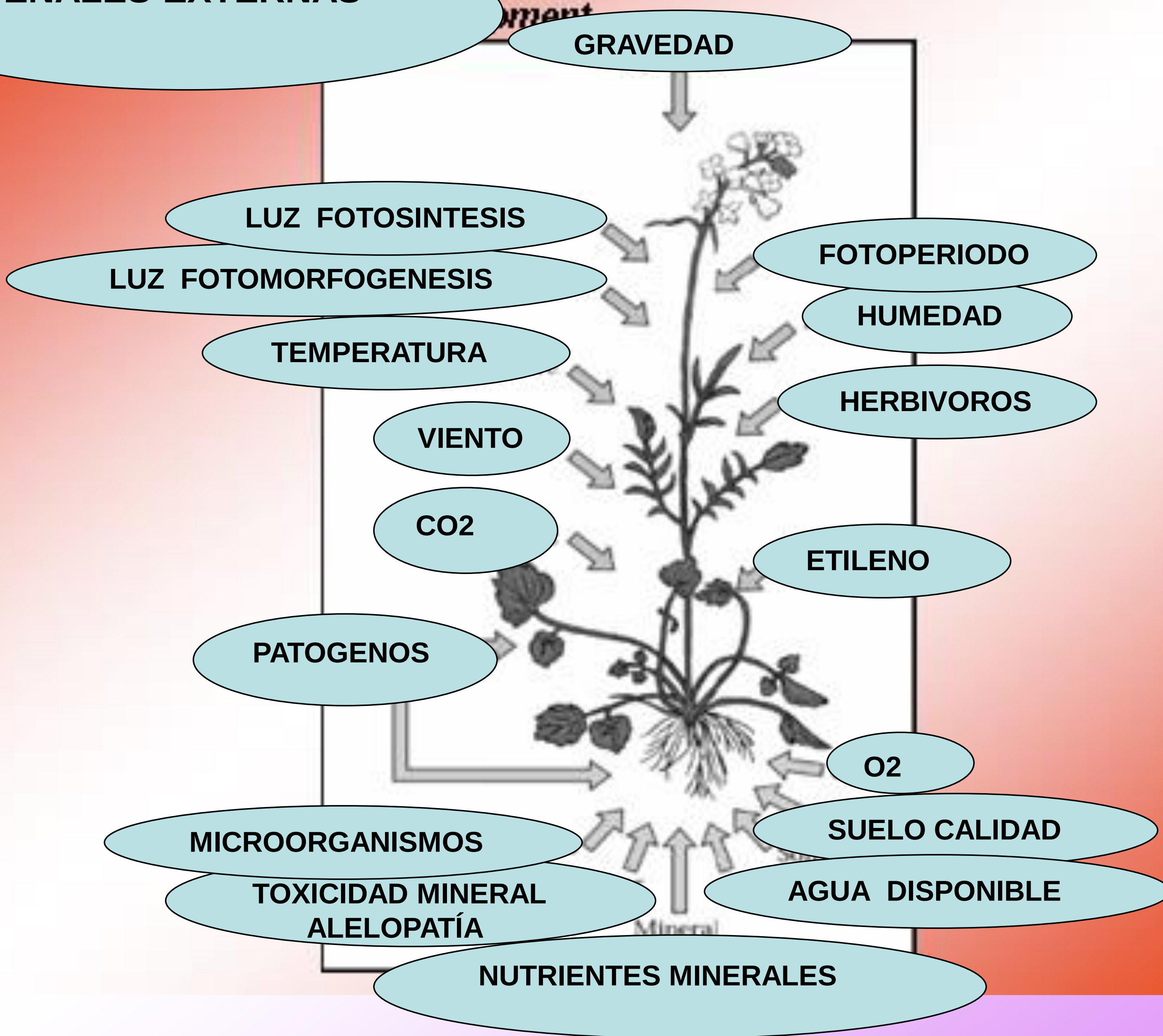
HORMONAS VEGETALES

SEÑALES EXTERNAS



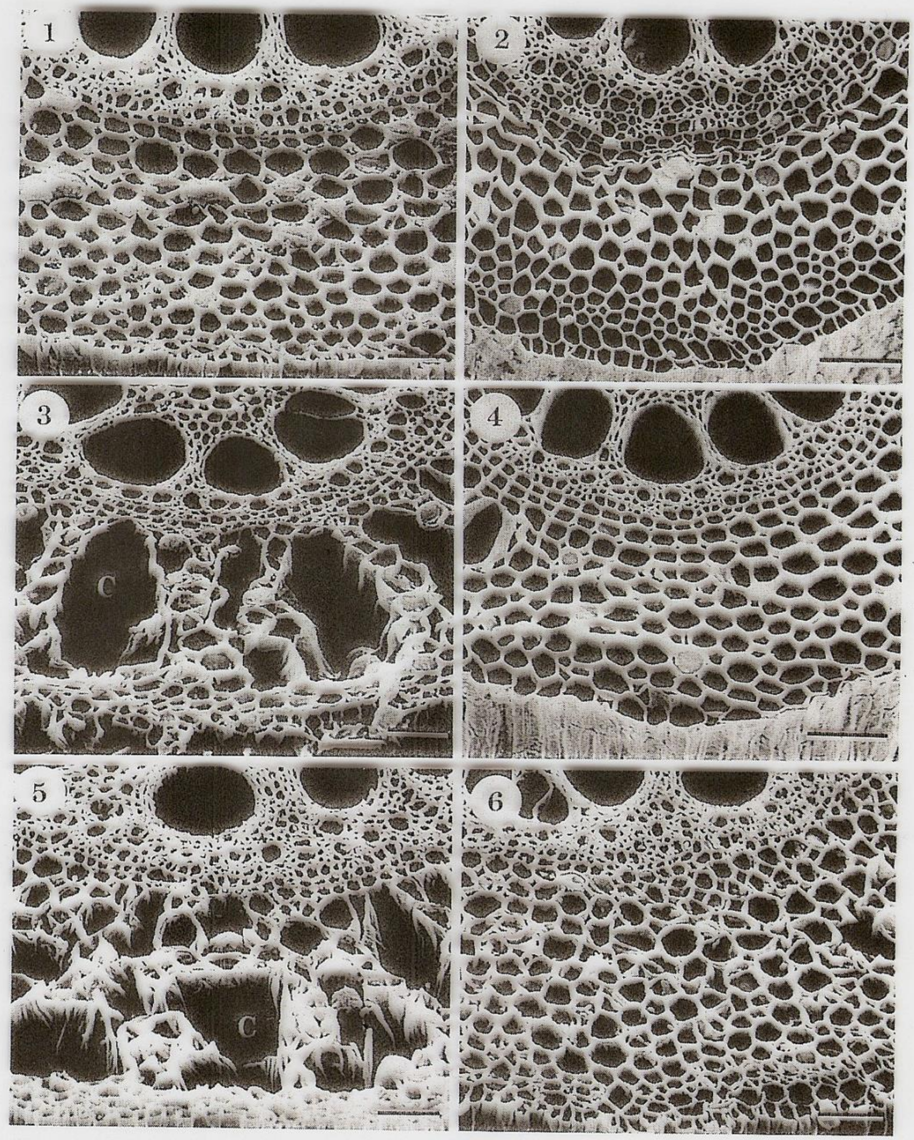


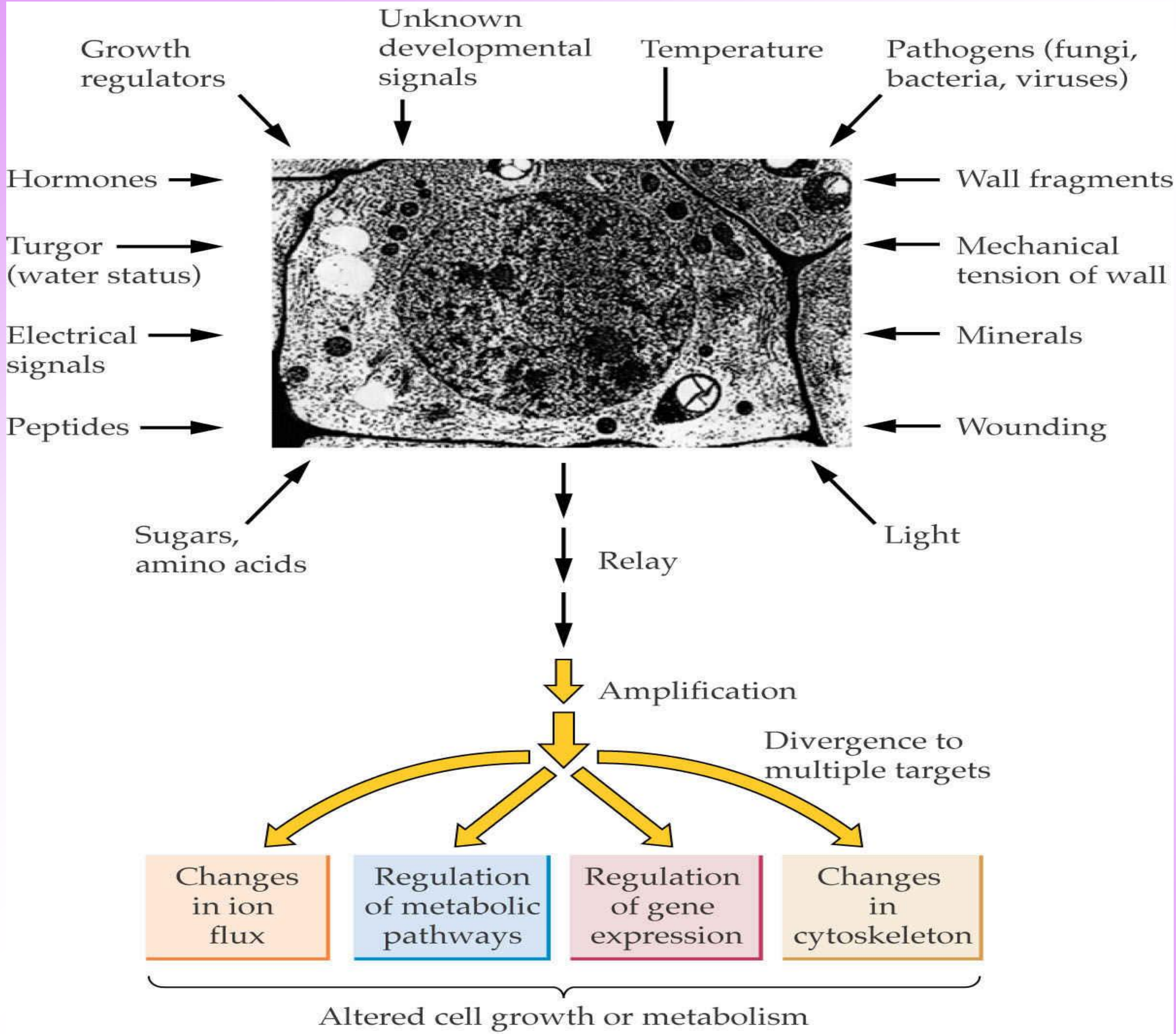
Figure 4.16. Scanning electron micrographs of transverse sections of second whorl adventitious roots of corn. Sections were prepared from root zone of approximately the same age, 4 to 5 days. (×58). Bar = 50 μm. 1, Control grown in aerated solution; 2, root grown in 0.6 μM Ag(I); 3, root treated with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

Mecanismo de acción.
Cadena de percepción y transducción de la señal.

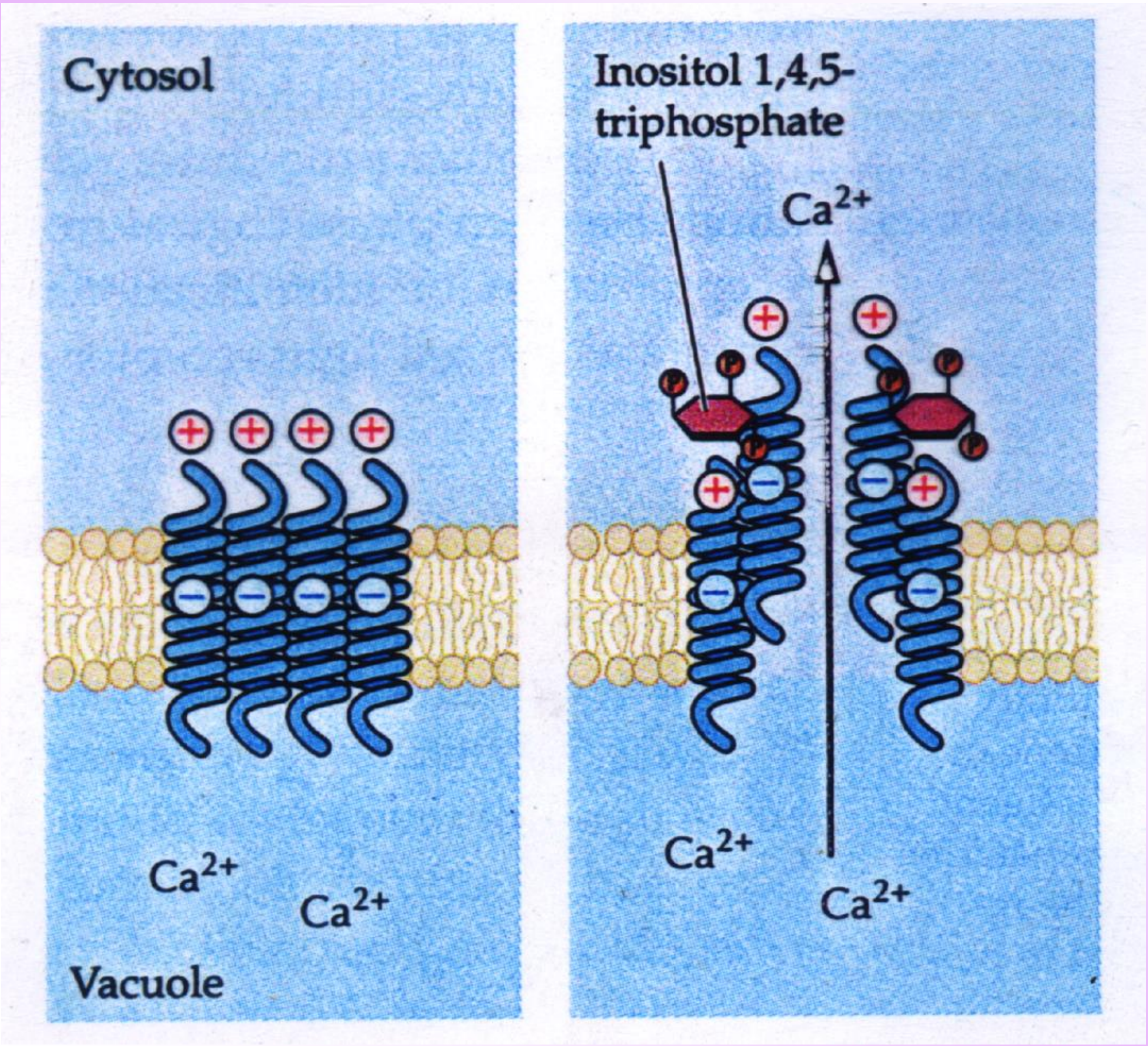
- ✓ **Esta dado por una reacción primaria capaz de iniciar una serie de eventos moleculares que conducen a un efecto fisiológico medible.**
  - ✓ Percepción de la señal (primer mensajero-receptor)
  - ✓ Generación y trasmisión de la señal (transducción).
  - ✓ Activación de un cambio bioquímico (respuesta).

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.**



Growth regulators
Unknown developmental signals
Temperature
Pathogens (fungi, bacteria, viruses)
Hormones
Turgor (water status)
Electrical signals
Peptides
Wall fragments
Mechanical tension of wall
Minerals
Wounding
Sugars, amino acids
Light
Relay
Amplification
Divergence to multiple targets
Changes in ion flux
Regulation of metabolic pathways
Regulation of gene expression
Changes in cytoskeleton
Altered cell growth or metabolism


Cytosol
Ca2+
Ca2+
Vacuole
Inositol 1,4,5-
triphosphate
Ca2+
Ca2+
Ca2+

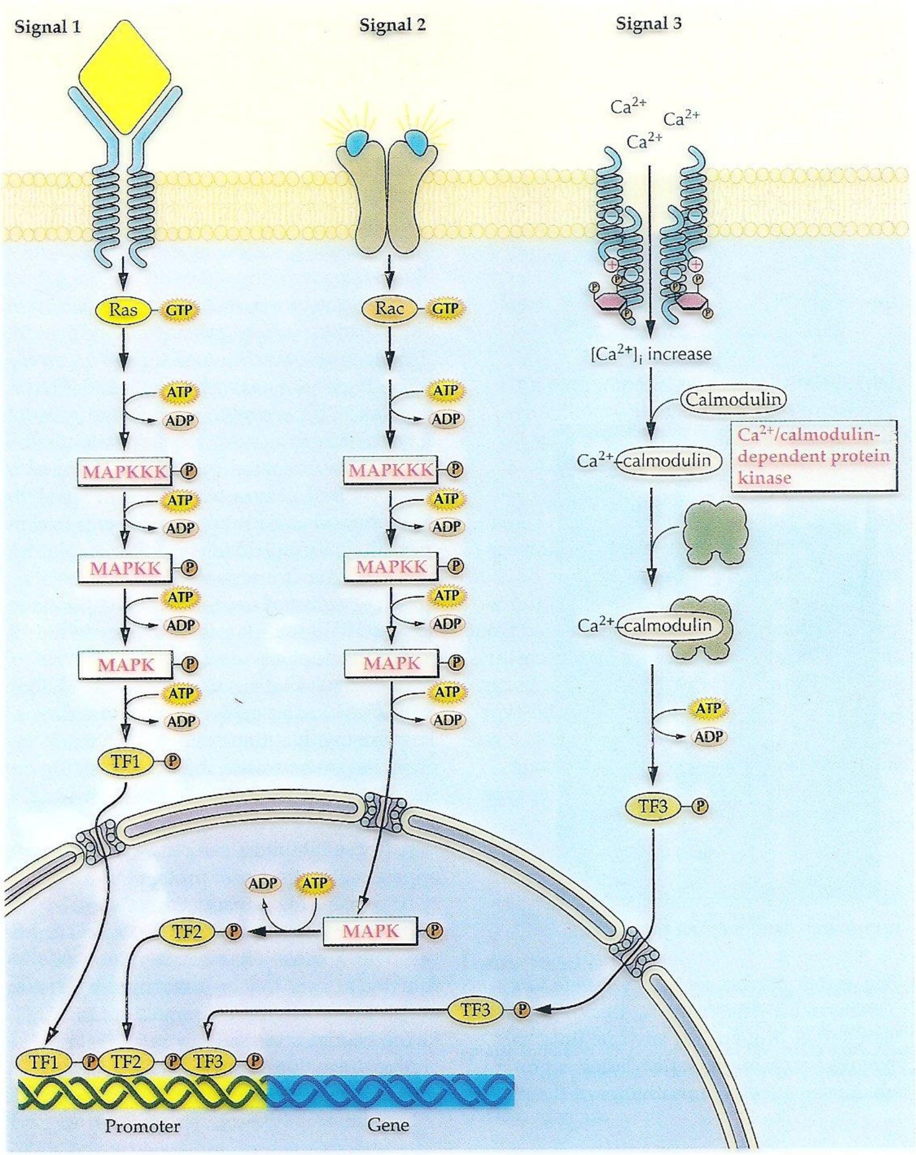
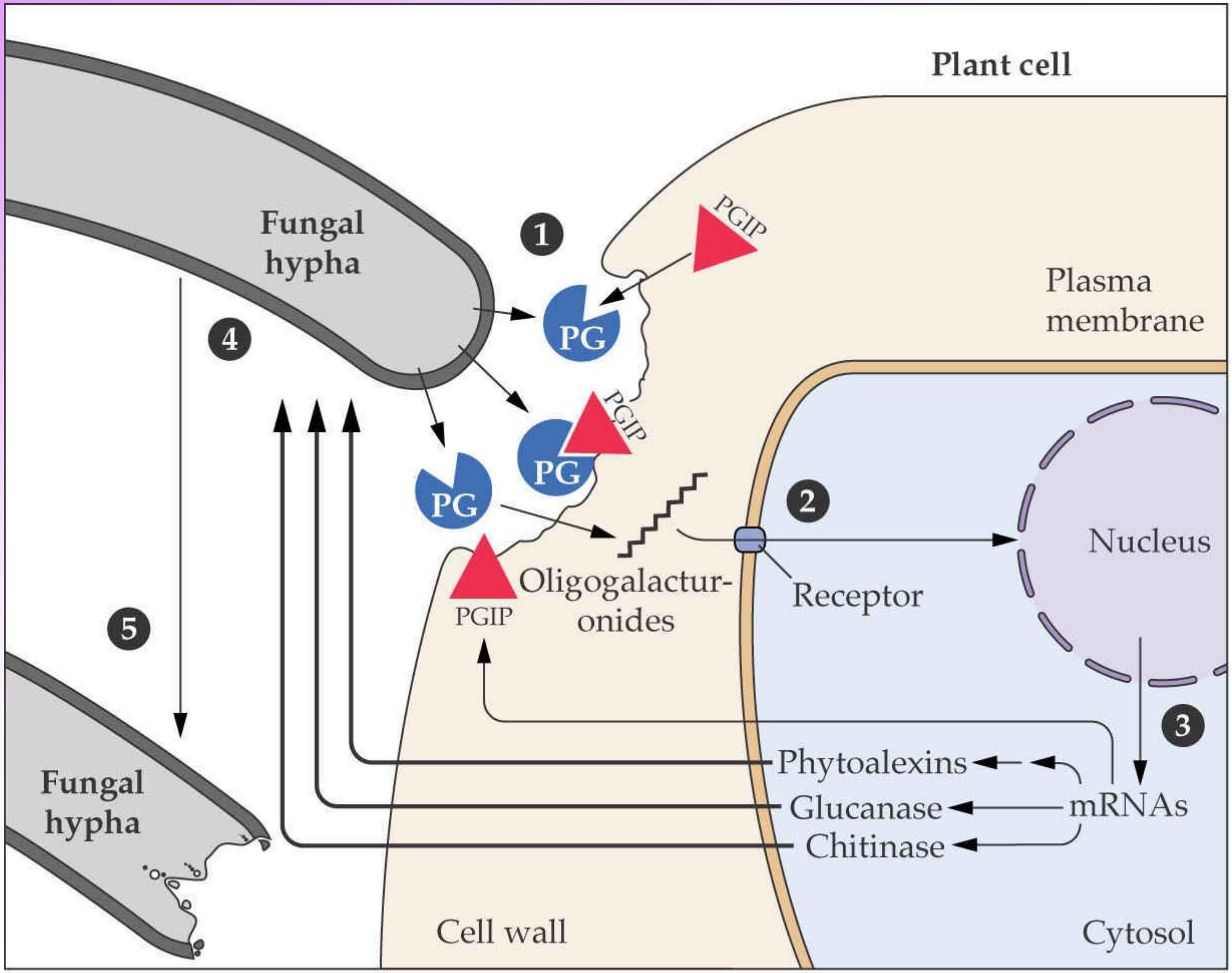
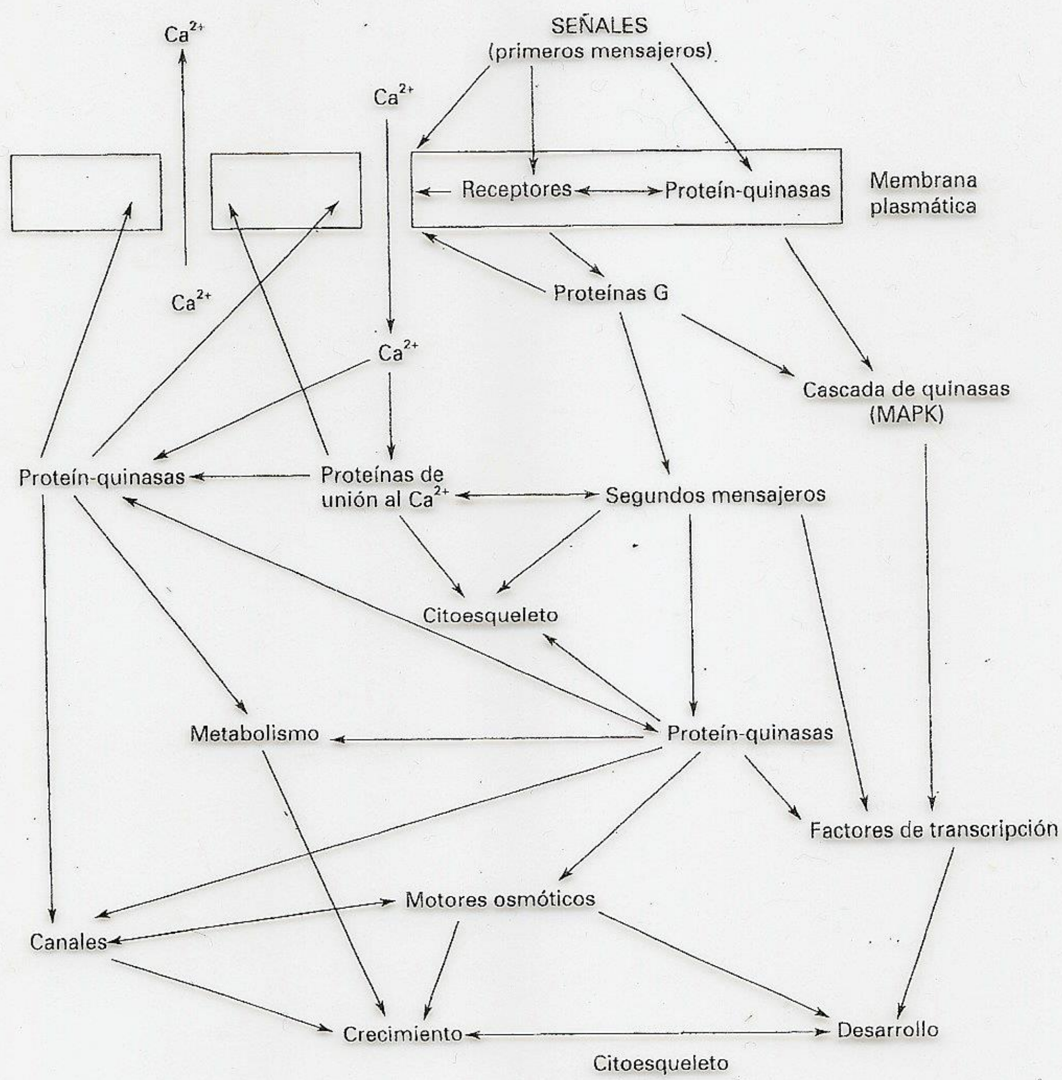


Figure 18.63
Many signals are transduced by protein kinase cascades that regulate gene expression. One such transduction sequence is believed to underlie regulation of gene expression involving a small GTPase (Ras- or Rac-like protein) and mitogen-activated protein kinase (MAPK) cascade leading to transcription 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).

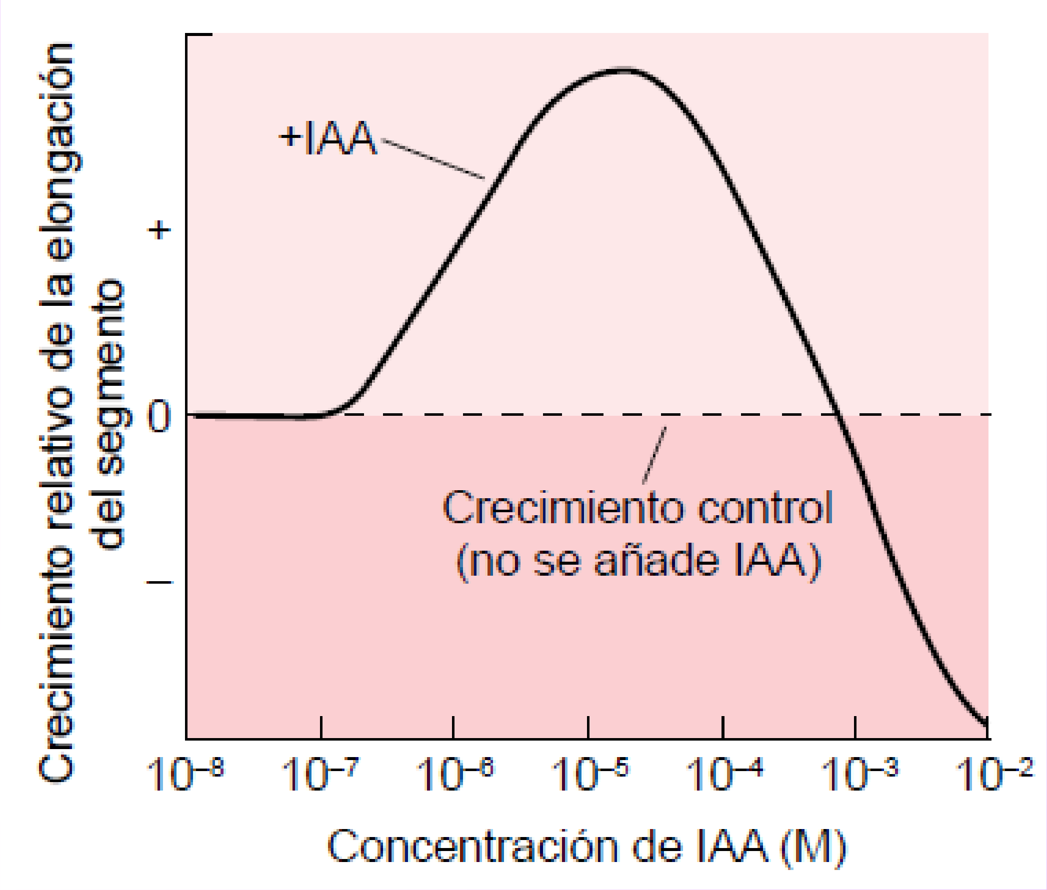

Plant cell
Fungal hypha
1
PGIP
Plasma membrane
4
PG
PG
PGIP
PG
2
Nucleus
Oligogalactur-onides
Receptor
PGIP
5
3
Phytoalexins
Fungal hypha
Glucanase
mRNAs
Chitinase
Cell wall
Cytosol



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 mayos 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

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

Reguladores Vegetales

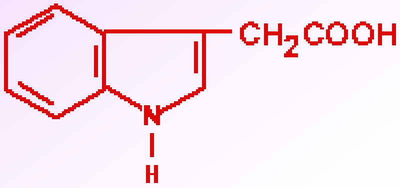
Sustancias sintetizadas artificialmente que producen respuestas similares a las hormonas.

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

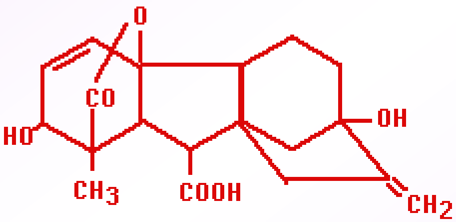
- HORMONAS
  - AUXINAS (AIA,...).
  - GIBERELINAS (GA_1,...GA_{84}).
  - CITOCININAS
  - ETILENO
  - FITOALEXINAS
  - POLIAMINAS
  - ACIDO JASMONICO
  - ACIDO SALICILICO
  - INHIBIDORES
    - ACIDO ABCISICO (ABA)
    - ACIDO TUBERONICO
    - DERIV. DEL BENZOICO
      - BENZOICO
      - GALICO
    - DERIV. DEL CINAMICO
      - CINAMICO
      - CUMARICO
      - FERULICO
  - FLORIGEN ?

- REGULADORES
  - TIPO AUXINICO (AIA; AIB; AIP;2,4 D; 2,4 DB; etc.)
  - GIBERELINAS
  - CITOCININAS (BA; BAP)
  - INHIBIDORES (CYCOCEL O CCC; ALAR O B_9; HM; CIIPC)
  - LIBERADORES DE ETILENO (ETHEPHON; ETHREL).

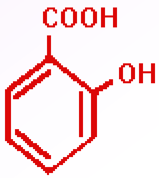
- ✓<u>**Auxinas**</u>
- ✓**Giberelinas**
- ✓**Citocininas**
- ✓**Ácido abscísico**
- ✓**Etileno**
- ✓**Ácido jasmónico**
- ✓**Ácido salicílico**



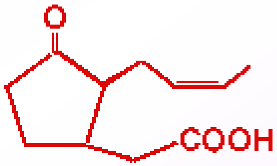
Indole-3-acetic acid



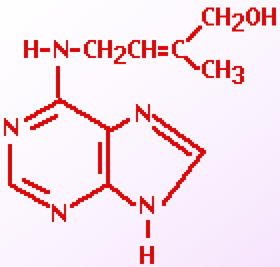
Gibberellic acid



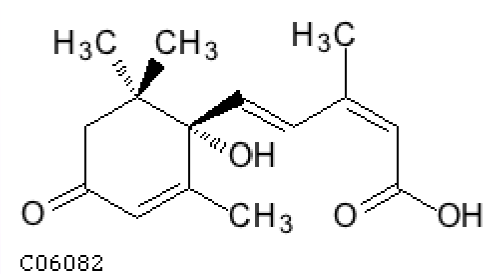
Salicylic acid



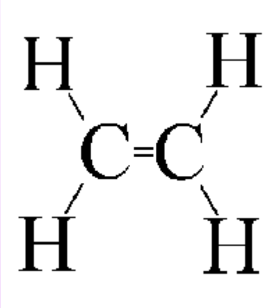
Jasmonic acid



Cytokinin
(Zeatin)



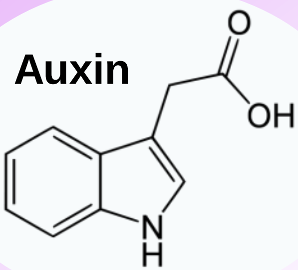
Ácido abscísico



Etileno

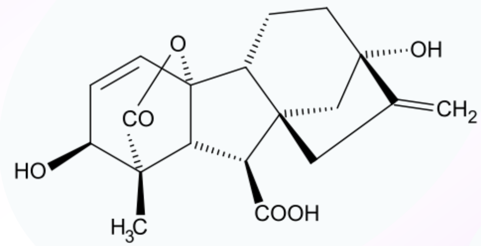
Phytohormones – old timers and newcomers

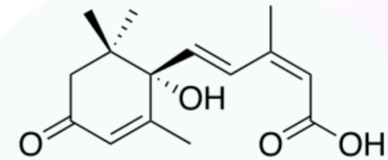
Auxin



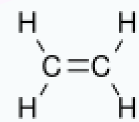
Cytokinins

Gibberellins

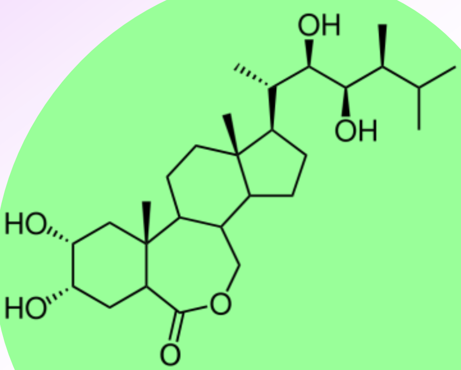




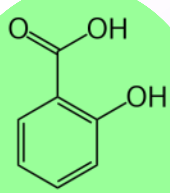
Abscisic Acid



Ethylene

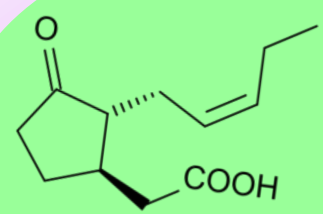


Brassinosteroids

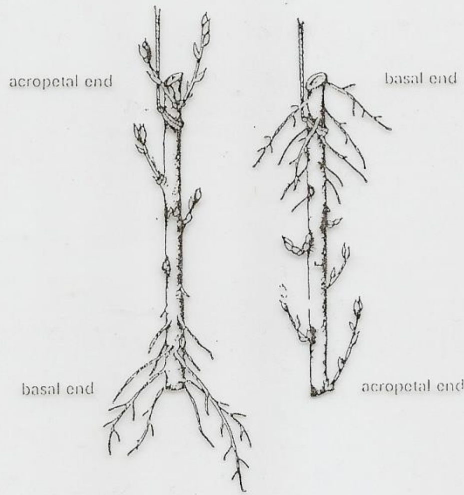


Salicylates

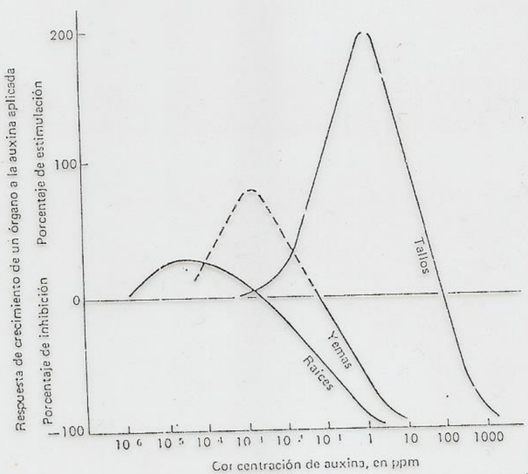
Strigolactones



Jasmonates



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, 1959. 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.**

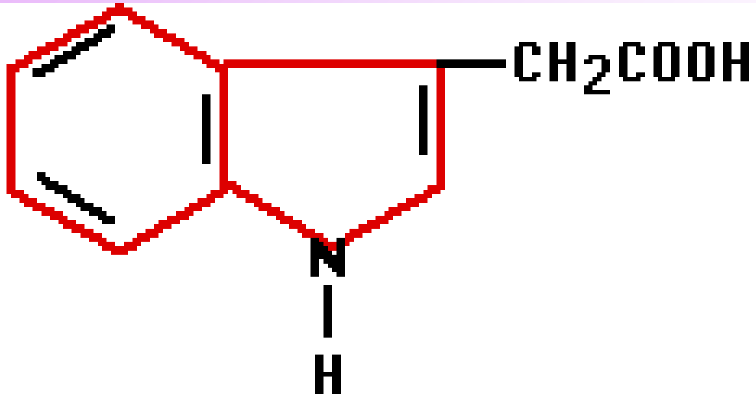
HORMONAS VEGETALES:

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

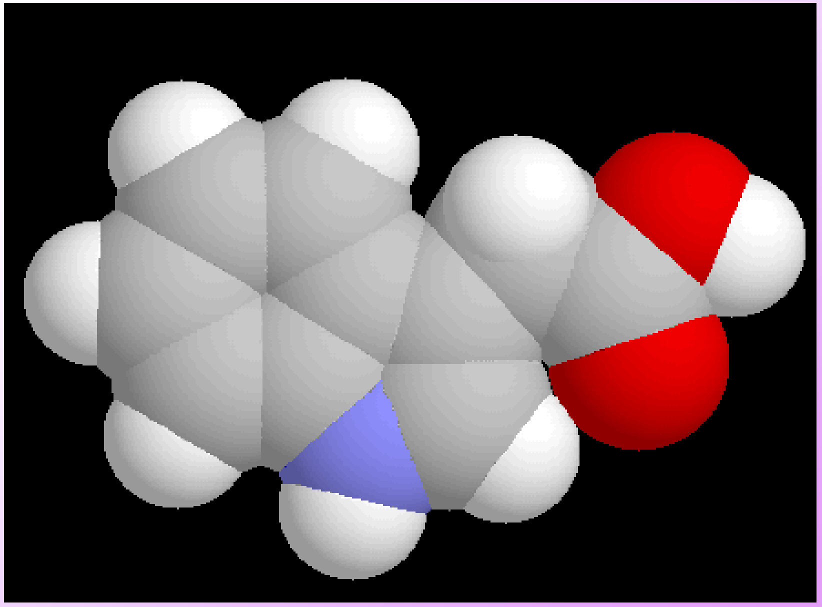
situaciones de estrés
meristemas vegetativos son inducidos a floración
percepción de plantas vecinas

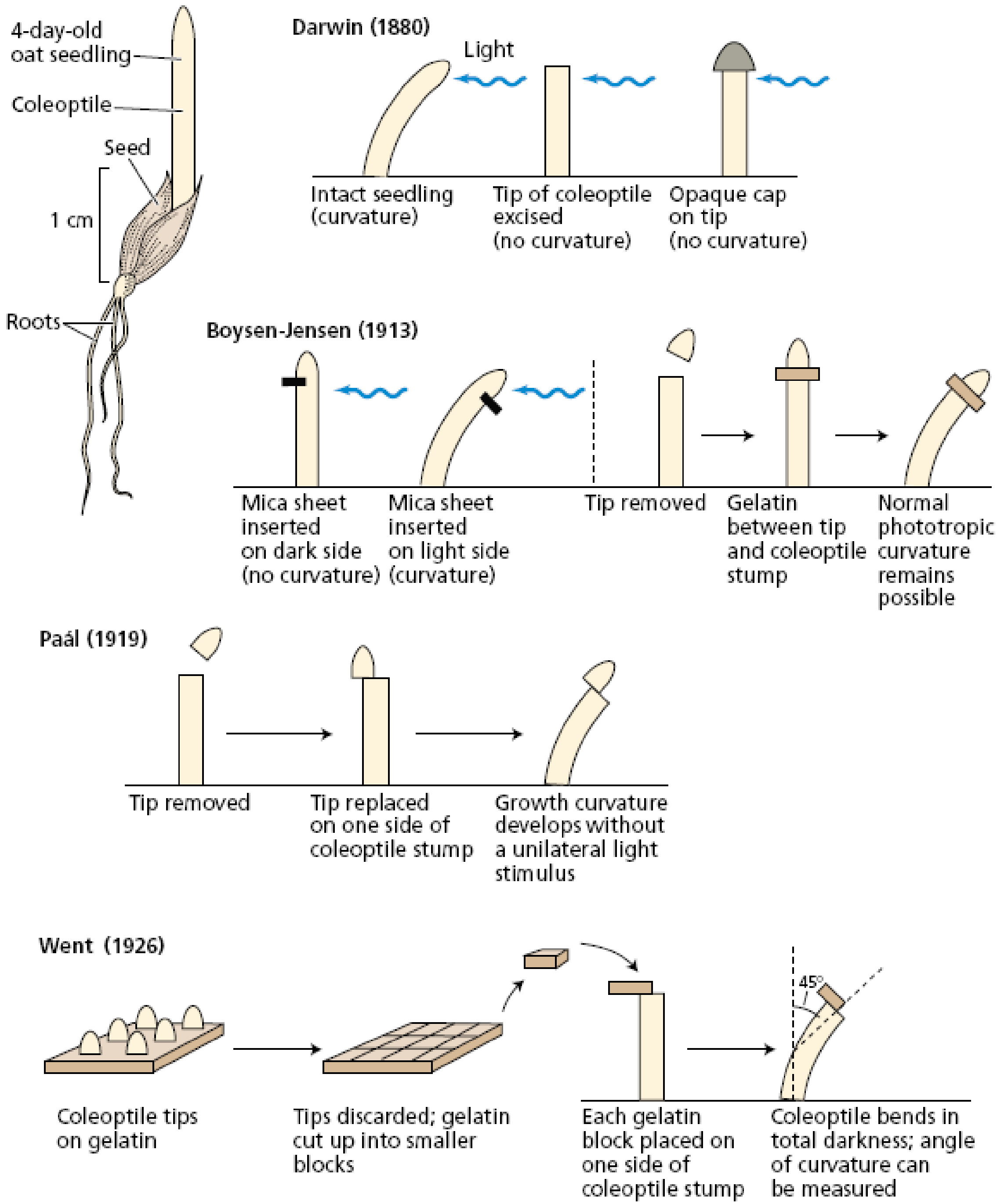
Las señales son amplificadas y transducidas por las hormonas.
Fenómenos de correlación e intercomunicación.

Auxin



Indole-3-acetic acid (IAA)





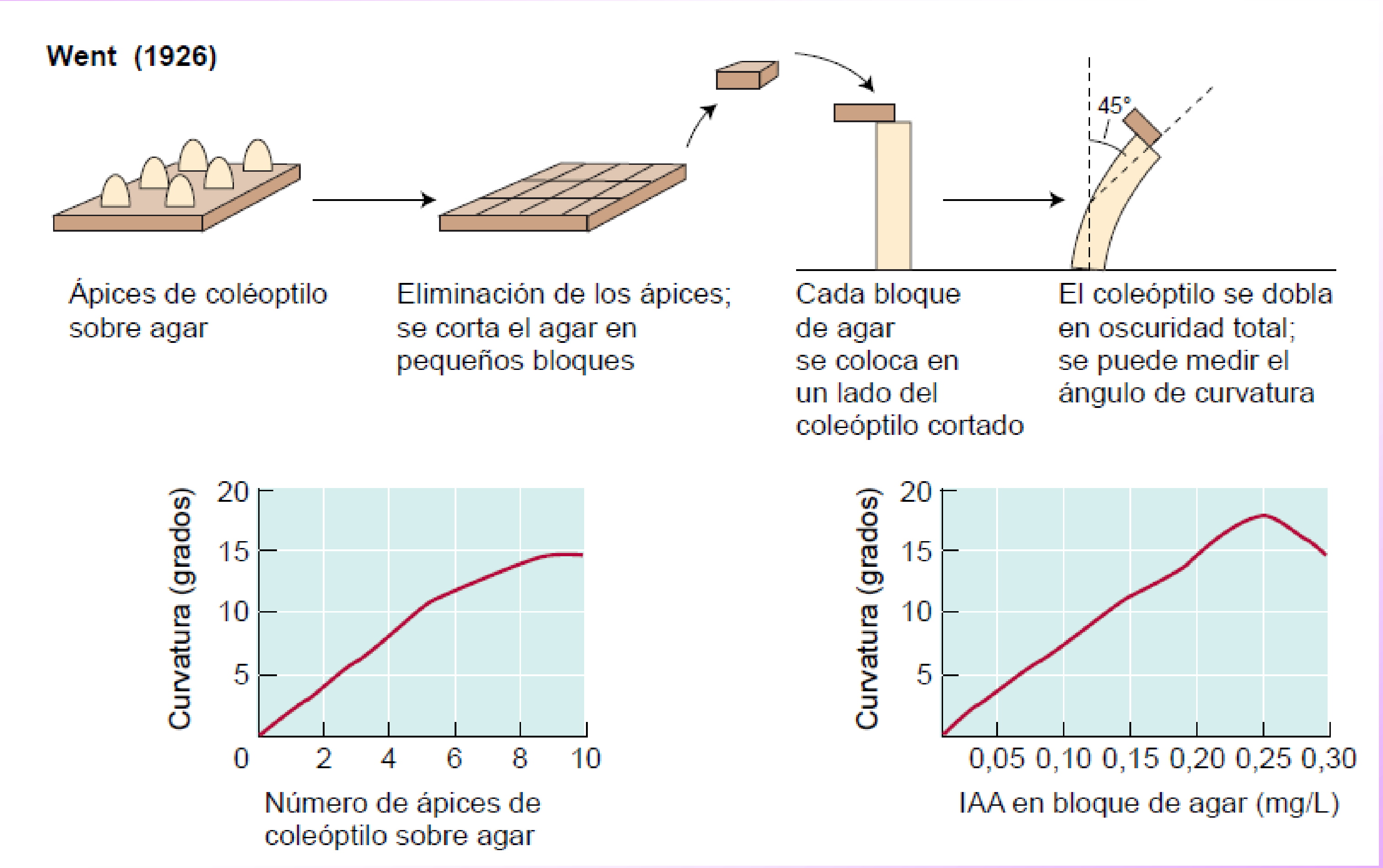
From experiments on coleoptile phototropism, Darwin concluded in 1880 that a growth stimulus is produced in the coleoptile tip and is transmitted to the growth zone.

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

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

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.



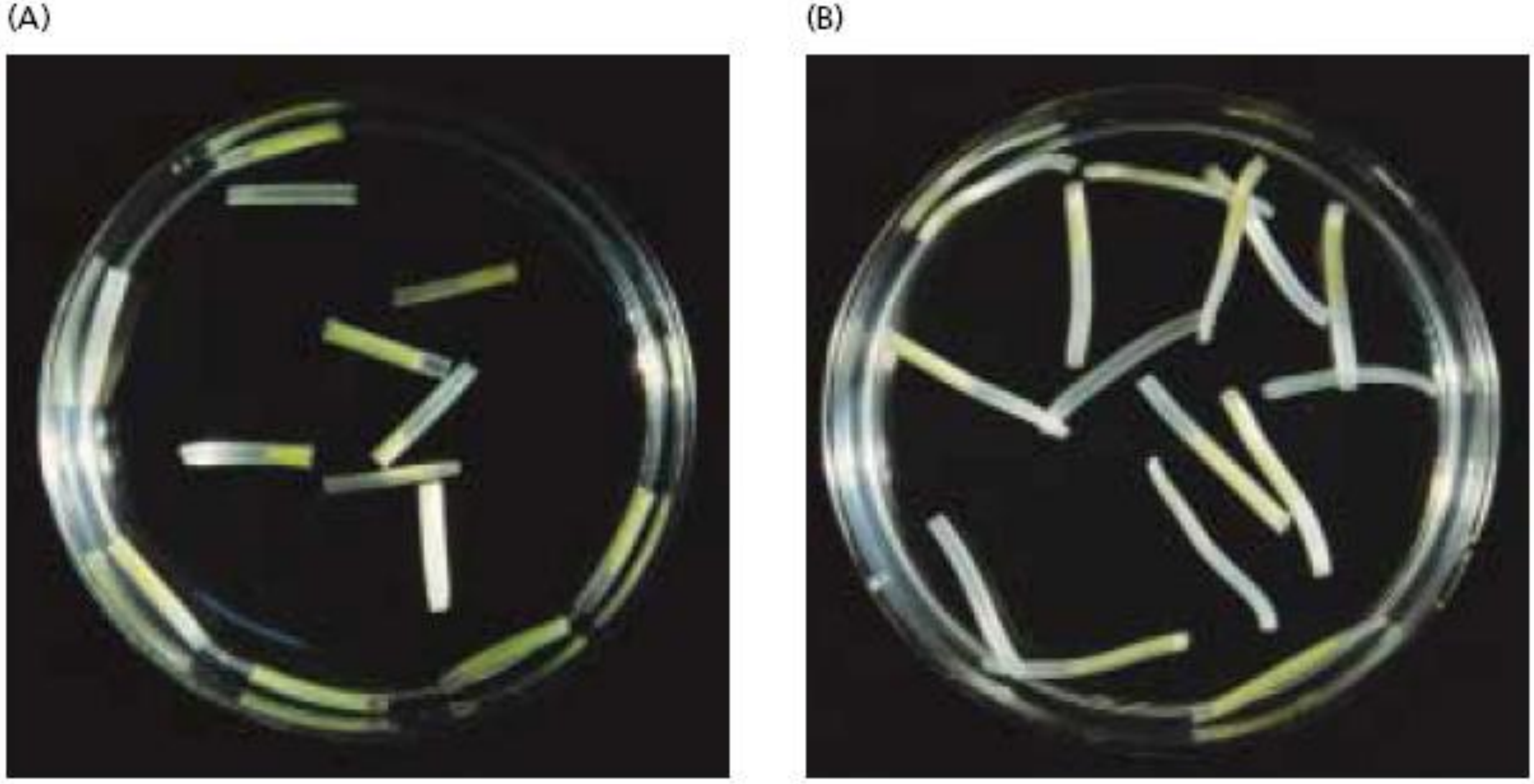
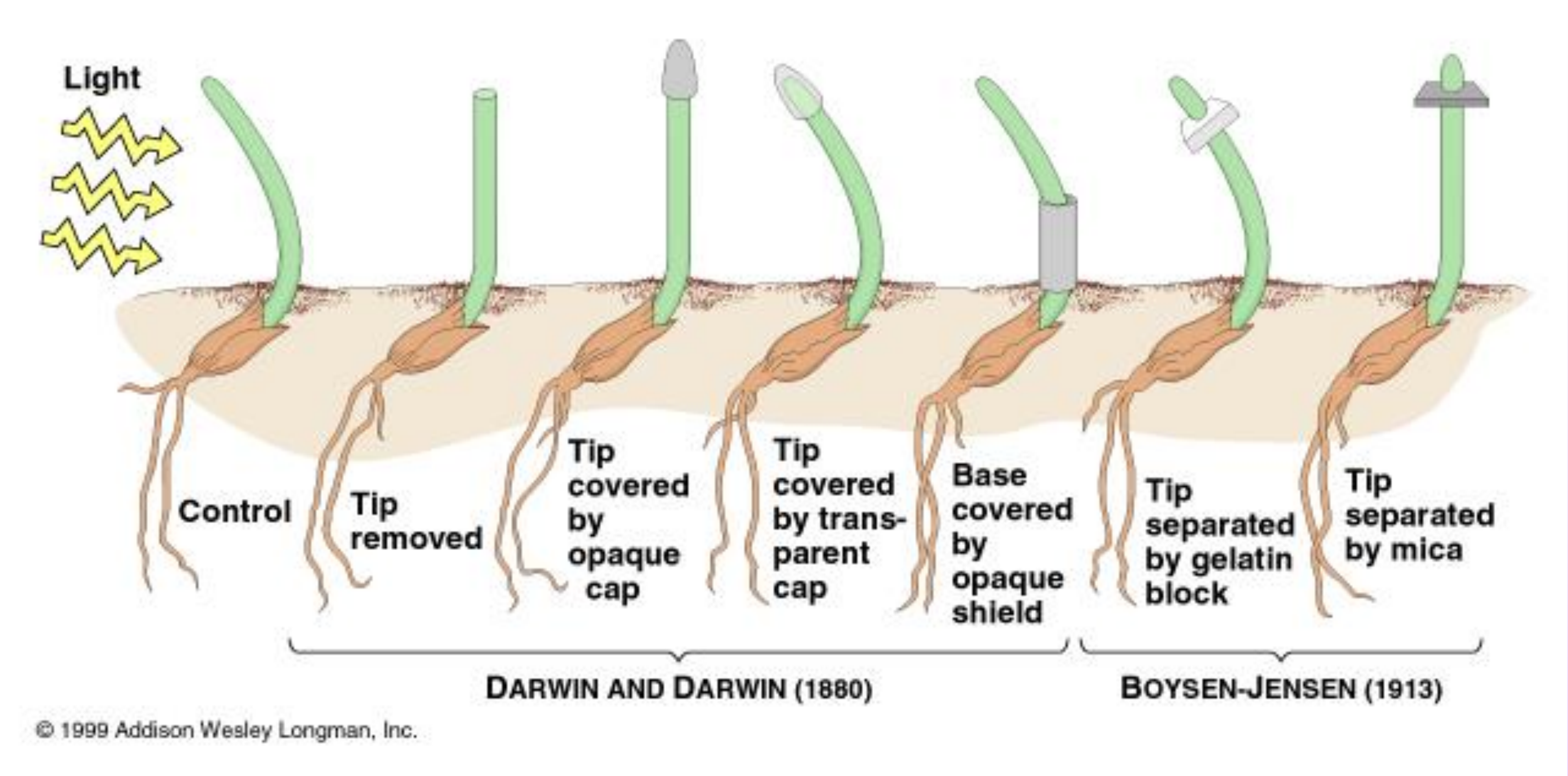
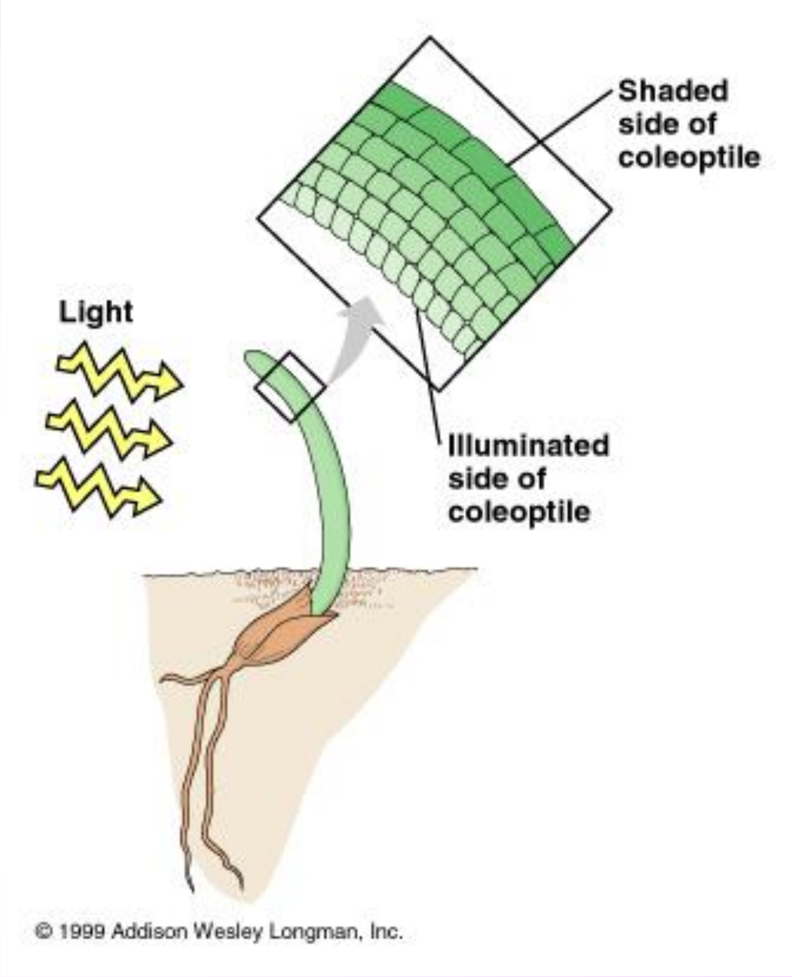


FIGURE 19.2 Auxin stimulates the elongation of oat coleoptile sections. These coleoptile sections were incubated for 18 hours in either water (A) or auxin (B). The yellow tissue inside the translucent coleoptile is the primary leaves. (Photos © M. B. Wilkins.)

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^{-1})
  - In coleoptiles (1g 20,000 tons^{-1})
- 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

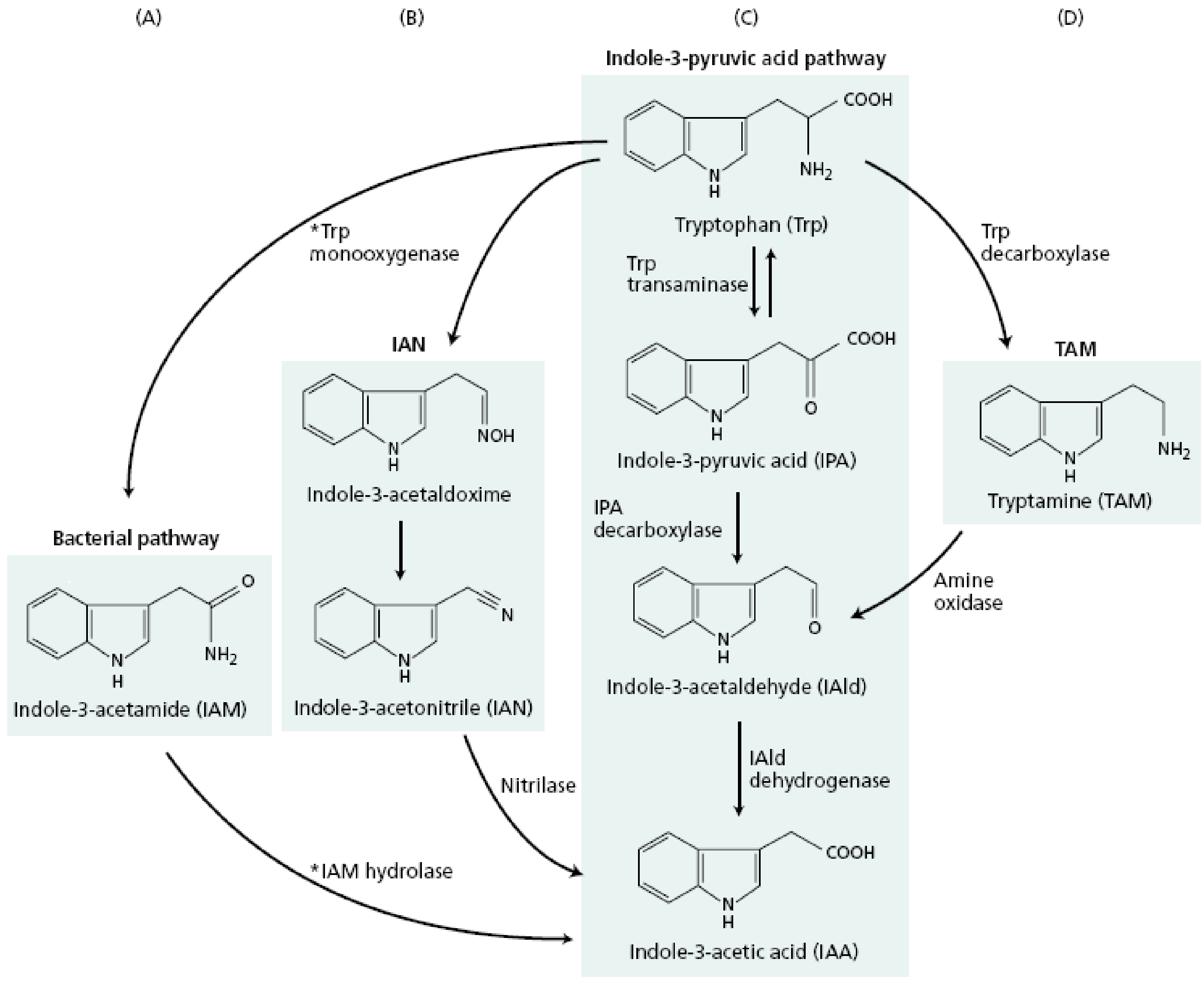
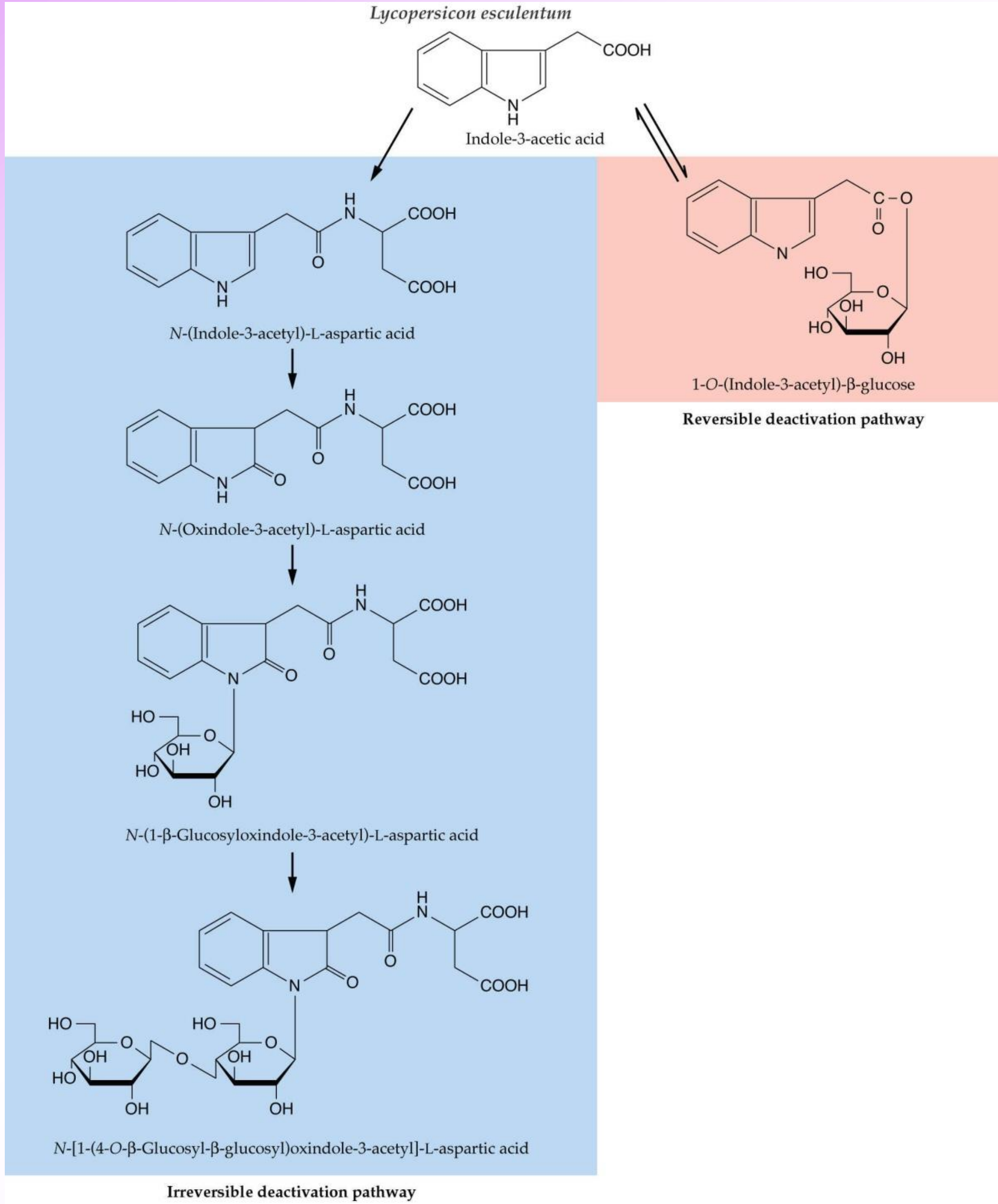


FIGURE 19.6 Tryptophan-dependent pathways of IAA biosynthesis in plants and bacteria. The enzymes that are present only in bacteria are marked with an asterisk. (After Bartel 1997.)



Lycopersicon esculentum
Indole-3-acetic acid
N-(Indole-3-acetyl)-L-aspartic acid
N-(Oxindole-3-acetyl)-L-aspartic acid
N-(1-β-Glucosyloxindole-3-acetyl)-L-aspartic acid
N-[1-(4-*O*-β-Glucosyl-β-glucosyl)oxindole-3-acetyl]-L-aspartic acid
Irreversible deactivation pathway
1-*O*-(Indole-3-acetyl)-β-glucose
Reversible deactivation pathway

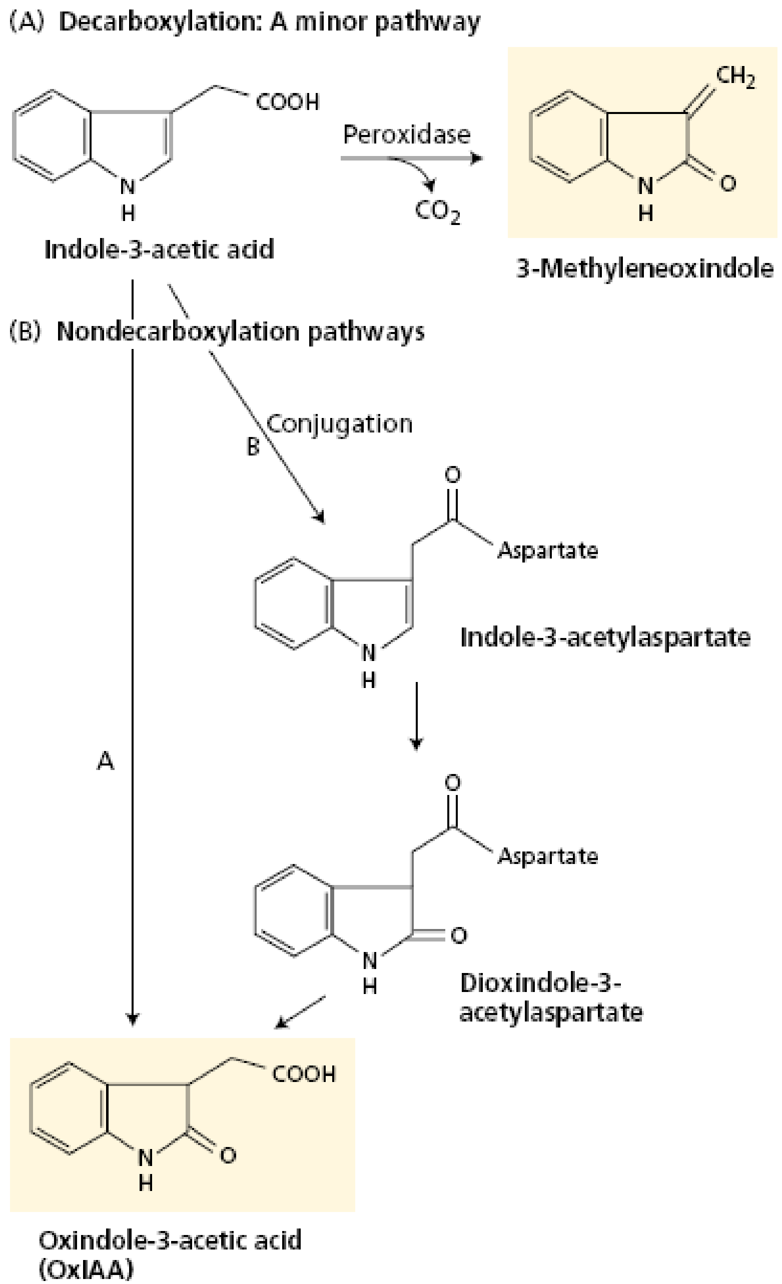
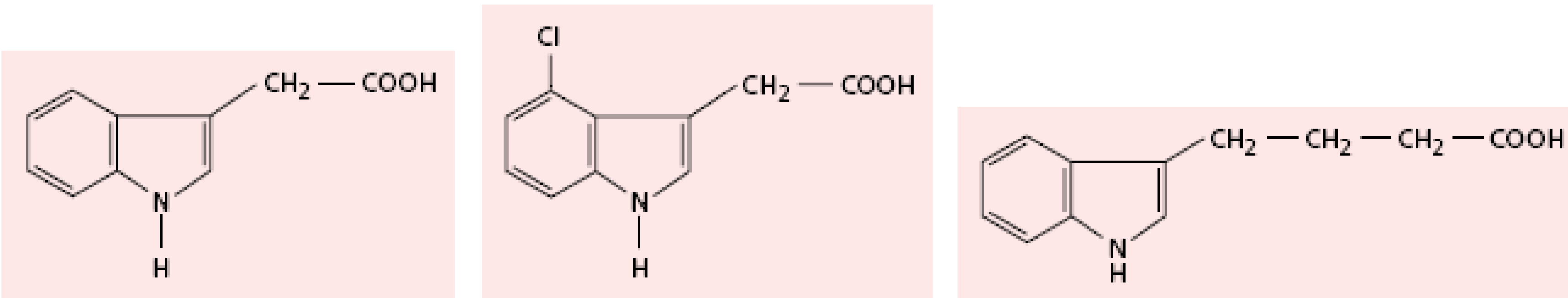


FIGURE 19.10 Biodegradation of IAA. (A) The peroxidase route (decarboxylation pathway) plays a relatively minor role. (B) The two nondecarboxylation routes of IAA oxidative degradation, A and B, are the most common metabolic pathways.

AUXINAS NATURALES



Indole-3-acetic acid (IAA) | **4-Chloroindole-3-acetic acid (4-Cl-IAA)** | **Indole-3-butyric acid (IBA)**

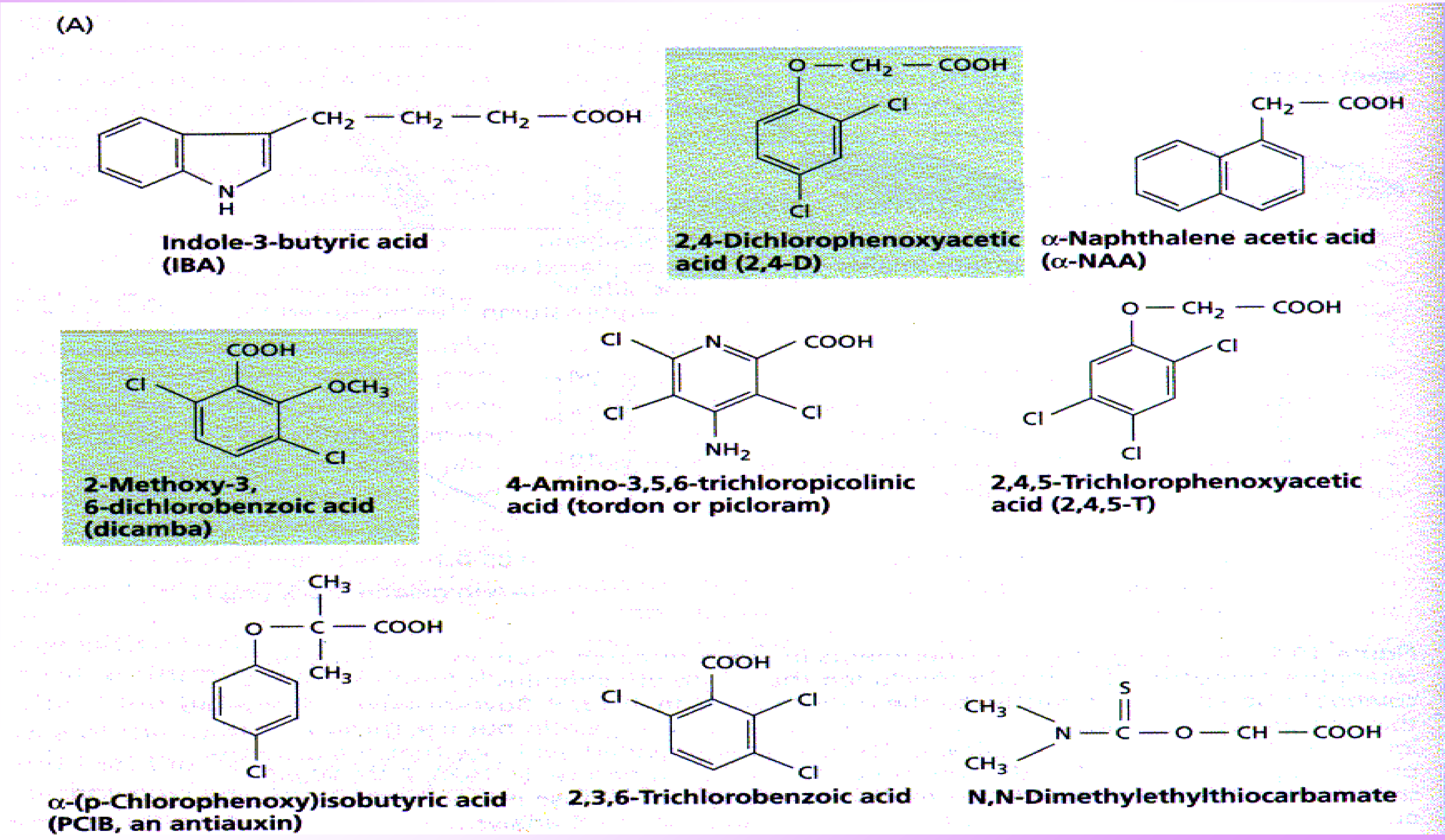
FIGURE 19.3 Structure of three natural auxins. Indole-3-acetic acid (IAA) occurs in all plants, but other related compounds in plants have auxin activity. Peas, for example, contain 4-chloroindole-3-acetic acid. Mustards and corn contain indole-3-butyric acid (IBA).

AUXINAS.

BALANCE:

- SINTESIS
- FOTOOXIDACIÓN
- OXIDACIÓN ENZIMAS
- COMPLEJO con azucares y aminoácidos.
- TRANSPORTE

AUXINAS SINTÉTICAS



Auxinas

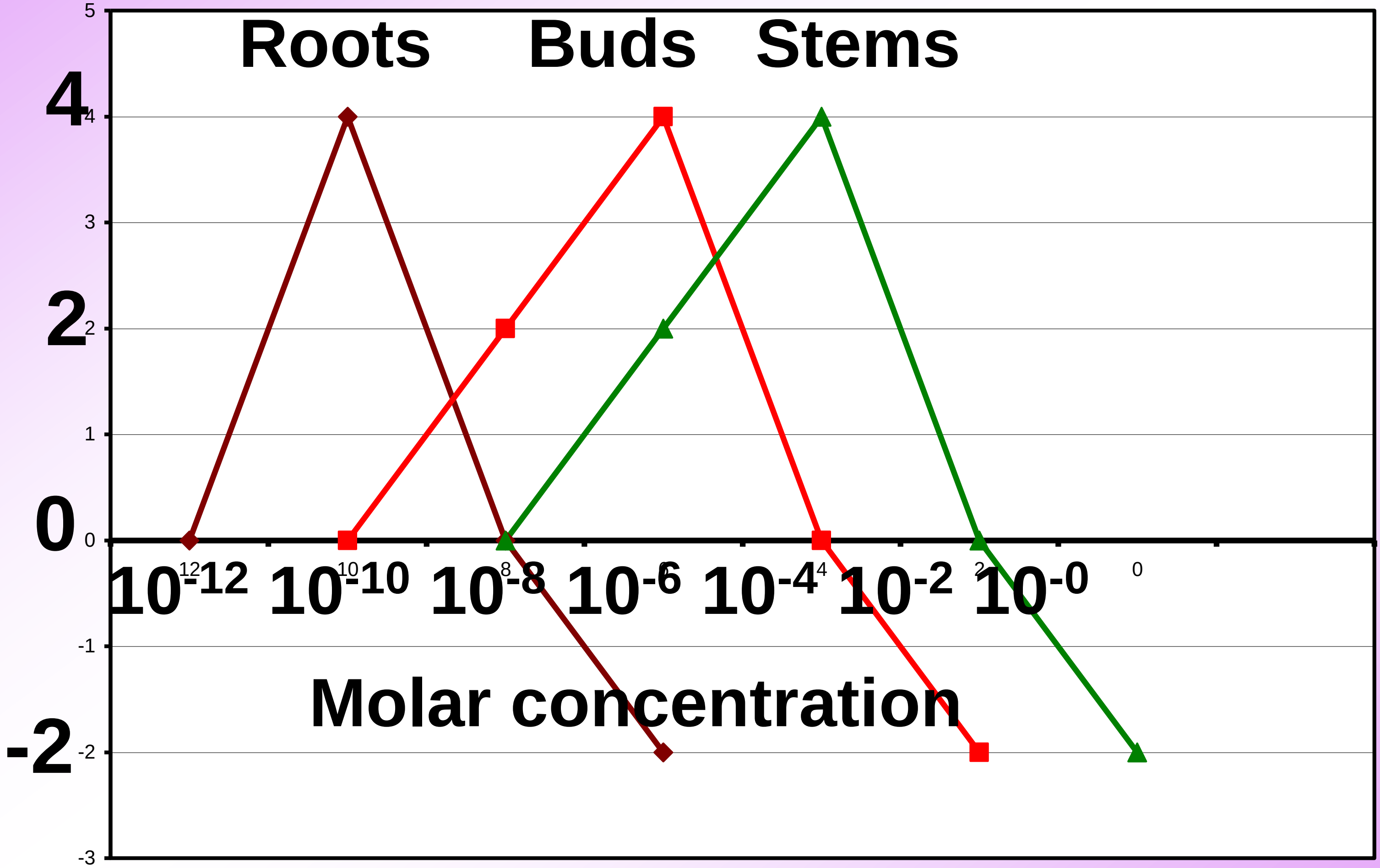
- ***Funciones principal:***
- Ø Actúan en la función de la mitosis, produciendo así el crecimiento de la planta mediante división y el alargamiento de sus células.
- Ø Inhibición del desarrollo de las yemas laterales, favoreciendo el de las apicales.
- Ø Promueven la iniciación de las raíces en los esquejes de los tallos.
- Ø Partenocarpia y regulación del crecimiento del fruto.
- Ø Determinación del sexo en cucurbitaceas.
- Ø Retarda la caída de hojas y frutos, según dosis.

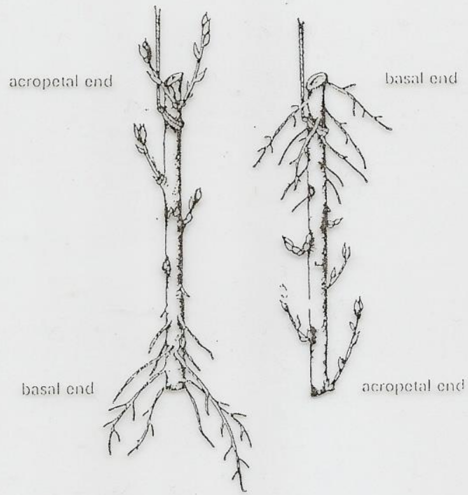
AUXIN ACTION

- **Cell Wall Relaxation**
- **Cell Elongation**
- **Stimulation of Cell division**
- **Enzyme Effects**
- **RNA and Protein Synthesis**
- **Prevents Abscission**
- **Ethylene Production**

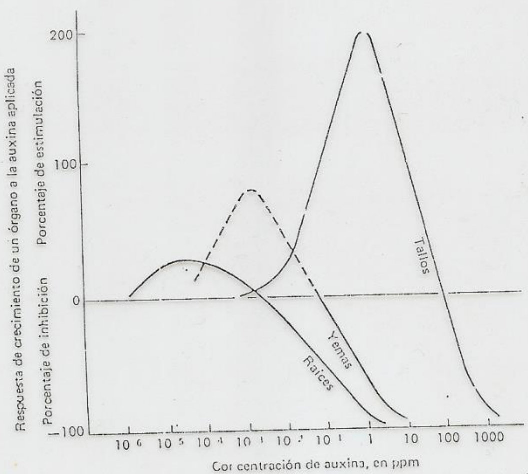
Apical Dominance
Direction of Translocation
Organ Formation
Tissue organization
Tropic and Nastic Responses

AUXIN ACTIVITY



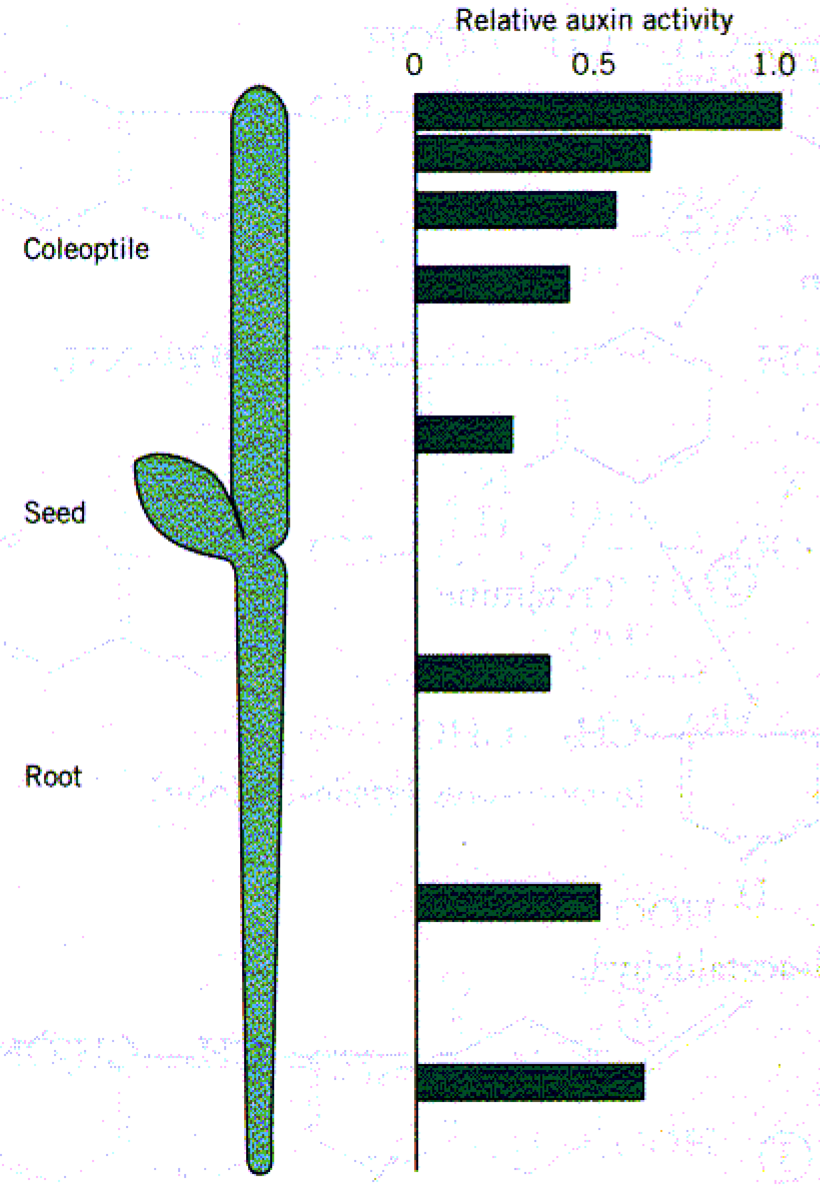


Polarity of root and bud formation in willow shoots suspended in moist air. (From E. W. Sinnott, 1960, *Plant Morphogenesis*, McGraw-Hill, New York, p. 120. Used by permission.)



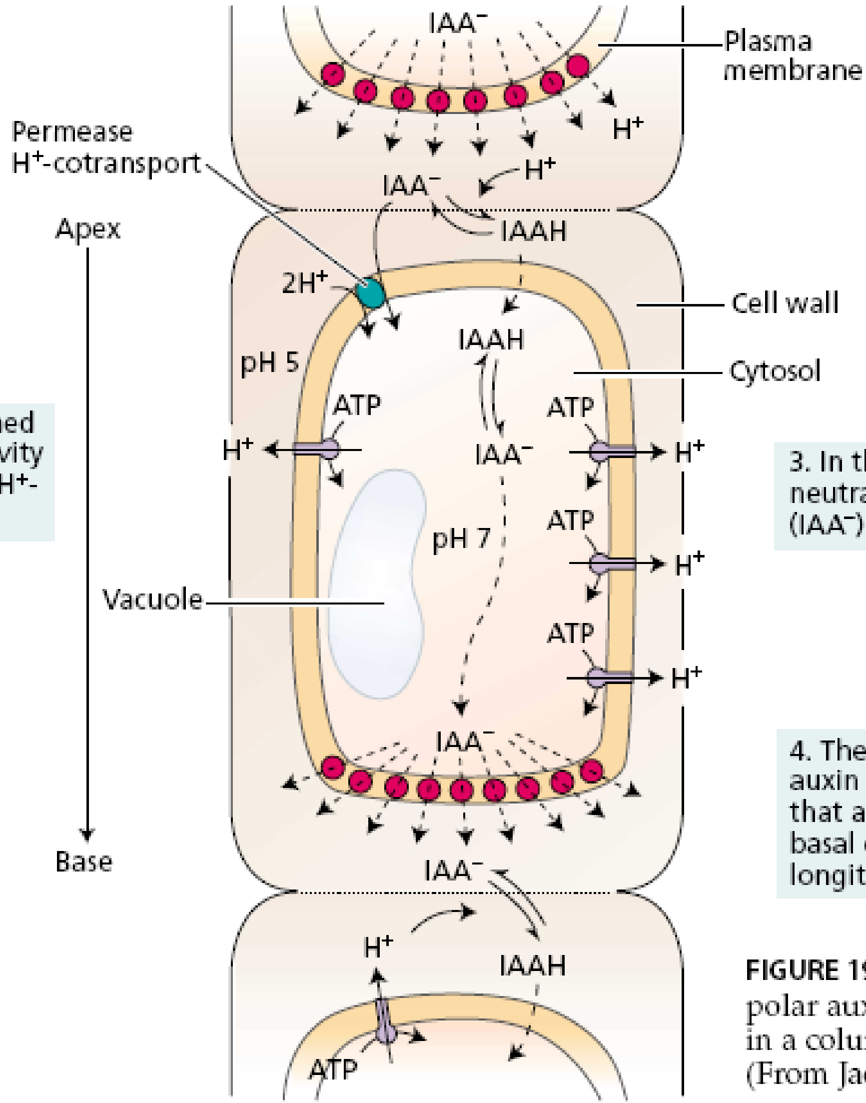
... Curvas de respuesta que muestran el efecto de las diversas concentraciones de IAA sobre el crecimiento de tres órganos de la planta. (Según L. J. Audus, 1959. Plant growth substances. Interscience Publishers. New York.)

RELATIVE AUXIN CONCENTRATION



Auxinas

- ***Como actúan:***
- Una característica sorprendente de las auxinas es la fuerte polaridad en su transporte a través de la plantaexhibida , 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^-).

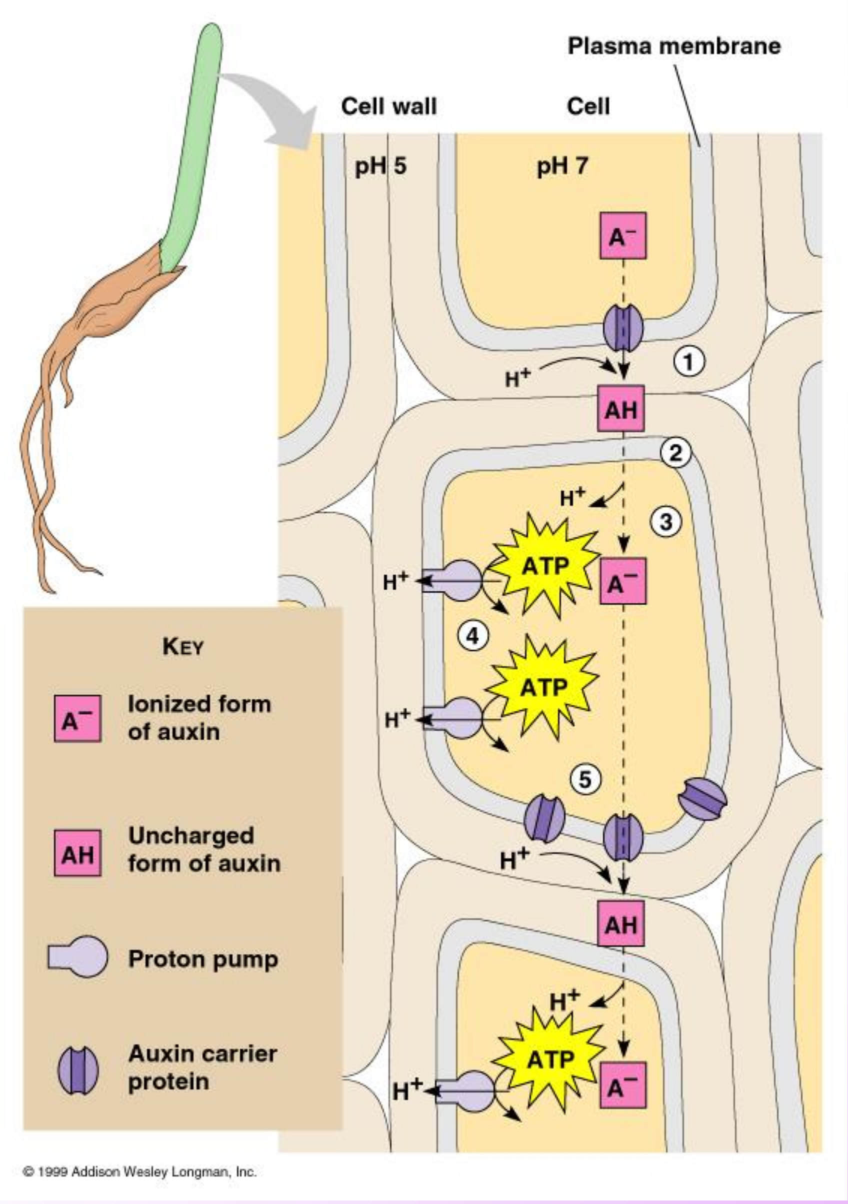
2. The cell wall is maintained at an acidic pH by the activity of the plasma membrane H^+-ATPase.

3. In the cytosol, which has a neutral pH, the anionic form (IAA^-) 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.

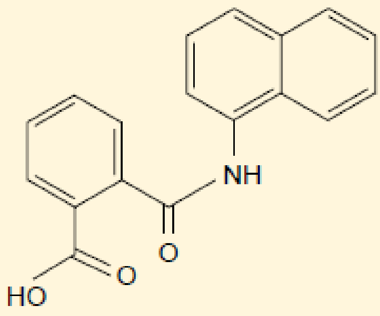
FIGURE 19.13 The chemiosmotic model for polar auxin transport. Shown here is one cell in a column of auxin-transporting cells. (From Jacobs and Gilbert 1983.)

Polar transport of Auxin

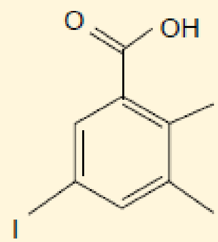


Inhibidores del transporte de auxinas

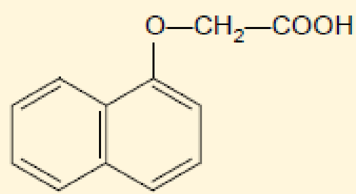
Inhibidores del transporte de auxina que no se encuentran en plantas



NPA (Ácido 1-N-naftilftalámico)

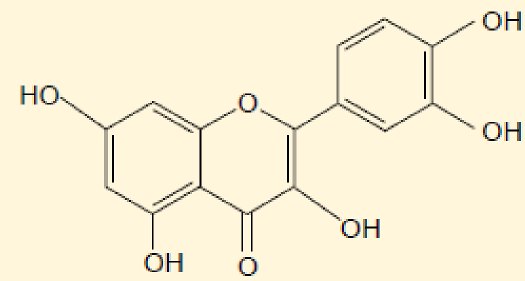


TIBA (Ácido 2,3,5-triyodobenzoico)

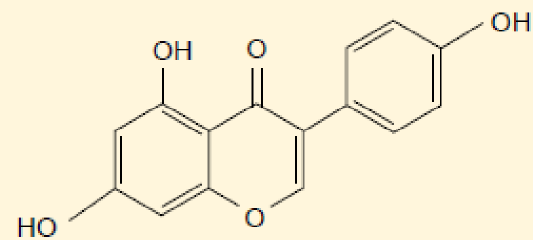


1-NOA (Ácido 1-naftoxiacético)

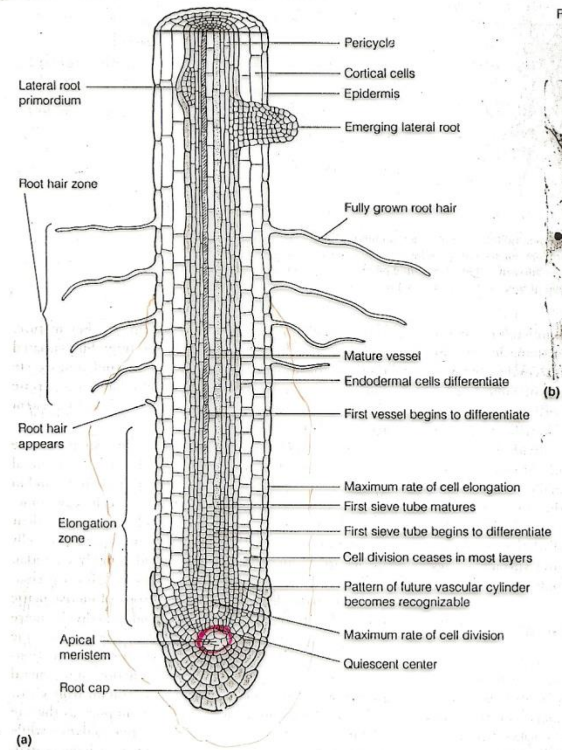
Inhibidores del transporte de auxina que son producidos naturalmente



Quercetina (flavonol)



Genisteina



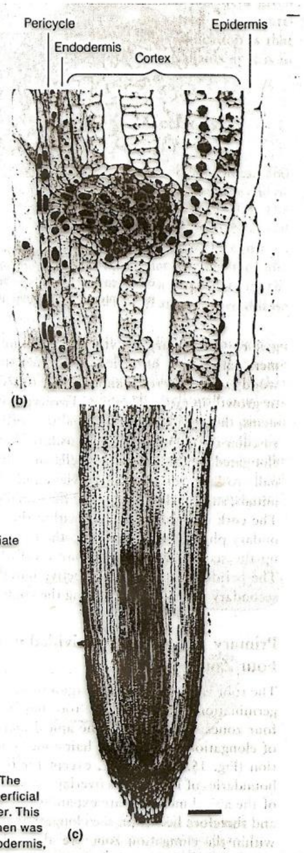
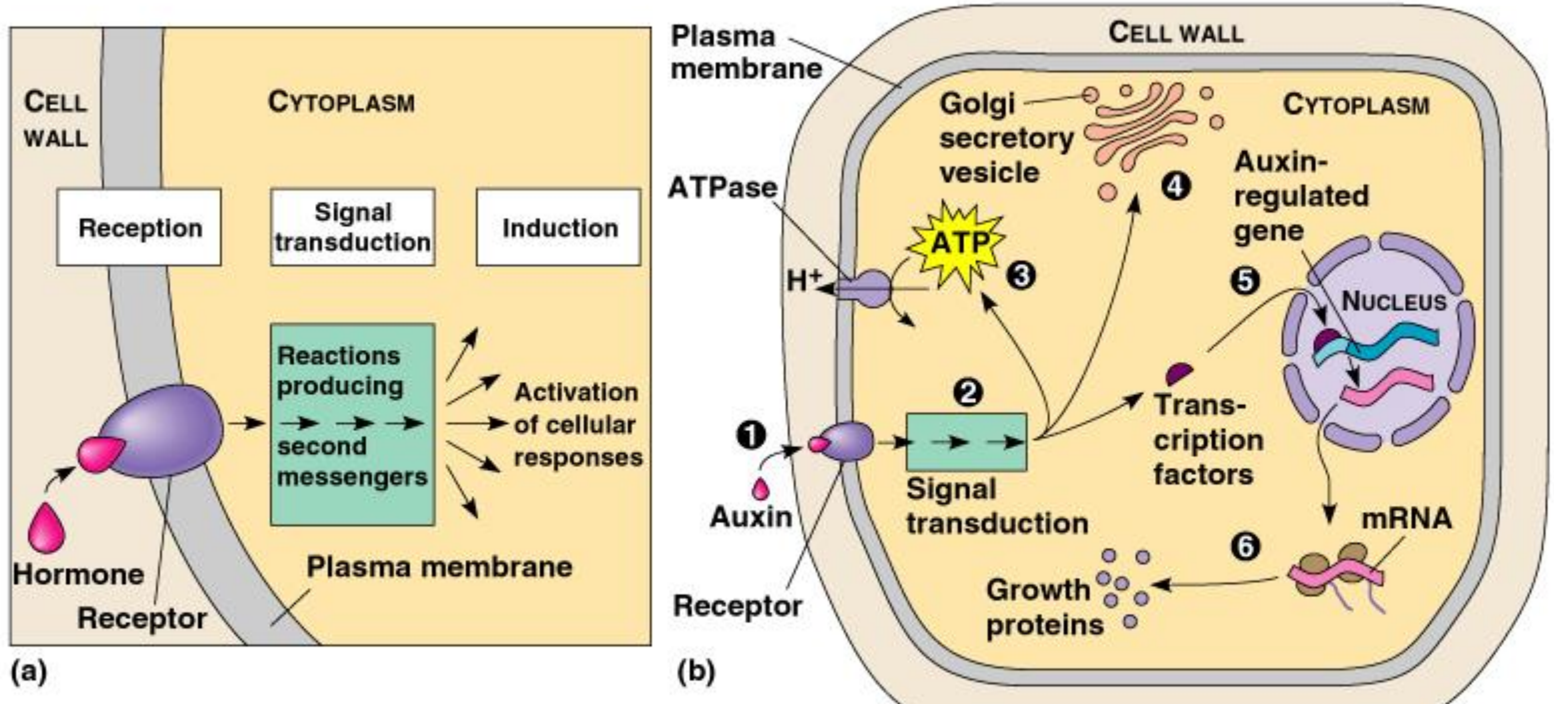


FIGURE 15.2. Primary root growth. (a) Diagram of a primary root cut in longitudinal section. The cellular structure of the root has been greatly simplified for clarity. (b) In contrast to the superficial origin of new shoot axes, lateral roots arise deep within the root tissue, in the pericycle layer. This micrograph shows a longitudinal section of a root of the fern *Ceratopteris*. When the specimen was fixed, the developing lateral root was in the process of pushing its way out through the endodermis, cortex, and epidermis of the root. Bar = 50 μm. (*Ceratopteris* micrograph courtesy of C. H. Busby.) (c) Cells in the apical meristem, as seen here in a longitudinal section of a corn (*Zea mays*) root, expand and divide rapidly, generating many files of cells. At increasing distances from the tip, as the rate of cell division falls, the cells become larger and begin to differentiate into specialized cell types. Cells in the meristem and future vascular cylinder are less vacuolate than cells in the cortex and stain more intensely. Section stained with Toluidine Blue O. Bar = 200 μm. (Courtesy of A. Hardham.)

Signal-transduction pathways in plants



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.

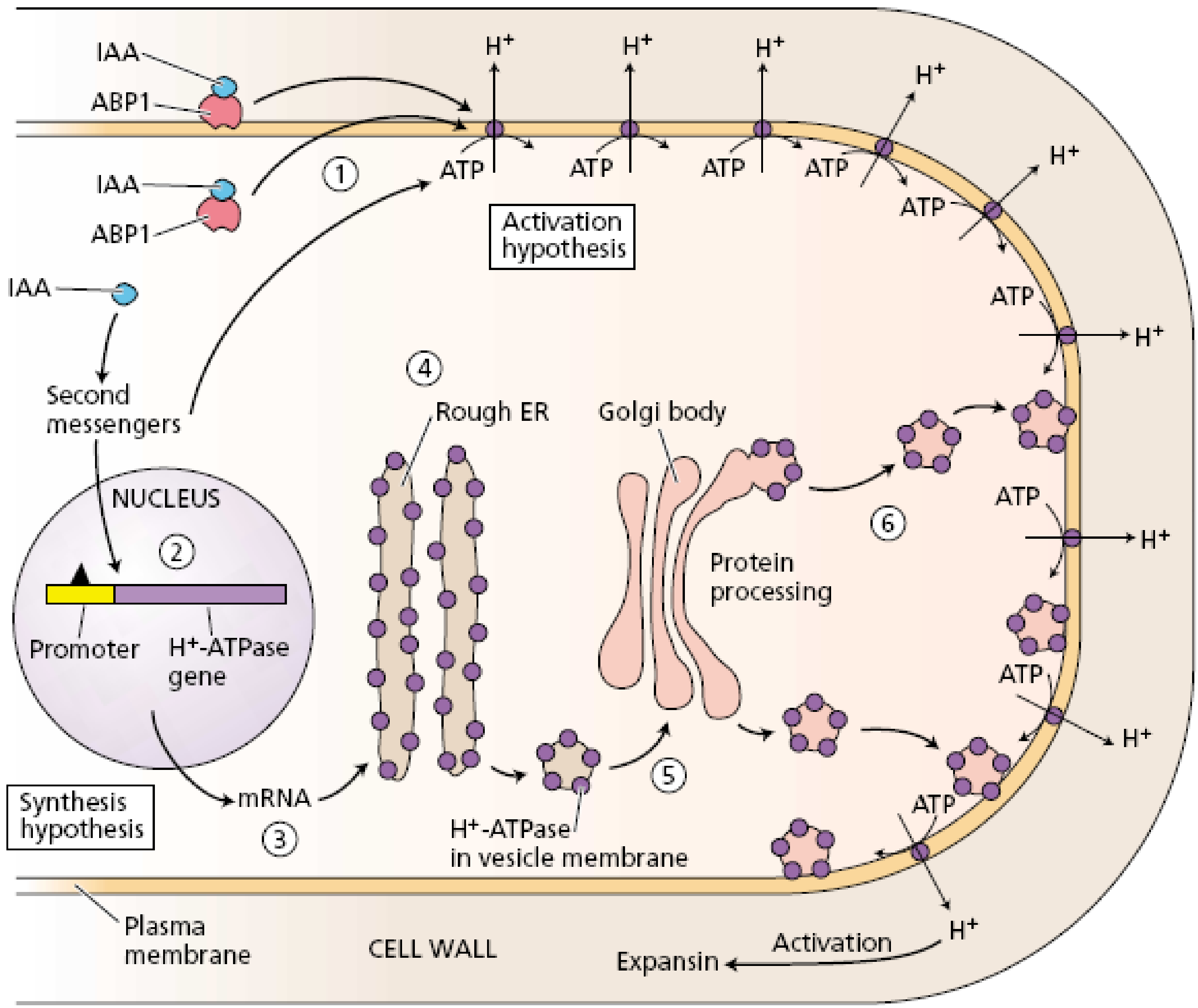
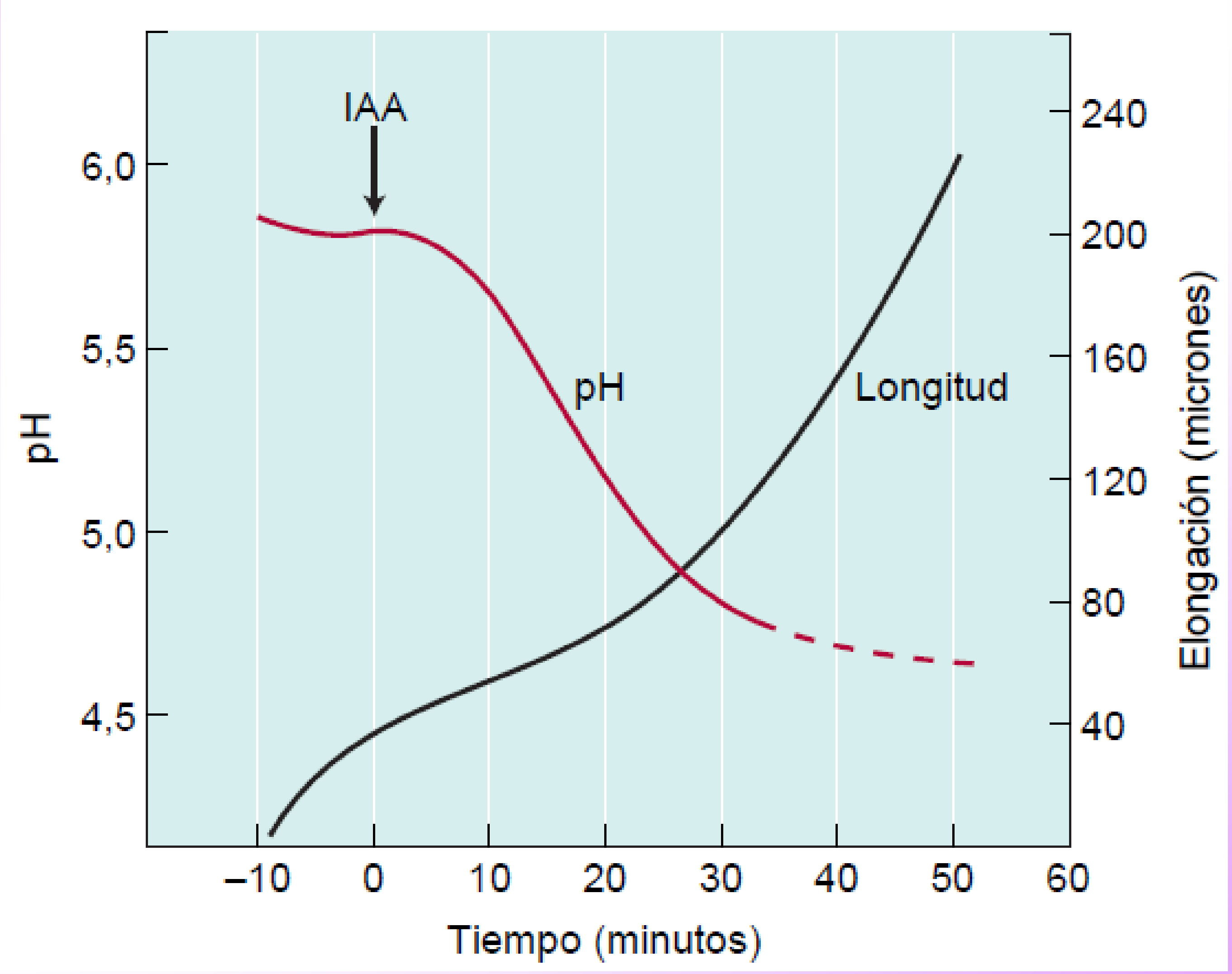


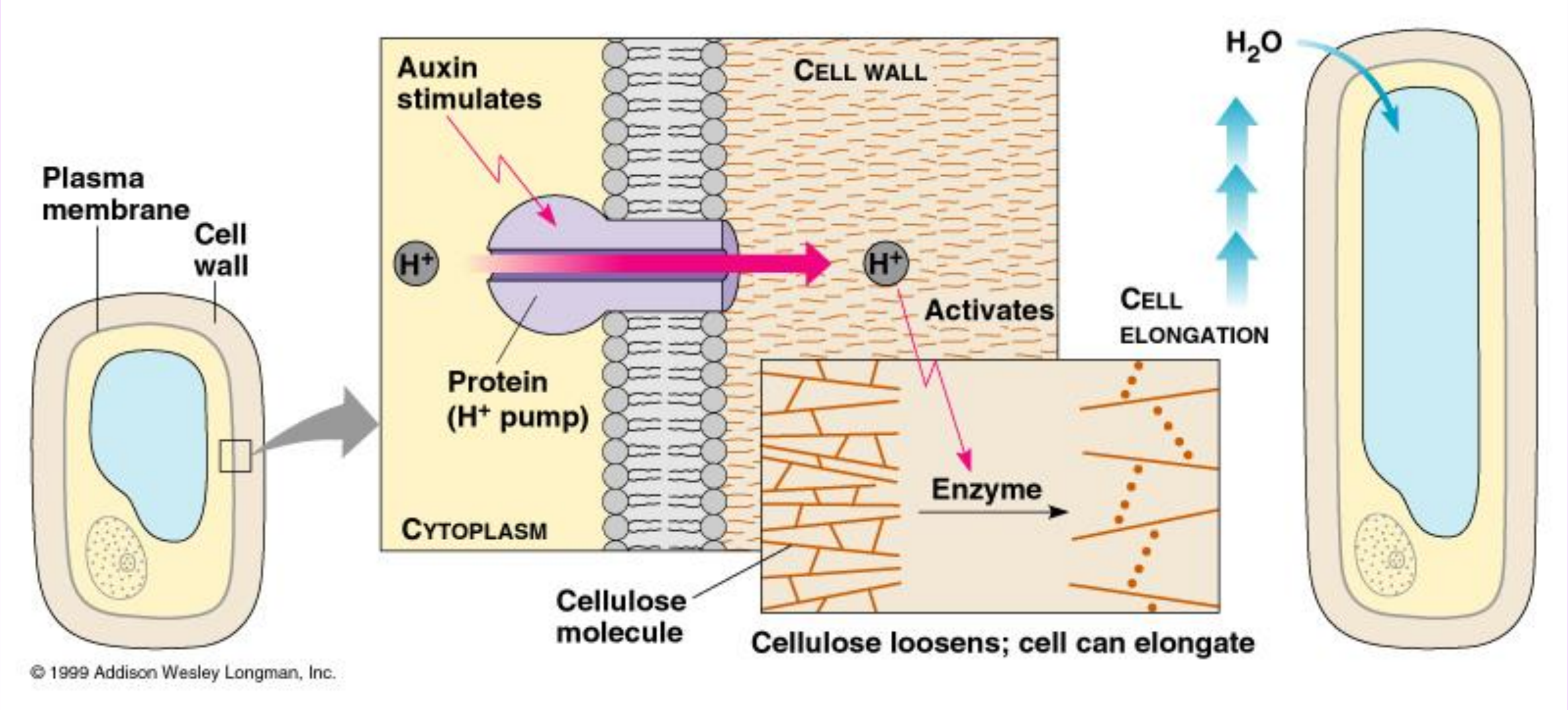
FIGURE 19.25 Current models for IAA-induced H^+ extrusion. In many plants, both of these mechanisms may operate. Regardless of how H^+ pumping is increased, acid-induced wall loosening is thought to be mediated by expansins.

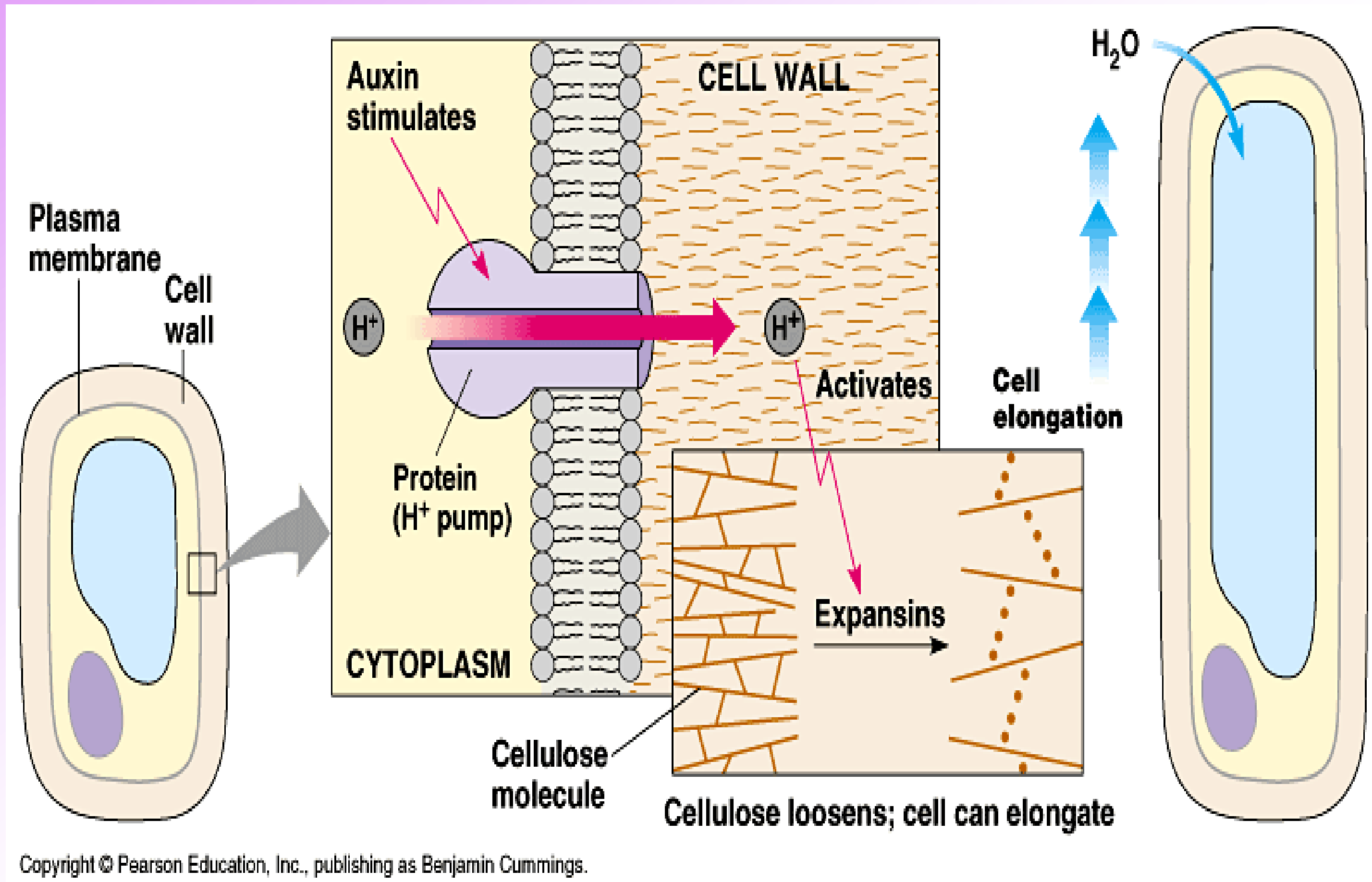
Efectos fisiológicos

Extensibilidad de la pared celular



Loosening of cell wall





Ψsol = Ψc = Ψs + Ψp

-0,1 = - 0,1 = -1,1 + 1 MPa

-0,1 = - 0,6 = -1,1 + 0,5 Mpa

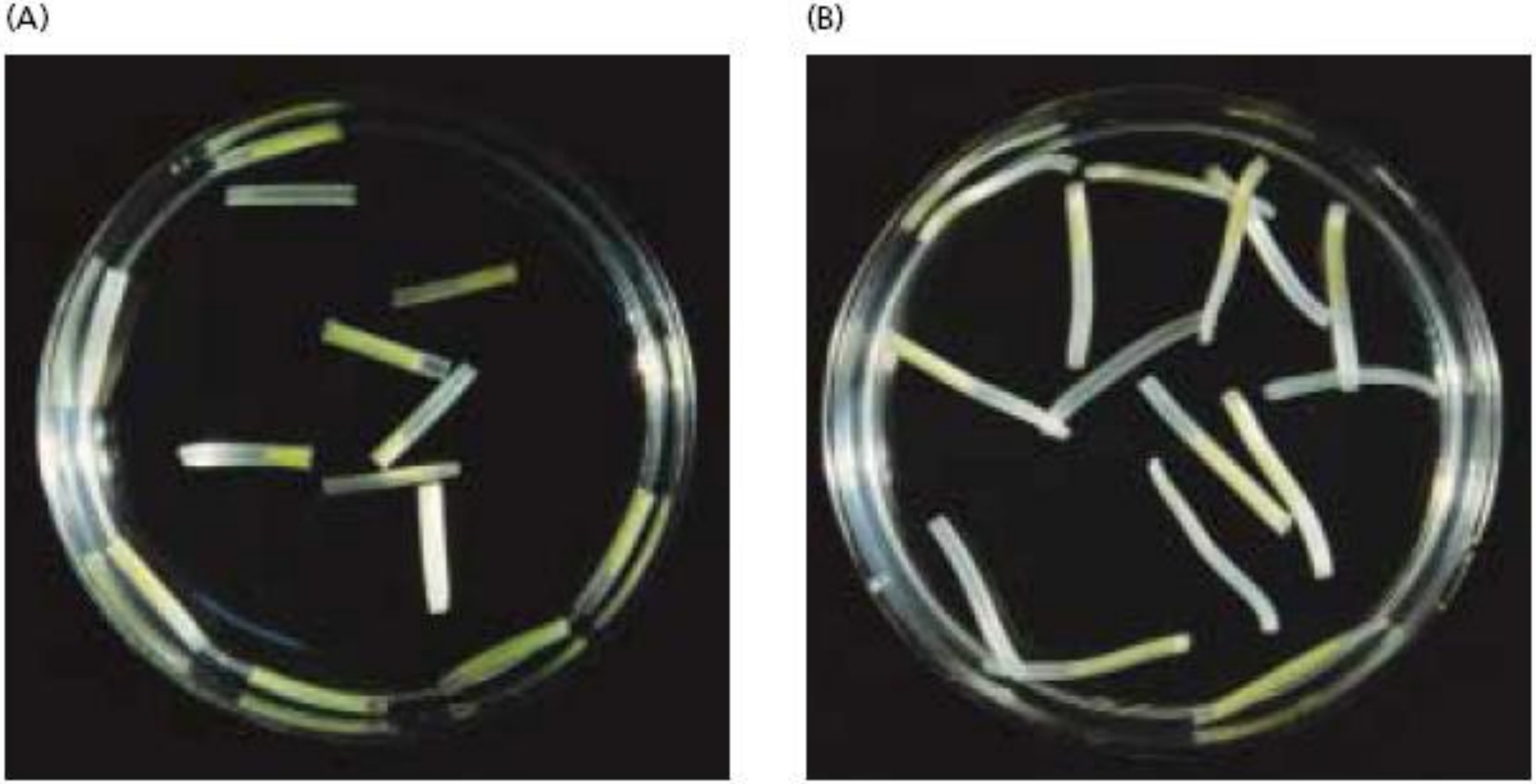


FIGURE 19.2 Auxin stimulates the elongation of oat coleoptile sections. These coleoptile sections were incubated for 18 hours in either water (A) or auxin (B). The yellow tissue inside the translucent coleoptile is the primary leaves. (Photos © M. B. Wilkins.)

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.)

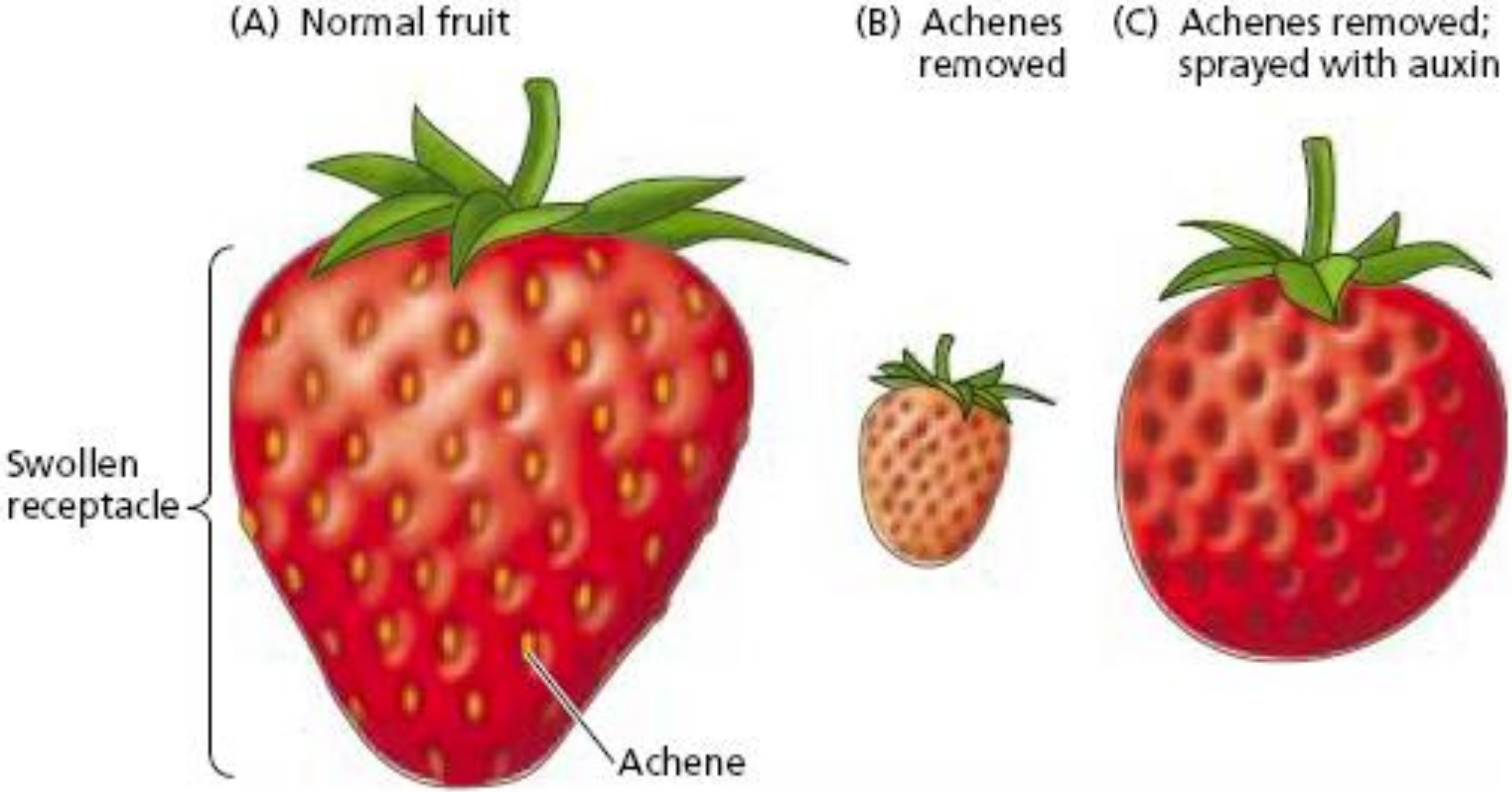
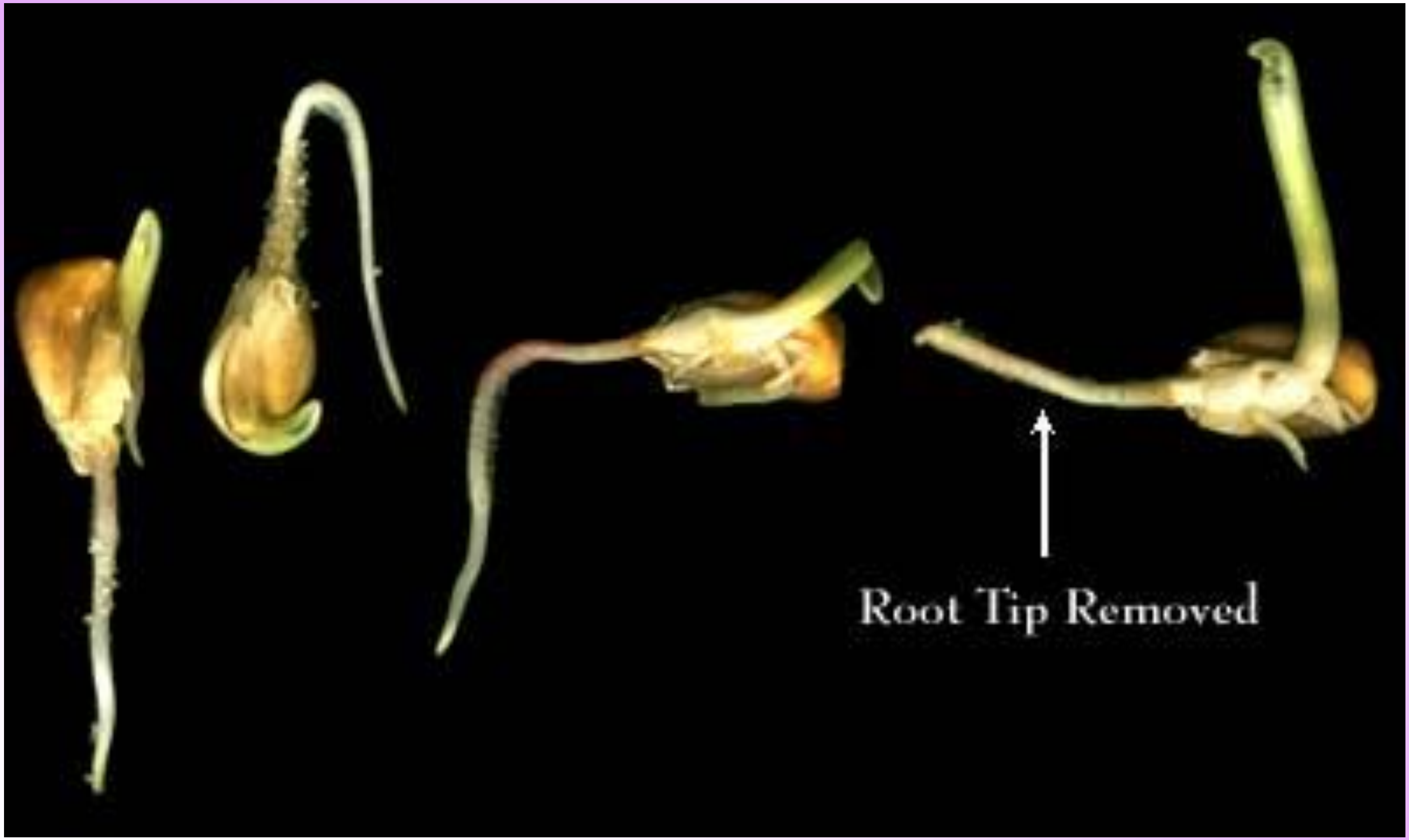
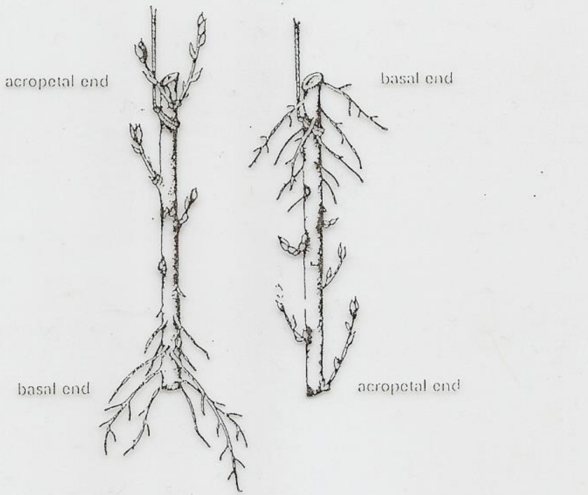


FIGURE 19.39 (A) The strawberry "fruit" is actually a swollen receptacle whose growth is regulated by auxin produced by the "seeds," which are actually achenes–the true fruits. (B) When the achenes are removed, the receptacle fails to develop normally. (C) Spraying the achene-less receptacle with IAA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

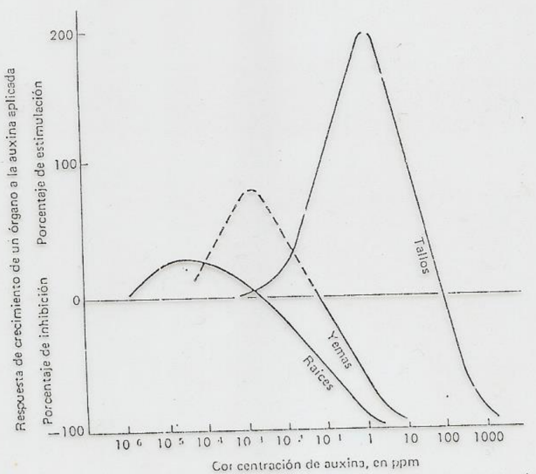
FIGURE 19.29 Lateral auxin gradients are formed in *Arabidopsis* hypocotyls during the differential growth responses to light (A) and gravity (B). The plants were transformed with the *DR5::GUS* reporter gene. Auxin accumulation on the shaded (A) or lower (B) side of the hypocotyls is indicated by the 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, 1959. Plant growth substances. Interscience Publishers. New York.)

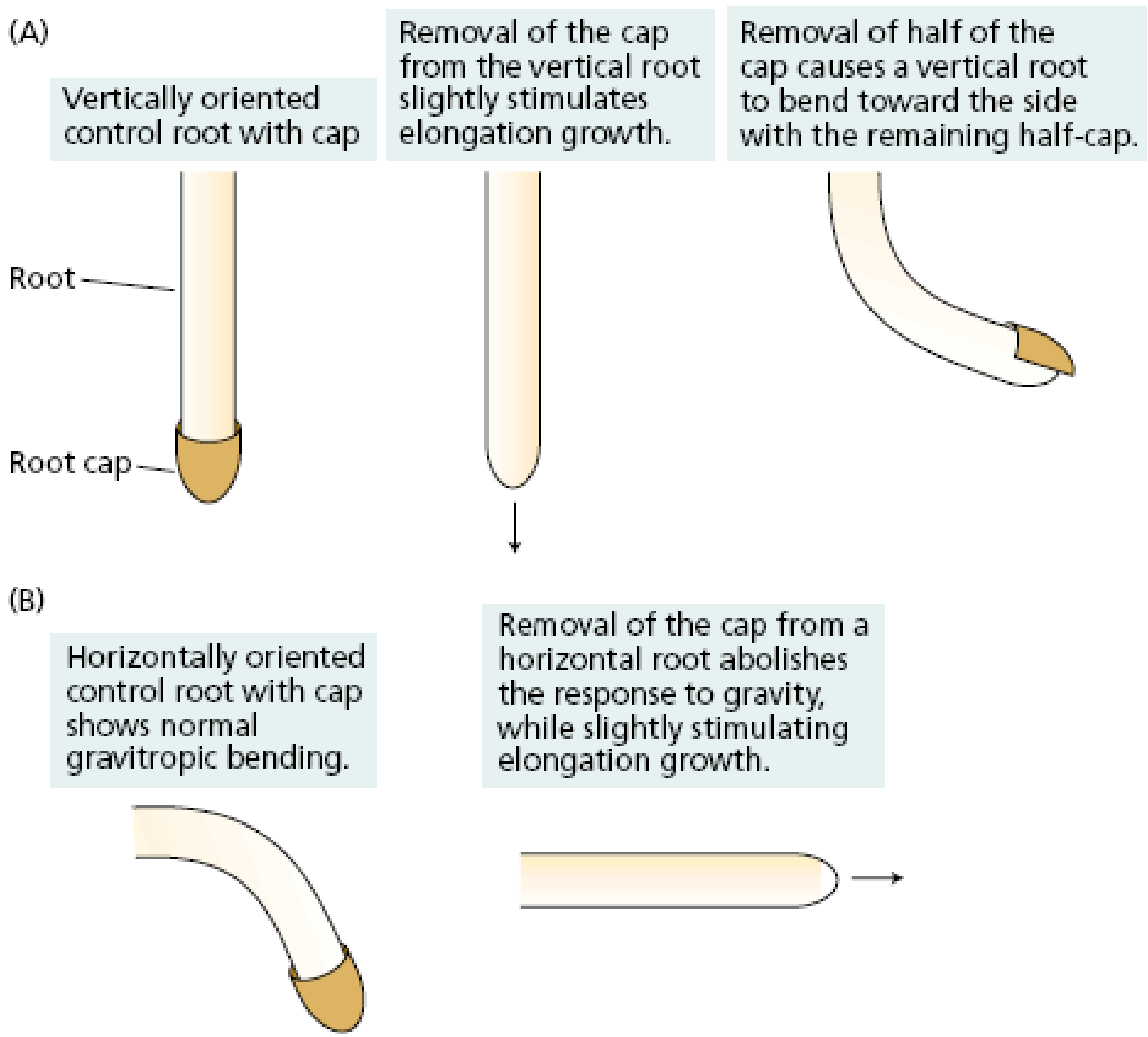


FIGURE 19.31 Microsurgery experiments demonstrating that the root cap produces an inhibitor that regulates root gravitropism. (After Shaw and Wilkins 1973.)

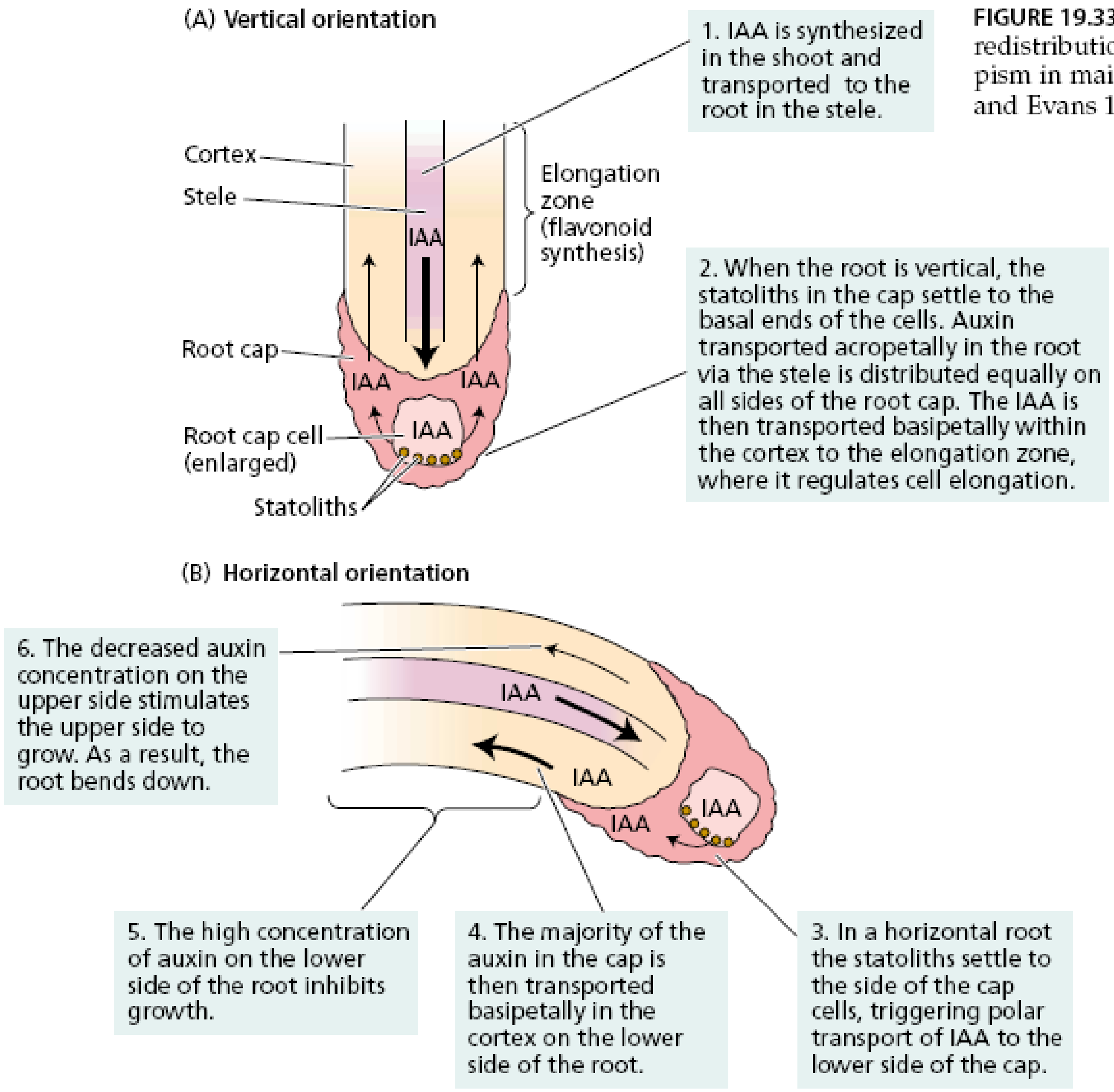


FIGURE 19.33 Proposed model for the redistribution of auxin during gravitropism in maize roots. (After Hasenstein and Evans 1988.)

Gravitropism Also Involves Lateral Redistribution of Auxin

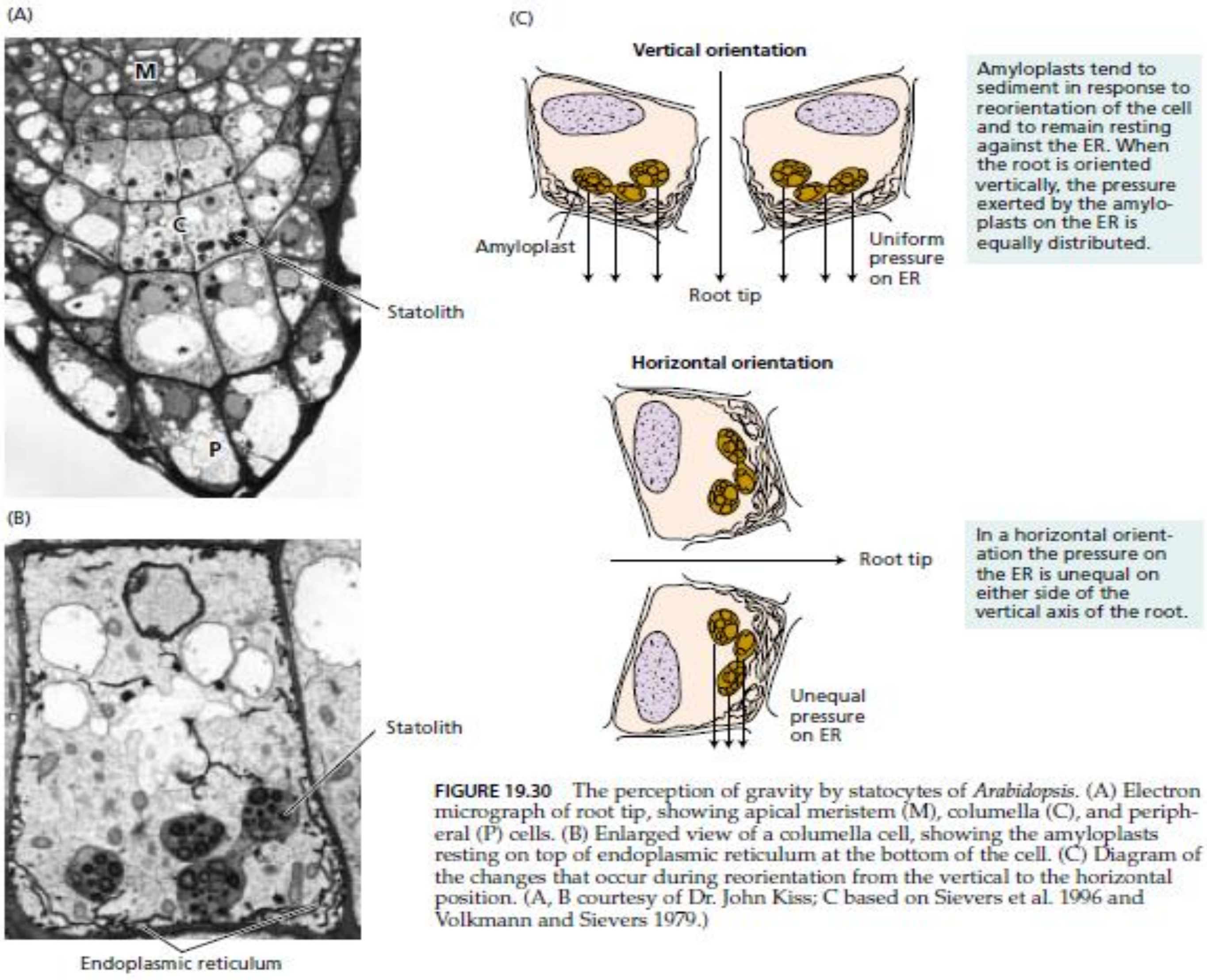
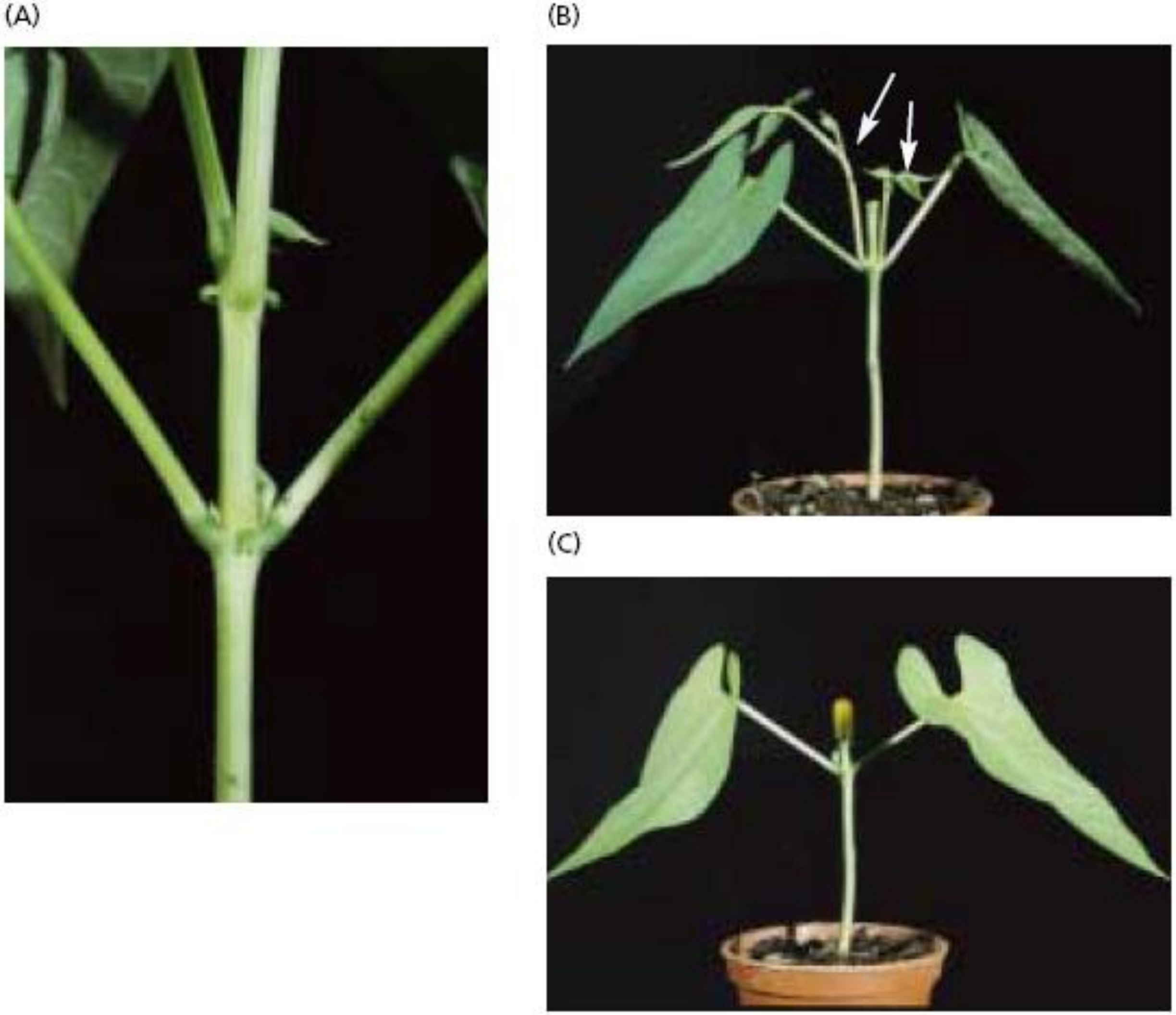


FIGURE 19.30 The perception of gravity by statocytes of *Arabidopsis*. (A) Electron micrograph of root tip, showing apical meristem (M), columella (C), and peripheral (P) cells. (B) Enlarged view of a columella cell, showing the amyloplasts resting on top of endoplasmic reticulum at the bottom of the 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.)



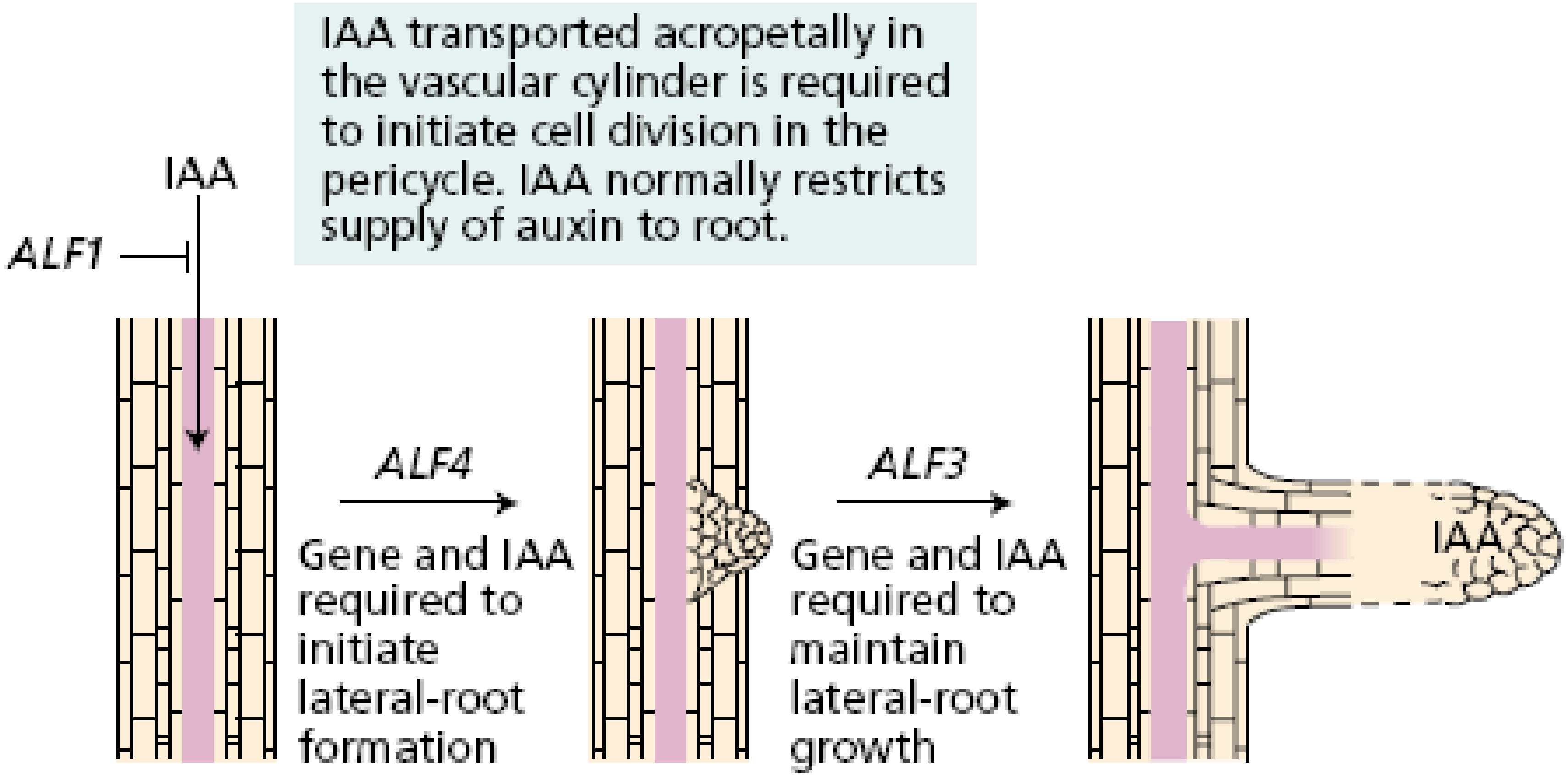


FIGURE 19.38 A model for the formation of lateral roots, based on the *alf* mutants of *Arabidopsis*. (After Celenza et al. 1995.)

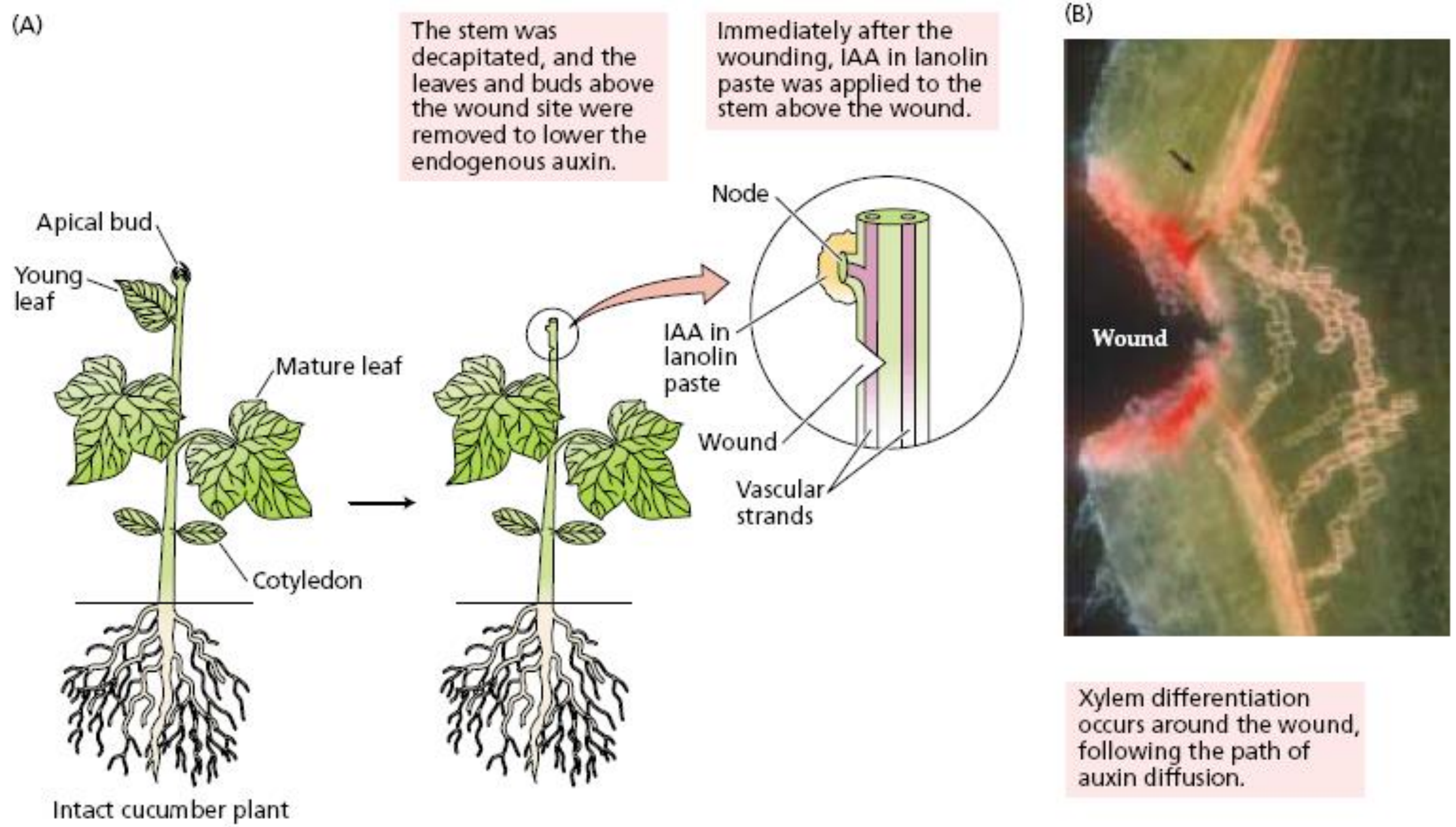
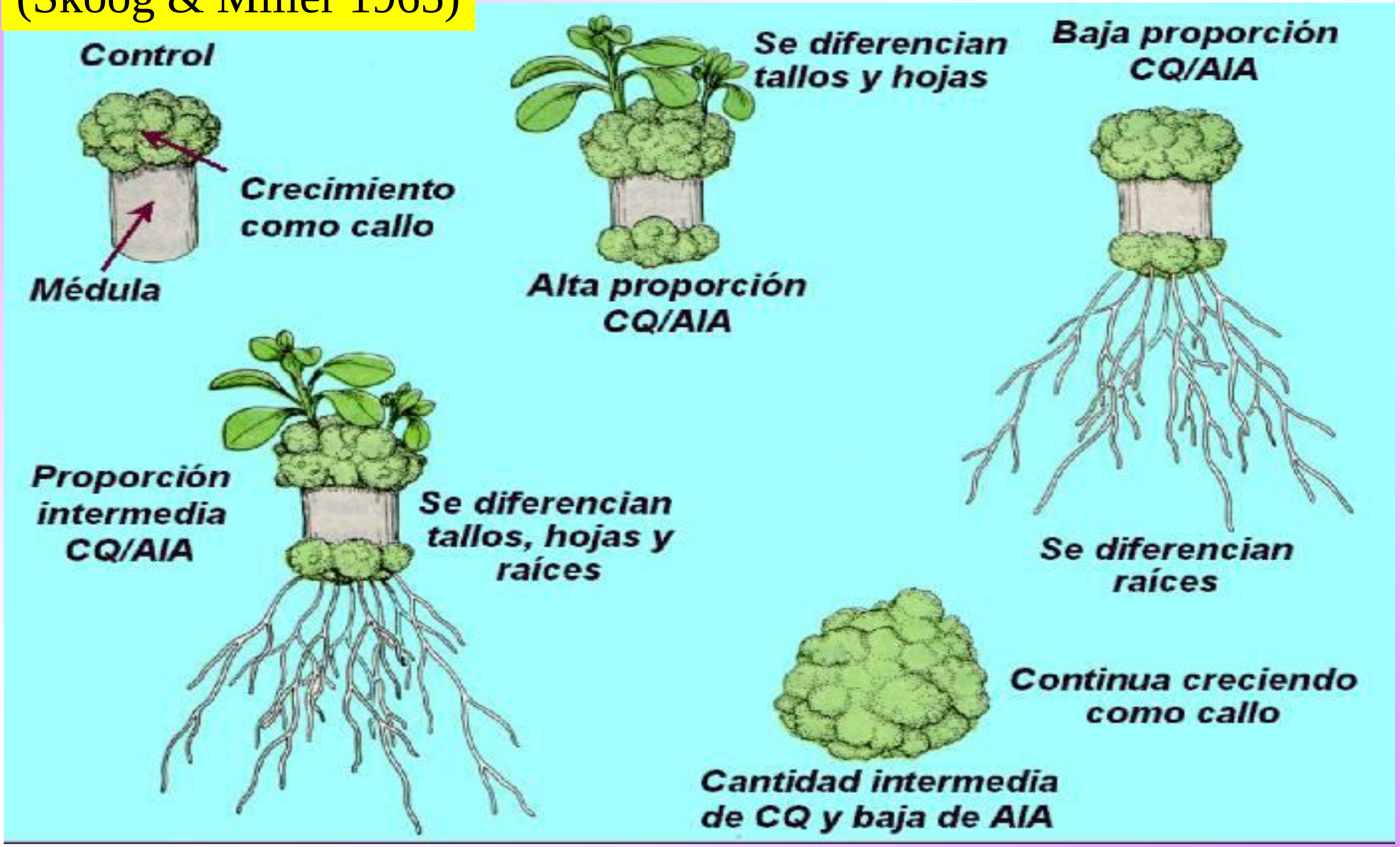


FIGURE 19.40 IAA-induced xylem regeneration around the wound in cucumber (*Cucumis sativus*) stem tissue. (A) Method for carrying out the wound regeneration experiment. (B) Fluorescence micrograph showing regenerating vascular tissue around the wound. (B courtesy of R. Aloni.)

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

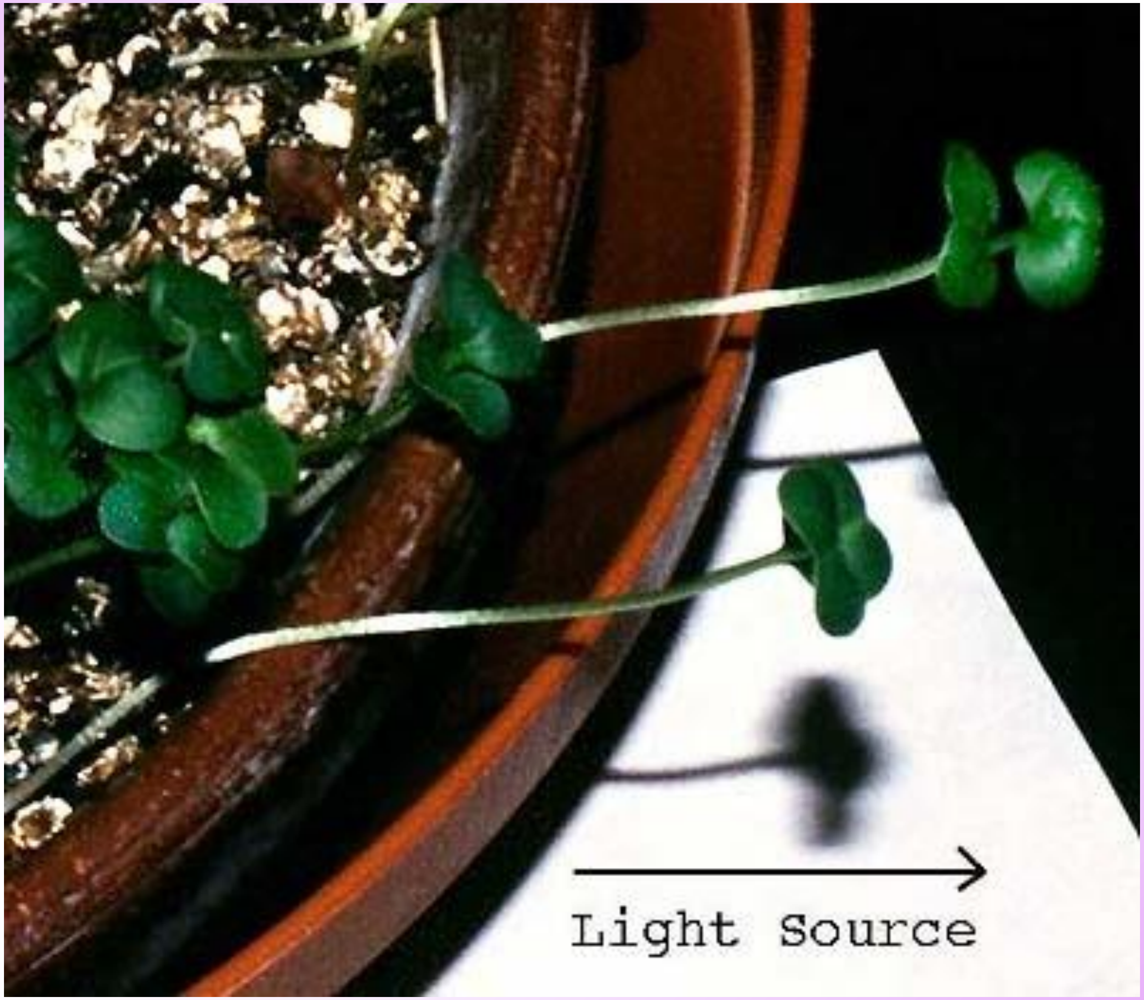
(Skoog & Miller 1965)



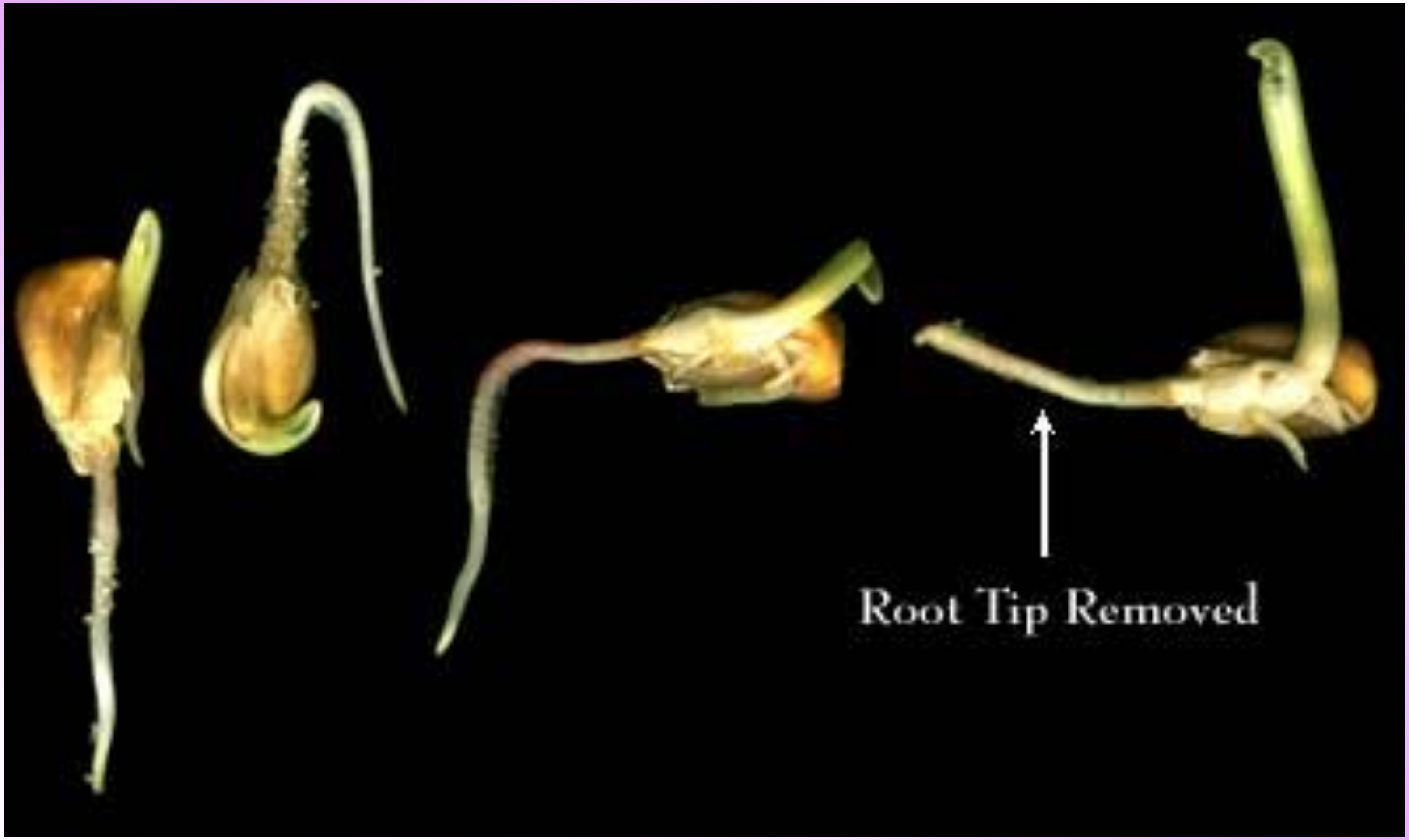
Tropic responses

Directional movements in response to a directional stimulus

Phototropism



Geotropism



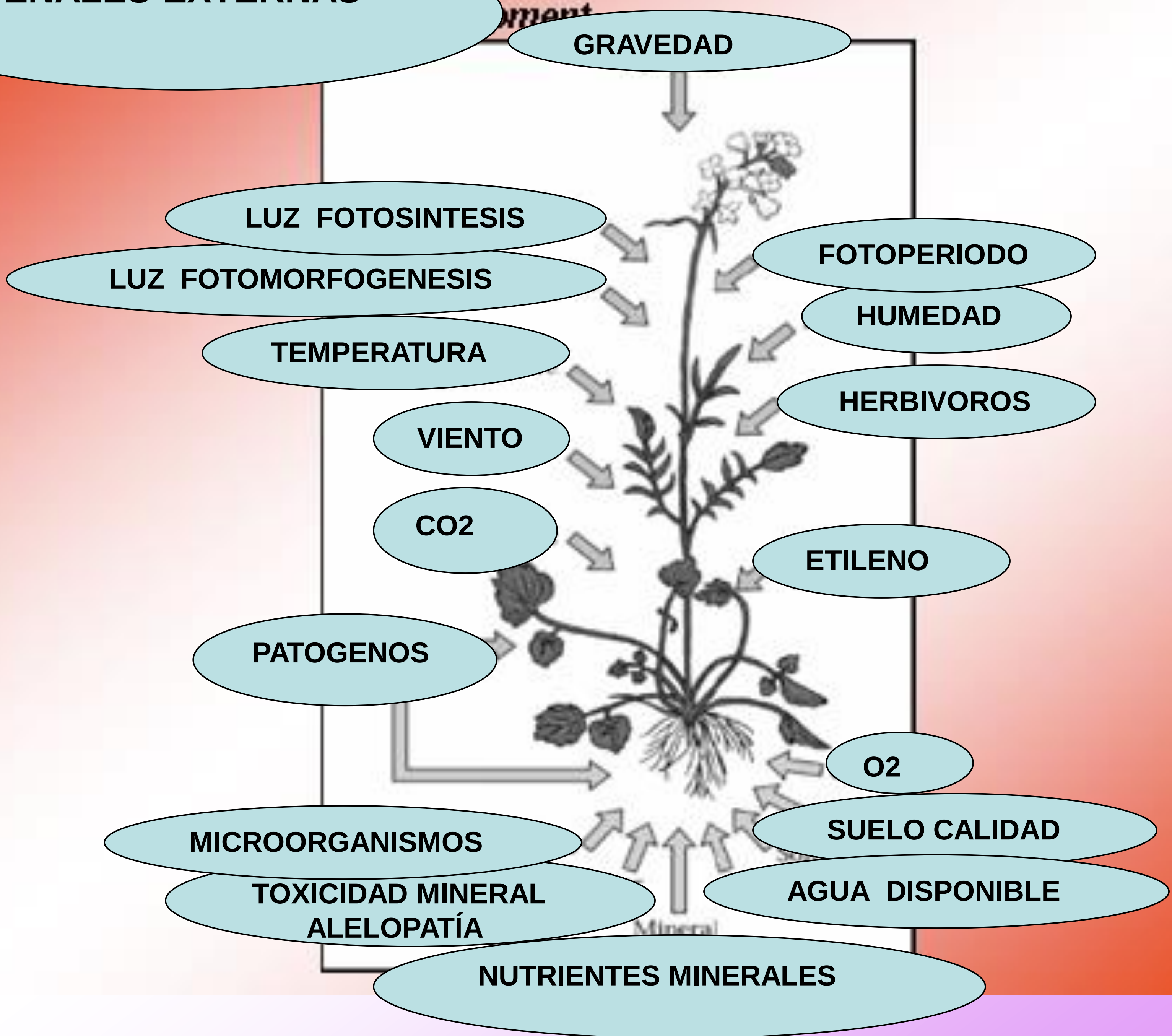
Thigmotropism

HERBICIDAS AUXÍNICOS

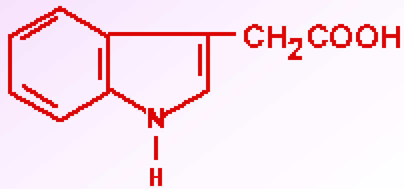
Aplicaciones comerciales

- **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 cucubitaceas**
- **<u>Abscisión o retardo</u> de hojas, flores y frutos.**

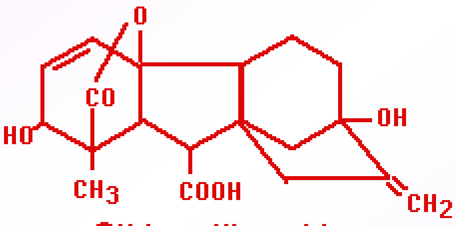
SEÑALES EXTERNAS



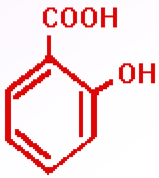
- ✓Auxinas
- ✓<u>Giberelinas</u>
- ✓Citocininas
- ✓Ácido abscísico
- ✓Etileno
- ✓Ácido jasmónico
- ✓Ácido salicílico



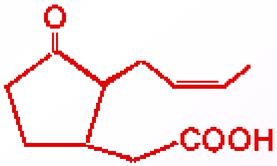
Indole-3-acetic acid



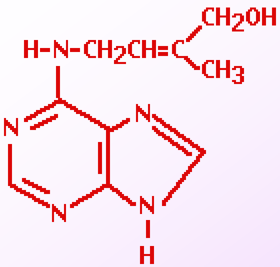
Gibberellic acid



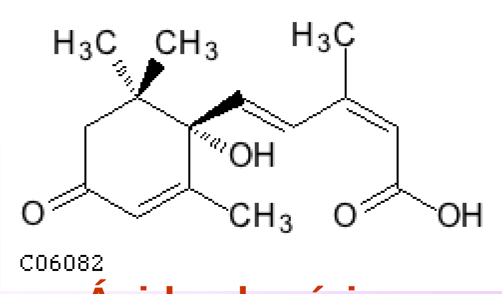
Salicylic acid



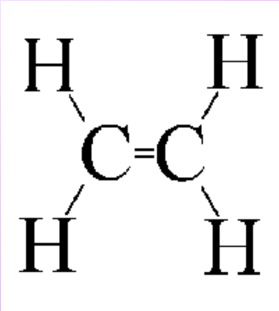
Jasmonic acid



Cytokinin
(Zeatin)



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 20th century occurred because of increased use of fertilizer and the introduction of semidwarf varieties of grains.

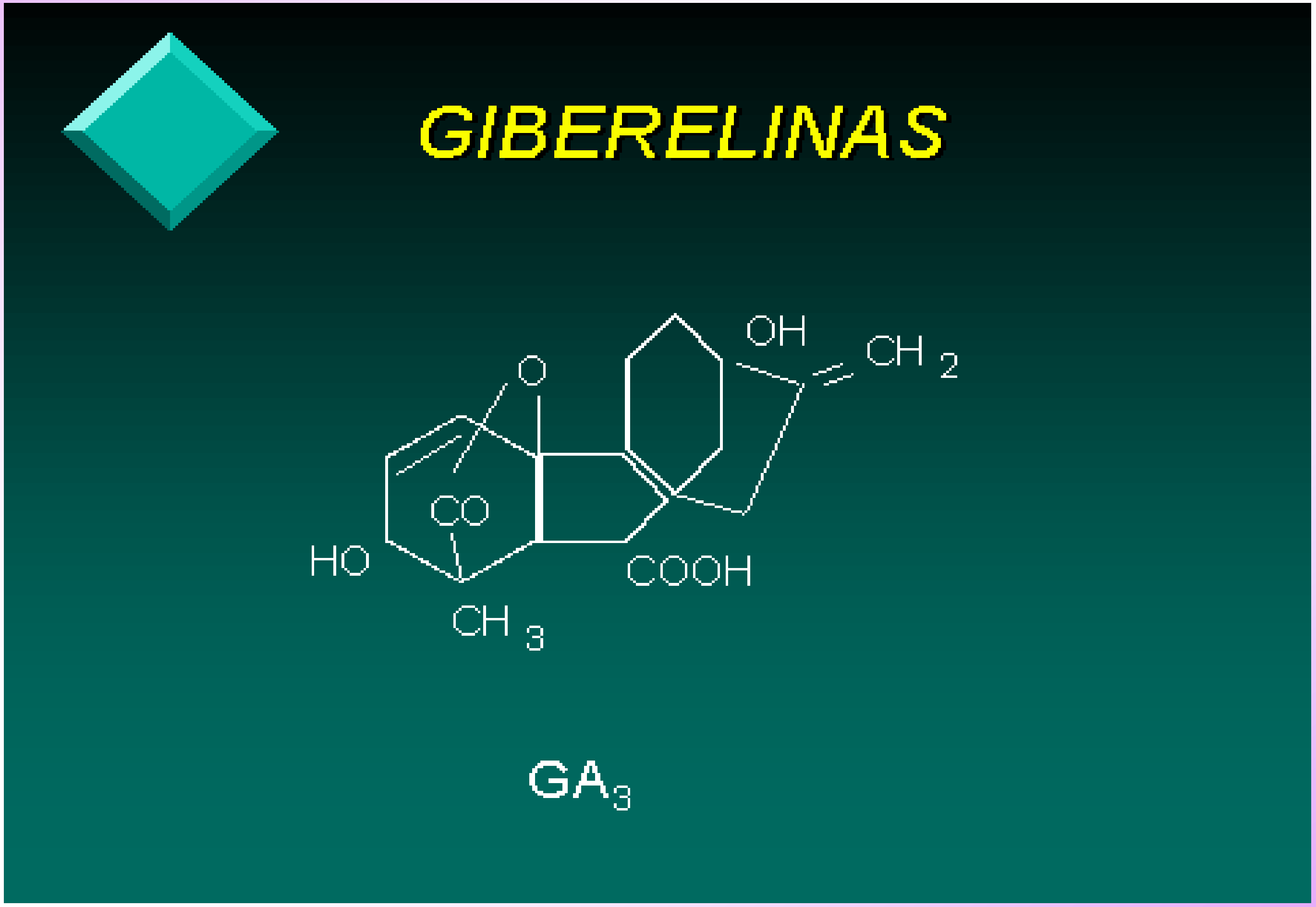
The semidwarf varieties put more energy into seed production than stem growth, and are sturdier and less likely to fall over.

Photos courtesy of S. Harrison, LSU Ag center and The World Food Prize.

QUE SON LAS GIBERELINAS

Son compuestos isoprenoides que proceden del acido 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 mas abundantes en tejidos de rápido crecimiento y desarrollo como los meristemos apicales

ESTRUCTURA QUIMICA DEL ACIDO GIBERELICO.



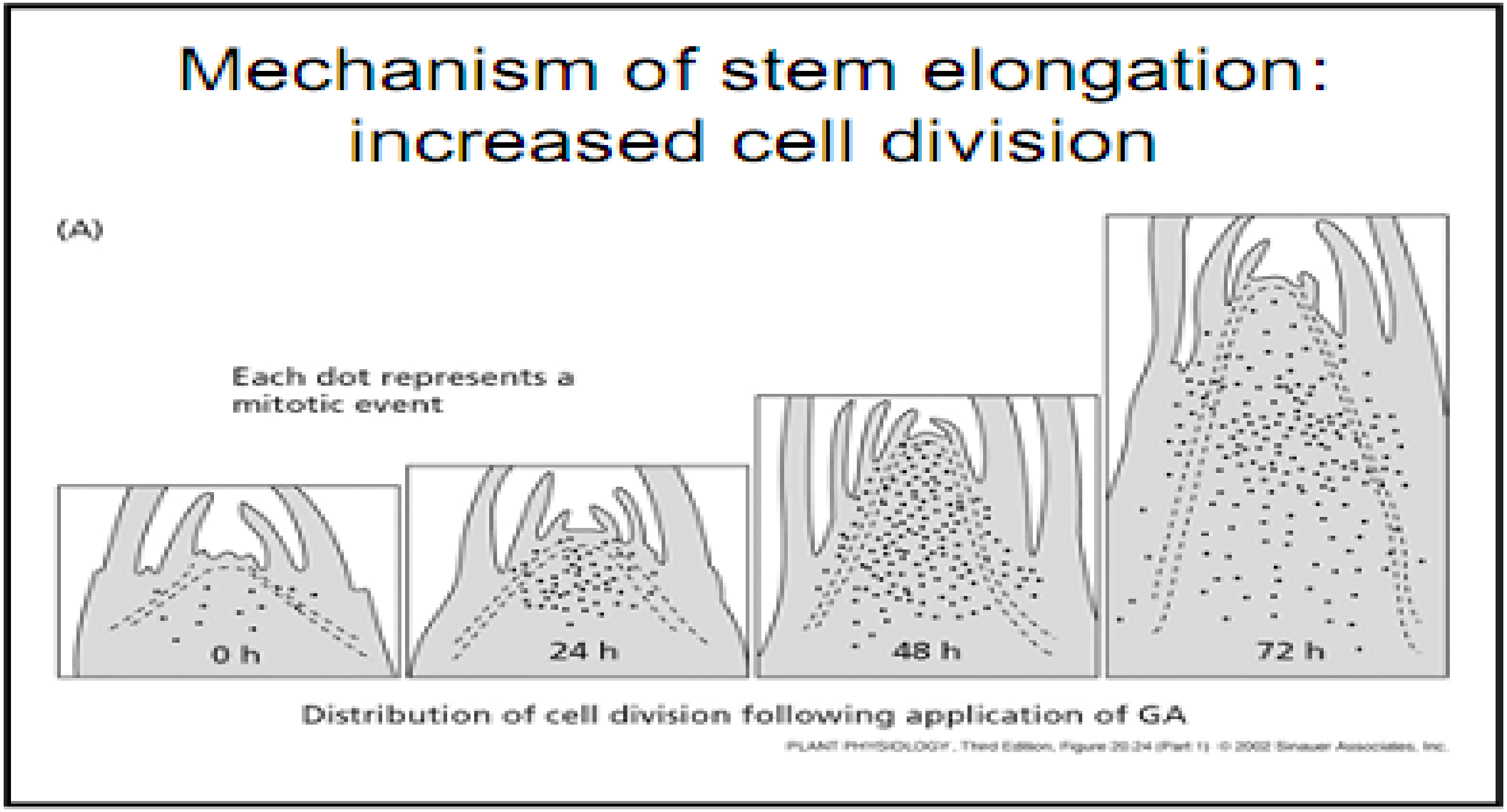
Las giberalinas son sintetizadas en los primordios apicales de las hojas, en puntas de las raíces y en semillas en desarrollo.

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 estadíos de las semillas, ya sea en reposo o no.

Han sido identificadas y cuantificadas por cromatografía gaseosa.

Giberelinas en el Crecimiento



FUNCIONES

- Incrementan el crecimiento de los tallos, en plantas enanas (plantas enteras)
- Inducen la brotación de yemas

* Interrupen 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.

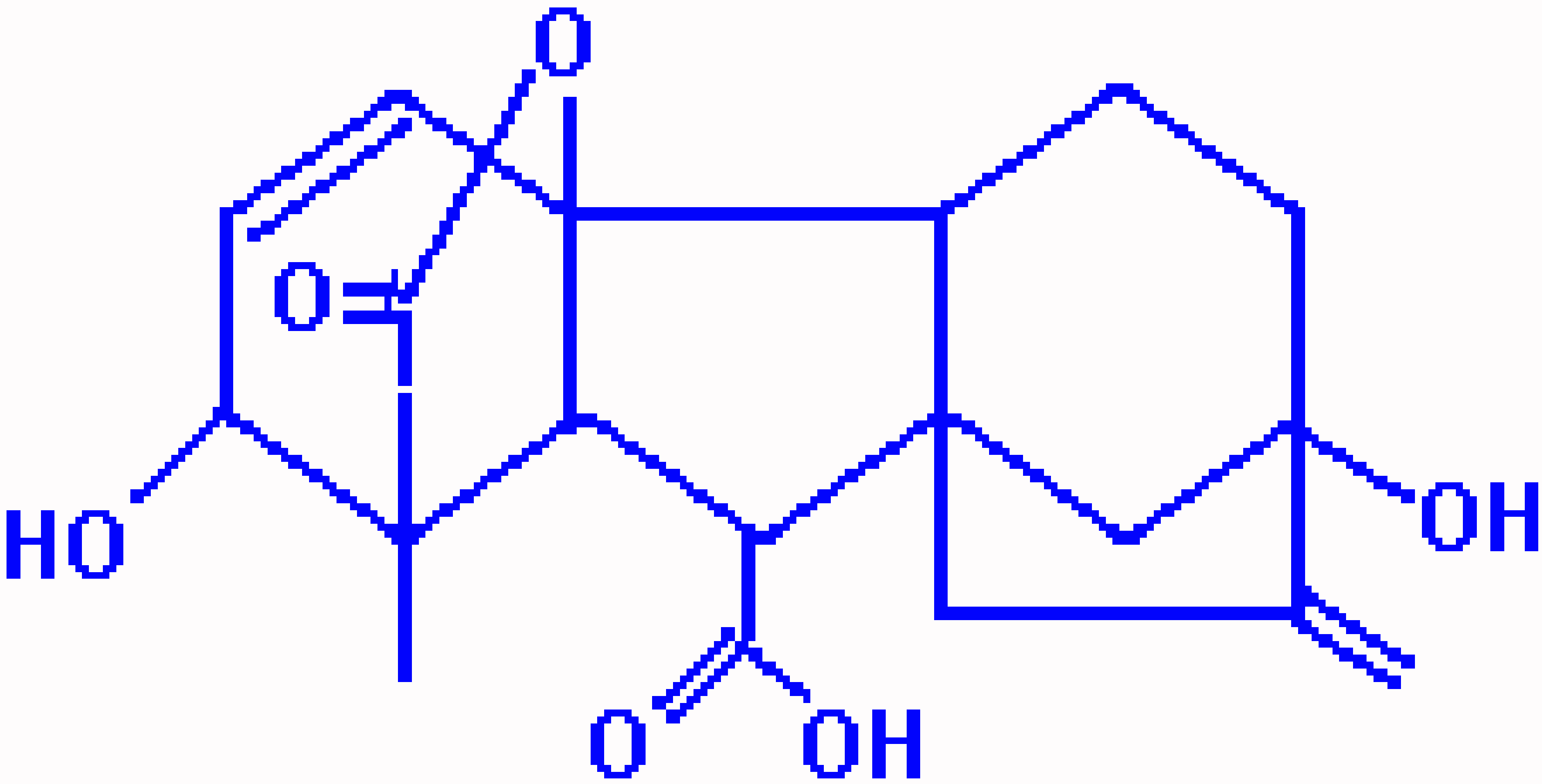
❖Algunos Efectos

-Crecimiento de elongación.

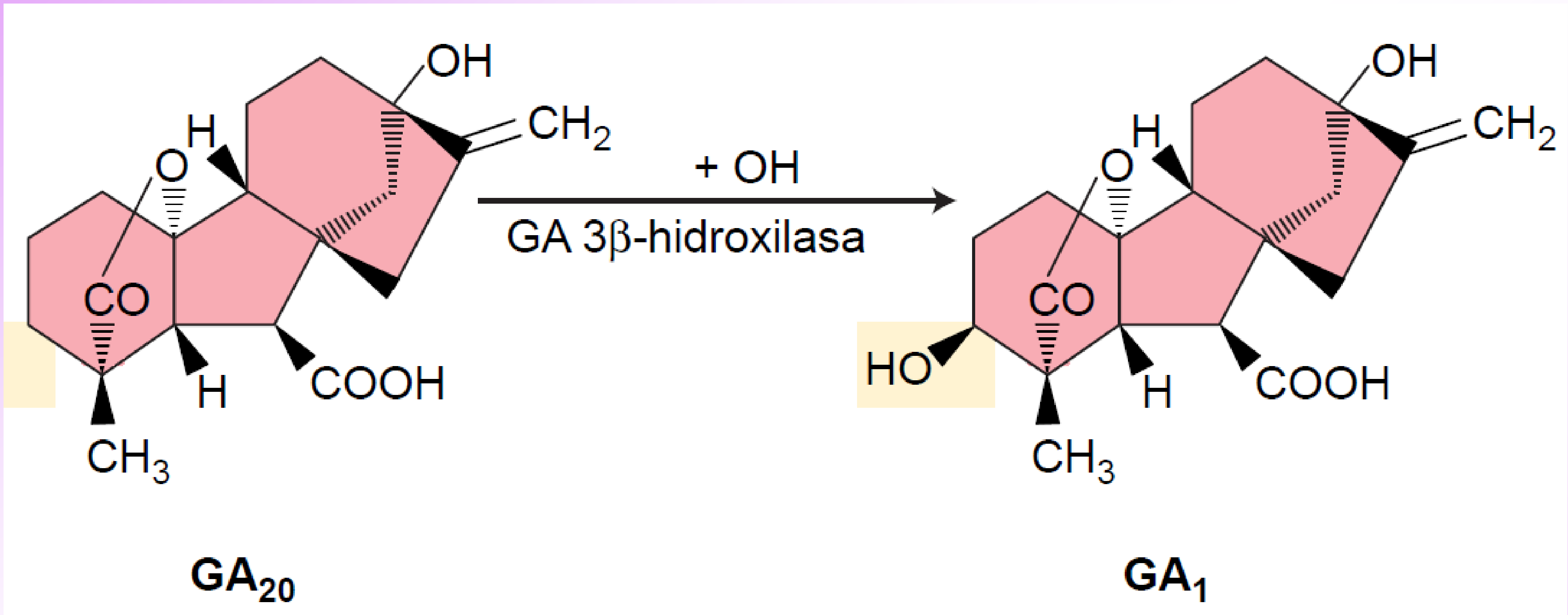
-División del cambium

-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_3)



GA_1 es la forma activa

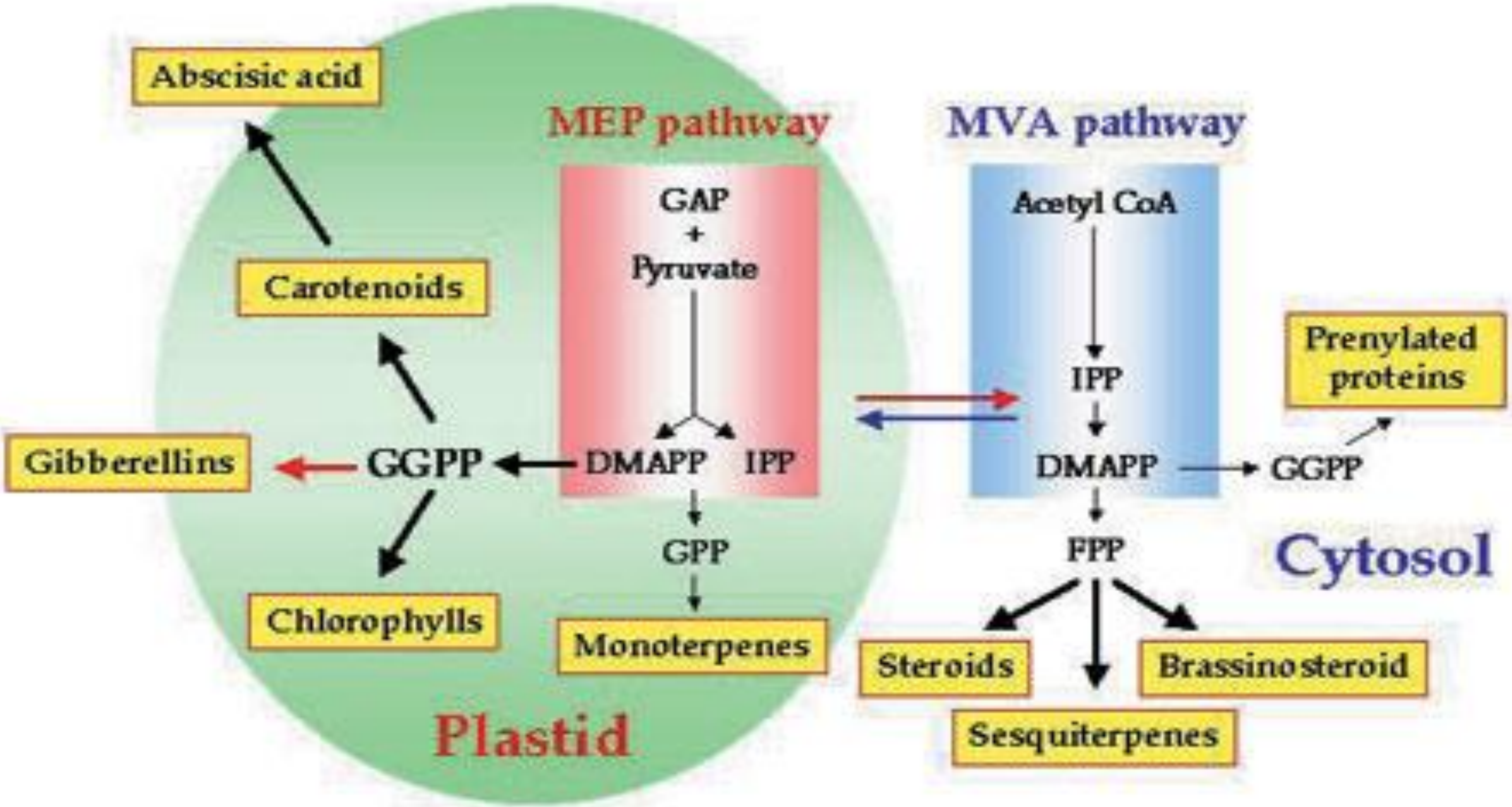
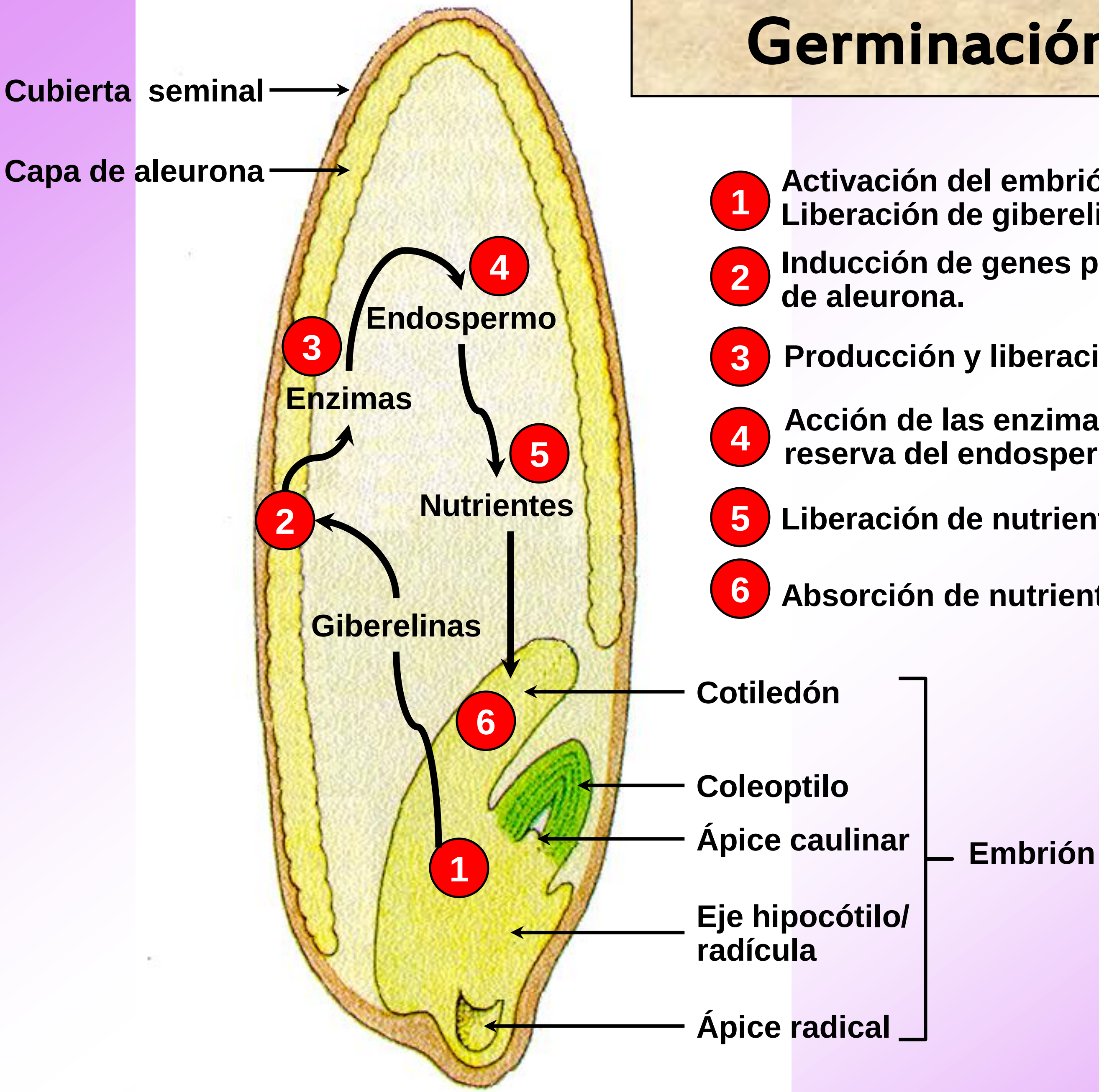


Fig. 2 Plant hormone biosyntheses in plastids

Germinación en cereales



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.

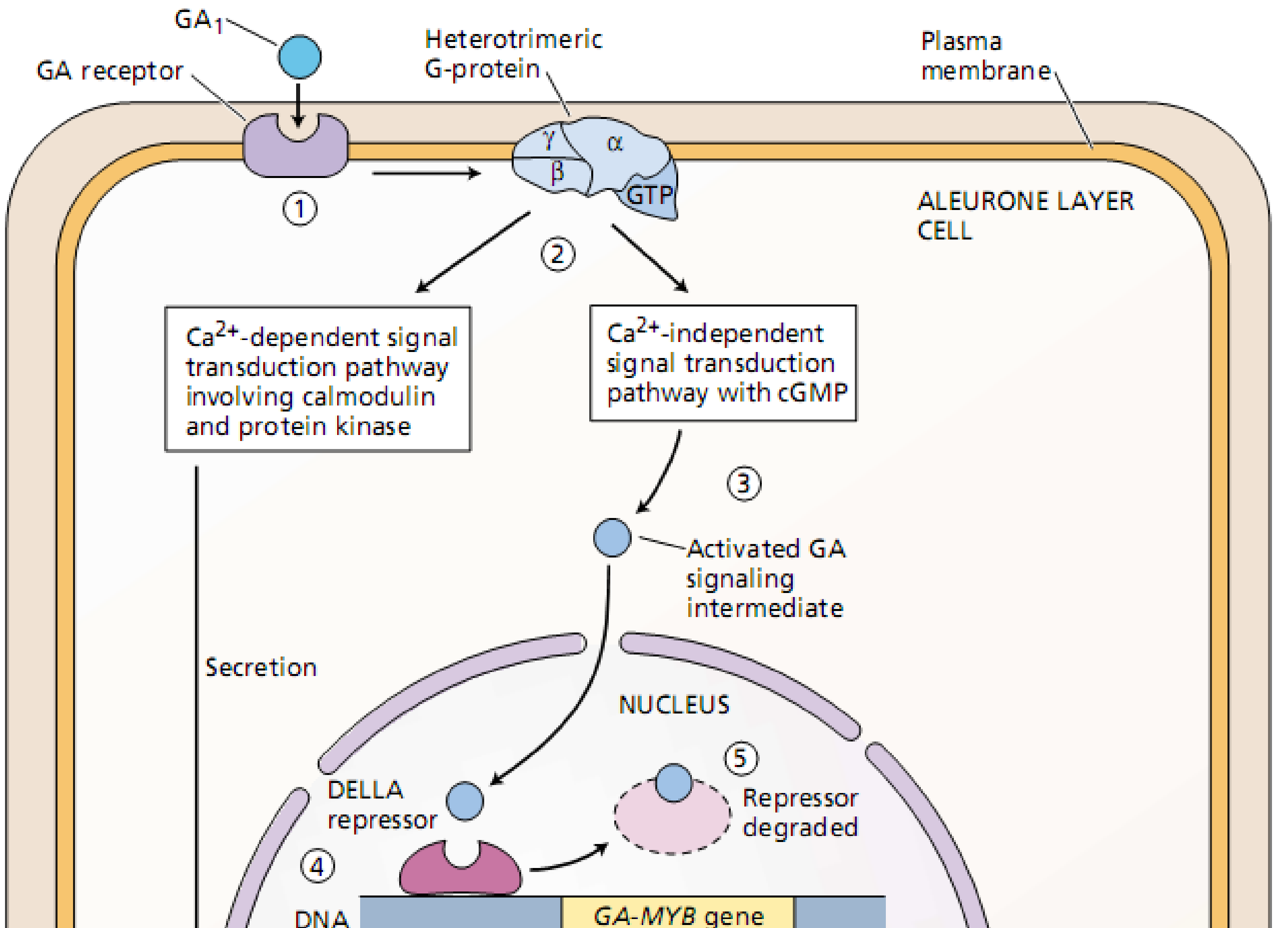
1. GA_1 from the embryo first binds to a cell surface receptor.

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.

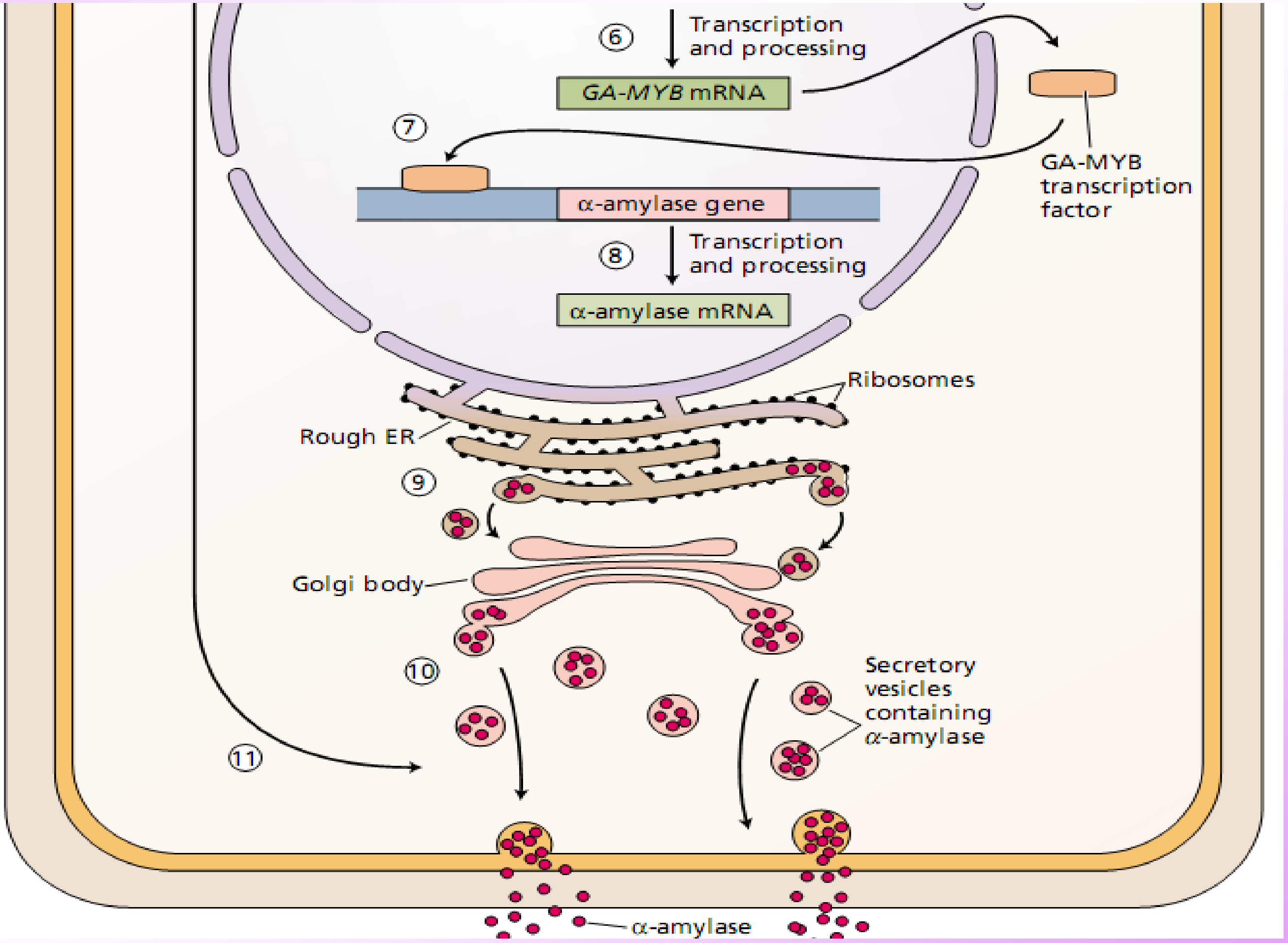
7. The newly synthesized MYB protein then enters the nucleus and binds to the promoter genes for α-amylase and other hydrolytic enzymes.

8. Transcription of α-amylase and other hydrolytic genes is activated.

9. α-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

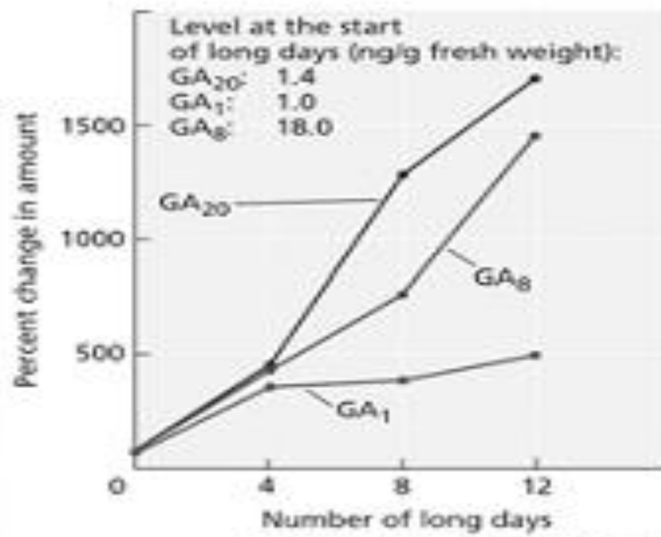


FIGURE 20.14 Spinach plants undergo stem and petiole elongation only in long days, remaining in a rosette form in short days. Treatment with the GA biosynthesis inhibitor AMO-1618 prevents stem and petiole elongation and maintains the rosette growth habit even under long days. Gibberellic acid can reverse 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.)

Floración, remplaza 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

CSIRO PLANT INDUSTRY

Dwarf Tall

High yielding semi-dwarf rice has reduced endogenous gibberellin

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

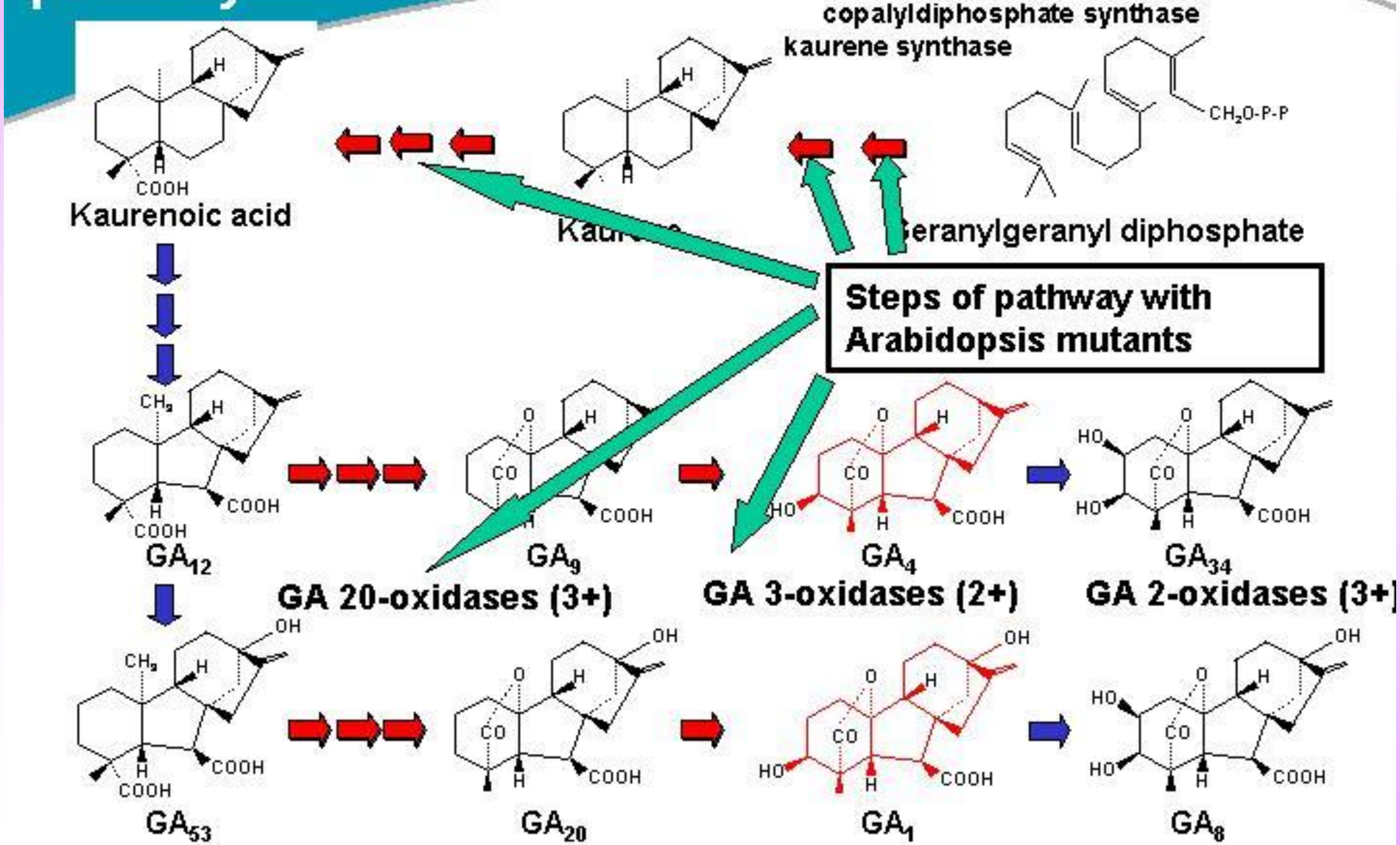
The model plant Arabidopsis has been used to understand gibberellin biosynthesis

CSIRO
PLANT INDUSTRY

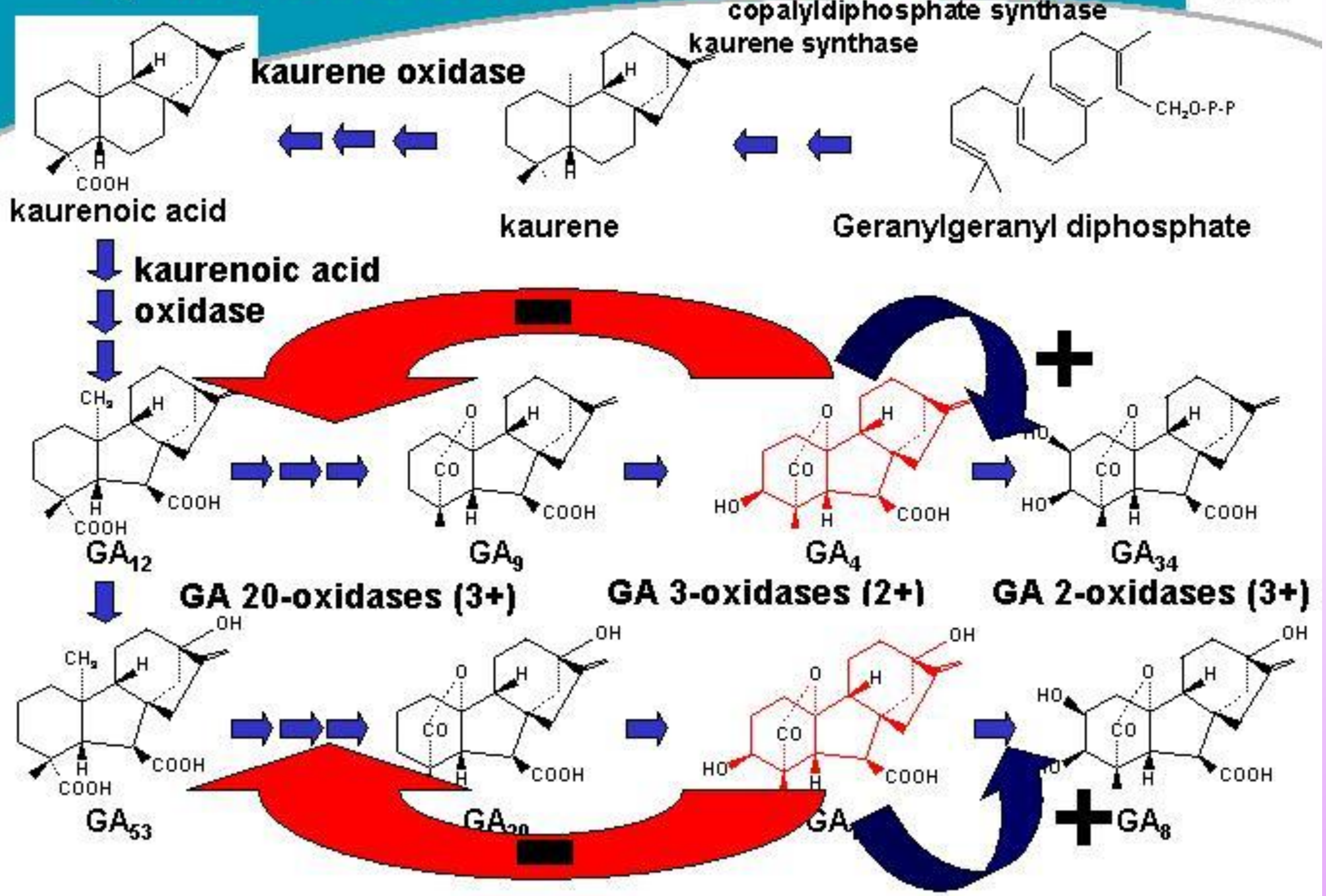
Dwarf Mutant
ga3

Dwarf Mutant
plus
Gibberellin

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



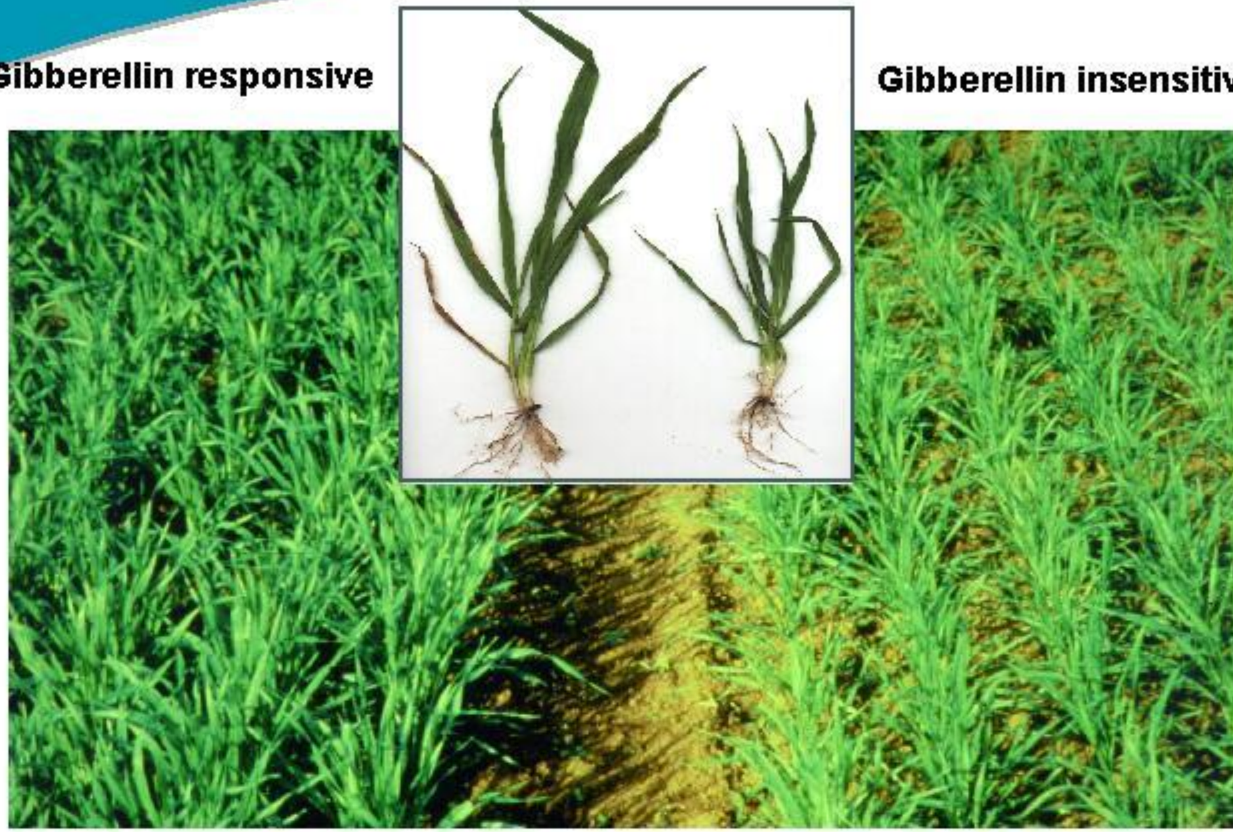
Gibberellin biosynthesis is regulated by the amount of active gibberellin

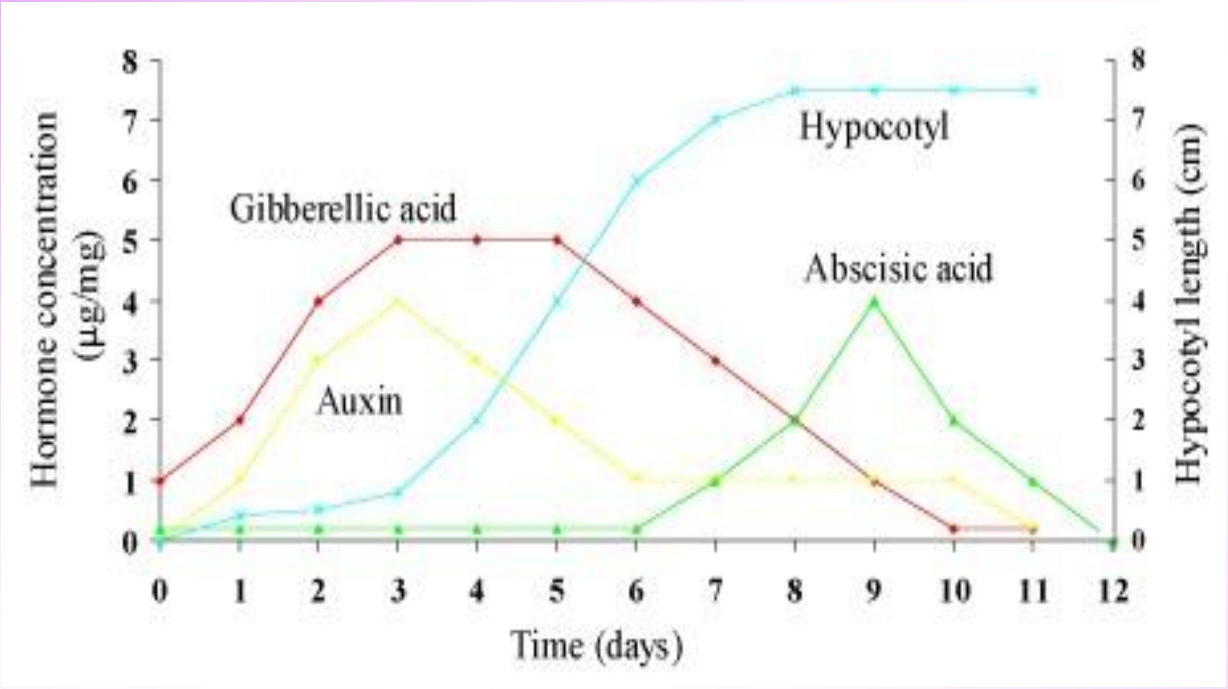


Gibberellin-responsive plants have better early growth

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?

EFECTOS 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.

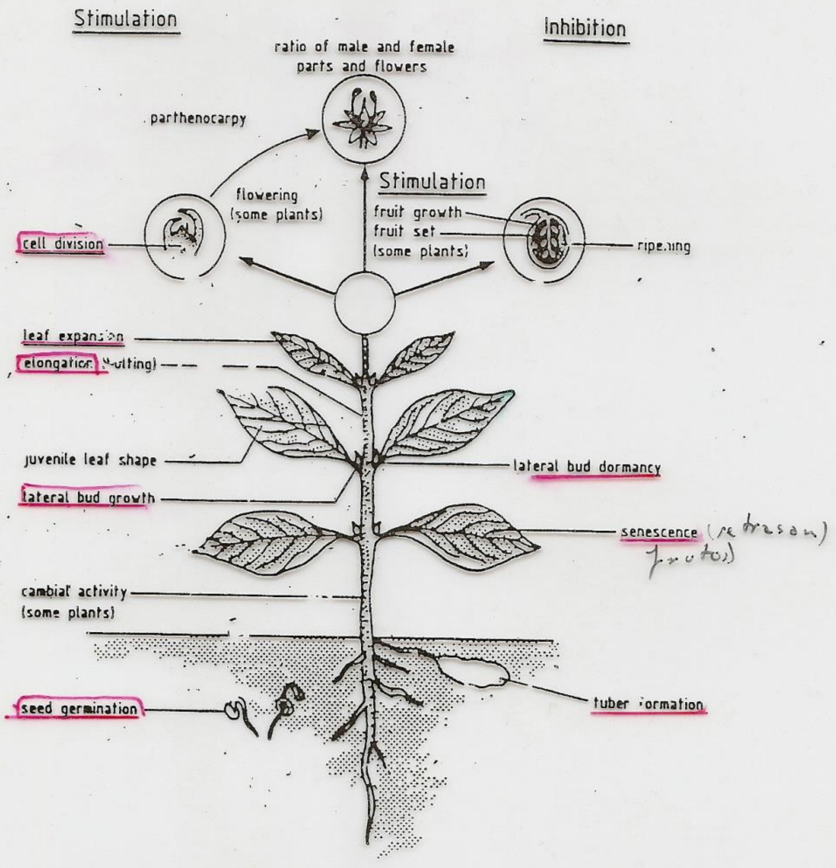
Retraso de la senescencia de algunas hojas y de cascara de citricos.

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

GIBBERELLIC ACID (GA)



(MATTHYSE and SCOTT, 1984)


Muchas
gracias