

Chapter 37, 39 Plant Regulation



(a)

(b)



Plant Reactions

- Stimuli & a Stationary Life
 - ◆ animals respond to stimuli by changing behavior
 - move toward positive stimuli
 - move away from negative stimuli
 - ◆ plants respond to stimuli by adjusting growth & development



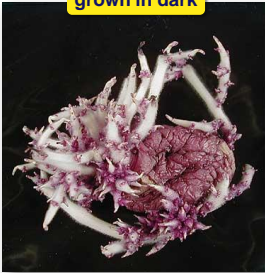
(a)

(b)

What mechanism causes this response?

grown in dark

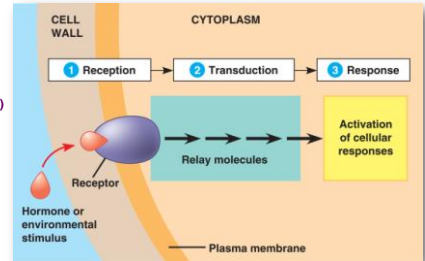
1 week exposure to light



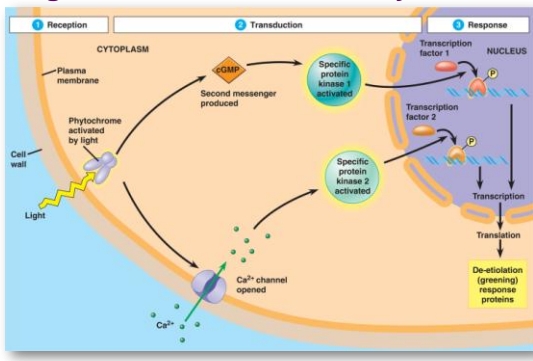
Signal Transduction Pathway

- signal triggers receptor
- receptor triggers internal cellular messengers & then cellular response

- receptor
- signal pathway (2nd messengers)
- response



Signal Transduction Pathway

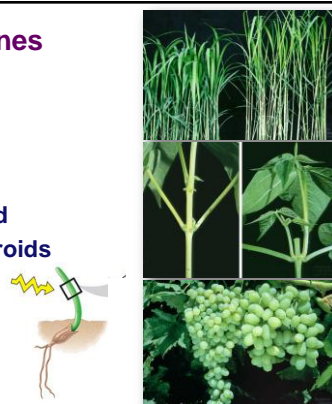


Plant Hormones

- Chemical signals that coordinate different parts of an organism
 - ◆ only minute amounts are required
 - ◆ produced by a part of the "body"
 - ◆ transported to another part
 - ◆ binds to specific receptor
 - ◆ triggers response in target cells & tissues

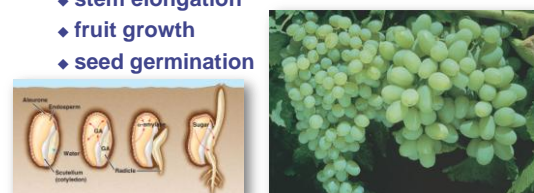
Plant Hormones

- gibberellins
- auxins
- cytokinins
- ethylene
- abscisic acid
- brassinosteroids



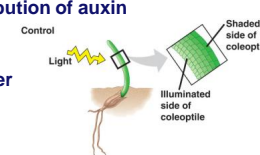
Gibberellins

- Family of hormones
 - ◆ over 100 different gibberellins identified
- Effects
 - ◆ act on aleurone layer under seed coat
 - ◆ stem elongation
 - ◆ fruit growth
 - ◆ seed germination



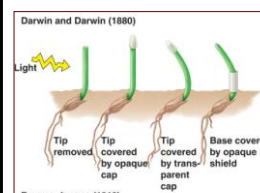
Auxin

- Indolacetic acid (IAA)
 - ◆ stimulates cell elongation
 - near apical meristems
 - ◆ enhances apical dominance
 - apical buds inhibit growth of axillary buds
 - ◆ classical explanation of phototropism
 - asymmetrical distribution of auxin
 - cells on darker side elongate faster than cells on brighter side

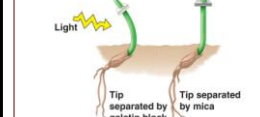


Phototropism

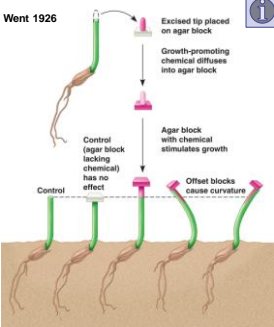
Darwin and Darwin (1880)



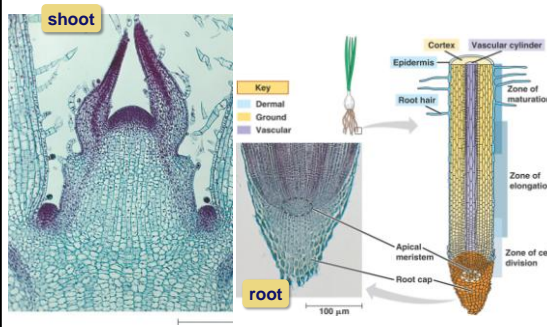
Boysen-Jensen (1913)



Went 1926



Zones of Meristematic Growth

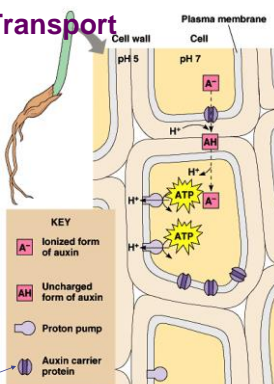


Key:

- Dermal
- Ground
- Vascular

Polarity of Auxin Transport

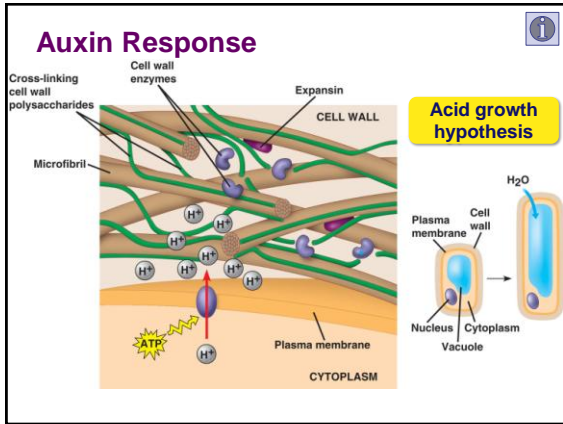
1. Auxin picks up H⁺ between cells & is neutralized
2. Neutral auxin passes through membrane
3. Cellular pH 7 causes auxin to ionize & is trapped in cell
4. Auxin stimulates proton pump
5. Auxin leaves through carriers



KEY:

- Ionized form of auxin
- Uncharged form of auxin
- Proton pump
- Auxin carrier protein

auxin anion efflux carrier



Cytokinins

- Family of hormones
 - modified forms of adenine
 - produced in roots, fruits & embryos
- Effects
 - control of cell division & differentiation
 - enhances apical dominance
 - interaction of auxin & cytokinins

(A) Intact plant (A) shows a plant with a single dominant apical bud. (B) Plant with apical bud removed (B) shows a plant with multiple lateral branches, demonstrating the removal of apical dominance.

Ethylene

- Ethylene is a gas released by plant cells
- Multiple effects
 - response to mechanical stress
 - triple response
 - slow stem elongation
 - thickening of stem
 - curvature to horizontal growth
 - apoptosis
 - leaf abscission
 - fruit ripening

The diagram shows a stem in a pot with increasing ethylene concentration (ppm per volume) from left to right. The stem exhibits a triple response: it becomes shorter, thicker, and curves horizontally.

Apoptosis & Leaf Abscission

- Balance of ethylene & auxin
 - many events in plants involve pre-programmed cell death
 - death of annual plant after flowering
 - differentiation of xylem vessels
 - loss of cytosol
 - shedding of autumn leaves

The micrograph shows a cross-section of a leaf abscission zone. The protective layer is on the stem side, and the abscission layer is where the leaf detaches. The petiole is on the leaf side. A scale bar indicates 0.5 mm.

Fruit Ripening

- Hard, tart fruit protects developing seed from herbivores
- Ripe, sweet, soft fruit attracts animals to disperse seed
 - burst of ethylene triggers ripening process
 - breakdown of cell wall = softening
 - conversion of starch to sugar = sweetening
 - positive feedback system
 - ethylene triggers ripening
 - ripening stimulates more ethylene production

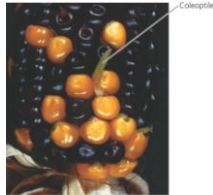
Applications

- Truth in folk wisdom!
 - one bad apple spoils the whole bunch
 - ripening apple releases ethylene to speed ripening of fruit nearby
- Ripen green bananas by bagging them with an apple
- Climate control storage of apples
 - high CO₂ storage = reduces ethylene production

Abscisic Acid (ABA)

▪ **Effects**

- ◆ slows growth
- ◆ seed dormancy
 - high concentrations of ABA
 - ◆ germination only after ABA is inactivated down or leached out
 - survival value: seed will germinate only under optimal conditions
 - ◆ light, temperature, moisture
- ◆ drought tolerance
 - rapid stomate closing



Brassinosteroids

▪ **Steroids**

▪ **Effects**

- ◆ similar to auxins
- ◆ cell elongation & division in shoots & seedlings

Responses to Light

▪ **Photomorphogenesis**

- ◆ effect of light on plant growth

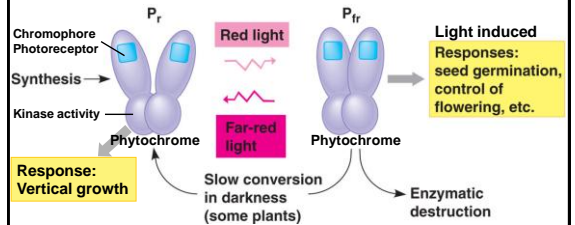
▪ **Light detection**

- ◆ intensity
- ◆ direction
- ◆ wavelength
 - blue-light receptors
 - phytochromes (red-light receptors)

Phytochrome Photoreceptors

▪ **Molecular switch reaction to red light**

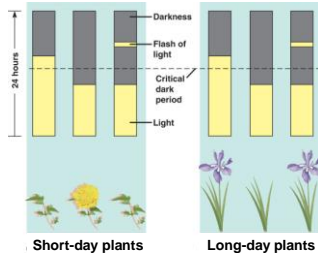
- ◆ conversion of $P_r \rightarrow P_{fr}$ in sunlight stimulates germination, flowering, branching...
- ◆ conversion of $P_{fr} \rightarrow P_r$ in dark inhibits other responses: growth in height & stimulates other responses: growth in height



Flowering Response

▪ **Triggered by photoperiod**

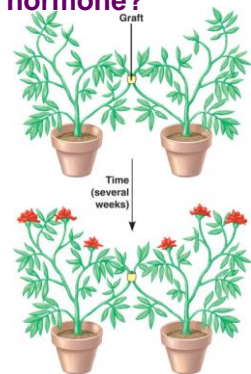
- ◆ relative lengths of day & night
- ◆ night length—"critical period"—is trigger



Plant is sensitive to red light exposure!

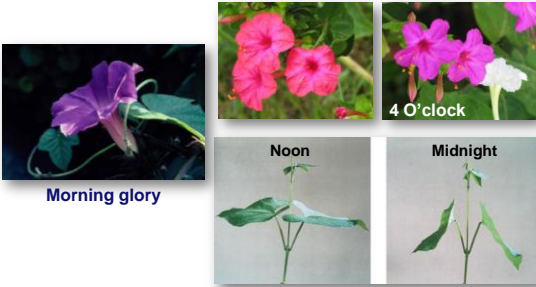
Is there a flowering hormone?

- **Plant on left is induced to flower & then grafted onto plant on right**
 - ◆ plant on right is triggered to flower



Circadian Rhythms

- Internal (endogenous) 24-hour cycles



Morning glory

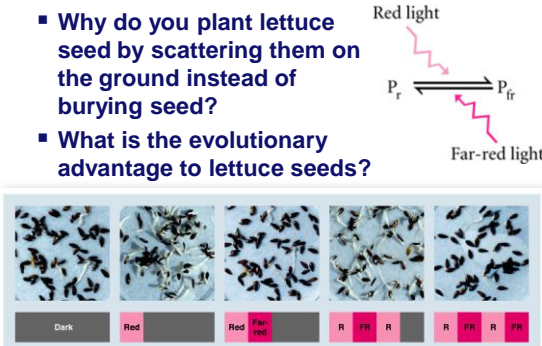
Noon

Midnight

4 O'clock

Practical Application

- Why do you plant lettuce seed by scattering them on the ground instead of burying seed?
- What is the evolutionary advantage to lettuce seeds?



Red light

Far-red light

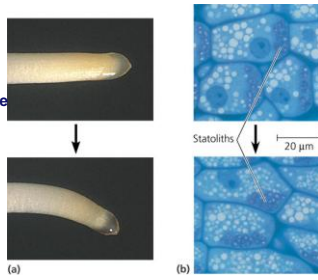
$P_r \rightleftharpoons P_{fr}$

Dark Red Red Far-red R FR R R FR FR

Responses to Gravity

- How does a sprouting shoot “know” to grow towards the surface from underground?

- environmental cues?
 - roots = positive gravitropism
 - shoots = negative gravitropism
 - settling of statoliths (dense starch grains) may detect gravity



(a)

(b)

Statoliths

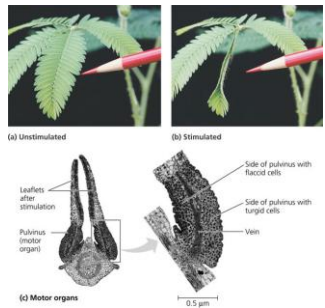
20 μ m

Responses to Touch

- Thigmotropism

Mimosa (sensitive plant) closes leaves in response to touch.

Caused by changes in osmotic pressure = rapid loss of K^+ = rapid loss of H_2O = loss of turgor in cells.



(a) Unstimulated

(b) Stimulated

Leaflets after stimulation

Pulvinus (motor organ)

Side of pulvinus with flaccid cells

Side of pulvinus with turgid cells


Vein

(c) Motor organs

0.5 μ m

Plant Defenses

- Defenses against herbivores



parasitoid wasp larvae emerging from a caterpillar

1 Wounding

1 Chemical in saliva

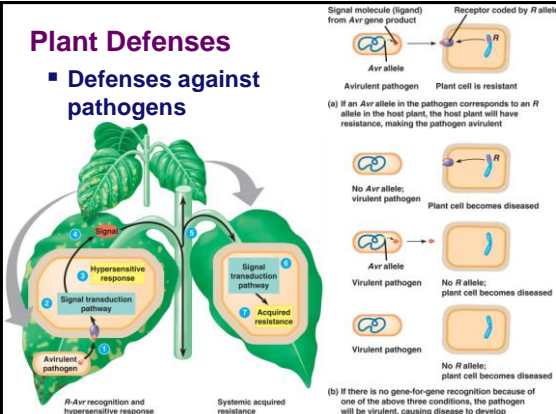
2 Signal transduction pathway

3 Synthesis and release of volatile attractants

4 Recruitment of parasitoid wasps that lay their eggs within caterpillars

Plant Defenses

- Defenses against pathogens



Signal molecule (ligand) from Avr gene product

Receptor coded by R allele

Avr allele

R

Avirulent pathogen

Plant cell is resistant

(a) If an Avr allele in the pathogen corresponds to an R allele in the host plant, the host plant will have resistance, making the pathogen avirulent

No Avr allele: virulent pathogen

Plant cell becomes diseased

Avr allele

Virulent pathogen

No R allele: plant cell becomes diseased

Virulent pathogen

No R allele: plant cell becomes diseased

(b) If there is no gene-for-gene recognition because of one of the above three conditions, the pathogen will be virulent, causing disease to develop

R-Avr recognition and hypersensitive response

Systemic acquired resistance

1 Wounding

2 Chemical in saliva

3 Signal transduction pathway

4 Hypersensitive response

5 Acquired resistance