Chapter 39: Plant Responses to Signals

AP Biology 2013

1

Response to Stimuli

- Plants must respond to environmental changes because they are sessile
  - Ex. Bending of grass seedling toward light begins by the plant sensing the direction, quantity and color of the light

- Plants have cellular receptors they use to detect changes in their environment
- For a stimulus to elicit a response, certain cells must have an appropriate receptor
- A potato growing in the darkness will produce shoots that do not appear healthy and will lack elongated roots (adaptation for growing in darkness called etiolation)
- After the potato is exposed to light the plant undergoes profound changes called deetiolation in which shoots and roots grow normally

(a) Before exposure to light (b) After a week's exposure to natural daylight

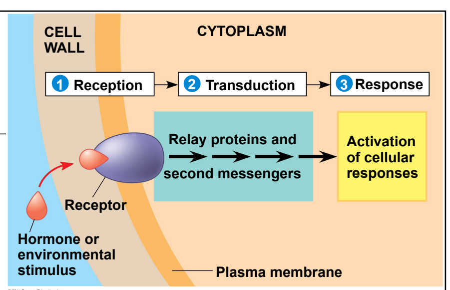
Fig. 39.2

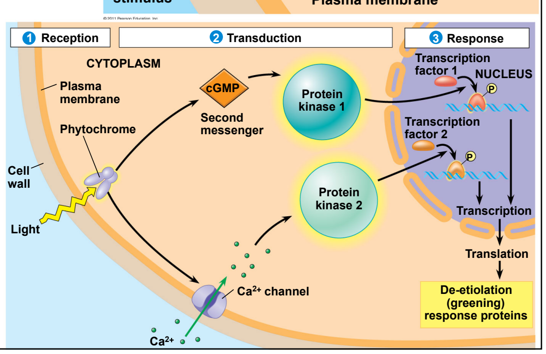
2

Cell Signal Processing

Figs. 39.3 & 39.4

- Reception - internal and external signals are detected by receptors (proteins that change in response to a specific stimuli)
- Transduction - second messengers transfer and amplify signals from receptors to proteins that cause specific responses
- Response - regulation of one or more cellular activities (often involve increased activity of enzymes)





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Regulation

- Transcriptional Regulation - Transcription factors bind directly to specific regions of DNA and control the transcription of specific genes
- Post-Translational Modification of Proteins - involves the activation of existing proteins involved in the signal response
- De-Etioloation Proteins - enzymes that function in signal responses related to photosynthesis and precursors to chlorophyl production

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Plant Hormones

- Coordinate growth, development, and response to stimuli

- Hormones - chemical signals that coordinate the different parts of an organism
  - Tropism - a growth response that results in curvatures of whole plant organs toward or away from a stimulus (ex. phototropism)

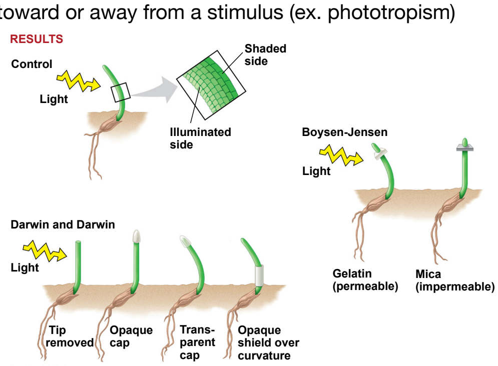

Fig. 39.5

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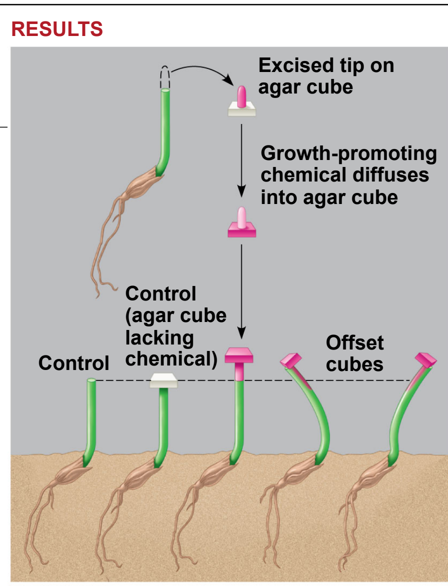
Auxin

Fig. 39.6

- 1926, Frits Went

- Extracted the chemical messenger for phototropism (auxin) by modifying earlier experiments
- Involved in the formation and branching of roots
- Can also be used as herbicides through overdose to kill eudicots
- Impacts secondary growth by inducing cell division in the vascular cambium and influencing differentiation of secondary xylem



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Hormones

- Hormones control plant growth and development by impacting division, elongation, and differentiation of cells
- Plant hormones are produced in very low concentrations but small amounts can have a huge effect on the growth and development of a plant organ
- Auxin - term used for any chemical substance that promotes cell elongation in different target tissues
- Auxin transporters - move hormones out of the basal end of one cell and into the apical end of neighboring cells (proton pumps play a major role)

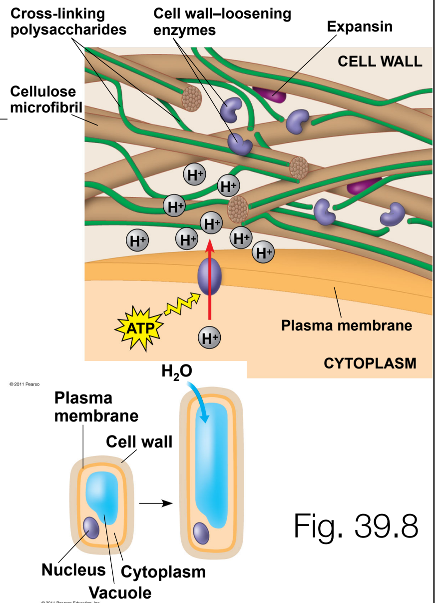

Fig. 39.8

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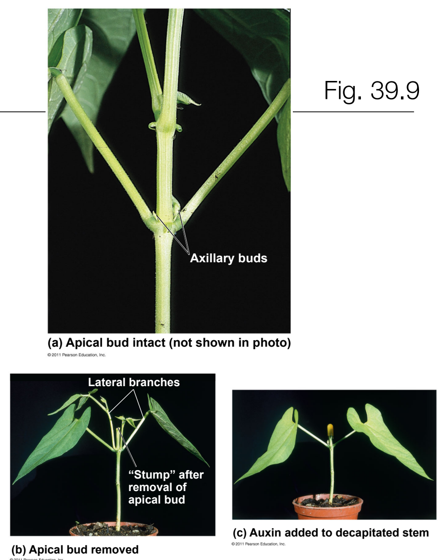
Cytokinins

- Stimulate cell division
- Produced in actively growing tissues such as roots, embryos, and fruits
- Works together with auxin to control apical dominance by allowing the terminal bud to suppress development of axillary buds
    - If the terminal bud is removed, the plants become bushier.
- Slow the aging of some plant organs by inhibiting protein breakdown, stimulating RNA and protein synthesis, and mobilizing nutrients.

Fig. 39.9



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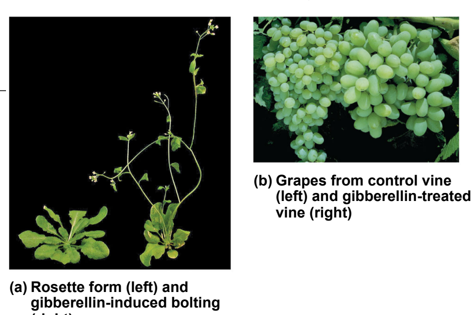
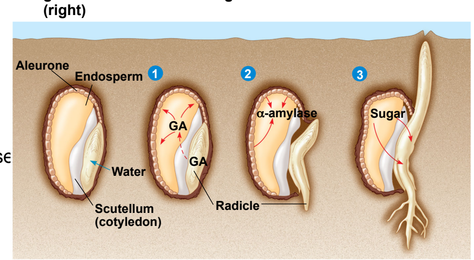
Figs. 39.10 & 39.11

Gibberellins

- Impact stem elongation, fruit growth, and seed germination
- Stimulate growth of both leaves and stems
- In many plants, auxin and gibberellins must be present for fruit to set.
- Used commercially to produce seedless fruits
- After water is imbibed, the release of gibberellins from the embryo signals the seeds to break dormancy and germinate.





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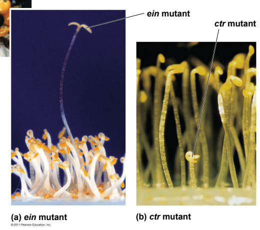
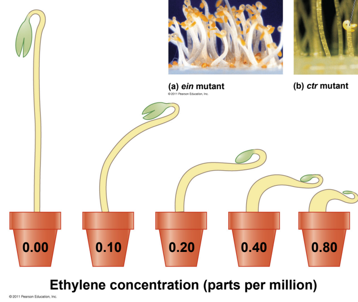
Figs. 39.12 - 39.14

Other Hormones

- Brassinosteroids - similar to sex hormones of animals and induce cell elongation and division
- Abscisic Acid (ABA) - involved in seed dormancy and drought tolerance
  - Precocious germination result of a lack of a functional transcription factor required for ABA to induce expression of certain genes
- Ethylene - produced in response to stress (drought, flooding, mechanical pressure, injury, and infection)
  - Induces the triple response which allows a growing shoot to avoid obstacles





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Other Hormonal Controls

- Senescence - programmed death of cells or organs associated with a burst of ethylene
- Leaf abscission - change in the balance of auxin and ethylene controls leaf abscission (process that occurs in the autumn when a leaf falls
- Fruit ripening - increase in ethylene production triggers the ripening of fruit

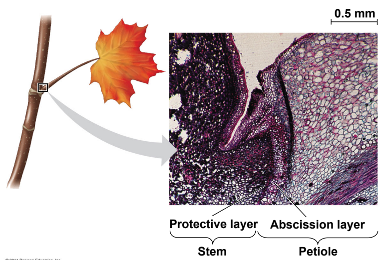

Fig. 39.15

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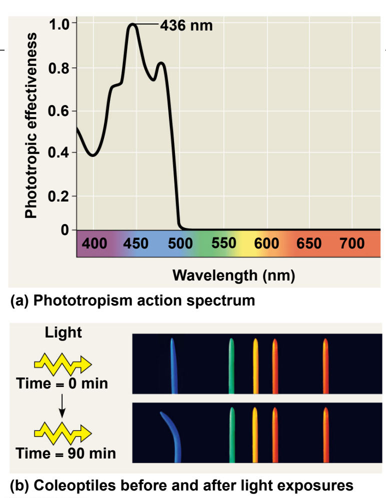
Fig. 39.16

Responses to Light

- Light cues are key to plant growth and development. This effect on morphology is called photomorphogenesis.
- Plants not only detect the presence of light but also its direction, intensity, and wavelength (color).
- An action spectrum depicts the relative response of a process to different wavelengths of light.
- Blue-light photoreceptors control hypocotyl elongation, stomatal opening, and phototropism.



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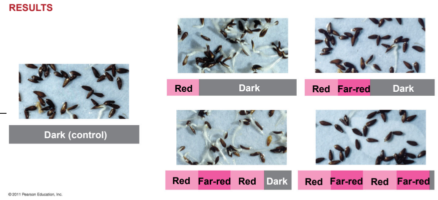
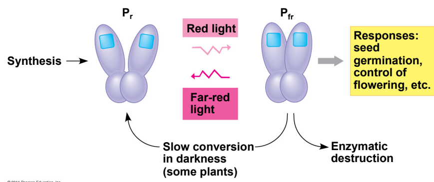
Responses to Light

- Phytochromes - regulate many plant responses to light throughout its life.
    - Photoreceptor responsible for the opposing effects of red and far-red light
    - Exist in two photoreversible states with conversion of P_r to P_{fr} triggering many developmental responses.
    - Also provides the plant with information about the quality of light. "Shade avoidance" causes the phytochrome ration to shit in favor of P_r when a tree is shaded.





Figs. 39.17 & 39.19

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Biological Clocks and Circadian Rhythms

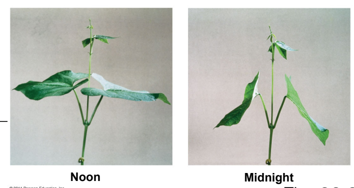

Fig. 39.20

- Plant processes oscillate during the day
- Legumes lower their leaves in the evening and raise them during the day
- Circadian rhythms - cyclical responses to environmental stimuli (approximately 24 hours long)
- Phytochrome conversion marks sunrise and sunset
- Photoperiod - relative lengths of night and day used to determine time of year
    - Photoperiodism - physiological response to photoperiod
    - Dictates flowering

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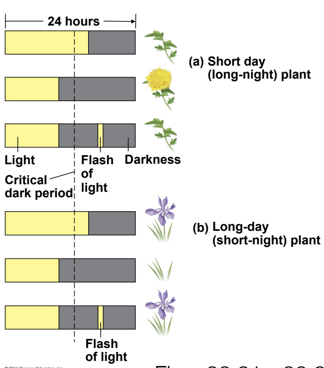
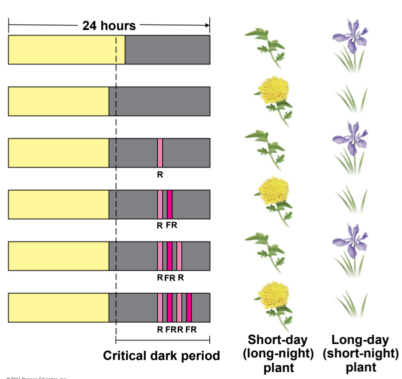
Critical Night Length

- 1940s - Discovered that flowering and other photoperiod responses are controlled by night length and not day length
- Action spectra show that phytochrome is the pigment that receives red light, which can interrupt the nighttime portion of the photoperiod.





Figs. 39.21 - 39.22

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Is there a flowering hormone?

- Has not been chemically identified
- May be a single hormone or change in the concentrations of several hormones
- The outcome of the transition to flower is the change of a bud's meristem from a vegetative to a flowering state.

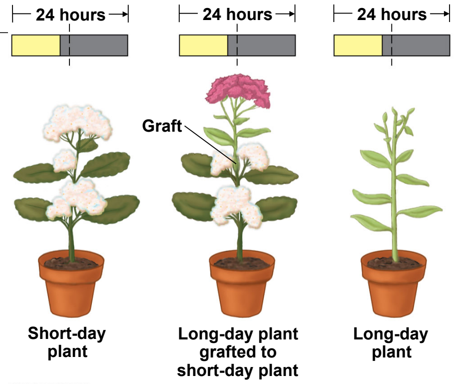

Fig. 39.23

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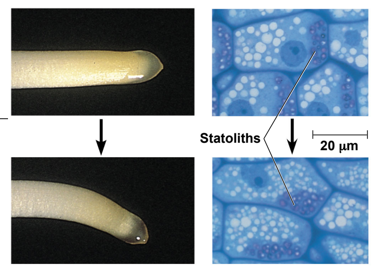
Other Stimuli

- Gravity - response known as gravitropism (roots show positive gravitropism and stems show negative gravitropism)
  - May detect it by the settling of statoliths (specialized plastids containing dense starch grains)
- Mechanical stimuli - thigmomorphogenesis
  - Rubbing stems of young plants a couple of times daily results in shorter plants
  - Growth in response to touch is called thigmotropism (occurs in vine and other climbing plants)



(a) Primary root of maize bending gravitropically (LMs)

(b) Statoliths settling to the lowest sides of root cap cells (LMs)

Figs. 39.24 & 39.25

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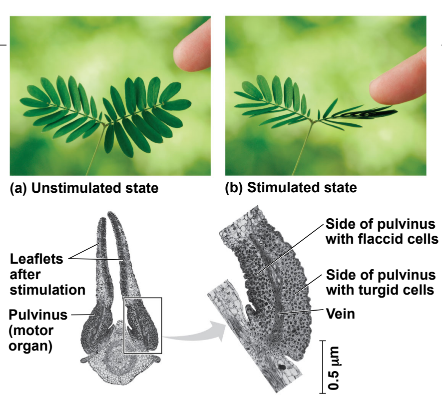
Other Stimuli

- Mechanical stimuli
  - Rapid leaf movements as a response to mechanical stimulation
    - Transmission of electrical impulses called action potentials
    - Ex. *Mimosa pudica* (sensitive plant)



(a) Unstimulated state

(b) Stimulated state

(c) Cross section of a leaflet pair in the stimulated state (LM)

Fig. 39.26

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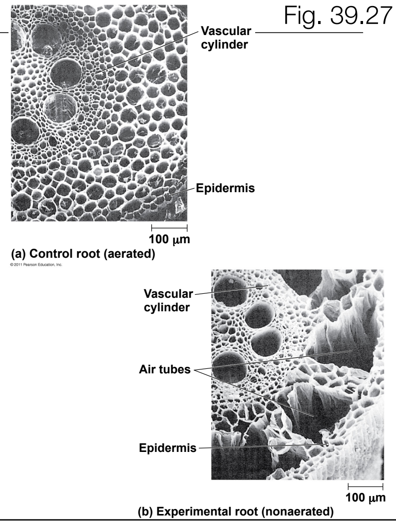
Environmental Stresses

- Have adverse effects on a plant's survival, growth, and reproduction

- Drought - response is to reduce transpiration and growth of deeper roots
- Flooding - enzymatic destruction of cells to create air tubes the survive oxygen deprivation
- Salt stress - produces solutes tolerated at high concentrations keeping the water potential of some cells more negative than that of the soil solution
- Heat stress - heat shock proteins help survive heat stress
- Cold stress - alter lipid concentrations of membranes

Fig. 39.27



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Plant Defenses

- Defense against herbivores
  - Physical defenses (thorns) and chemical defenses (distasteful or toxic compounds)
  - Some plants recruit predatory animals to defend the plant against specific species
- Defense against Pathogens
  - First line of defense is a physical barrier (epidermis and periderm) and once it enters a chemical attack is used to kill the pathogen and prevent spreading
  - Plants can also recognize pathogens

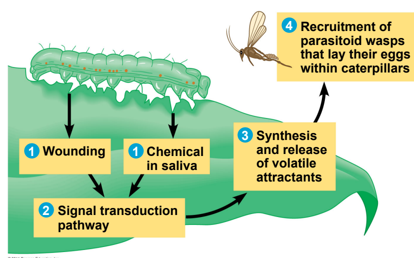

Fig. 39.28

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Plant Responses

Infected tobacco leaf with lesions

- Hypersensitive plant will seal off the infection and kill both the pathogen and host cells in the region of the infection
- Systemic acquired resistance (SAR)
  - Set of generalized defense responses in organs distant from the original site of infection (triggered by salicylic acid)

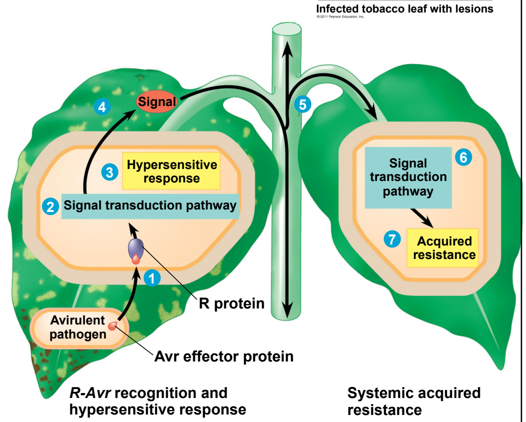

Fig. 39.29

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