Knight's Essential Botany

Plant Tissues

When you look outside at plants you should notice that there is an amazing variation in their form. Despite these variations in form, all plants have the same basic mechanisms for plant development and possess a similar internal structure.
The plant body of most vascular plants consists of an aboveground part ⇒ the **shoot system**, which includes the stems, leaves, buds, flowers and fruits and a below ground part ⇒ the **root system**, which includes the roots.

Shoot System:
- Provide framework to position leaves.
- Stems can be modified as primary photosynthetic structures (cacti)
- Leaves function as main photosynthetic structures consisting of flattened blade joined to stem by petiole.

Root System:
- Anchor the plant (prevent soil erosion)
- Absorb and conduct water and nutrients. Enhanced using root hairs.
- Store food (beet and radish)

These systems differ in their arrangement in different species of plants. The cells of these systems are arranged in three tissue systems:

- **Dermal tissue system:**
  - Covers and protects plant.
  - Secretes cuticle on stems and leaves.
  - Roots hairs of root are extensions of epidermis that increase surface area for water absorption.
  - Form guard cells.
- **Vascular tissue system:**
  - Arranged differently in monocots and dicots.
  - Consists of the xylem and phloem.
  - Continuous throughout plant
  - In leaves is called the vein.
- **Ground tissue system:**
  - Most extensive system.
  - Filler between vascular tissue and epidermis.
  - Function in storage, photosynthesis and support.

Primary Cell Types

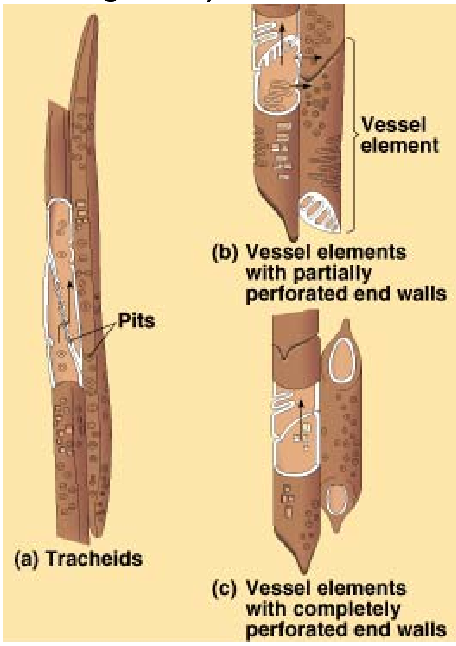
As you read about each of the following types of cells, remember that cell structure often reveals its function.

- **Parenchyma:**
  - Least specialized. The typical plant cell.
  - Dominant cell type of ground tissue. Primary metabolic cell.
  - Primary cell wall is thin and flexible; Lacks secondary cell walls.
  - Stores pigments and flesh of fruit.
  - Can be lignified for support.

- **Collenchyma:**
  - Living
  - Lack secondary walls.
  - Unevenly thickened primary cell wall, primary cell wall is thicker than in parenchyma.
  - Forms strands in celery for support. Usually just inside of the epidermis.

- **Sclerenchyma:**
  - Dead of functional maturity. (*lack protoplast*)
  - Thick secondary cell wall.
  - Found in non-growth areas. Function in support.
  - Two types of Sclerenchyma:
    - **Fibers**—long, slender, tapered and occurring in bundles.
      - Pitted cell walls
    - **Sclerids**—shorter than fibers, irregularly shaped.
      - Occur in sheets as the seed coat.
      - Thicker cell walls than fibers.

Vascular Tissue (Water and Sugar Conducting Cells)



- **Xylem**
  - Has secondary cell walls.
  - Dead, hollow tubes specialized for transporting water and dissolved solutes from roots to leaves.
  - Water carrying cells (tracheids and vessel elements) often supported with fibers making it rigid. Parenchyma cells are also present to help load minerals in and out of the vessel members and tracheids.

Two Primary cell types in xylem:

- **Tracheids**
  - Long thin with 2° Cell Walls; Lignified.
  - Pits in the sides allow water movement between cells. Lack secondary cell walls in pits.
  - Only type found in seedless vascular plants and gymnosperms.

- **Vessel Elements**
  - Thinner walls; Wider than tracheids therefore more efficient.
  - End walls absent or perforated forming continuous vessels.
  - Found almost exclusively in angiosperms (along with tracheids).

- **Phloem**
  - Food conducting tissue.
  - Living at functional maturity although nucleus disintegrates at maturity

  - **Sieve tube Members** (A*ngiosperms*)
    - End-to-end arrangement to form large, continuous sieve tubes.
    - Sieve plates at ends.
    - At maturity the nucleus disintegrates and the organelles are reduced in function. These cells therefore require the assistance of companion cells.
      - **Companion cells** specialized parenchyma
        - "*Services*" sieve tube member--- carriers out metabolic functions. Contains all of the organelles necessary for metabolism. Function in sugar loading and unloading.
        - Plasmodesmata connects cytoplasm of companion and its sieve tube member.

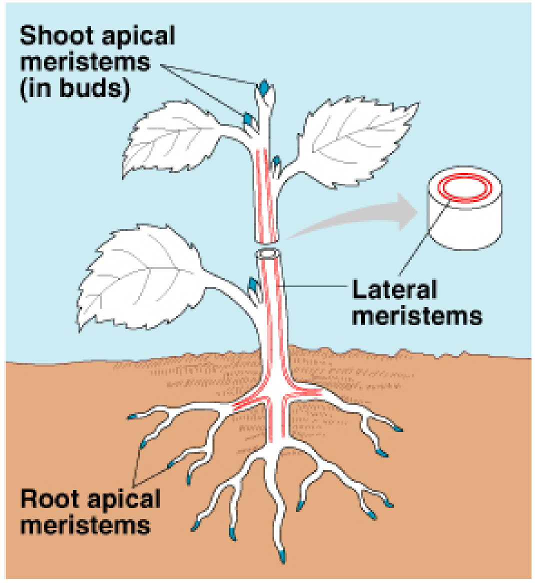
  - **Sieve cells**- (*found in gymnosperms and seedless vascular plants*)
    - Less specialized than sieve tube members → pore size equal. No sieve plates at end.
    - Long with tapered ends.

Plants have localized regions of tissues that are capable of growth throughout the lifetime of the plant. These tissues create growth in the length and thickness (girth) of the plant within the stems and roots. This lifelong growth is called ***indeterminate growth*** (in contrast to ***determinate growth***, which is found in animals and is defined as growth having a defined limit) and occurs within special embryonic cells call ***meristems***.

What is a Meristem?

- ☒ Self-perpetuating, embryonic cells that remain undifferentiated.
- ☒ As they divide, one cell stays and remains localized (called an initial) while the other is displaced and becomes specialized (called a derivative).

They are the ultimate source of all cells in the plants. They can form primary and secondary meristems that produce primary and secondary tissues, respectively.



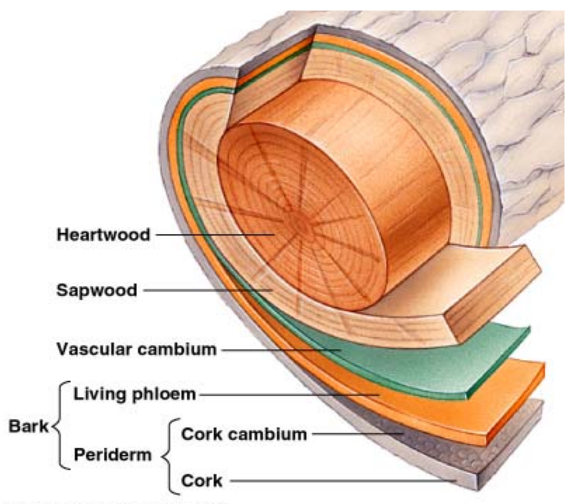
Two types of growth are found in plants:

- ❖ **Primary growth:**
  - ➢ Increases length of plant.
  - ➢ Occurs at **apical meristems**. Each apical meristem (root and shoot meristem) is responsible for the production of specialized derivatives that are called the **primary meristems.**
  - ➢ Produces the primary tissues of plants (dermal, vascular and ground) and cause elongation of root/shoot.
    - **Protoderm→ epidermis**. Root hairs form from epidermis. Guard cells and trichomes of leaves, epidermal cells of stems.
    - **Procambium →** vascular cylinder (stele in roots and vascular bundles in stems); **primary xylem and phloem.** Distribution of vascular tissues in monocots and dicots differs and is one way to distinguish the two classes.
    - **Ground meristem →** ground tissue. Pith and cortex of root and stem and mesophyll of leaves.
  - ➢ Occurs within zone of cell division, followed by zone of cell elongation and then zone of cell differentiation (maturation).
  - ➢ Found at the tip of the terminal bud on a shoot and within the root cap.
  - ➢ Axillary buds form lateral branches at the surface of the shoot.
  - ➢ Some specialized regions may be found.
    - **Endodermis**: between the epidermis and vascular tissues of roots. All materials entering into vascular cylinder must pass through these cells that regulate which minerals and nutrients will enter the stele. Provides mechanism to increase concentration of needed minerals in vascular cylinders through pumps in the cells.
      - Surrounded by **Casparian Strip** which is made of suberin.
    - **Pericycle**: inside of the endodermis. Has meristematic properties and forms lateral roots that push out through the cortex of the root. (*remember that branches form from the axillary buds along the epidermis of the stem*).

Secondary growth caused by Secondary Meristems:

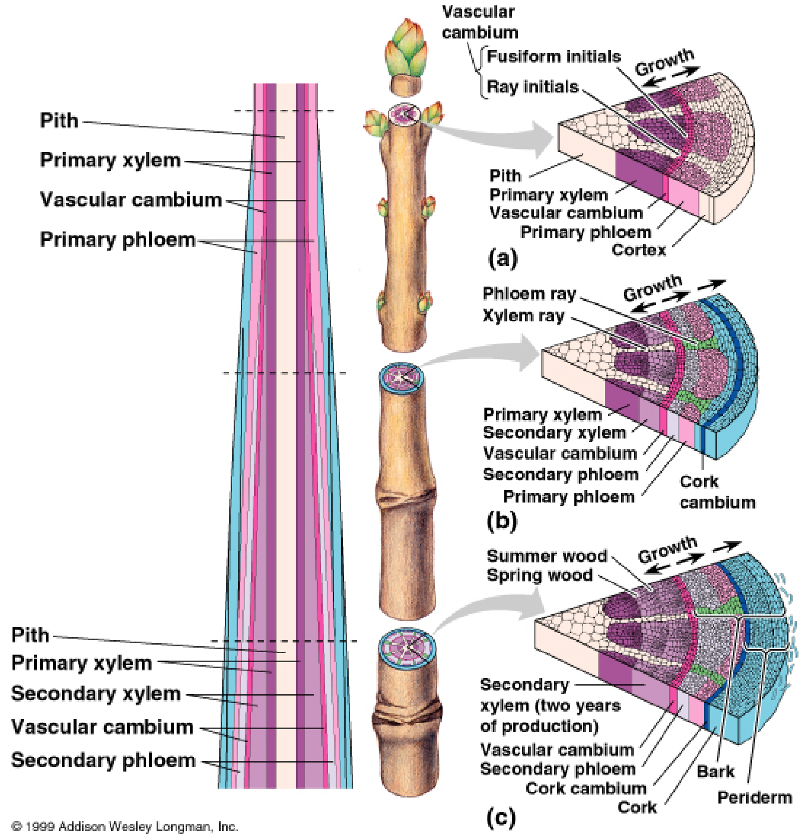
- ➢ Occurs in woody plants only (all gymnosperms and most dicot angiosperms; rare in monocots (Joshua Tree is one notable exception).
- ➢ Increases the thickness (girth) of the plant allowing for increased height.
- ➢ Occurs at lateral meristems located along long axis of roots and stems as a cylinder.

- ➢ **Two Lateral Meristems:**
  - **Vascular cambium**- Produces the **secondary xylem and phloem.**
    - On the inner portion, toward the center.
    - Produces secondary xylem (to the inside of v.c.) and phloem (to the outside of v.c.) in stems.



- Secondary xylem (tracheids, vessel elements and fiber cells with lignified cell walls) becomes wood which forms annual rings showing periods of growth (spring and summer) and dormancy (winter). Xylem that is functioning and transporting water is called **sapwood**. Older xylem that is located toward the center of the stem functions only for support and is called **heartwood**.

- **Cork cambium**- produces the outer covering of roots and stems
  - On the outer portion, outside of the vascular cambium.
  - Fixed in size, does not increase in diameter.
  - Forms protective layers of cork that replaces the primary epidermis in stems.
  - Bark is all the tissues external to the vascular cambium which includes the phloem, phelloderm (specialized parenchyma cells that form to the inside of the cork cambium), cork cambium and cork (cells that form to outside of cork cambium)
  - In roots the cork cambium forms the **periderm** which is impermeable to water and replaces the epidermis since it was sloughed off as the secondary phloem was pushing outward. Roots with secondary growth function in anchoring while water and solutes are absorbed at younger locations.



Transport Systems in Plants.

While animals have a heart and vessels to transport material throughout their bodies, plants use very different although effective mechanisms to accomplish the same goals. Plants must transport CO_2, O_2, water, nutrients absorbed from the roots and the products of photosynthesis that serves as the carbon backbone for the rest of the plant.

Absorption of water at the roots.

Water and minerals enter plants through the following transport pathway:

Soil → epidermis → root cortex (stele) → xylem

Soil → Epidermis.

✓ Water is absorbed through the numerous root hairs present in fibrous and taproots.
✓ The epidermis of the root lacks a cuticle so water can pass in between the cells or move into the cells.

Epidermis → Cortex.

✓ Water moves from the epidermis, through the cortex to the vascular cylinder (stele).
✓ Water that has passed into the plant can move laterally by two different methods:

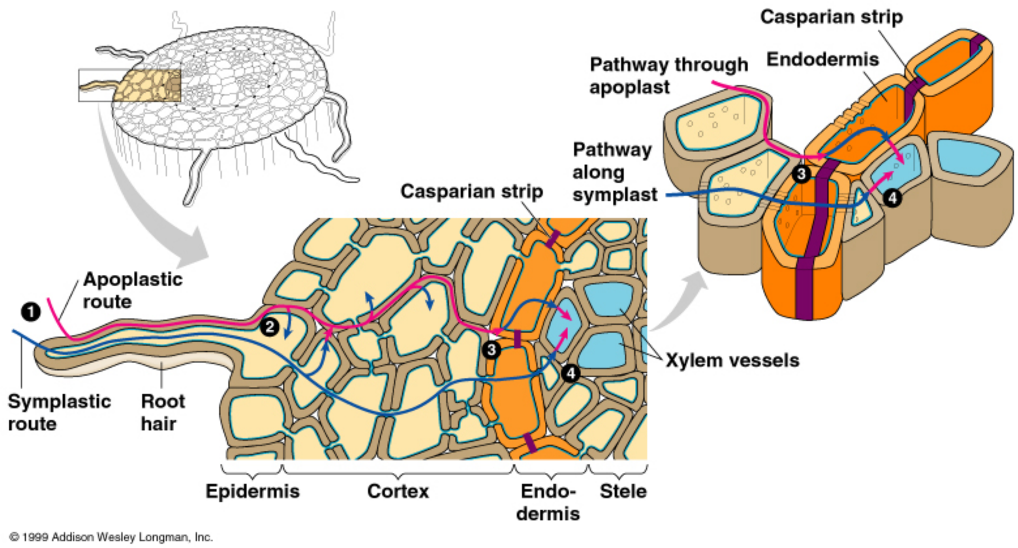
- **Apoplastic route ("ap"—apart/away)**: water ***moves in between*** epidermal cells and passes between cells without actually entering a cell. Water and solutes can move this way, through the **cortex** of the root until it reaches the **Casparian Strip** of the **stele**. At this point it must enter the endodermal cells where selection can occur. This route exposes a large number of cells to the solution and offers the opportunity for water and mineral uptake by the largest number of cells.

- **Symplastic route ("sym"—in)**: water crosses the cell and moves through the cells to neighboring cells via the **plasmodesmata** connecting the cells. Selective mineral absorption takes place at the root hair.

Regardless of the route taken, water must pass through a membrane prior to its entrance into the stele.

Cortex → xylem.

✓ Water and minerals must pass through the endodermal cells where they can move passively and actively into the xylem.



How does water get up to the top of a Giant Redwood?

Moving Xylem Sap Up a Shoot
Transpiration-Cohesion-Tension Mechanism/Cohesion Theory

Water moves from roots to stems and then into leaves. The **transpiration** of water from the leaf pulls xylem upward. Since water is hydrogen bonded to its neighbor, the **cohesion** of water with its neighbors transmits this upward pull along the entire length of the xylem. The **Adhesion** of water molecules to the sides of the vessel elements and/or tracheids helps pull against the force of gravity.

I. The drying power of air causes transpiration (rate dependent upon temperature [as temperature increases 10°C, evaporation rate is doubled], wind or air currents and whether the stomata are opened/closed.)

II. Transpiration causes a negative pressure (tension) in the xylem from the leaves down to the roots.

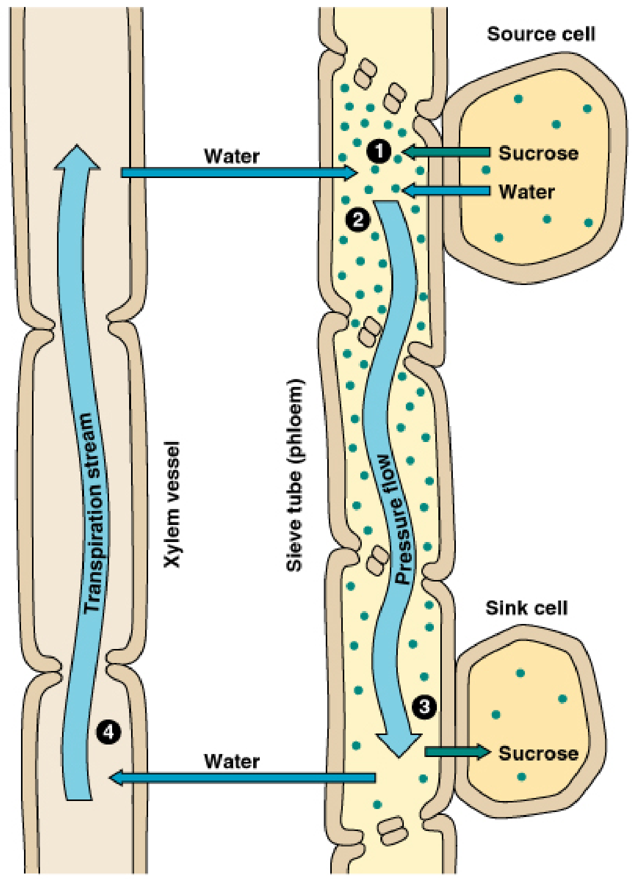
III. Cohesion of water molecules due to hydrogen bonding allows for the pulling up of water from the top of the plant. As long as the chain is not broken, water can be pulled up. If the chain is broken, air is introduced into the vessel and will no longer function. This cell may be short-circuited in the flow and water re-routed around it.

IV. The small diameter of tracheids and vessel elements allows the adhesion of water to the sides of the cells to work against the force of gravity.

Phloem Transport (aka. Translocation)

- The products of photosynthesis must be transported throughout the body of a plant to be used as a source of carbon for the synthesis of all organic molecules and as a source of energy. Sugar rich phloem sap is generally moved from the leaves where it is synthesized toward the roots. This occurs when a plant makes the sugar and then stores it in a tuber or root for instance. This stored resource may be utilized when food is needed for growth. This would be the case in the spring during rapid growth during the second season of a plants life.
- Generally, we say that sugar moves from **Source to Sink**. The source and sink can change though. The flow of the sugar is directed by a gradient of hydrostatic pressure and is powered by an osmotic pump. It is very important that you understand osmotic potential and water potential.

1. Sugar produced at a source (leaves) is loaded into sieve-tubes. This sugar can move through cells and plasmodesmata, between cells or can be actively transported from transfer cells into the sieve-tube members. ATP is used to power a carrier molecule that moves the glucose into the sieve-tube.
2. The accumulation of sugar in the sieve-tube (which lowers the water potential in the cell!) pulls water in from the apoplast by osmosis. This increases the hydrostatic pressure in the sieve-tube at the source. This pressure starts a flow of solution from the cell that was loaded with sugar to any sieve-tube with a lower pressure.
3. The solution will continue to move from high pressure to lower pressure.
4. At the sink end of the system, sucrose is being removed from the sieve-tubes (which increases the water potential at this end of the sieve-tubes), lowering the hydrostatic pressure.
5. The sugar may be stored in parenchyma cells for later use (as starch).



Control of Plant Growth

As a plant matures, tissues and organs develop as a response to heredity, positional information and external stimuli. Signals that the plant receives come in the form of external stimuli such as light but also chemical signals in the form of hormones that are able to move throughout the plant. These hormones function in a manner similar to the hormones of animals. They are produced in one part of the plant and move throughout the body of plant eliciting their responses to their target tissues; and they do so in minute quantities.

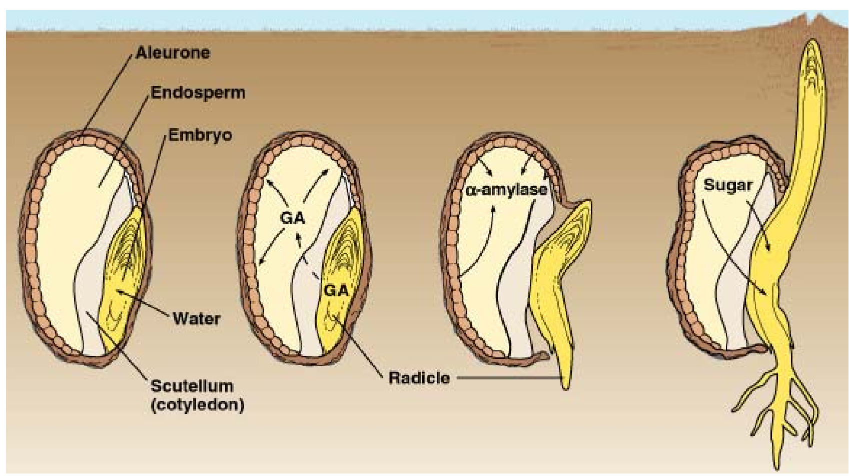
The first known plant hormone was discovered during studies of the growth of oat coleoptiles. Coleoptiles are modified leaves of monocots that surround the first true leaves and stems of a germinating seedling. These experiments were attempting to explain how oat coleoptiles responded to light. The growth of an oat shoot toward light is called positive **phototropism** and was studied by Charles Darwin and his son, Francis in the 1880's and later by Frits Went in the 1920's. The hormone that caused this movement toward light was later identified as **Auxin**, the first plant hormone identified.

- **Auxin**- (IAA is naturally found; there are many synthetic forms)
  - produced in apical meristem down toward roots. Only moves one direction (down), which requires the use of a pH gradient.
  - **Stem elongation**; coleoptile development in grasses; promotes adventitious root growth; promotes growth of vascular cambium and differentiation of secondary xylem; produced by developing seed to initiate fruit maturation and growth.
  - Increases plasticity of cells leading to growth (*Acid growth hypothesis*). **When light illuminates one side of a shoot, auxin diffuses to side opposite of light, causing elongation of those cells which causes the shoot to bend toward the light!**
  - Removal of the terminal bud stimulates lateral growth from lateral/axillary meristems at node (where leaves attach to the stem). Auxin inhibits lateral meristems from growing so the removal of the apical meristem would allow the plant to grow laterally (gets bushy).
  - High concentrations inhibit root growth; useful as a selective herbicide (makes dicots grow to death—Round-Up).

- **Cytokinin**
  - **Stimulates meristematic growth →** increase mitosis.
  - Primarily produced in roots and travels to the shoots in the xylem sap.
  - Promotes growth of lateral buds (axillary bud growth)
  - Inhibits/delays leaf drop-**senescence** [breakdown of chlorophyll and proteins leading to death. Naturally occurs in all organisms. *Old Botantists Never Die, They Senesce*] If you take leaves that are yellowing and add cytokinin to them the will become green again (or at least delay their senescence).
  - Promotes differentiation of cells of **callus** (undifferentiated cell mass). If a callus has high concentrations of cytokinins added to it it will causes shoots to form from the callus.

Antagonistic With Auxin

- **Gibberellins** (GA) Identified as source of "*Foolish seedling disease*" in rice. Caused by release of gibberellin from infecting fungus.
  - Synthesized in apical meristem of root and shoot
  - Elongation of internode region (enhanced by auxin) of stems.
  - Signals break of dormancy in seeds (i.e. Germination) and winter buds. Stimulates cell division and elongation.
    - Hydrate tissue (***imbibtion***—absorption of water) (increase mRNA production for amylase, increase protein synthesis)
    - GA released→ diffuses into Aleurone layer of seed.
    - Aleurone layer produces hydrolytic enzymes. Makes a soluble material available to embryo.
    - Cell division and elongation occurs.
    - Radicle (embryonic root) released



- **Abscisic Acid** ABA
  - Synthesized in mature leaves, fruit, roots. **Stimulates/Promotes dormancy**.
  - Suppresses growth/elongation of buds.
  - Stimulates formation of bud scale formation (winter buds) around apical meristems.
  - Controls opening/closing of stomata. When water is scarce, stomata will close to prevent further water loss after mesophyll cells that have wilted excrete abscisic acid.

- **Ethylene** (gas at normal temperatures and pressures)
  - Suppresses stem/root elongation; slows growth
  - **Triggers senescence and leaf drop (senescence)**. Stimulates gene expression of enzymes that break down chlorophyll and proteins.

- **Abscission** (dropping of plant parts such as flowers, leaves and fruit) of leaf controlled by auxin---ethylene combination; breaks down cells of petiole.
- Released from damaged or ripening tissues.
- Injured leaf no longer receiving auxin→ increase ethylene→abscission of leaf.
- **Triggers fruit ripening**. Conversion of starch or organic acids to sugars, softening of cell wall, rupturing of cell membrane and loss of cell fluid (drying). One overripe fruit will release ethylene and stimulate senescence (ripening) of adjacent fruit. "*One bad apple ruins the whole bunch*." This is why picked apples are stored in warehouses containing low ethylene and high concentrations of CO_2 (inhibits the effect of ethylene).

Plant responses to Light

Plant development is strongly influenced by environmental factors, the most important of which is light. Responding to light is a major way in which plants adapt to their surroundings and match their activities to the time of day and season of the year. **Phytochromes** are pigments that act as photoreceptors at tell the plant information about the quality of light that the plant is receiving. It is the conversion of this photoreceptor that is responsible for measuring the photoperiods a plant is exposed to.

This protein exists in two forms, depending on the wavelength of light that it has been exposed to:

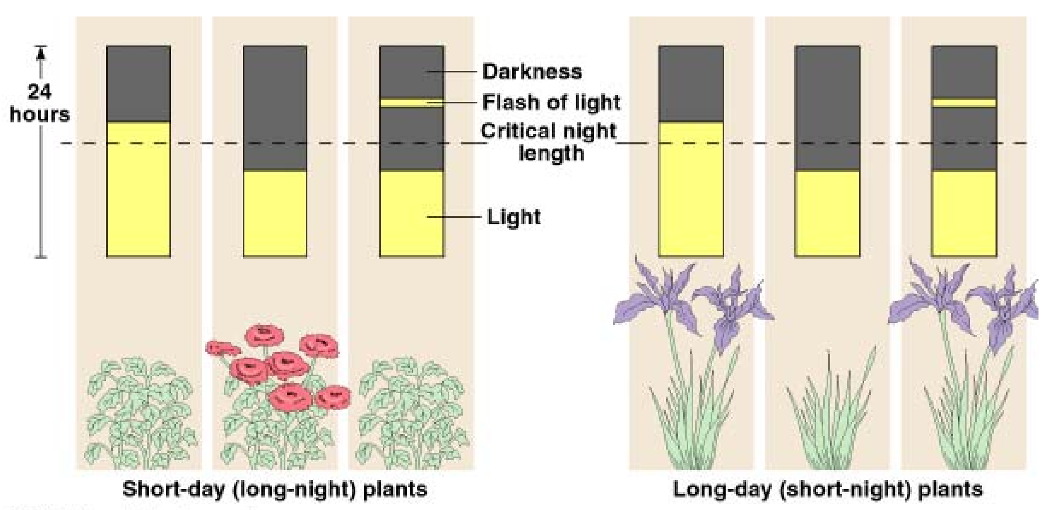
Pr (red absorbing) is converted to **Pfr** (far-red absorbing) when exposed to red light.
Pfr is converted back to **Pr** when it is exposed to far-red light.
The two forms are photoreversible.
Pfr (active form) is the form that triggers the developmental responses to light such as germination.

During daytime, **Pr** accumulates as **Pfr** is converted to **Pr** and as it is synthesized in the **Pr** form. At sundown, **Pfr** is converted to **Pr**. When light is present (sunrise) **Pr** is converted to the active form **Pfr**.

Photoperiodism is the plants response to the relative amount of light and dark in a 24 hour period, and controls the flowering of many plants. Plants are able to measure seasonal changes in the relative amounts of light and dark during a day and respond accordingly. The responses that a plant makes are dependent upon a critical night length.

Short-day plants flower during early spring or fall, when the nights are relatively longer and the days are relatively shorter [between July and December]. They require a light period *shorter than a critical length* in order to flower.
[Flower if duration of night is **longer** than a critical length]
Ex. Chrysanthemum, poinsettia, soybean, strawberry.

Long-day plants flower mostly in summer, when the nights are relatively shorter and the days are relatively longer [between January and June]. They flower only when the light period is *longer than a certain number of hours*.
[Flower if duration of night is **shorter** than a critical length]
Ex. Spinach, radish, iris, lettuce, potato, clover.



A short day plant will flower when the night exceeds some critical length. Disrupting its night length with a flash of light will prevent flowering. A long day plant must have a night shorter than a critical length in order to flower.

Day-neutral plants flower without respect for the day length.