Plants

Photosynthesis to Reproduction

Photosynthesis

- Autotrophic Nutrition

  --energy of light is converted into chemical bond energy of organic compounds

  --most of the chemical energy *used by all living organisms* comes from photosynthetic ability of autotrophs such as plants, algae, and phytoplankton.

- Photosynthesis can occur due to the ability of specific leaf pigments to absorb certain wavelengths of light, *making this light available for the plants to convert to chemical bond energy.*

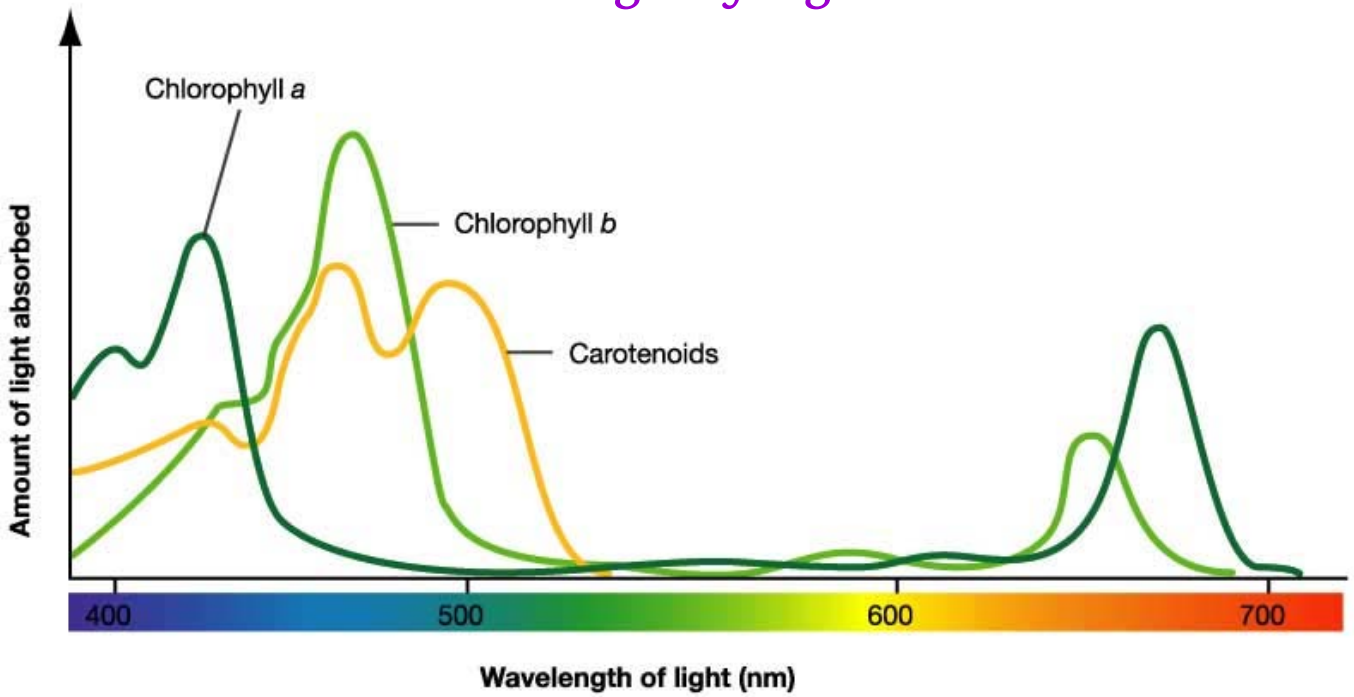
Photosynthetic Pigments

- Photosynthetic organisms absorb red and blue wavelengths of light the best.
- The most common photosynthetic pigment is chlorophyll which is green in color.
- Accessory pigments include carotenes and xanophylls which are present in most leaves but are masked in the spring and summer by the abundant presence of chlorophyll (remember chlorophyll gene gets turned from the intensity & duration of sunlight.
- In the fall, the chlorophyll gene is turned off (less sun) and the other photosynthetic leaf colors become more evident.

NOTE: the masking of accessory pigments by chlorophyll during the spring and summer is an example of how ***GENE ACTION is INFLUENCED by the ENVIRONMENT!***

Photosynthetic Pigments

Photosynthetic Pigments and Absorption of Specific Wavelengths of Light



--Photosynthetic leaf pigments absorb the spectrum of visible white light: ROY G BIV.

--Chlorophyll a and b absorb RED and BLUE wavelengths of light the best. Chlorophyll reflects GREEN light, so it gets the least amount of energy from wavelengths of green light

Chloroplasts

- Photosynthetic leaf pigments are found in structures called plasmids.
- Chlorophyll is found in structures called chloroplasts.
- Other photosynthetic pigments are housed in plastids called chromoplasts.

Chloroplasts in Elodea cells

Structure of Chloroplast

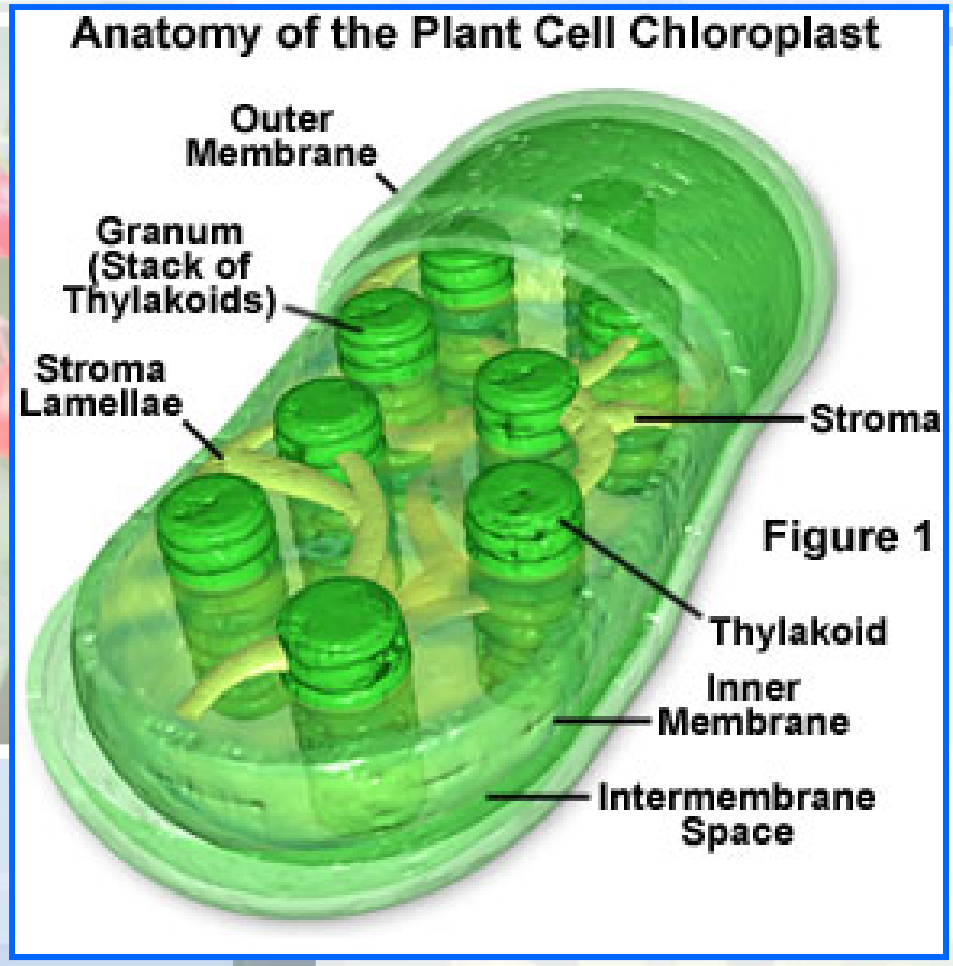
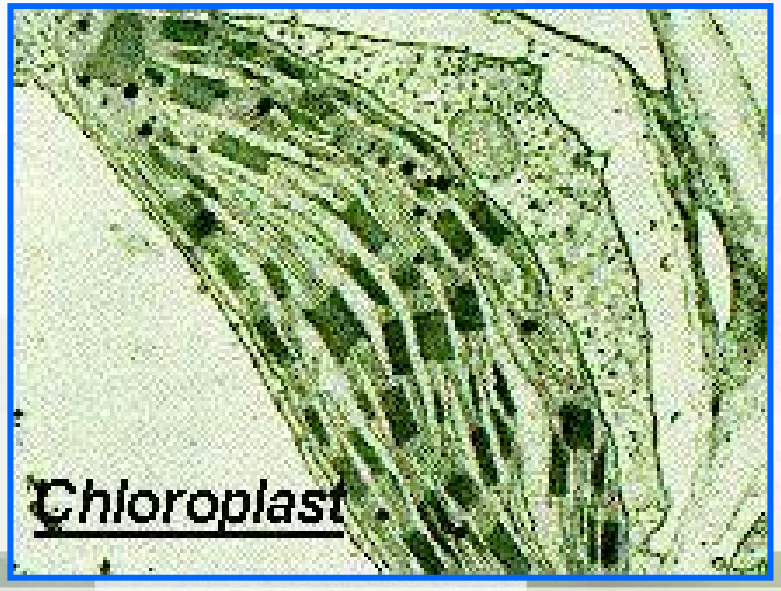


Figure 1

Chloroplasts are made up of grana (thylakoid membranes) which are sacs of parallel membranes in which chlorophyll and enzymes are embedded. Light reactions of photosynthesis take place in the grana.

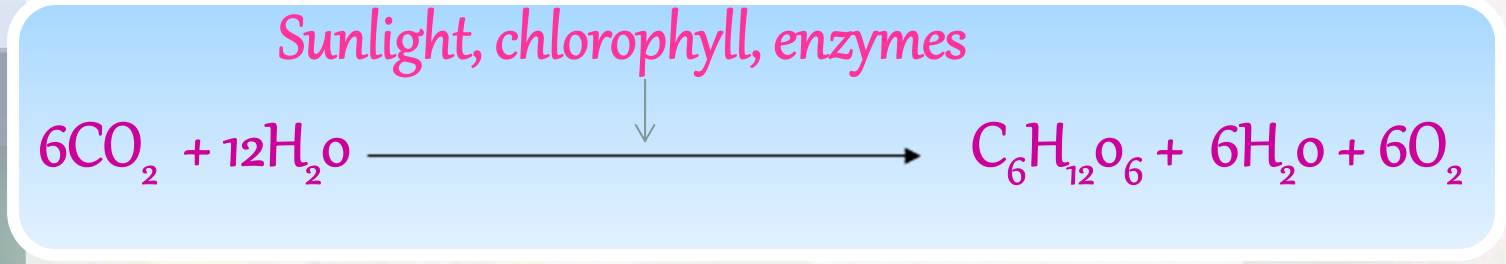


The regions surrounding the grana are called the stroma which contain the enzymes necessary for the dark or carbon fixation reactions.

Overview of Photosynthesis

- Raw materials: water & carbon dioxide
- Also necessary: enzymes, chlorophyll & light energy
- Process: light energy is converted in the chloroplasts though a series of enzyme mediated reactions into chemical bond energy of food molecules such as glucose
- Products: Glucose
- Metablic Wastes : oxygen and water.

Chemical Equation for Photosynthesis:



Results of Photosynthesis

- Glucose formed during photosynthesis may be:
  - --used as an immediate energy source during aerobic respiration
  - --used to synthesize other organic compounds such as lipids & proteins
  - --converted into starch for storage
- When plants used their stored materials, they must first break down starch into soluble materials such as glucose. This digestion occurs INTRACELLULARLY (within each cell)
- Once digestion of the starch is complete, *the simple sugars may be used within the same cells or may be transported to other cells of the plant for use or further storage.*

Light Reactions of Photosynthesis

- Light energy is absorbed by the chlorophyll embedded in the grana.

Part One of the Light Reactions:

- *Photolysis* – the splitting of water with light

  --*some of the absorbed light energy is used to split water into hydrogen and oxygen atoms*

  --oxygen from the splitting of the water is released from the leaf as a metabolic waste

  --the hydrogen is picked by a hydrogen carrier *NADP to become NADPH,* carrying the hydrogen to the dark reactions in the stroma.

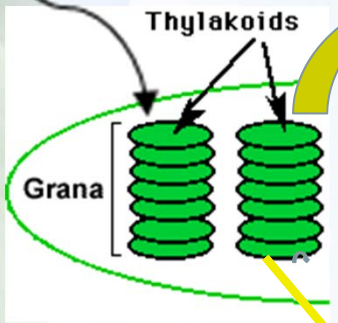
Part Two of the Light Reactions:

- Some of the captured light energy is *used to synthesize ATP, converting light energy into chemical bond energy.* The ATP is sent to the stroma.

Diagram of the Light Dependent Reactions

GRANA of chloroplast

Light energy is absorbed by the chlorophyll



Photolysis

$H_2O \rightarrow 2H^+ + O$

To atmosphere

Carries the hydrogen to the dark reactions in the stroma

$NADP + NADPH$

Hydrogen carrier

ATP-ase

$ADP + P \rightarrow ATP + H_2O$

ATP goes to the stroma to the dark reactions

Light energy is changed to chemical bond energy with the synthesis of ATP

ATP and Hydrogen go to the stroma where the rest of photosynthesis occurs

Light Independent Reactions (Dark Reactions)

- The dark reactions require no light, but do take place during the day in the stroma of the chloroplast, using the products of the light reactions.
- These reactions are also referred as the carbon fixation reactions or the Calvin Cycle.
- During the dark reactions, CO_2 taken from the air, hydrogen atoms from the light reactions, and chemical energy stored on the bonds of the ATP are combined in a series of chemical reactions which produce a number intermediate compounds including a 3 carbon sugar phosphoglyceraldehyde, commonly known as PGAL.
- Glucose and other organic molecules are synthesized from PGAL.
- Water is released as a metabolic waste.

Carbon Fixation Reactions (Calvin Cycle)

Dark Reactions –in the Stroma of the chloroplast

NADPH drops off hydrogen

ATP is hydrolyzed to release chemical bond energy

CO_2 from the atmosphere enters in the dark reactions

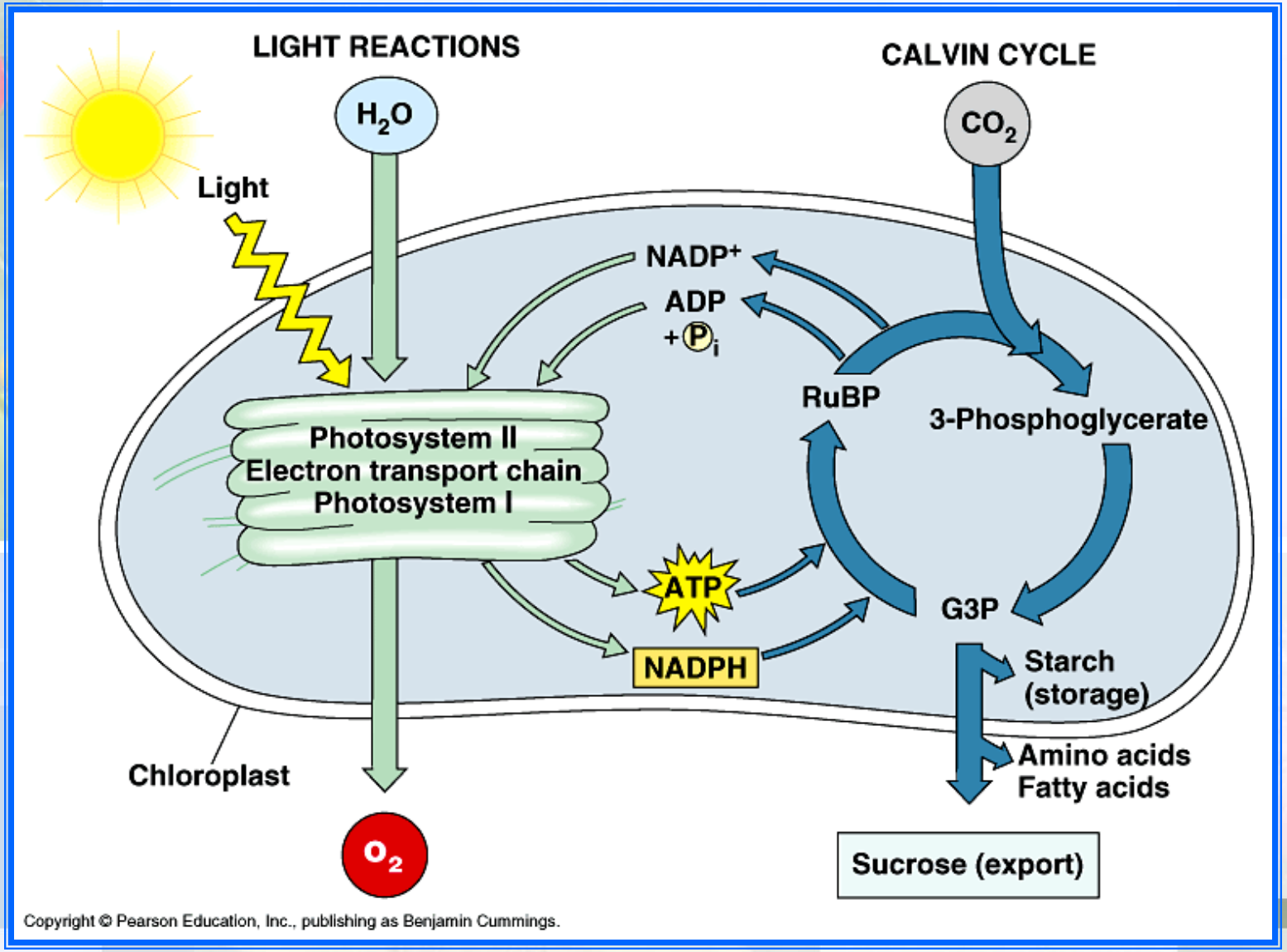
$$2H + CO_2 + \text{chemical bond energy} \longrightarrow \underset{\text{3 carbon compound}}{PGAL} \longrightarrow C_6H_{12}O_6 + H_2O$$

--PGAL must be created first through carbon fixation.

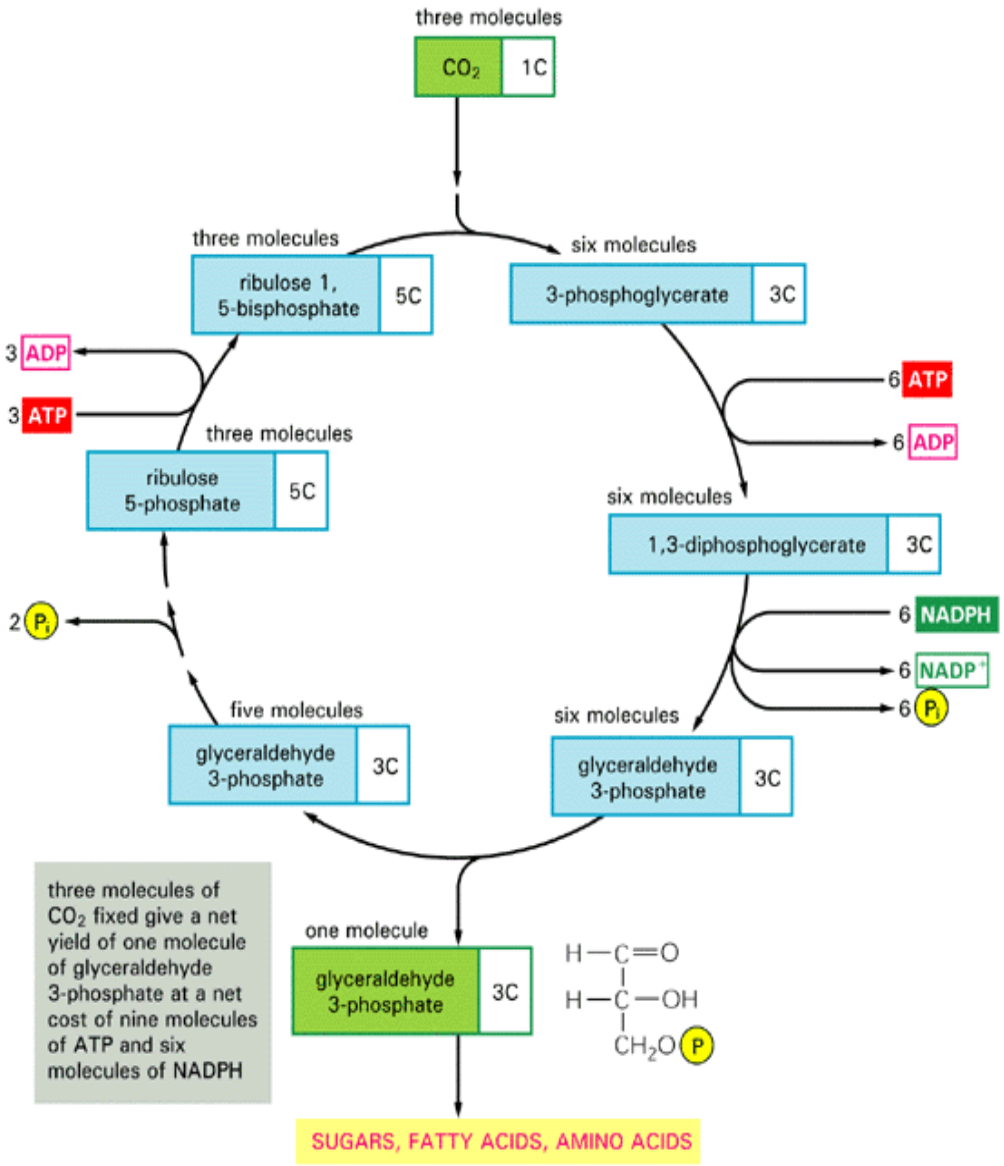
--Frpm PGAL , glucose or other organic compounds the plant needs can be synthesized (protein, lipids)

--Once glucose is made, the plant must go through cellular respiration to release energy for its life activities.

Overview-Photosynthesis



Summary - Calvin Cycle



PGAL (phosphglyceraldyde), G3P or glyceraldehyde-3-phosphate (several names, 1 compound) is one the most important intermediate compounds made during the Calvin cycle.

RUBISCO - RuBP (ribulose biphosphate carboxylase oxygenase) is an enzyme necessary for the Calvin cycle to occur. Rubisco is probably the most abundant protein on Earth.

From PGAL, sugars, fatty acids, and amino acids can be synthesized.

Research

- Current understanding of the metabolic pathways of the light and dark reactions come from the use of carbon and oxygen isotopes.
- Oxygen-18

  --by using *water synthesized with oxygen-18,*

  scientists were able to trace the pathway of water as it entered the leaf.

  --Oxygen released during the light reactions comes solely from the photolysis of water during the light reactions
- Carbon 14

  -- Radioactive carbon has been used to trace the *metabolic pathway of carbon dioxide in the Calvin Cycle (dark reactions)*

  --Results indicate that the carbon found in glucose and other synthesized organic compounds comes solely from the carbon dioxide taken from the air.

Leaf Structure

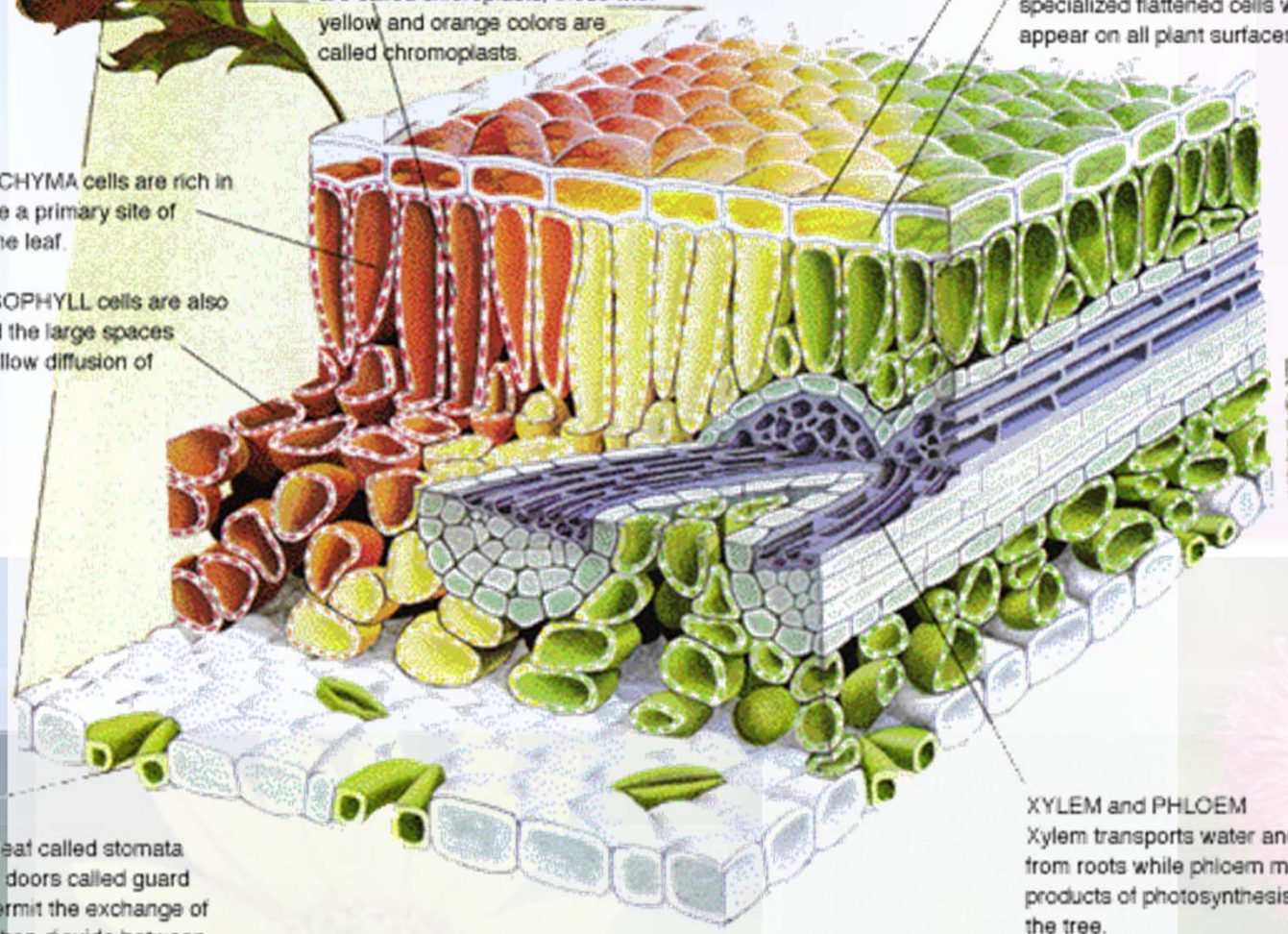
PLASTIDS
The colors in leaves are contained in tiny structures within the cells called plastids. Plastids with green chlorophyll are called chloroplasts, those with yellow and orange colors are called chromoplasts.

Leaf surfaces are coated with a WAXY CUTICLE to prevent water loss.

The EPIDERMIS is a layer of specialized flattened cells which appear on all plant surfaces.

PALISADE PARENCHYMA cells are rich in chloroplasts and are a primary site of photosynthesis in the leaf.

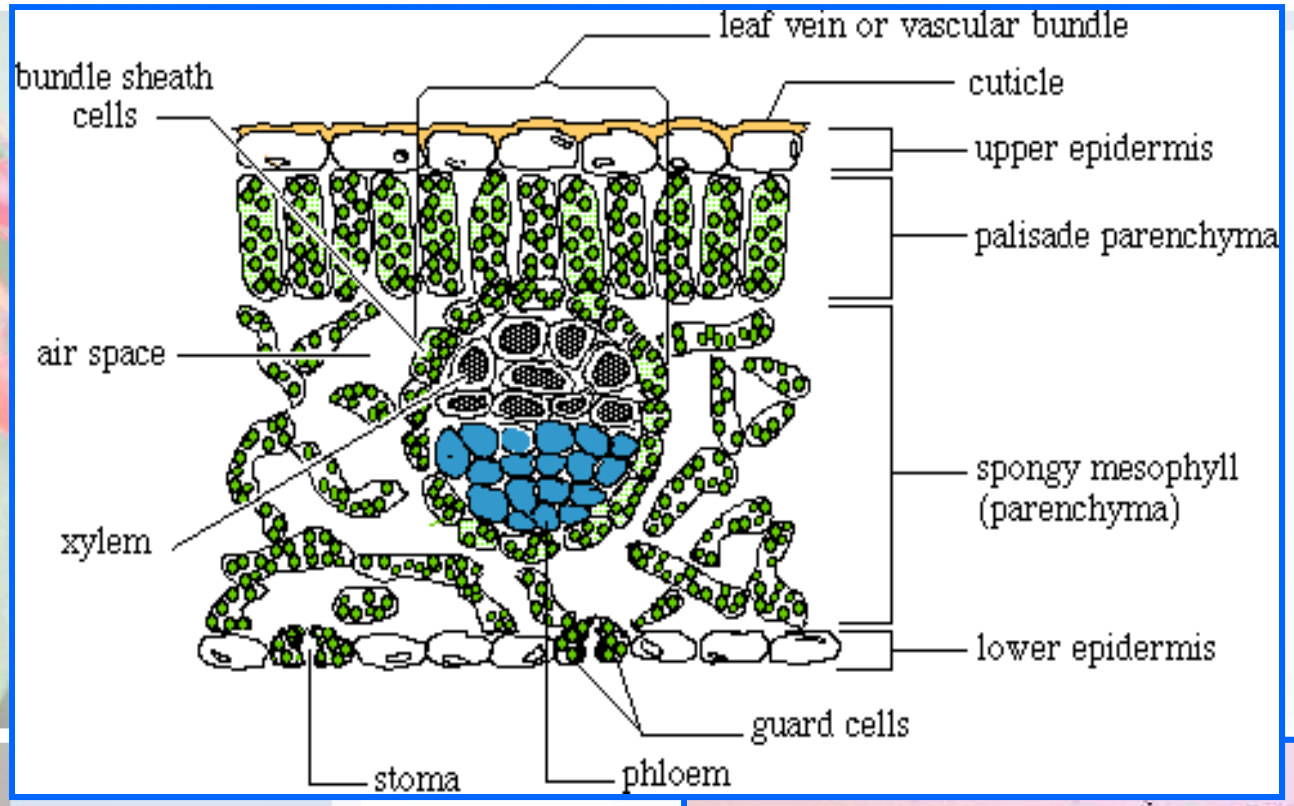
The SPONGY MESOPHYLL cells are also photosynthetic, and the large spaces between the cells allow diffusion of carbon dioxide.

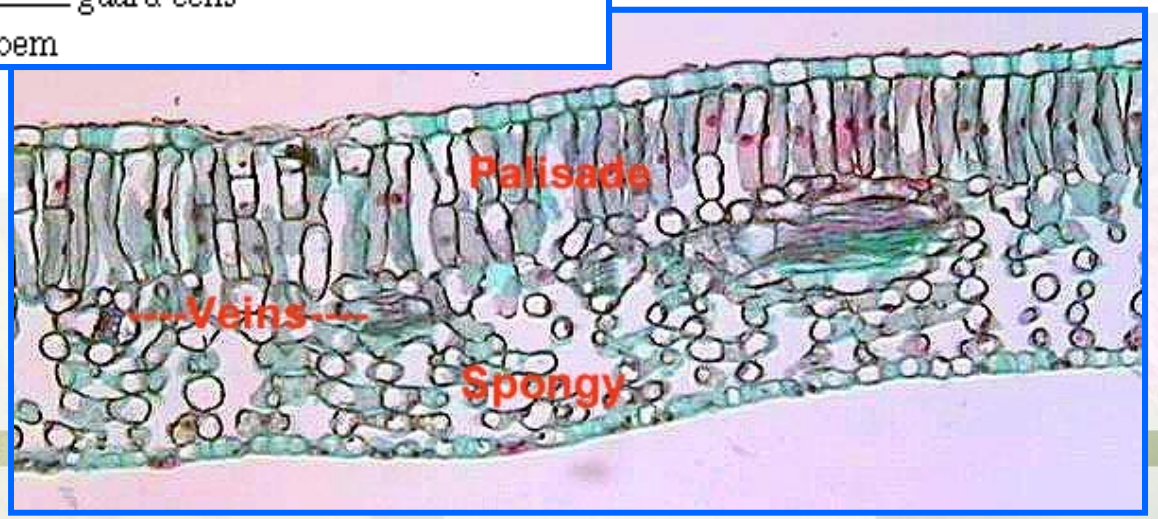


STOMA
Openings in the leaf called stomata are controlled by doors called guard cells. Stomata permit the exchange of moisture and carbon dioxide between the leaf and atmosphere.

XYLEM and PHLOEM
Xylem transports water and minerals from roots while phloem moves the products of photosynthesis throughout the tree.

Leaf Structure (cont'd)





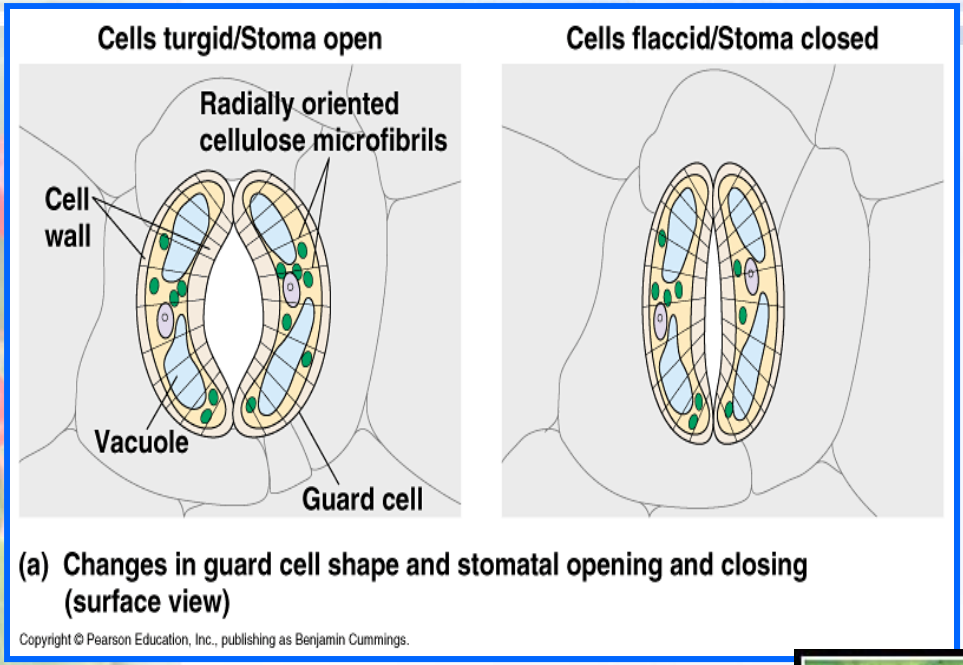
Leaf Structure (cont'd)

- Large surface area permits maximum absorption of light energy
- Cuticle: protective waxy covering of the leaf.
- Epidermis: outer single layer of cells that lies beneath the cuticle.
  --Generally contains no pigment to allow light to reach the photosynthetic layer below.
- The cuticle and epidermis together function to:
  --protect the inner tissues of the leaf from water loss
  --increase the leaf's ability to resist invasion of inner tissues by fungi
  --protect the leaf from mechanical injury
- Palisades Layer: made up of elongated cells filled with many chloroplasts.
  --Located directly below the upper epidermis., site of photosynthesis
- Spongy Layer: has many interconnected air spaces with cells that have moist cell surfaces to encourage the circulation and exchange of gases including oxygen, carbon dioxide, and water vapor.
  – found directly beneath the palisades layer, has some chloroplasts

Leaf Structure (cont'd)

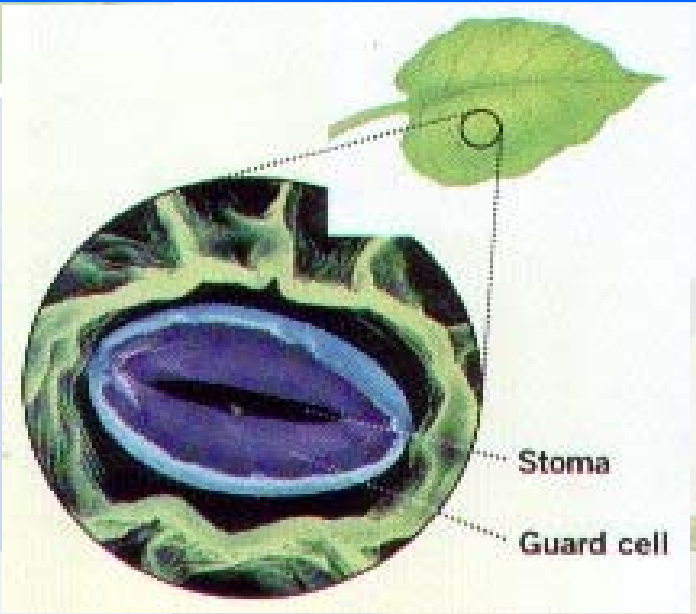
- Stomates: openings typically found in the lower cuticle and epidermis.
  - generally continuous with the intercellular spaces of the spongy layer
  - permit the exchange of gases between the leaf and the environment
- Guard Cells: regulate the opening size of the stomate
  - there is a pair of guard cells around each stomate
  - these cells are kidney shaped and contain chloroplasts
  - when guard cells LOSE water, the stomates CLOSE, stomates OPEN when guard cells gain water & swell.
  - Stomates are CLOSED during the HOTTEST parts of the day to prevent water loss from leaves.

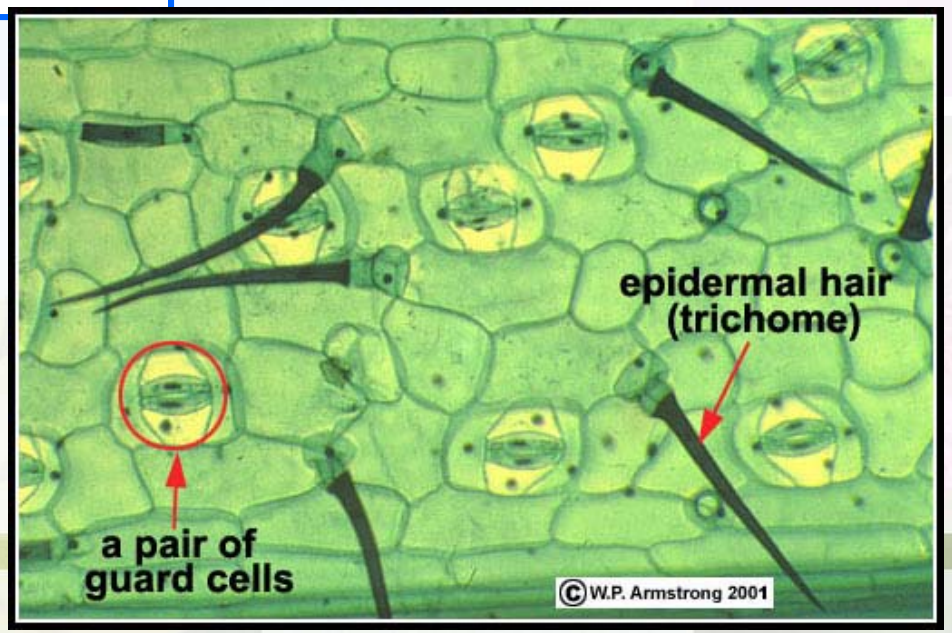
Guard Cells (cont'd)



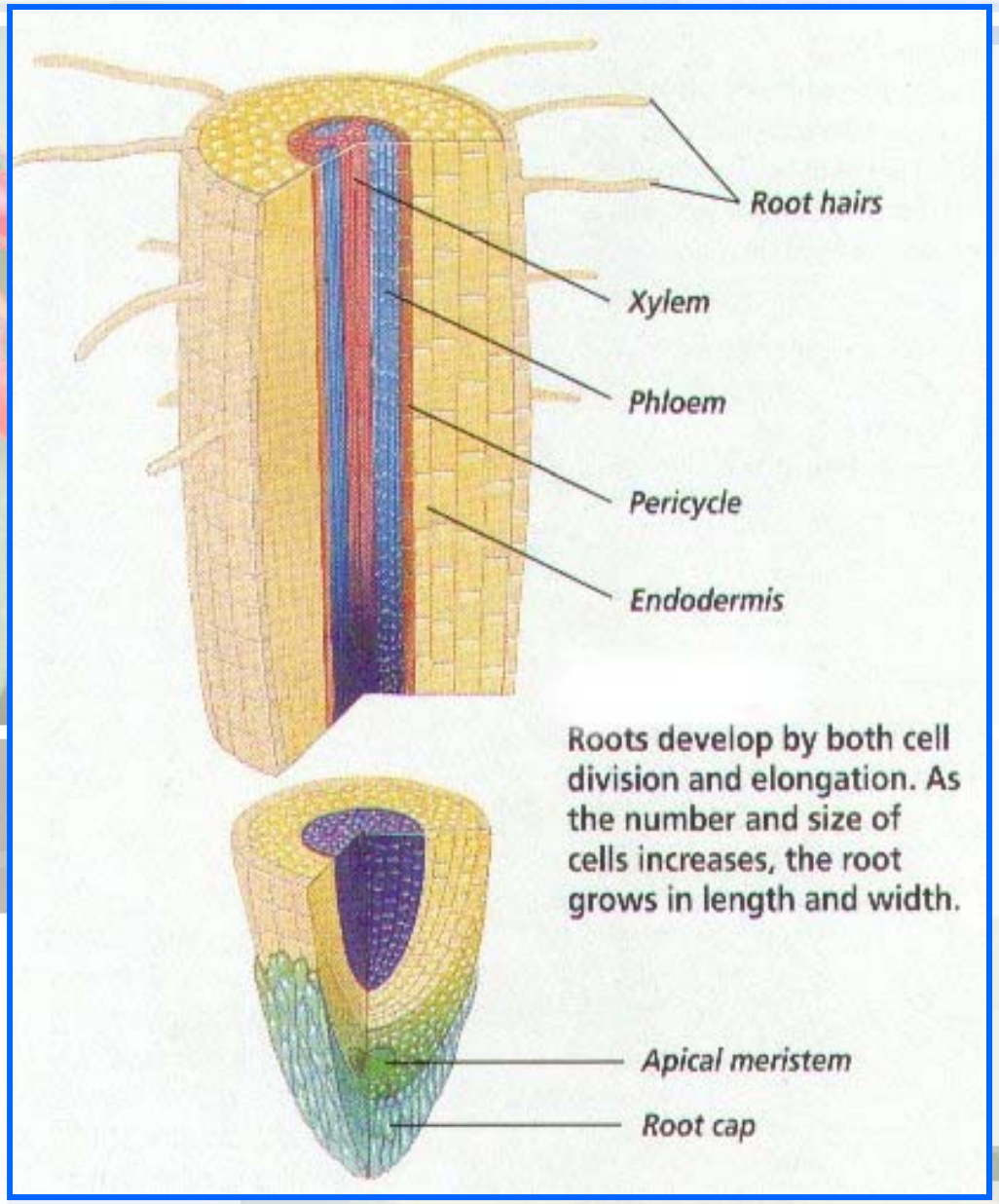
(a) Changes in guard cell shape and stomatal opening and closing (surface view)

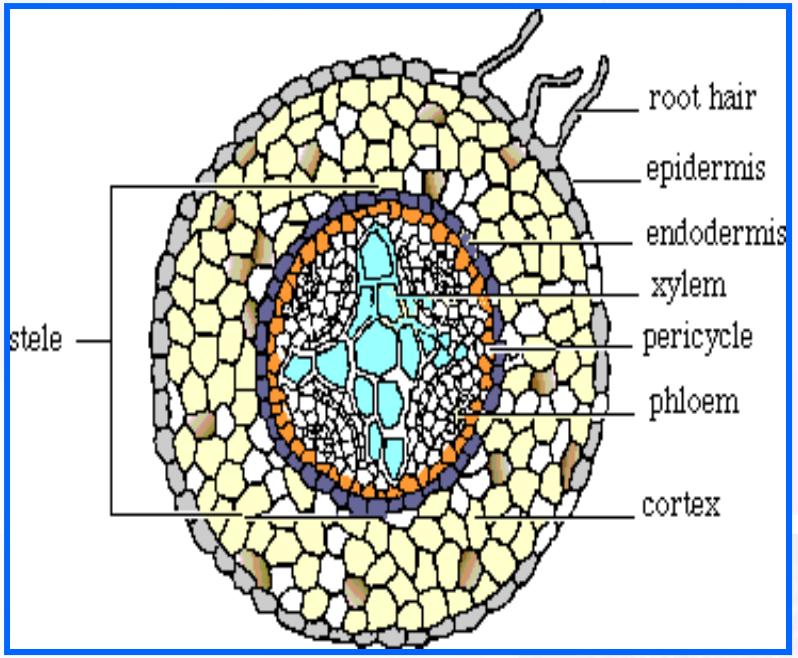
- When guard cells LOSE water, the stoma CLOSE, while the stoma OPEN when guard cells gain water & swell.
- Stomata are CLOSED during the HOTTEST parts of the day to prevent water loss from leaves.





Root Structure





Root Structure (cont'd)

- Roots are specialized structures that anchor the plant, store nutrients, absorb water, nitrates, and other dissolved minerals and carries these materials to the stem.
- Growth of the root into the soil occurs through the cell division at the root tip.
- Root Functions:

--anchor plants into the soil

--absorb water and dissolved minerals

--may store carbohydrates (i.e. carrot, turnip, potato)

--may store water during dry periods

Root Structure (cont'd)

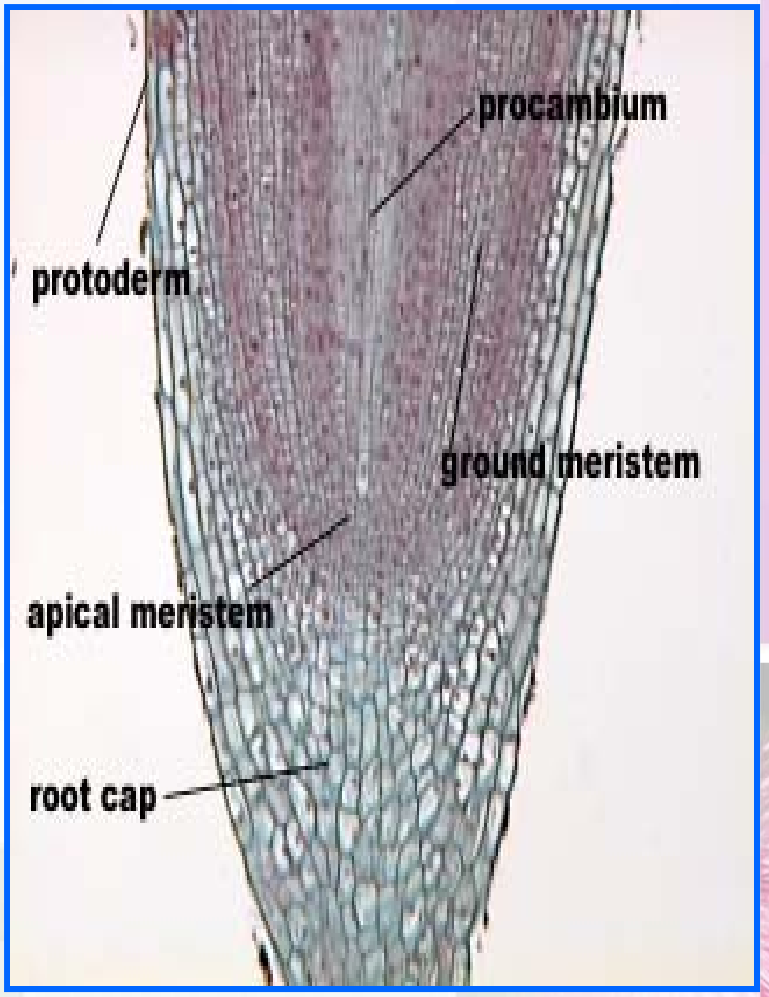
Root Cap:

-- forms a protective covering for the embryonic cells known as the meristematic zone of the root tip.

-- the root tips is pushed through the soil by the addition of cells behind it.

-- The outer cells of the root tip are crushed in this process and release a lubricating fluid that aids in the passage of the root tip through the soil.

--new cells are continuously being formed at the embryonic region. As they elongate, they begin to differentiate and become specialized.



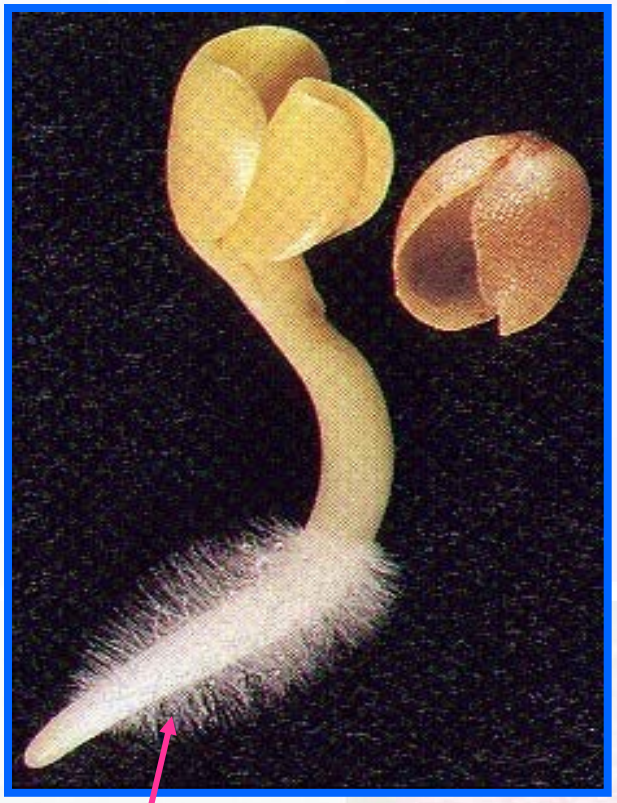
Root Structure (cont'd)

Root Hairs

-- the root has an outer layer, the epidermis, which is one cell layer thick.

--just behind the root tip, epidermal cells produce hairlike extensions of their cell membranes. These root hairs penetrate the soil and increase the surface area for greater absorption of water and dissolved minerals.

--water and dissolved minerals from the soil enter the root hairs and epidermis of the root by diffusion, osmosis, and active transport.



Root Hairs

Root Structure (cont'd)

- Cortex: located just beneath the epidermis of the root.

--consists of loosely packed cells which store food and transport water absorbed through the epidermis and root hairs to the conducting tissue of the xylem and phloem.

- Central Cylinder: consists primarily of xylem and phloem cells.

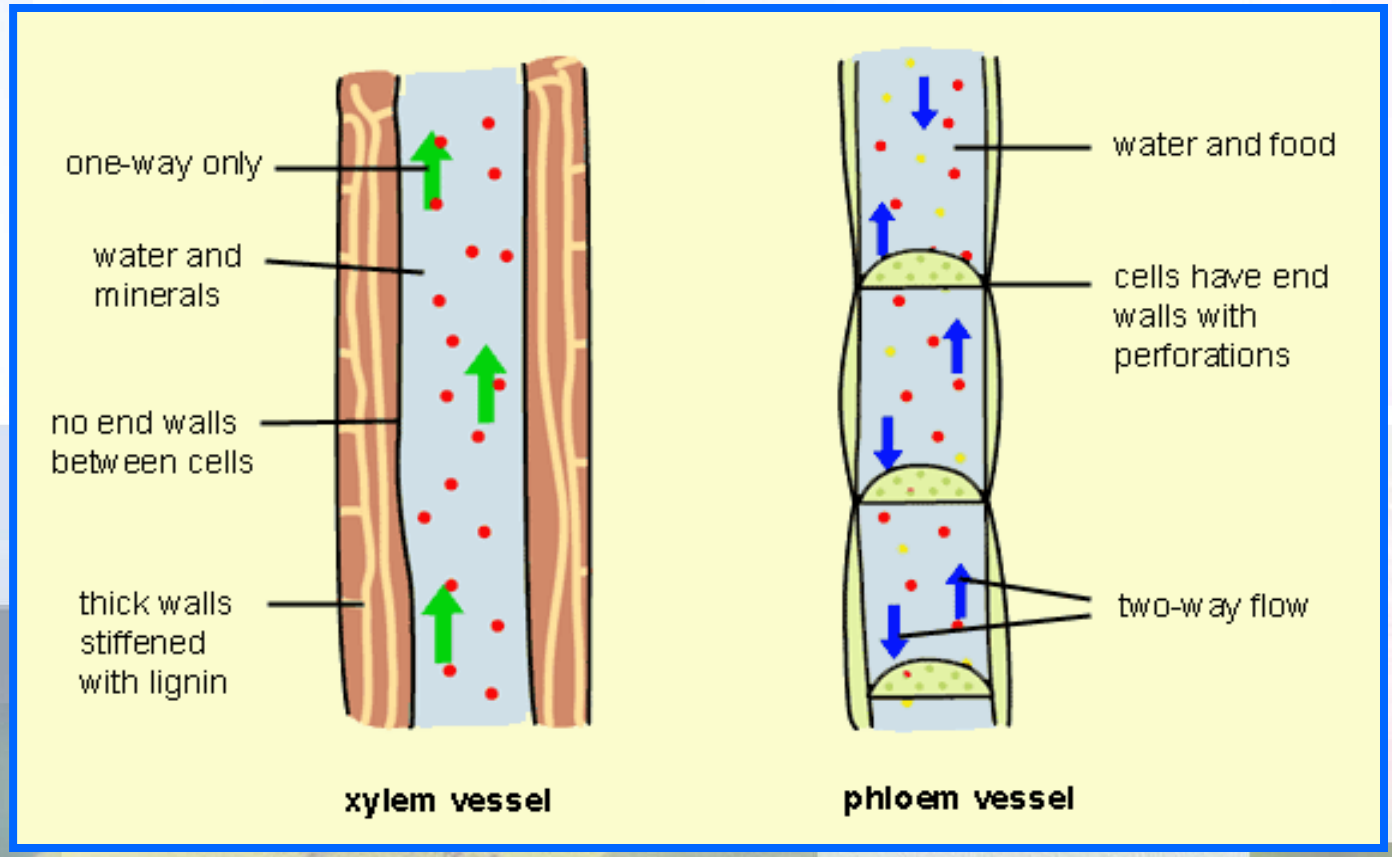
-- xylem: specialized vascular tissue that extends from the roots to the leaves.

--transports water and dissolved minerals upward in the plant.

--Composed of continuous tubes of thickened cell walls of dead cells.

Root Structure (cont'd)

- **Phloem:** vascular tissue that is involved in the transport of organic food materials from the leaves throughout the rest of the plant for immediate use or storage.



YouTube - Root Osmosis

Transport in Stems

functions of stems:

--house a continuation of the xylem and phloem

--Stems are adapted to support leaves and expose them to light

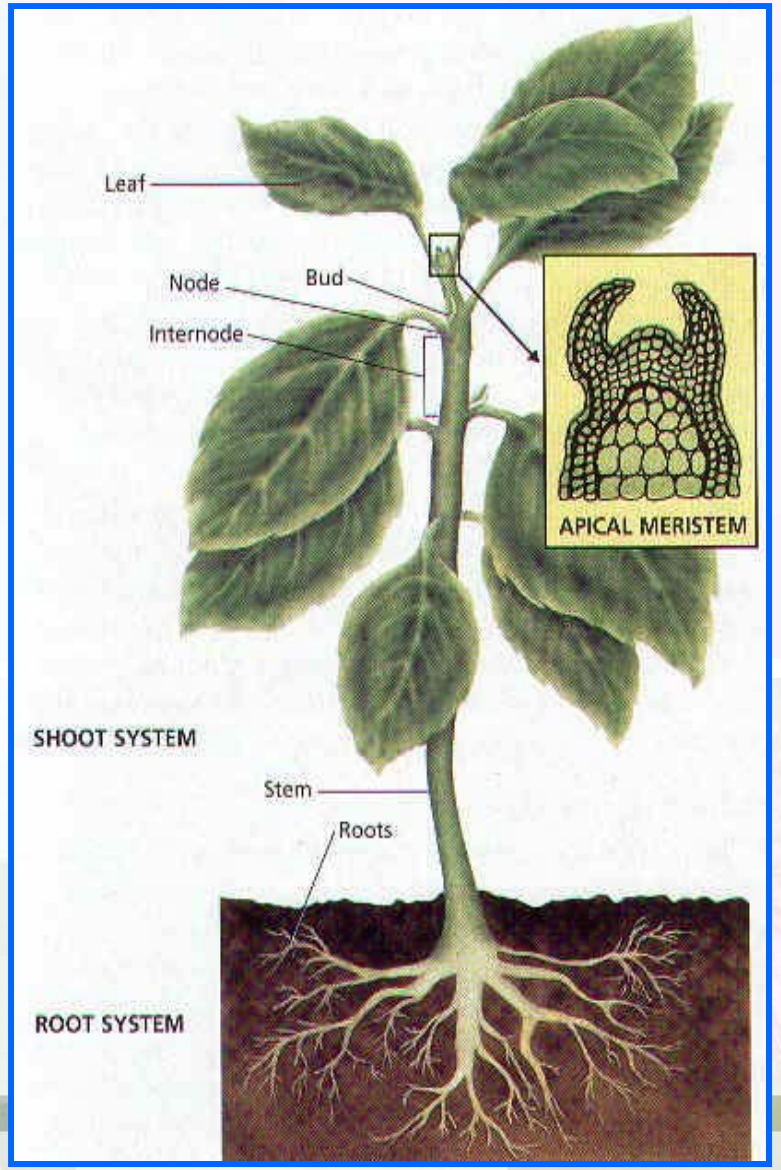
--transport water & minerals between the roots and the leaves and between various tissues of the plant

--transport sugars (usually sucrose) from source (where they're made - leaves) to sink (where they're stored – roots)

--tubers (potatoes) underground food storage stems

--stems grow from the tip or apical meristem (vertical growth)

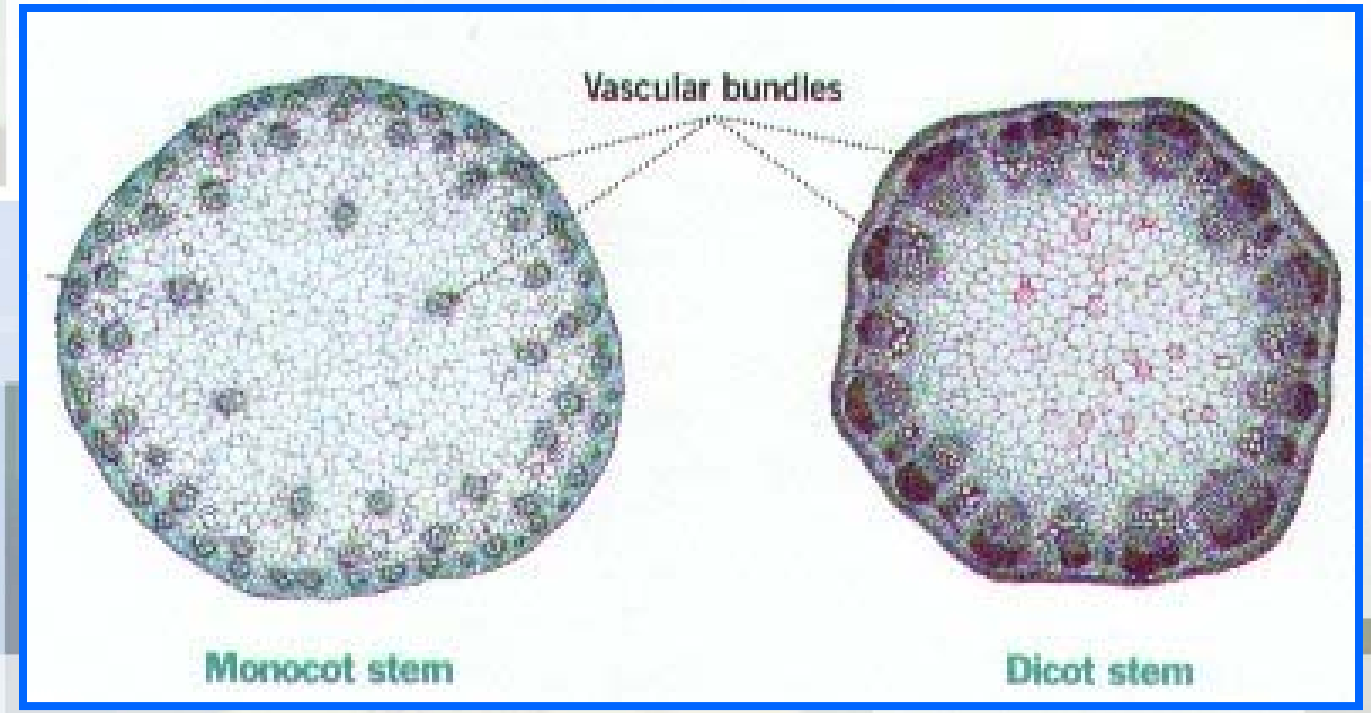
--Leaves are attached to stems at nodes & have lateral buds that can develop into new stems or branches



Vascular Bundles

Monocots vs Dicots – Vascular Bundle Arrangements in Stems

- Vascular Tissue is arranged in bundles with xylem toward the inside & phloem toward the outside.
- Vascular bundles are scattered throughout monocot stems.
- Vascular bundles are arranged in rings in dicot stems.



Transport of Water

Cohesion Theory

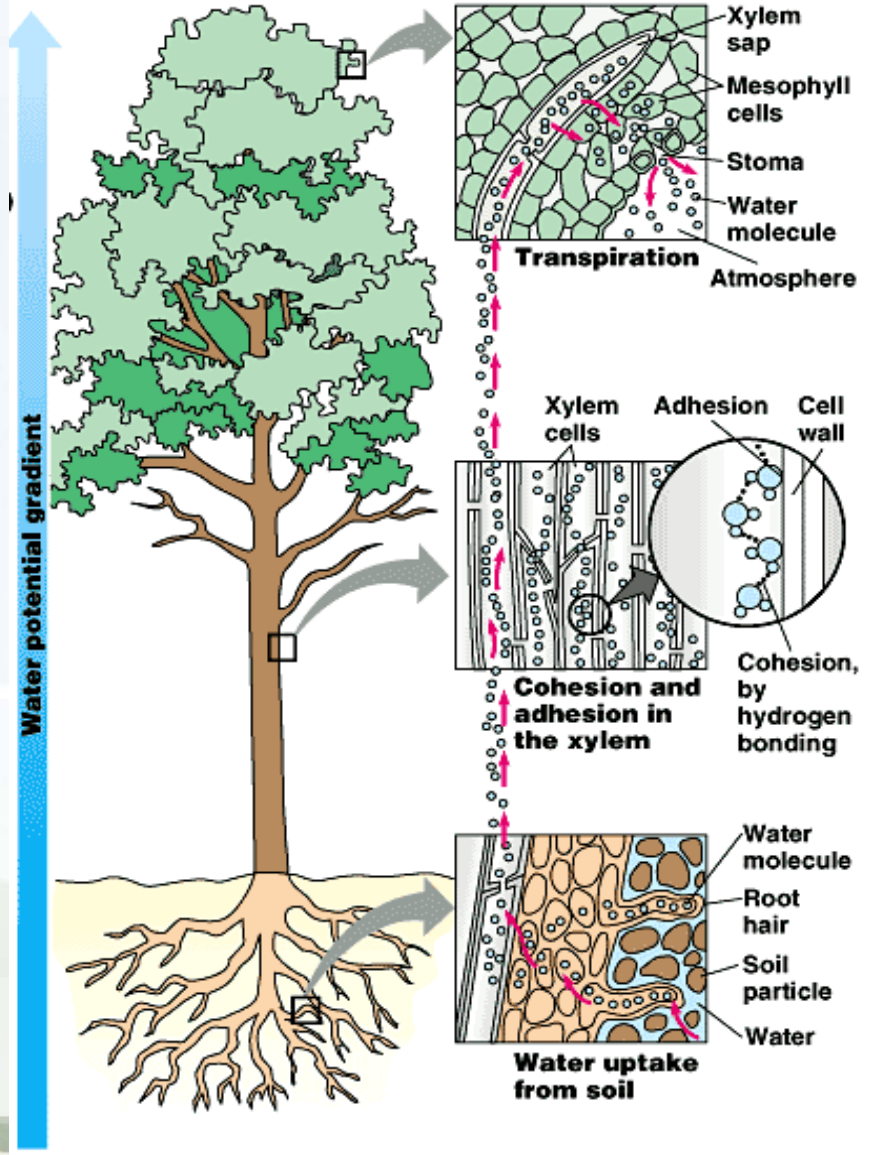
- Transport of water and minerals occurs in the xylem.
- It is believed that water movement in the xylem is driven upward with the help of the following forces:

-- transpiration: the evaporation of water from leaves & stems

--capillary action: cohesive forces of water molecules attraction for each other (like--like) and adhesive forces of water molecules attraction for the walls of the xylem (like—unlike).

--As water evaporates from the roots, more water enters the roots.

- Transpiration produces a NEGATIVE pressure in the xylem pulling water UPWARD
- Water is "helped" upward with the forces of adhesion and cohesion.



YouTube – Simple Transport

Gas Exchange

Leaves:

- gas exchange takes place in the spongy layer of the leaf where interior air spaces connect with the environment through the stomates.

Stems:

- Lenticels – stems of woody plants contain small areas of loosely exposed cells that permit gas exchanges with the environment.

lenticel

Roots:

- Gas exchange occurs in the moist membranes of the root hairs and other epidermal cells.

Chemical Regulation

Hormone	Major Functions	Where Produced
Auxin	Stimulates cell elongation; involved in phototropism, gravitropism, apical dominance, and vascular differentiation; stimulates ethylene synthesis and induces adventitious roots on cuttings	Meristems of apical buds, embryo of seed, young leaves
Cytokinin	Stimulates cell division, reverses apical dominance, involved in shoot growth, delays leaf sequence	Synthesized in roots and transported to other organs
Ethylene	Stimulates fruit ripening, leaf and flower senescence, and abscission	Tissues of ripening fruits, nodes of stems, senescent leaves and flowers
Abscisic Acid	Inhibits growth, stimulates stomatal closure, maintains dormancy	Leaves, stems, green fruit
Gibberellin	Stimulates shoot elongation, stimulates bolting and flowering in biennials, regulates production of hydrolytic enzymes in grains	Meristems of apical buds and roots, young leaves, embryo

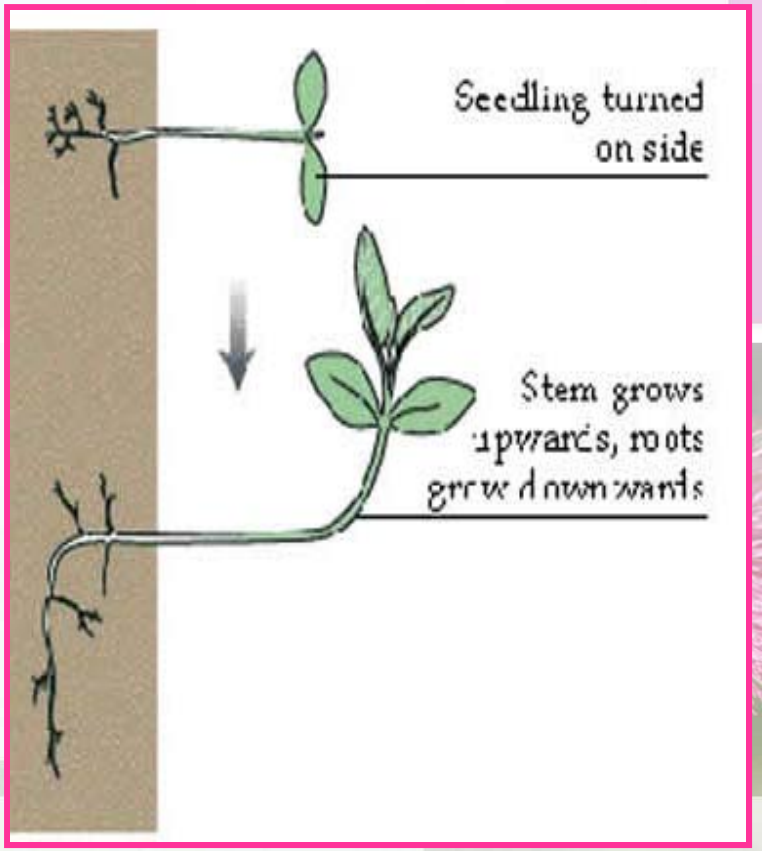
Tropisms

Tropisms

- the responses of plants to certain environmental stimuli
- responses are usually directional (with respect to the stimulus) and involve some sort of movement.
- Usually involve growth hormones -- auxins

Geotropism

- plant's response to gravity
- auxins accumulate on the top side of the roots, elongating the cells, causing them to grow downward.
- Auxins accumulate on the underside of the stem, elongating the cells, pushing the stems upward.



Tropisms (cont'd)

Phototropism

- When one side of a stem is better lit, auxins are accumulated on the dark (unlit) side. The dark side grows disproportionately faster than the let side, the plant bends toward the light.