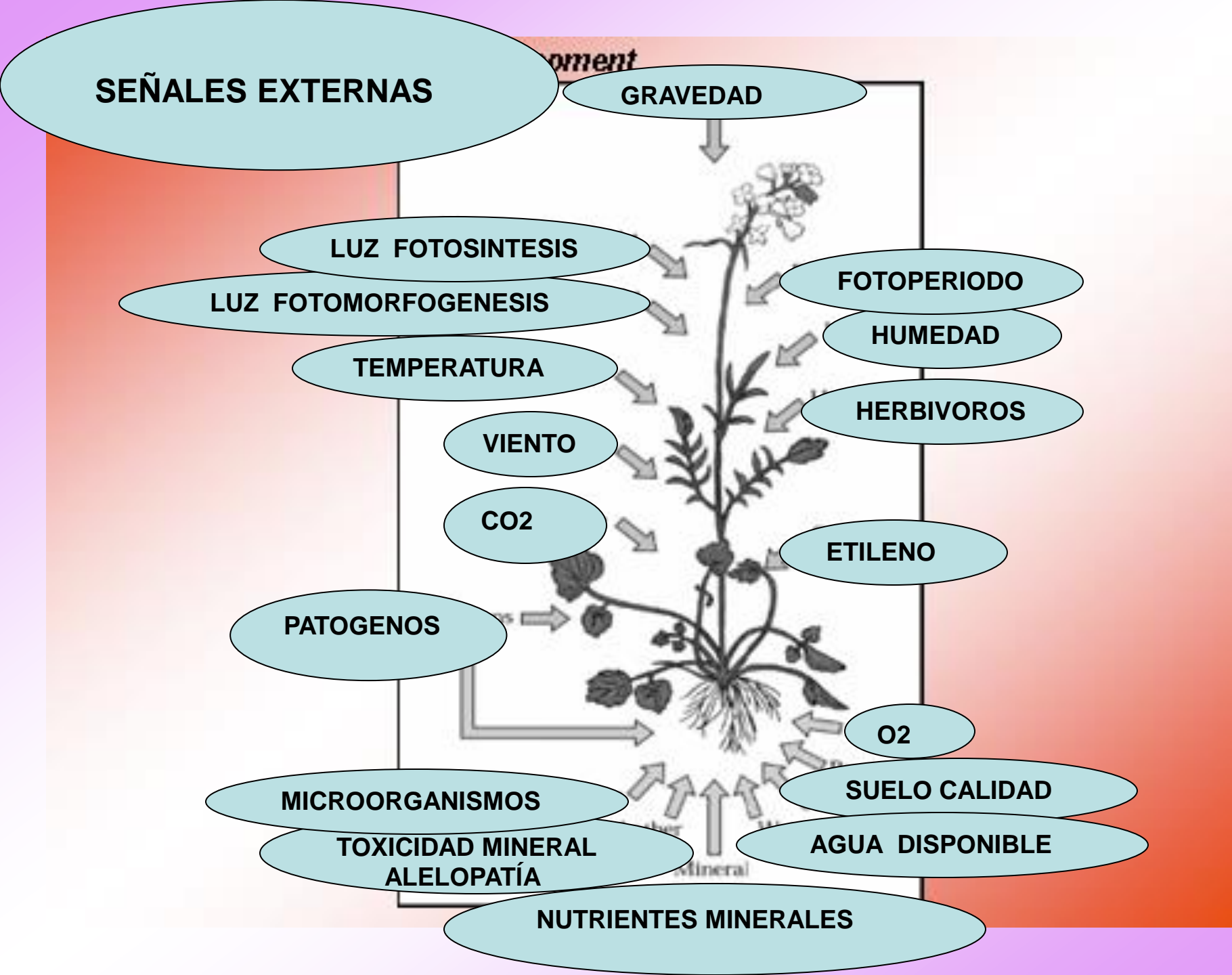
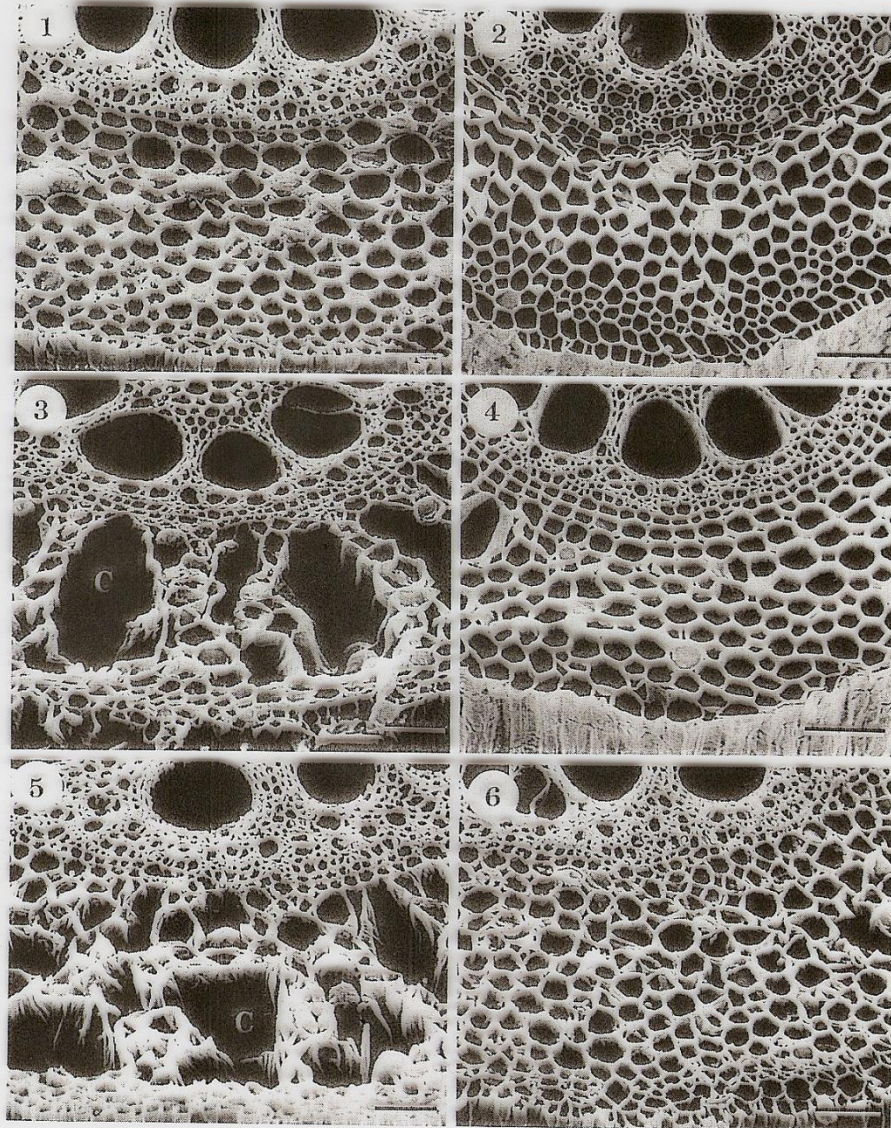


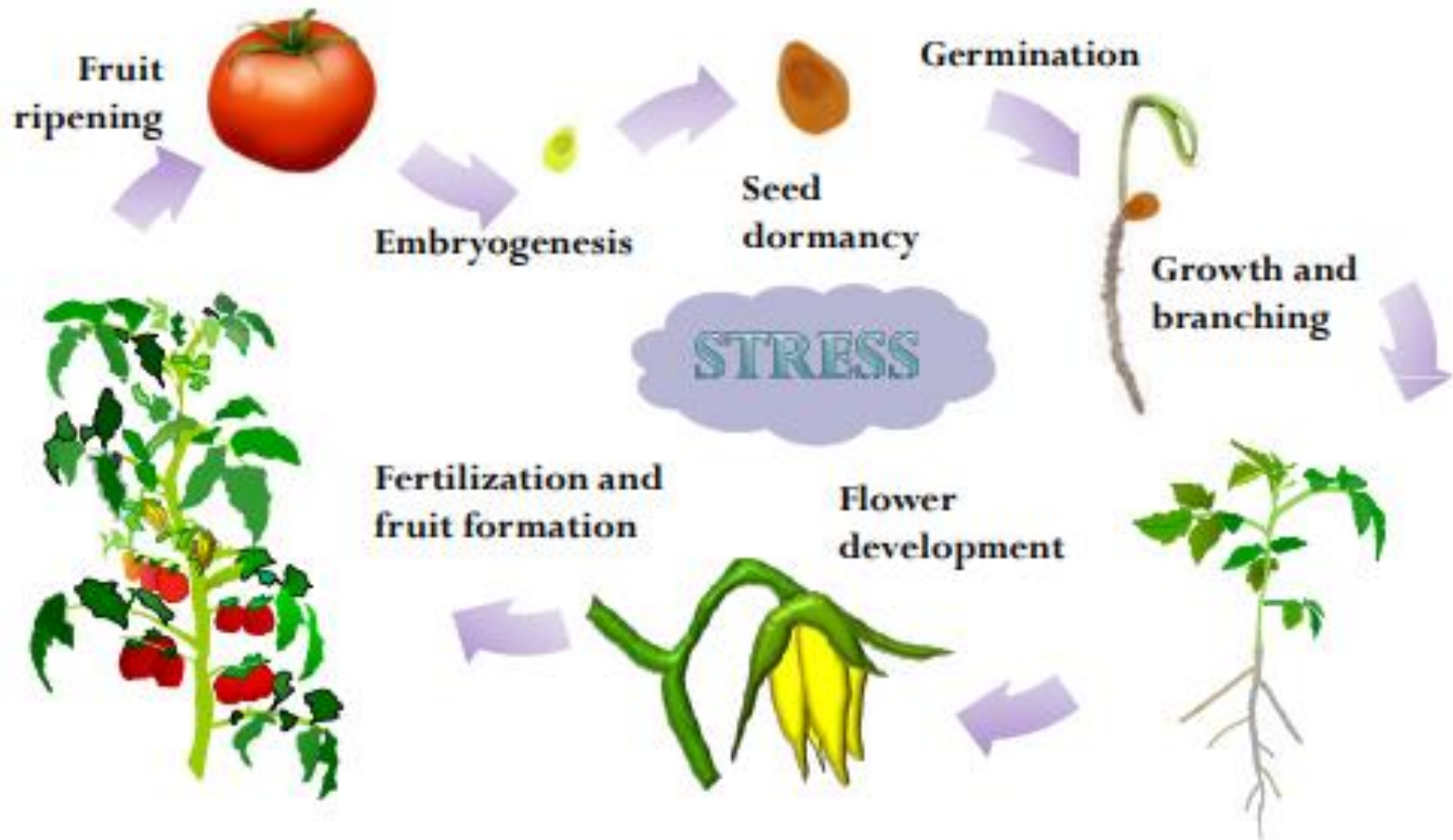
# ***HORMONAS VEGETALES***

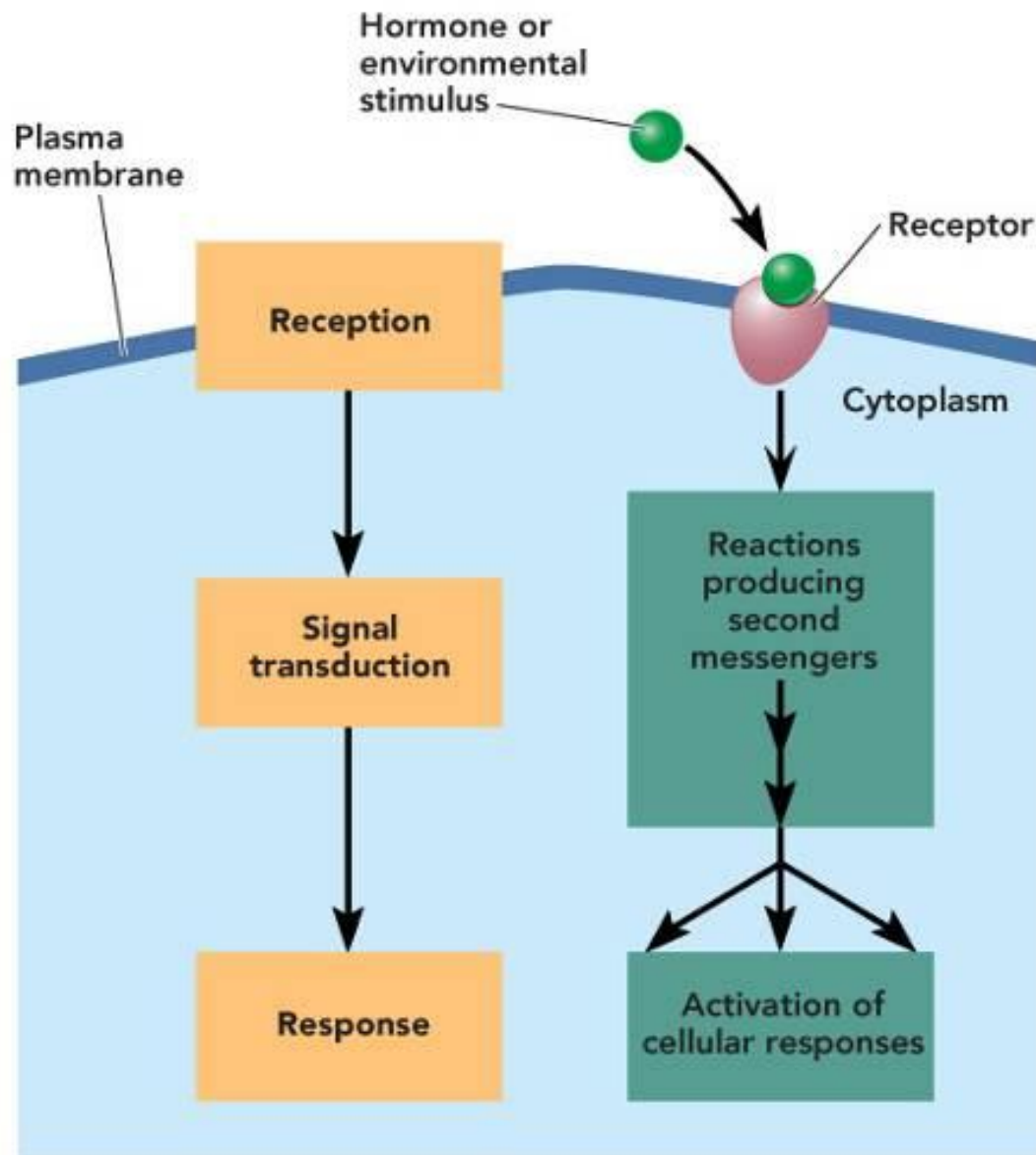




**Figure 4.16.** Scanning electron micrographs of transverse sections of second whorl adventitious roots of corn. Sections were prepared from root zone of approximately the same age, 4 to 5 days. ( $\times 58$ ). Bar =  $50 \mu\text{m}$ . 1, Control grown in aerated solution; 2, root grown in  $0.6 \mu\text{M}$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

Las hormonas participan en todas la etapas del ciclo vital



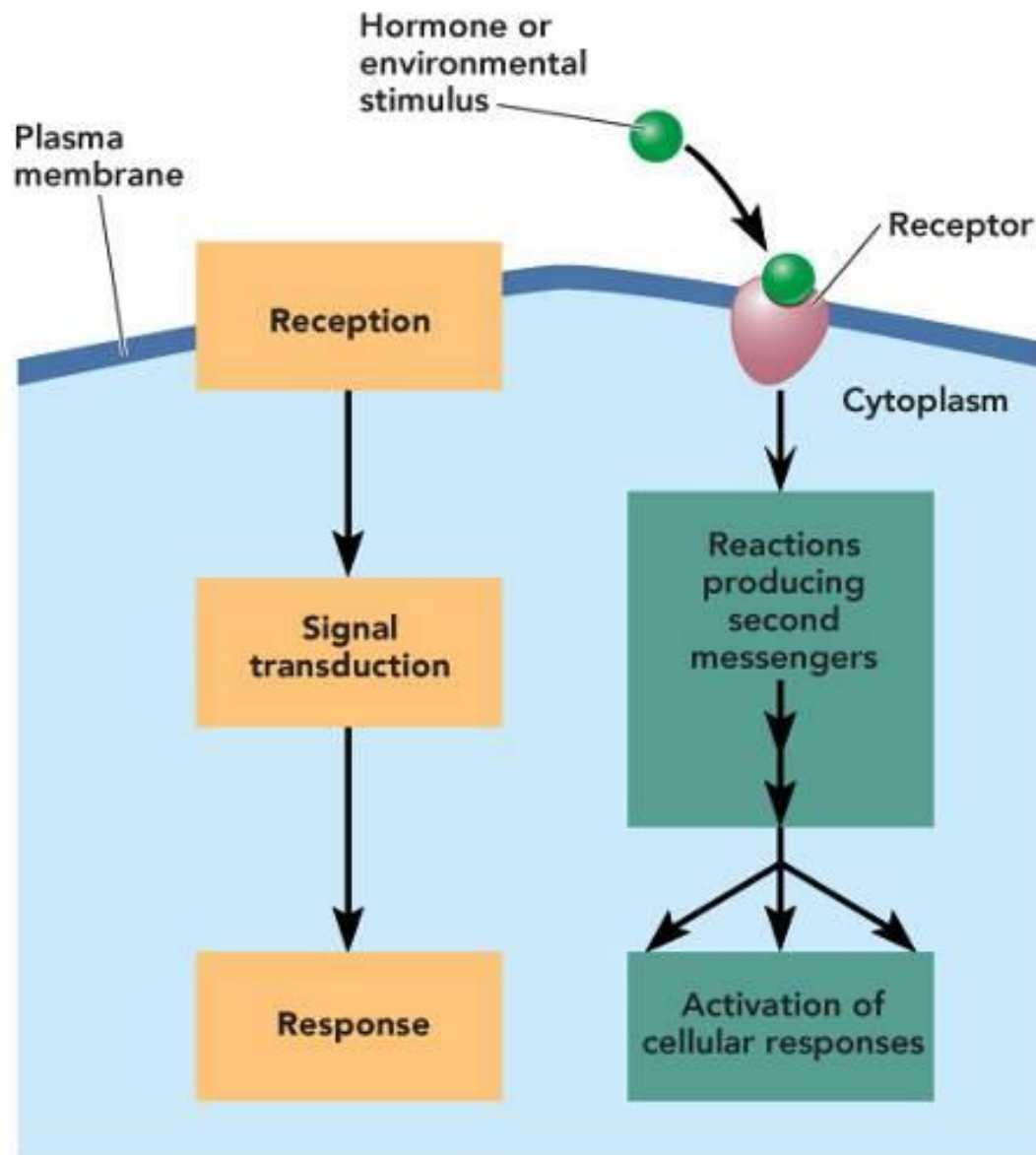


Mecanismo de acción.

Cadena de percepción y transducción de la señal.

✓ **Esta dado por una reacción primaria capaz de iniciar una serie de eventos moleculares que conducen a un efecto fisiológico medible.**

- ✓ Percepción de la señal (primer mensajero-receptor)
- ✓ Generación y trasmisión de la señal (transducción).
- ✓ Activación de un cambio bioquímico (respuesta).

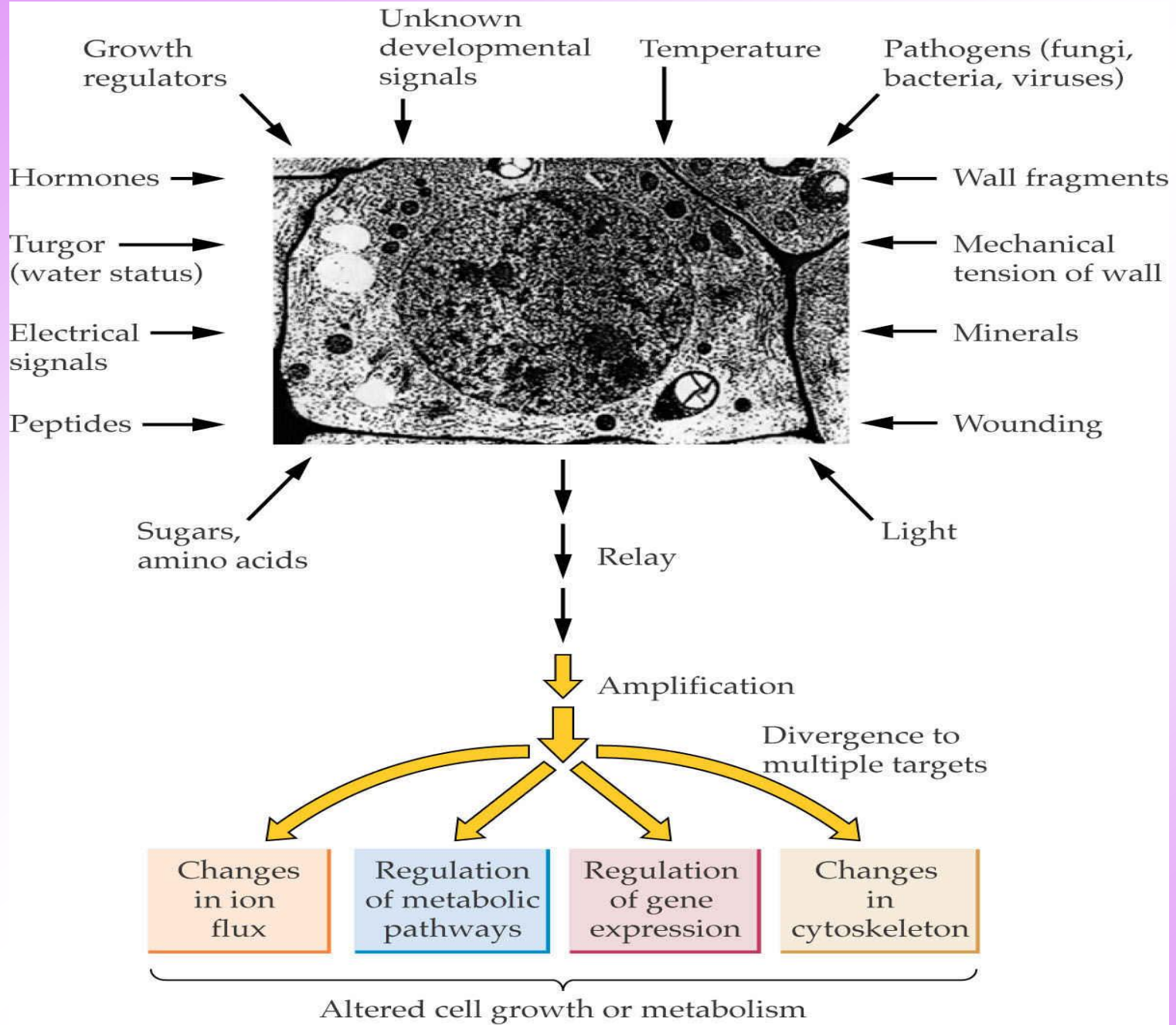


Mecanismo de acción.

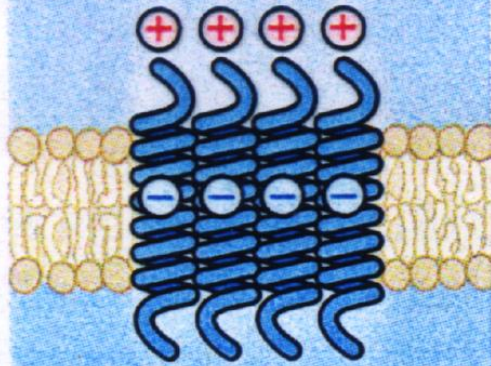
Cadena de percepción y transducción de la señal.

- ✓ **La señal hormonal se percibe por proteínas de membrana o solubles.**
- ✓ **La transducción de la señal activa una cascada de protein-quinasas o la síntesis o liberación de segundos mensajeros.**
- ✓ **Respuesta.**





Cytosol

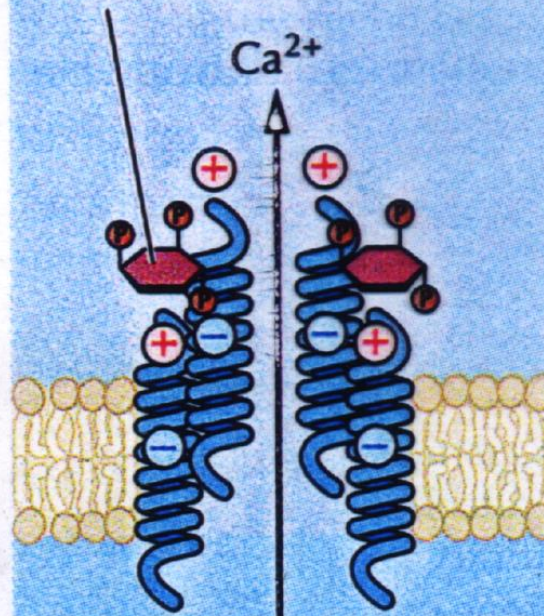


$Ca^{2+}$

$Ca^{2+}$

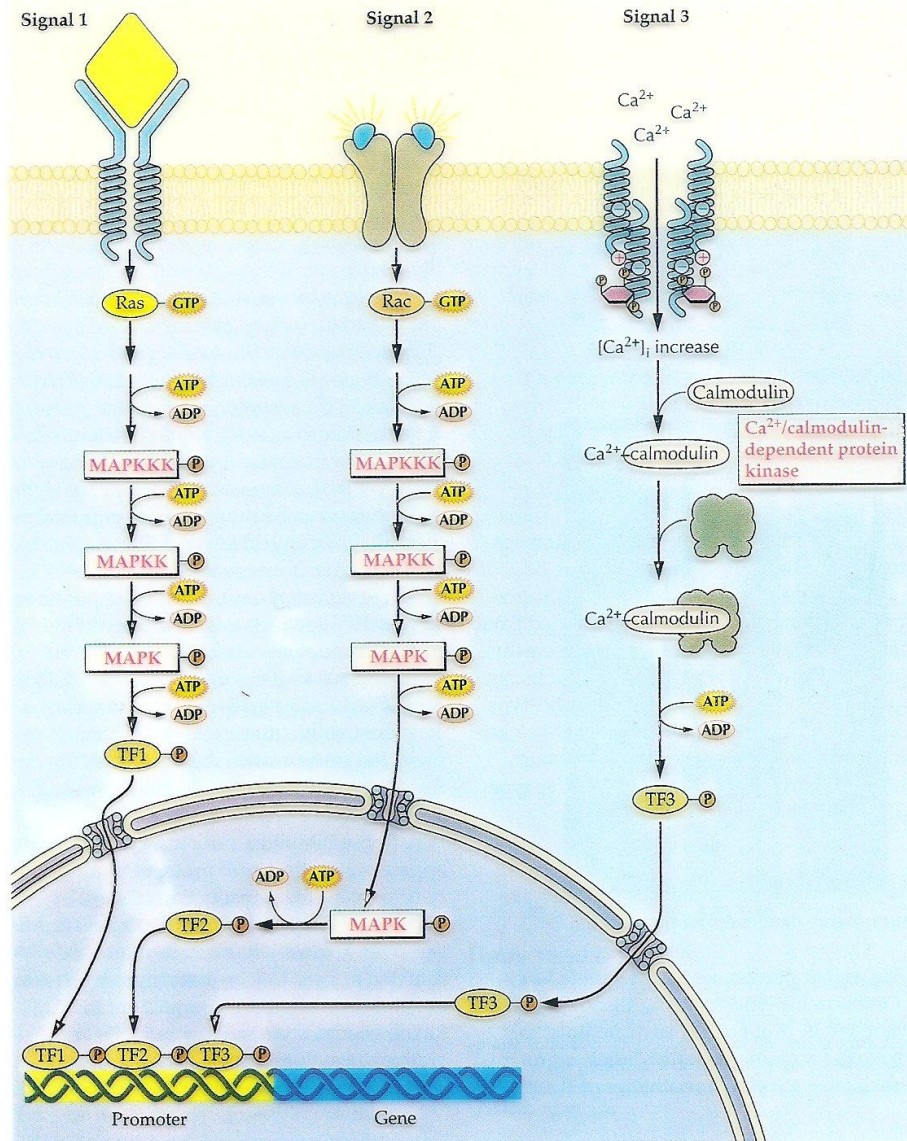
Vacuole

Inositol 1,4,5-triphosphate



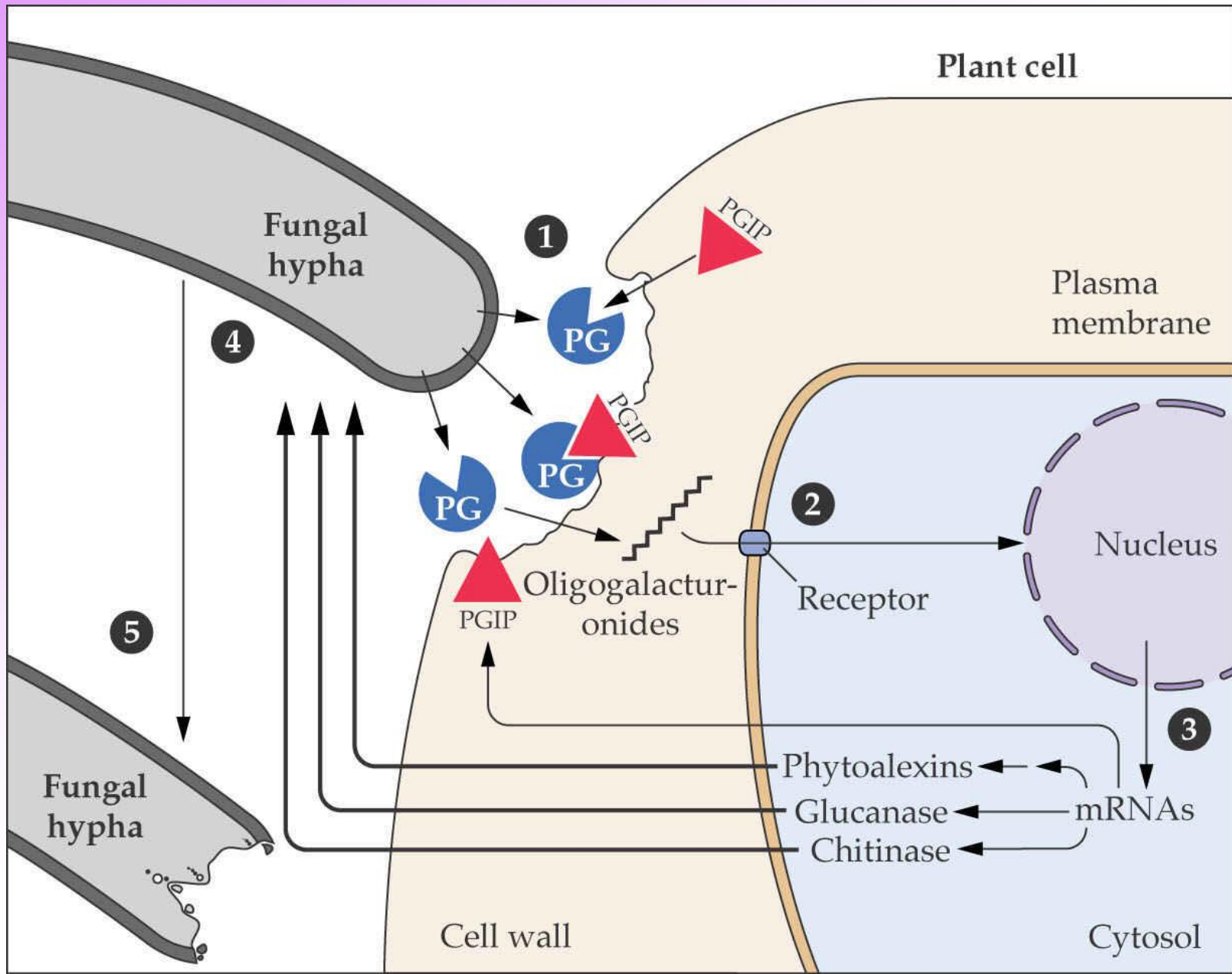
$Ca^{2+}$

$Ca^{2+}$

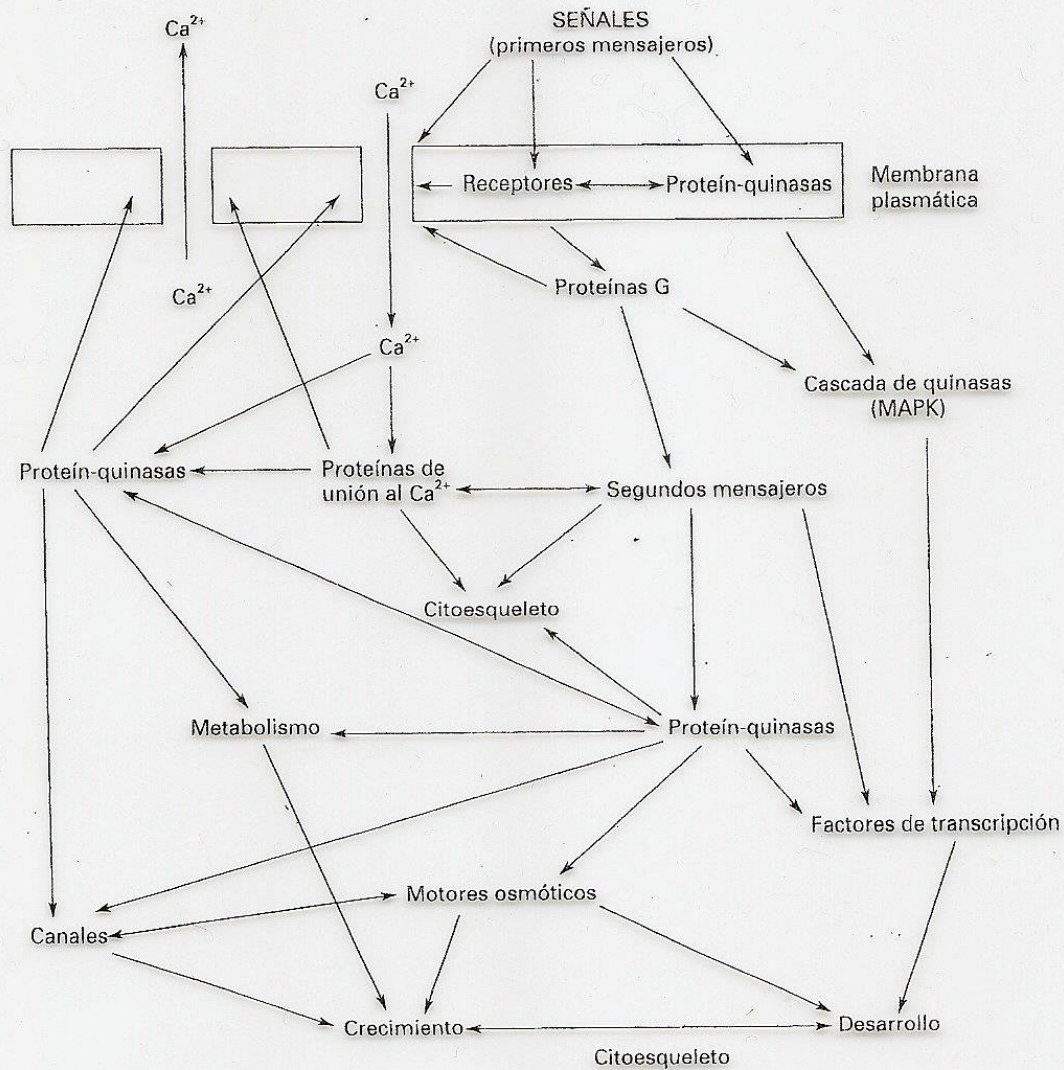


**Figure 18.63**

Many signals are transduced by protein kinase cascades that regulate gene expression. One such transduction sequence is believed to underlie regulation of gene expression involving a small GTPase (Ras- or Rac-like protein) and mitogen-activated protein kinase (MAPK) cascade leading to transcription factor phosphorylation. Transduction chains from different signals using a MAPK cascade (e.g., signals 1 and 2) or through alteration of  $[Ca^{2+}]_i$  (e.g., signal 3) can all affect the same gene through the phosphorylation of different transcription factors (TFs). The TFs may move through the nuclear membrane when they are phosphorylated (signals 1 and 3); alternatively, MAPK may move into the nucleus after phosphorylation by MAPKK (signal 2).



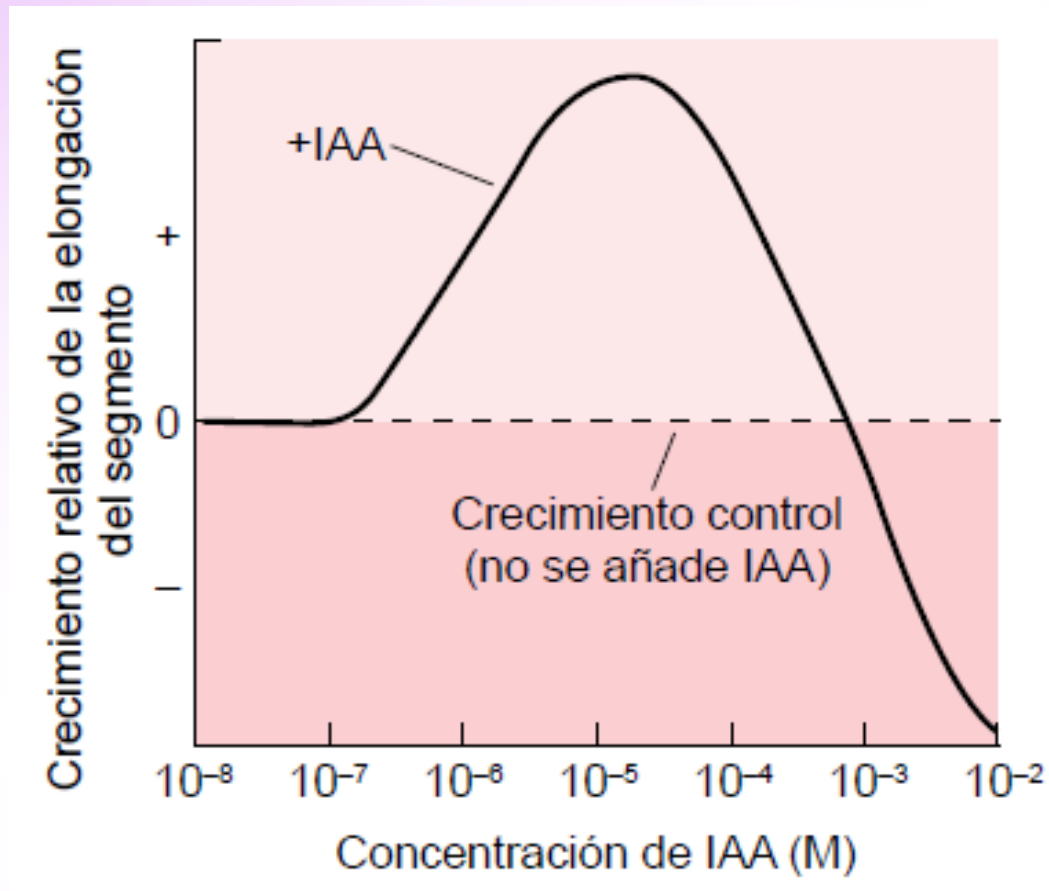
Introducción al desarrollo. Concepto de hormona vegetal



Modelo de percepción y transducción de señales en células vegetales. Las señales, incluyendo las hormonas pueden alterar los potenciales de membrana, activar los receptores o modificar proteín-quinasas. En el modelo no se muestran los receptores solubles ni la síntesis de segundos mensajeros (adaptado de Trewavas y Malhó, 1997).

# Actividad biológica: elongación celular.

Promueven el crecimiento de tallos y coleoptilos, mientras que inhiben el crecimiento en raíces



## **HORMONAS VEGETALES:**

- ✓ **Sustancias orgánicas, pequeñas, no nutrientes**
- ✓ **Regulan procesos fisiológicos a bajas concentraciones**
- ✓ **Se sintetizan en un lugar y se trasladan.**
- ✓ **Su síntesis no se realiza en tejidos especiales (glándulas?), aunque existen sitios en el vegetal con mayor capacidad.**
- ✓ **Ejercen efectos pleiotrópicos (numerosos procesos)**
- ✓ **La respuesta es una función de la concentración hormonal y la sensibilidad de los órganos.**
- ✓ **Interactúan entre ellas según un balance cuantitativo**

### **≠ con hormonas animales:**

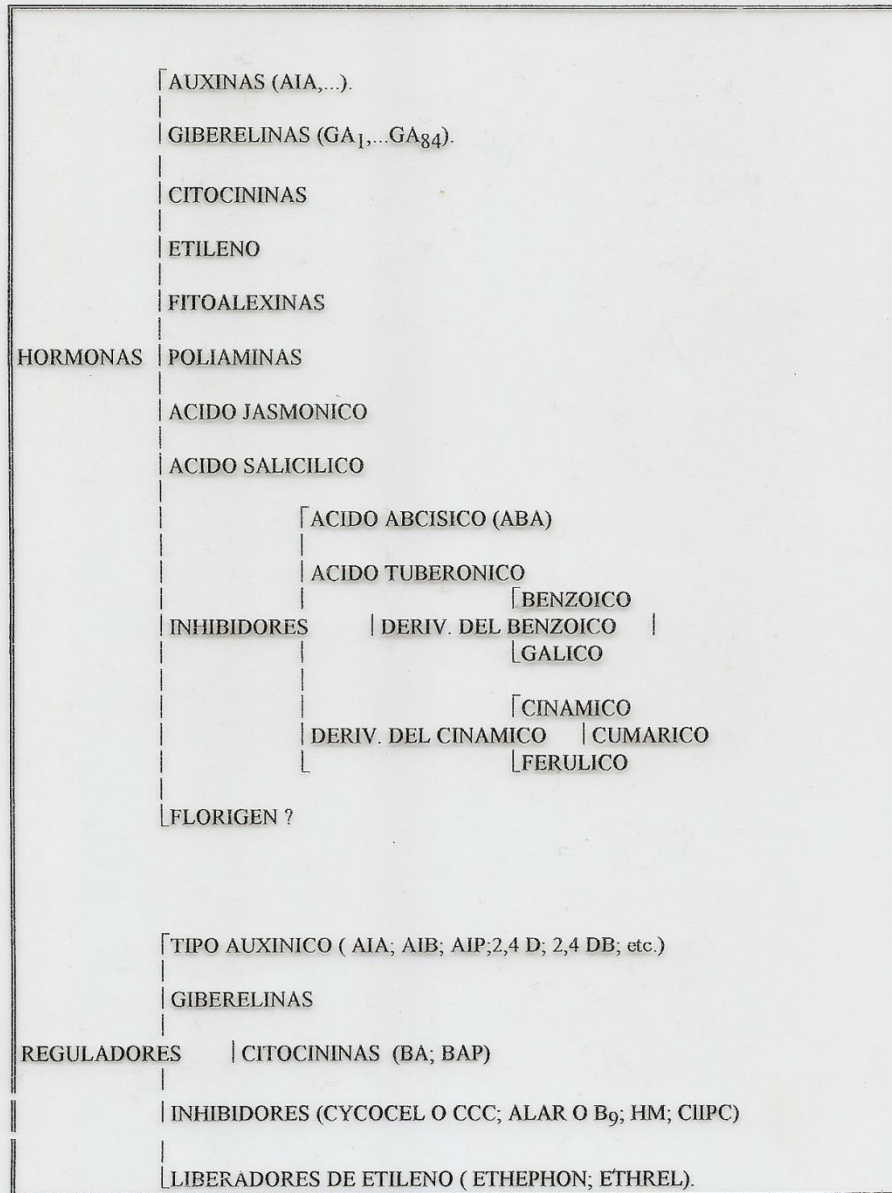
- **Lugar de síntesis**
- **Cada hormona tiene varias funciones**
- **En cada proceso participan varias hormonas**

# **Reguladores Vegetales**

Sustancias sintetizadas artificialmente que producen respuestas similares a las hormonas.



CUADRO 1 Clasificación de hormonas y reguladores, identificados y/o difundidos y de uso agronómico, respectivamente.



# Fenómenos de correlación

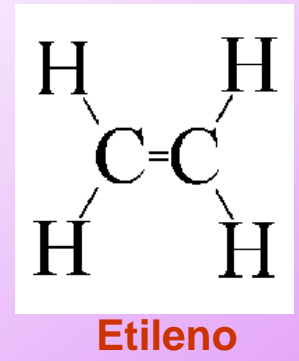
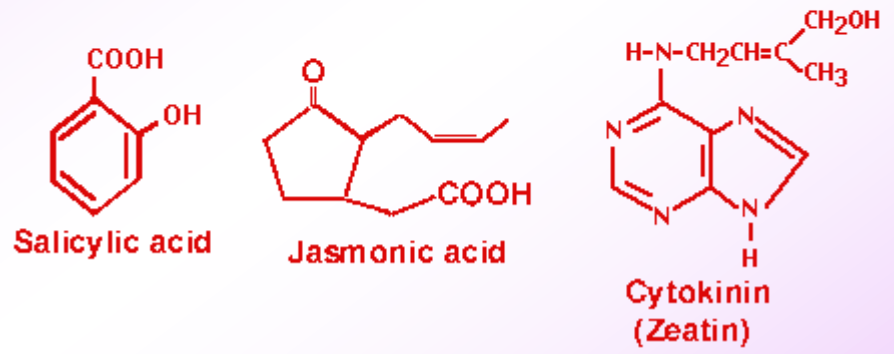
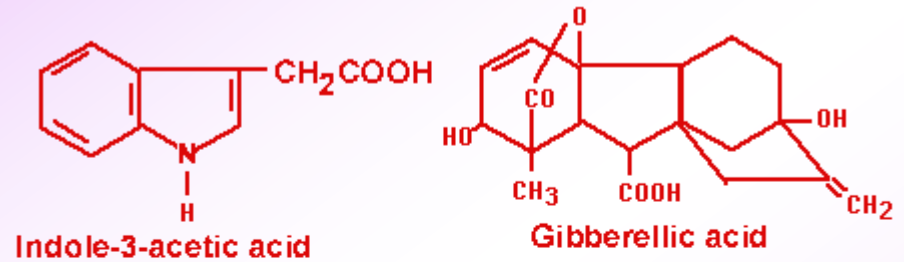
- Coordinación entre distintas partes de la planta, para percibir y responder a fluctuaciones en el ambiente.
- Una parte del vegetal influye sobre el crecimiento y morfogénesis de otra parte del vegetal.

## Ejemplos:

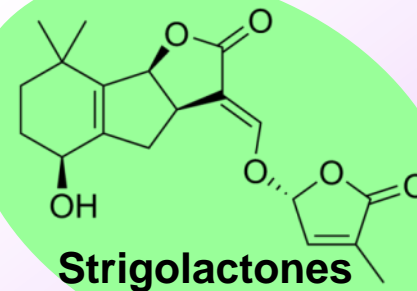
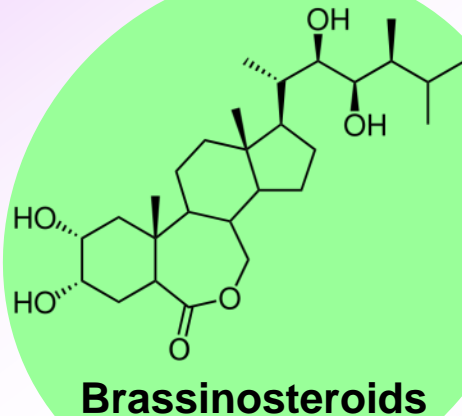
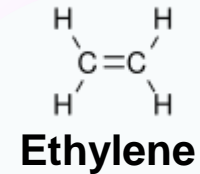
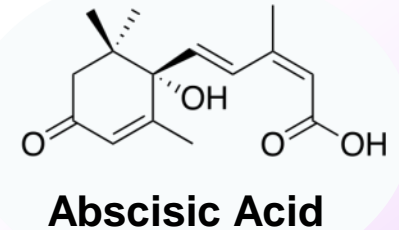
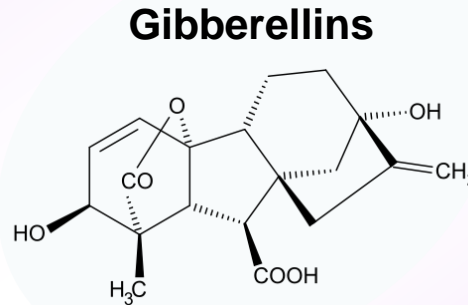
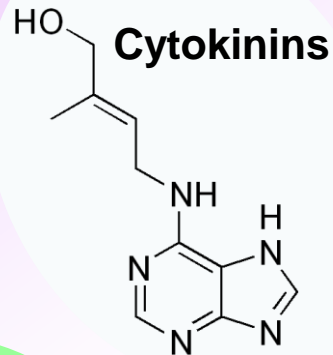
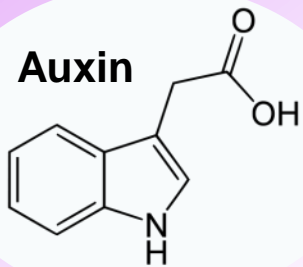
- Dominancia apical
- Senescencia de hojas, flores y frutos
- Abscisión de hojas, flores, frutos y ramas
- Dormición de yemas
- Floración
- Polaridad
- Fenómenos de sensibilidad

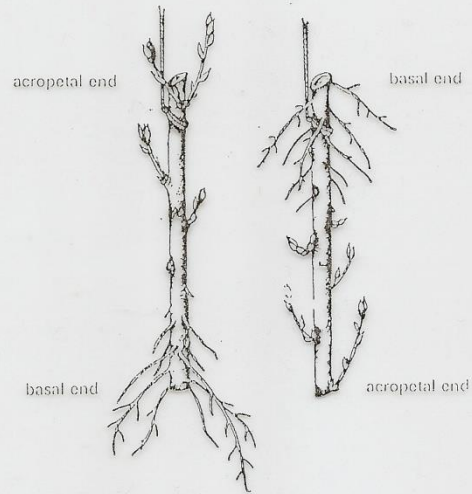


- ✓ Auxinas
- ✓ Giberelinas
- ✓ Citocininas
- ✓ Ácido abscísico
- ✓ Etileno
- ✓ Ácido jasmónico
- ✓ Ácido salicílico

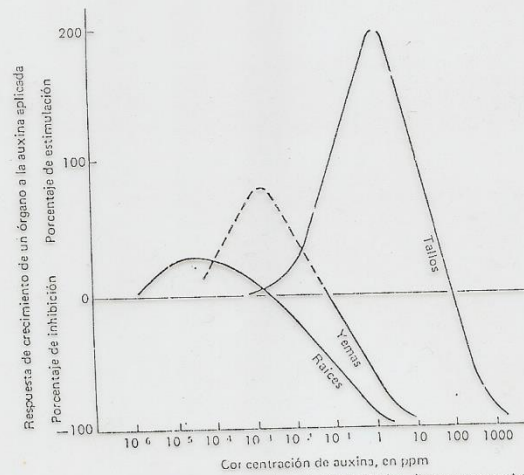


# Phytohormones – old timers and newcomers





Polarity of root and bud formation in willow shoots suspended in moist air. (From E. W. Sinnott, 1960, *Plant Morphogenesis*, McGraw-Hill, New York, p. 120. Used by permission.)



Curvas de respuesta que muestran el efecto de las diversas concentraciones de IAA sobre el crecimiento de tres órganos de la planta. (Según L. J. Audus, 1950. *Plant growth substances*. Interscience Publishers, New York.)

- ✓ **El control de la respuesta es una función de la concentración hormonal y la sensibilidad de los tejidos a las hormonas.**

## **HORMONAS VEGETALES:**

**Capacidad de percibir y responder a las fluctuaciones del ambiente y subsistir a lo largo de la evolución.  
(las plantas no se desplazan).**

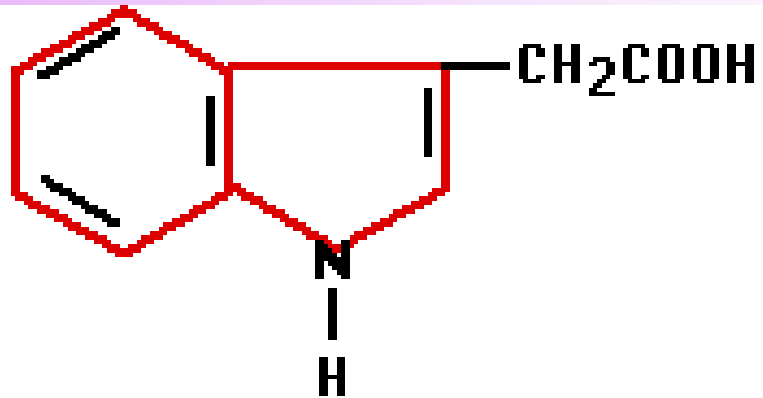
situaciones de estrés

meristemas vegetativos son inducidos a floración

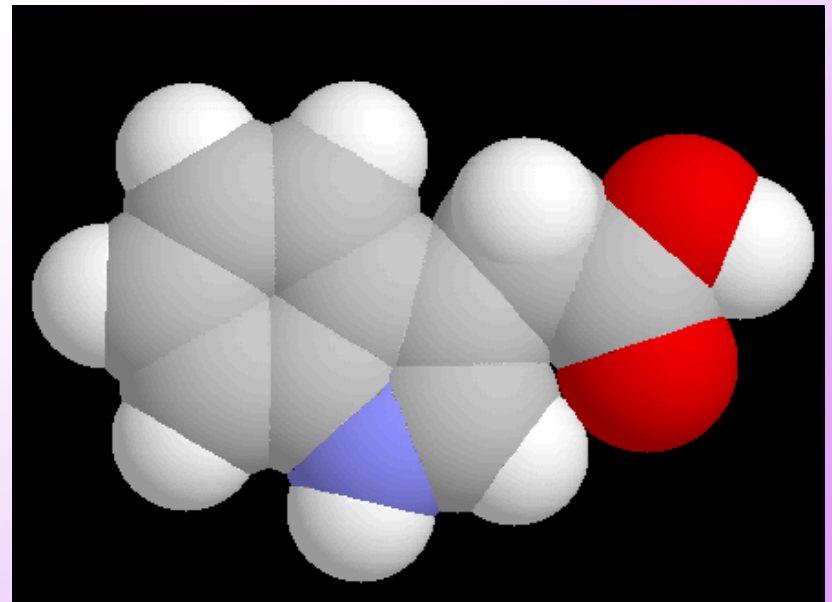
percepción de plantas vecinas

**Las señales son amplificadas y transducidas por las hormonas.  
Fenómenos de correlación e intercomunicación.**

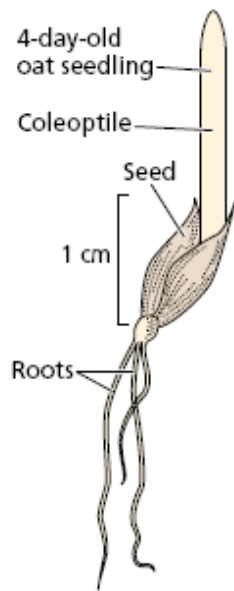
# Auxin



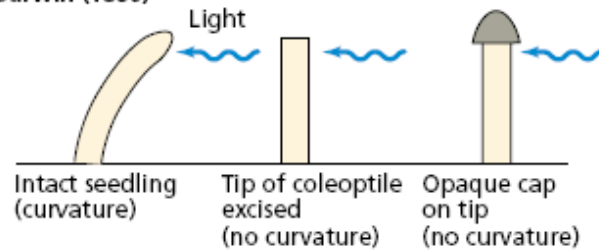
**Indole-3-acetic acid (IAA)**





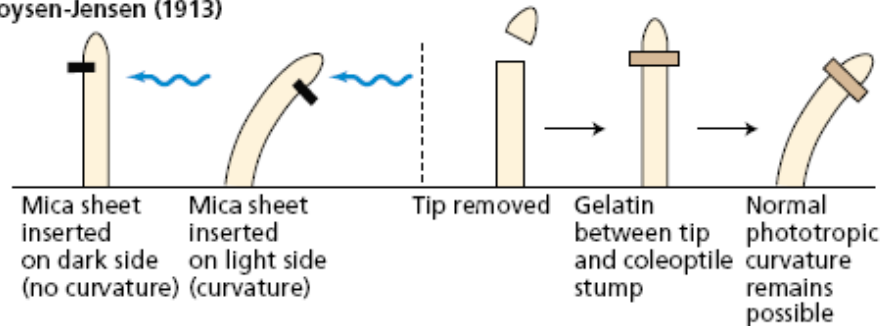


**Darwin (1880)**



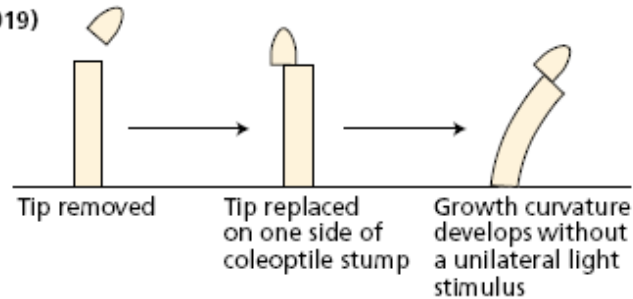
From experiments on coleoptile phototropism, Darwin concluded in 1880 that a growth stimulus is produced in the coleoptile tip and is transmitted to the growth zone.

**Boysen-Jensen (1913)**



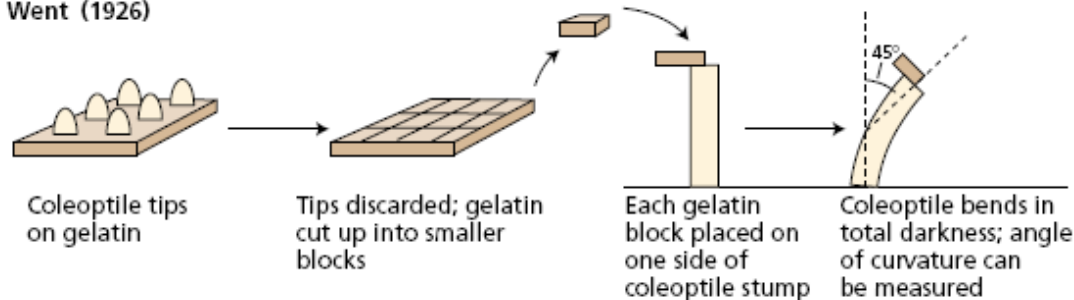
In 1913, P. Boysen-Jensen discovered that the growth stimulus passes through gelatin but not through water-impermeable barriers such as mica.

**Paál (1919)**



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

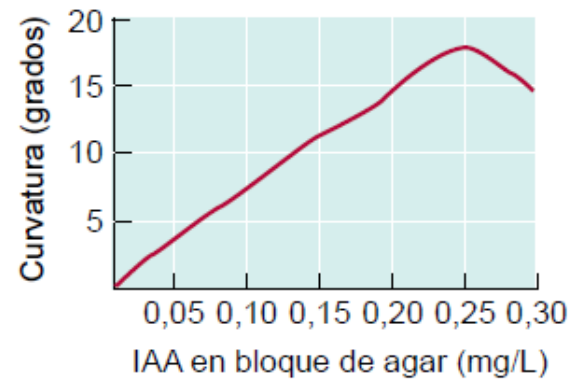
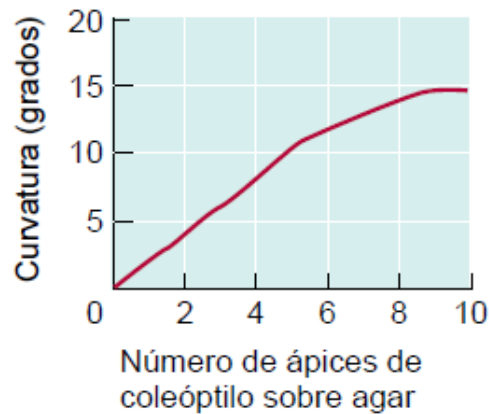
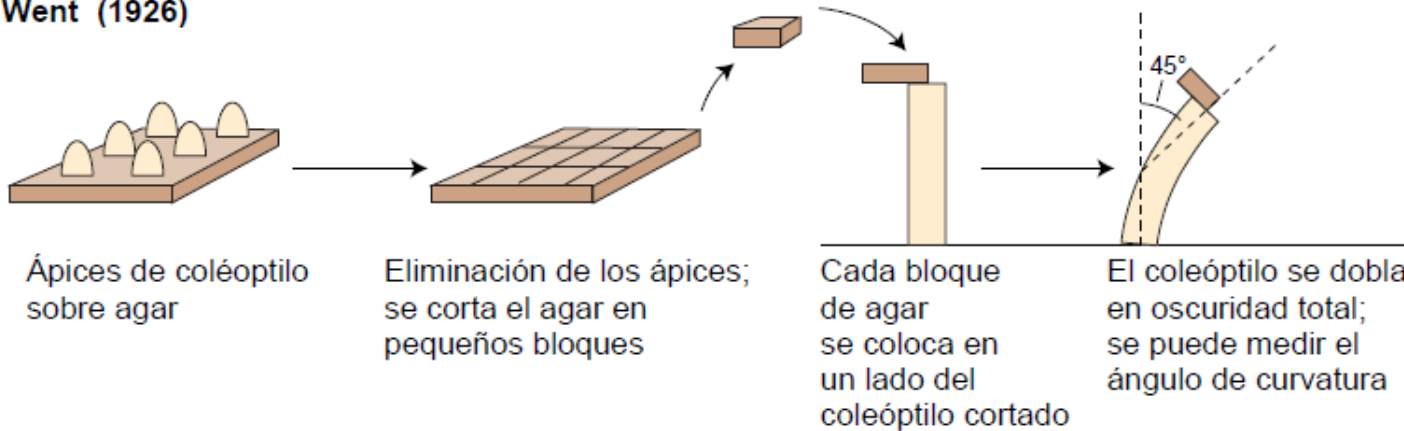
**Went (1926)**



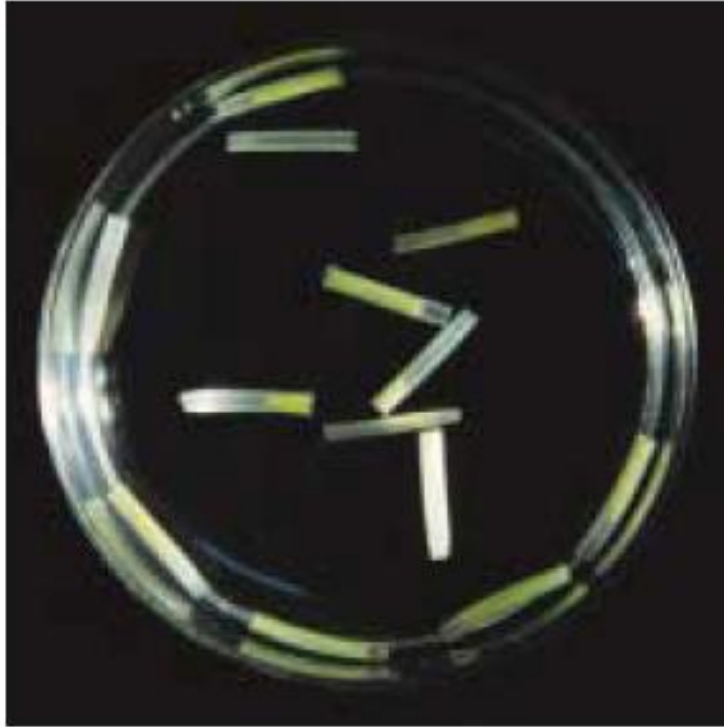
In 1926, F. W. Went showed that the active growth-promoting substance can diffuse into a gelatin block. He also devised a coleoptile-bending assay for quantitative auxin analysis.

# Bioensayo «*curvatura del coleoptilo de Went*» permite análisis cuantitativos.

Went (1926)



(A)

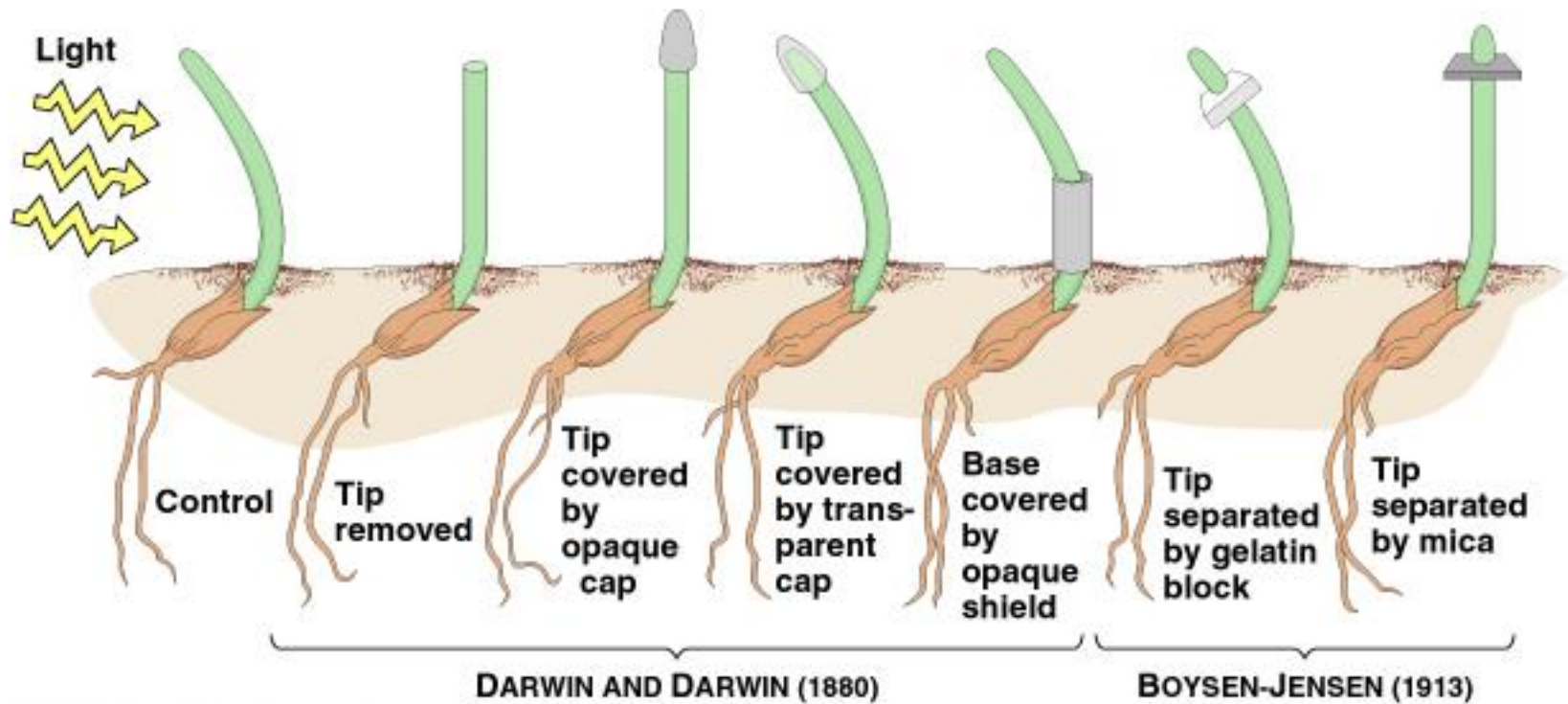


(B)

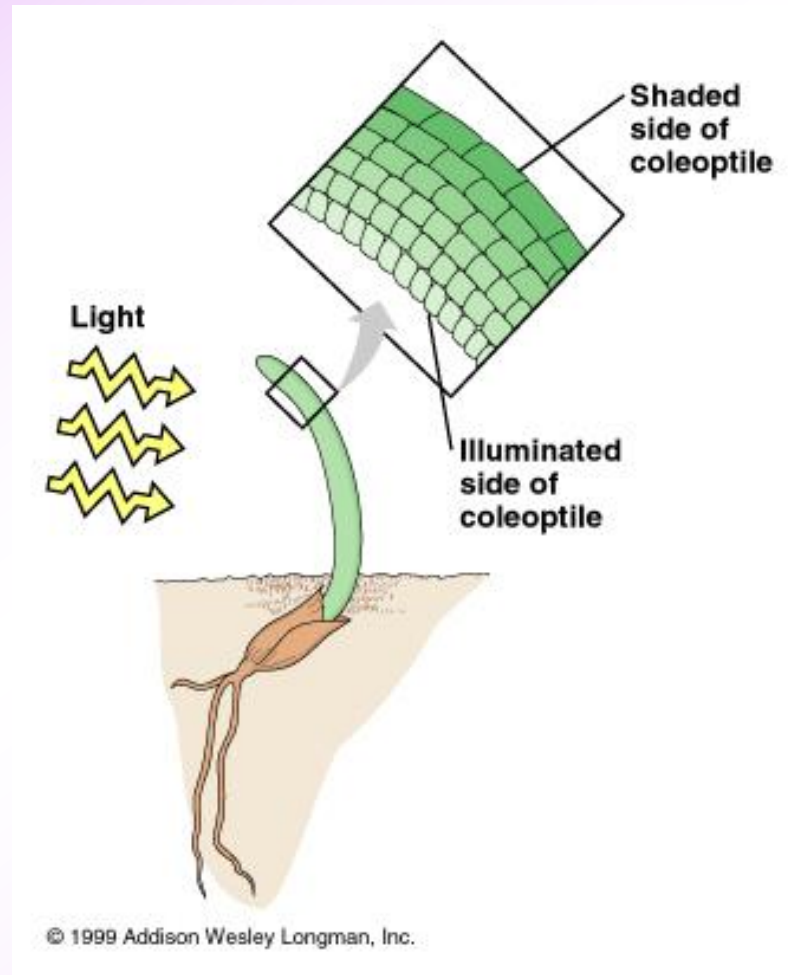


**FIGURE 19.2** Auxin stimulates the elongation of oat coleoptile sections. These coleoptile sections were incubated for 18 hours in either water (A) or auxin (B). The yellow tissue inside the translucent coleoptile is the primary leaves. (Photos © M. B. Wilkins.)

# Auxin associated with phototropism - early experiments demonstrate tip as receptor.



# Growth movement

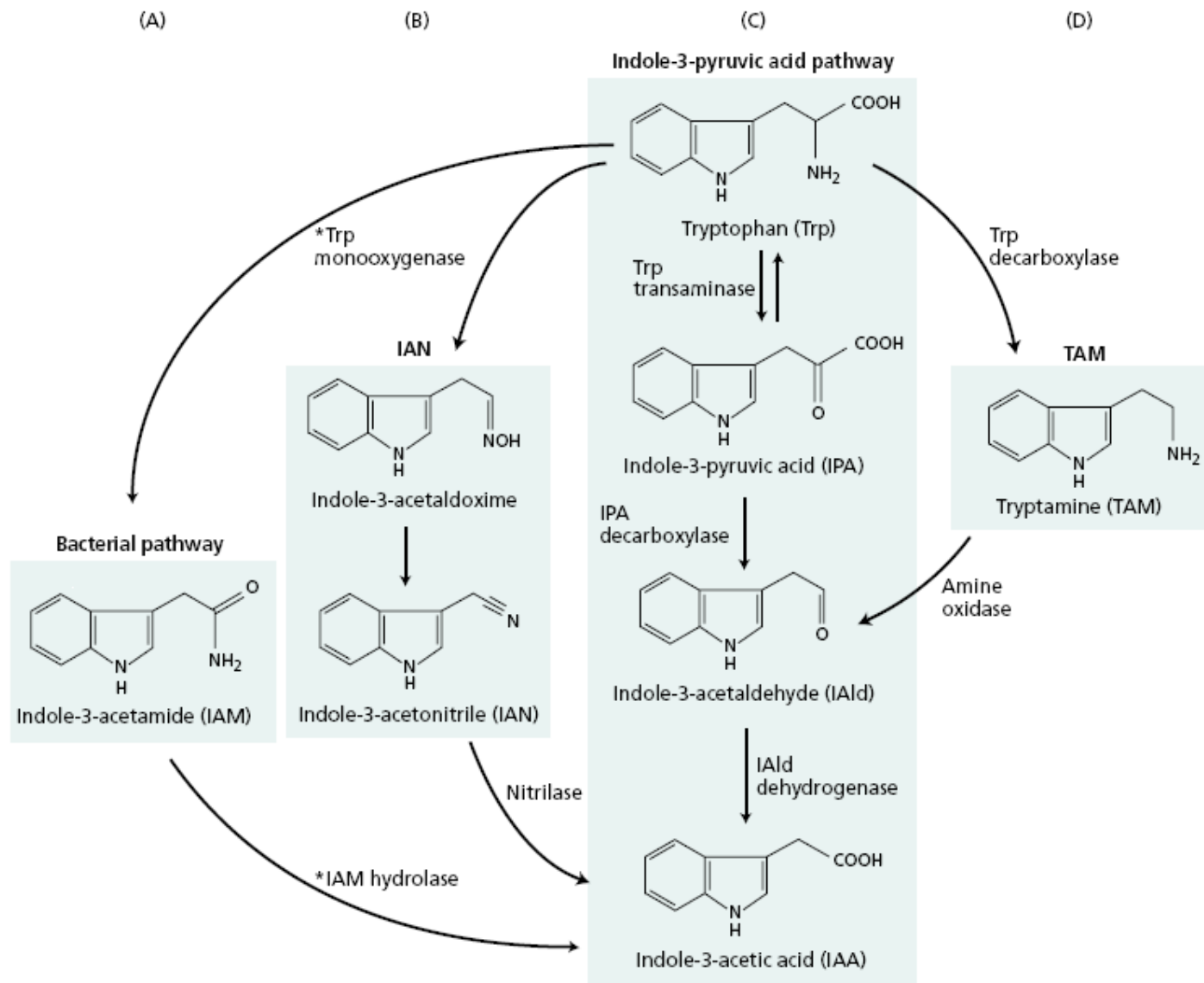


# Auxin

- Discovered as substance associated with phototropic response.
- Occurs in very low concentrations.
  - Isolated from human urine, (40mg 33 gals<sup>-1</sup>)
  - In coleoptiles (1g 20,000 tons<sup>-1</sup>)
- Differential response depending on dose.

# Síntesis

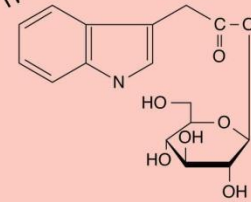
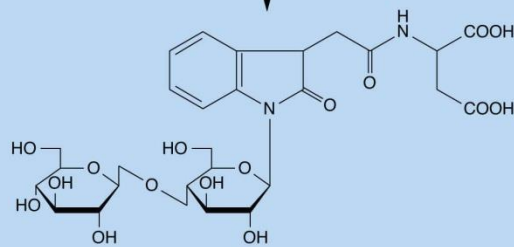
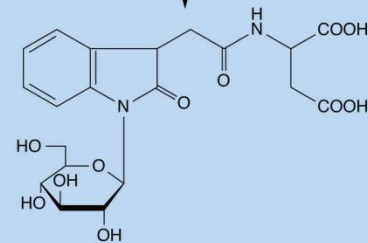
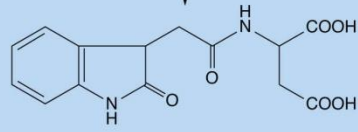
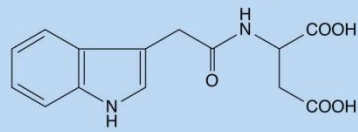
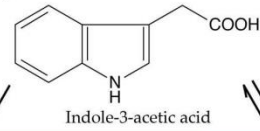
- Meristemas apicales
- Ápices de coleoptilos
- Tallos y hojas jóvenes en expansión
- Frutos en desarrollo
- Semillas
- Tejidos en rápido crecimiento y división
- Tejidos dañados



**FIGURE 19.6** Tryptophan-dependent pathways of IAA biosynthesis in plants and bacteria. The enzymes that are present only in bacteria are marked with an asterisk. (After Bartel 1997.)



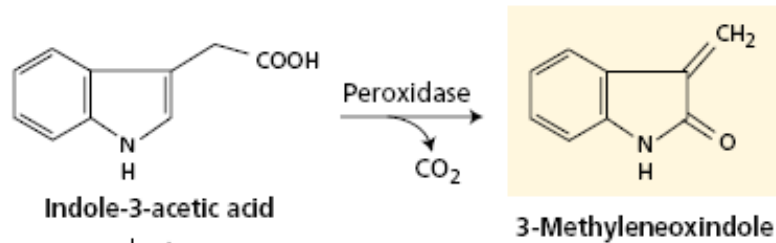
*Lycopersicon esculentum*



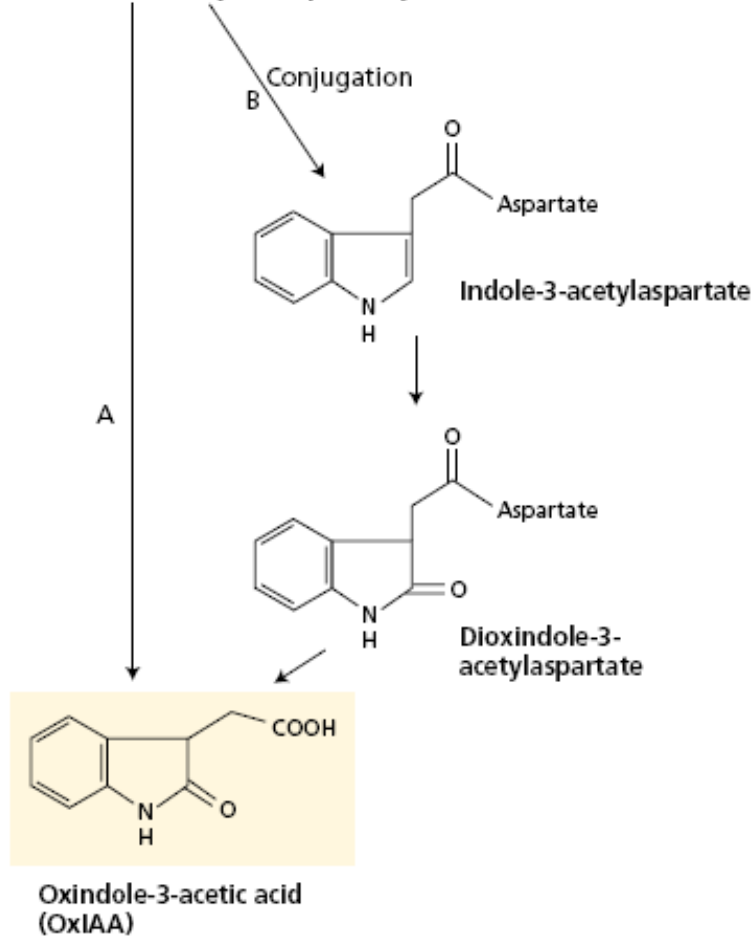
Reversible deactivation pathway

Irreversible deactivation pathway

(A) Decarboxylation: A minor pathway

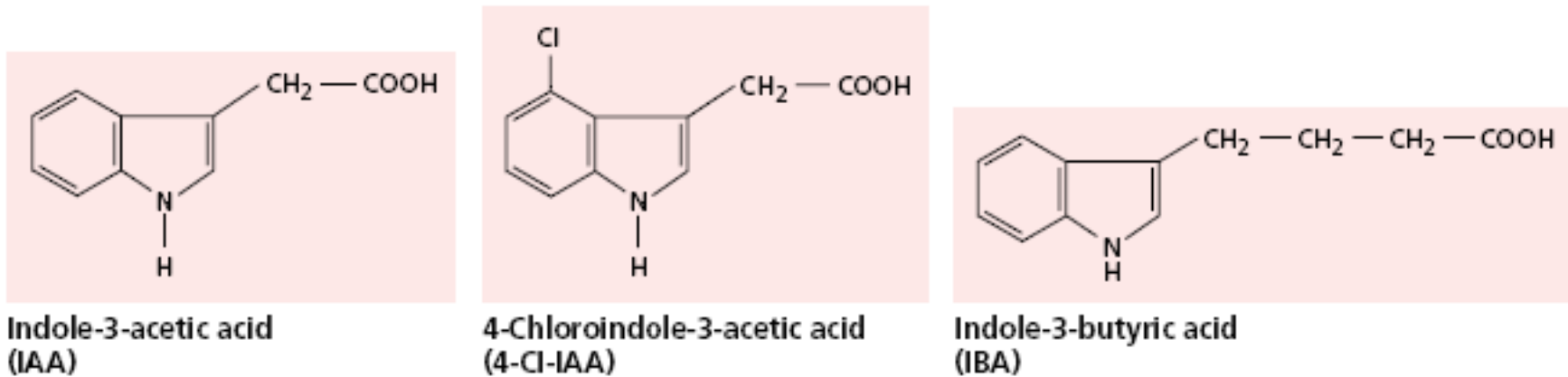


(B) Nondecarboxylation pathways



**FIGURE 19.10** Biodegradation of IAA. (A) The peroxidase route (decarboxylation pathway) plays a relatively minor role. (B) The two nondecarboxylation routes of IAA oxidative degradation, A and B, are the most common metabolic pathways.

# AUXINAS NATURALES



**FIGURE 19.3** Structure of three natural auxins. Indole-3-acetic acid (IAA) occurs in all plants, but other related compounds in plants have auxin activity. Peas, for example, contain 4-chloroindole-3-acetic acid. Mustards and corn contain indole-3-butyric acid (IBA).

# AUXINAS.

## BALANCE:

SINTESIS

FOTOOXIDACIÓN

OXIDACIÓN ENZIMAS

COMPLEJO con azucares y

. aminoácidos, Auxinas ligadas (inactivas).

TRANSPORTE

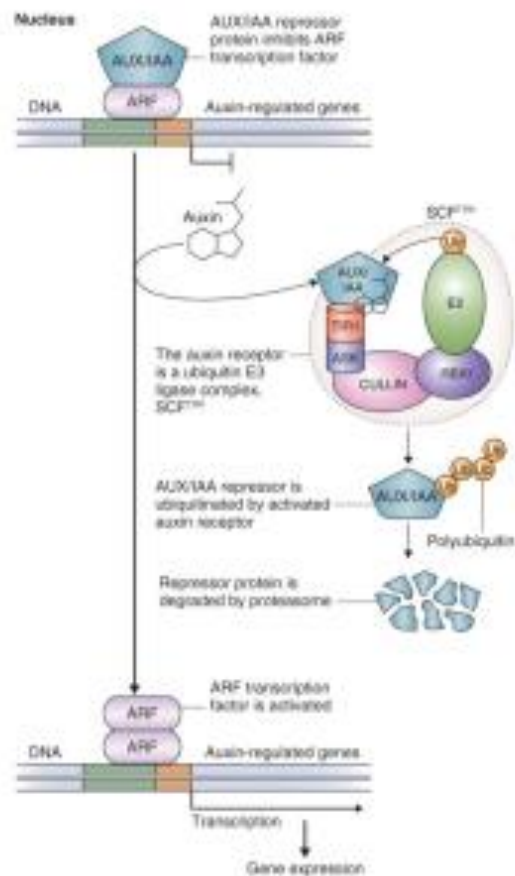
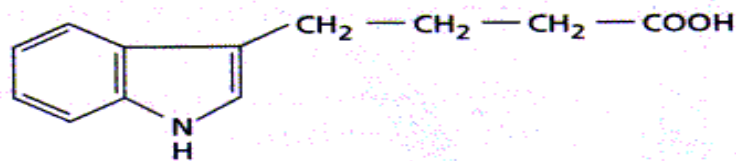


Figure 10.11

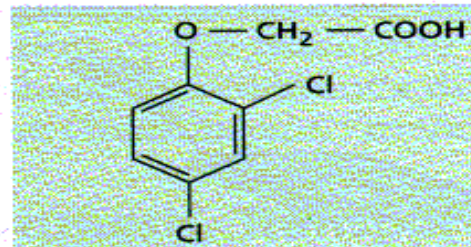
Model showing signal transduction during the response to auxin. In the absence of IAA, AUX/IAAs repress auxin-regulated genes by complexing with auxin response factors (ARFs). In the presence of IAA, AUX/IAA proteins become ubiquitinated by SCF<sup>TIR1</sup> E3 ligase complex and are broken down by the proteasome. ARF can then function, often forming ARF-ARF dimers that allow the transcription of auxin-responsive genes.

# AUXINAS SINTÉTICAS

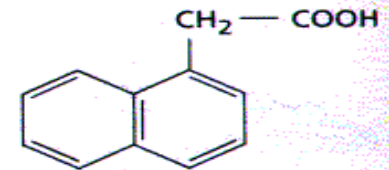
(A)



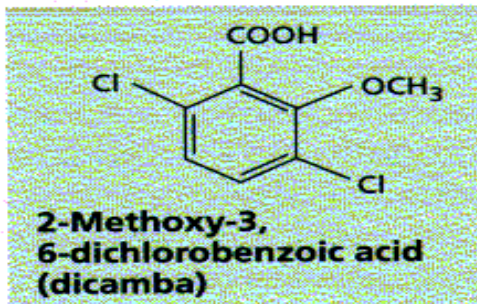
**Indole-3-butyric acid (IBA)**



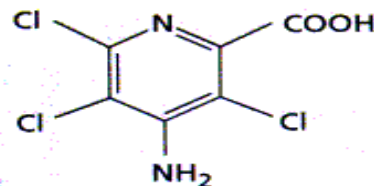
**2,4-Dichlorophenoxyacetic acid (2,4-D)**



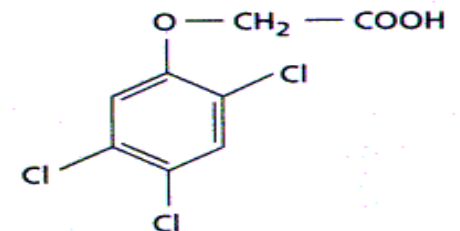
**$\alpha$ -Naphthalene acetic acid ( $\alpha$ -NAA)**



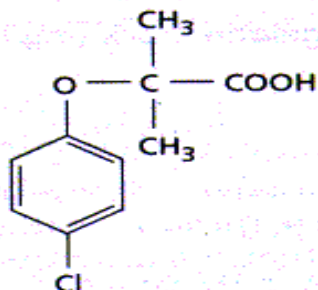
**2-Methoxy-3,6-dichlorobenzoic acid (dicamba)**



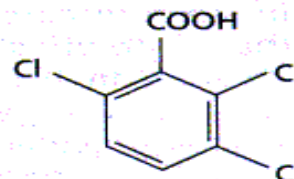
**4-Amino-3,5,6-trichloropicolinic acid (tordon or picloram)**



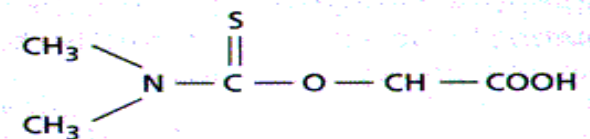
**2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)**



**$\alpha$ -(p-Chlorophenoxy)isobutyric acid (PCIB, an antiauxin)**



**2,3,6-Trichlorobenzoic acid**



**N,N-Dimethylethylthiocarbamate**

# Auxinas

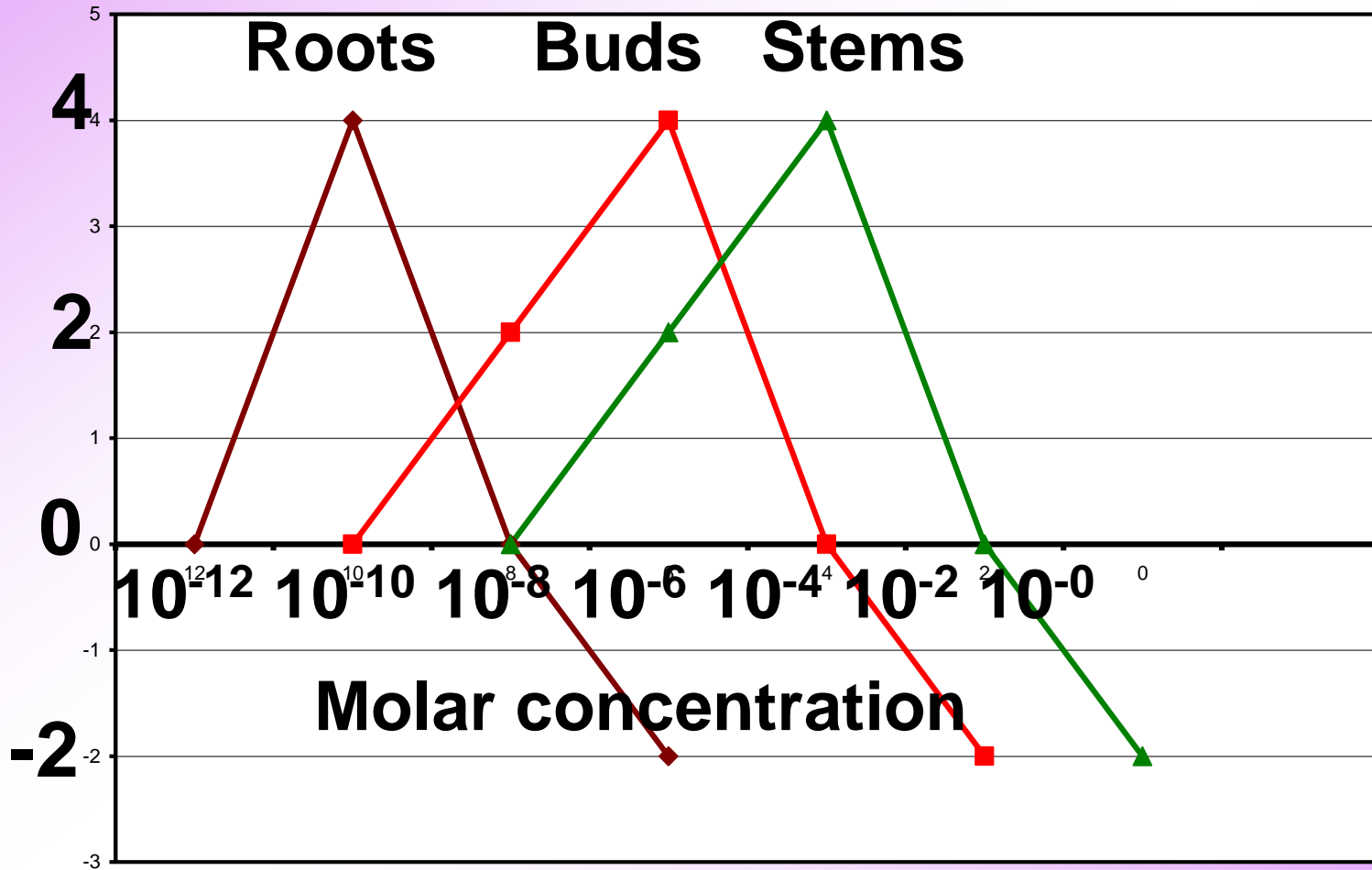
- ***Funciones principal:***
- Ø En el Crecimiento: Actúan en el crecimiento de la planta mediante división (mitosis), alargamiento y diferenciación de sus células.
- Ø Inhibición del desarrollo de las yemas laterales, favoreciendo el de las apicales.
- Ø Promueven la iniciación de las raíces en los esquejes de los tallos.
- Ø Partenocarpia y regulación del crecimiento del fruto.
- Ø Determinación del sexo en cucurbitáceas y floración en Anana.
- Ø Retarda o promueve la caída de hojas, flores y frutos, según dosis.
- Ø Tropismos en respuesta a la luz, gravedad y tacto

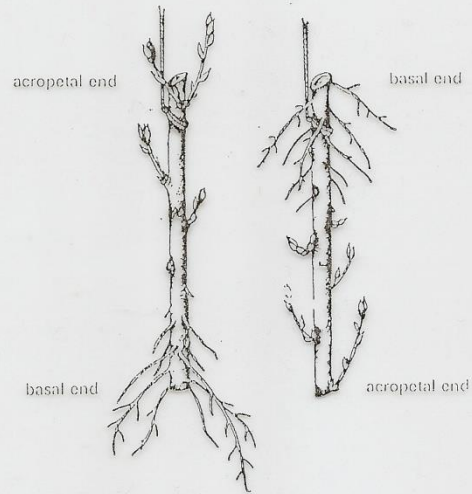
# AUXIN ACTION

- **Cell Wall Relaxation**
  - **Cell Elongation**
  - **Stimulation of Cell division**
  - **Enzyme Effects**
  - **RNA and Protein Synthesis**
  - **Prevents Abscission**
  - **Ethylene Production**
- Apical Dominance**
  - Direction of Translocation**
  - Organ Formation**
  - Tissue organization**
  - Tropic and Nastic Responses**

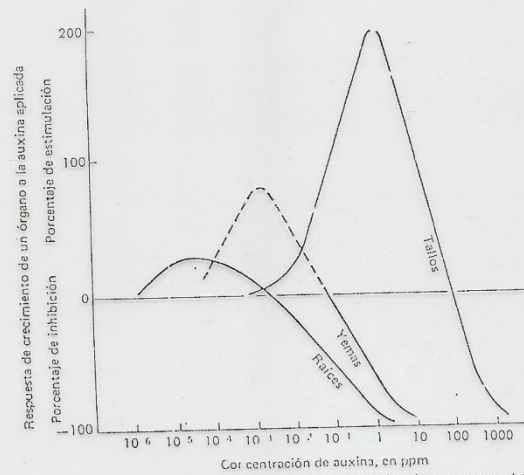


# AUXIN ACTIVITY



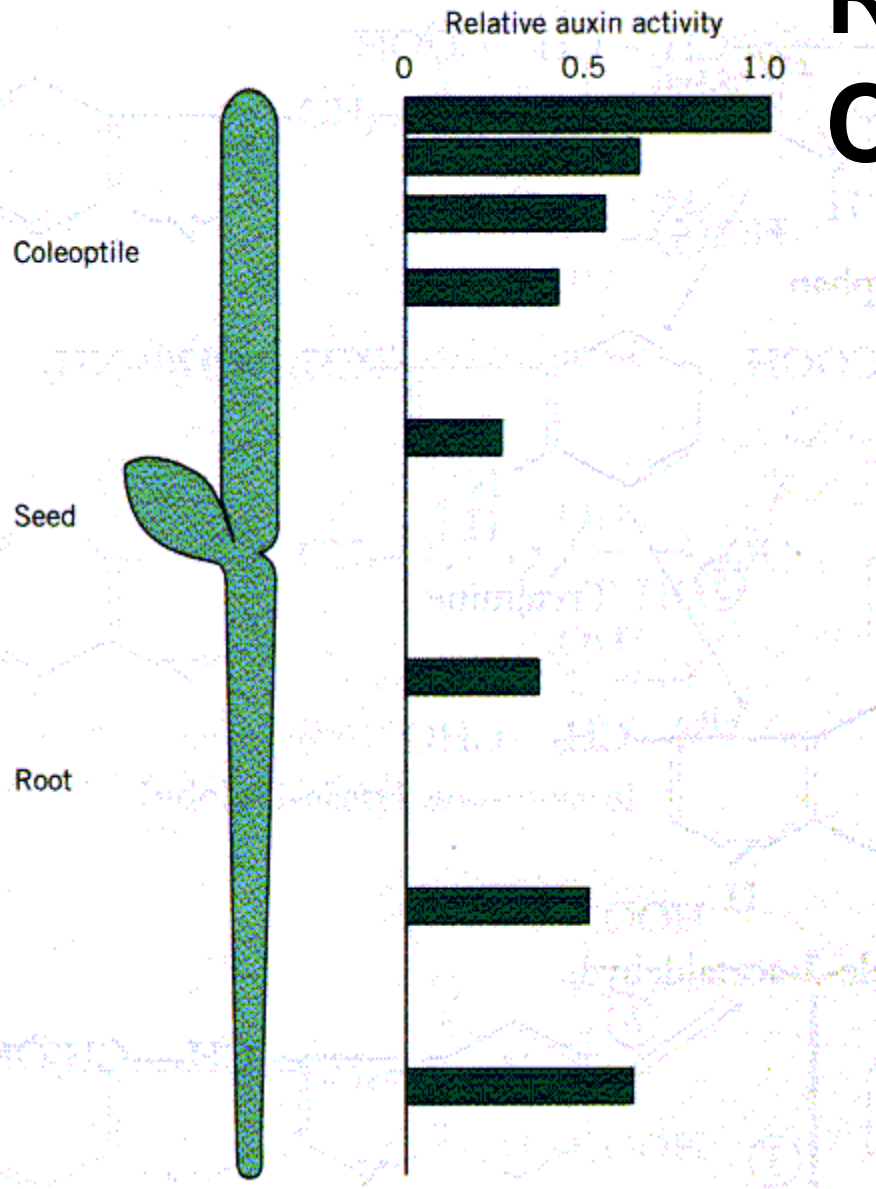


Polarity of root and bud formation in willow shoots suspended in moist air. (From E. W. Sinnott, 1960, *Plant Morphogenesis*, McGraw-Hill, New York, p. 120. Used by permission.)



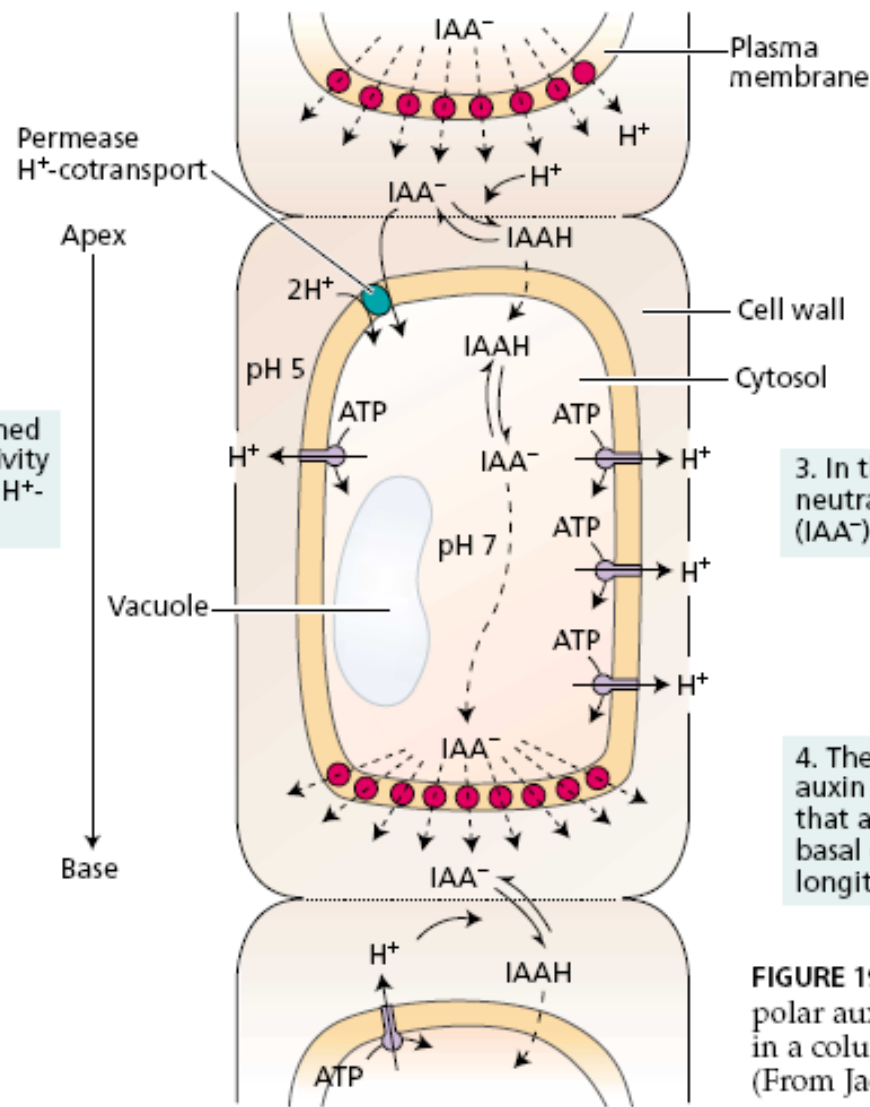
Curvas de respuesta que muestran el efecto de las diversas concentraciones de IAA sobre el crecimiento de tres órganos de la planta. (Según L. J. Audus, 1950. *Plant growth substances*. Interscience Publishers, New York.)

# RELATIVE AUXIN CONCENTRATION



# Auxinas

- ***Como actúan:***
- Una característica sorprendente de las auxinas es la fuerte polaridad exhibida en su transporte a través de la planta, la auxina es transportada por medio de un mecanismo dependiente de ATP, alejándose desde el ápice hasta su base.



1. IAA enters the cell either passively in the undissociated form (IAAH) or by secondary active cotransport in the anionic form (IAA<sup>-</sup>).

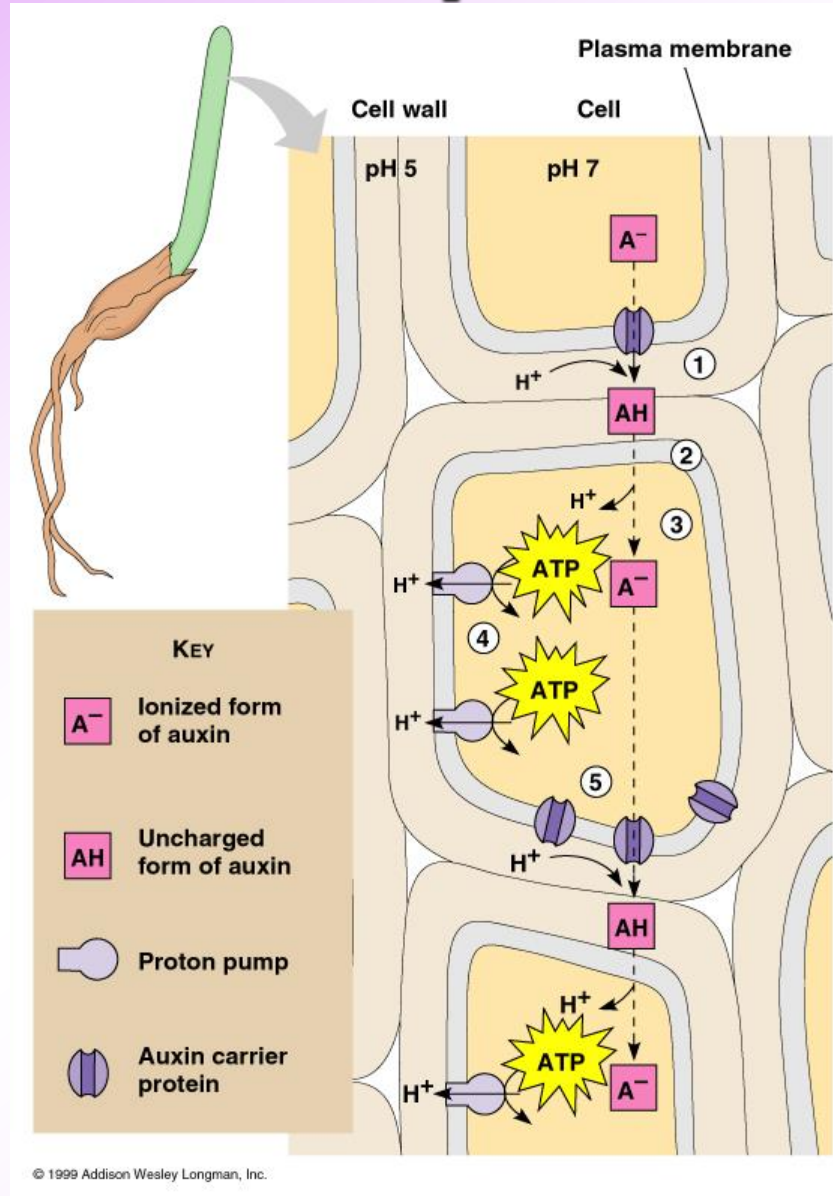
2. The cell wall is maintained at an acidic pH by the activity of the plasma membrane H<sup>+</sup>-ATPase.

3. In the cytosol, which has a neutral pH, the anionic form (IAA<sup>-</sup>) predominates.

4. The anions exit the cell via auxin anion efflux carriers that are concentrated at the basal ends of each cell in the longitudinal pathway.

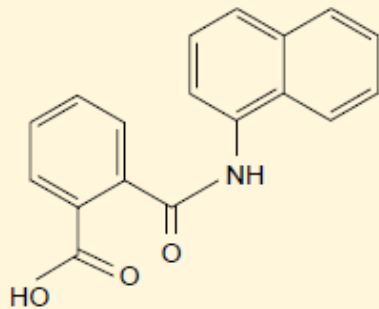
**FIGURE 19.13** The chemiosmotic model for polar auxin transport. Shown here is one cell in a column of auxin-transporting cells. (From Jacobs and Gilbert 1983.)

# Polar transport of Auxin

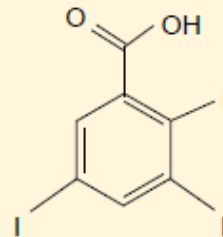


# Inhibidores del transporte de auxinas

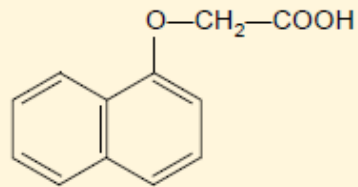
## Inhibidores del transporte de auxina que no se encuentran en plantas



NPA (Ácido 1-N-naftilftalámico)

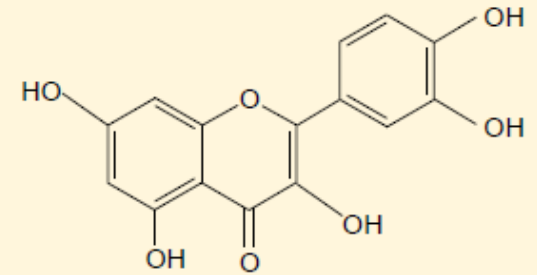


TIBA (Ácido 2,3,5-triyodobenzoico)

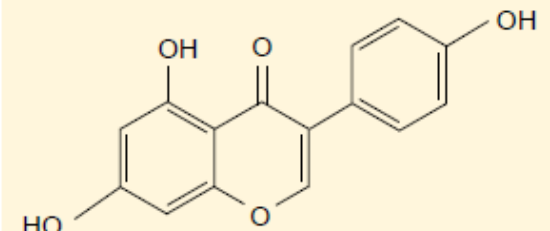


1-NOA (Ácido 1-naftoxiacético)

## Inhibidores del transporte de auxina que son producidos naturalmente

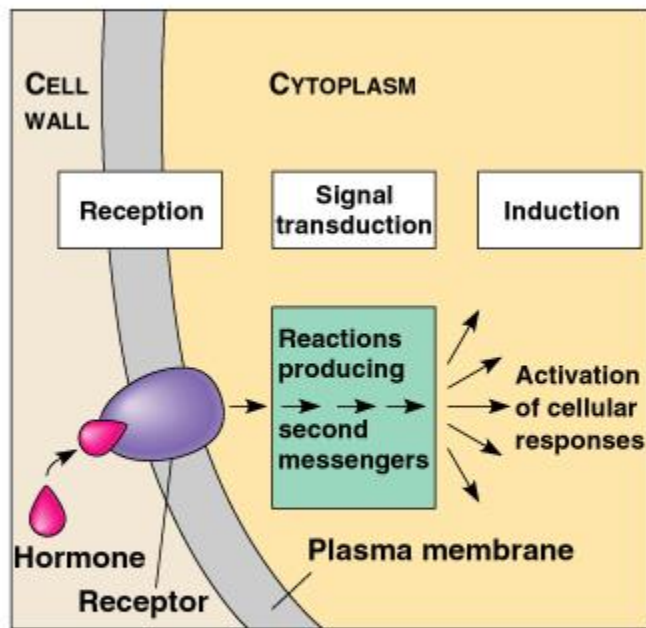


Quercetina (flavonol)

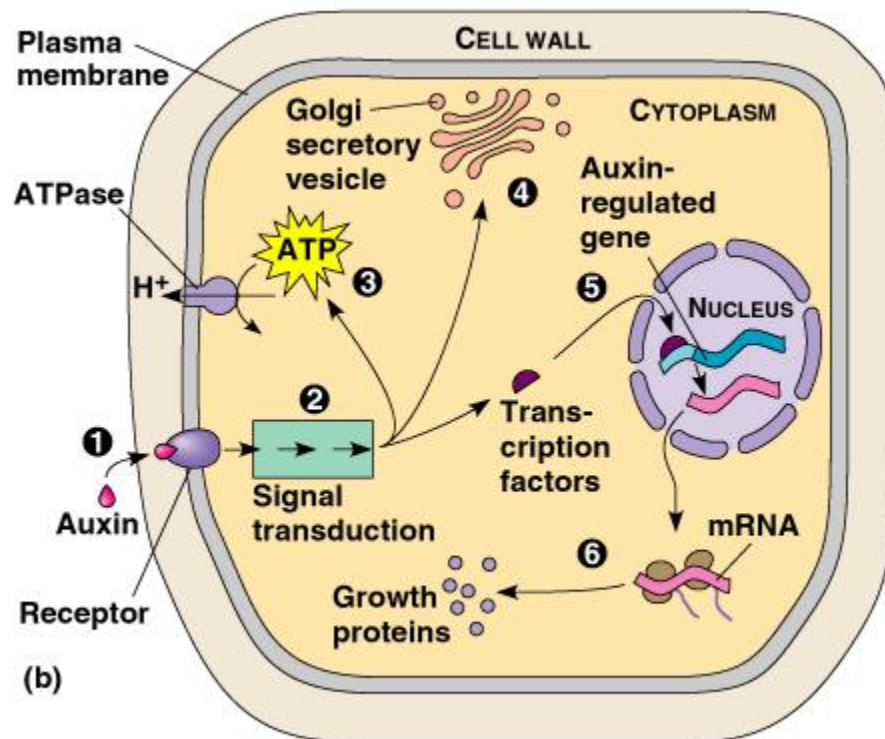


Genisteína

# Signal-transduction pathways in plants



(a)

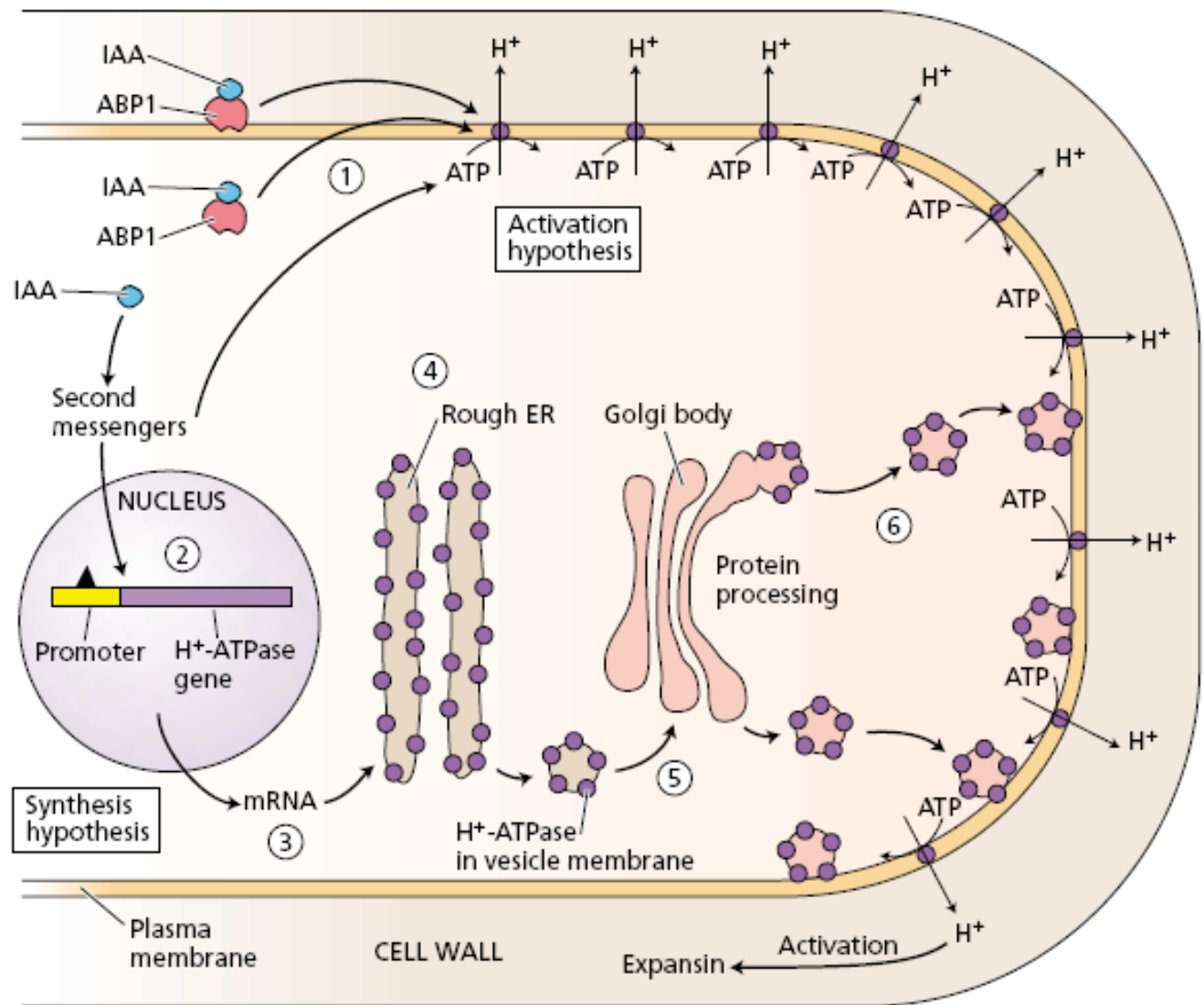


(b)



**Activation hypothesis:** Auxin binds to an auxin-binding protein (ABP1) located either on the cell surface or in the cytosol. ABP1-IAA then interacts directly with plasma membrane  $H^+$ -ATPase to stimulate proton pumping (step 1). Second messengers, such as calcium or intracellular pH, could also be involved.

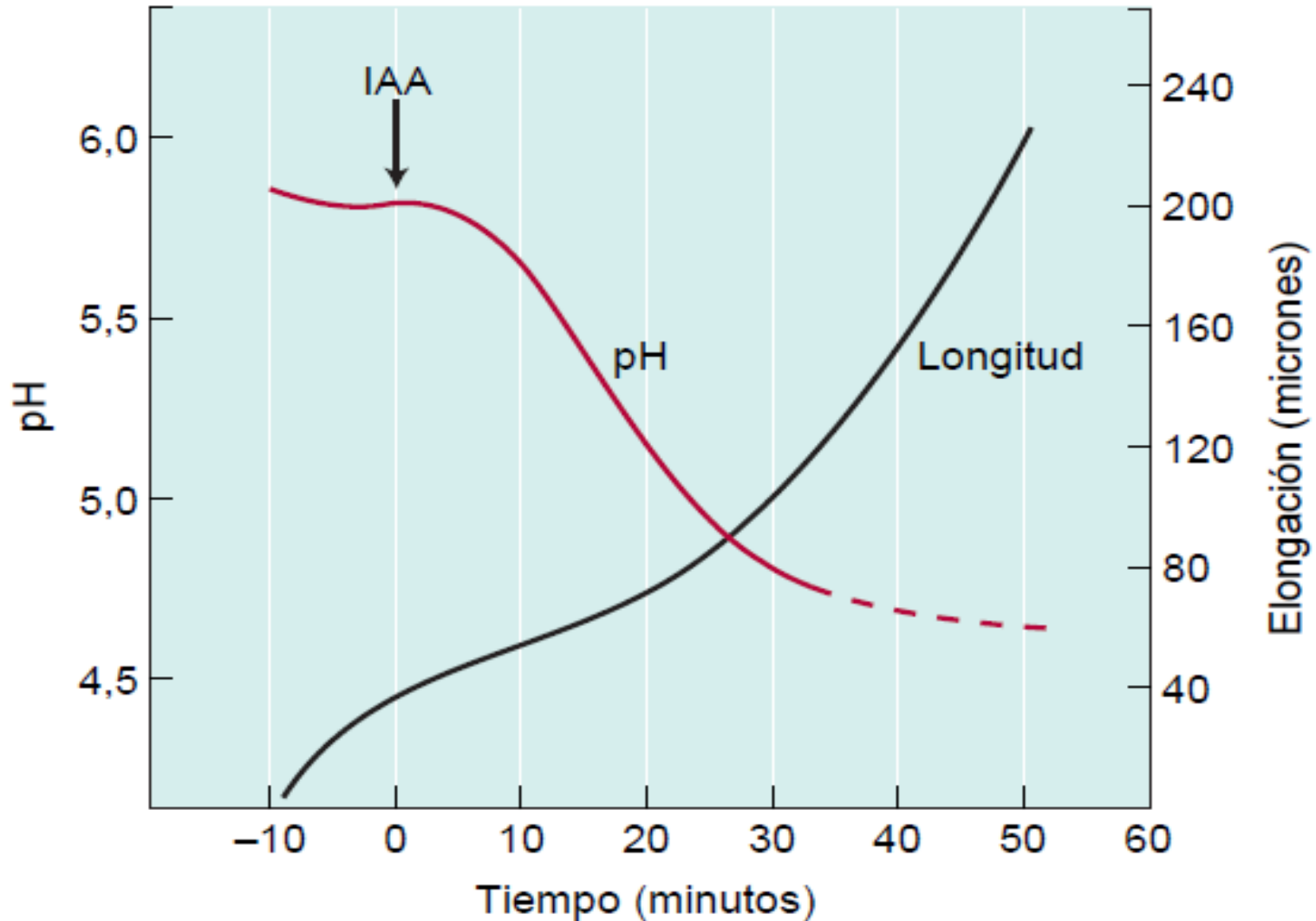
**Synthesis hypothesis:** IAA-induced second messengers activate the expression of genes (step 2) that encode the plasma membrane  $H^+$ -ATPase (step 3). The protein is synthesized on the rough endoplasmic reticulum (step 4) and targeted via the secretory pathway to the plasma membrane (steps 5 and 6). The increase in proton extrusion results from an increase in the number of proton pumps on the membrane.



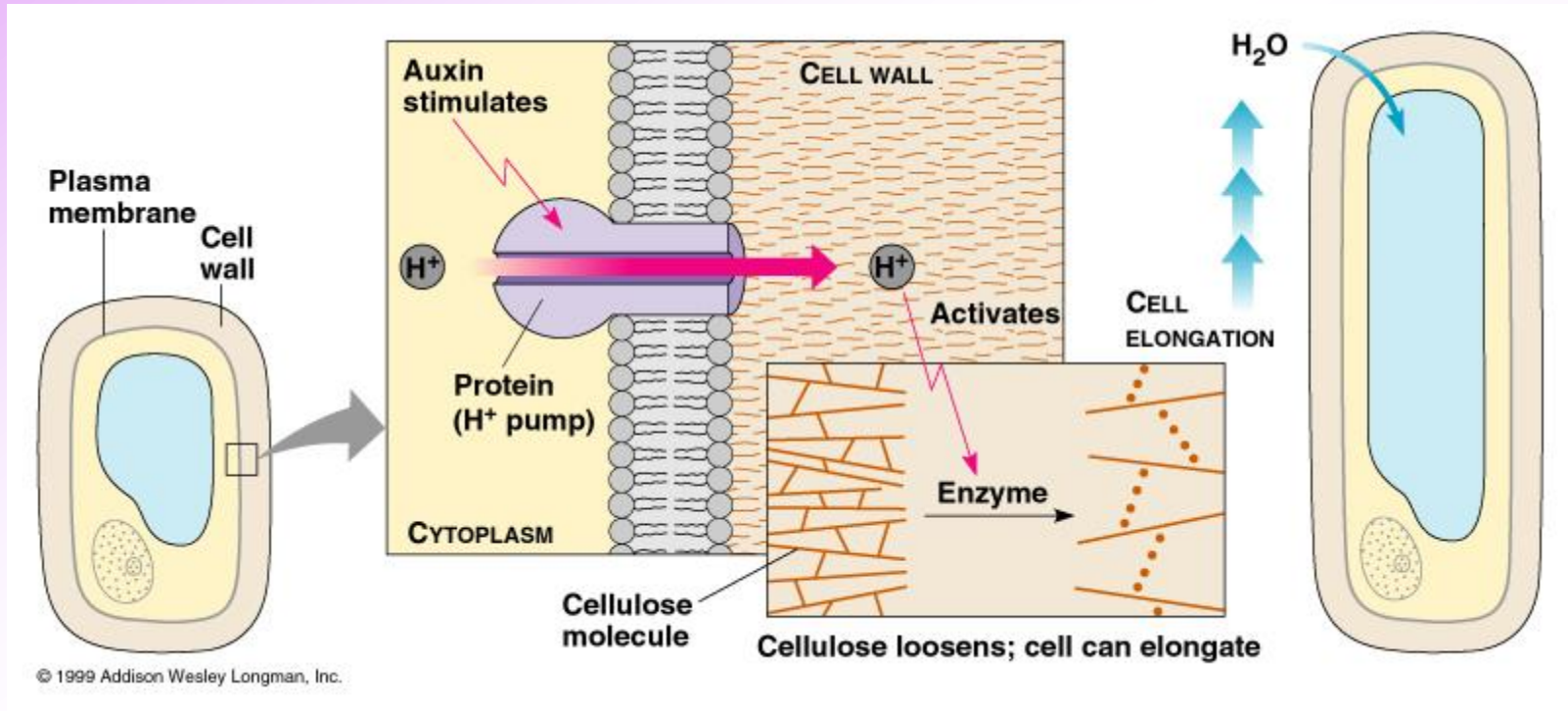
**FIGURE 19.25** Current models for IAA-induced  $H^+$  extrusion. In many plants, both of these mechanisms may operate. Regardless of how  $H^+$  pumping is increased, acid-induced wall loosening is thought to be mediated by expansins.

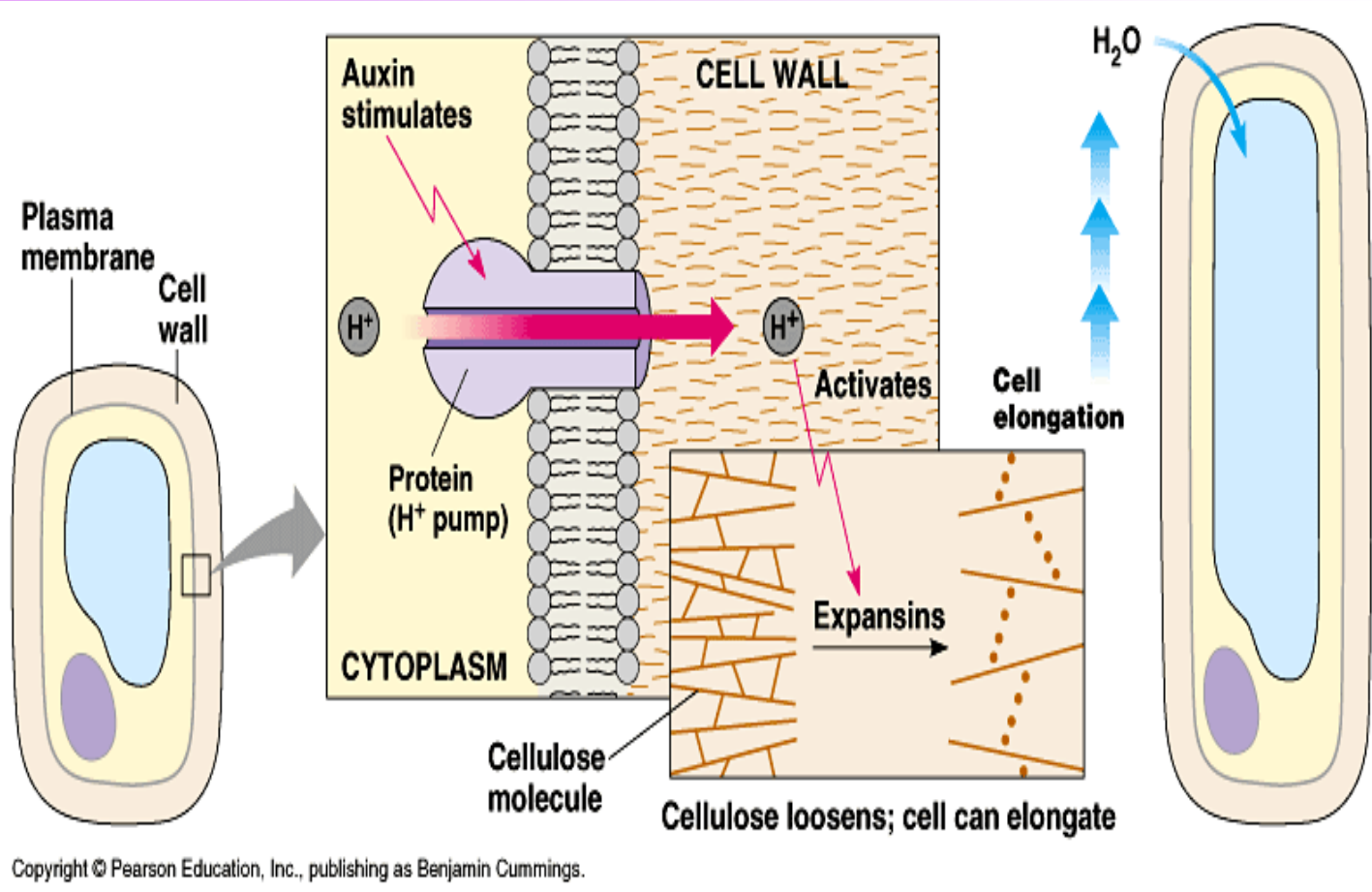
# Efectos fisiológicos

## Extensibilidad de la pared



# Loosening of cell wall





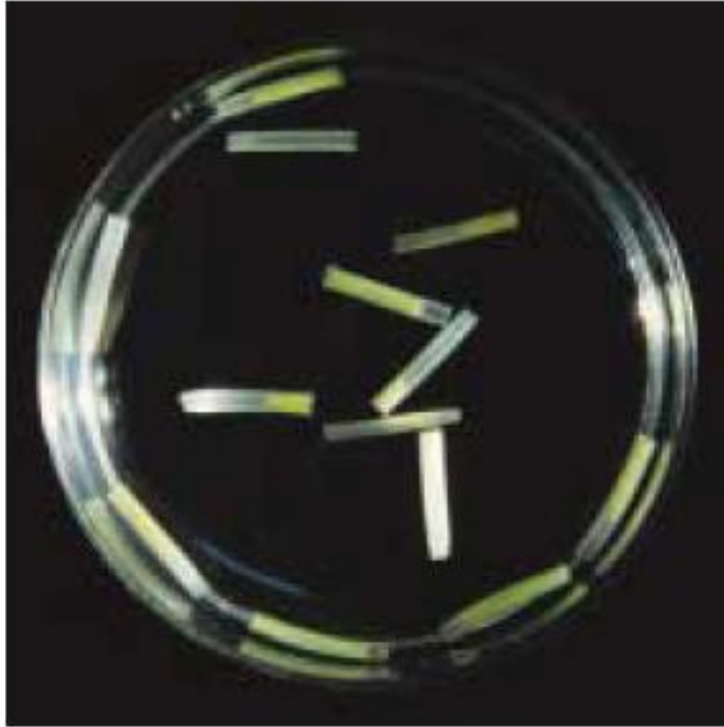
$$\Psi_{sol} = \Psi_c = \Psi_s + \Psi_p$$

$$-0,1 = -0,1 = -1,1 + 1 \text{ MPa}$$

$$-0,1 = -0,6 = -1,1 + 0,5 \text{ Mpa}$$



(A)



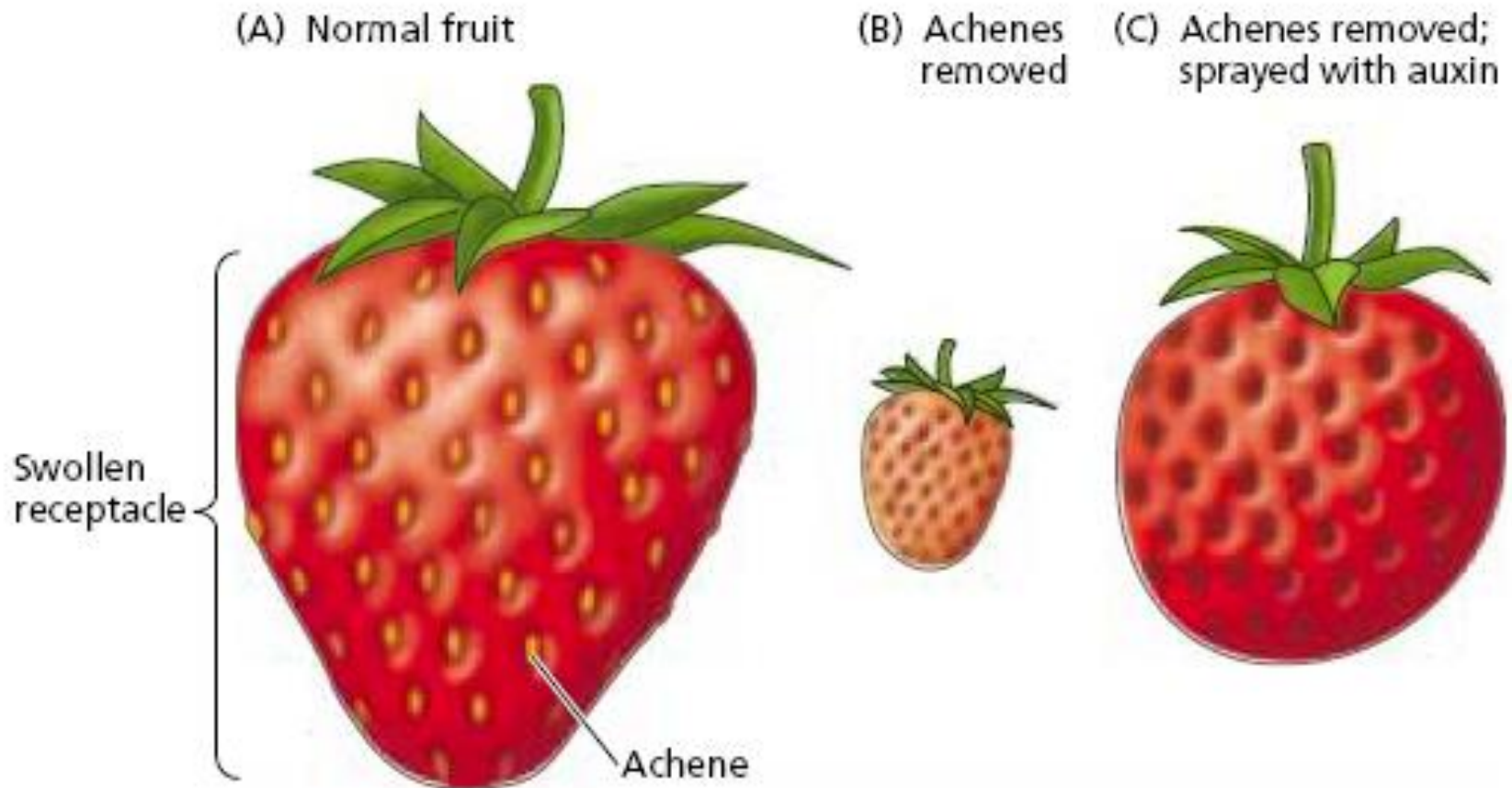
(B)



**FIGURE 19.2** Auxin stimulates the elongation of oat coleoptile sections. These coleoptile sections were incubated for 18 hours in either water (A) or auxin (B). The yellow tissue inside the translucent coleoptile is the primary leaves. (Photos © M. B. Wilkins.)



**FIGURE 19.12** Roots grow from the basal ends of these bamboo sections, even when they are inverted. The roots form at the basal end because polar auxin transport in the shoot is independent of gravity. (Photo ©M. B. Wilkins.)



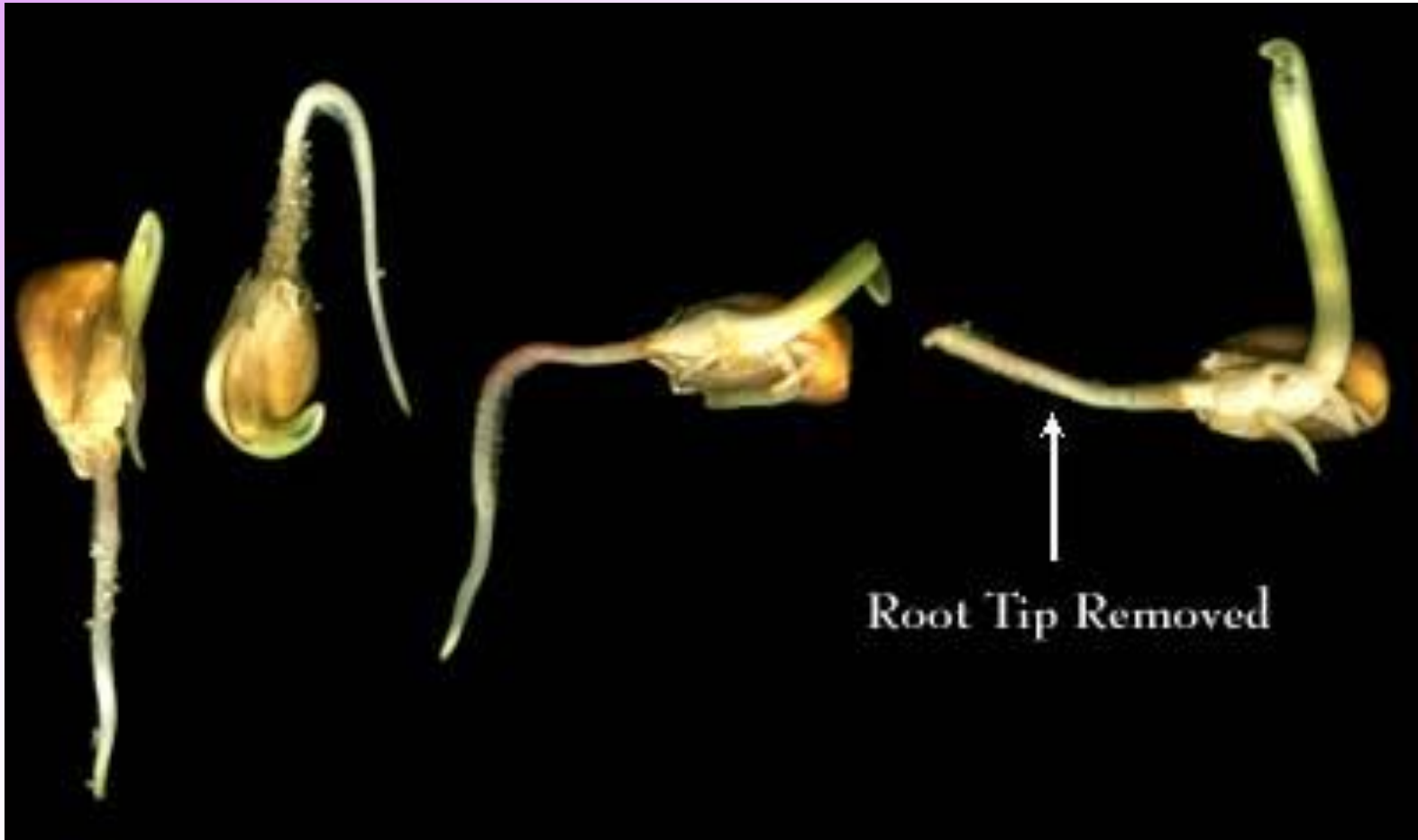
**FIGURE 19.39** (A) The strawberry “fruit” is actually a swollen receptacle whose growth is regulated by auxin produced by the “seeds,” which are actually achenes—the true fruits. (B) When the achenes are removed, the receptacle fails to develop normally. (C) Spraying the achene-less receptacle with IAA restores normal growth and development. (After A. Galston 1994.)

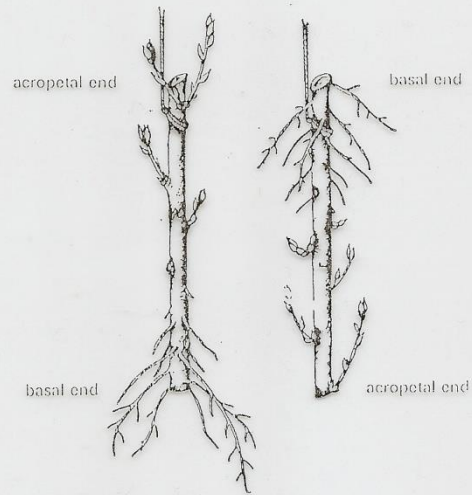


**FIGURE 19.29** Lateral auxin gradients are formed in *Arabidopsis* hypocotyls during the differential growth responses to light (A) and gravity (B). The plants were transformed with the *DR5::GUS* reporter gene. Auxin accumulation on the shaded (A) or lower (B) side of the hypocotyls is indicated by the blue staining shown in the insets. (Photos courtesy of Klaus Palme.)

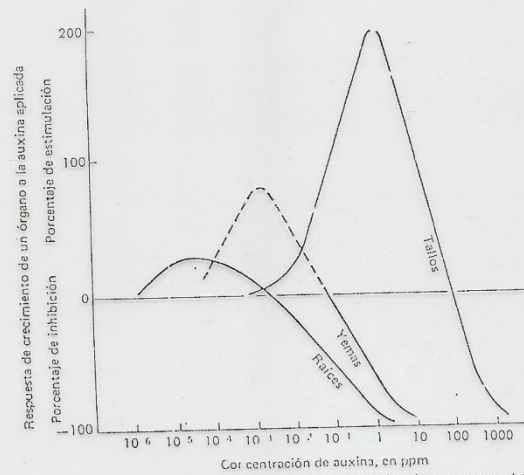


# Geotropism

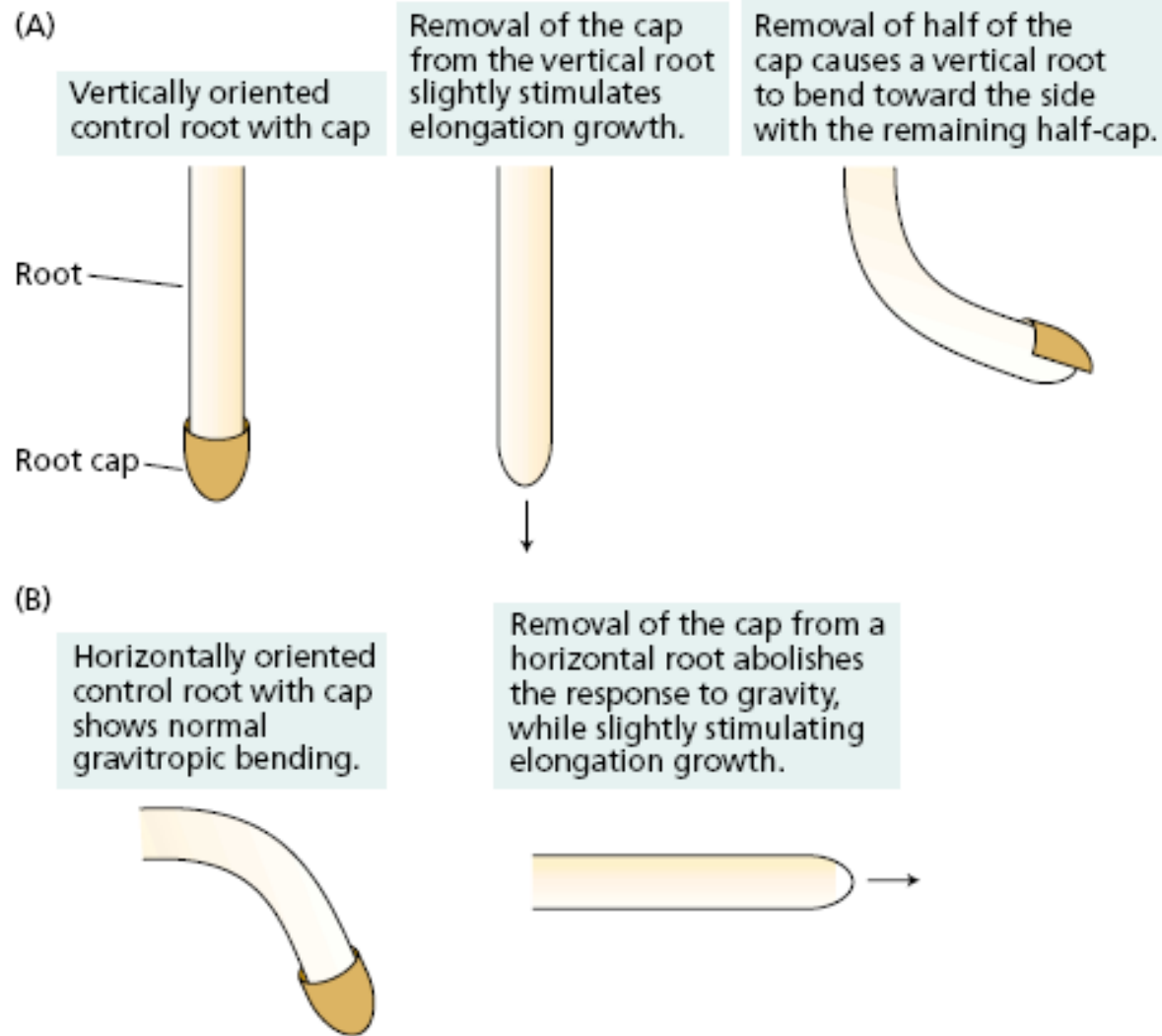




Polarity of root and bud formation in willow shoots suspended in moist air. (From E. W. Sinnott, 1960, *Plant Morphogenesis*, McGraw-Hill, New York, p. 120. Used by permission.)

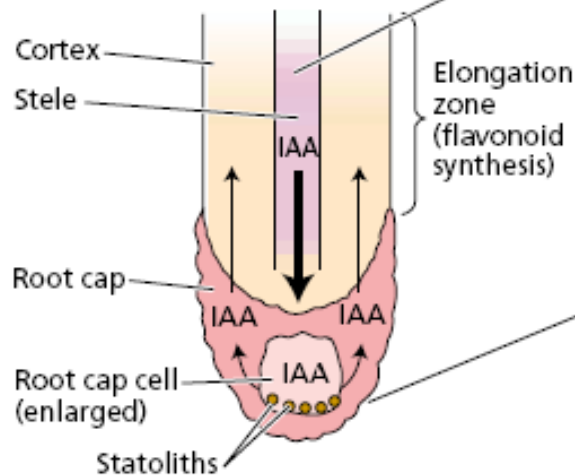


Curvas de respuesta que muestran el efecto de las diversas concentraciones de IAA sobre el crecimiento de tres órganos de la planta. (Según L. J. Audus, 1950. *Plant growth substances*. Interscience Publishers, New York.)



**FIGURE 19.31** Microsurgery experiments demonstrating that the root cap produces an inhibitor that regulates root gravitropism. (After Shaw and Wilkins 1973.)

(A) Vertical orientation



1. IAA is synthesized in the shoot and transported to the root in the stele.

2. When the root is vertical, the statoliths in the cap settle to the basal ends of the cells. Auxin transported acropetally in the root via the stele is distributed equally on all sides of the root cap. The IAA is then transported basipetally within the cortex to the elongation zone, where it regulates cell elongation.

**FIGURE 19.33** Proposed model for the redistribution of auxin during gravitropism in maize roots. (After Hasenstein and Evans 1988.)

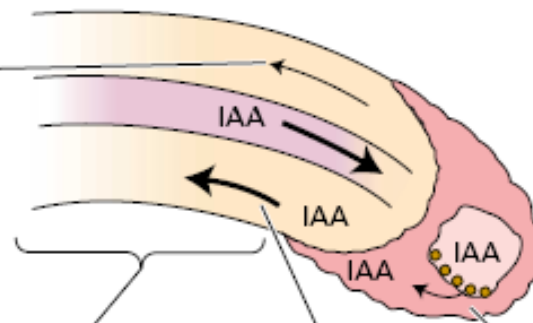
(B) Horizontal orientation

6. The decreased auxin concentration on the upper side stimulates the upper side to grow. As a result, the root bends down.

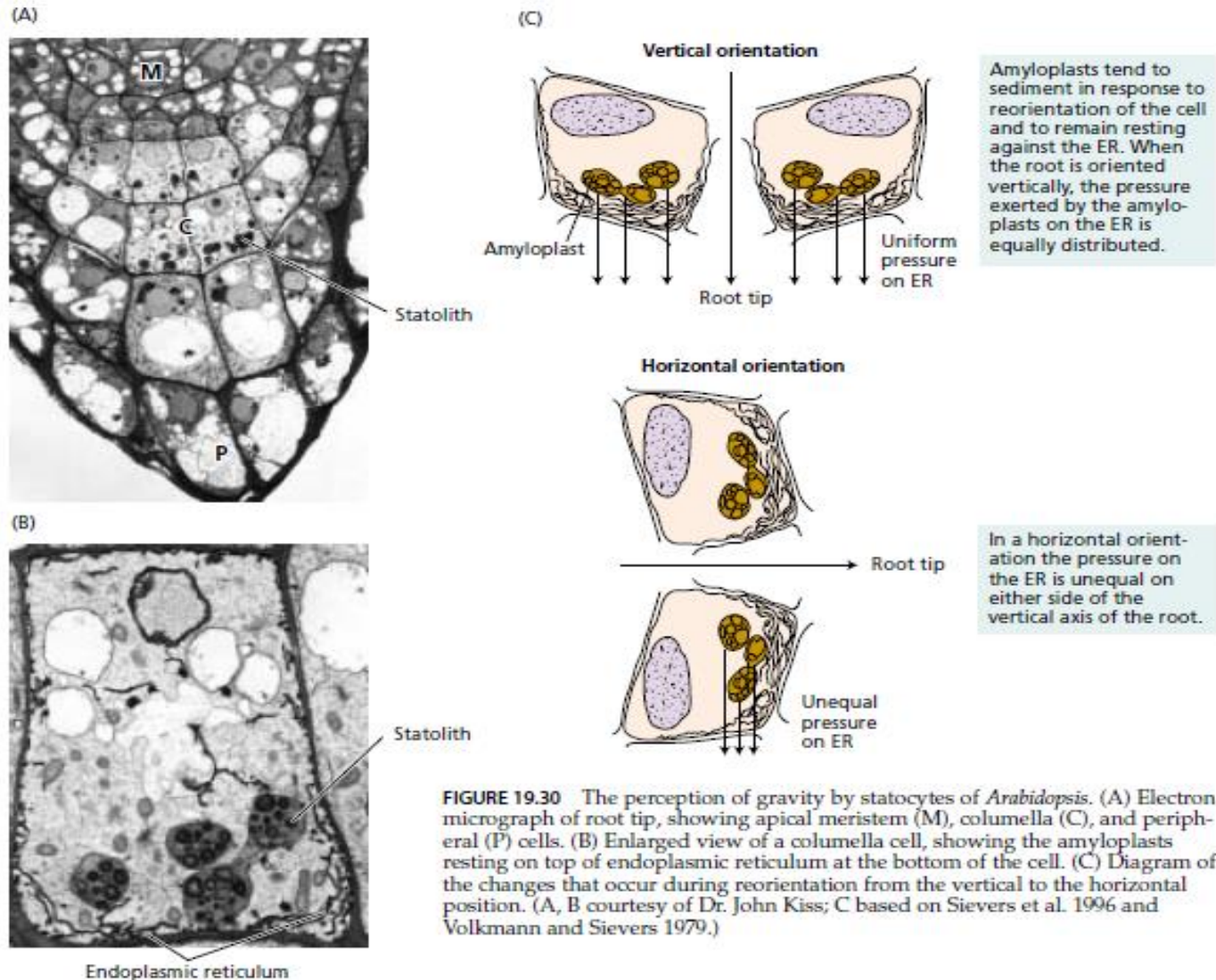
5. The high concentration of auxin on the lower side of the root inhibits growth.

4. The majority of the auxin in the cap is then transported basipetally in the cortex on the lower side of the root.

3. In a horizontal root the statoliths settle to the side of the cap cells, triggering polar transport of IAA to the lower side of the cap.



# Gravitropism Also Involves Lateral Redistribution of Auxin



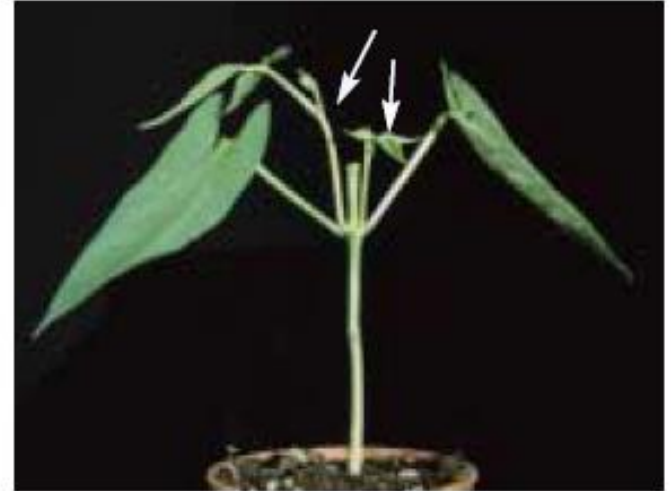
**FIGURE 19.30** The perception of gravity by statocytes of *Arabidopsis*. (A) Electron micrograph of root tip, showing apical meristem (M), columella (C), and peripheral (P) cells. (B) Enlarged view of a columella cell, showing the amyloplasts resting on top of endoplasmic reticulum at the bottom of the cell. (C) Diagram of the changes that occur during reorientation from the vertical to the horizontal position. (A, B courtesy of Dr. John Kiss; C based on Sievers et al. 1996 and Volkmann and Sievers 1979.)

**FIGURE 19.36** Auxin suppresses the growth of axillary buds in bean (*Phaseolus vulgaris*) plants. (A) The axillary buds are suppressed in the intact plant because of apical dominance. (B) Removal of the terminal bud releases the axillary buds from apical dominance (arrows). (C) Applying IAA in lanolin paste (contained in the gelatin capsule) to the cut surface prevents the outgrowth of the axillary buds. (Photos ©M. B. Wilkins.)

(A)



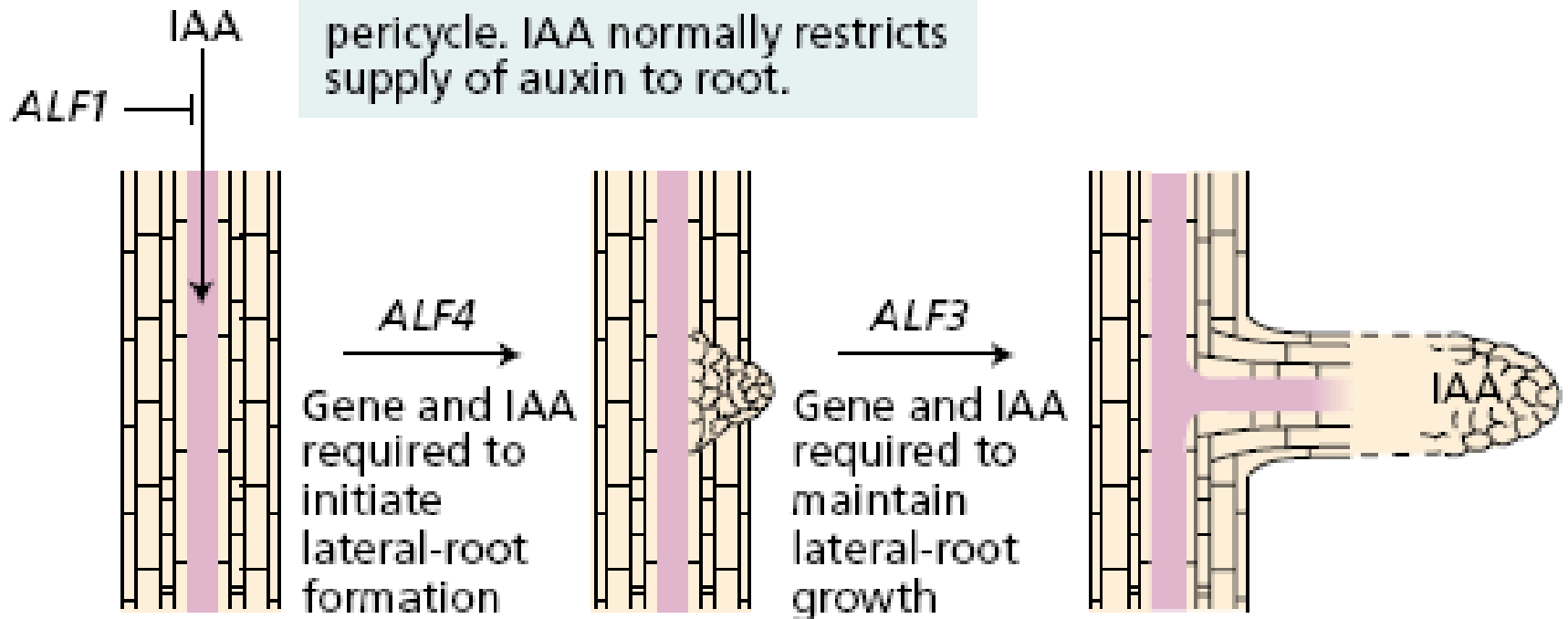
(B)



(C)

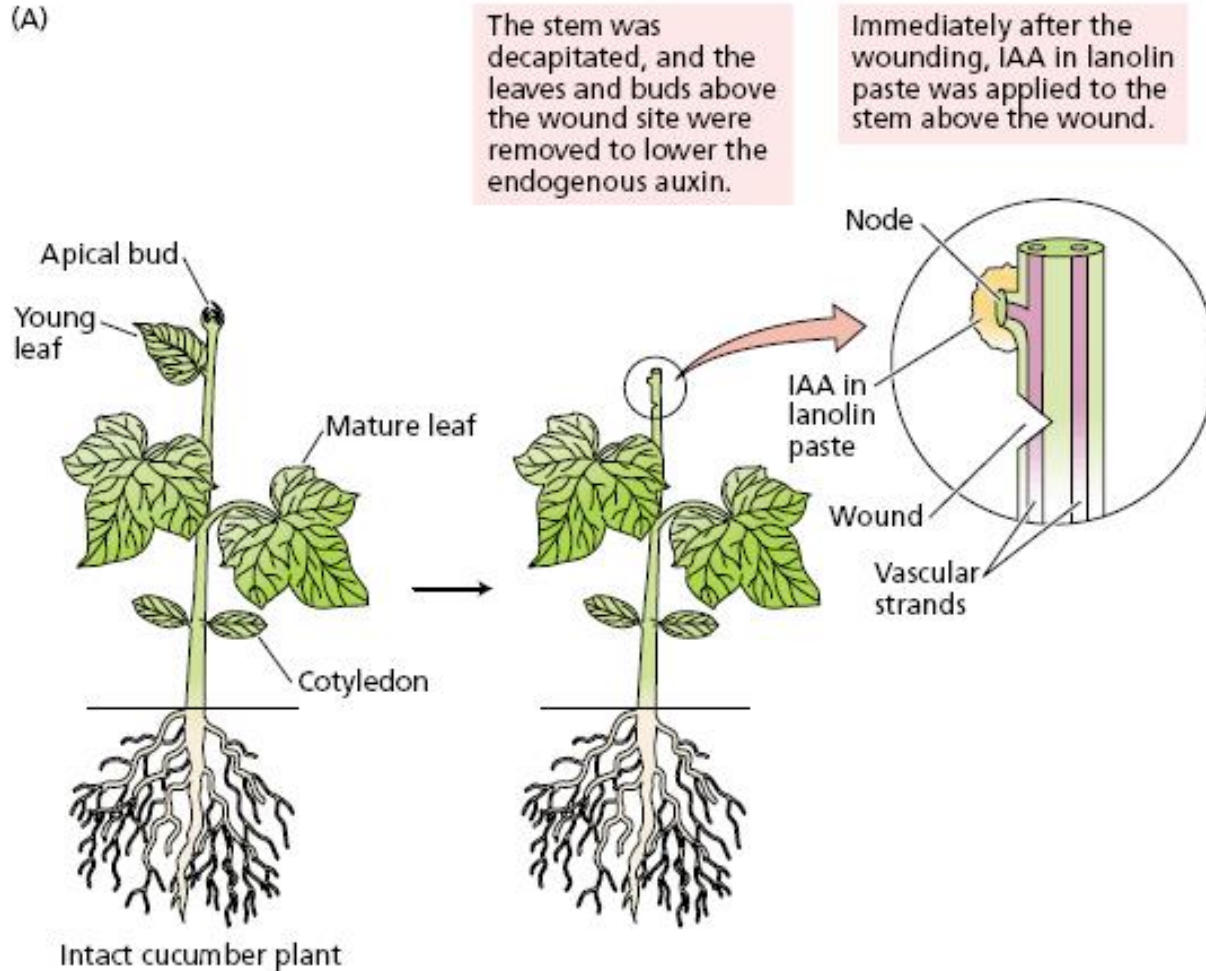


IAA transported acropetally in the vascular cylinder is required to initiate cell division in the pericycle. IAA normally restricts supply of auxin to root.



**FIGURE 19.38** A model for the formation of lateral roots, based on the *alf* mutants of *Arabidopsis*. (After Celenza et al. 1995.)

(A)



(B)



Xylem differentiation occurs around the wound, following the path of auxin diffusion.

**FIGURE 19.40** IAA-induced xylem regeneration around the wound in cucumber (*Cucumis sativus*) stem tissue. (A) Method for carrying out the wound regeneration experiment. (B) Fluorescence micrograph showing regenerating vascular tissue around the wound. (B courtesy of R. Aloni.)



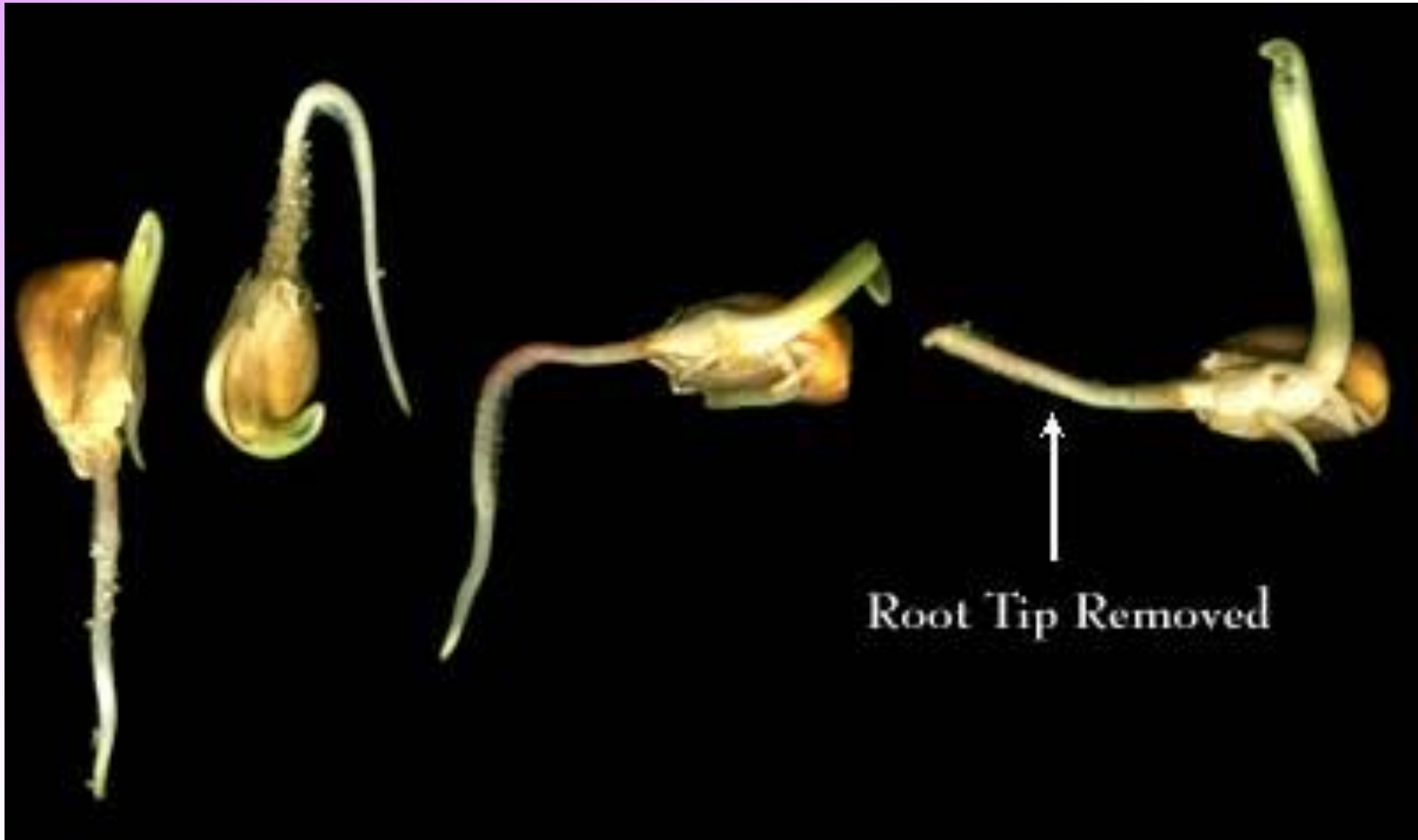
# **Tropic responses**

Directional movements in  
response to a directional stimulus

# Phototropism



# Geotropism



# Thigmotropism





# HERBICIDAS AUXÍNICOS



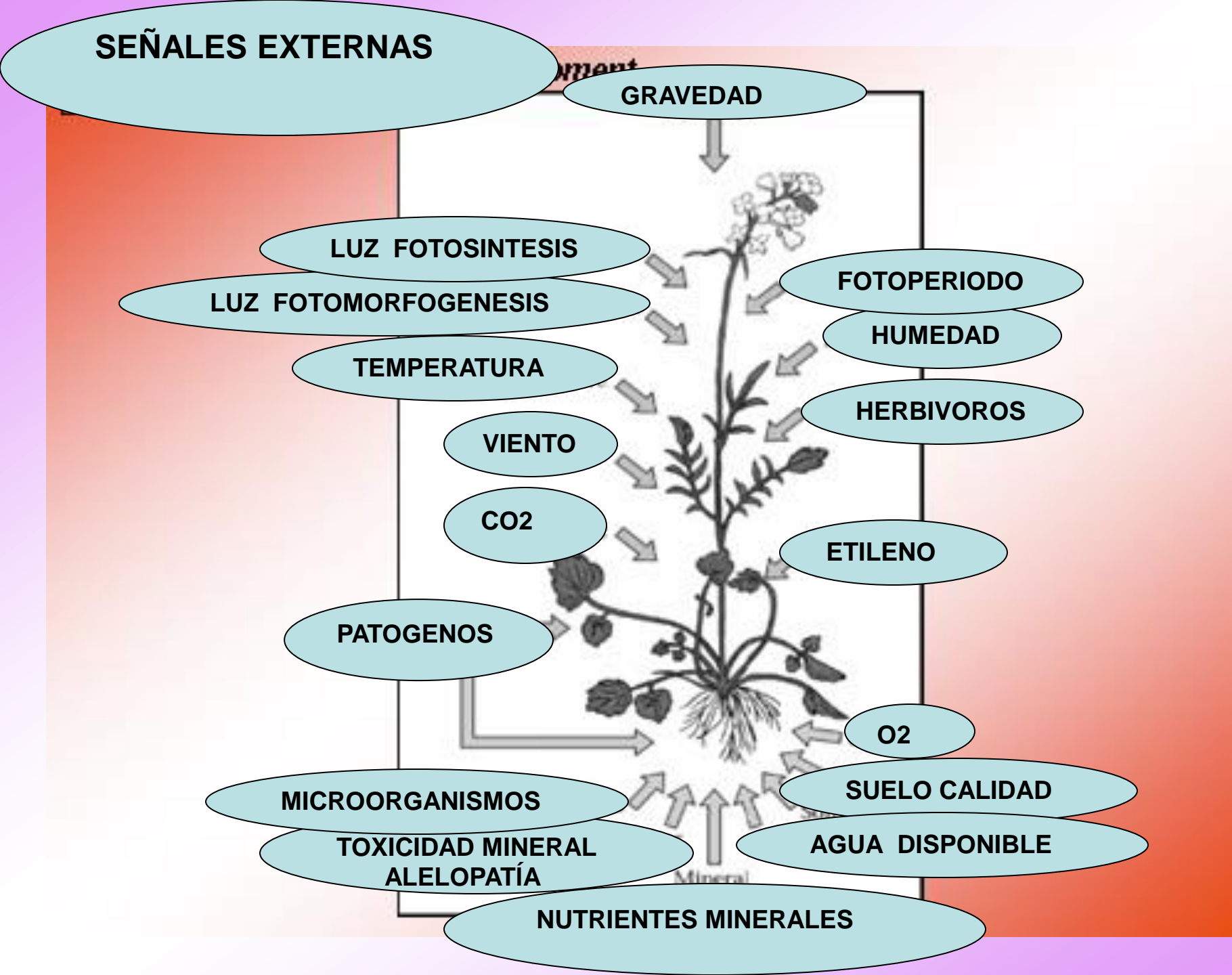
# DICAMBA, Auxinico



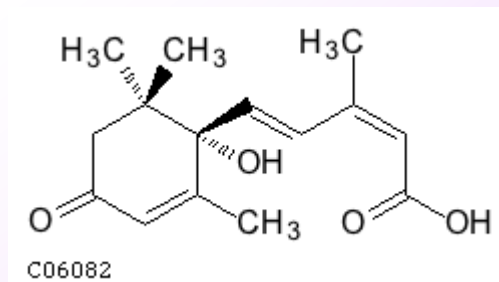
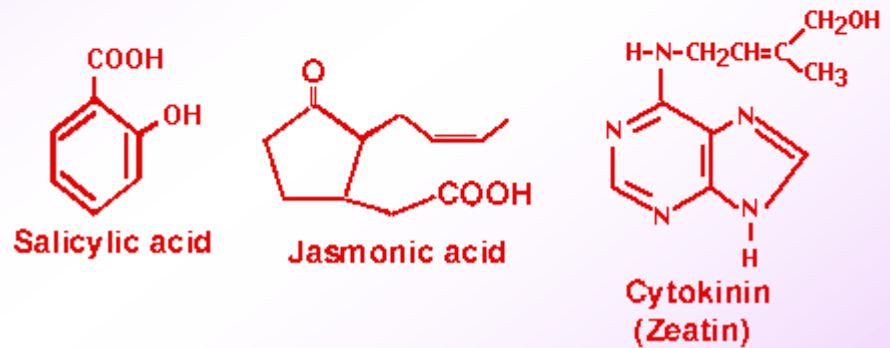
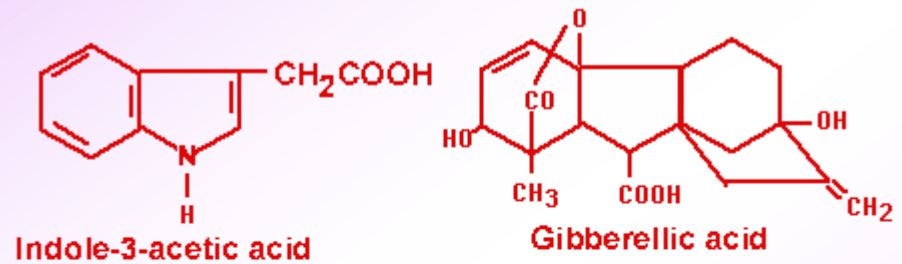
# Aplicaciones comerciales

- **Inducción de partenocarpia en frutos**
- **Enraizamiento y propagación de estacas**
- **Acción herbicida**
- **Inhibición de brotación de yemas en tubérculos de papa**
- **Floración sincronizada en ananá**
- **Flores femeninas en cucurbitáceas**
- **Abscisión o retardo de hojas, flores y frutos.**

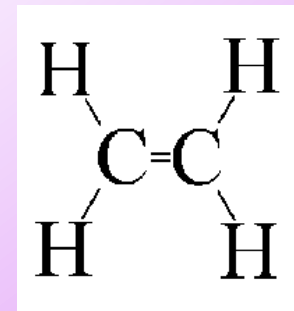




- ✓ Auxinas
- ✓ Giberelinas
- ✓ Citocininas
- ✓ Ácido abscísico
- ✓ Etileno
- ✓ Ácido jasmónico
- ✓ Ácido salicílico



Ácido abscísico



Etileno

# Giberelinas



# Genes controlling GA synthesis are important genes “green revolution”



Distinguished plant breeder and Nobel Laureate  
[Norman Borlaug](#) 1914-2009

Tremendous increases in crop yields (the Green Revolution) during the 20<sup>th</sup> century occurred because of increased use of fertilizer and the introduction of semidwarf varieties of grains.

The semidwarf varieties put more energy into seed production than stem growth, and are sturdier and less likely to fall over.

Photos courtesy of S. Harrison, [LSU Ag center](#) and [The World Food Prize](#).

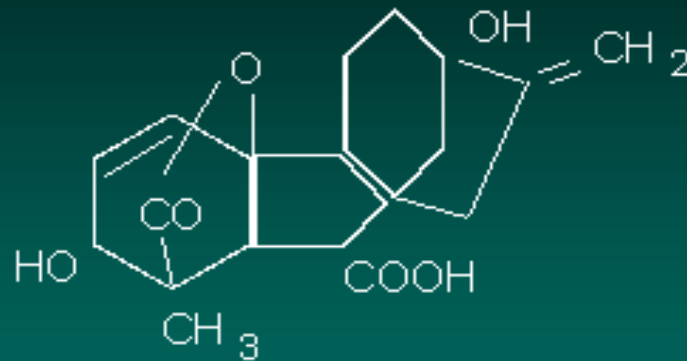
# QUE SON LAS GIBERELINAS

**Son compuestos isoprenoides que proceden del ácido mevalónico y forman parte del grupo de las hormonas reguladoras del crecimiento. Existen varios tipos de giberelinas, siendo los más comunes: GA1, GA3, GA4, GA7 y GA9. Se encuentran en todos los órganos de las plantas superiores, siendo más abundantes en tejidos de rápido crecimiento y desarrollo como los meristemos apicales**

# ESTRUCTURA QUIMICA DEL ACIDO GIBERELICO.



## *GIBERELINAS*



GA<sub>3</sub>

Las giberlinas son sintetizadas en los primordios apicales de las hojas, en puntas de las raíces y en semillas en desarrollo.

Se trasladan por aposimplasto, xilema y floema

Son las promotoras de la iniciación enzimática en el proceso de germinación, y se encuentran en diferentes concentraciones dependiendo de los estadios de las semillas, ya sea en reposo o no.

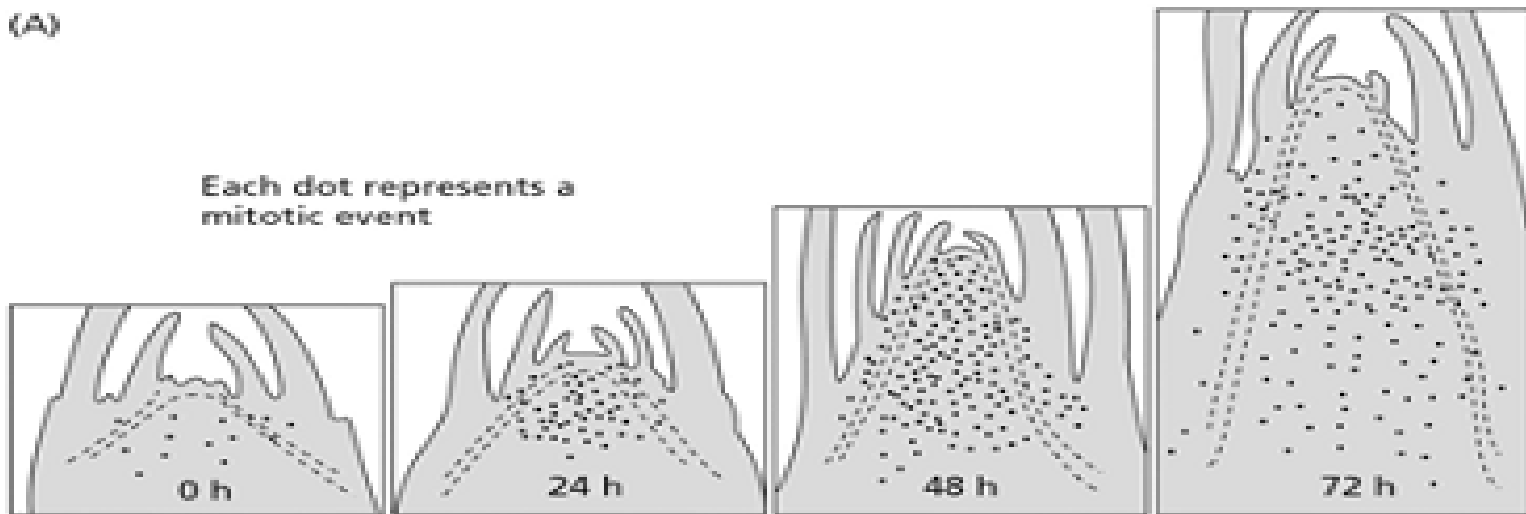
Han sido identificadas y cuantificadas por cromatografía gaseosa.

# Giberelinas en el Crecimiento

## Mechanism of stem elongation: increased cell division

(A)

Each dot represents a  
mitotic event



Distribution of cell division following application of GA

PLANT PHYSIOLOGY, Third Edition, Figure 26.24 (Part 1) © 2002 Sinauer Associates, Inc.



# FUNCIONES

- Incrementan el crecimiento de los tallos, en plantas enanas (plantas enteras)
- Inducen la brotación de yemas
- \* Interrumpen el período de Dormición de las semillas
- \* Promueven el desarrollo de los frutos, partenocarpia.
- Promueven la división del cambium.
- Promueve la división celular en el meristema subapical
- \* Incrementan el alargamiento celular.
- \* Producen cambios en la morfogénesis.

## ❖ Lugares principales de formación

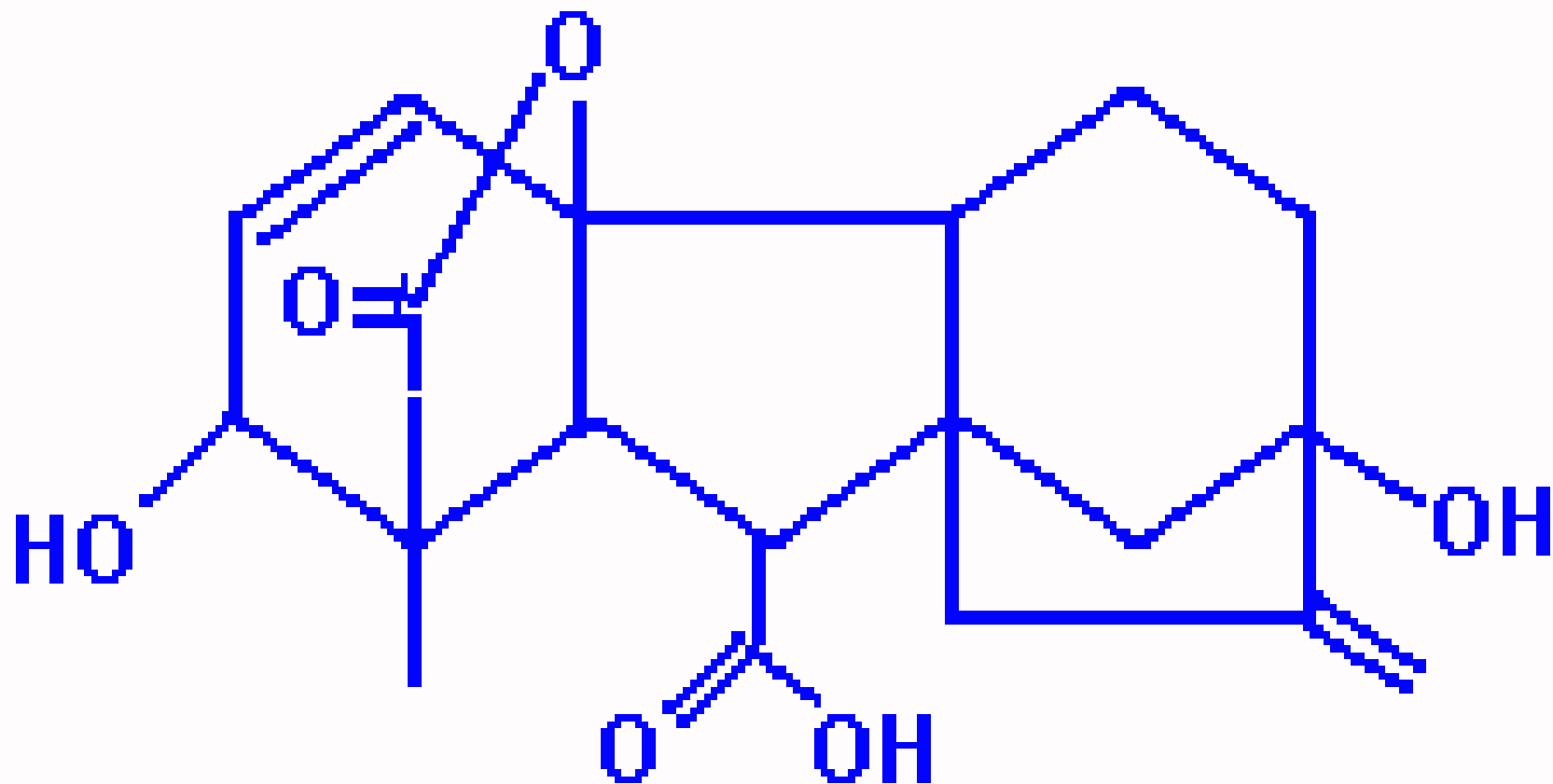
- Meristemos primarios
- Embriones y frutos inmaduros
- Hojas jóvenes

## ❖ Transporte dentro de la planta

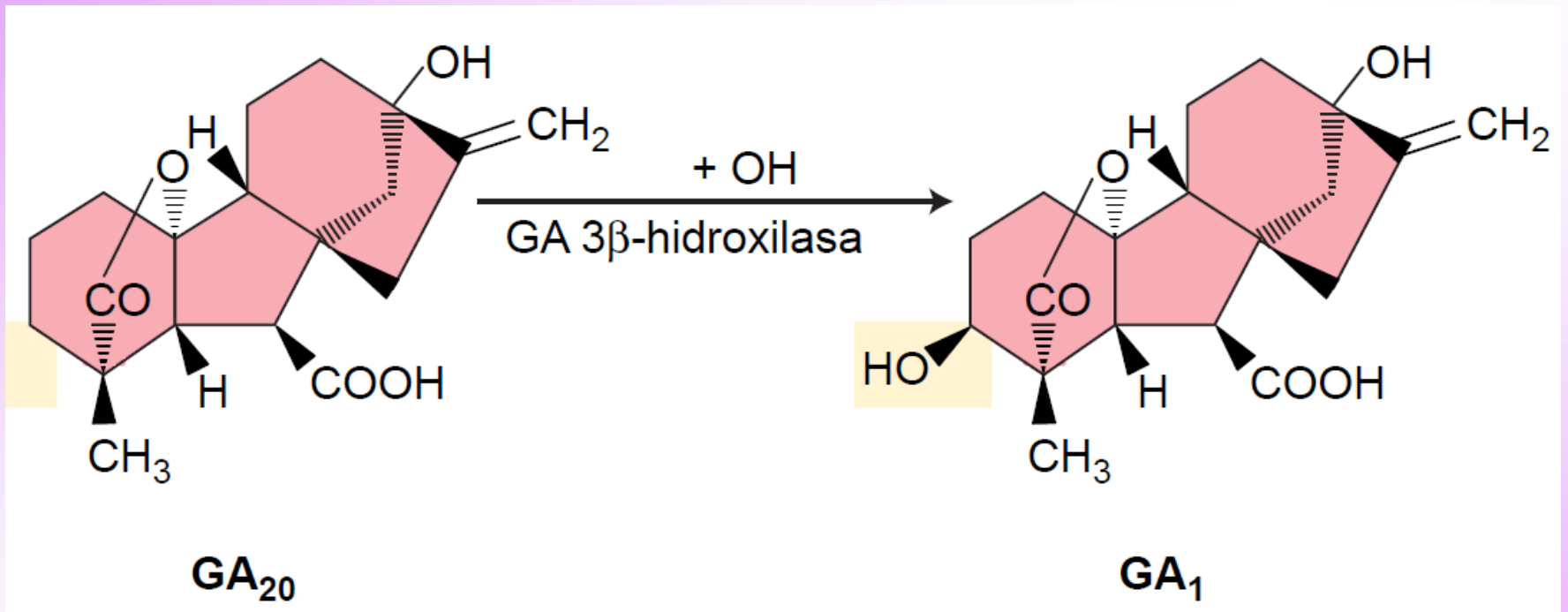
- Apolar
- Por apoplasto y simpasto, sin gasto de ATP.

## ❖ Algunos Efectos

- Crecimiento de elongación.
- División del cambium
- Inducen la floración en plantas que requieren vernalización y DL
- Rompen la Dormición en los estados de Reposo en semillas y yemas.



**Gibberellic acid (GA<sub>3</sub>)**



GA<sub>1</sub> es la forma activa

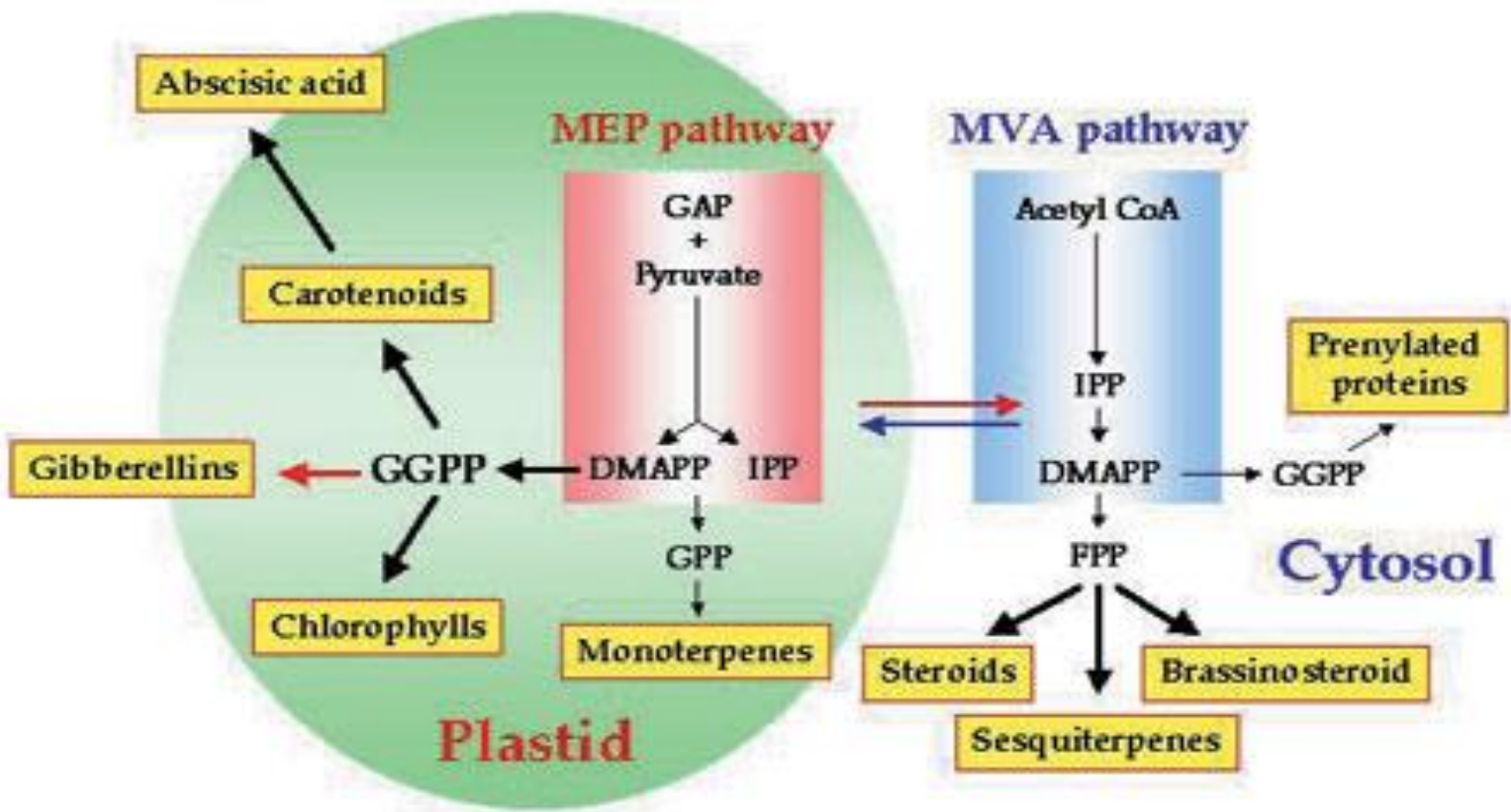
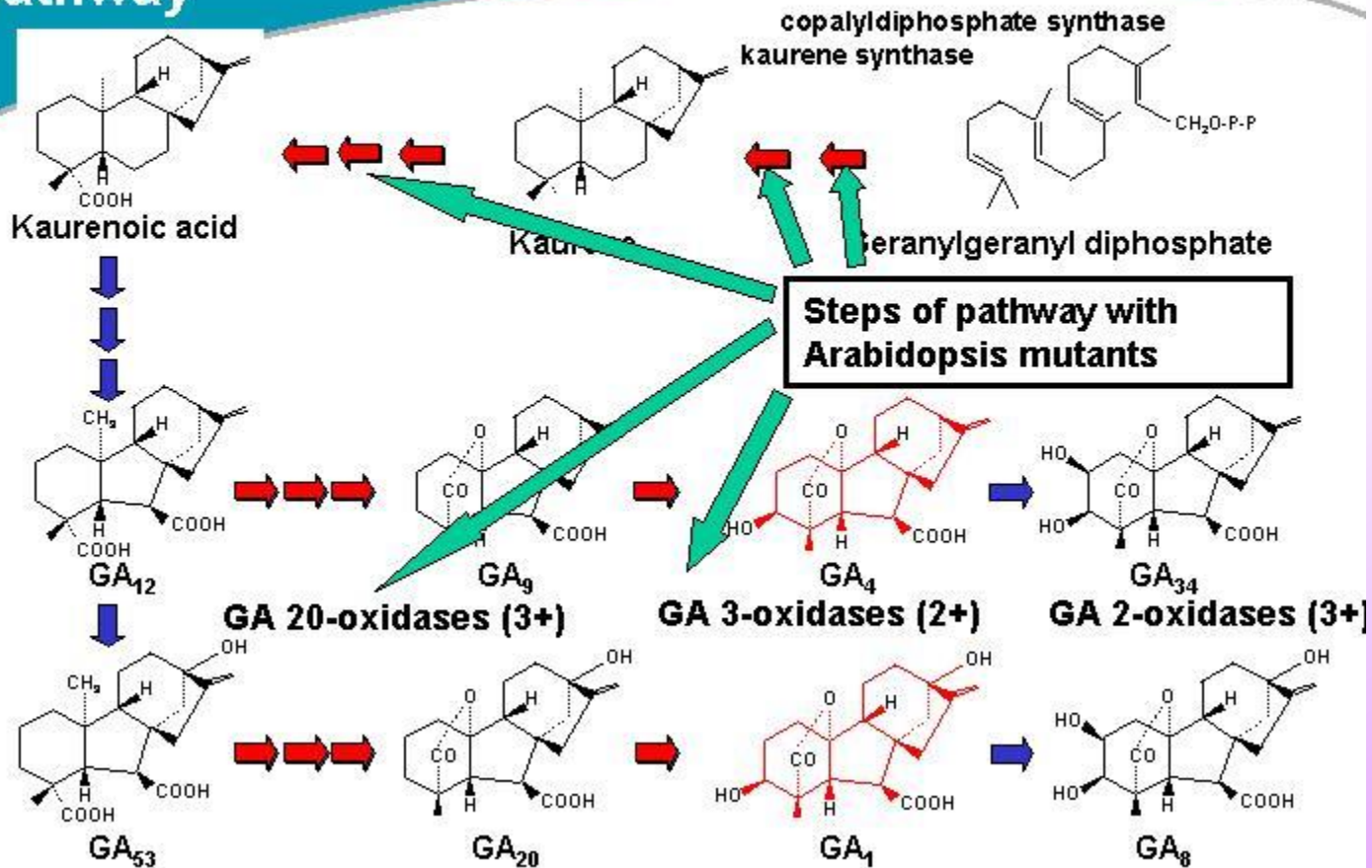
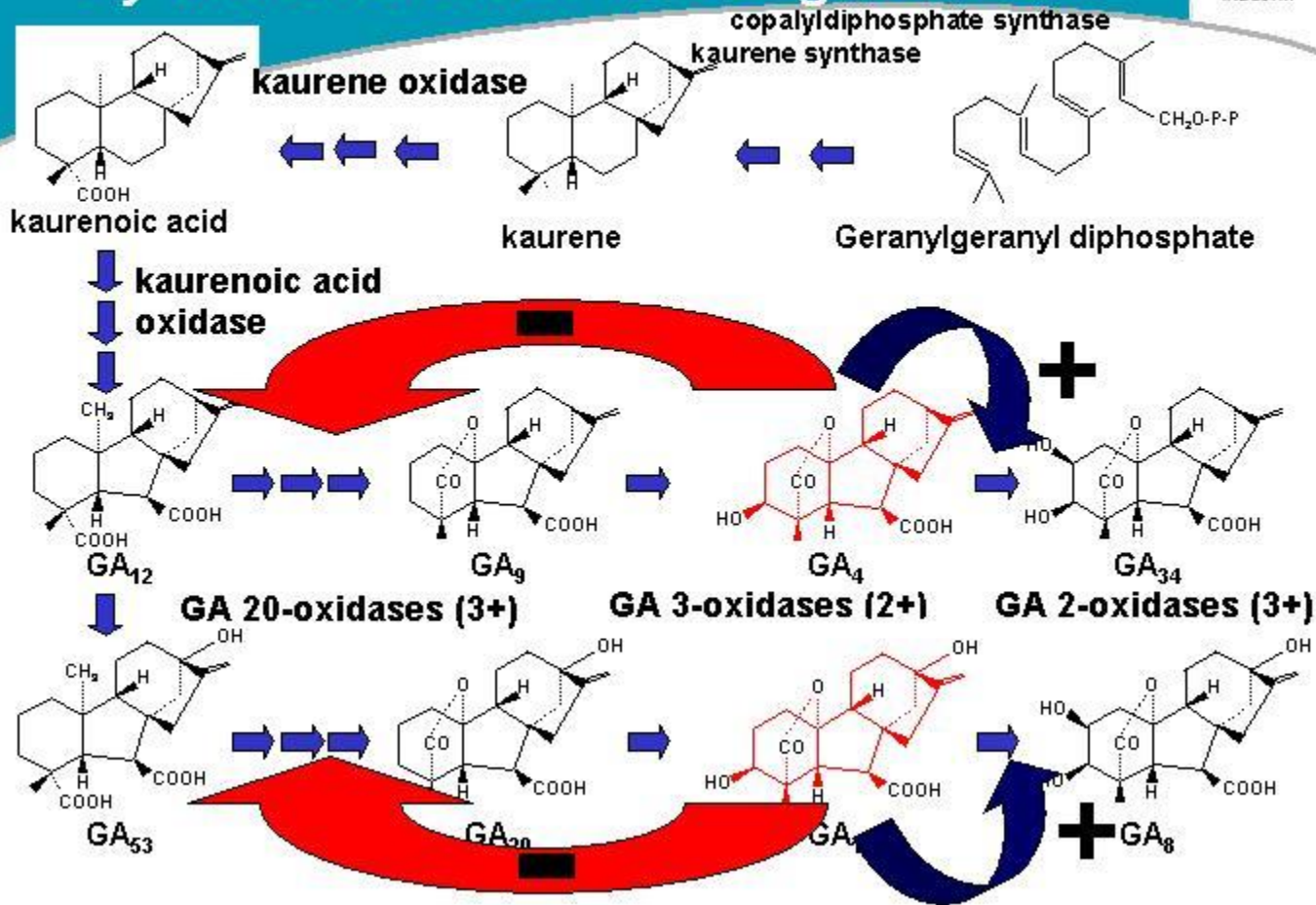


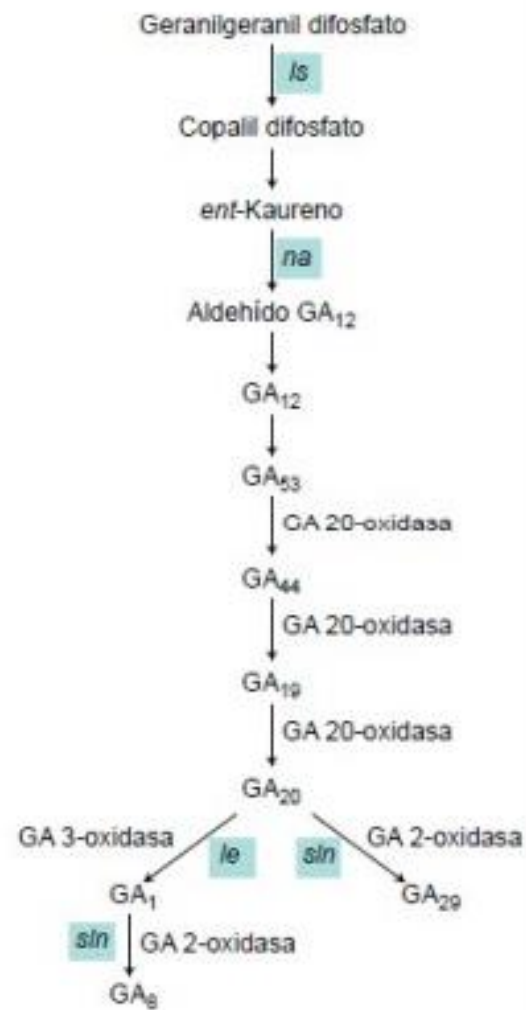
Fig. 2 Plant hormone biosyntheses in plastids

# Dwarf mutants of Arabidopsis define most of the enzymes of the gibberellin biosynthesis pathway



# Gibberellin biosynthesis is regulated by the amount of active gibberellin





Parte de la ruta biosintética de GAs mostrando las abreviaturas y ubicaciones de los genes mutantes que bloquean la síntesis en arveja.

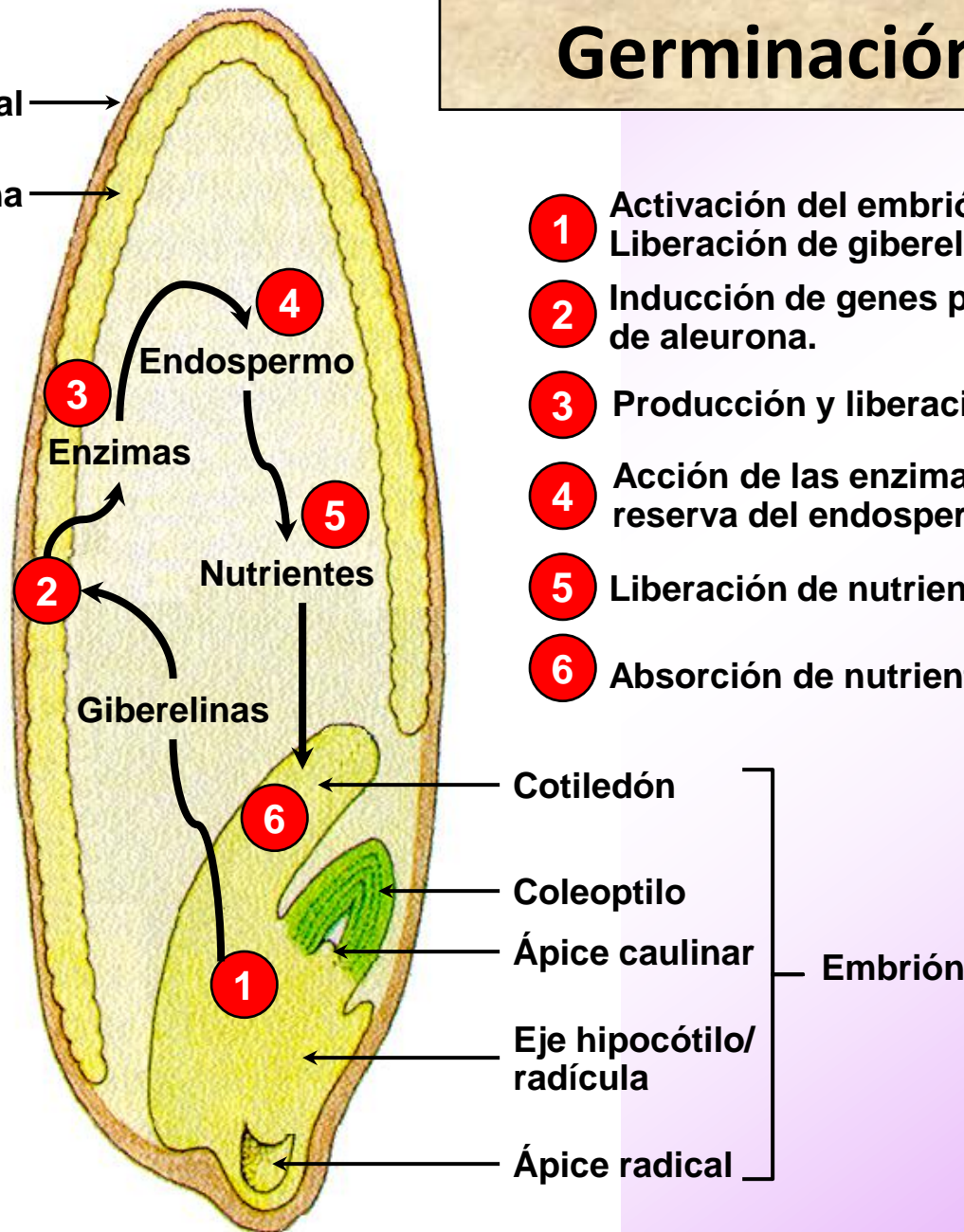




# Germinación en cereales

Cubierta seminal →

Capa de aleurona →



- 1 Activación del embrión.  
Liberación de giberelinas
- 2 Inducción de genes por las giberelinas en la capa de aleurona.
- 3 Producción y liberación de enzimas hidrolíticos.
- 4 Acción de las enzimas sobre los materiales de reserva del endospermo.
- 5 Liberación de nutrientes (monómeros)
- 6 Absorción de nutrientes por el embrión.

Cotiledón

Coleoptilo

Ápice caulinar

Eje hipocótilo/  
radícula

Ápice radical

Embrión

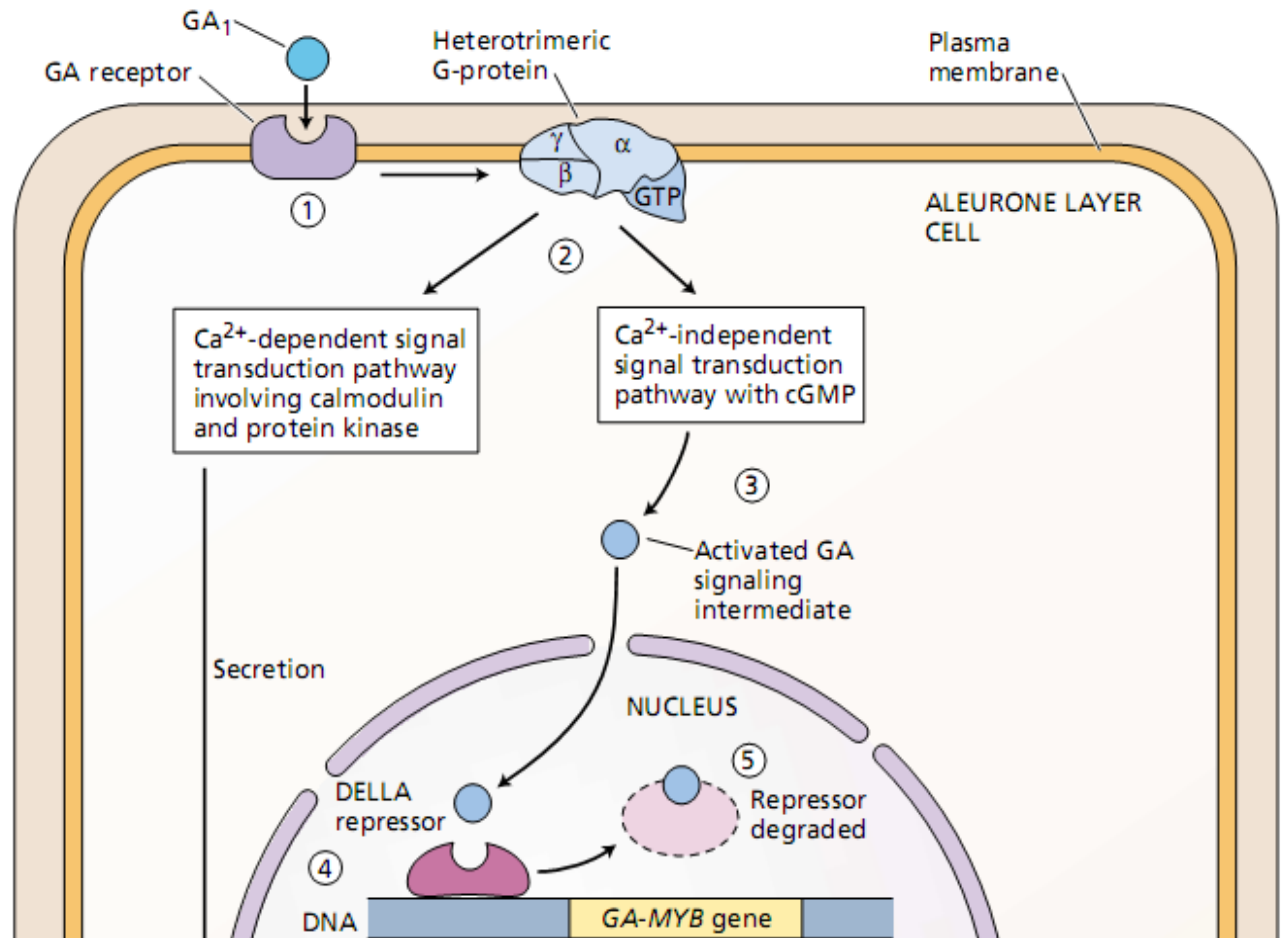
1. GA<sub>1</sub> from the embryo first binds to a cell surface receptor.

2. The cell surface GA receptor complex interacts with a heterotrimeric G-protein, initiating two separate signal transduction chains.

3. A calcium-independent pathway, involving cGMP, results in the activation of a signaling intermediate.

4. The activated signaling intermediate binds to DELLA repressor proteins in the nucleus.

5. The DELLA repressors are degraded when bound to the GA signal.



6. The inactivation of the DELLA repressors allows the expression of the MYB gene, as well as other genes, to proceed through transcription, processing, and translation.

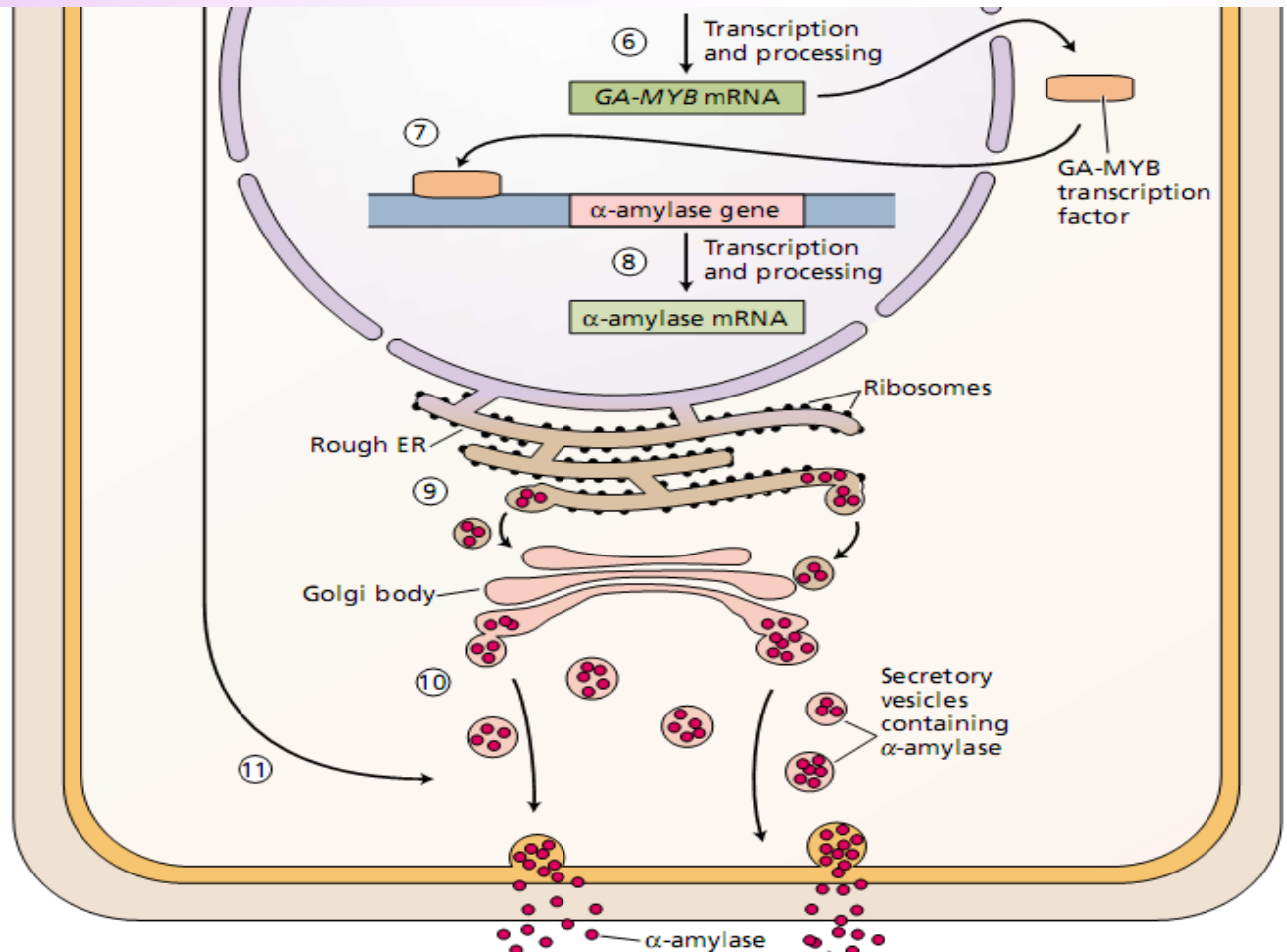
7. The newly synthesized MYB protein then enters the nucleus and binds to the promoter genes for  $\alpha$ -amylase and other hydrolytic enzymes.

8. Transcription of  $\alpha$ -amylase and other hydrolytic genes is activated.

9.  $\alpha$ -Amylase and other hydrolases are synthesized on the rough ER.

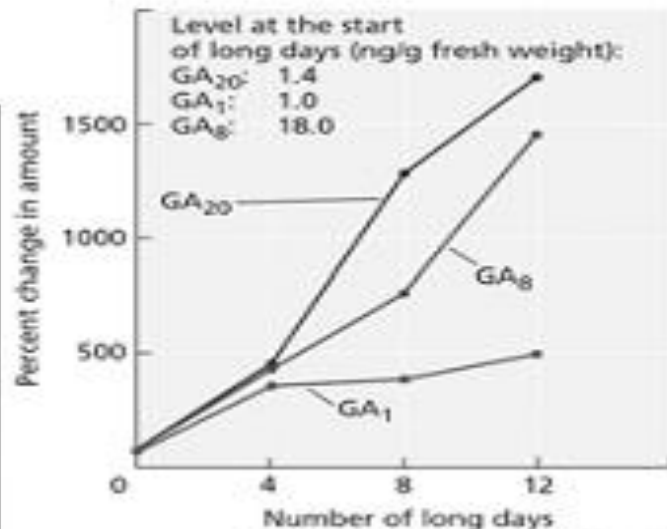
10. Proteins are secreted via the Golgi.

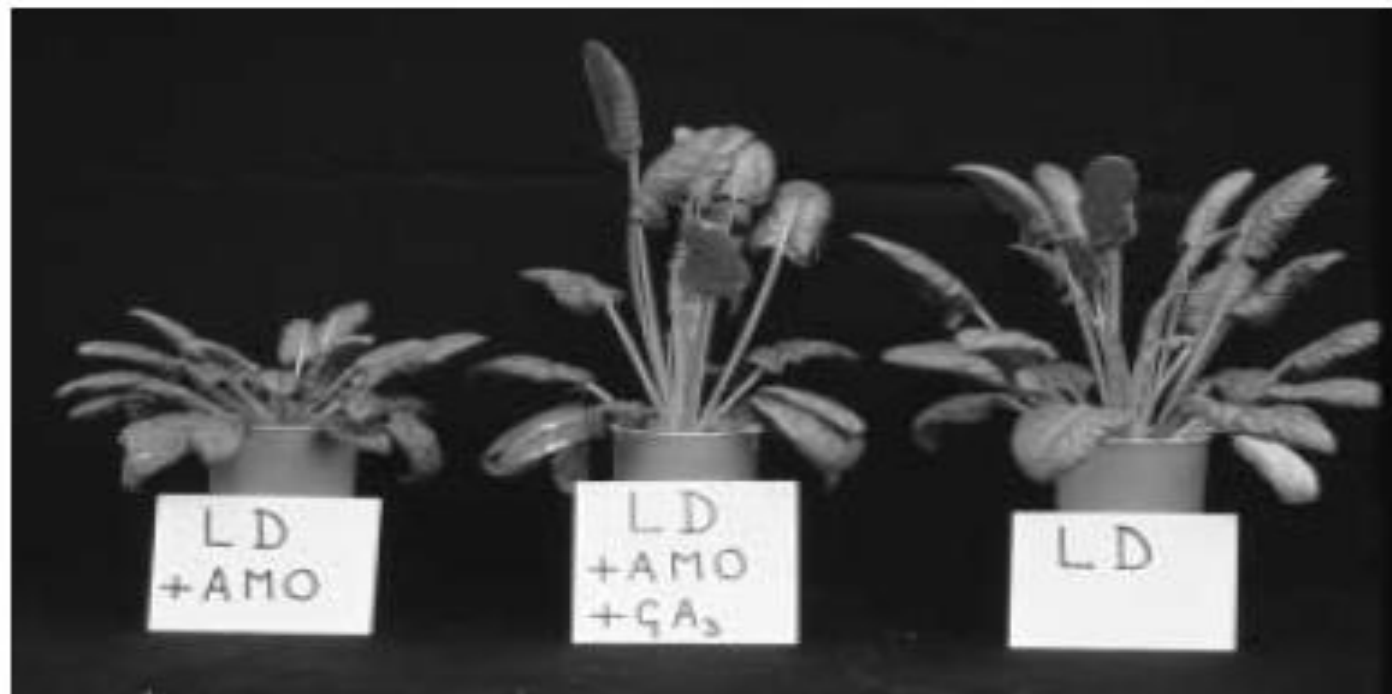
11. The secretory pathway requires GA stimulation via a calcium-calmodulin-dependent signal transduction pathway.



## GA synthesis is modulated by

- GA levels (feedback or feed-forward)
- Light
- Photoperiod





**FIGURE 20.14** Spinach plants undergo stem and petiole elongation only in long days, remaining in a rosette form in short days. Treatment with the GA biosynthesis inhibitor AMO-1618 prevents stem and petiole elongation and maintains the rosette growth habit even under long days. Gibberellic acid can reverse the inhibitory effect of AMO-1618 on stem and petiole elongation. As shown in Figure 20.16, long days cause changes in the gibberellin content of the plant. (Courtesy of J. A. D. Zeevaart.)

# Formación de Tubérculos

**FIGURE 20.17** Tuberization of potatoes is promoted by short days. Potato (*Solanum tuberosum* spp. *Andigena*) plants were grown under either long days or short days. The formation of tubers in short days is associated with a decline in  $GA_1$  levels (see Chapter 24). (Courtesy of S. Jackson.)



Long days

Short days

# Floración, remplace la vernalización y DL



**FIGURE 20.2** Cabbage, a long-day plant, remains as a rosette in short days, but it can be induced to bolt and flower by applications of gibberellin. In the case illustrated, giant flowering stalks were produced. (© Sylvan Wittwer/Visuals Unlimited.)



# Gibberellins in agriculture and horticulture

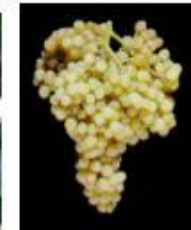


**Dwarf**

**Tall**

High yielding semi-dwarf rice has reduced endogenous gibberellin

-GA



+GA



Fewer flowers and larger fruit

Delayed fruit harvest

Increased fruit size

GAs are used commercially to increase fruit size in table grapes and to regulate citrus flowering and rind maturation

The model plant *Arabidopsis* has been used to understand gibberellin biosynthesis



Dwarf Mutant  
*ga3*



Dwarf Mutant  
plus  
Gibberellin

# Gibberellin-responsive plants have better early growth

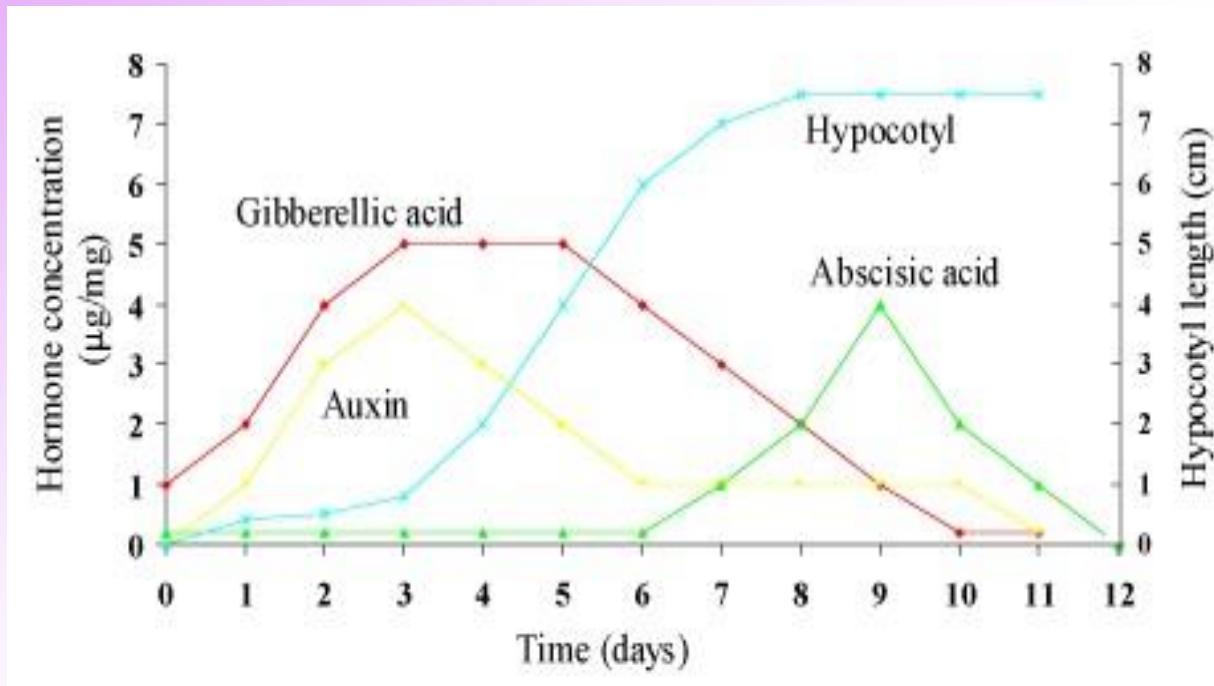


**Gibberellin responsive**



**Gibberellin insensitive**





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?

# EFFECTOS FISIOLÓGICOS

- Incrementan el crecimiento de los tallos, en plantas enanas.
- Inducen la brotación de yemas
- \* Interrupe el período de Dormición de las semillas
- \* Promueven partenocarpia, en vid, ciruela, durazno (frutos unicarpelar).
- Promueve la división celular en el meristema subapical
- \* Incrementan el alargamiento celular (en presencia de Auxinas).
- \* Producen cambios en la morfogénesis foliar.

Promueven la actividad del cambium.

Desarrollo: reemplaza la vernalización y fotoperiodos largos en plantas de DL (días largos) en DC.

Induce la movilización de reservas en semillas germinando.

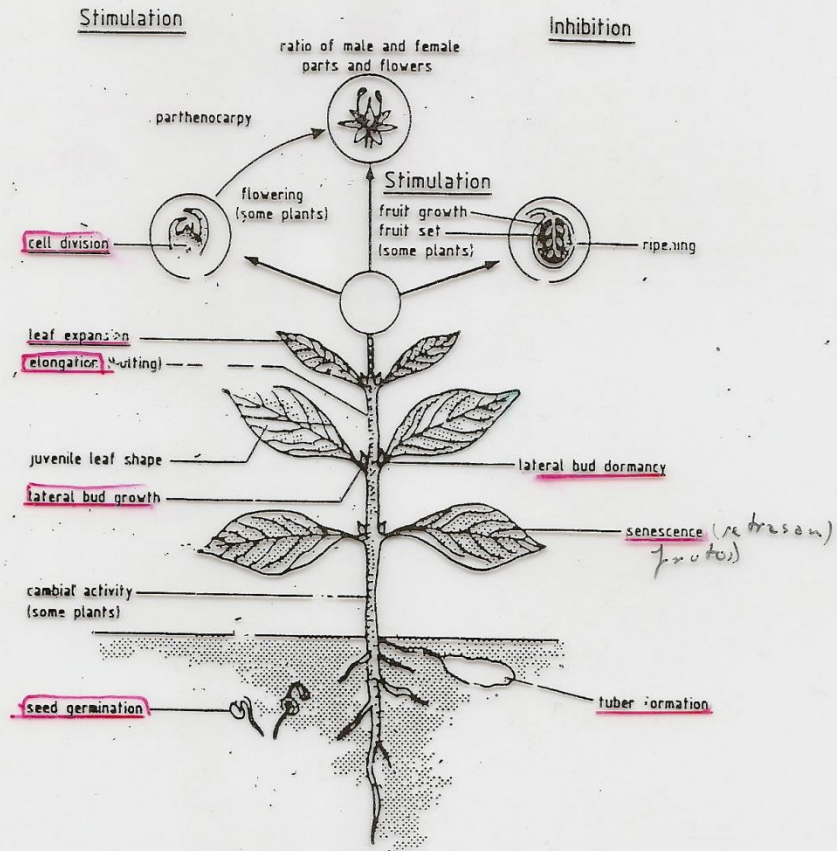
Retraso de la senescencia de algunas hojas y de cascara de citricos.

Alargamiento del escapo floral del alcaucil, pencas de las hojas de apio, y pedúnculos de flores y bayas de vid.

Inhibe la formación de tubérculos en papa

Promoción de flores masculinas en cucurbitaceas

# GIBBERELIC ACID (GA)



(MATTHYSE and SCOTT, 1984)

A scenic autumn landscape featuring a path covered in fallen yellow leaves. The path is flanked by trees with vibrant yellow foliage and a wooden fence on the right. The scene is bathed in warm, golden light, creating a peaceful and nostalgic atmosphere.

***Muchas  
gracias***