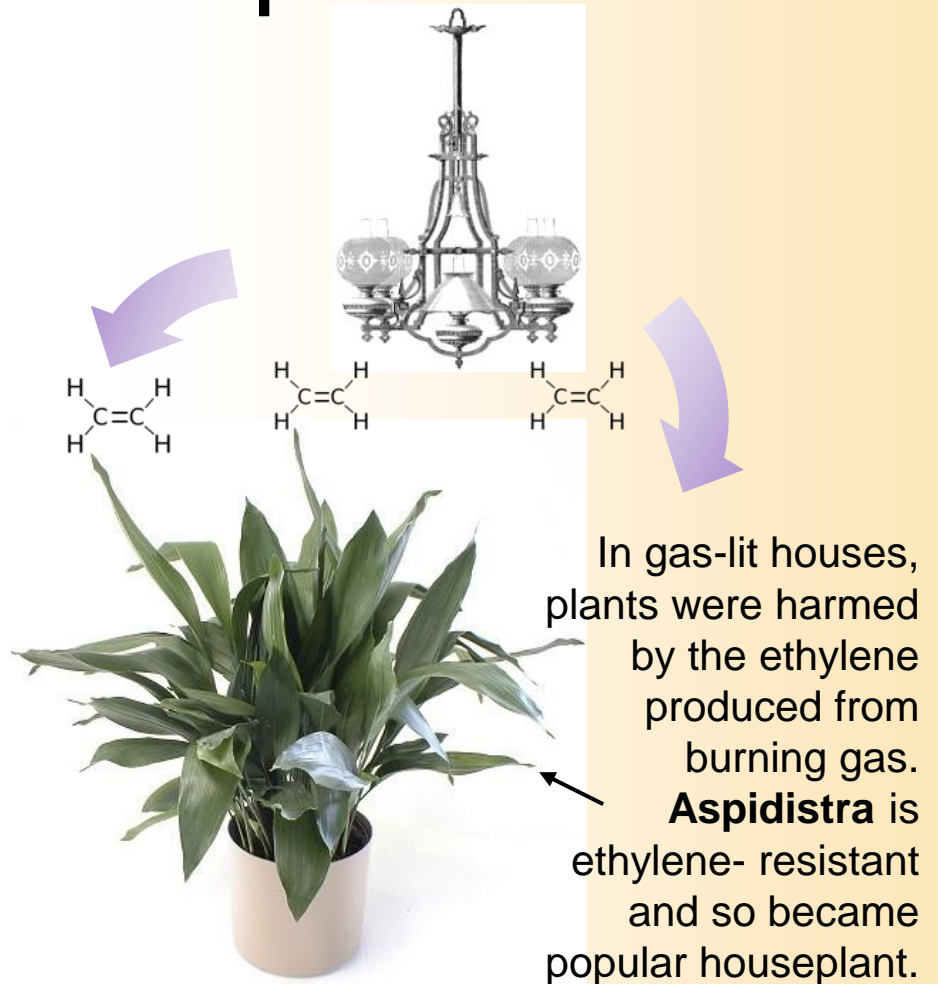
Ethylene is a gaseous hormone that promotes fruit softening and flavor and color development

# Ethylene promotes senescence of leaves and petals

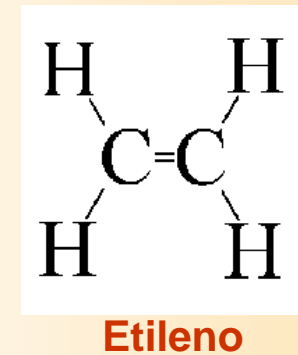
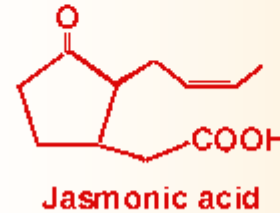
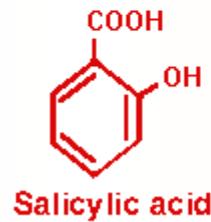
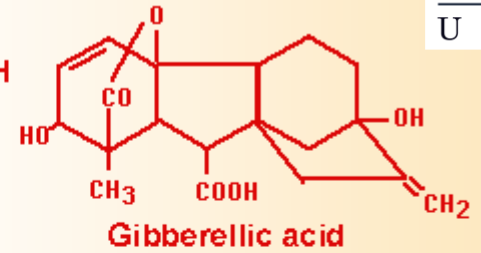
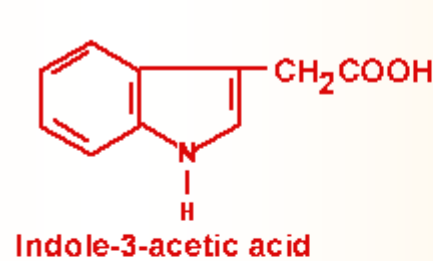
Air (control)    7 days ethylene

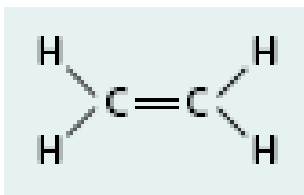


**Ethylene promotes leaf and petal senescence.**

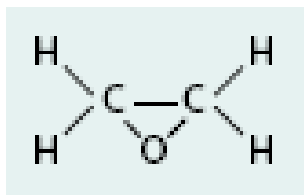


- ✓ Auxinas
- ✓ Giberelinas
- ✓ Citocininas
- ✓ Ácido abscísico
- ✓ Etileno\*
- ✓ Ácido jasmónico
- ✓ Ácido salicílico

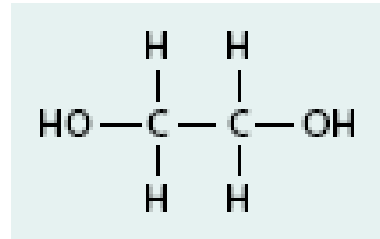




**Ethylene**

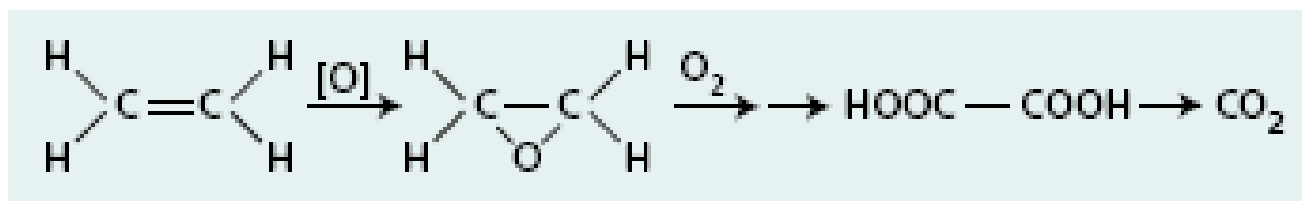


**Ethylene  
oxide**



**Ethylene glycol**

### Complete oxidation of ethylene



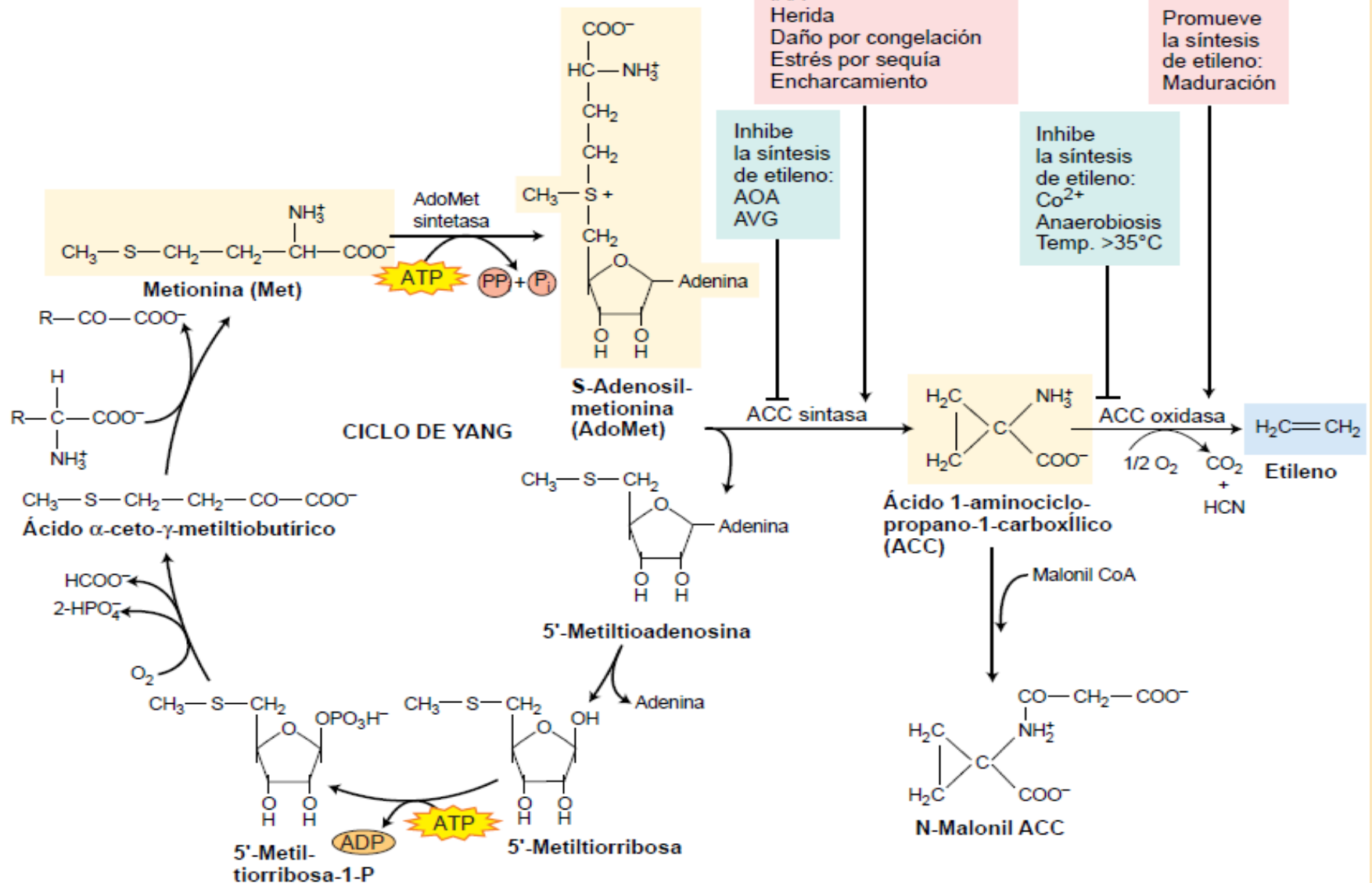
**Ethylene**

**Ethylene  
oxide**

**Oxalic acid**

**Carbon  
dioxide**

# Síntesis de etileno



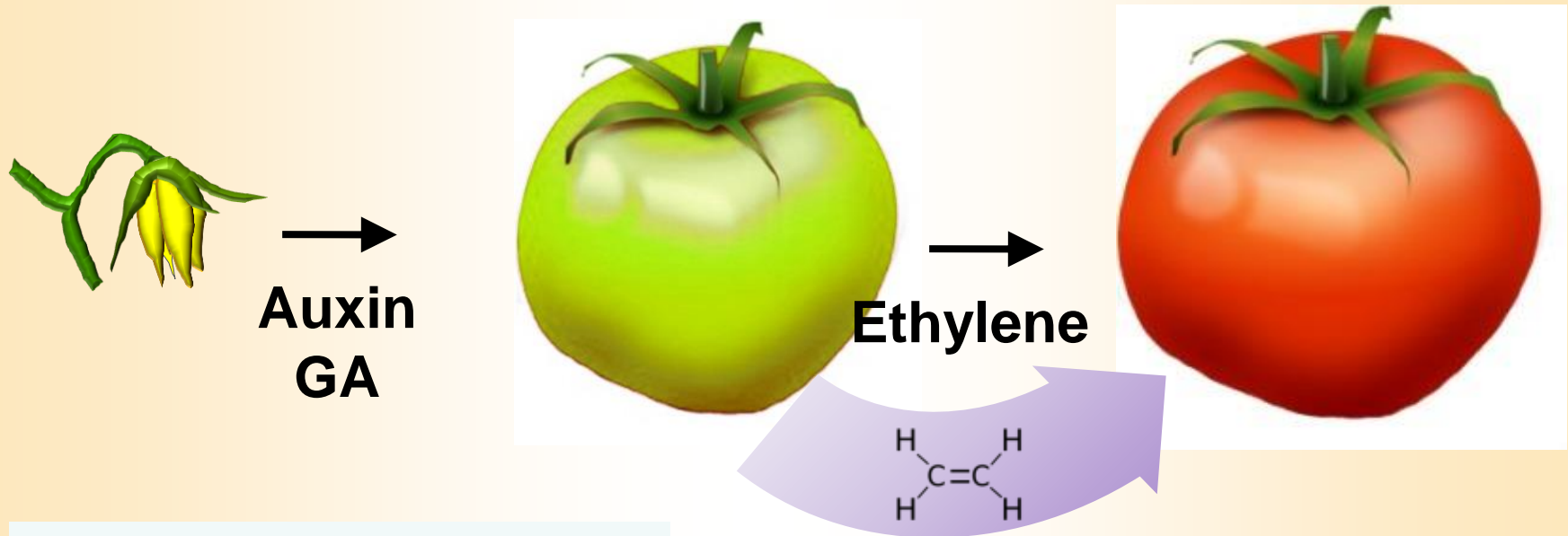
# Inhibidores de la síntesis de etileno

- AVG bloquea el paso a ACC
- AOA bloquea el paso a ACC
- $\text{Co}^{2+}$  (bloquea el paso de ACC a ET, ACC oxidasa)

# Inhibidores de la acción del etileno

- $\text{Ag}^+$  (Nitrato o Tiosulfato de  $\text{Ag}^+$ )
- $\text{CO}_2$  (Altas concentraciones 5-10%)
- MCP (1-metil ciclopropeno, se une al receptor de ET)

# Fruit ripening is induced by ethylene

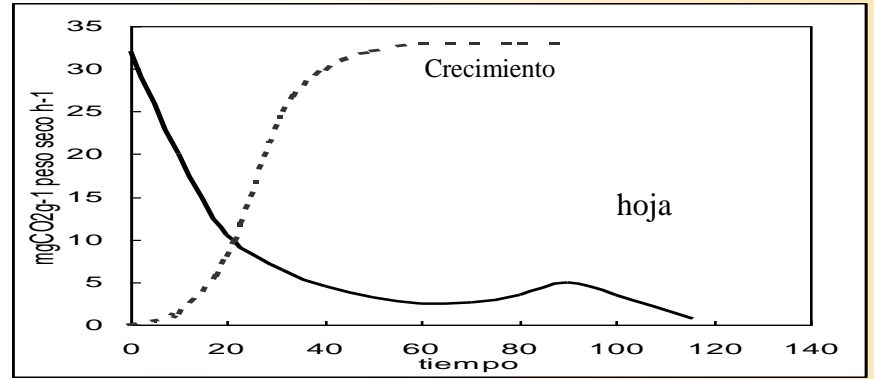
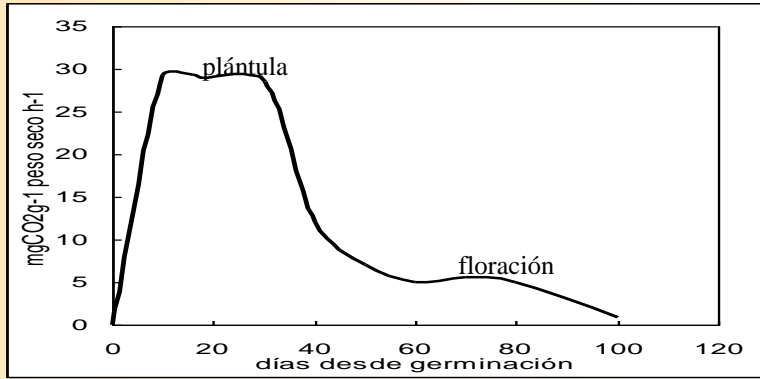


Ethylene is a gaseous hormone that promotes fruit softening and flavor and color development

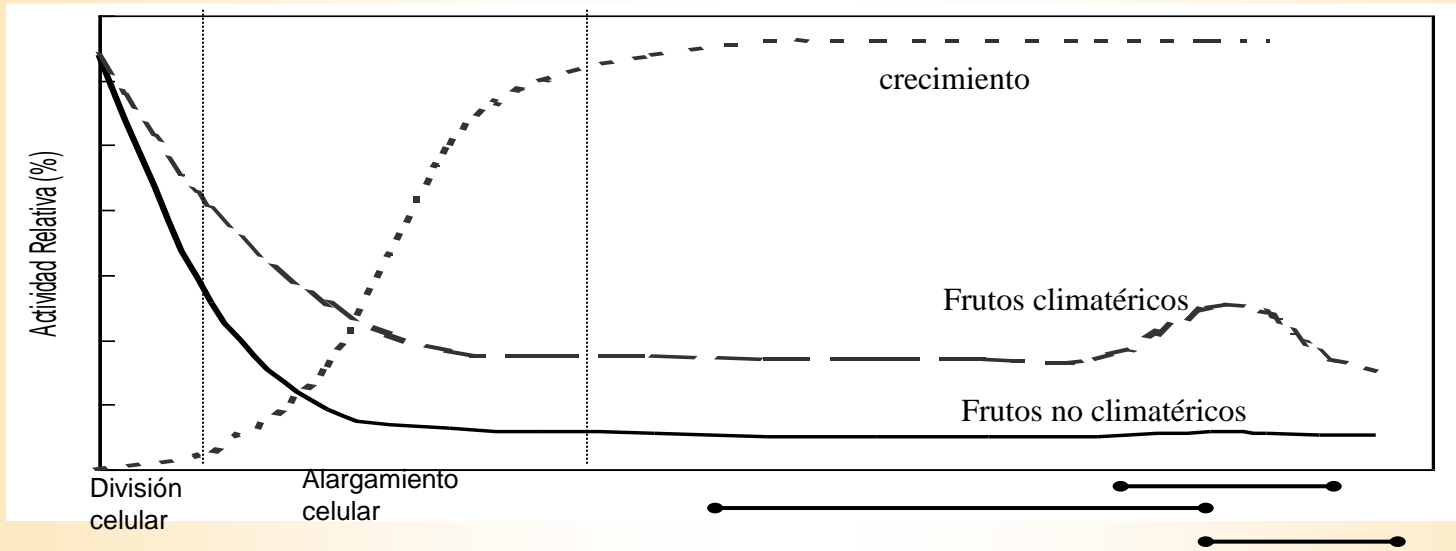


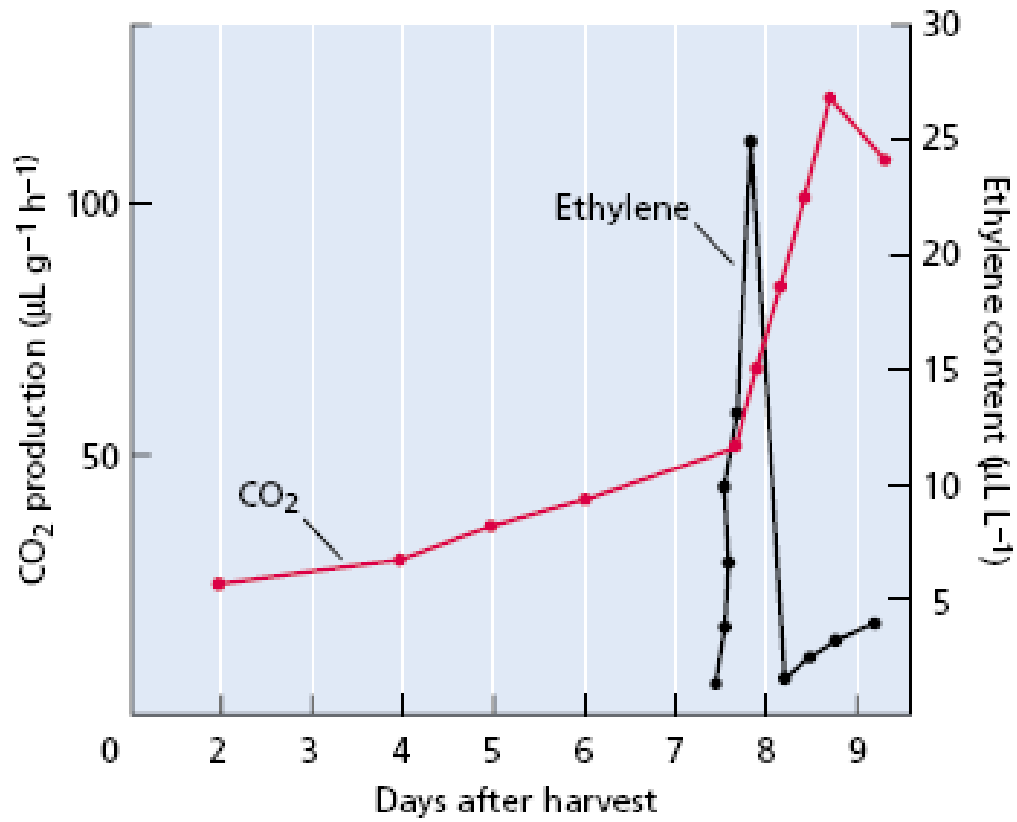
- Durante la época de maduración de muchos frutos hay un gran incremento en la respiración celular, manifestado por una mayor producción de CO<sub>2</sub> y de etileno. Esta fase se conoce como *climaterio*, y los frutos que la desarrollan, *frutos climatéricos*. Los frutos que muestran una maduración gradual, tales como los cítricos, uvas, y fresas, se denominan *frutos no climatéricos*.

CLIMATÉRICOS	NO CLIMATÉRICOS
MANZANA ALBARICOQUE AGUACATE PLÁTANO CHIRIMOYA HIGO MELÓN MELOCOTÓN PERA TOMATE SANDÍA	CEREZA CALABAZA UVA POMELO PIÑA LIMÓN NARANJA MANDARINA FRESA

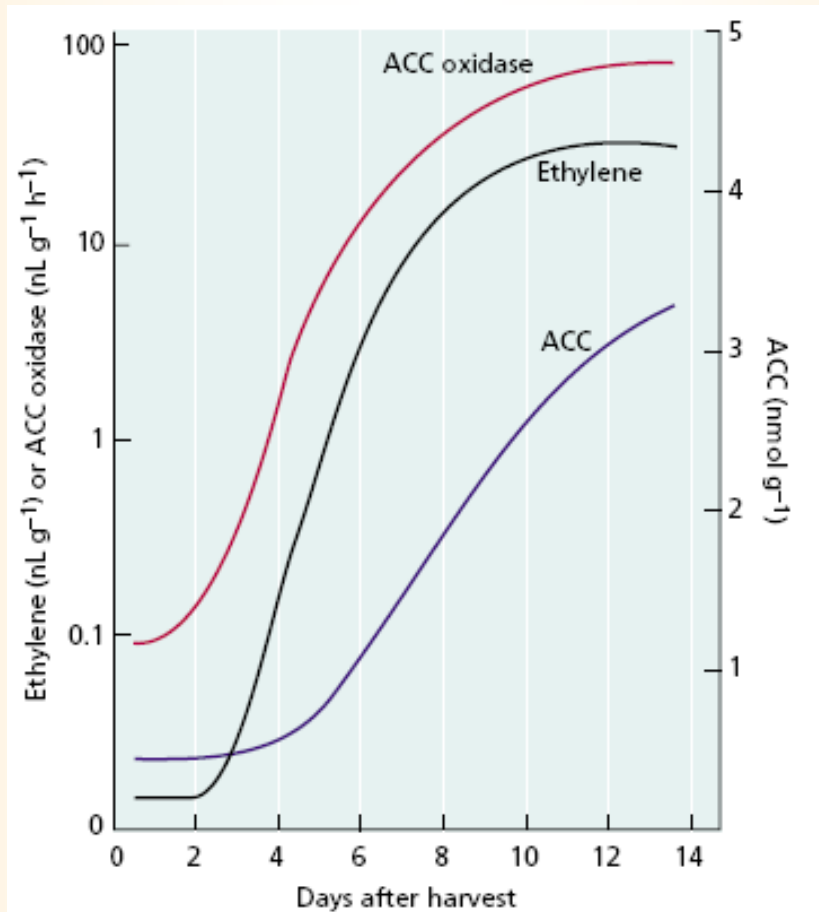


### Climaterio





**FIGURE 22.4** Ethylene production and respiration. In banana, ripening is characterized by a climacteric rise in respiration rate, as evidenced by the increased CO<sub>2</sub> production. A climacteric rise in ethylene production precedes the increase in CO<sub>2</sub> production, suggesting that ethylene is the hormone that triggers the ripening process. (From Burg and Burg 1965.)



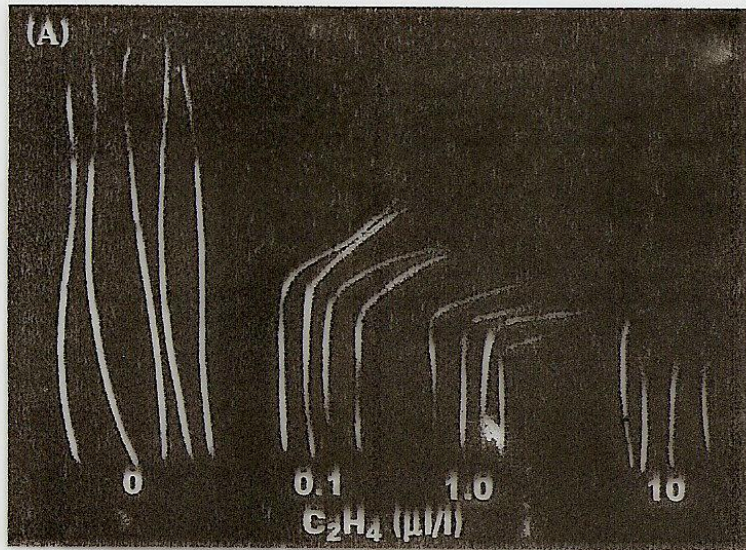
**FIGURE 22.2** Changes in ethylene and ACC content and ACC oxidase activity during fruit ripening. Changes in the ACC oxidase activity and ethylene and ACC concentrations of Golden Delicious apples. The data are plotted as a function of days after harvest. Increases in ethylene and ACC concentrations and in ACC oxidase activity are closely correlated with ripening. (A from Hoffman and Yang 1980; B from Yang 1987.)

# Etileno: efectos fisiológicos

- Estimula la germinación de semillas
- Induce el agrandamiento celular
- Inhibe el crecimiento del tallo y de la raíz
- Controla las respuestas al estrés
- Induce epinastias en las hojas
- Participa en la diferenciación radical
- Controla la maduración de frutos
- Induce la floración en Bromeliáceas y mango
- Induce flores femeninas en cucurbitáceas

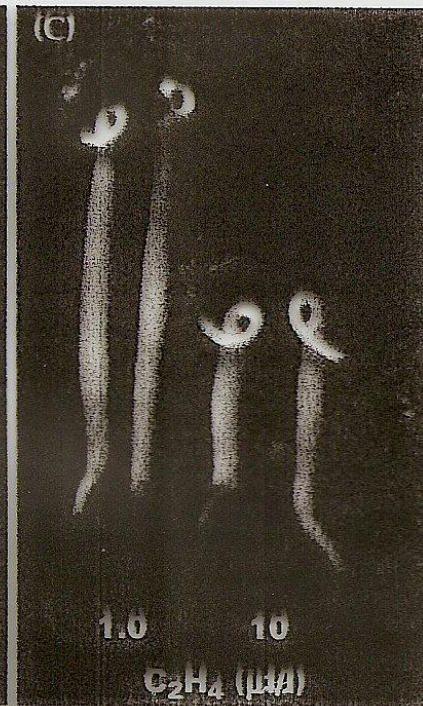
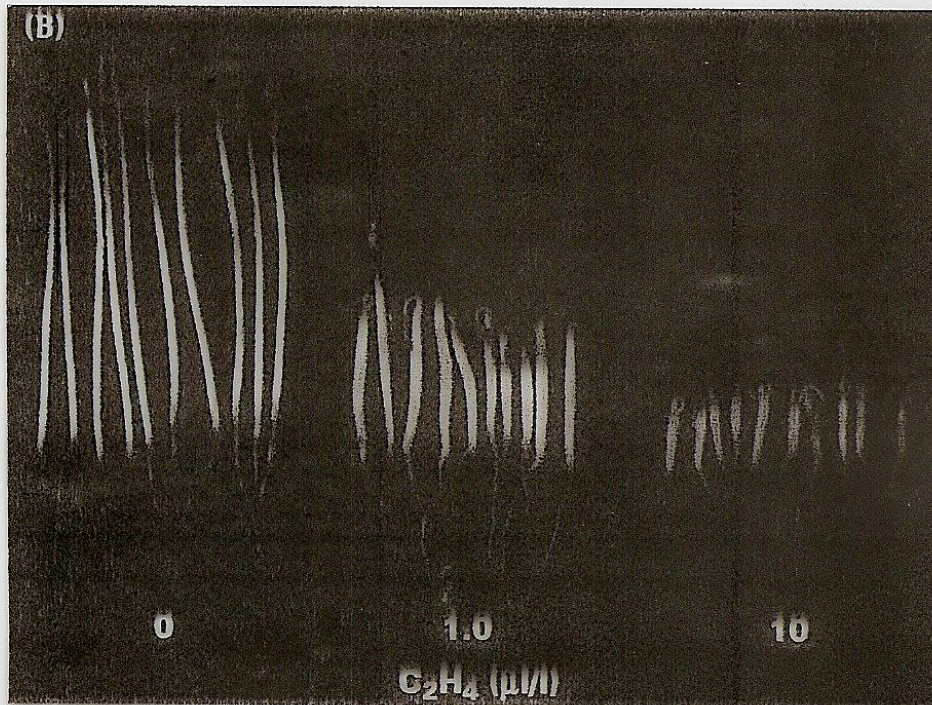
# Etileno: efectos fisiológicos

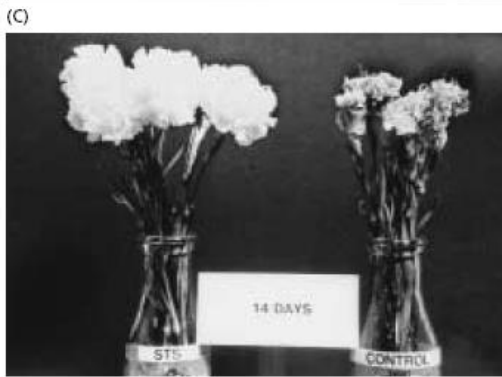
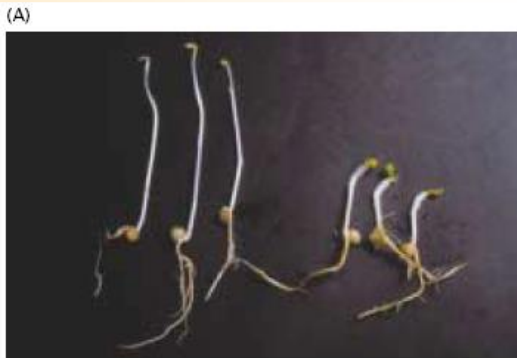
- Involucrado en fenómenos de inundación: plantas tolerantes y no-tolerantes
- Interviene en el crecimiento de las plántulas (gancho plumular, crecimiento horizontal)
- Formación de raíces adventicias en altas concentraciones ( $10 \mu\text{M}$ )
- Induce la senescencia de hojas, frutos y flores
- Induce la abscisión de hojas, frutos y flores



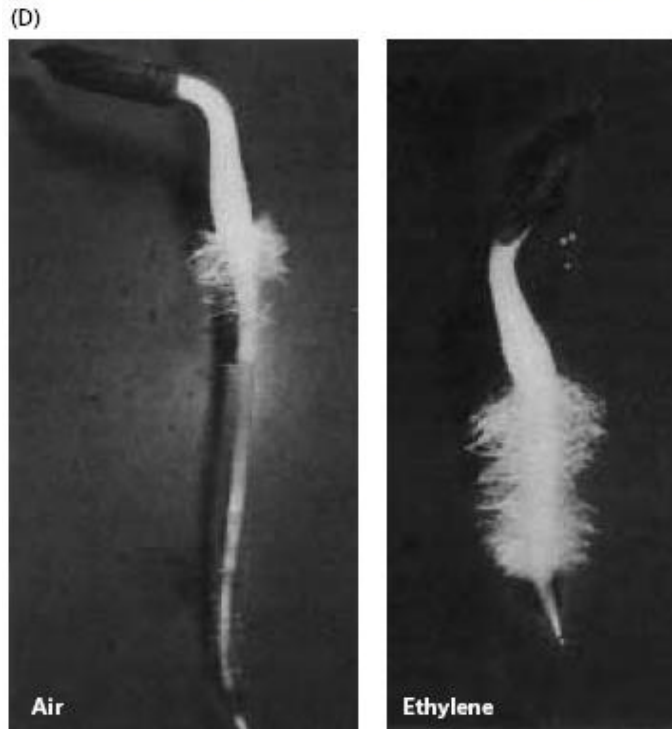
**Figure 17.53**

The triple response to ethylene of six-day-old etiolated pea seedlings and four-day-old etiolated mung bean seedlings. (A) Untreated control pea seedlings (0) and pea seedlings grown for two days in air supplemented with ethylene at 0.1, 1.0, and 10  $\mu/l/ml$ . Note the concentration-dependent effects of ethylene on diageotropism, inhibition of epicotyl elongation, and lateral enlargement of the epicotyl. (B) Control mung bean seedlings (0) and mung bean seedlings grown for two days in air supplemented with 1 and 10  $\mu/l/ml$  ethylene, which induces a concentration-dependent inhibition of hypocotyl elongation, lateral enlargement of the hypocotyl, and extreme bending of the apical hook. (C) Magnification of ethylene-treated etiolated mung bean seedlings.





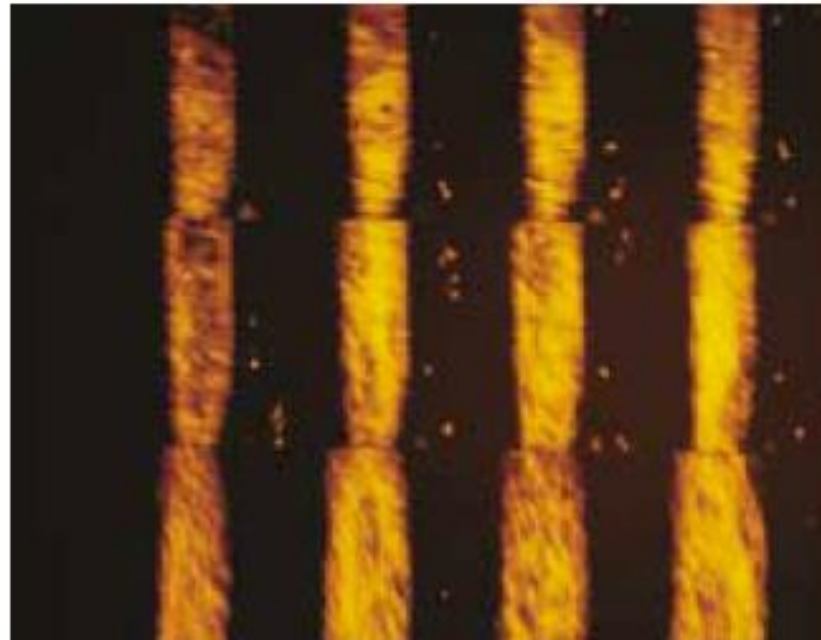
**FIGURE 22.5** Some physiological effects of ethylene on plant tissue in various developmental stages. (A) Triple response of etiolated pea seedlings. Six-day-old pea seedlings were treated with 10 ppm (parts per million) ethylene (right) or left untreated (left). The treated seedlings show a radial swelling, inhibition of elongation of the epicotyl, and horizontal growth of the epicotyl (diageotropism). (B) Epinasty, or downward bending of the tomato leaves (right), is caused by ethylene treatment. Epinasty results when the cells on the upper side of the petiole grow faster than those on the bottom. (C) Inhibition of flower senescence by inhibition of ethylene action. Carnation flowers were held in deionized water for 14 days with (left) or without (right) silver thiosulfate (STS), a potent inhibitor of ethylene action. Blocking of ethylene results in a marked inhibition of floral senescence. (D) Promotion of root hair formation by ethylene in lettuce seedlings. Two-day-old seedlings were treated with air (left) or 10 ppm ethylene (right) for 24 hours before the photo was taken. Note the profusion of root hairs on the ethylene-treated seedling. (A and B courtesy of S. Gepstein; C from Reid 1995, courtesy of M. Reid; D from Abeles et al. 1992, courtesy of F. Abeles.)





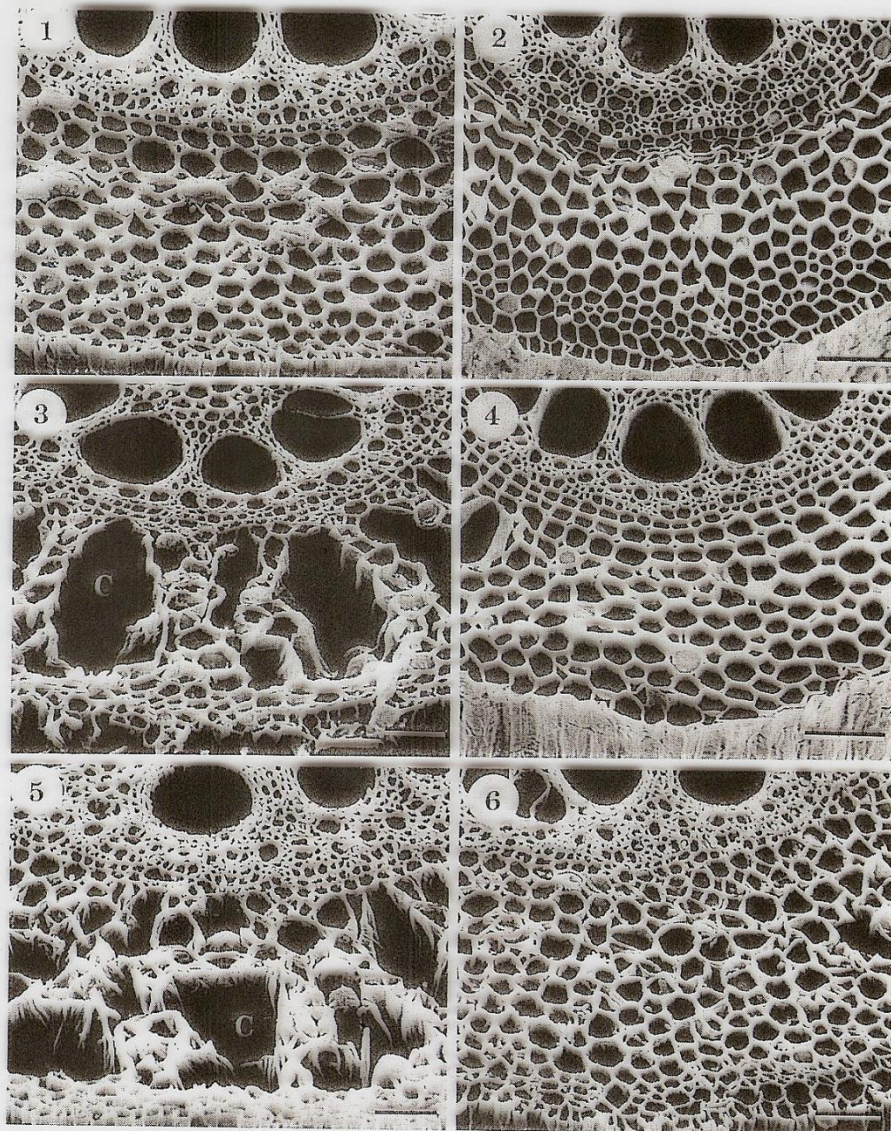


**FIGURE 22.7** The triple response in *Arabidopsis*. Three-day-old etiolated seedlings grown in the presence (right) or absence (left) of 10 ppm ethylene. Note the shortened hypocotyl, reduced root elongation and exaggeration of the curvature of the apical hook that results from the presence of ethylene.

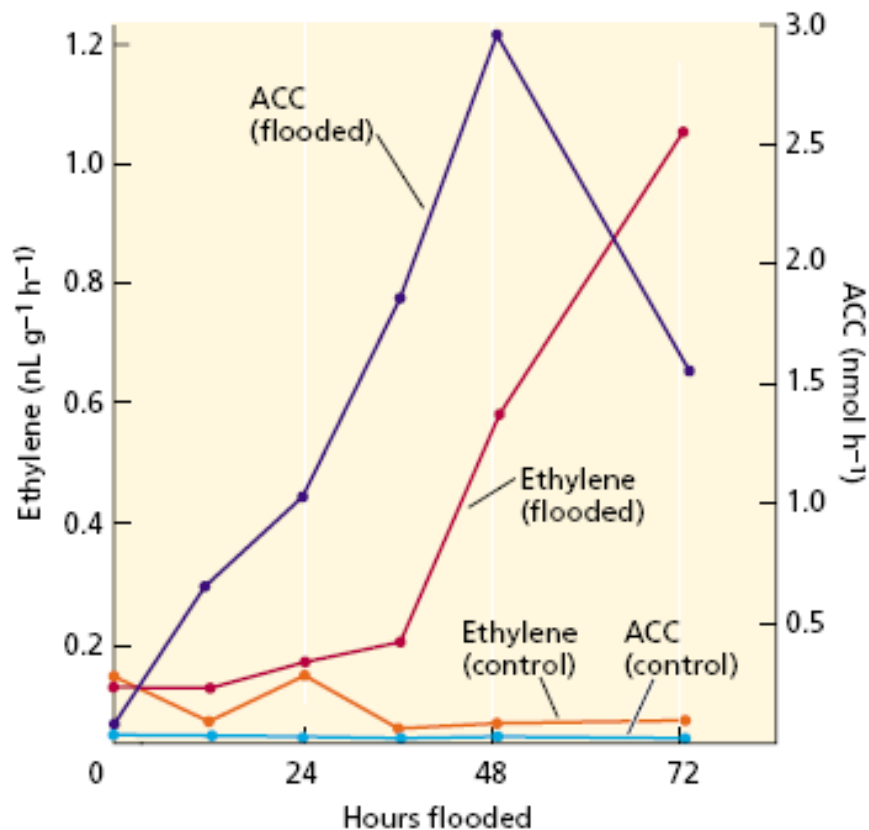


Transverse microtubules

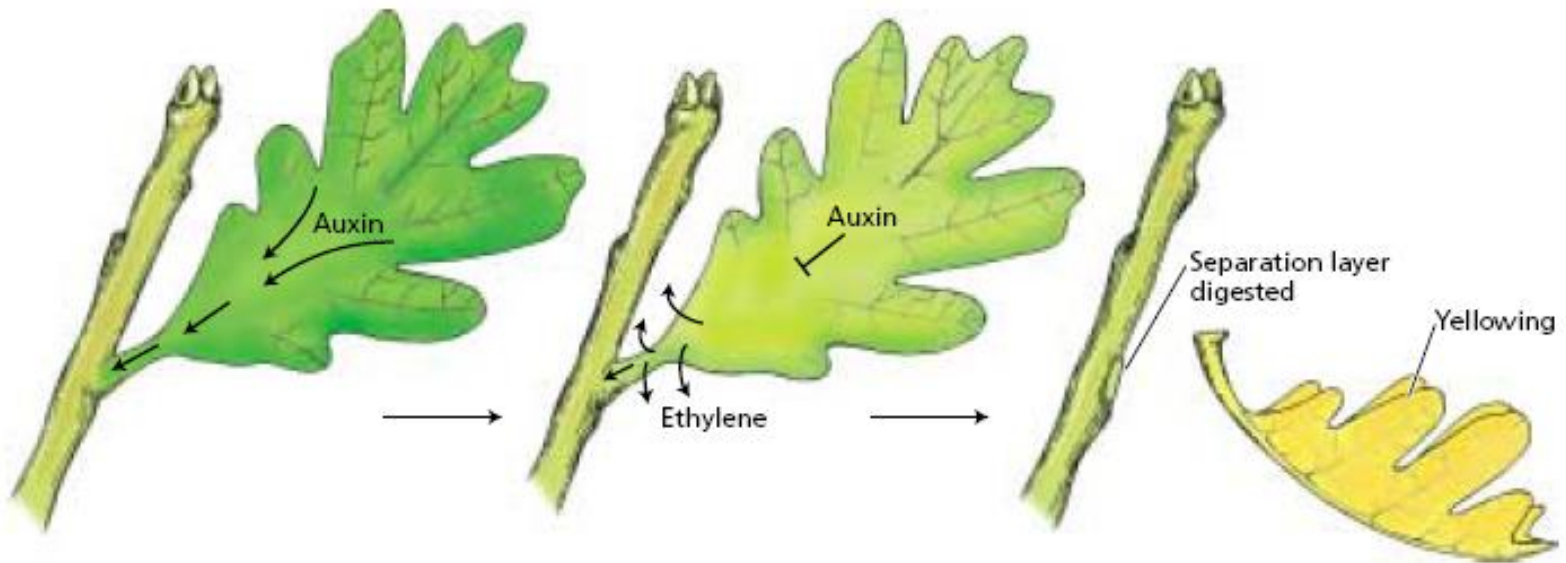
**FIGURE 22.8** Reorientation of microtubules from transverse to vertical in pea stem epidermis cells in response to wounding. A living epidermal cell was microinjected with rhodamine-conjugated tubulin, which incorporates into the plant microtubules. A time series of approximately 6-minute intervals shows the cortical microtubules undergoing reorientation from net transverse to oblique/longitudinal. The reorientation seems to involve the appearance of patches of new "discordant" microtubules in the new direction, concomitant with the disappearance of microtubules from the previous alignment. (From Yuan et al. 1994, photo courtesy of C. Lloyd.)



**Figure 4.16.** Scanning electron micrographs of transverse sections of second whorl adventitious roots of corn. Sections were prepared from root zone of approximately the same age, 4 to 5 days. ( $\times 58$ ). Bar = 50  $\mu\text{m}$ . 1, Control grown in aerated solution; 2, root grown in 0.6  $\mu\text{M}$  Ag(I); 3, root treated with 5  $\mu\text{l/liter}$  ethylene; 4, 5  $\mu\text{l/liter}$  ethylene plus 0.6 mM Ag(I); 5, root from nonaerated solution; 6, nonaerated solution plus 0.6  $\mu\text{M}$  Ag(I); C, cortical gas space. Courtesy of DRE81217.



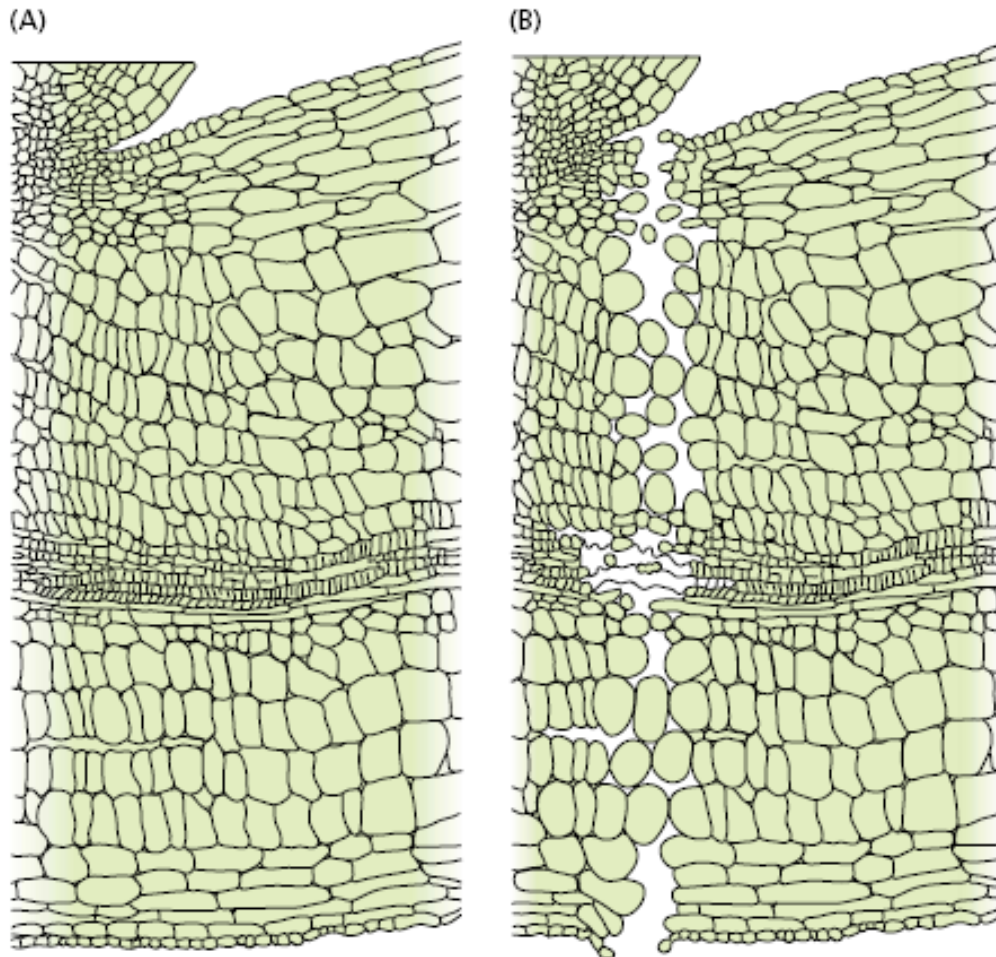
**FIGURE 22.6** Changes in the amounts of ACC in the xylem sap and ethylene production in the petiole following flooding of tomato plants. ACC is synthesized in roots, but it is converted to ethylene very slowly under anaerobic conditions of flooding. ACC is transported via the xylem to the shoot, where it is converted to ethylene. The gaseous ethylene cannot be transported, so it usually affects the tissue near the site of its production. The ethylene precursor ACC is transportable and can produce ethylene far from the site of ACC synthesis. (From Bradford and Yang 1980.)



**Leaf maintenance phase**  
 High auxin from leaf reduces ethylene sensitivity of abscission zone and prevents leaf shedding.

**Shedding induction phase**  
 A reduction in auxin from the leaf increases ethylene production and ethylene sensitivity in the abscission zone, which triggers the shedding phase.

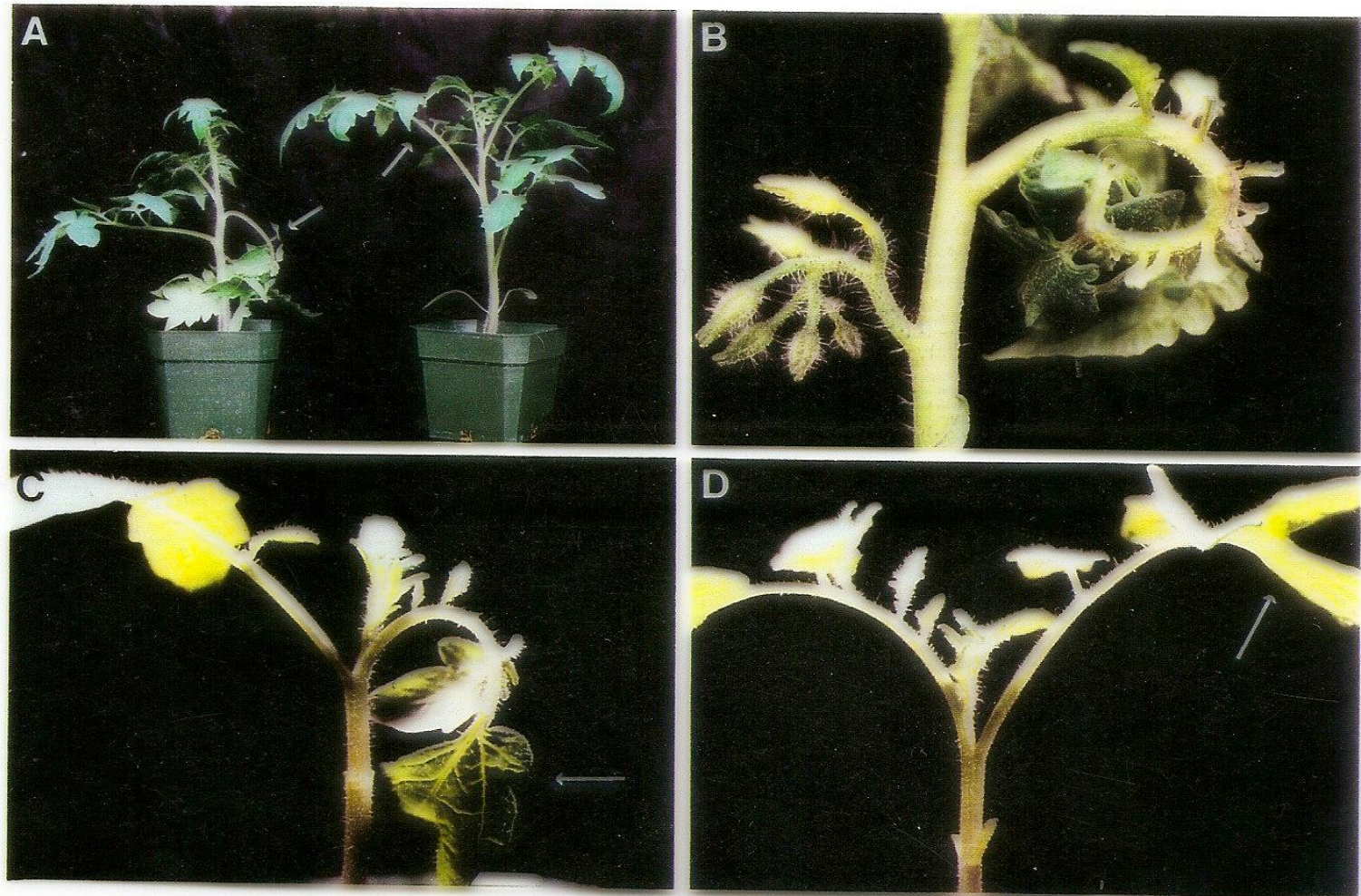
**Shedding phase**  
 Synthesis of enzymes that hydrolyze the cell wall polysaccharides, resulting in cell separation and leaf abscission.



**FIGURE 22.9** During the formation of the abscission layer, in this case that of jewelweed (*Impatiens*), two or three rows of cells in the abscission zone (A) undergo cell wall breakdown because of an increase in cell wall-hydrolyzing enzymes (B). The resulting protoplasts round up and increase in volume, pushing apart the xylem tracheary cells, and facilitating the separation of the leaf from the stem. (From Sexton et al. 1984.)

**FIGURE 22.10** Effect of ethylene on abscission in birch (*Betula pendula*). The plant on the left is the wild type; the plant on the right was transformed with a mutated version of the *Arabidopsis* ethylene receptor, ETR1-1. The expression of this gene was under the transcriptional control of its own promoter. One of the characteristics of these mutant trees is that they do not drop their leaves when fumigated 3 days with 50 ppm of ethylene.





**Figure 2.** The Epinastic Response to Ethylene Is Inhibited in *Nr* Petioles.

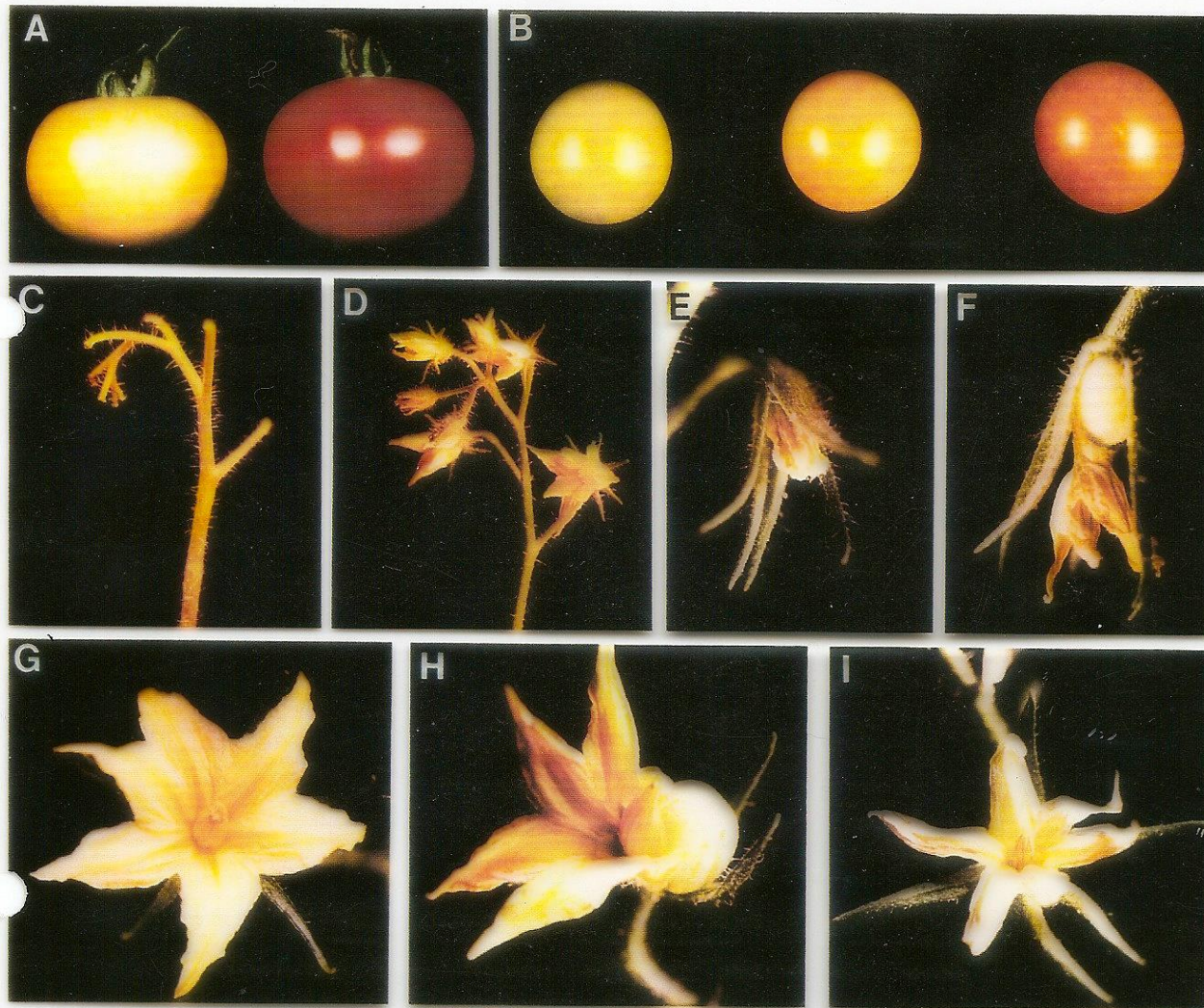
**(A)** Leaflets of UC82B (left) and line 5673, which expresses ACC deaminase (right), that were infiltrated with 20  $\mu$ L of 20 mM ACC and photographed 16 hr later (arrows indicate infiltrated leaves).

**(B)** UC82B plant that expresses the ACC synthase gene constitutively (line 7776).

**(C)** Pearson *nr/nr* plant that was infiltrated with 20  $\mu$ L of 20 mM ACC (in leaf indicated by arrow) and photographed 16 hr later.

**(D)** Pearson *Nr/Nr* plant that was infiltrated with 20  $\mu$ L of 20 mM ACC (in leaf indicated by arrow) and photographed 16 hr later.



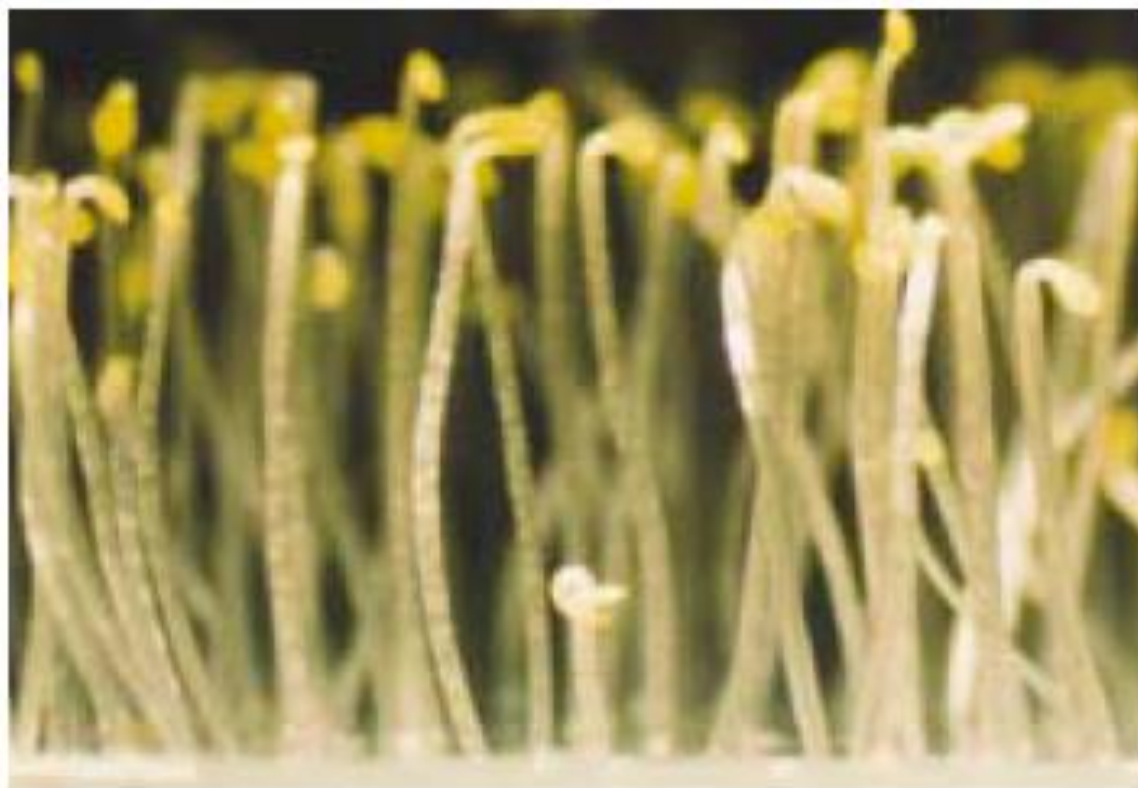


**Figure 4.** The Effects of Ethylene on Abscission and Senescence in Tomato.

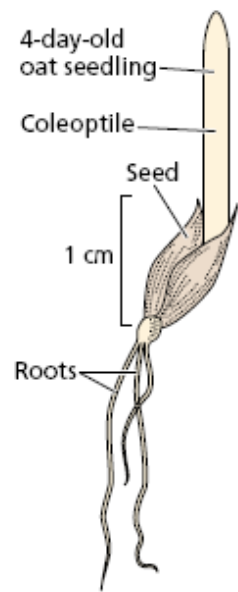
- (A) Tomato fruit from Pearson *Nr/Nr* (left) and Pearson *nr/nr* (right) plants ~3 and 2 weeks, respectively, after breaker stage.
- (B) Tomato fruit from Ailsa Craig *Nr/Nr* (left), Ailsa Craig *Nr/nr* (middle), and Ailsa Craig *nr/nr* (right) plants 7 days after breaker stage.
- (C) Tomato inflorescence from a Pearson *nr/nr* plant after 3 days of exposure to 50  $\mu\text{L/L}$  ethylene.
- (D) Tomato inflorescence from a Pearson *Nr/Nr* plant after 3 days of exposure to 50  $\mu\text{L/L}$  ethylene.
- (E) A 6-day-old senescent Pearson *nr/nr* flower.
- (F) A 9-day-old senescent Pearson *nr/nr* flower with a small developing fruit.
- (G) An 11-day-old Pearson *Nr/Nr* flower showing no signs of senescence.
- (H) A 13-day-old Pearson *Nr/Nr* flower (a sepal was removed for clarity) with a developing fruit showing limited signs of senescence.
- (I) A Pearson *Nr/Nr* flower (>15 days old) showing the type of petal senescence characteristic of unfertilized flowers of the mutant.



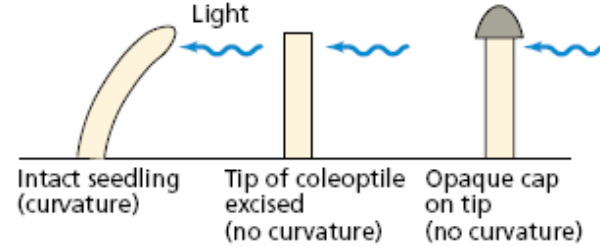
**FIGURE 22.12** Screen for the *etr1* mutant of *Arabidopsis*. Seedlings were grown for 3 days in the dark in ethylene. Note that all but one of the seedlings are exhibiting the triple response: exaggeration in curvature of the apical hook, inhibition and radial swelling of the hypocotyl, and horizontal growth. The *etr1* mutant is completely insensitive to the hormone and grows like an untreated seedling. (Photograph by K. Stepnitz of the MSU/DOE Plant Research Laboratory.)



**FIGURE 22.15** Screen for *Arabidopsis* mutants that constitutively display the triple response. Seedlings were grown for 3 days in the dark in air. A single *ctr1* mutant seedling is evident among the taller, wild-type seedlings. (Courtesy of J. Kieber.)

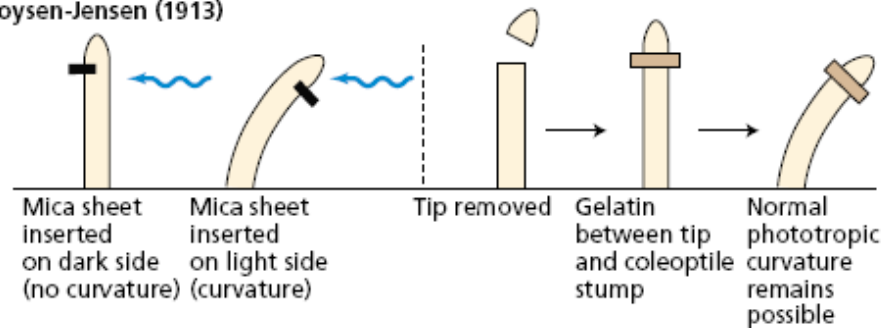


**Darwin (1880)**



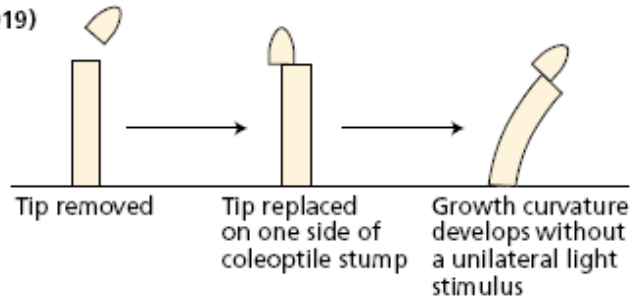
From experiments on coleoptile phototropism, Darwin concluded in 1880 that a growth stimulus is produced in the coleoptile tip and is transmitted to the growth zone.

**Boysen-Jensen (1913)**



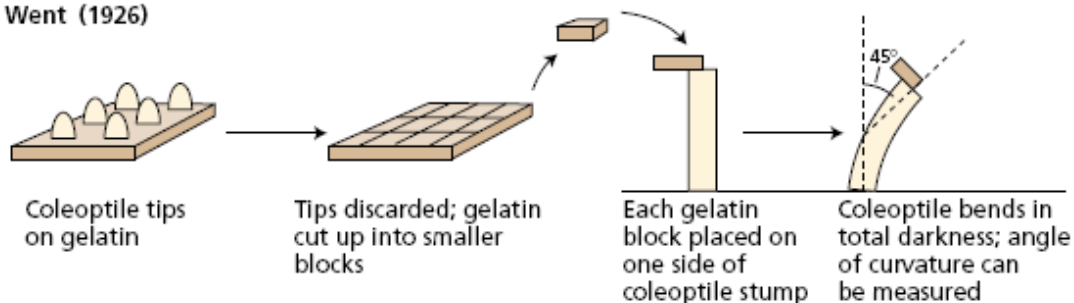
In 1913, P. Boysen-Jensen discovered that the growth stimulus passes through gelatin but not through water-impermeable barriers such as mica.

**Paál (1919)**



In 1919, A. Paál provided evidence that the growth-promoting stimulus produced in the tip was chemical in nature.

**Went (1926)**



In 1926, F. W. Went showed that the active growth-promoting substance can diffuse into a gelatin block. He also devised a coleoptile-bending assay for quantitative auxin analysis.

# **Crecimiento diferencial de variedades susceptibles y tolerantes de cebada sometidas a una atmósfera de etileno y al ataque del pulgón verde de los cereales**

*El ataque del pulgón produce un efecto localizado en la zona de alimentación, que podría explicarse por la acción tóxica de su saliva y, además, afecta sistemáticamente a toda la planta a partir de los dos días de ataque: menor longitud de láminas y vainas, retraso en la emisión de nuevas hojas y menor crecimiento radical. También ocurre la aparición de clorosis, extendiéndose a más del 80% de la superficie foliar a los diez días de infestación. Estas alteraciones se producen en menor proporción en variedades tolerantes.*

*Es conocido que el Etileno produce cambios en el hábito de crecimiento de la parte aérea, raíz y la senescencia. En trabajos previos se observó que el ataque del pulgón disminuyó el crecimiento de los coleoptilos de cebada (susceptible) debido a un menor alargamiento celular y, paralelamente, tuvieron un mayor diámetro de coleoptilos. Esto fue correlacionado con la producción de etileno (liberado) de plántulas infestadas. Los pulgones aislados no producen etileno.*

*El objetivo del presente trabajo fue determinar a) Si hay diferencias entre el crecimiento de coleoptilos de cebada de cvs. Susceptibles y Tolerantes, en el momento del alargamiento celular, por la acción sistémica del pulgón. b) Si las plántulas del cv. Tolerante producen etileno ante el ataque del pulgón y c) La alteración de los coleoptilos de ambos cultivares en una atmósfera de etileno.*

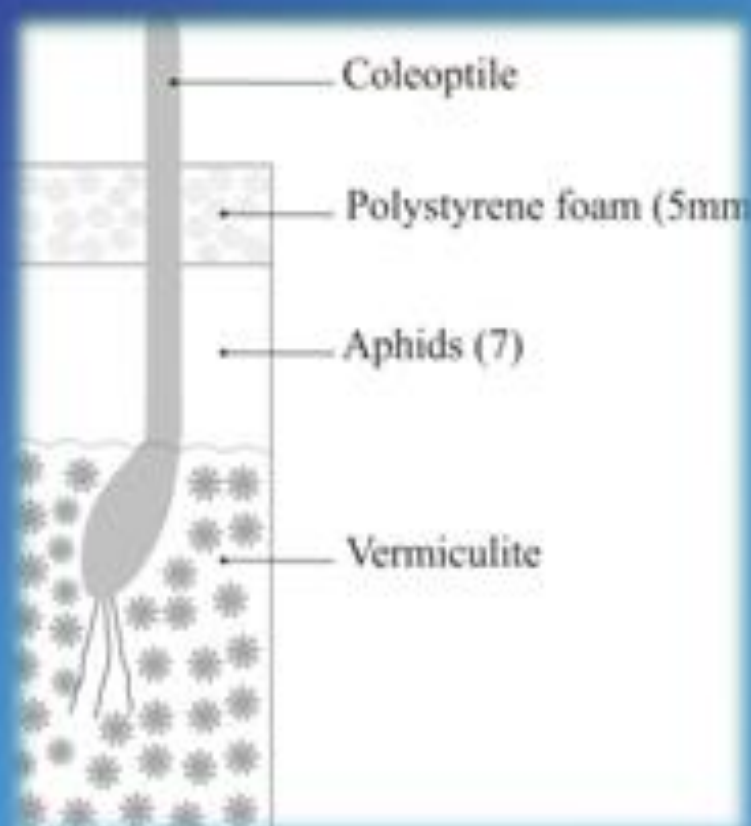


Tabla 1. Longitud de las células ( $\mu$ )  $\pm$  2SE

Tratamiento	KS	BT
Testigo	220,8 $\pm$ 9,6	220,8 $\pm$ 9,6
Pulgón	204,3 $\pm$ 8,7	208,4 $\pm$ 10,4

Tabla 2. Diámetro de los coleoptilos (mm)  $\pm$  2SE a 9mm de la lectura inicial

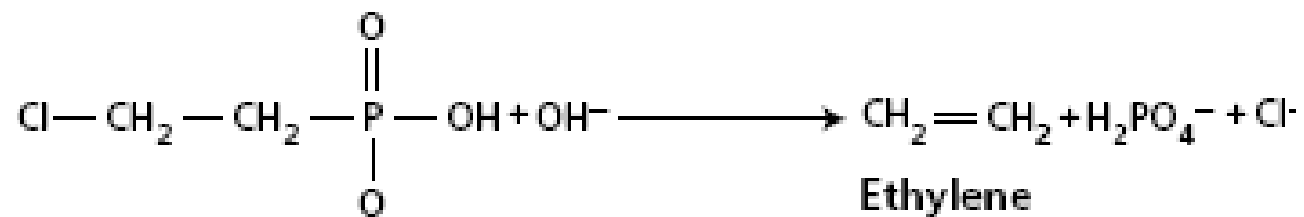
Tratamientos	KS	BT
Testigo	2,832 $\pm$ 0,074	2,790 $\pm$ 0,087
Pulgón	2,332 $\pm$ 0,055	2,928 $\pm$ 0,078

Tabla 3. Producción de etileno a las 24 hs de infestación ( $\mu$ g/l PP)  $\pm$  2SE

Tratamiento	KS	BT
Testigo	0,48 $\pm$ 0,38	0,48 $\pm$ 0,32
Pulgón	2,32 $\pm$ 0,61	2,18 $\pm$ 0,34

Tabla 4. Incremento de los coleoptilos (mm)  $\pm$  2SE, a las 24 hs. En una atmósfera de etileno, y porcentaje sobre testigo

Tratamientos	KS	BT
0 (Testigo)	24,93 $\pm$ 0,64	22,72 $\pm$ 0,68
0,3 ppm	12,56 $\pm$ 0,78 (54%)	12,78 $\pm$ 0,93 (55,2%)
1 ppm	13,08 $\pm$ 0,69 (74,2%)	12,01 $\pm$ 0,48 (57,8%)
3 ppm	8,32 $\pm$ 0,48 (33,7%)	10,08 $\pm$ 0,71 (73,5%)



**2-Chloroethylphosphonic acid  
(ethephon)**

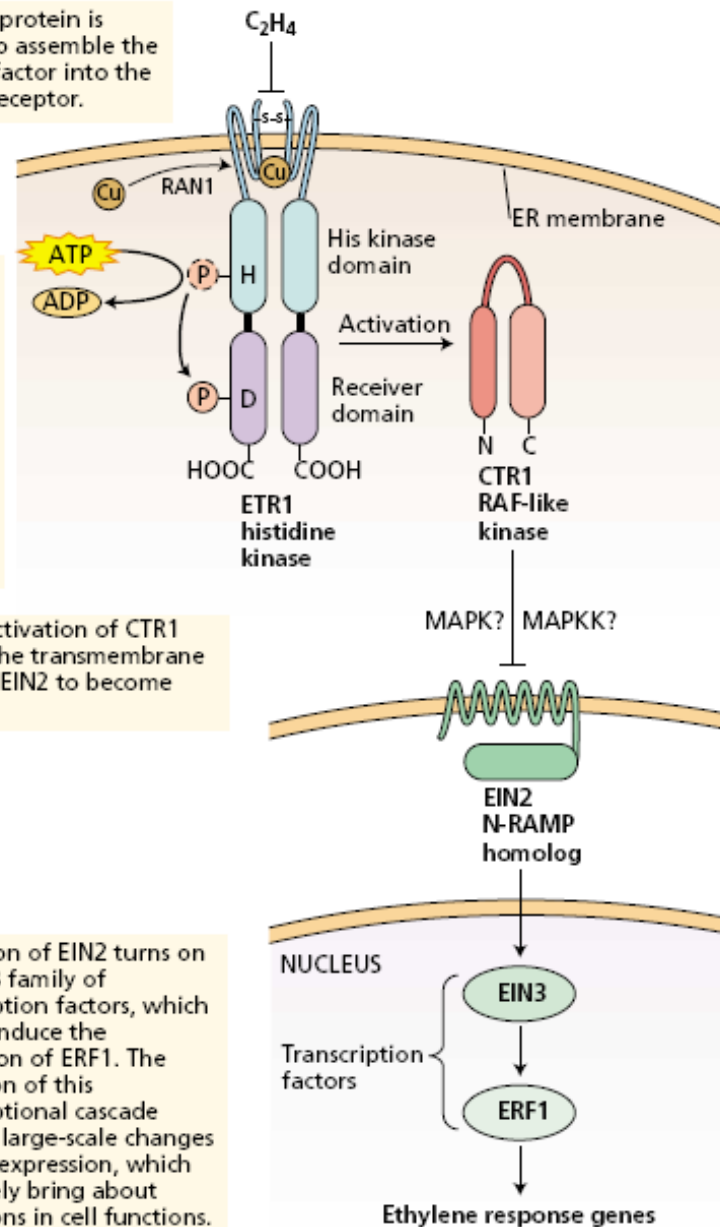
**Ethylene**

The RAN1 protein is required to assemble the copper cofactor into the ethylene receptor.

In the absence of ethylene, ETR1 and the other ethylene receptors activate the kinase activity of CTR1. This leads to a repression of the ethylene response pathway, possibly through a MAP kinase cascade. The binding of ethylene to the ETR1 dimer results in its inactivation, which causes CTR1 to become inactive.

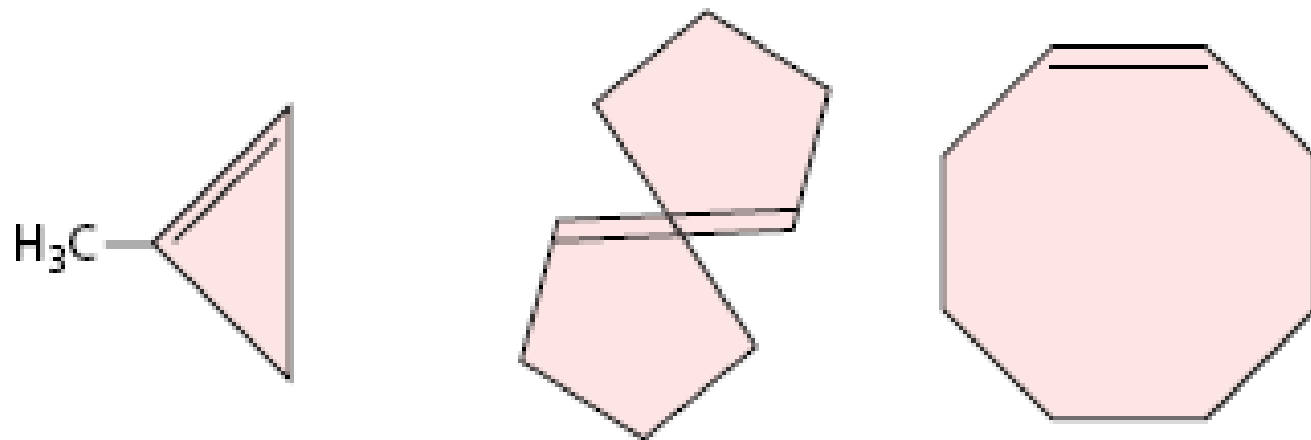
The inactivation of CTR1 allows the transmembrane protein EIN2 to become active.

Activation of EIN2 turns on the EIN3 family of transcription factors, which in turn induce the expression of ERF1. The activation of this transcriptional cascade leads to large-scale changes in gene expression, which ultimately bring about alterations in cell functions.



**FIGURE 22.16** Model of ethylene signaling in *Arabidopsis*. Ethylene binds to the ETR1 receptor, which is an integral membrane protein of the ER membrane. Multiple isoforms of ethylene receptors may be present in a cell; only ETR1 is shown for simplicity. The receptor is a dimer, held together by disulfide bonds. Ethylene binds within the trans-membrane domain, through a copper co-factor, which is assembled into the ethylene receptors through the RAN1 protein.





1-Methylcyclopropene  
(MCP)

*trans*-Cyclooctene

*cis*-Cyclooctene

FIGURE 22.3 Inhibitors that block ethylene binding to its receptor. Only the *trans* form of cyclooctene is active.

# Etileno: efectos fisiológicos

- Estimula la germinación de semillas
- Induce el agrandamiento celular
- Inhibe el crecimiento del tallo y de la raíz
- Controla las respuestas al estrés
- Induce epinastias en las hojas
- Participa en la diferenciación radical
- Controla la maduración de frutos
- Induce la floración en Bromeliáceas y mango
- Induce flores femeninas en cucurbitáceas

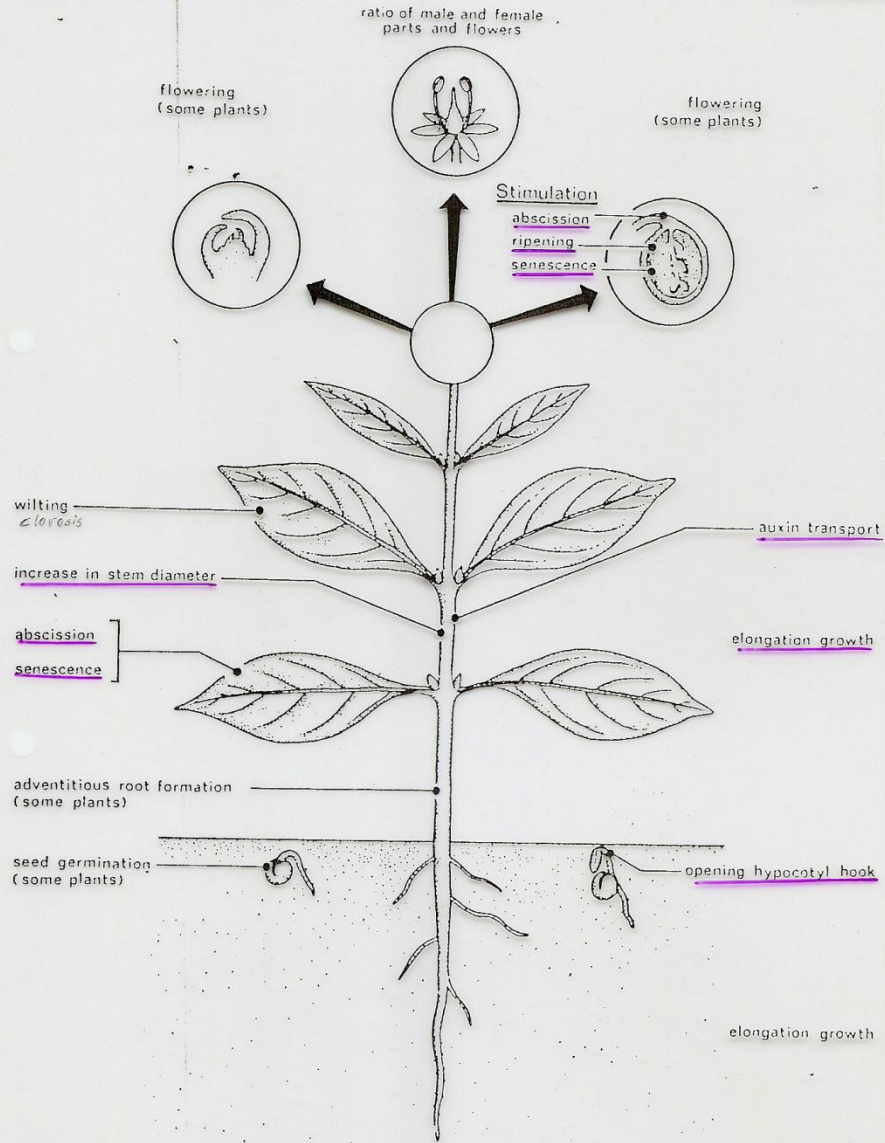
# Etileno: efectos fisiológicos

- Involucrado en fenómenos de inundación: plantas tolerantes y no-tolerantes
- Interviene en el crecimiento de las plántulas (gancho plumular, crecimiento horizontal)
- Formación de raíces adventicias en altas concentraciones ( $10 \mu\text{M}$ )
- Induce la senescencia de hojas, frutos y flores
- Induce la abscisión de hojas, frutos y flores

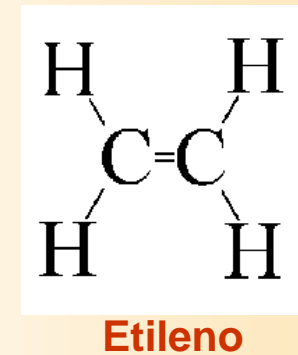
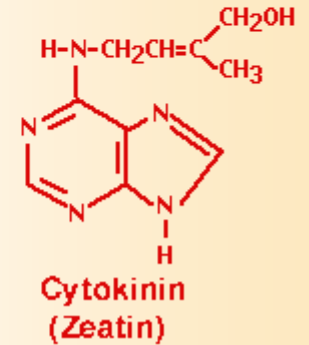
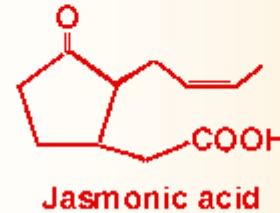
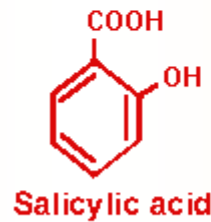
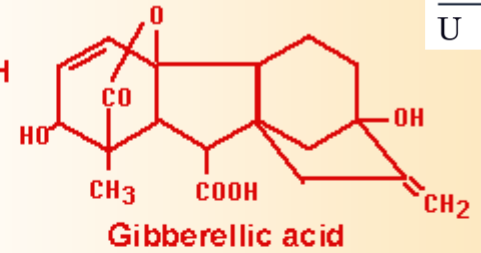
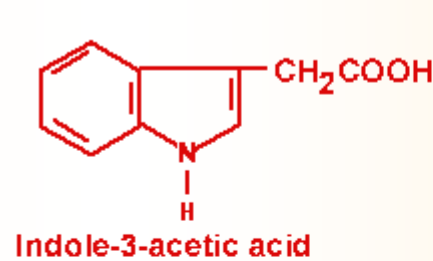
# ETHYLENE

## Stimulation

## Inhibition

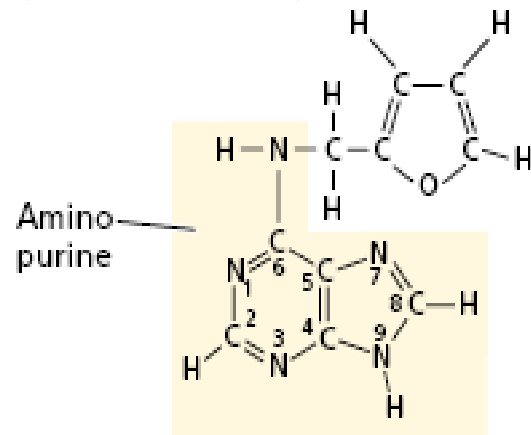


- ✓ Auxinas
- ✓ Giberelinas
- ✓ Citocininas\*
- ✓ Ácido abscísico
- ✓ Etileno
- ✓ Ácido jasmónico
- ✓ Ácido salicílico

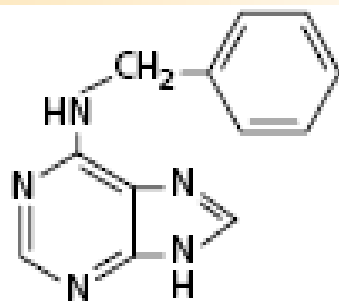




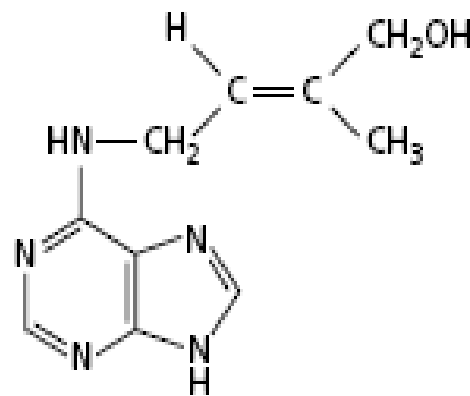
**FIGURE 21.1** Tumor that formed on a tomato stem infected with the crown gall bacterium, *Agrobacterium tumefaciens*. Two months before this photo was taken the stem was wounded and inoculated with a virulent strain of the crown gall bacterium. (From Aloni et al. 1998, courtesy of R. Aloni.)



Kinetin

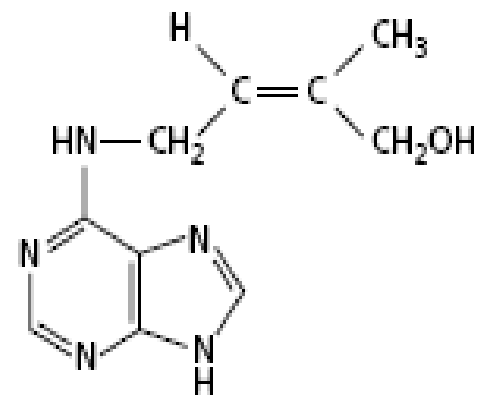


**Benzyladenine**  
(benzylaminopurine)  
(BA)

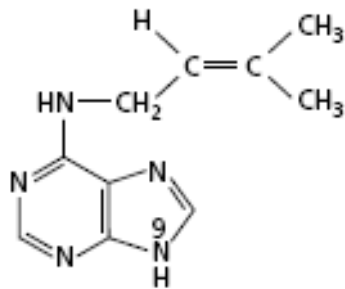


*trans*-Zeatin

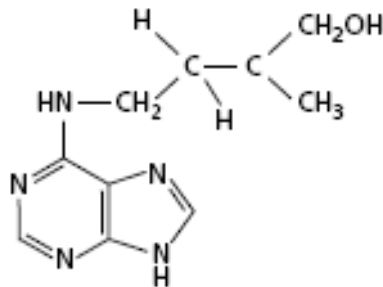
6-(4-Hydroxy-3-methylbut-2-enylamino)purine



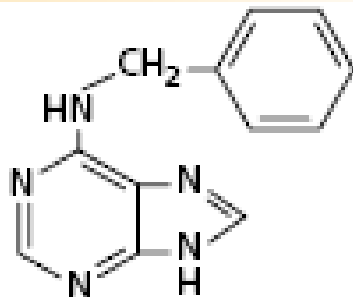
*cis*-Zeatin



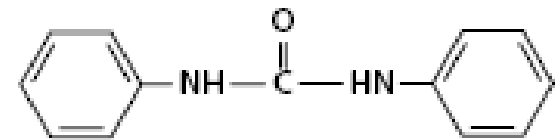
**N<sup>6</sup>-( $\Delta^2$ -Isopentenyl)-adenine (iP)**



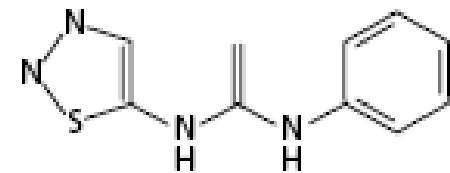
**Dihydrozeatin (DZ)**



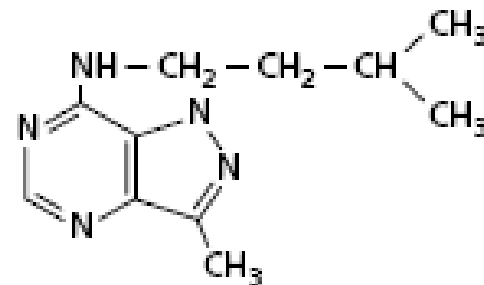
**Benzyladenine  
(benzylaminopurine)  
(BA)**



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

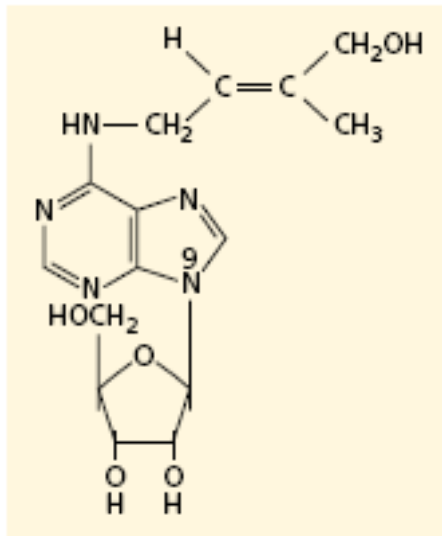


**Thidiazuron**

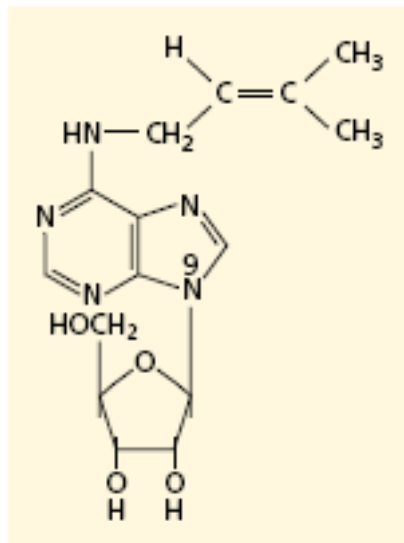


**3-Methyl-7-(3-methylbutylamino)pyrazolo[4,3-D]pyrimidine**



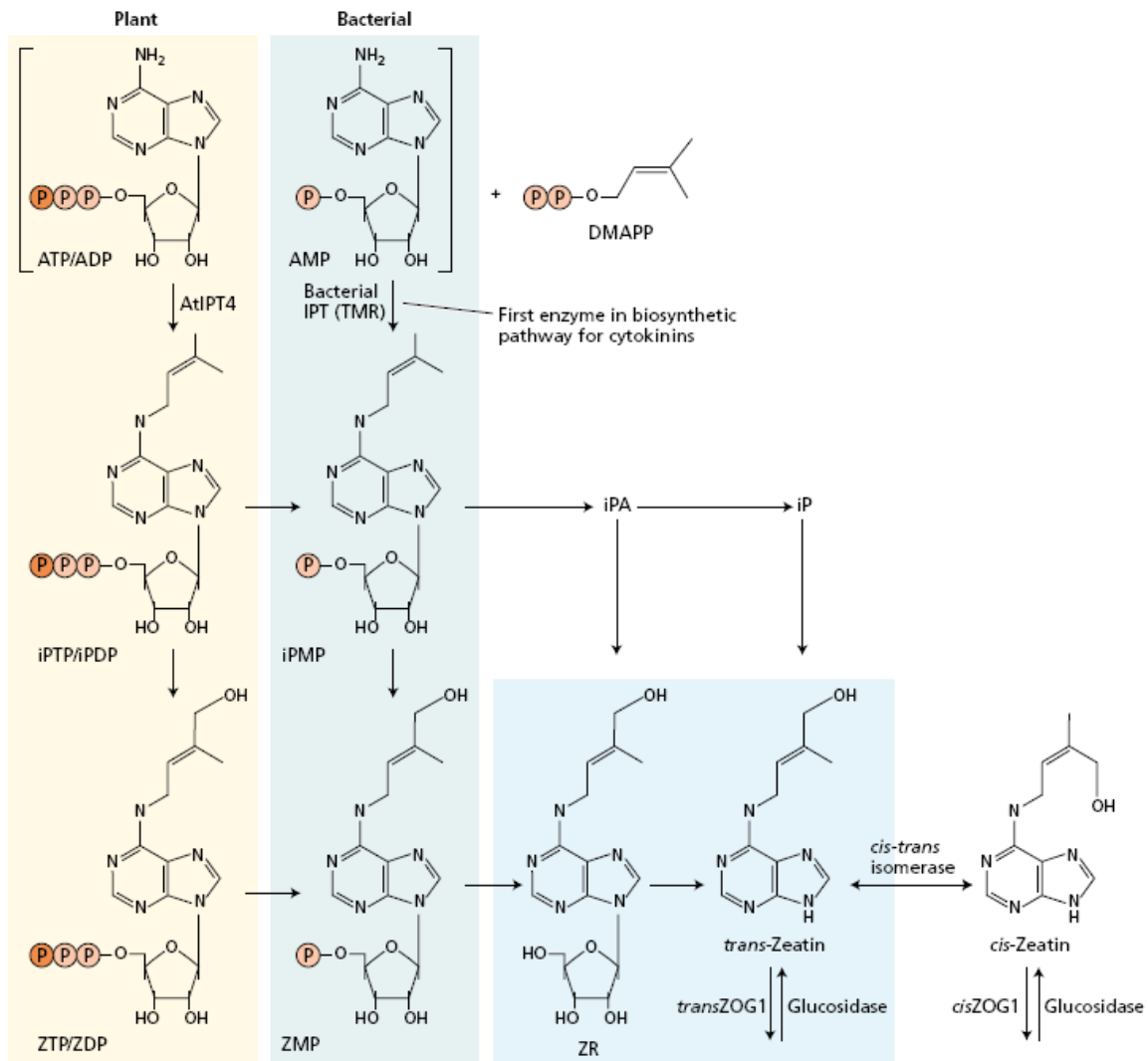


**Ribosylzeatin (zeatin riboside)**

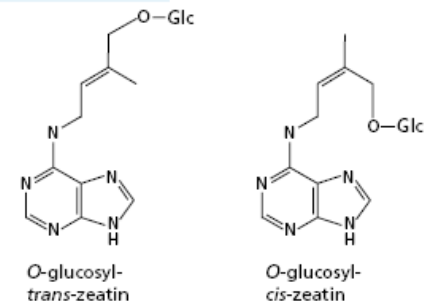


**N<sup>6</sup>-( $\Delta^2$ -Isopentenyl)adenosine ([9R]iP)**

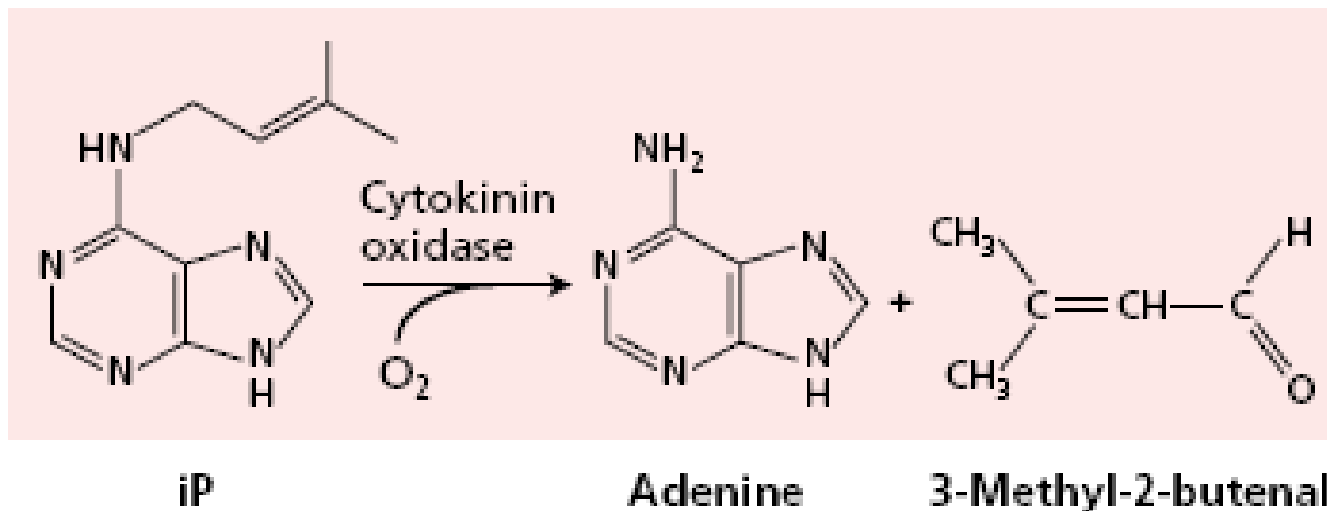
**FIGURE 21.2** Structures of ribosylzeatin and N<sup>6</sup>-( $\Delta^2$ -isopentenyl)adenosine ([9R]iP).



**FIGURE 21.6** Biosynthetic pathway for cytokinin biosynthesis. The first committed step in cytokinin biosynthesis is the addition of the isopentenyl side chain from DMAPP to an adenosine moiety. The plant and bacterial IPT enzymes differ in the adenosine substrate used; the plant enzyme appears to utilize both ADP and ATP, and the bacterial enzyme utilizes AMP. The products of these reactions (iPMP, iPDP, or iPTP) are converted to zeatin by an unidentified hydroxylase. The various phosphorylated forms can be interconverted and free *trans*-Zeatin can be formed from the riboside by enzymes of general purine metabolism. *trans*-Zeatin can be metabolized in various ways as shown, and these reactions are catalyzed by the indicated enzymes.



# La concentración de Citocininas esta controlada por: Su Síntesis, Degradación, Conjugación y Transporte



**FIGURE 21.7** Cytokinin oxidase irreversibly degrades some cytokinins.

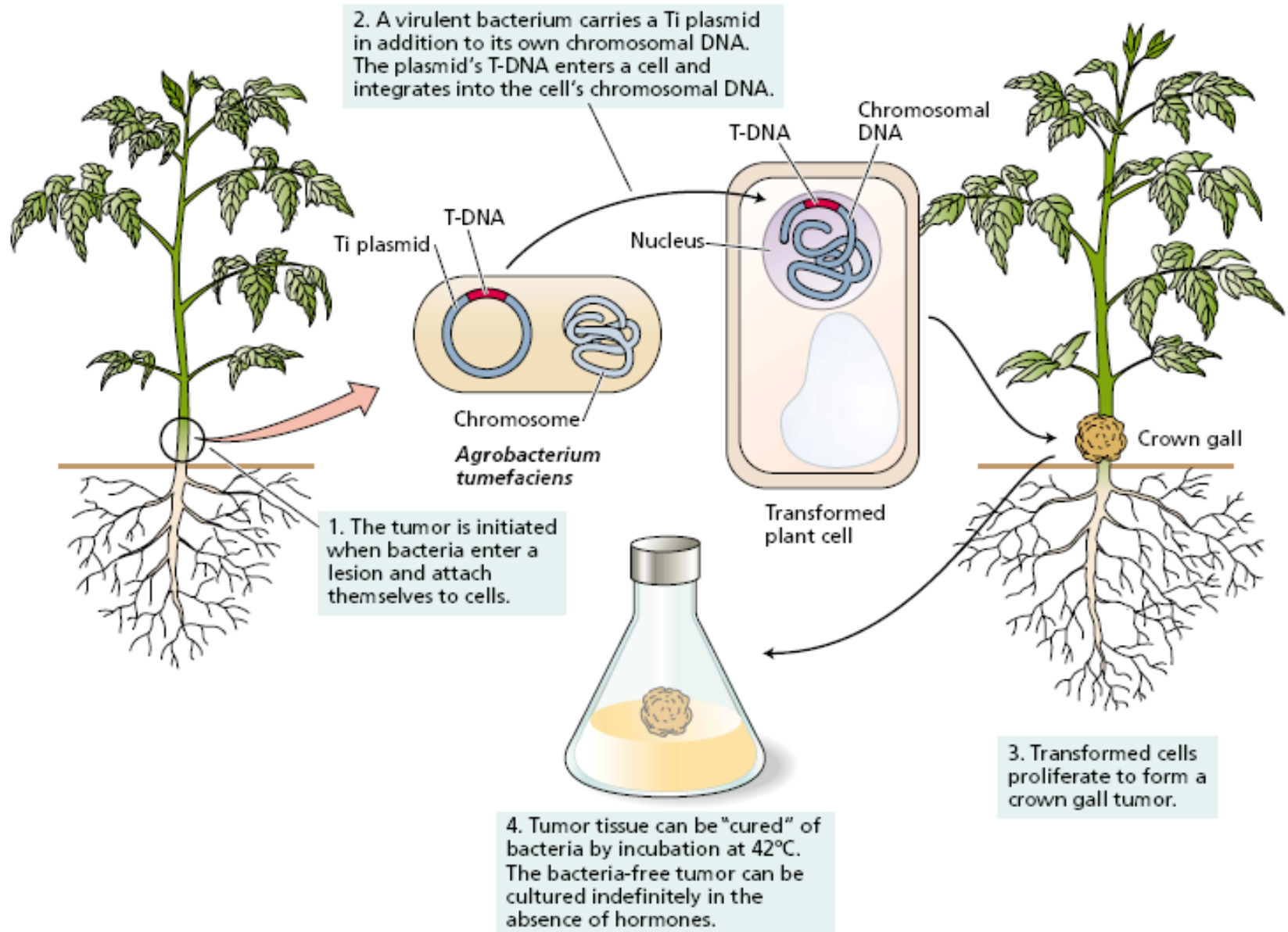
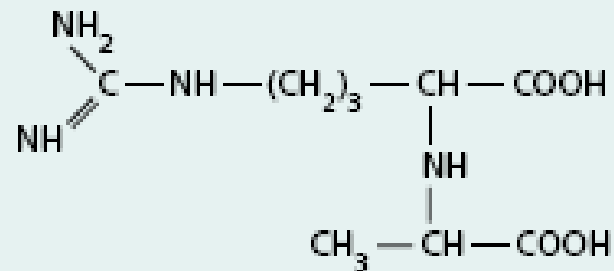
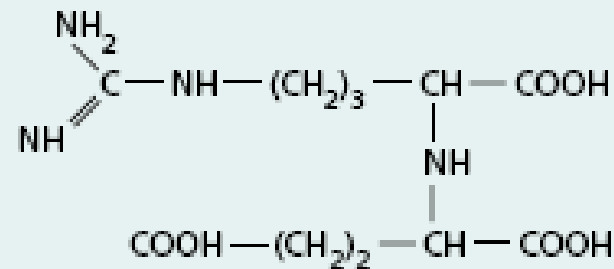


FIGURE 21.4 Tumor induction by *Agrobacterium tumefaciens*. (After Chilton 1983.)



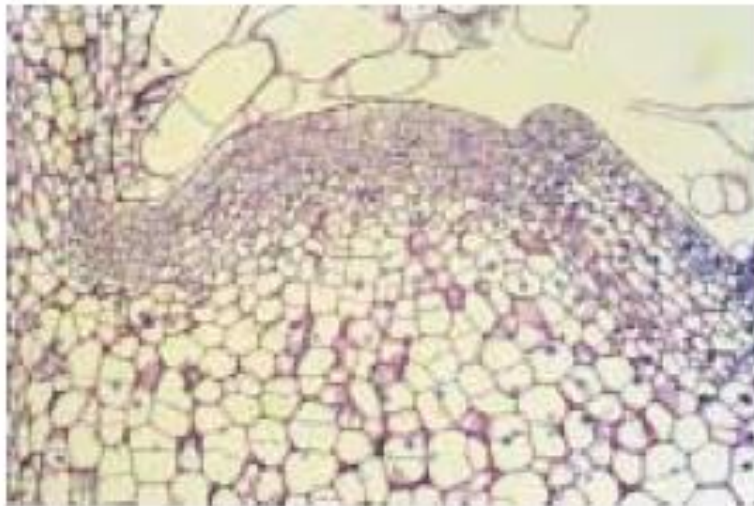
Octopine



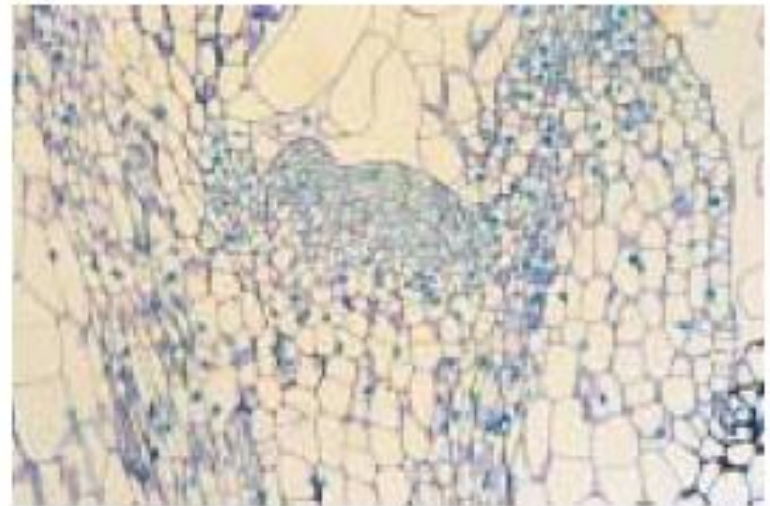
Nopaline

**FIGURE 21.5** The two major opines, octopine and nopaline, are found only in crown gall tumors. The genes required for their synthesis are present in the T-DNA from *Agrobacterium tumefaciens*. The bacterium, but not the plant, can utilize the opines as a nitrogen source.

(A)



(B)



**FIGURE 21.9** Cytokinin is required for normal growth of the shoot apical meristem. (A) Longitudinal section through the shoot apical meristem of a wild-type tobacco plant. (B) Longitudinal section through the shoot apical meristem of a transgenic tobacco overexpressing the gene that encodes cytokinin oxidase (*AtCKX1*). Note the reduction in the size of the apical meristem in the cytokinin-deficient plant. (From Werner et al. 2001.)



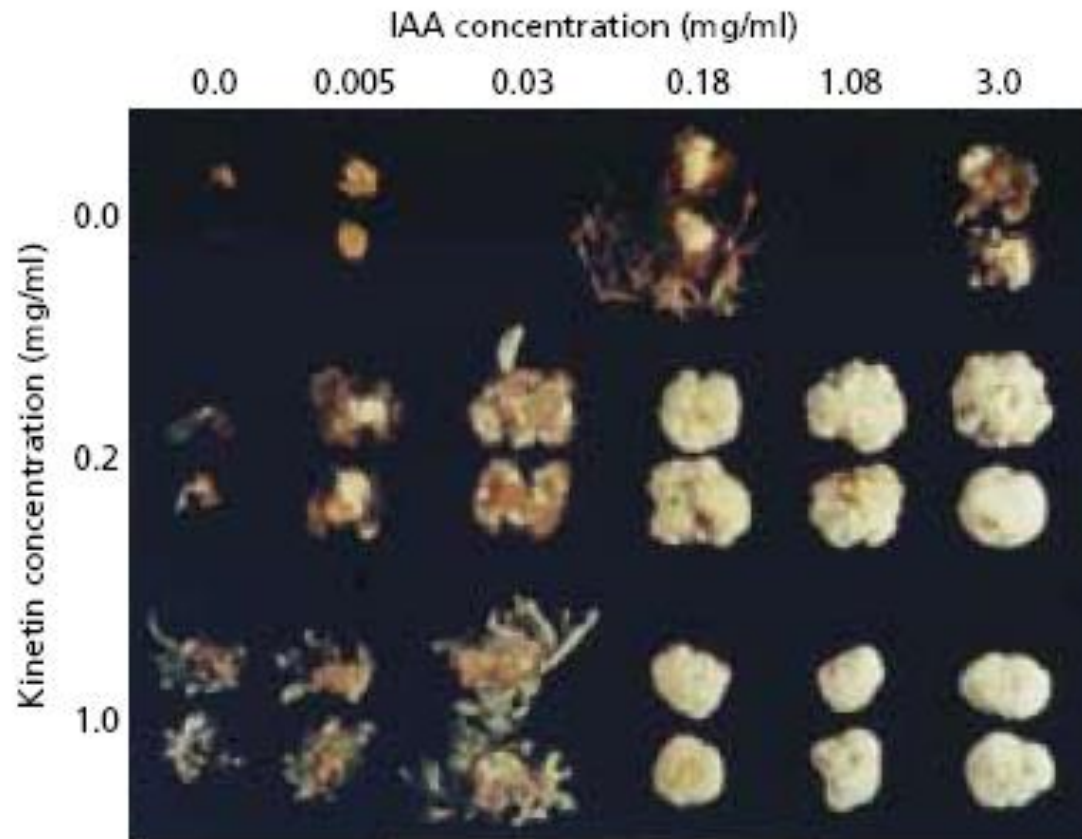
**FIGURE 21.8** Tobacco plants overexpressing the gene for cytokinin oxidase. The plant on the left is wild type. The two plants on the right are overexpressing two different constructs of the *Arabidopsis* gene for cytokinin oxidase: *AtCKX1* and *AtCKX2*. Shoot growth is strongly inhibited in the transgenic plants. (From Werner et al. 2001.)

# La relación auxina/citocinina regula la morfogénesis en cultivos de tejidos

(Skoog & Miller 1965)







**FIGURE 21.13** The regulation of growth and organ formation in cultured tobacco callus at different concentrations of auxin and kinetin. At low auxin and high kinetin concentrations (lower left) buds developed. At high auxin and low kinetin concentrations (upper right) roots developed. At intermediate or high concentrations of both hormones (middle and lower right) undifferentiated callus developed. (Courtesy of Donald Armstrong.)

Concentración de IAA (mg/ml)

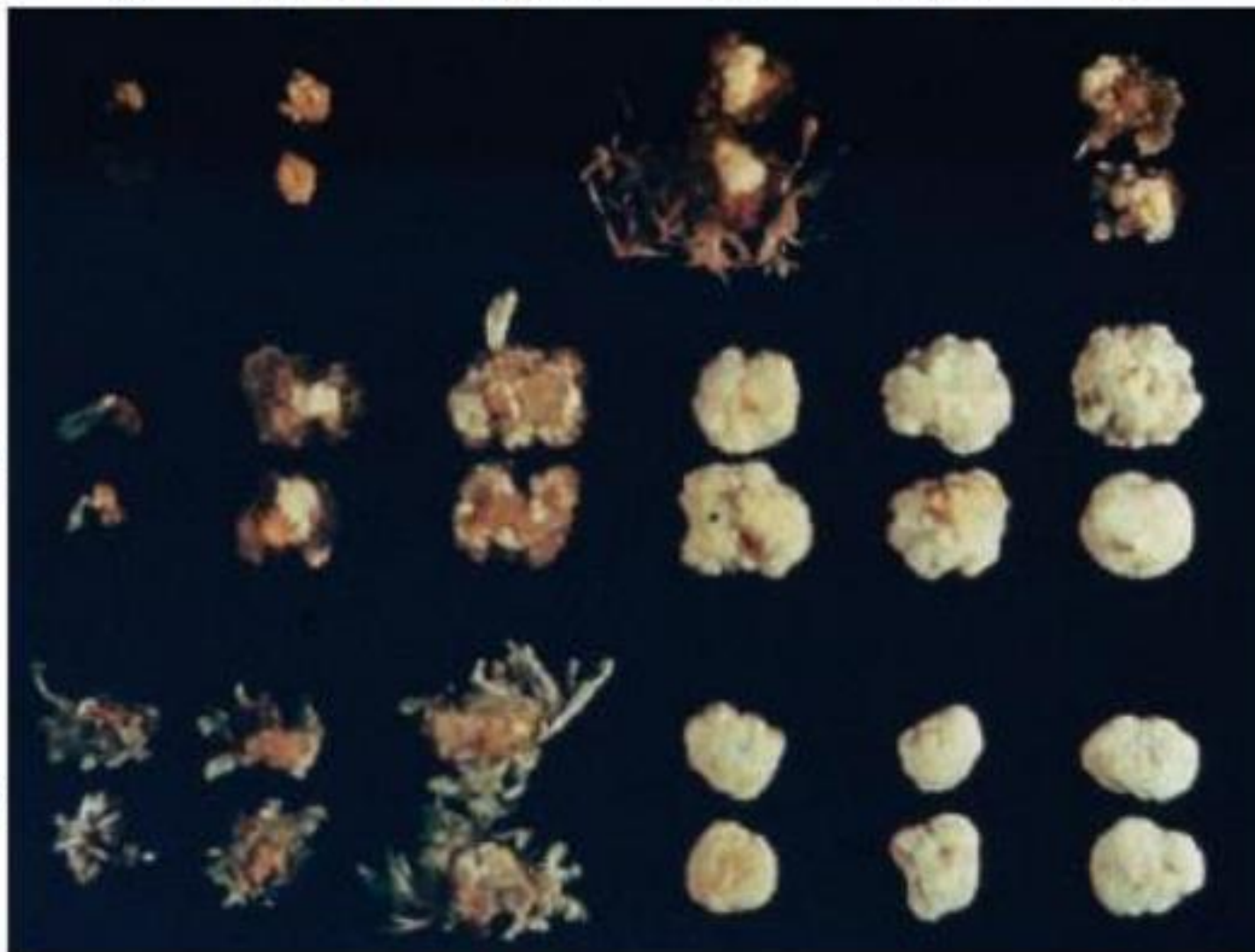
0,0    0,005    0,03    0,18    1,08    3,0

Concentración de quinetina (mg/ml)

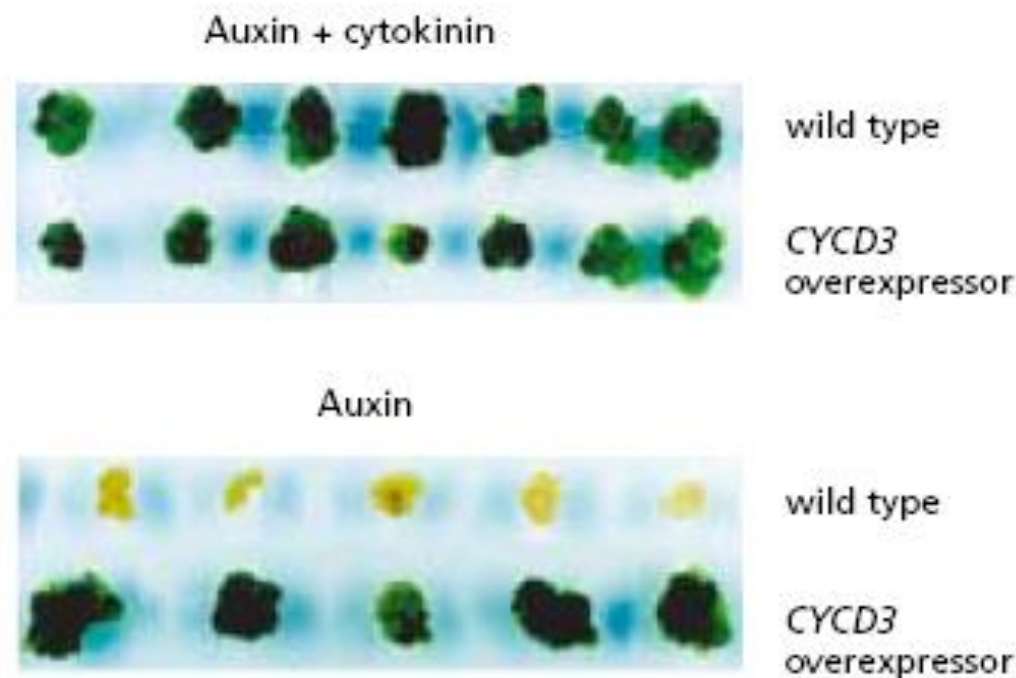
0,0

0,2

1,0



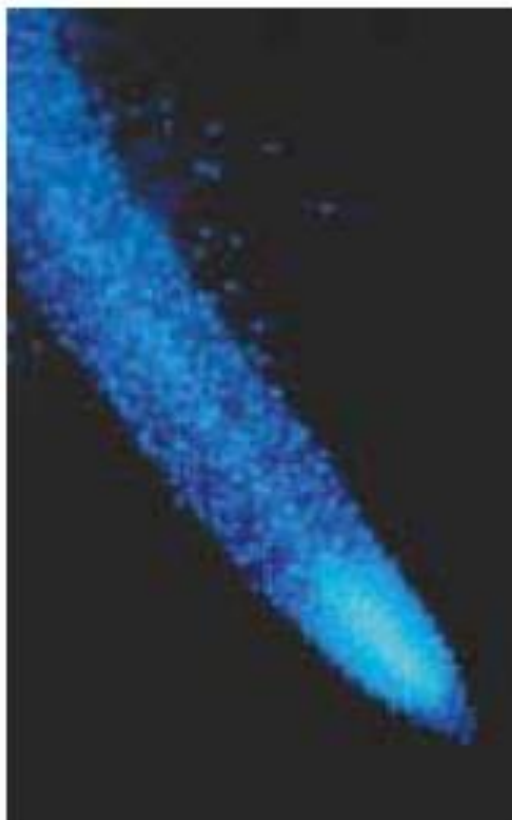
**FIGURE 21.12** *CYCD3*-expressing callus cells can divide in the absence of cytokinin. Leaf explants from transgenic *Arabidopsis* plants expressing *CYCD3* under a cauliflower mosaic virus 35S promoter were induced to form calluses through culturing in the presence of auxin plus cytokinin or auxin alone. The wild-type control calluses required cytokinin to grow. The *CYCD3*-expressing calluses grew well on medium containing auxin alone. The photographs were taken after 29 days. (From Riou-Khamlichi et al. 1999.)



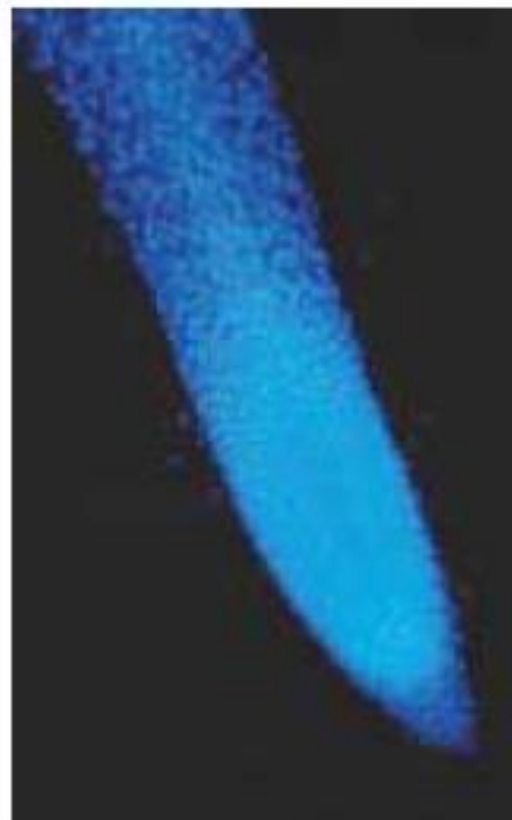


**FIGURE 21.10** Cytokinin suppresses the growth of roots. The cytokinin-deficient *AtCKX1* roots (right) are larger than those of the wild-type tobacco plant (left). (From Werner et al. 2001.)

(A)



(B)



**FIGURE 21.11** Cytokinin suppresses the size and cell division activity of roots. (A) Wild type. (B) *AtCKX1*. These roots were stained with the fluorescent dye, 4', 6-diamidino-2-phenylindole, which stains the nucleus. (From Werner et al. 2001.)



**FIGURE 21.3** Witches' broom on balsam fir (*Abies balsamea*).  
(Photo © Gregory K. Scott/Photo Researchers, Inc.)



**FIGURE 21.17** Expression of genetic tumors in the hybrid *Nicotiana langsdorffii* × *N. glauca*. (From Smith 1988.)



Plant expressing *ipt* gene remains green and photosynthetic

Age-matched control: advanced senescence, no photosynthesis

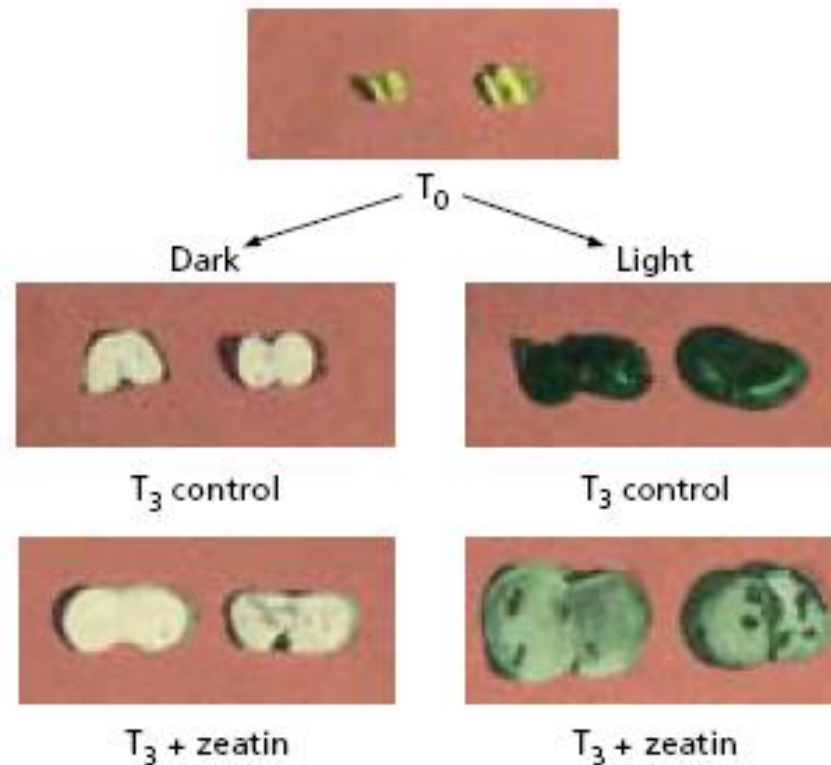
**FIGURE 21.18** Leaf senescence is retarded in a transgenic tobacco plant containing a cytokinin biosynthesis gene, *ipt*. The *ipt* gene is expressed in response to signals that induce senescence. (From Gan and Amasino 1995, courtesy of R. Amasino.)



# SENESCENCIA: planta, hojas, flores y fruto



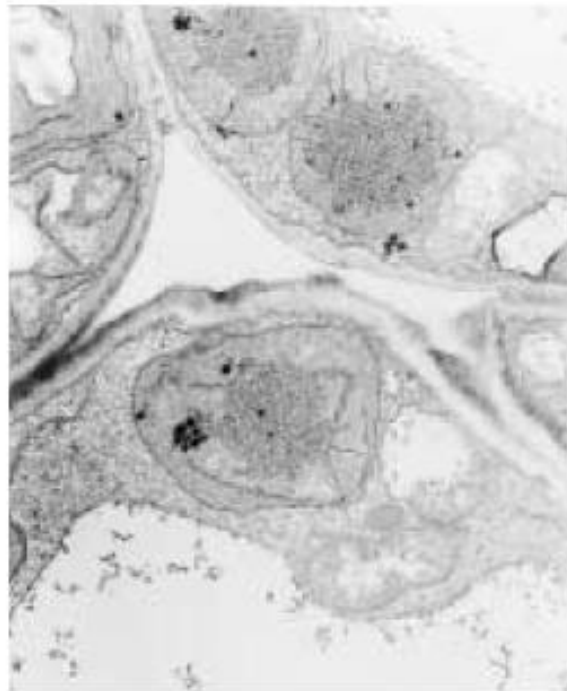
**FIGURE 16.36** Monocarpic senescence in soybeans (*Glycine max*). The entire plant on the left underwent senescence after flowering and producing fruit (pods). The plant on the right remained green and vegetative because its flowers were continually removed. (Courtesy of L. Noodén.)



**FIGURE 21.21** The effect of cytokinin on the expansion of radish cotyledons. The experiment described here shows that the effects of light and cytokinin are additive.  $T_0$  represents germinating radish seedlings before the experiment began. The detached cotyledons were incubated for 3 days ( $T_3$ ) in either darkness or light with or without 2.5 mM zeatin. In both the light and the dark, zeatin-treated cotyledons expanded more than in the control. (From Huff and Ross 1975.)

**FIGURE 21.20** Cytokinin influence on the development of wild-type *Arabidopsis* seedlings grown in darkness. (A) Plastids develop as etioplasts in the untreated, dark grown control. (B) Cytokinin treatment resulted in thylakoid formation in the plastids of dark-grown seedlings. (From Chory et al. 1994, courtesy of J. Chory, © American Society of Plant Biologists, reprinted with permission.)

(A)



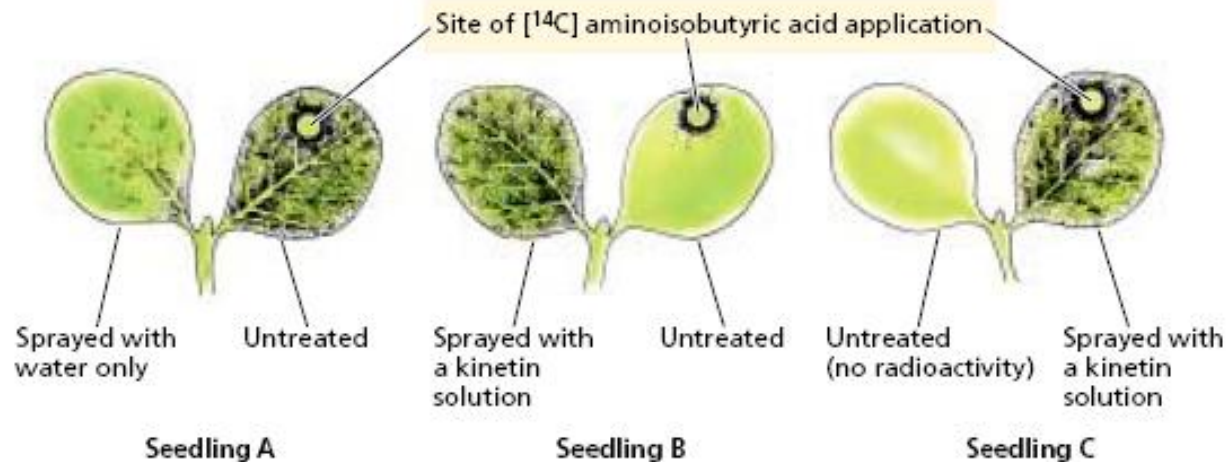
(B)



In seedling A, the left cotyledon was sprayed with water as a control. The left cotyledon of seedling B, and the right cotyledon of seedling C, were each sprayed with a solution containing 50mM kinetin.

The dark stippling represents the distribution of the radioactive amino acid as revealed by autoradiography.

The results show that the cytokinin-treated cotyledon has become a nutrient sink. However, radioactivity is retained in the cotyledon to which the amino acid was applied when the labeled cotyledon is treated with kinetin (seedling C).



**FIGURE 21.19** The effect of cytokinin on the movement of an amino acid in cucumber seedlings. A radioactively labeled amino acid that cannot be metabolized, such as

aminoisobutyric acid, was applied as a discrete spot on the right cotyledon of each of these seedlings. (Drawn from data obtained by K. Mothes.)

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.

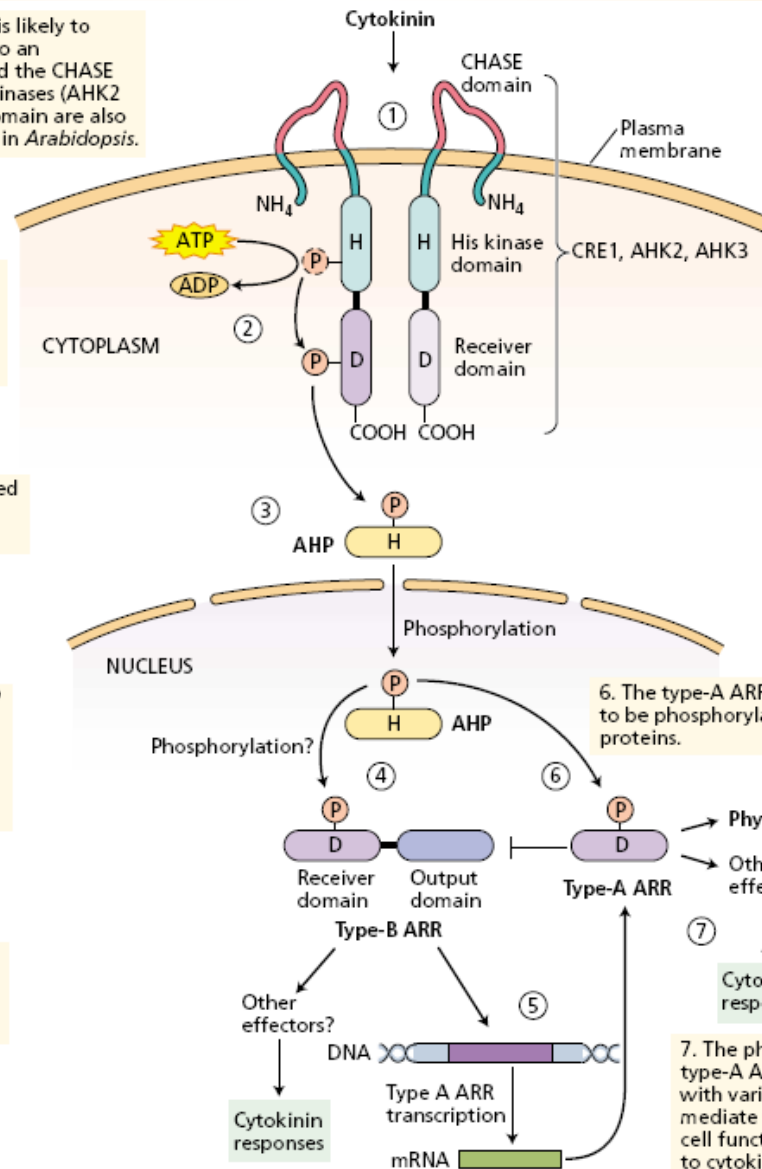
3. The phosphate is then transferred to a conserved histidine present in an AHP protein.

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.

6. The type-A ARRs are likely also to be phosphorylated by the AHP proteins.

7. The phosphorylated type-A ARRs interact with various effectors to mediate the changes in cell function appropriate to cytokinin (indicated in the model as "cytokinin responses").

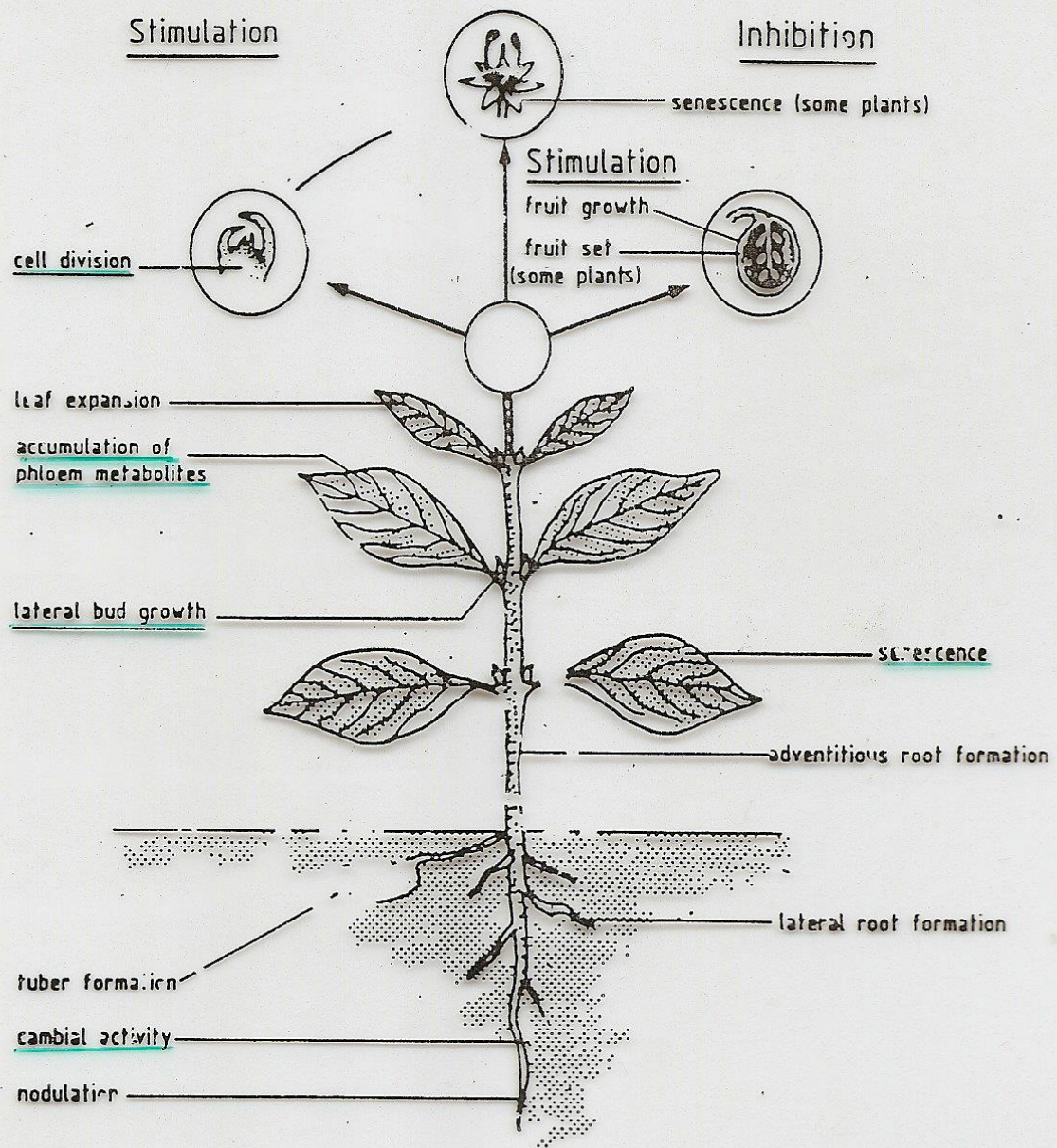


**FIGURE 21.27** Model of cytokinin signaling. The near future should see significant refinement of this model, the tools are now in hand to analyze the interactions among these elements.

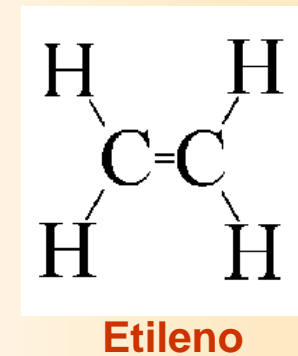
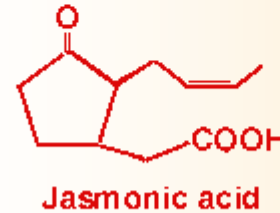
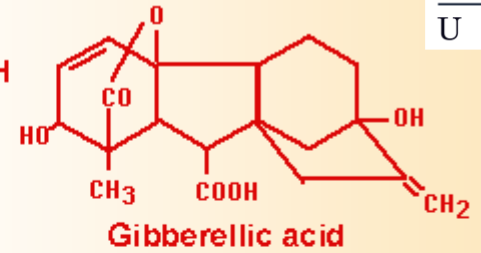
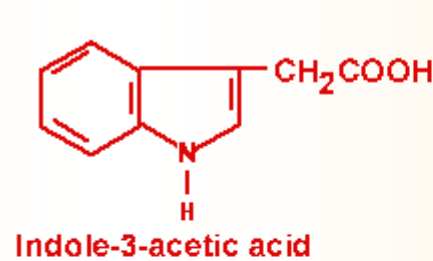
# Acción Fisiológica de las Citocininas

- Promueve la Citocinesis e induce mas hojas en los ápices.
- Morfogénesis en cultivos de tejidos, yemas adventicias (Relación Auxinas/Citocininas).
- Inducen la formación de yemas adventicias en tallos.
- Retraso en la Senescencia de Plantas, Hojas, Flores y Frutos e inducción de la movilización de nutrientes.
- Promueve el agrandamiento celular en hojas y cotiledones.
- Promueve la actividad del Cambium.
- Promueve el desarrollo de cloroplastos y la síntesis de Clorofila.
- Promueve la Partenocarpia de frutos.
- Interactúa con las Auxinas en la Dominancia Apical.
- Crean centros de gran actividad metabólica en sitios de hojas donde se aplican.

# CYTOKININ (K)



- ✓ Auxinas
- ✓ Giberelinas
- ✓ Citocininas
- ✓ Ácido abscísico\*
- ✓ Etileno
- ✓ Ácido jasmónico
- ✓ Ácido salicílico

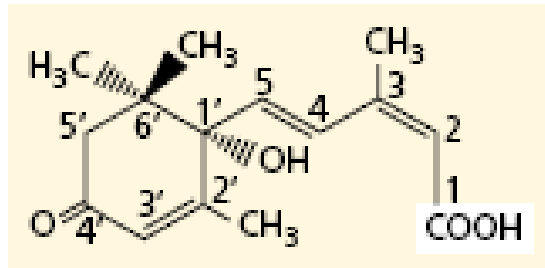




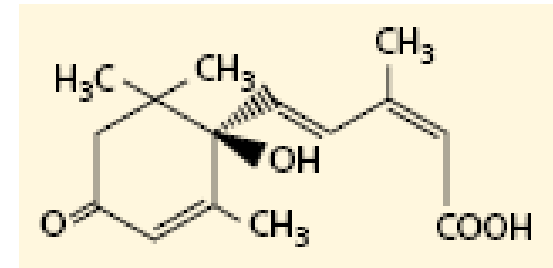
## *Descubrimiento del Ac. Abscisico*

### ABSCISIÓN de frutos de algodón

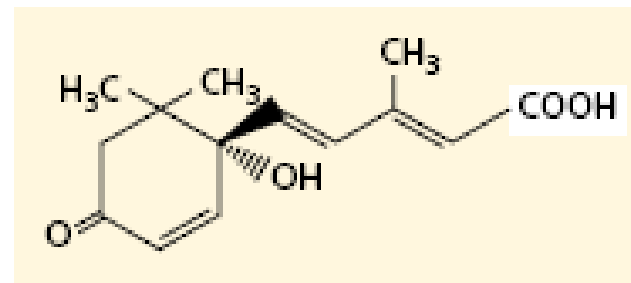
- REPOSO: Ausencia de Crecimiento
- DORMICIÓN Ausencia de Crecimiento por factores Internos. En yemas y semillas.
- QUIESCENCIA: Ausencia de crecimiento por factores Externos (Temperatura, Agua y Oxigeno)



*(S)*-*cis*-ABA  
(naturally occurring  
active form)



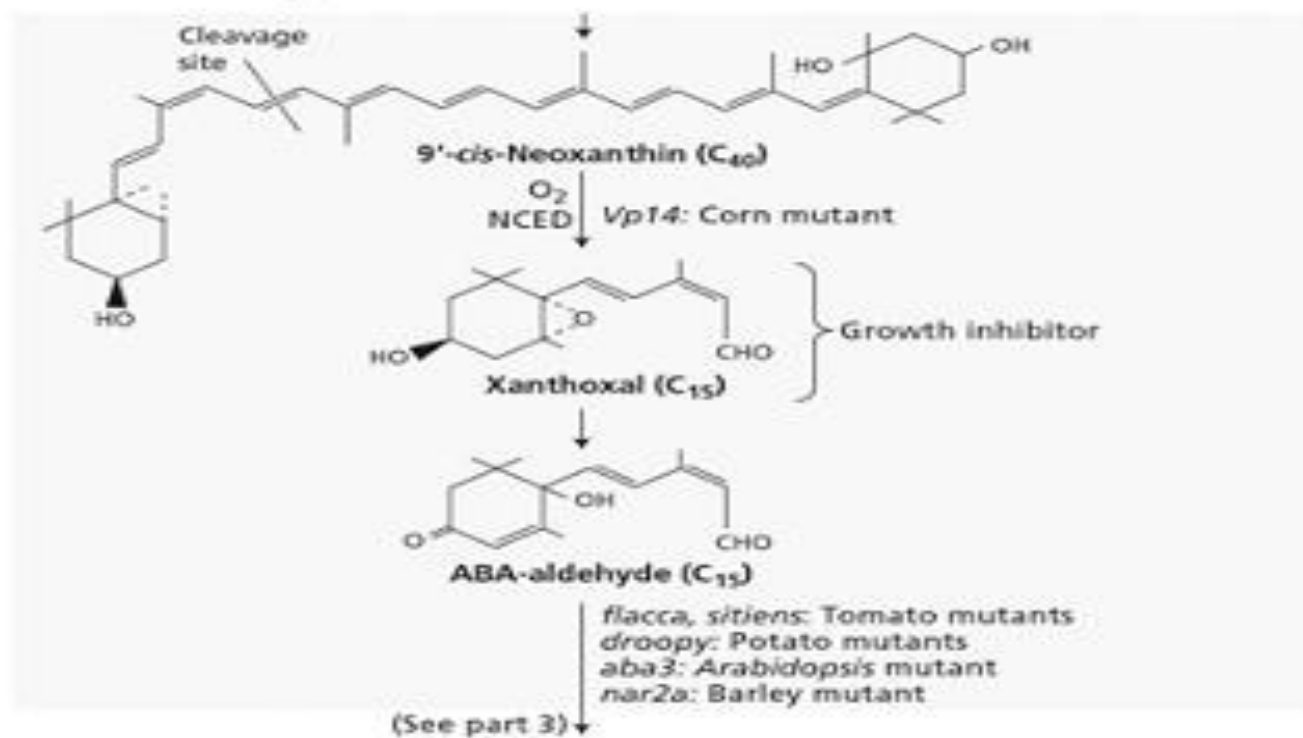
*(R)*-*cis*-ABA  
(inactive in stomatal closure)



*(S)*-2-*trans*-ABA (inactive, but  
interconvertible with active  
*[cis]* form)

**FIGURE 23.1** The chemical structures of the *S* (counterclockwise array) and *R* (clockwise array) forms of *cis*-ABA, and the *(S)*-2-*trans* form of ABA. The numbers in the diagram of *(S)*-*cis*-ABA identify the carbon atoms.

# ABA is synthesized from carotenoids

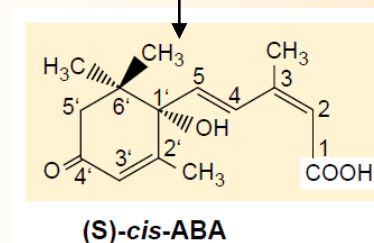
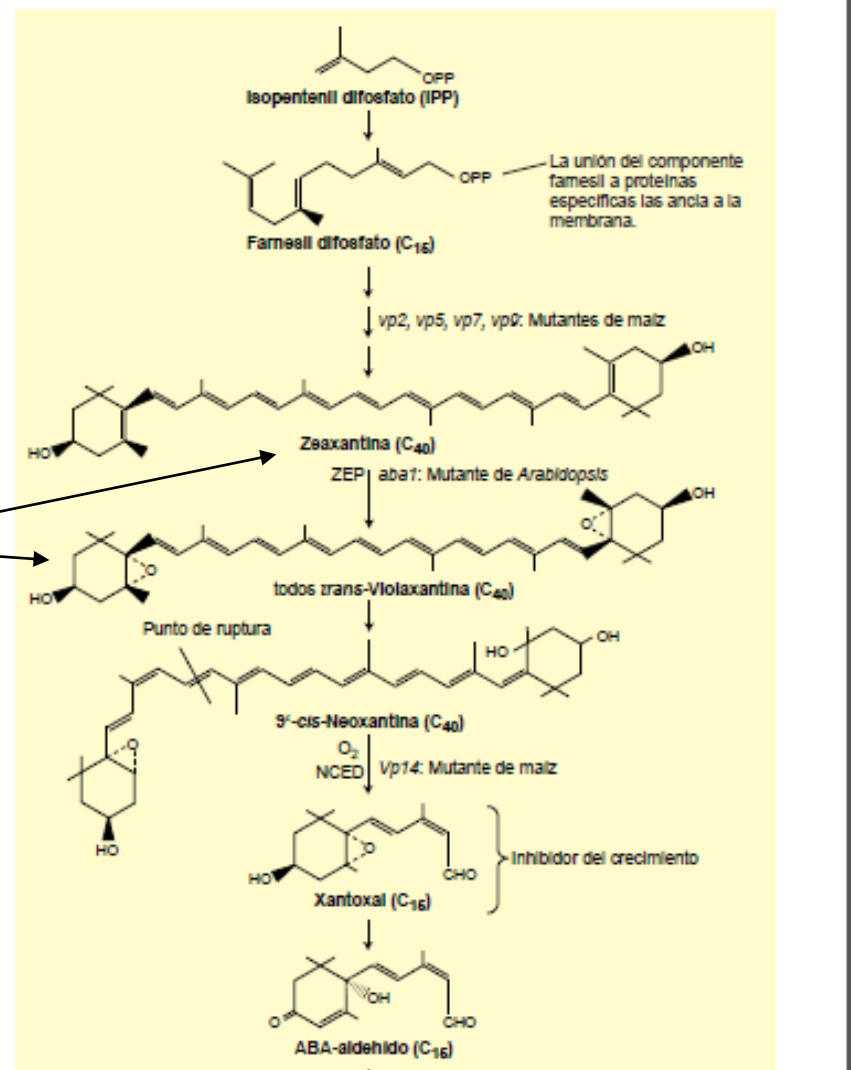


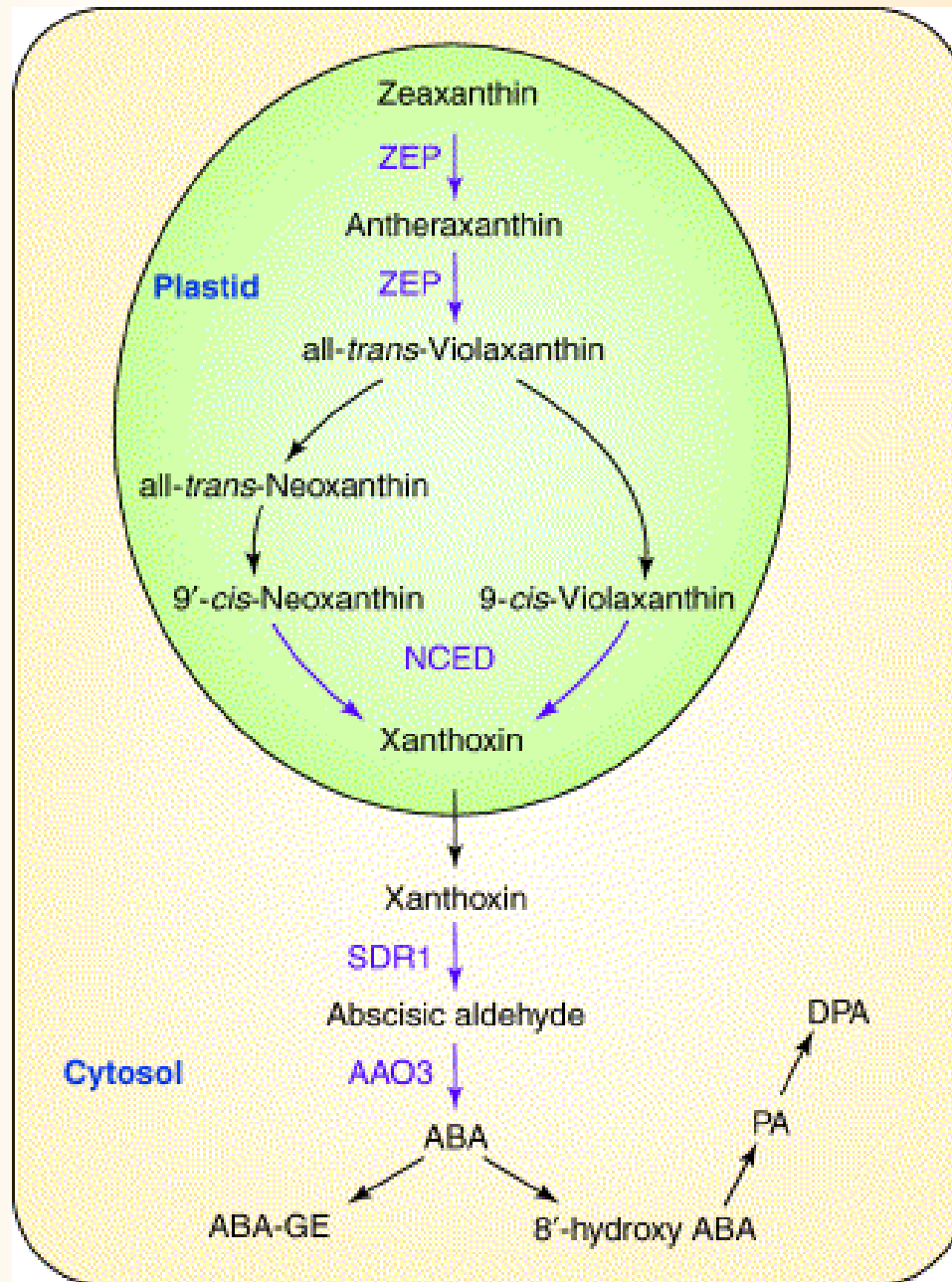
# ABA, biosíntesis

Las etapas iniciales de la síntesis de ABA ocurren en **plástidos**.

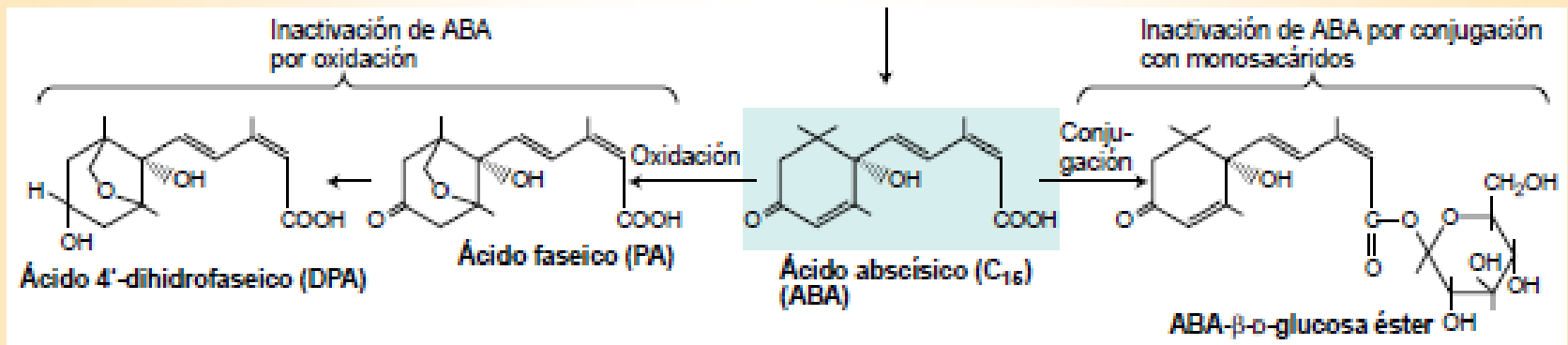
Los intermediarios en la síntesis son **carotenoides**.

La última etapa ocurre en el citosol.





# La concentración de ABA es regulada por su síntesis, degradación, conjugación y transporte.



# ABA

## Efectos fisiológicos

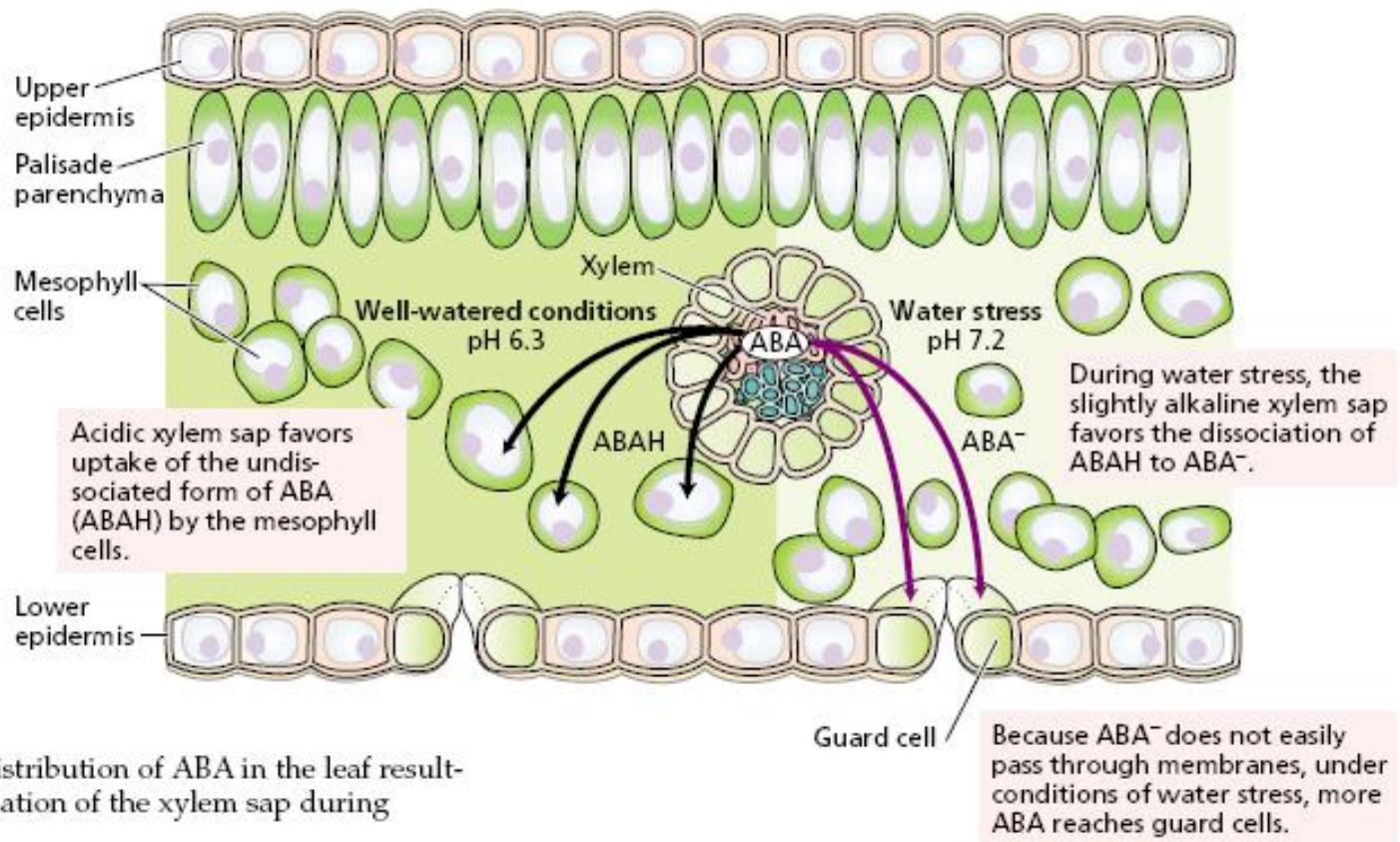
- El efecto del ABA en la abscisión de hojas es indirecto: estimula la producción de etileno.
- Participa en la respuesta de las plantas al estrés abiótico: por ejemplo en la sequía provoca un rápido cierre de estomas.
- Incrementa su concentración frente al estrés salino, térmico (frio, calor) o por lesiones.

# ABA

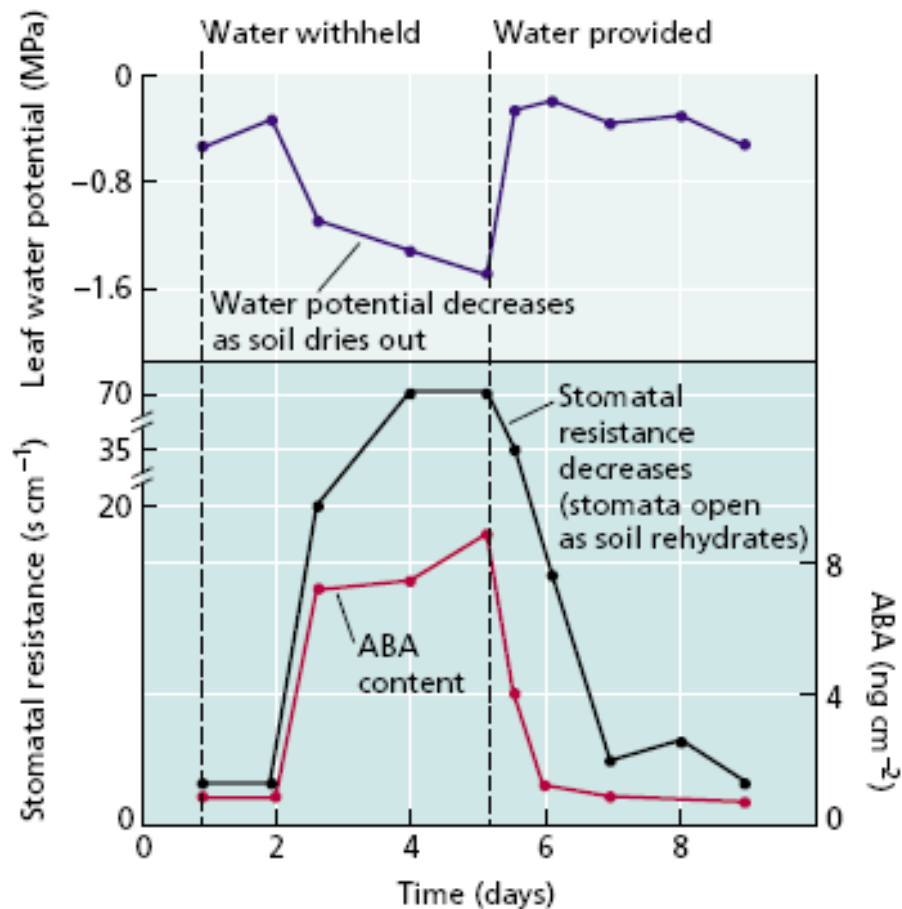
## Efectos fisiológicos

- Controla el desarrollo embrionario de las semillas.
- Inhibe el crecimiento vegetativo.
- Participa en la senescencia de hojas, frutos y flores y en la síntesis de etileno.
- Impone dormición en semillas y yemas.
- Inhibe la germinación.

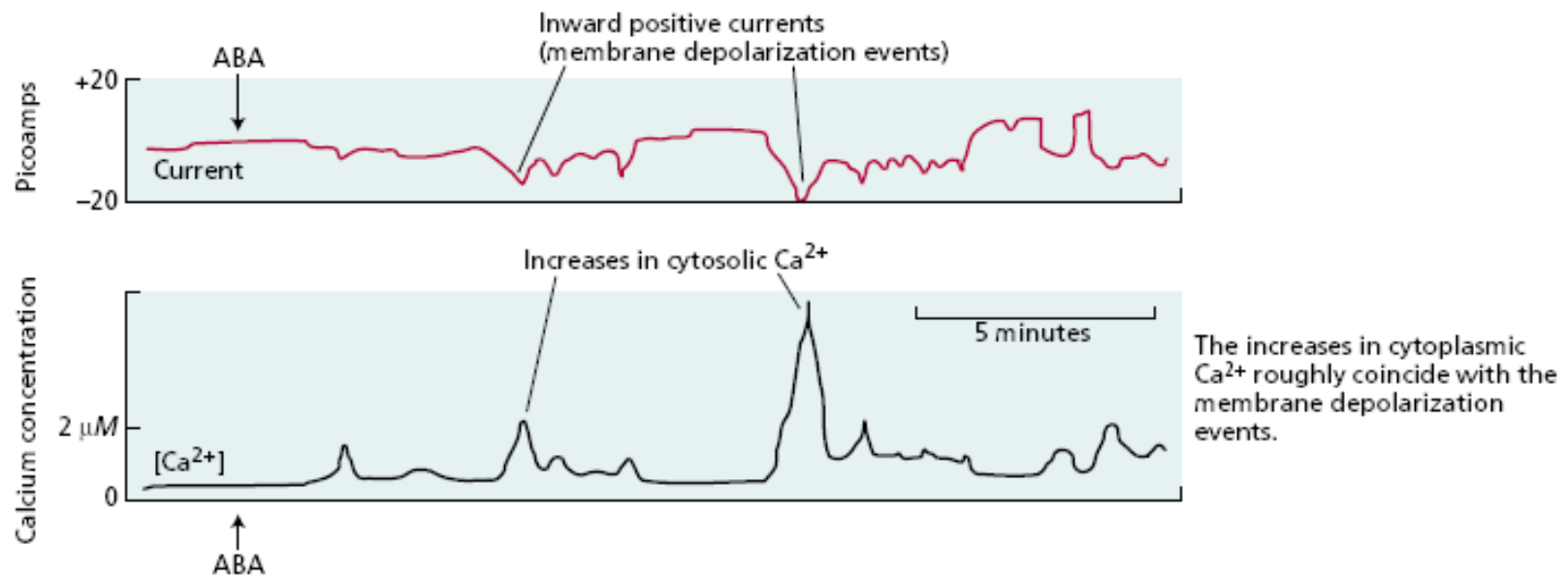




**FIGURE 23.4** Redistribution of ABA in the leaf resulting from alkalinization of the xylem sap during water stress.

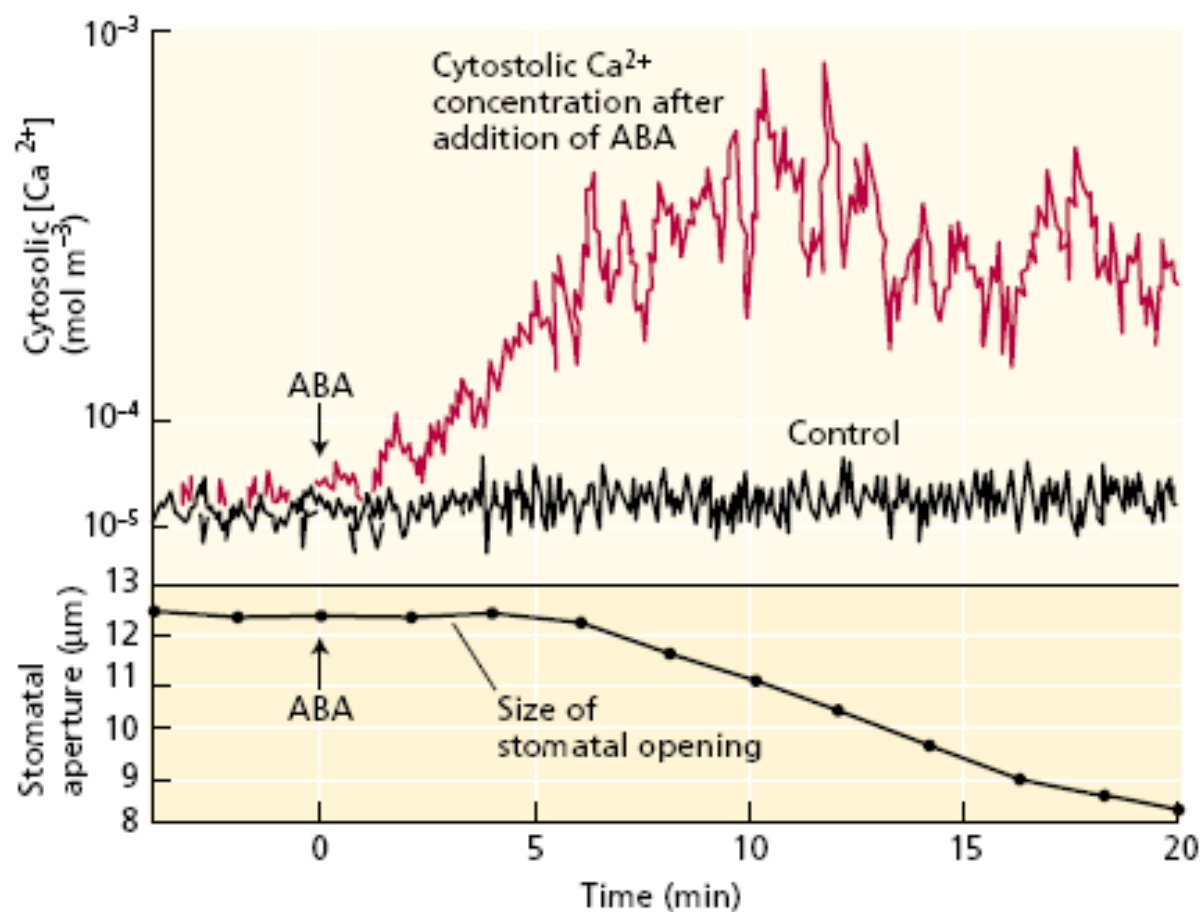


**FIGURE 23.5** Changes in water potential, stomatal resistance (the inverse of stomatal conductance), and ABA content in maize in response to water stress. As the soil dried out, the water potential of the leaf decreased, and the ABA content and stomatal resistance increased. The process was reversed by rewatering. (After Beardsell and Cohen 1975.)

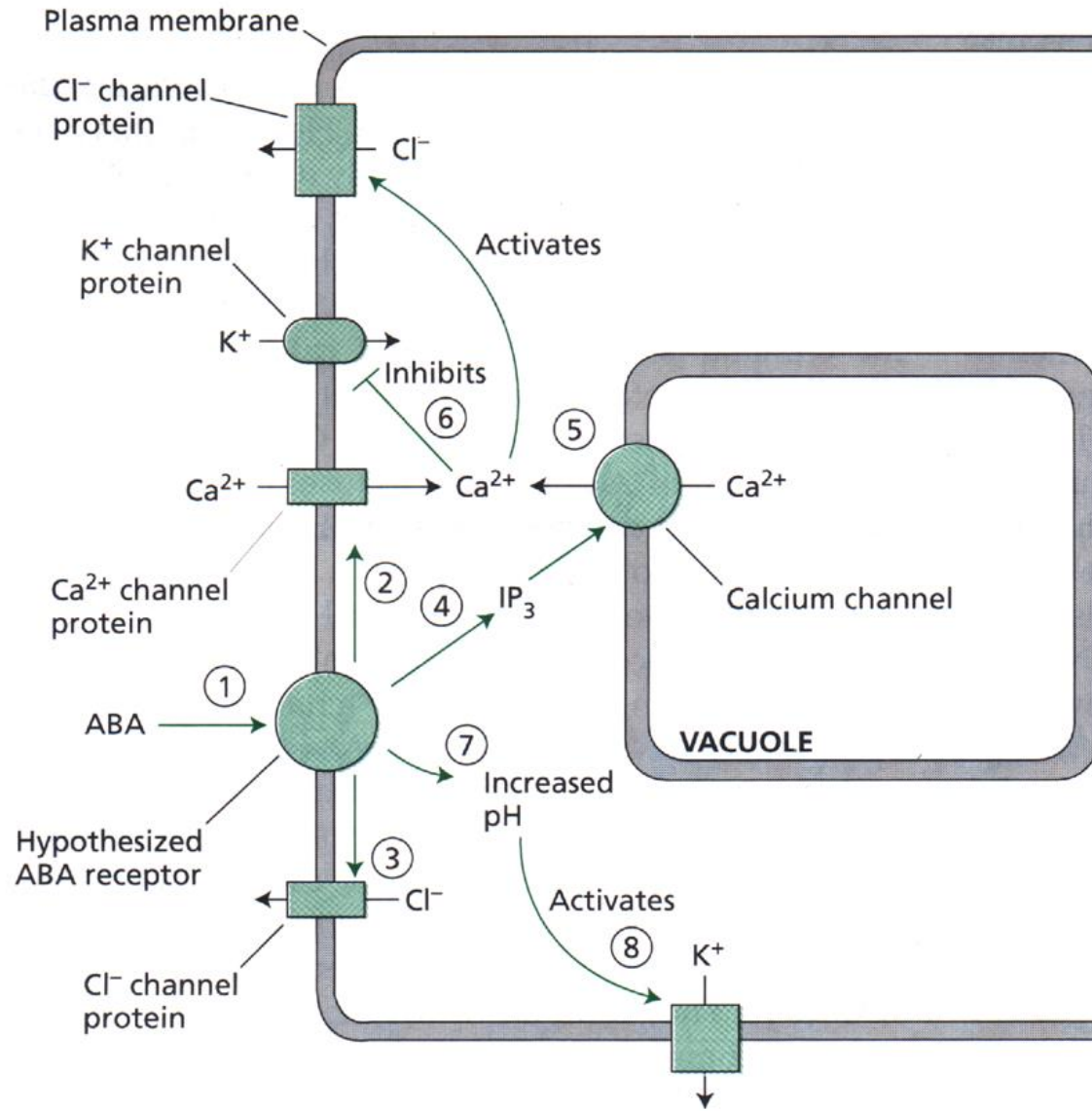


**FIGURE 23.8** Simultaneous measurements of ABA-induced inward positive currents and ABA-induced increases in cytosolic  $\text{Ca}^{2+}$  concentrations in a guard cell of *Vicia faba* (broad bean). The current was measured by the patch

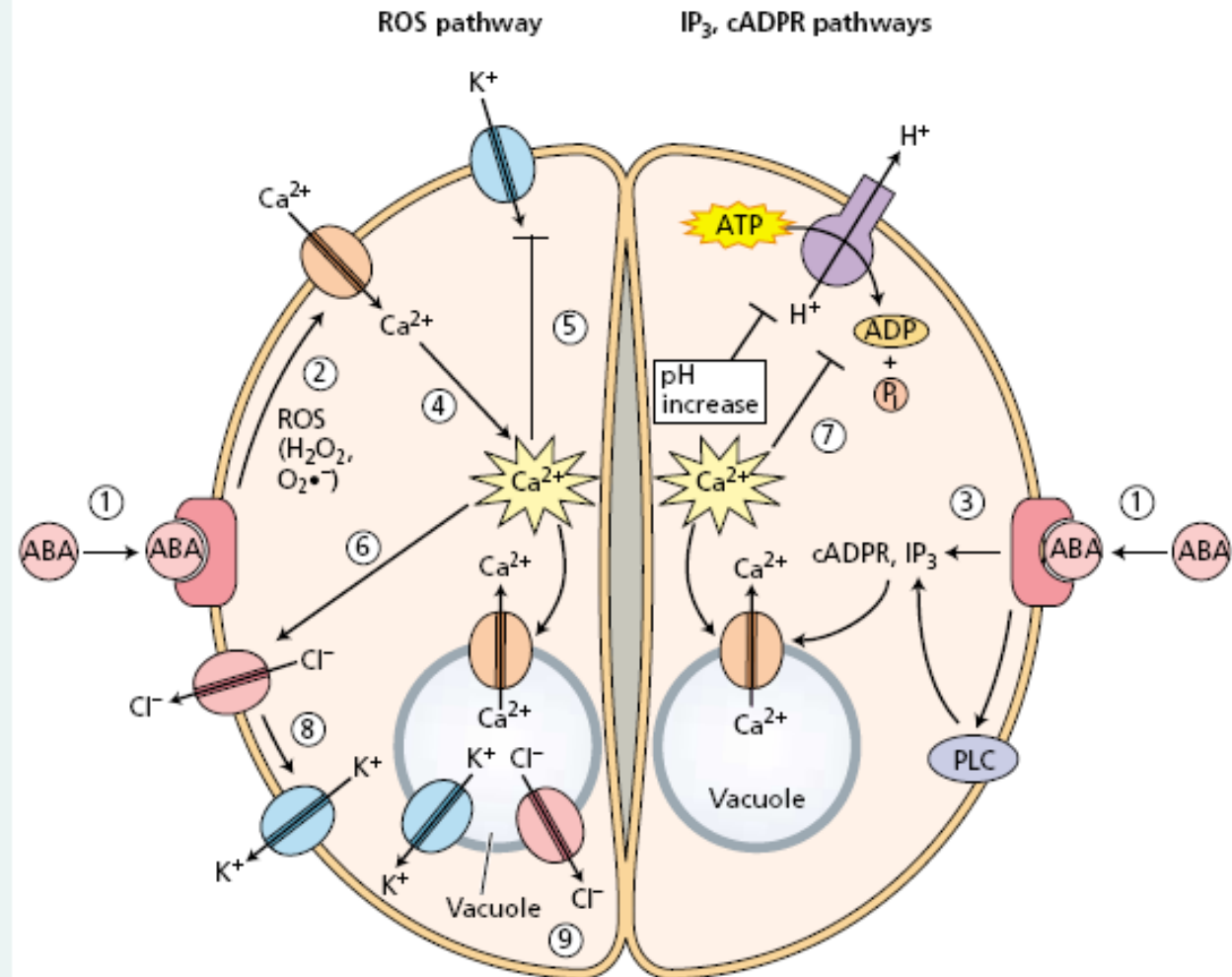
clamp technique; calcium was measured by use of a fluorescent indicator dye. ABA was added to the system at the arrow in each case. (From Schroeder and Hagiwara 1990.)



**FIGURE 23.9** Time course of the ABA-induced increase in guard cell cytosolic  $Ca^{2+}$  concentration (upper panel) and ABA-induced stomatal aperture (lower panel). (From Mansfield and McAinsh 1995.)

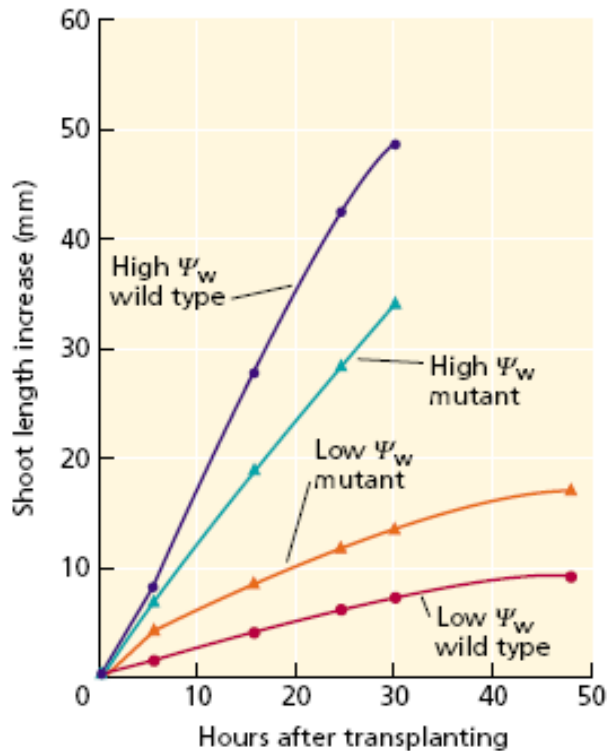


1. ABA binds to its receptors.
2. ABA-binding induces the formation of reactive oxygen species, which activate plasma membrane  $\text{Ca}^{2+}$  channels.
3. ABA increases the levels of cyclic ADP-ribose and  $\text{IP}_3$ , which activate additional calcium channels on the tonoplast.
4. The influx of calcium initiates intracellular calcium oscillations and promotes the further release of calcium from vacuoles.
5. The rise in intracellular calcium blocks  $\text{K}^+$  channels.
6. The rise in intracellular calcium promotes the opening of  $\text{Cl}^-$  channels on the plasma membrane, causing membrane depolarization.
7. The plasma membrane proton pump is inhibited by the ABA-induced increase in cytosolic calcium and a rise in intracellular pH, further depolarizing the membrane.
8. Membrane depolarization activates  $\text{K}^+$  channels.
9.  $\text{K}^+$  and anions to be released across the plasma membrane are first released from vacuoles into the cytosol.

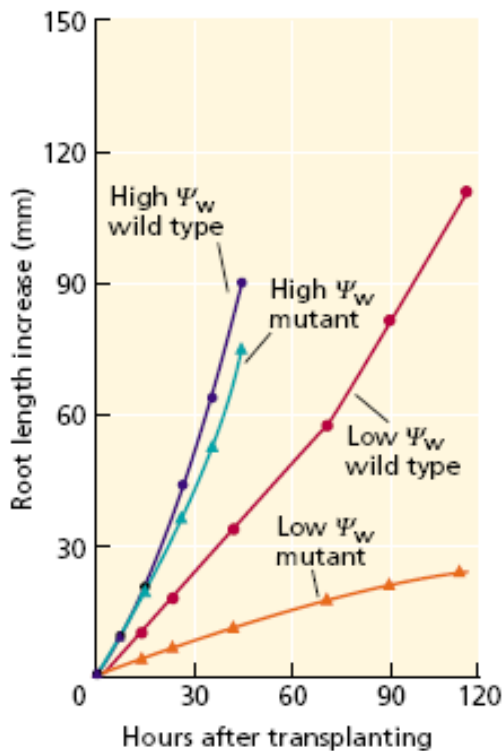


**FIGURE 23.12** Simplified model for ABA signaling in stomatal guard cells. The net effect is the loss of potassium and its anion ( $\text{Cl}^-$  or malate $^{2-}$ ) from the cell. (R = receptor; ROS = reactive oxygen species; cADPR = cyclic ADP-ribose; G-protein = GTP-binding protein; PLC = phospholipase C.)

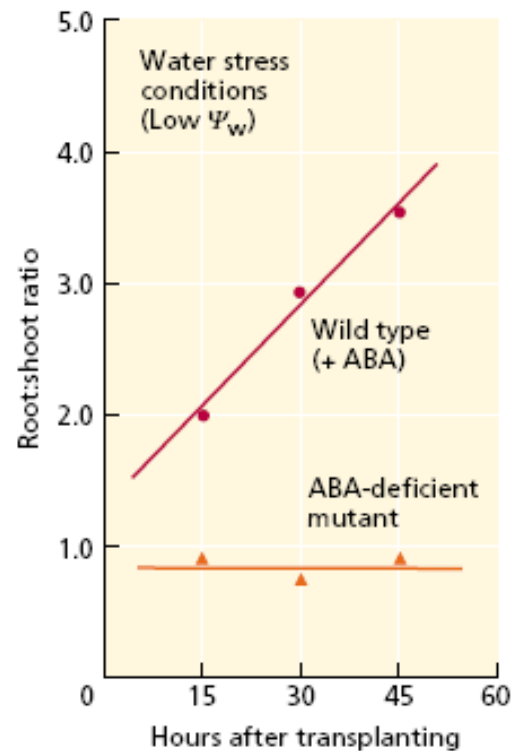
(A) Shoot



(B) Root

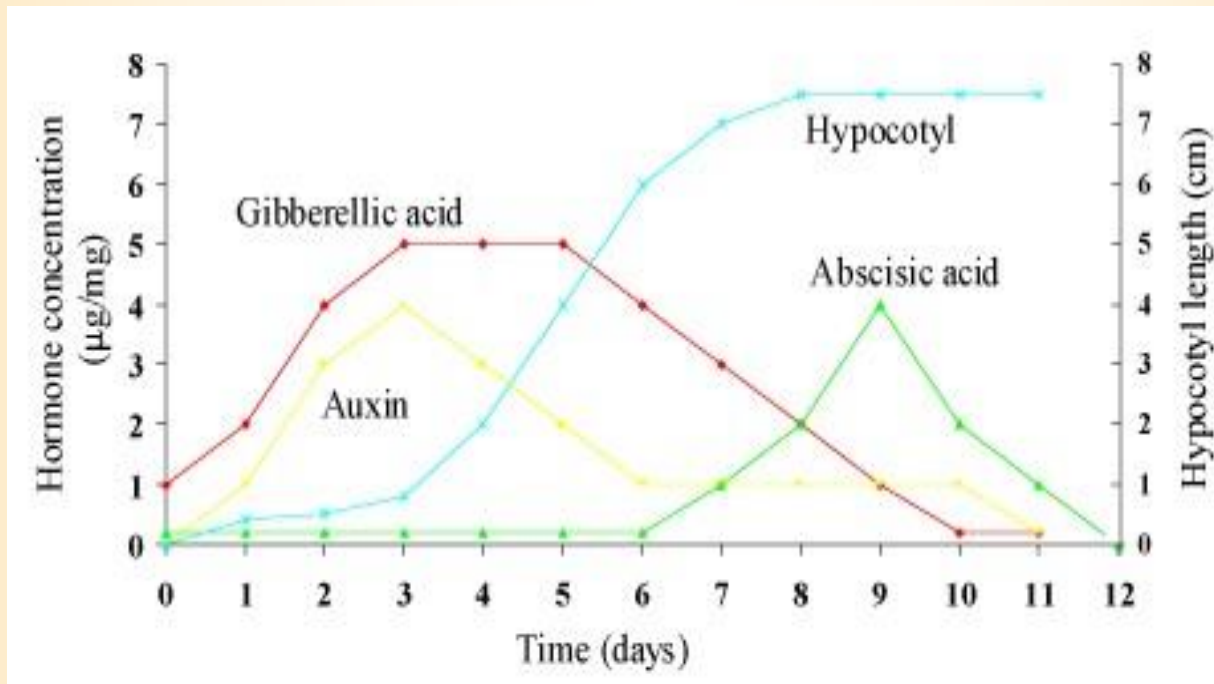


(C) Root:shoot ratio



**FIGURE 23.6** Comparison of the growth of the shoots (A) and roots (B) of normal versus ABA-deficient (viviparous) maize plants growing in vermiculite maintained either at high water potential ( $-0.03$  MPa) or at low water potential ( $-0.3$  MPa in A and  $-1.6$  MPa in B). Water stress (low water potential) depresses the growth of both shoots and roots

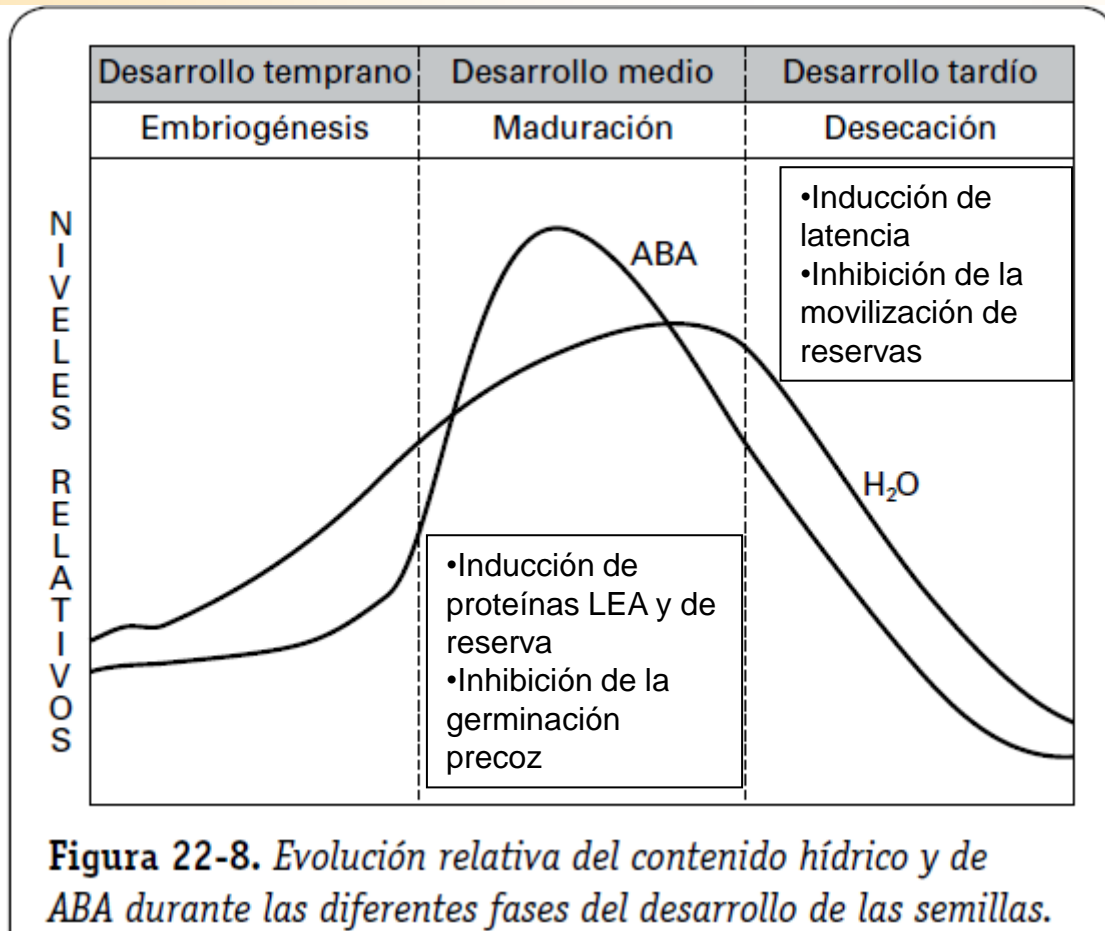
compared to the controls. (C) Note that under water stress conditions (low  $\Psi_w$ ), the ratio of root growth to shoot growth is much higher when ABA is present (i.e., in the wild type) than when it is absent (in the mutant). (From Saab et al. 1990.)



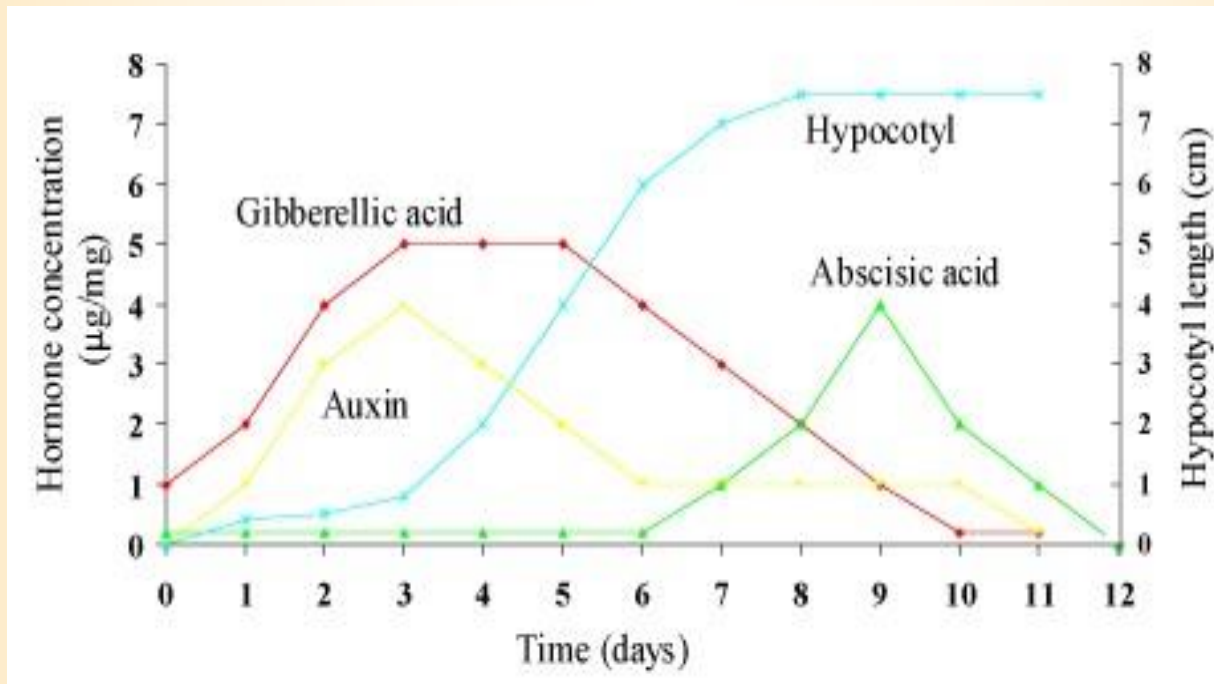
Plant hormones play a role in regulating seed germination. The graph below shows changes in hormone concentrations (left axis) and hypocotyl growth (right axis) over time for mung bean. Which hormone(s) most likely regulates hypocotyl (bean sprout) growth during mung bean germination?



# ABA, Controla el desarrollo embrionario de las semillas.



**El ABA favorece la acumulación de reservas y la tolerancia a la desecación de las semillas.**



Plant hormones play a role in regulating seed germination. The graph below shows changes in hormone concentrations (left axis) and hypocotyl growth (right axis) over time for mung bean. Which hormone(s) most likely regulates hypocotyl (bean sprout) growth during mung bean germination?

Las mutantes de maíz deficientes en ABA (*vp 14*) presentan germinación de las semillas en la planta madre, **viviparismo**.



# ABA accumulates in maturing seeds



Embryonic  
patterning

Reserve  
accumulation

Desiccation  
tolerance

Seed maturation requires ABA synthesis and accumulation of specific proteins to confer desiccation tolerance to the seed.

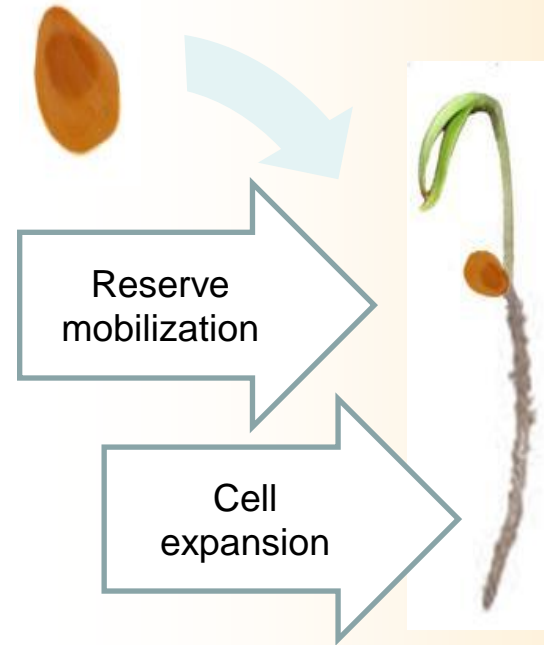
## ABA promueve la dormición de semillas

- Es importante la relación ABA:GAs

ABA inhibe la producción de enzimas hidrolíticas inducida por GAs durante la germinación.

# GA es requerido para la germinación y para la brotación de yemas

Seed germination requires elimination of ABA and production of GA to promote growth and breakdown of seed storage products.



# El ABA se acumula en las yemas durante la dormición

- Es importante la relación de concentraciones entre ABA (inhibidor del crecimiento) y citoquininas y giberelinas (estimuladores del crecimiento).

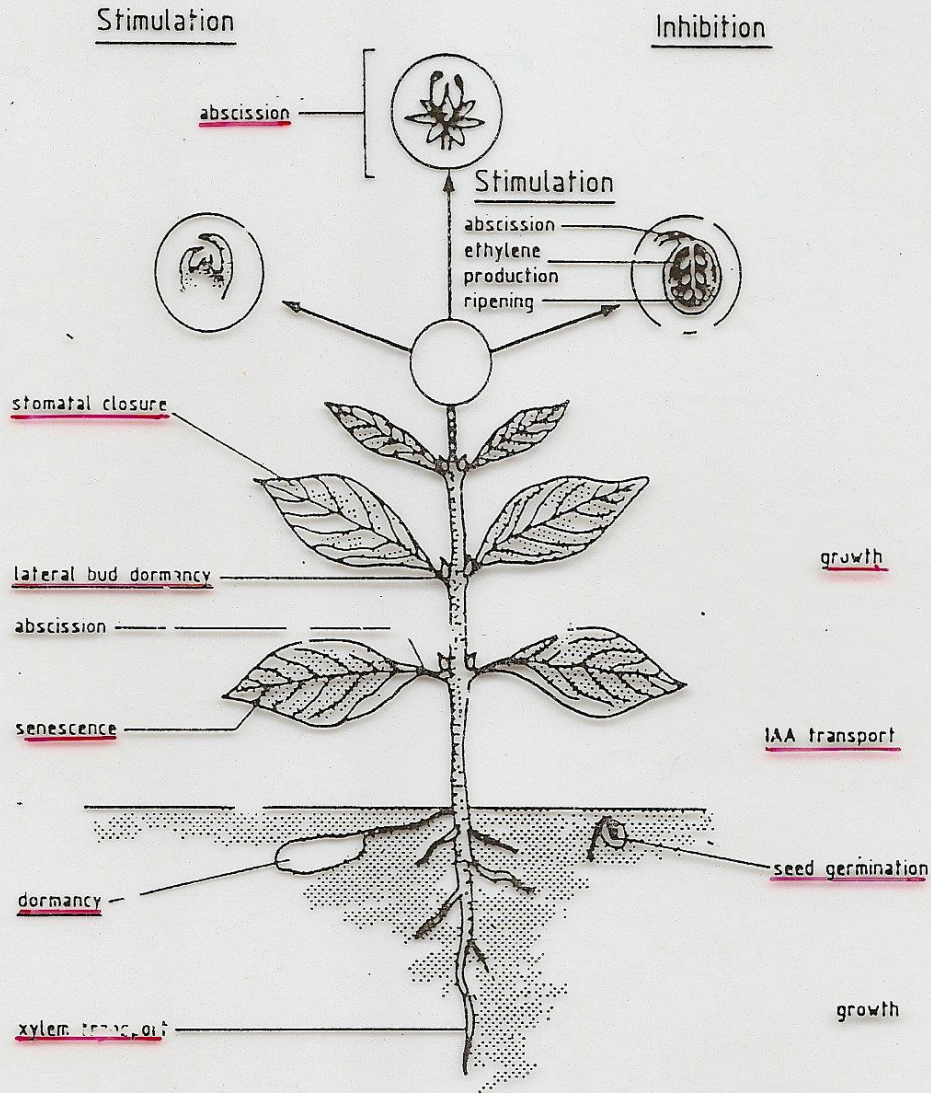




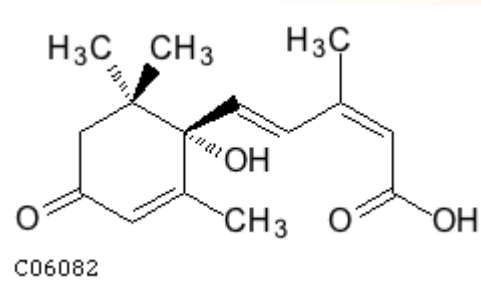
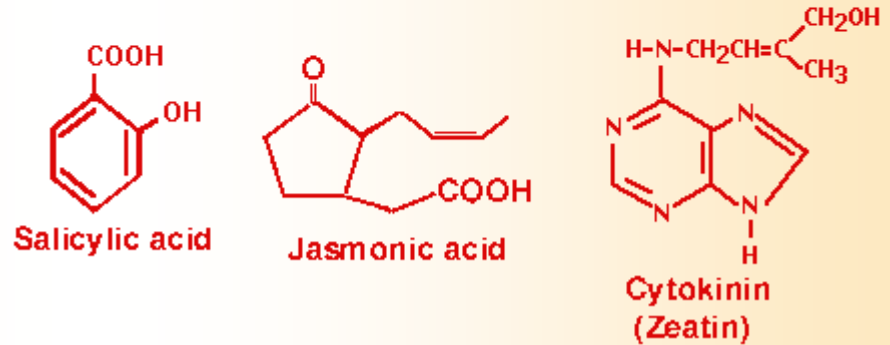
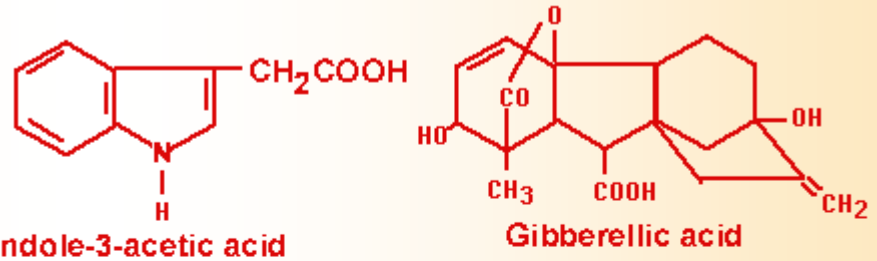
# **Aplicaciones comerciales**

- **El ABA no es utilizado comercialmente en agricultura.**
- **Sí otros inhibidores del crecimiento:**
- **Cl IPC y IPC para la dormición de yemas de tubérculos de papa**
- **Inhibidores de la síntesis de AG3**  
**CCC, ALAR, AMO 1618, Phosphon D,**  
**Ancymidol, Paclobutrazol, Tetcyclasis.**  
**BX 112, LAB 198999.**

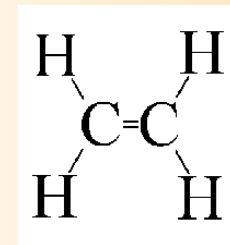
# ABSCISIC ACID (ABA)



- ✓ Auxinas
- ✓ Giberelinas
- ✓ Citocininas
- ✓ Ácido abscísico
- ✓ Etileno
- ✓ Ácido jasmónico
- ✓ Ácido salicílico
- ✓ Brasinosteroides
- ✓ Strigolactonas
- ✓ Poliaminas

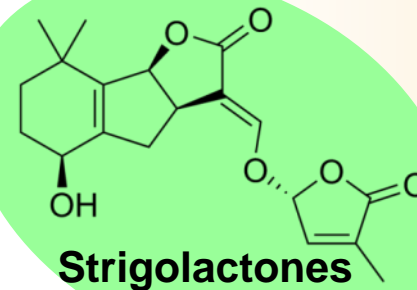
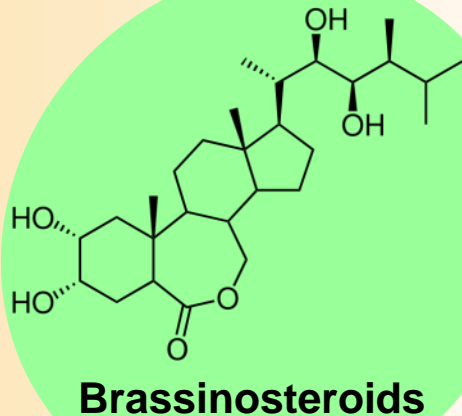
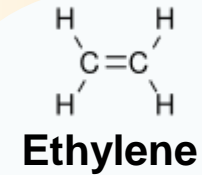
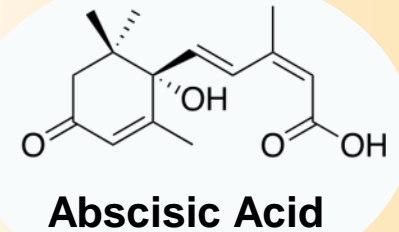
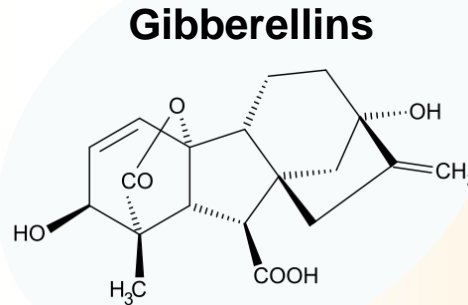
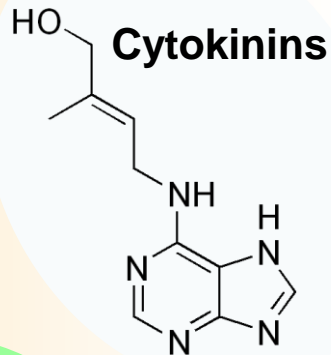
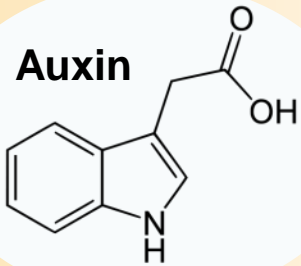


Ácido abscísico



Etileno

# Phytohormones – old timers and newcomers



## ACCION FISIOLOGICA DE OTRAS SUSTANCIAS CON ACCION HORMONAL.

### 1. Acido Jasmónico.

- 1.1. - Promueve la senescencia.
- 1.2. - Promueve la degradación de la clorofila.
- 1.3. - Inhibe la germinación de semillas.
- 1.4. - Induce la espiras en los zarcillos.
- 1.5. - Induce la formación de tubérculos.

### 2. Acido Salicílico.

- 2.1. - Desencadena la respiración insensible al cianuro en especies termogénicas.
- 2.2. - Inducción de la floración en numerosas especies.
- 2.3. - Induce resistencia a patógenos.

### 3. Poliaminas.

- 3.1. - Promueve la división celular.
- 3.2. - Embriogénesis.
- 3.3. - Inducen tolerancia a estreses.

# Jasmonatos



Están representados por el ácido jasmónico (JA) y su metilester el **metil-jasmonato** ( MeJA).

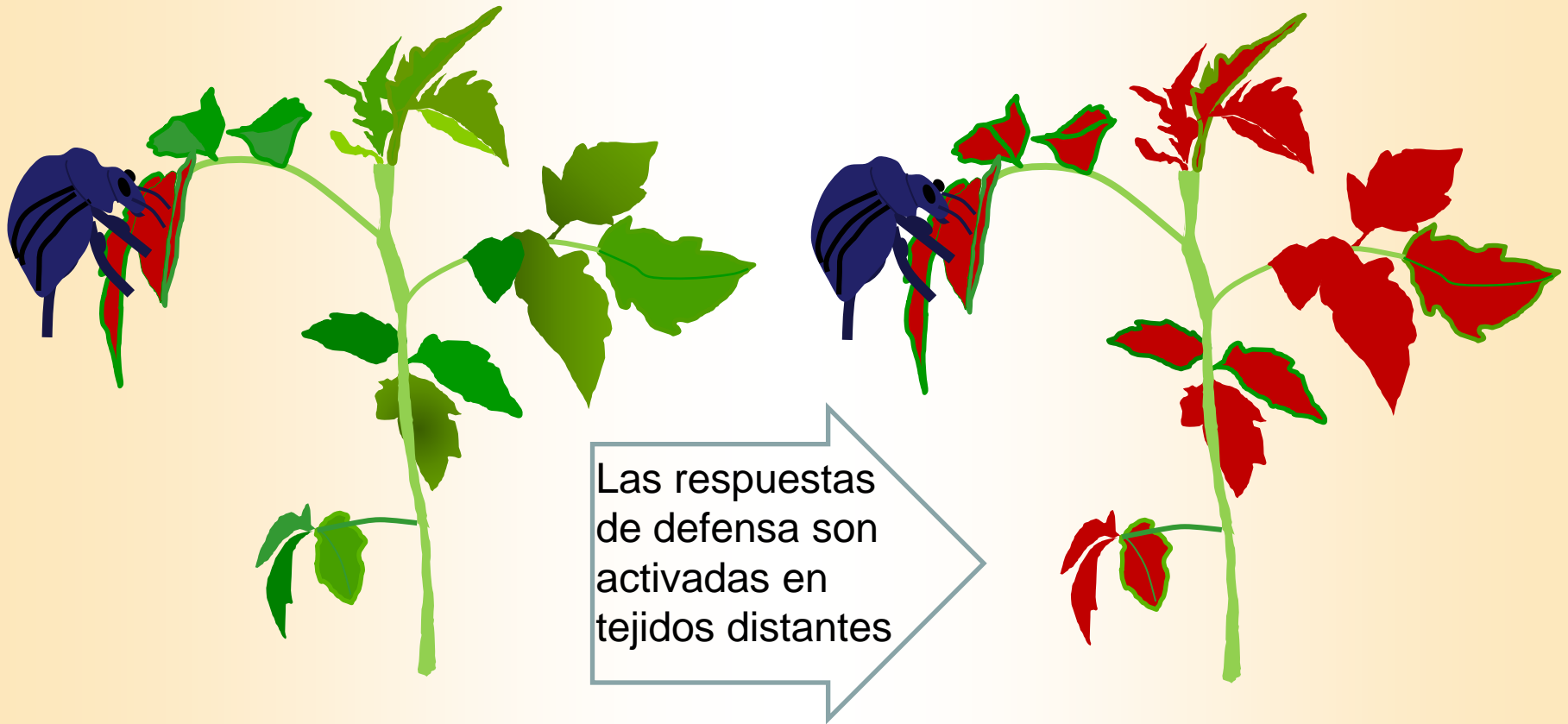
Fueron aislados inicialmente de las flores del Jazmín (*Jasminum* sp.), del cual se extrae el metil ester, un importante producto en la industria de perfumes.

# *Biosíntesis*

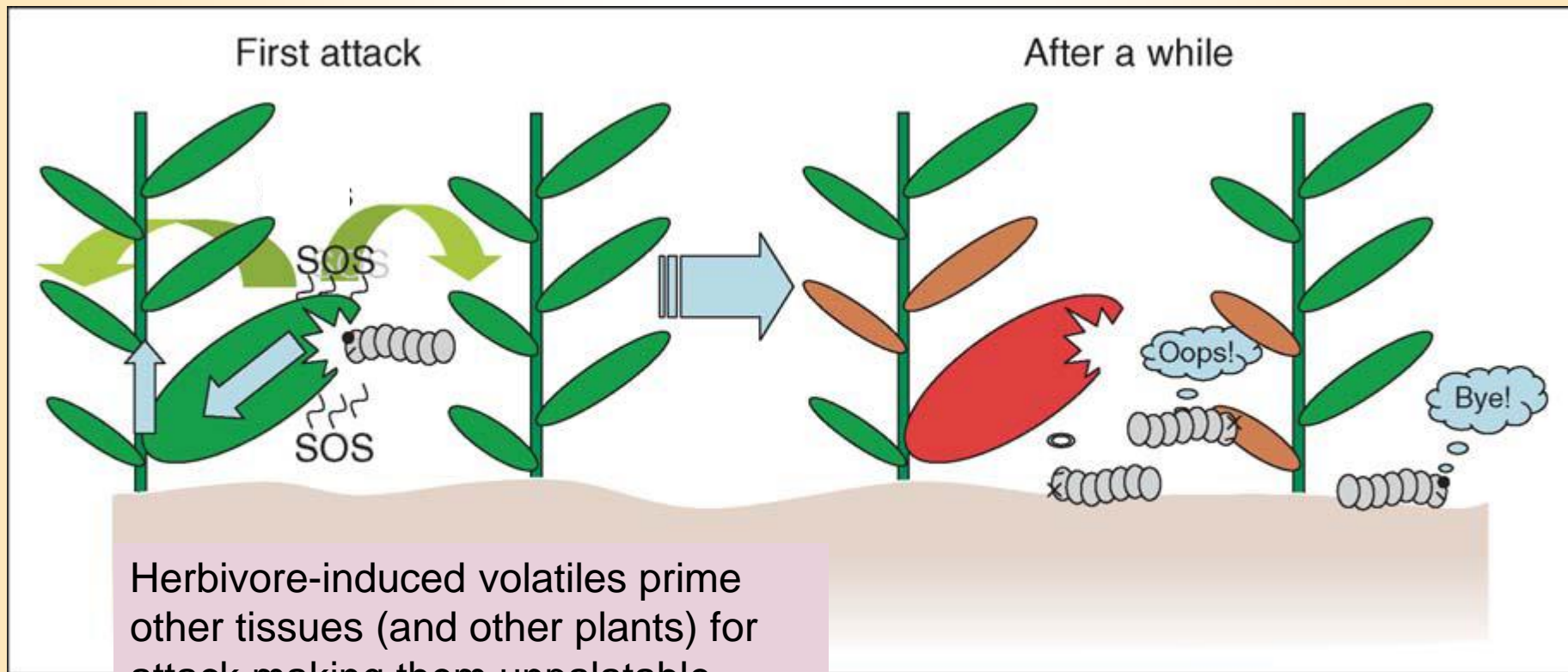
El ácido jasmónico (JA) es sintetizado a partir del ácido linoléico, un importante ácido graso, a través de la degradación oxidativa y formación de un anillo de ciclopentano.



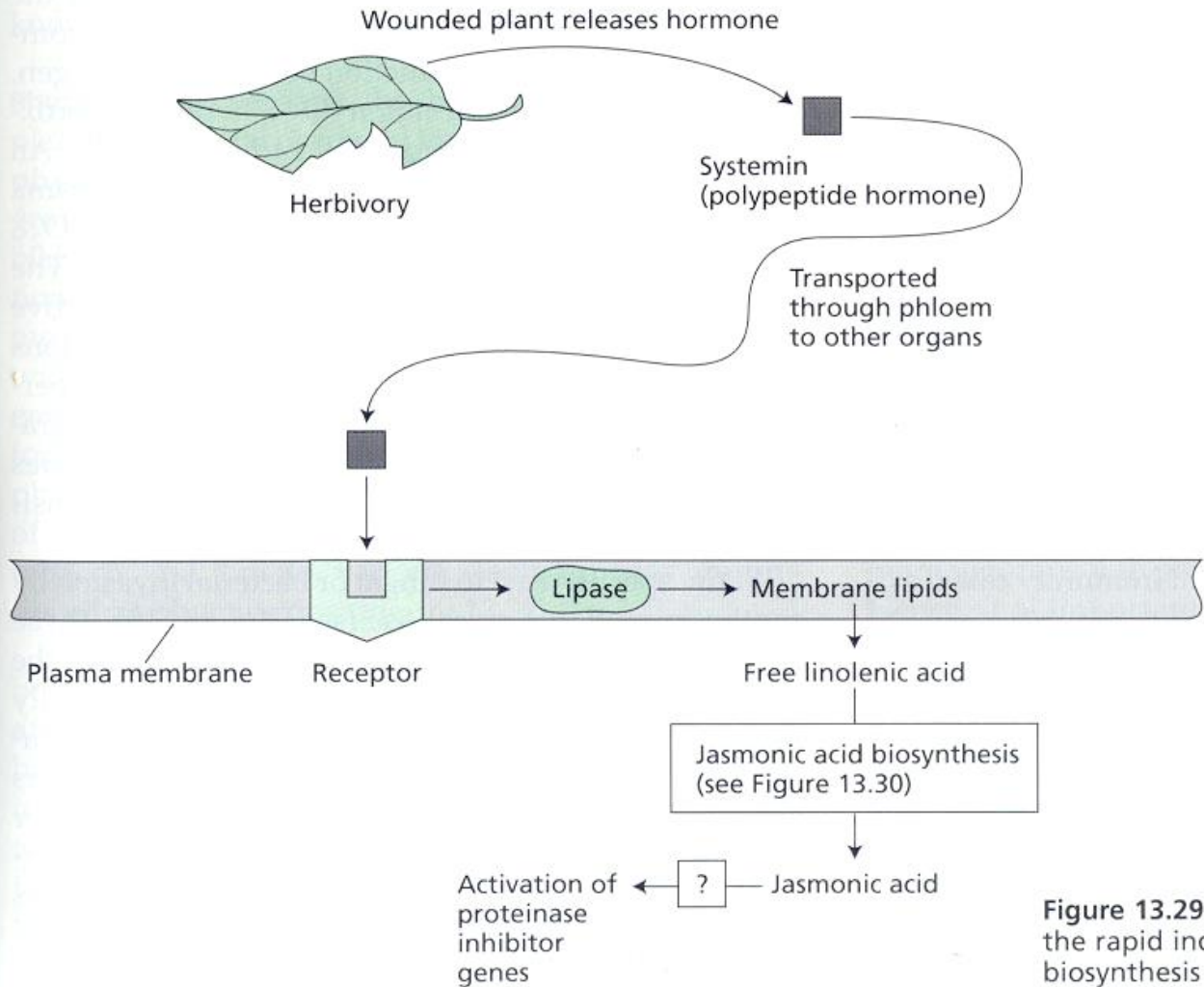
# Jasmonatos, participan en las respuestas sistémicas de defensa



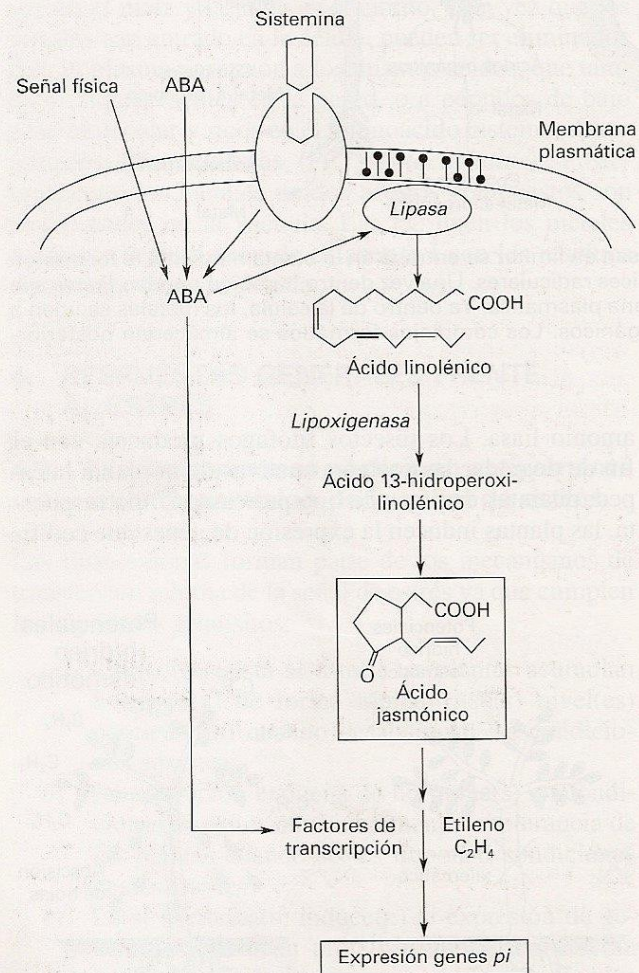
# Jasmonatos, estimulan la producción de compuestos volátiles de señalización



Herbivore-induced volatiles prime other tissues (and other plants) for attack making them unpalatable (indicated in red).



**Figure 13.29** Proposed signaling pathway for the rapid induction of proteinase inhibitor biosynthesis in wounded tomato plants.

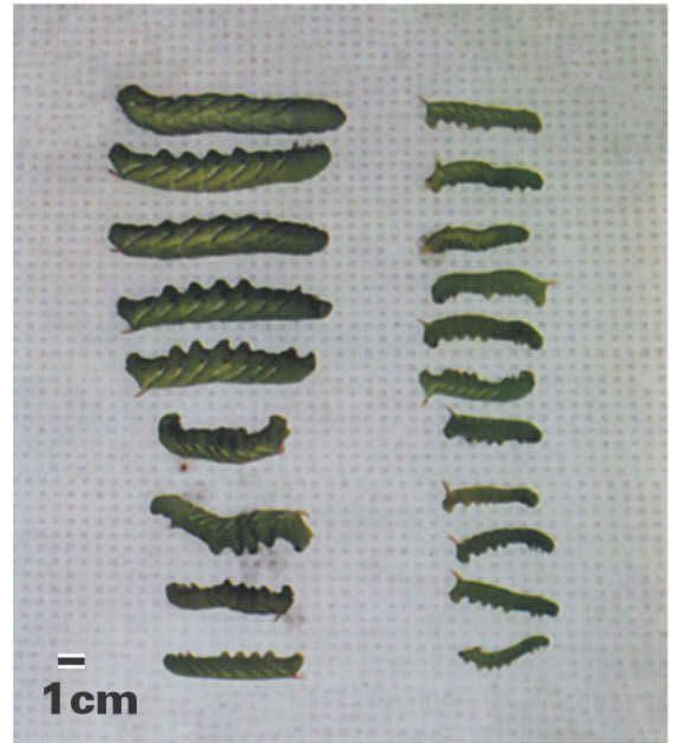


**Figura 30-7.** La inducción de la expresión de los genes que codifican los inhibidores de proteasas (genes *pi*) comienza con la acumulación de ácido abscísico (ABA) en la célula, procedente de otras zonas de la hoja atacadas por los insectos o estimulado por señales físicas o por la unión de la sistemina a un receptor del plasmalema. El ABA estimula entonces la actividad de una lipasa que libera ácido linolénico de los glicerolípidos del plasmalema, el cual se transforma en ácido jasmónico a través de la ruta de los ácidos octadecanoicos, por la acción secuencial de varias enzimas. El ataque de insectos induce la expresión de un gen que codifica la lipoxigenasa, la primera enzima de la ruta. El ácido jasmónico, actuando en coordinación con el ABA y el etileno, induce la expresión de los genes *pi* y la acumulación de inhibidores de proteasas.

(A)



(B)



# *Efectos fisiológicos*

- Participan en respuestas a herbívoros y hongos
- Los jasmonatos inhiben muchos procesos como el la germinación y crecimiento
- En forma similar al ácido abscísico promueven:
  - la senescencia,
  - la abscisión,
  - la formación de tubérculos,
  - la maduración de frutos y
  - la formación de pigmentos.

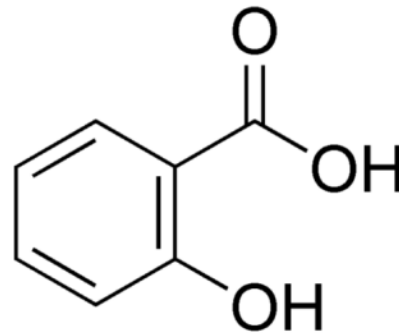
# Salicilatos

**Los salicilatos se conocieron primeramente como compuestos presentes en los sauces (*Salix* spp; Salicaceae).**



# Acido salicílico – hormona vegetal y analgésico

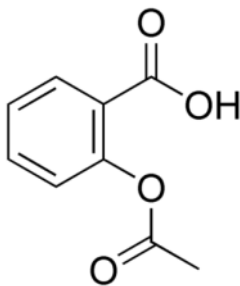
- Response to biotrophic pathogens
- Induced defense response
- Systemic acquired resistance



**Salicylic Acid**



Salicylic acid is named for the willow *Salix* whose analgesic properties were known long before the chemical was isolated.

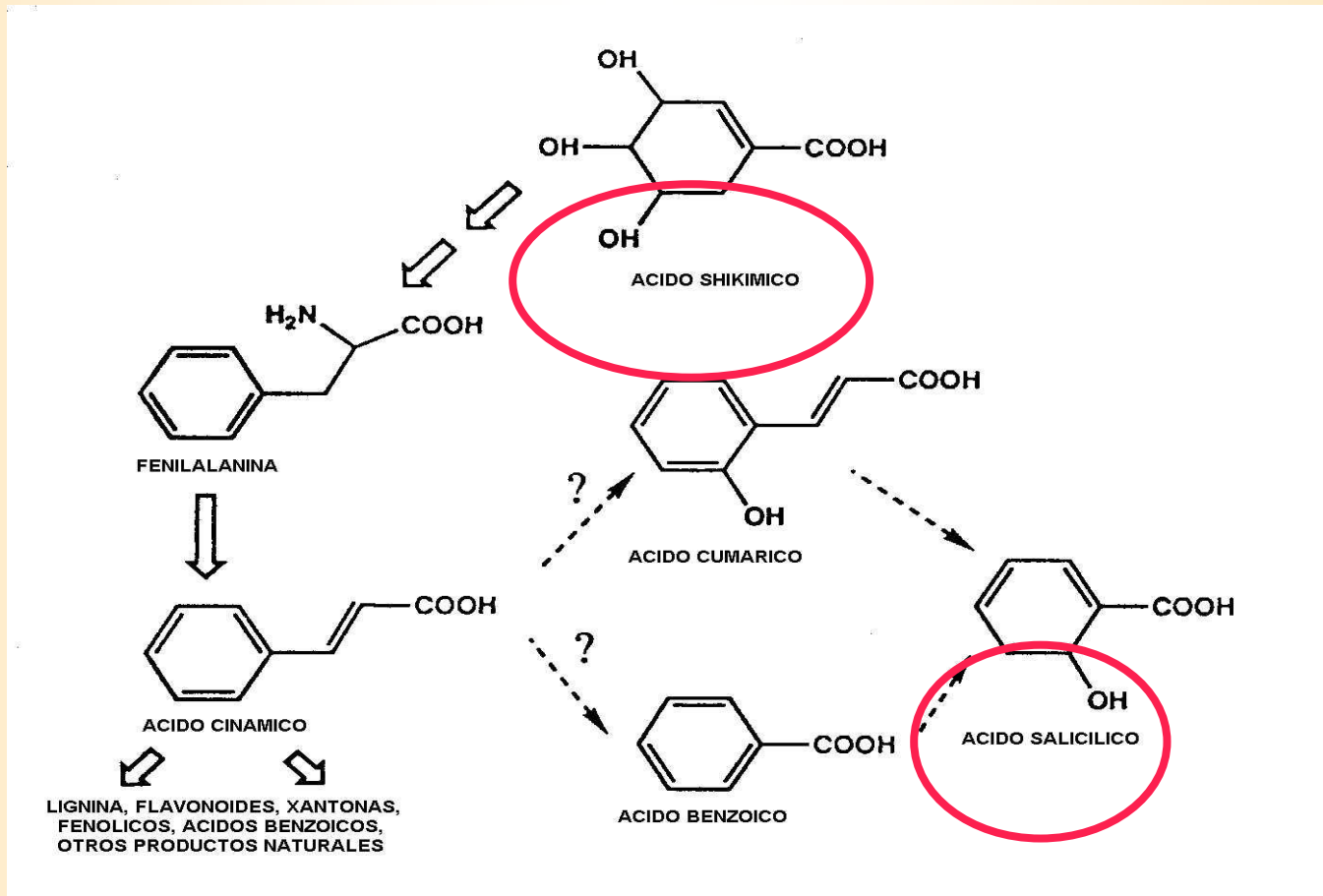


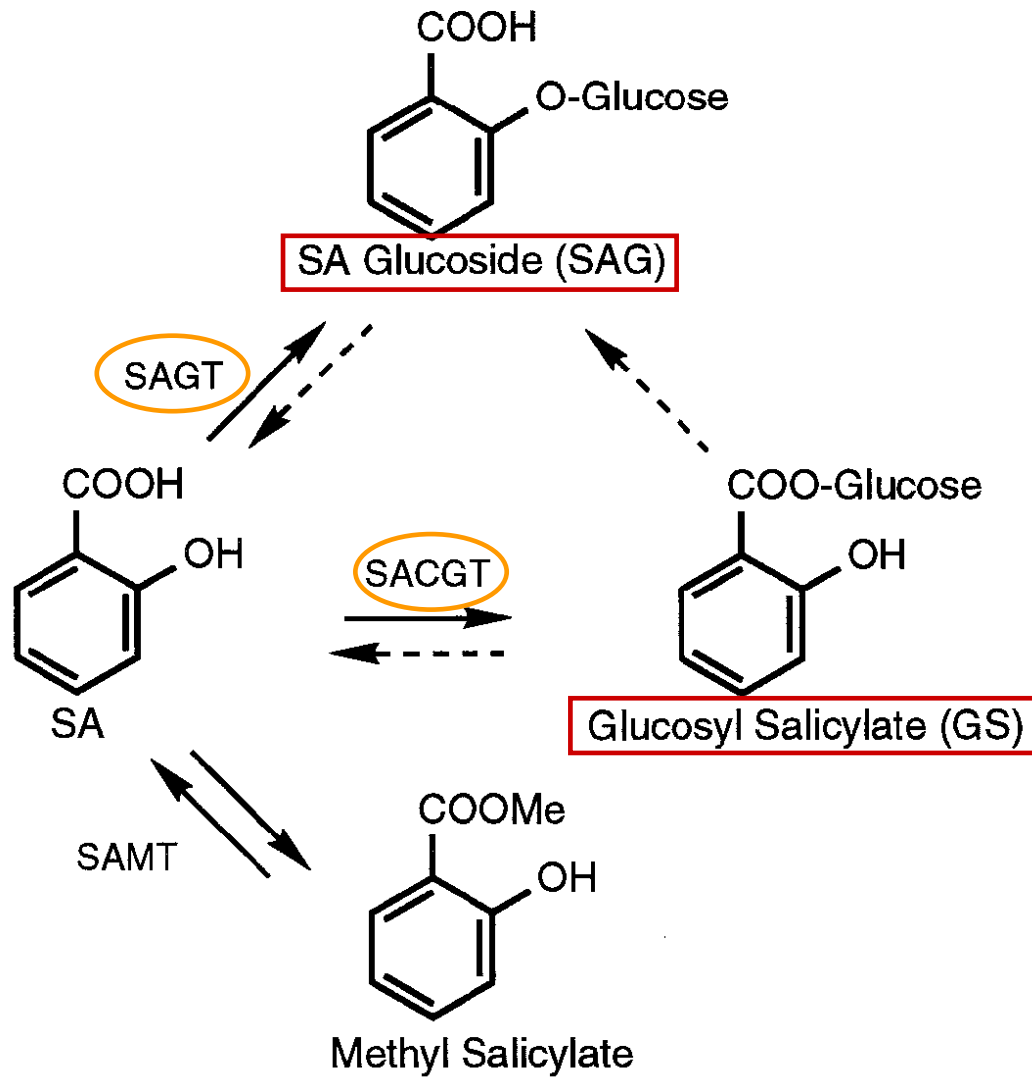
**Acetylsalicylic Acid - aspirin**



# Biosíntesis

El ácido salicílico es sintetizado a partir del aminoácido fenilalanina.





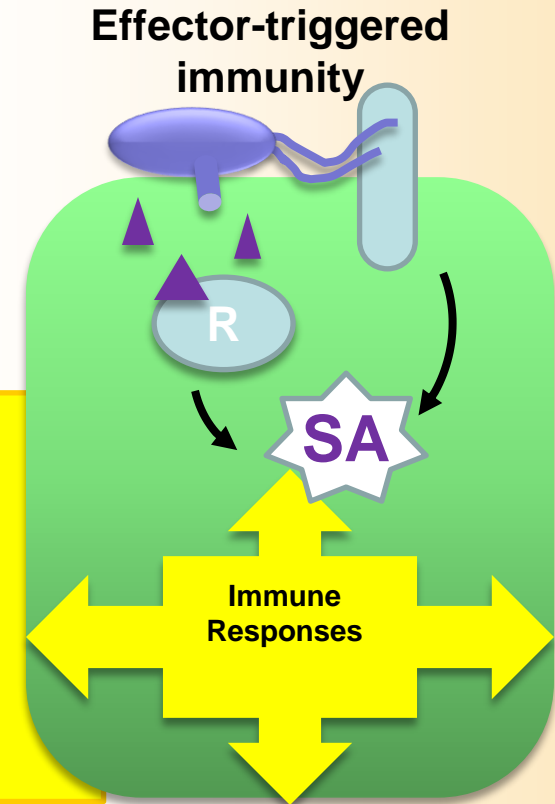
## Acido Salicílico

- Retarda la senescencia
- Regulación de termogénesis
- Respuesta hipersensible
- Resistencia sistémica adquirida

# La respuesta hipersensible involucra muerte celular

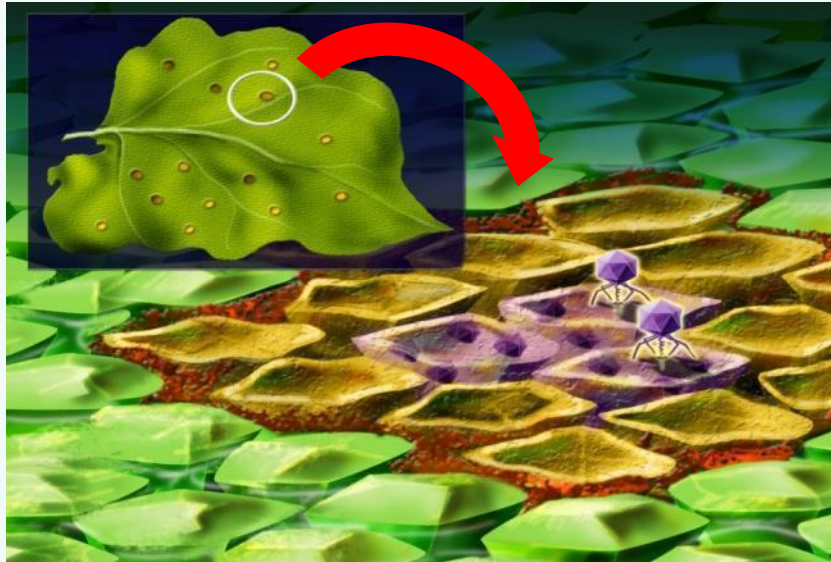


Pathogen Response (PR) genes  
Antimicrobial compounds  
Strengthening of plant cell walls  
Programmed cell death  
Hypersensitive response (HR)

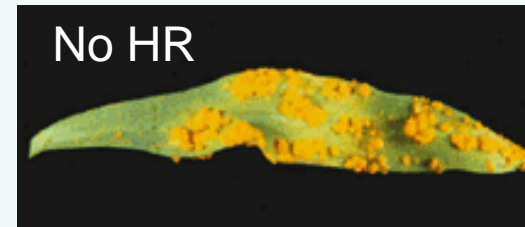


From Cawly, J., Cole, A.B., Király, L., Qiu, W., and Schoelz, J.E. (2005) The plant gene *CCD1* selectively blocks cell death during the hypersensitive response to cauliflower mosaic virus infection. *MPMI* 18: [212-219](#); Redrawn from Pieterse, C.M.J, Leon-Reyes, A., Van der Ent, S., and Saskia C M Van Wees, S.C.M. (2009) *Nat. Chem. Biol.* 5: [308–316](#).

# The hypersensitive response seals the pathogen in a tomb of dead cells

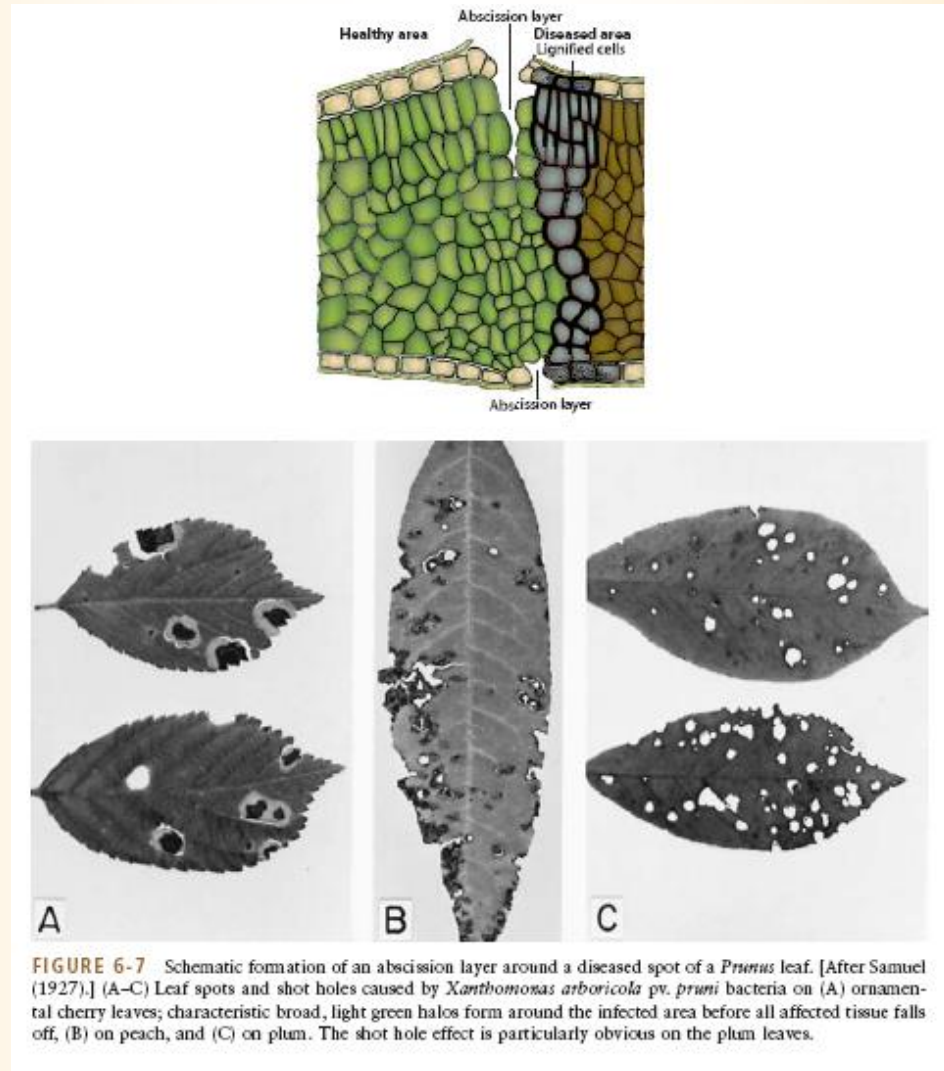


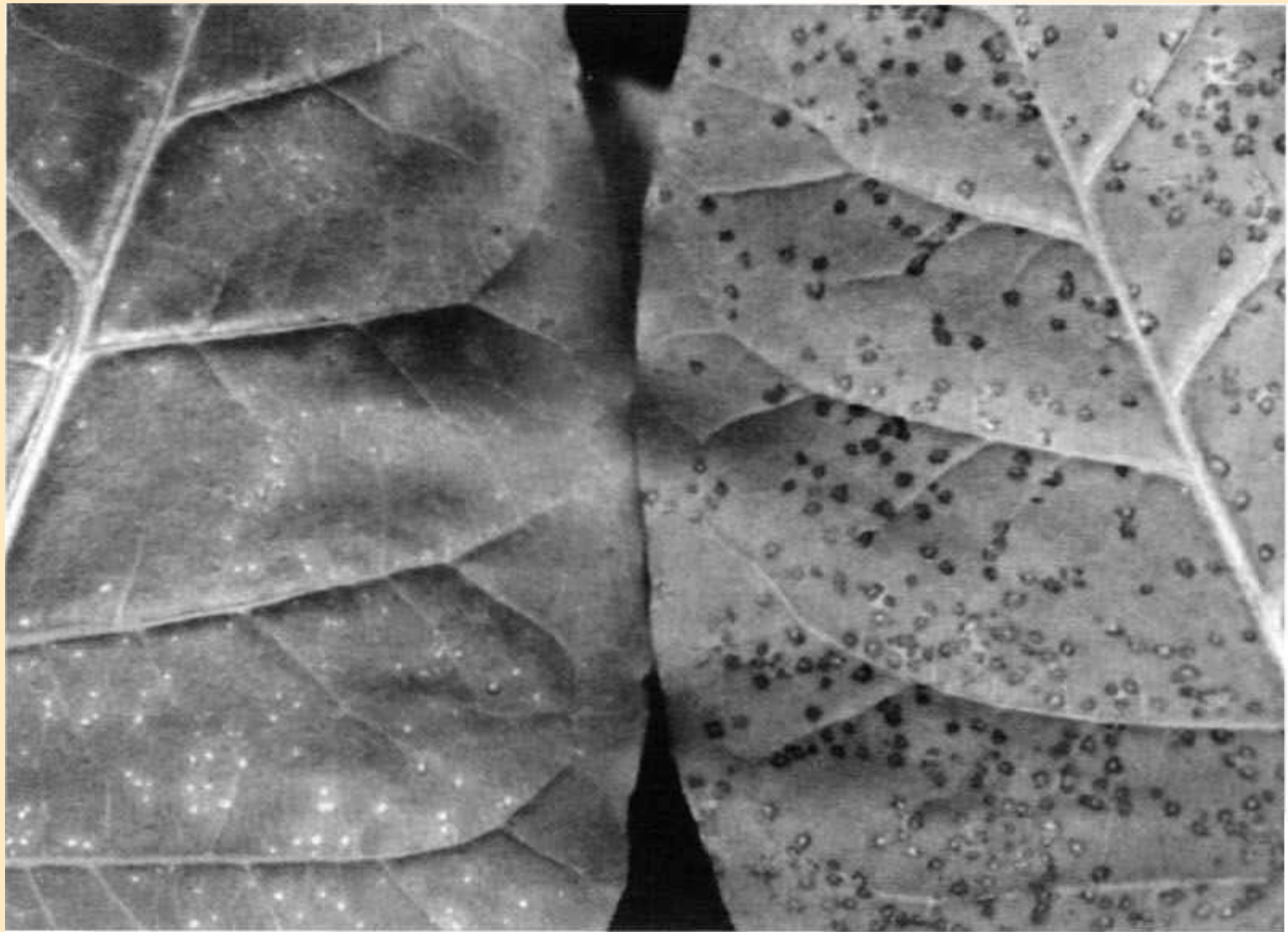
The HR kills the infected cells and cells surrounding them and prevents the pathogen from spreading.



Without a hypersensitive response, the pathogen can multiply.

# Formación de capa de abscisión





## REGULADORES VEGETALES

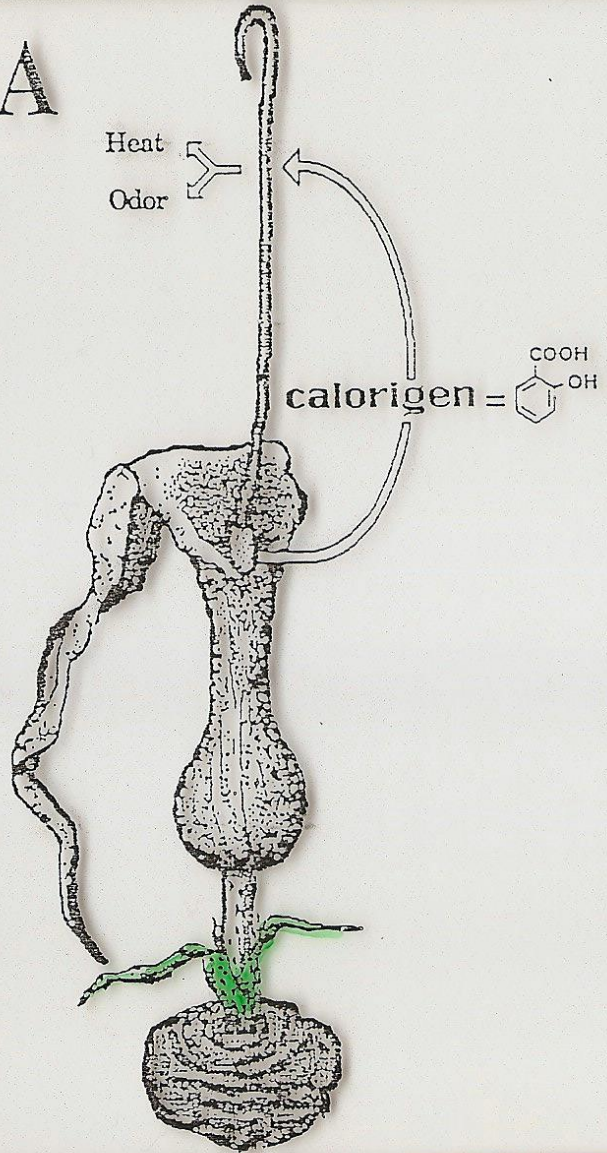
ACIDO SALICILICO (ácido 2-hidroxibenzoico).  
Ingrediente de aspirina.

Efectos fisiológicos:

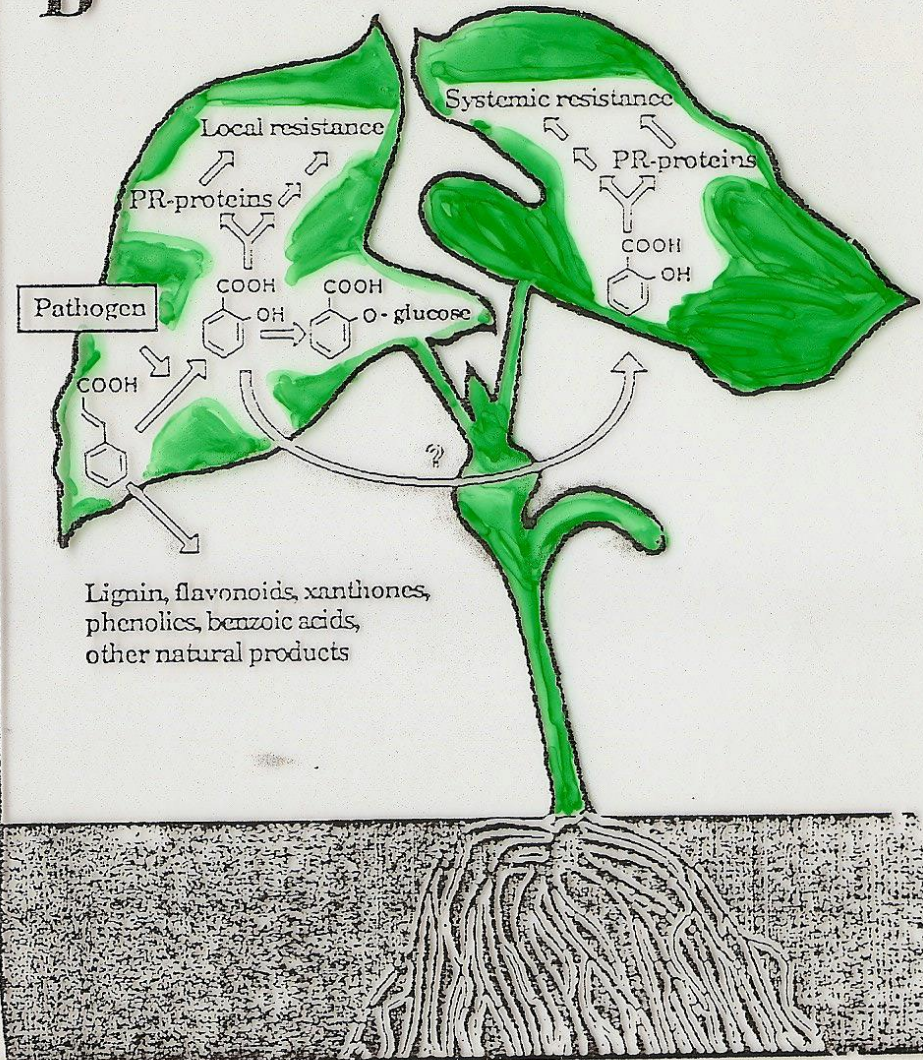
- producción termogénica en inflorescencias (espata) de *Arum lilies*. El ác. Salicílico se produce en flores estaminadas y luego se traslada.
- producción de aromas en inflorescencias (espata) de *Arum lilies*.
- Se relaciona con la respiración insensible al cianuro. Aumento de temperatura y aromas muy volátiles, para atraer a los insectos polinizadores.
- Promoción de resistencia a ciertos patógenos, incluyendo virus del tabaco y hongos patógenos. Síntesis de proteínas relacionadas a la patogenia, que incrementa la resistencia de hojas atacadas y hojas vecinas.

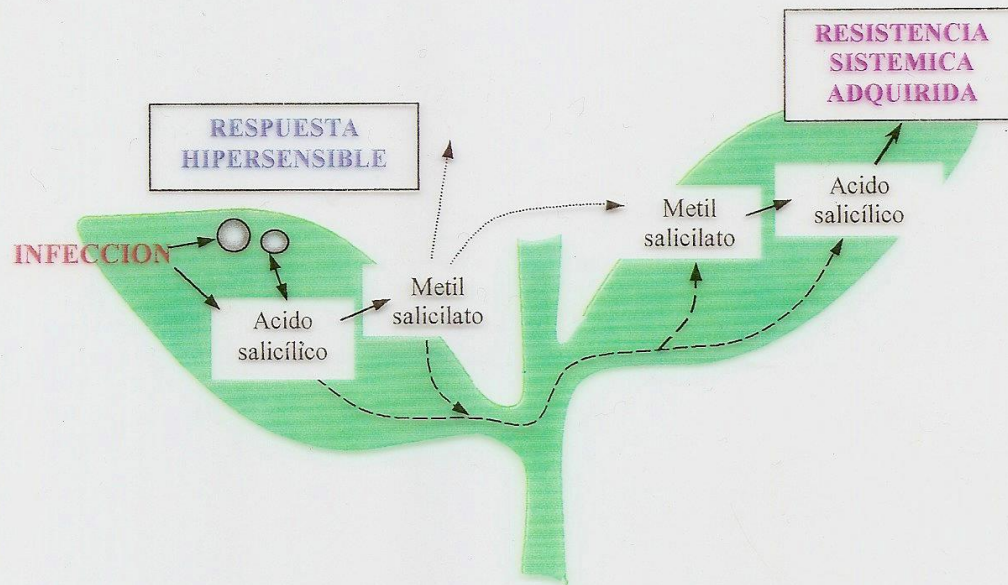


A



B



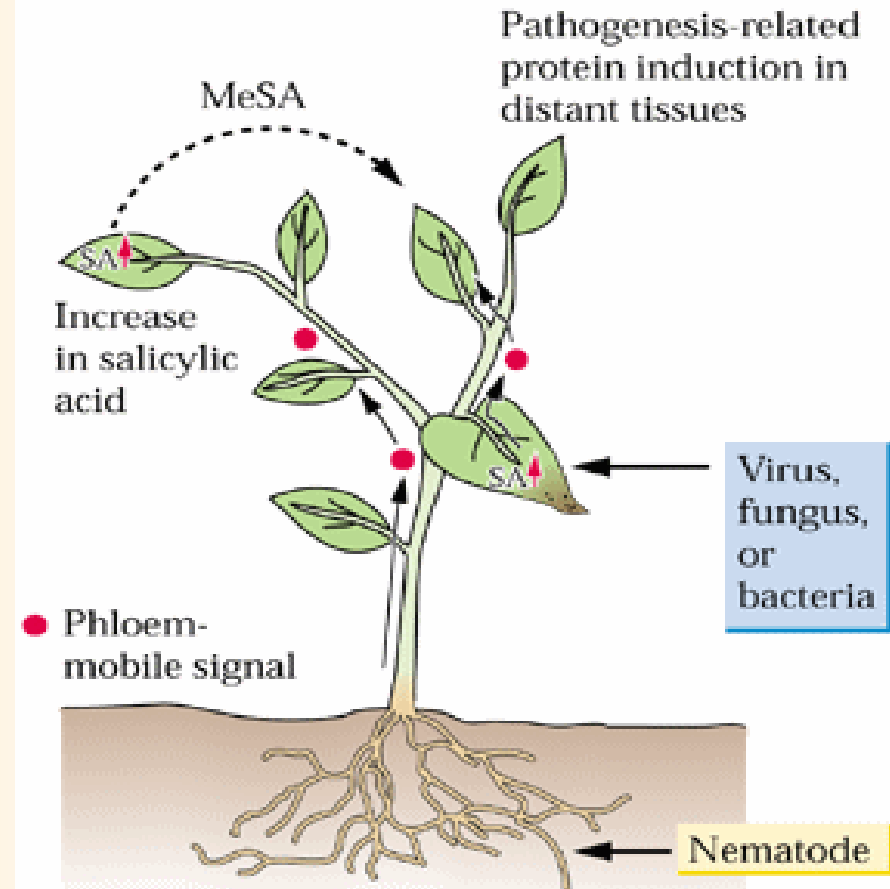


Respuesta de defensa a una infección patógena.

La infección de patógenos a plantas resistentes resulta generalmente en una respuesta hipersensible (la formación de lesiones necróticas y un restringido crecimiento y dispersión del patógeno). Una variedad de respuestas de defensa se inducen localmente alrededor de los sitios de infección: aumento en las especies reactivas del oxígeno, inducción de genes de proteínas patogénicas relacionadas (PR), peroxidasas y enzimas involucradas en el ablandamiento de la pared celular y biosíntesis de fitoalexinas. Algunos de estos genes también son activados sistémicamente, y se cree que juegan un rol importante en el desarrollo de la resistencia sistémica adquirida (RSA). La síntesis y acumulación de ácido salicílico parece ser necesaria para la activación de muchas de estas respuestas, tanto localmente como sistémicamente. Aun no se conoce bien como se produce la señal a distancia del ácido salicílico en la RSA. Se ha demostrado que el metil salicilato, derivado del metabolismo del ac. Salicílico, puede actuar como una señal aérea que activaría los mecanismos de defensa en las hojas distantes y aún en las plantas vecinas. Pero a temperatura ambiente es líquido y se trasladaría por el sistema vascular, como el ac. salicílico.

# Resistencia sistémica adquirida

## (A) Systemic acquired resistance



# ***Efectos fisiológicos***



- Termogénesis (ácido salicílico como fitohormona Calorígeno) en flores de Arum o Voodoo-lilie (*Sauromatum guttatum*), Araceae.
- Estimula la resistencia a patógenos a través de la producción de proteínas patogénicas y lignina en plantas (inductor natural de la resistencia).
- El metil salicilato (MeSA) es el mayor metabolito volátil del ácido salicílico producido por partes de plantas inoculadas con patógenos.
- Puede funcionar como una señal aérea que activa la resistencia a enfermedades en las plantas vecinas y en tejidos saludables de las plantas infectadas.
- Resistencia sistémica adquirida. Produce proteínas de protección y principalmente lignina.

## REGULADORES VEGETALES

### TRIACONTANOL.

Compuesto con estructura alcohólica, aislado de tallos de alfalfa.

Muy insoluble en agua a concentraciones de  $2 \cdot 10^{-16} \text{ M}$  o de  $9 \cdot 10^{-14} \text{ g L}^{-1}$ .

Promueve el crecimiento de planta entera de maíz, tomate, arroz, etc. cuando se pulveriza sobre las plántulas a concentraciones de muy bajas, tal como 0.1 nanogramo por litro.

Las respuestas son rápidas. En maíz y arroz se registran respuestas de crecimiento en 10 minutos luego de aplicar.

No se conoce con precisión el mecanismo de acción.

Potencial mejorador del rendimiento de los cultivos.

- Participa en:
  - prolongar la longevidad de las flores
  - inhibir biosíntesis de etileno
  - inducir germinación de la semilla
  - respuesta ante problemas mecánicos
  - revertir los efectos del ácido abscísico
  - Apertura estomática. Transpiración y fotosíntesis
  - Cambios en la anatomía de la hoja
  - Estructuración de cloroplastos
  - Resistencia a patógenos (virus del tabaco)

# Brasinosteroides

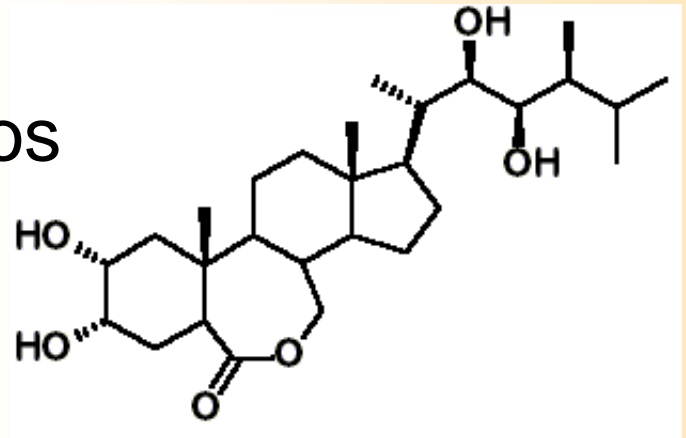
- Esteroides derivados de la brassina,
- son promotores del crecimiento.
- Aislados a partir del polen de colza (*Brassica napus*).
- Incrementan la sensibilidad a auxinas
- Localización: semillas, frutos, brotes, hojas , yemas florales, agallas y polen.



# Brasinoesteroides

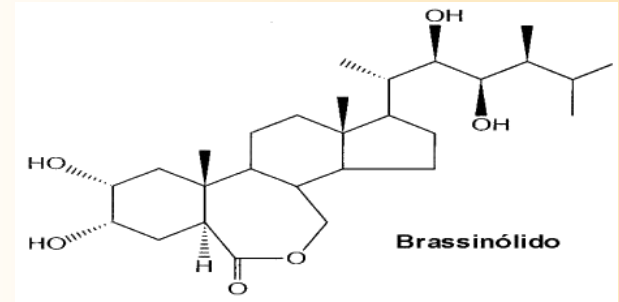
Participan en:

- División celular
- Elongación de raíces y tallos
- Fotomorfogénesis
- Senescencia
- Respuestas al estrés
- Promueven germinación en respuesta a la luz
- Promueven floración en respuesta a la longitud del día





# ***Estructura***



Los brasinoesteroides naturales son denotados por un sufijo numérico secuencial, Br1 denota brasinólido, otros siguen la secuencia Br2, ....Brn.

Son poli-hidroxi-esteroides de 27, 28 o 29 átomos de carbono

Las variaciones en los brasinoesteroides resultan de substituciones simples en los anillos A/B y las cadenas laterales creadas cuando ocurre la oxidación o reducción durante la biosíntesis.

Existen aproximadamente 60 brasinoesteroides naturales

# *Efecto en tabaco*

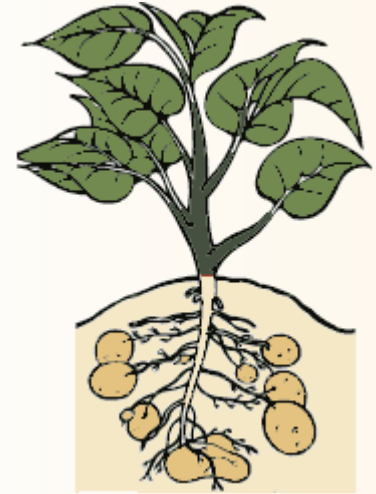
<i>Trats</i>	<i>Peso de raíces (g)</i>	<i>Área foliar de la planta (cm<sup>2</sup>)</i>	<i>Cont de nicotina (%)</i>
<b>Control</b>	<b>14.0</b>	<b>6750</b>	<b>1.4</b>
<b>0.01 ppm</b>	<b>26.8</b>	<b>8140</b>	<b>2.5</b>
<b>0.05 ppm</b>	<b>20.6</b>	<b>7398</b>	<b>2.0</b>
<b>1.00 ppm</b>	<b>16.3</b>	<b>6810</b>	<b>2.1</b>



***Efecto de la 24 Epibrasinólida en el rendimiento y calidad del tabaco***

# ***Efecto en papa***

❖ **Incrementan los rendimientos de las cosechas entre un 13 y un 34% según el momento de aplicación.**



❖ **Disminuyen la brotación prematura de los tubérculos**

❖ **Protegen al cultivo de afectaciones producidas por estrés biótico y abiótico.**

# Poliaminas

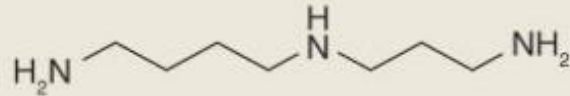
- Diferenciación y división celular
- Embriogénesis
- Desarrollo floral
- Maduración de frutos
- Formación de raíces
- Tolerancia a estrés abiótico
- Formación de tubérculos

# Poliaminas

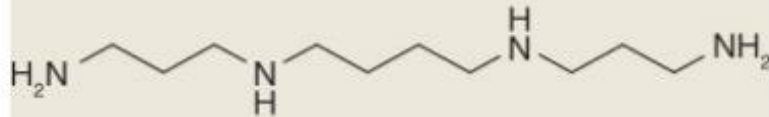
## Estructura química



Putrescine



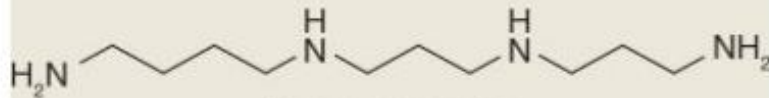
Spermidine



Spermine



Cadaverine



Thermospermine

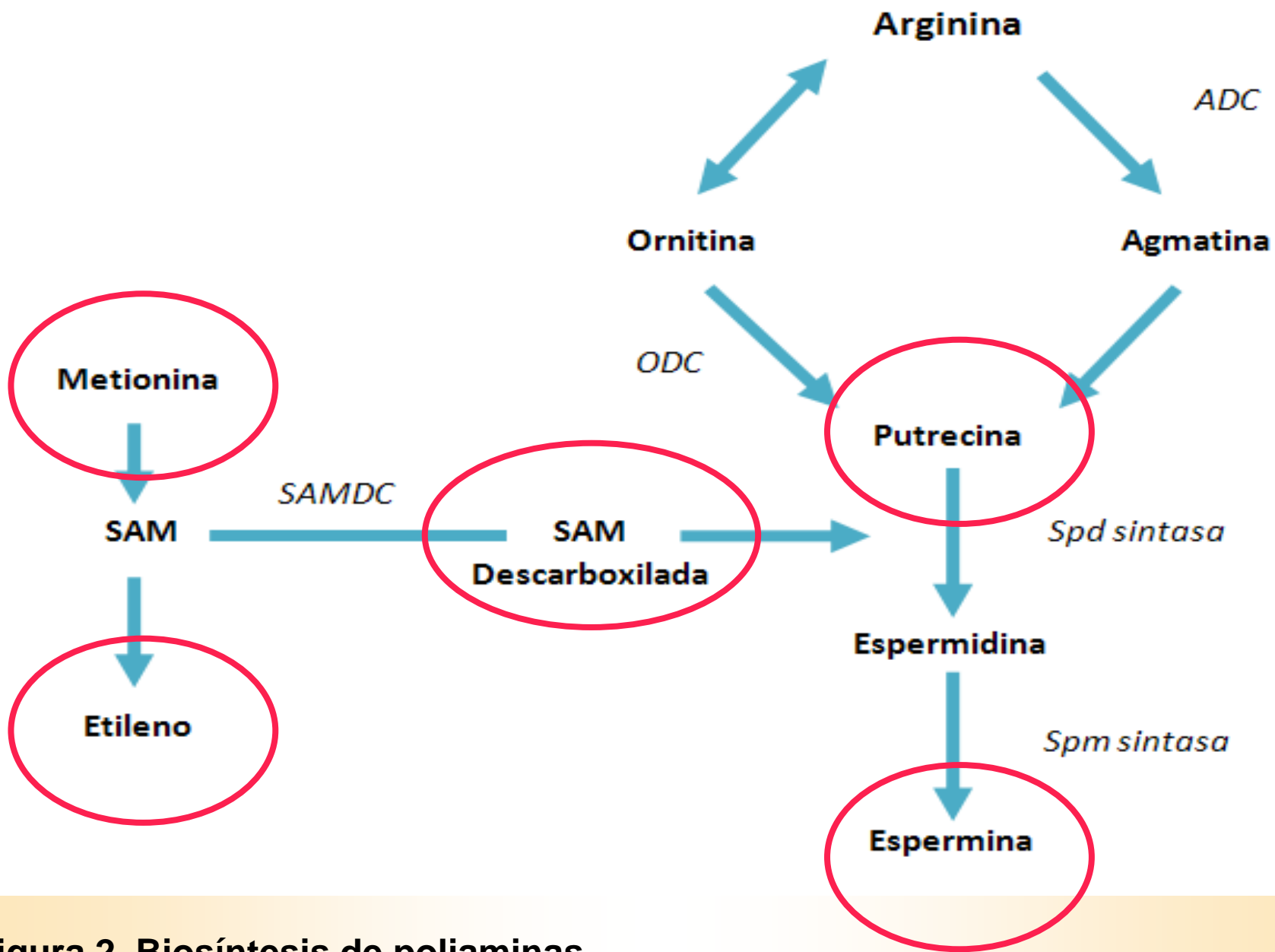


Figura 2. Biosíntesis de poliaminas

# Poliaminas

- Se encuentran en los tejidos en concentraciones relativamente altas (mM)
- Existen libres o unidos a compuestos fenólicos.
- Se encuentran distribuídas en todos los organismos
- Ejercen un control sobre el crecimiento.
- Estabilizan membranas celulares.
- Retardan la senescencia en flores cortadas.

# Poliaminas

- Participan en procesos como:
  - Morfogénesis
  - Embriogénesis
  - Senescencia de hojas
  - Respuesta a estrés biótico y abiótico
  - Maduración de frutos
  - Formación de órganos
  - Respuesta hipersensible frente a infección por virus y hongos.
  - Diferenciación del xilema.



## REGULADORES VEGETALES

POLIAMINAS. Contienen dos o mas grupos aminos.

Compuestos mas representativos:

PUTRESCINA             $(\text{NH}_2(\text{CH}_2)_4\text{NH}_2)$

CADAVERINA            $(\text{NH}_2(\text{CH}_2)_5\text{NH}_2)$

SPERMIDINA  $(\text{NH}_2(\text{CH}_2)_3\text{NH}(\text{CH}_2)_4\text{NH}_2)$

SPERMINA             $(\text{NH}_2(\text{CH}_2)_3\text{NH}(\text{CH}_2)_4\text{NH}(\text{CH}_2)_3\text{NH}_2)$

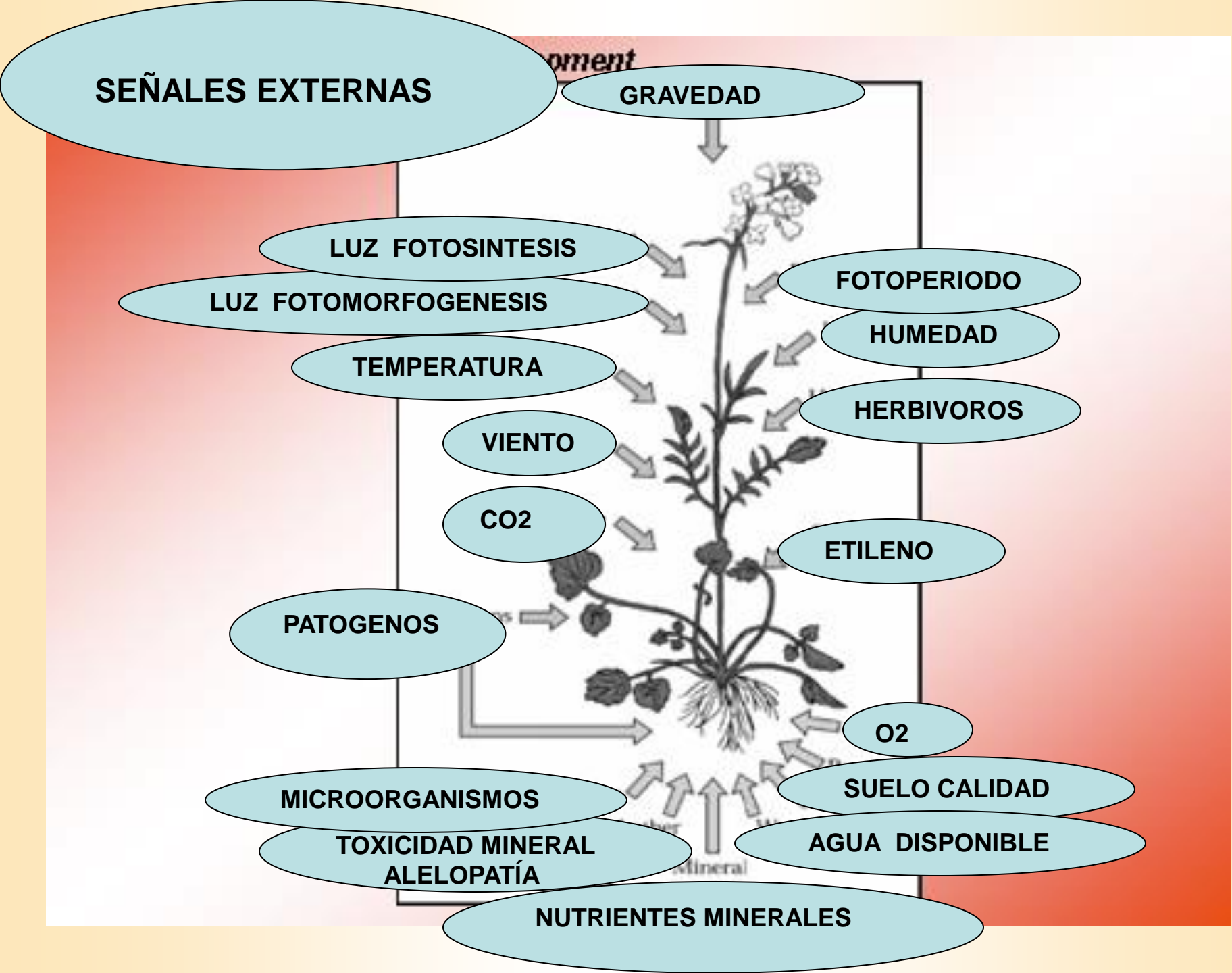
Compuestos que existen libres o unidos a componentes fenólicos, tal como cumárico o cafeico.

La presencia de las poliaminas es en concentraciones relativamente altas, dentro de los tejidos vegetales (concentraciones milimolares).

Efectos fisiológicos:

- promueve la división celular
- promueve el desarrollo de frutos
- estabiliza las membranas celulares
- reduce el efecto del estrés hídrico en las células
- estabiliza protoplastos aislados (probablemente por su efecto sobre las membranas)
- dilata la senescencia de flores cortadas

Los mecanismos de acción no estan aún claros, pero sus cargas positivas le posibilitan su unión con grupos (negativos) fosfatos del ADN o ARN, en el núcleo y ribosomas. En consecuencia, frecuentemente aumenta la transcripción del DNA y la traslación del ARN, en plantas y animales.





***Muchas  
gracias***