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Flowering Plants: Control of Growth Responses

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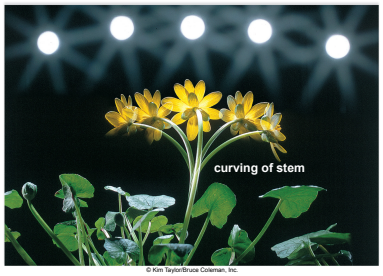

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BIOLOGY
10th Edition

Sylvia S. Mader

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Outline

- Plant Hormones
  - Auxins
  - Gibberellins
  - Cytokinins
  - Abscisic Acid
  - Ethylene
- Plant Responses
  - Tropisms
  - Nastic Movements
- Photoperiodism

Plant Hormones

- Flowering plants responding to
  - Environmental stimuli e.g. light, gravity, carbon dioxide levels, pathogen infection, drought, and touch
  - Respond to stimuli leads to their survival of the species.
- Their responses can be:
  - Short term - stomata open and close in response to light levels,
  - Long term - when they respond to gravity by the downward growth of the root and the upward growth of the stem.

Plant Hormones

- Almost all communication on a plant is done by hormones
  - Synthesized in one part of the plant
  - Travels within phloem in response to the appropriate stimulus

Plant Hormones

- Mechanism that brings about a response occurs at the cellular level.
  - Receptors containing pigment components responds to light.
    - Phytochrome has a region that is sensitive to red light.
    - Phototropin has a region that is sensitive to blue light.
  - Transduction pathway or second messenger initiates the response.
  - Cellular response occurs as a result.

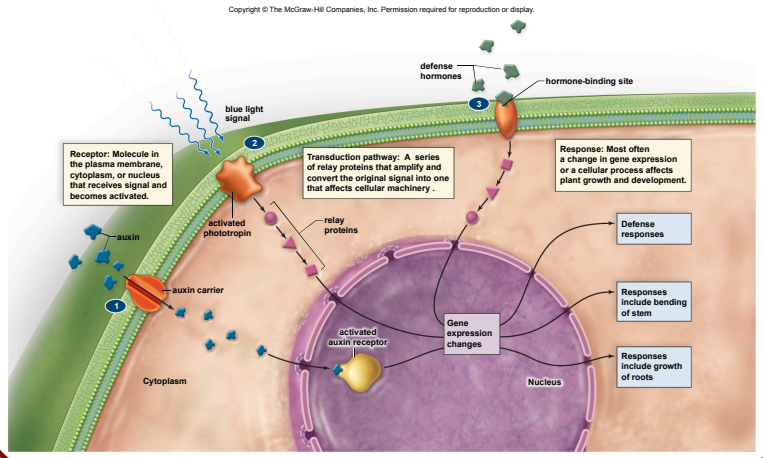
Auxins

- Auxin is produced in shoot and apical meristem and is found in young leaves and in flowers and fruits
  - Apically produced auxin prevents the growth of axillary buds
    - Apical dominance
  - Weak solution of auxin applied to woody cutting causes rapid growth of adventitious roots
    - Promotes fruit growth

How Auxins Work

- Auxins bind to plasma membrane receptors
- Activated proton pumps H^+ out of cell
  - Cell wall loosens
  - Turgor pressure increases due to the entry of water
  - Cell enlarges

Signal Transduction in Plants



Demonstrating Phototropism

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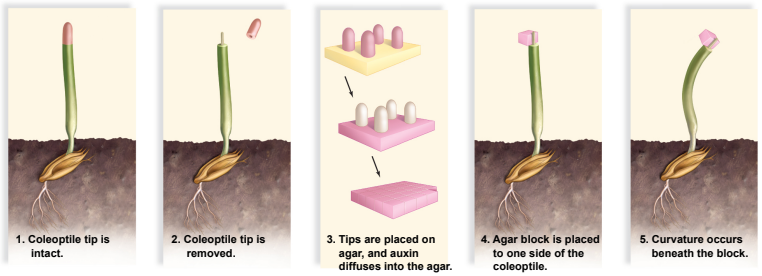

Expansion of the Cell Wall

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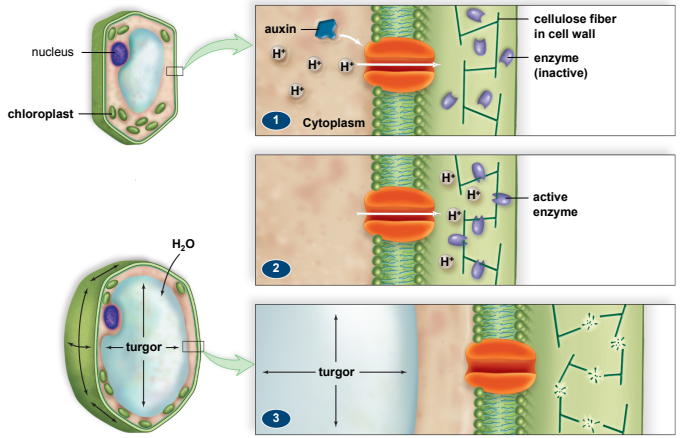

Plant Hormones: Gibberllins

- Gibberellins are growth-promoting hormones
- Bring about elongation of the resulting cells
- There are about 70 gibberellins
  - Each slightly differ chemically
  - The most common is gibberellic acid
- When Gibberellic acid is applied externally to plants:
- Stems are elongated e.g. cabbage can become 2 m tall
- Dormancy of buds broken

Gibberellins Cause Stem Elongation

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a: © Robert E. Lyons/Visuals Unlimited; b: © Sylvan Whittwer/Visuals Unlimited

Plant Hormones: Cytokinins

- The cytokinins are a class of hormones that promote cell division.
- Cytokinins have been isolated from various seed plants.
- Cytokinins have been used to prolong the life of flower cuttings as well as vegetables in storage.

Interaction of Hormones

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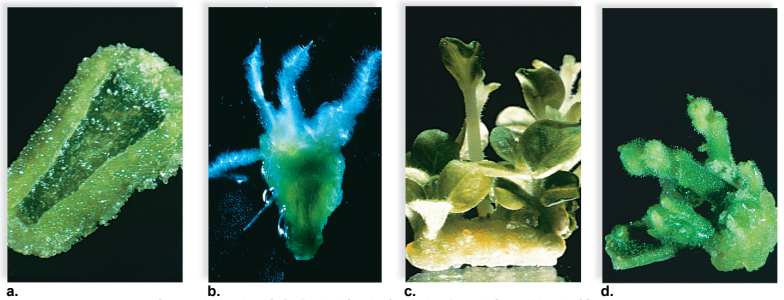

a. b. c. d.

Courtesy Alan Darvill and Stefan Eberhard, Complex Carbohydrate Research Center, University of Georgia

Science Focus

- Arabidopsis thaliana
  - A small flowering plant related to cabbage and mustard plants
  - Has no commercial value
  - It has become a model organism for the study of plant molecular genetics, including signal transduction.
    - It is small, so many hundreds of plants can be grown in a small amount of space.
    - Generation time is short – 5-6
    - It normally self-pollinates, but it can easily be cross-pollinated.
    - The number of base pairs in its DNA is relatively small

Overall Appearance of *Arabidopsis thaliana*

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a. Arabidopsis thaliana (Normal, Mutated center, Right): Courtesy Elliot Meyerowitz/California Institute of Technology

b. Arabidopsis thaliana (enlarged drawing)

Arabidopsis Mutants

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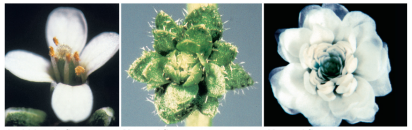

Arabidopsis flower | Mutated flower | Mutated flower

A flat of Arabidopsis

Lab

(Normal, Mutated center, Right): Courtesy Elliot Meyerowitz/California Institute of Technology. B(Flat): © Inga Spence/Visuals Unlimited; B (Lab): © Vo Trung Dung/Corbis Sygma

Plant Hormones: Abscisic Acid

- Abscisic acid (ABA) is produced by any "green tissue" (that contains chloroplasts).
- Abscisic acid is sometimes called the stress hormone.
  - Initiates and maintains seed and bud dormancy.
  - Brings about the closure of stomata.

Dormancy and Germination

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Dormancy and Winter

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Abscisic Acid Promotes Closure of Stomata

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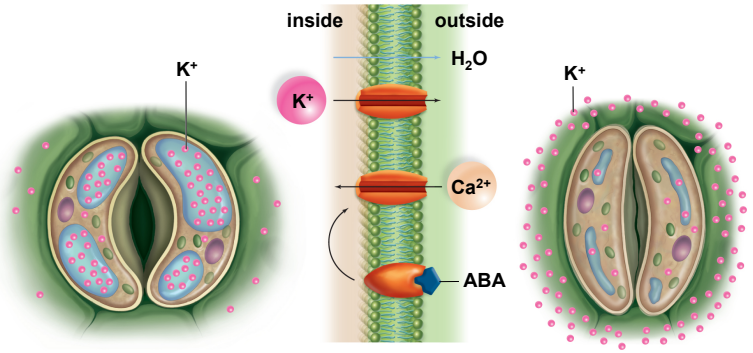

Ethylene

- Ethylene (H2C = CH2) is a gas formed from the amino acid methionine.
- This hormone is involved in:
  - Abscission and
    - Ethylene stimulates certain enzymes, such as cellulase, which helps cause leaf, fruit, or flower drop
  - Ripening of fruits
    - Increasing the activity of enzymes that soften fruits
      - Stimulates the production of cellulase, which weakens plant cell walls.
    - It also promotes the activity of enzymes that produce the flavor and smell of ripened fruits.

Ethylene and Fruit Ripening

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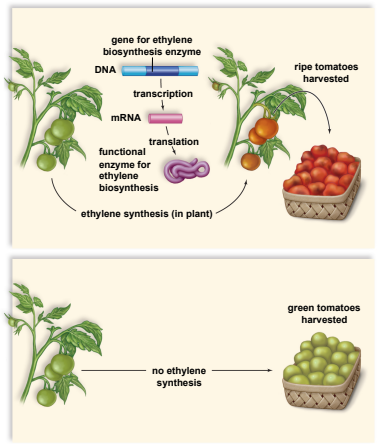

Ethylene and Abscission

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No abscission

© Kingsley Stern

Abscission

Plant Responses

- Tropisms
  - Plant growth toward or away from a unidirectional stimulus is called a tropism
    - Positive is towards stimulus
    - Negative is away from stimulus
  - Phototropism - Light
  - Gravitropism - Gravity
  - Thigmotropism - Touch

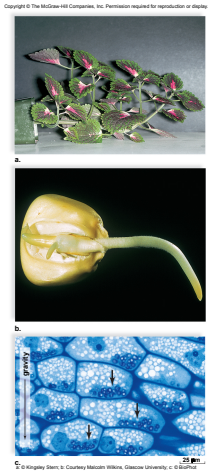
Phototropism

- Positive phototropism:
  - Occurs because cells on the shady side of the stem elongate
  - A pigment related to riboflavin thought to act as a photoreceptor when phototropism occurs
    - Auxin migrates to shady side of stem
    - Shady sides elongate faster than bright side

Gravitropism

- When a plant is placed on its side, the stem grows upward, opposite of the pull of gravity
- Stems with root caps grow downward
  - Root cells contain statoliths
- Auxin is responsible for:
  - Positive gravitropism of roots, and
  - Negative gravitropism of shoots

Gravitropism



Phototropin

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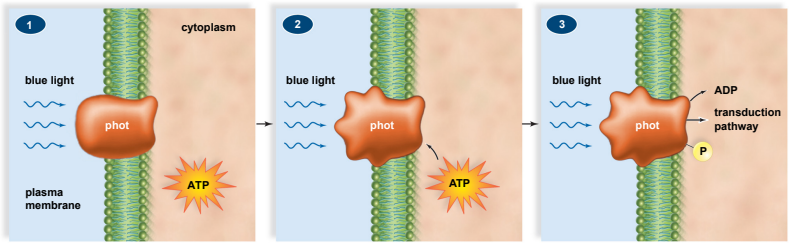

Thigmotropism

- Unusual growth due to contact with solid objects is called thigmotropism
  - Coiling of tendrils
- Thigmomorphogenesis occurs when the entire plant responds to the presence of environmental stimuli
  - Wind
  - Rain

Coiling Response

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Nastic Movements

- Nastic movements:
  - Do not involve growth and
  - Are not dependent on the stimulus direction
- Seismonastic movements result from:
  - Touch
  - Shaking, or
  - Thermal stimulation
- Sleep movements:
  - Occur daily in response to light and dark changes
  - Prayer Plant

Seismonastic Movement

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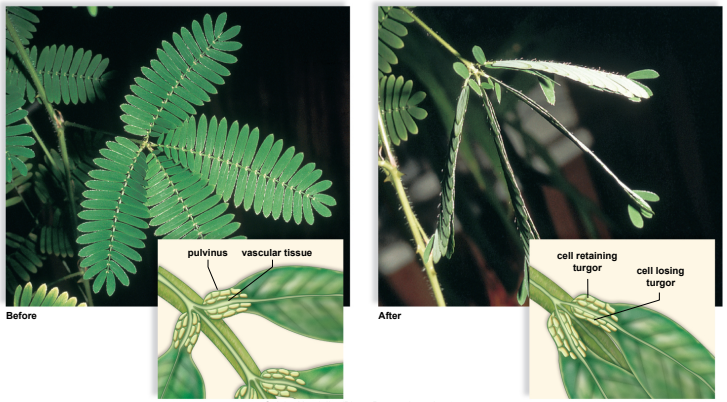

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Sleep Movement

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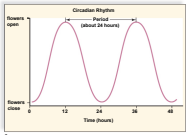

Circadian Rhythms

- Circadian rhythms:
  - Biological rhythms with a 24-hour cycle
  - Tend to be persistent
    - Rhythm is maintained in the absence of environmental stimuli
    - Caused by a biological clock

Phytochrome

- Phytochrome is a blue-green leaf pigment that alternately exists in two forms
  - Phytochrome red (P_r)
  - Phytochrome far-red (P_{fr})
- Conversion of forms allows a plant to detect photoperiod changes
- Also promotes seed germination and inhibits stem elongation

Phytochrome Control of Shoot Elongation

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a. Normal growth

b. Etiolation

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Phytochrome Conversion Cycle

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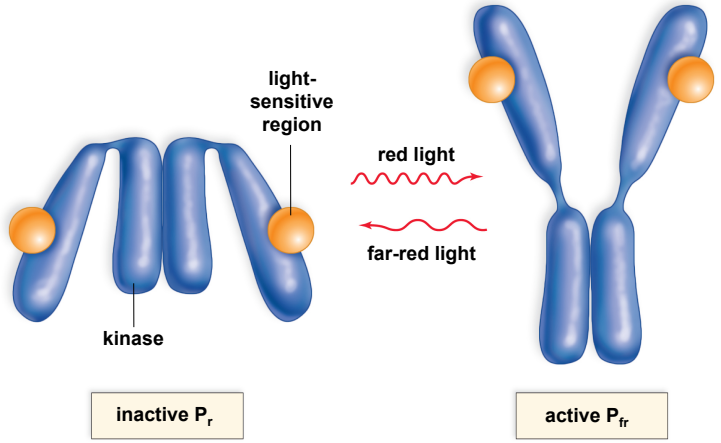

Photoperiodism

- Photoperiodism:
  - Any physiological response prompted by changes in day or night length
    - Short-day plants
    - Long-day plants
    - Day-neutral plants
- Some plants may require a specific sequence of day lengths in order to flower

Photoperiodism and Flowering

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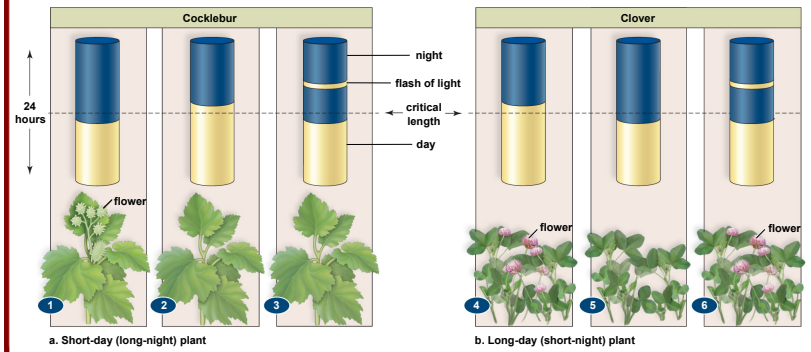

a. Short-day (long-night) plant

b. Long-day (short-night) plant

Flowering Plants Respond to the Biotic Environment

- Plants are always under attack by
  - Herbivores (animals that eat plants)
  - Parasites
- Physical and Chemical Defenses
  - Plants need several types of defenses

Plant Predators and Parasites

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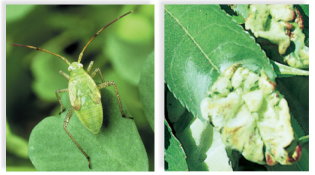

Alfalfa plant bug

Fungus infection

Monarch caterpillar and butterfly

(Bug): USDA/Agricultural Research Service, photo by Scott Bauer; (Fungus): © Kingsley Stern; (Caterpillar): © Frans Lanting/Minden Pictures; (Butterfly): © Dwight Kuhn

Wound Response in Tomato

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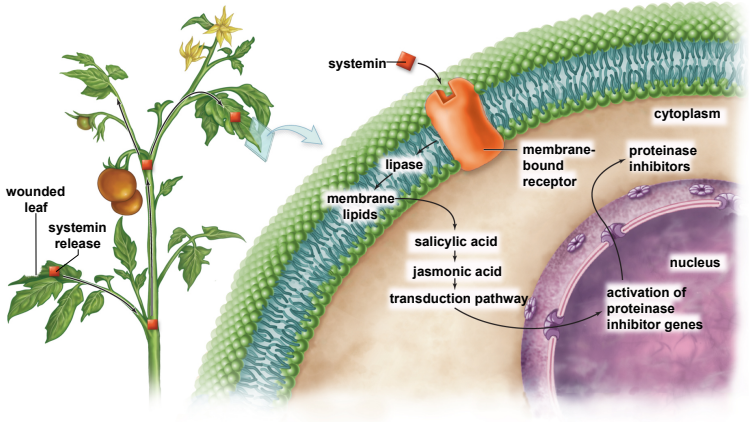

Review

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  - Auxins
  - Gibberellins
  - Cytokinins
  - Abscisic Acid
  - Ethylene
- Plant Responses
  - Tropisms
  - Nastic Movements
- Photoperiodism

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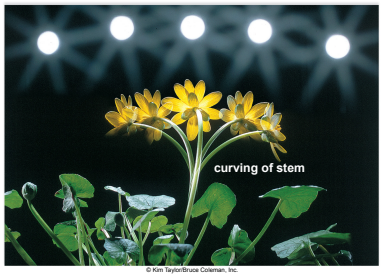

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