Plant Signal Transduction

Plants have cellular receptors

- That they use to detect important changes in their environment

For a stimulus to elicit a response

- Certain cells must have an appropriate receptor
Plant Hormones and Signal Transduction

• Any growth response
  – That results in curvatures of whole plant organs toward or away from a stimulus is called a tropism
  – Is often caused by hormones

EXPERIMENT 1880, Charles Darwin and his son Francis designed an experiment to determine what part of the coleoptile senses light. In 1913, Peter Boysen-Jensen conducted an experiment to determine how the signal for phototropism is transmitted.

RESULTS
• In 1926, Frits Went
  – Extracted the chemical messenger for phototropism,  **auxin**, by modifying earlier experiments.

**EXPERIMENT**
In 1926, Frits Went’s experiment identified how a growth-promoting chemical causes a coleoptile to grow toward light. He placed coleoptiles in the dark and removed their tips, putting some tips on agar blocks that he predicted would absorb the chemical. On a control coleoptile, he placed a block that lacked the chemical. On others, he placed blocks containing the chemical, either centered on top of the coleoptile to distribute the chemical evenly or offset to increase the concentration on one side.

**RESULTS**
The coleoptile grew straight if the chemical was distributed evenly. If the chemical was distributed unevenly, the coleoptile curved away from the side with the block, as if growing toward light, even though it was grown in the dark.
Structural Changes During Phototropism
Cell Elongation in Response to Auxin

(Acid-Growth Hypothesis)

Figure 39.8

1 Auxin increases the activity of proton pumps.

2 The cell wall becomes more acidic.

3 Wedge-shaped expansins, activated by low pH, separate cellulose microfibrils from cross-linking polysaccharides. The exposed cross-linking polysaccharides are now more accessible to cell wall enzymes.

4 The enzymatic cleaving of the cross-linking polysaccharides allows the microfibrils to slide. The extensibility of the cell wall is increased. Turgor causes the cell to expand.

5 With the cellulose loosened, the cell can elongate.
Plant Hormones

• **Auxins**
  – Chemical substances that promote *cell elongation* in different target tissues

• **Cytokinins**
  – Stimulate *cell division*

• **Gibberellins** stimulate growth of both leaves and stems
  - In stems, gibberellins stimulate *cell elongation and cell division*

• **Abscisic acid** (ABA) promotes seed dormancy and drought tolerance

• **Ethylene** is produced in response to stresses such as drought, flooding, mechanical pressure, injury, and infection. Also involved in fruit ripening.
Cytokinins, auxin, and other factors interact in the control of apical dominance.

- The ability of a terminal bud to suppress development of axillary buds.

*Axillary buds*

*Remove terminal bud*

*“Stump” after removal of apical bud*

*Lateral branches*
The Embryo of a Monocot
– Has a single cotyledon, a coleoptile, and a coleorhiza

(c) Maize, a monocot. Like all monocots, maize has only one cotyledon. Maize and other grasses have a large cotyledon called a scutellum. The rudimentary shoot is sheathed in a structure called the coleoptile, and the coleorhiza covers the young root.

Figure 38.8c
In a Common Garden Bean, a Eudicot

- The embryo consists of the hypocotyl, radicle, and thick cotyledons

(a) Common garden bean, a eudicot with thick cotyledons. The fleshy cotyledons store food absorbed from the endosperm before the seed germinates.

Figure 38.8a
Seed Germination - Monocots

- Monocots
  - Use a different method for breaking ground when they germinate
- The coleoptile
  - Pushes upward through the soil and into the air

(b) **Maize.** In maize and other grasses, the shoot grows straight up through the tube of the coleoptile.
Seed Germination - Dicots

- Germination of seeds depends on the physical process called *imbibition*
  - The uptake of water due to low water potential of the dry seed
- The **radicle**
  - Is the first organ to emerge from the germinating seed
- In many eudicots
  - A hook forms in the **hypocotyl**, and growth pushes the hook above ground
Gibberelins and Germination

• After water is imbibed, the release of gibberellins from the embryo
  – Signals the seeds to break dormancy and germinate

1. After a seed imbibes water, the embryo releases gibberellin (GA) as a signal to the aleurone, the thin outer layer of the endosperm.

2. The aleurone responds by synthesizing and secreting digestive enzymes that hydrolyze stored nutrients in the endosperm. One example is α-amylase, which hydrolyzes starch. (A similar enzyme in our saliva helps in digesting bread and other starchy foods.)

3. Sugars and other nutrients absorbed from the endosperm by the scutellum (cotyledon) are consumed during growth of the embryo into a seedling.
Abscisic Acid and Seed Dormancy

- Two of the many effects of abscisic acid (ABA) are
  - Seed dormancy
  - Drought tolerance

- Seed dormancy has great survival value
  - Because it ensures that the seed will germinate only when there are optimal conditions

- Precocious germination is observed in maize mutants that lack a functional transcription factor required for ABA to induce expression of certain genes
Ethylene and the Triple Response

- Plants produce ethylene
  - In response to stresses such as drought, flooding, mechanical pressure, injury, and infection
- Ethylene induces the triple response
  - Which allows a growing shoot to avoid obstacles
Effect of Light on Plant Growth - Blue Light

Phototropic effectiveness relative to 436 nm

Change in coleoptile shape following light exposure
Many legumes
  - Lower their leaves in the evening and raise them in the morning

How does a plant “know” what time it is?
Photoperiodism and Circadian Rhythms in Plants

- Cyclical responses to environmental stimuli are called **circadian rhythms**
  - Approximately 24 hours long
  - Can be entrained to exactly 24 hours by the day/night cycle

- **Photoperiod**, the relative lengths of night and day
  - The environmental stimulus plants use most often to detect the time of year

- **Photoperiodism**
  - A physiological response to photoperiod

**Photoperiodism Activity**
Photoperiods of Flowering Plants

Some developmental processes, including flowering in many species requires a certain photoperiod.

The length of the **dark period** is most important when trying to determine if a plant will flower.
1. Compared to wild type, a mutant plant that overproduces cytokinin will probably have ____ lateral branches. Explain.
   a) more  b) fewer  c) the same number of

2. Combining the mutant in #1 with one that causes the overproduction of auxin would ____ the effect you chose above. Explain.
   a) increase  b) decrease  c) not change

3. (True/False) A species of long-day plant will flower when the days are over 14 hours long. Which of the following light cycles would cause this plant species to flower?
   a. Continuous white light day and night, interrupted every 4 hours by flashes of red light
   b. A daily cycle of 9 hours of light followed by three periods of 4 hours and 50 minutes of uninterrupted dark, and 10 minutes of red light and white light.
Which Signal is Responsible for Entraining Plants to the Night/Day Cycle?

RESULTS

[Diagram showing light cycles for short-day (long-night) and long-day (short-night) plants.]

- Short-day (long-night) plant
- Long-day (short-night) plant
• A phytochrome
  – Is the photoreceptor responsible for the opposing effects of red and far-red light

A phytochrome consists of two identical proteins joined to form one functional molecule. Each of these proteins has two domains.

**Photoreceptor activity.** One domain, which functions as the photoreceptor, is covalently bonded to a nonprotein pigment, or chromophore.

**Kinase activity.** The other domain has protein kinase activity. The photoreceptor domains interact with the kinase domains to link light reception to cellular responses triggered by the kinase.

Figure 39.19
• Phytochromes exist in two photoreversible states
  – With conversion of $P_r$ to $P_{fr}$ triggering many developmental responses

Responses: seed germination, control of flowering, etc.
Effect of Light on Plant Growth - Red Light

Under which light conditions did the largest number of seeds germinate?

Under which light conditions did the fewest number of seeds germinate?

What signal do you think the flash of red light is sending to the seeds?