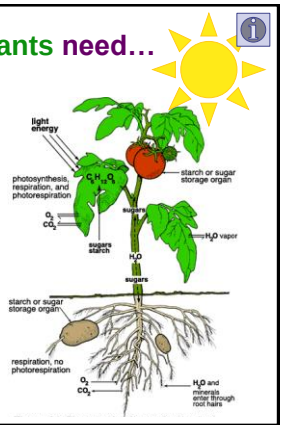
Chapter
35.1, 35.3, 10.4, 10.5
Regulation and Transport in Plants

Remember what plants need…

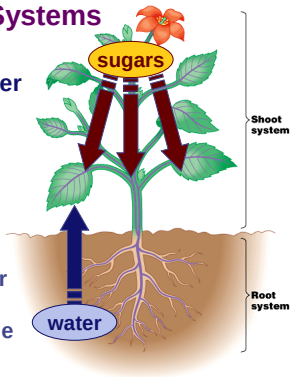
- Photosynthesis
  - light reactions
  - Calvin cycle
    - light ← sun
    - H_2O ← ground
    - CO_2 ← air

What structures have plants evolved to supply these needs?



Interdependent Systems

- Both systems depend on the other
  - roots receive sugars & other nutrients from photosynthetic parts
  - shoot system depends on water & minerals absorbed from the soil by roots



Putting it all together…

- Obtaining raw materials
  - sunlight
    - leaves = solar collectors
  - CO_2
    - stomates = gas exchange
  - H_2O
    - uptake from roots
  - minerals
    - uptake from roots

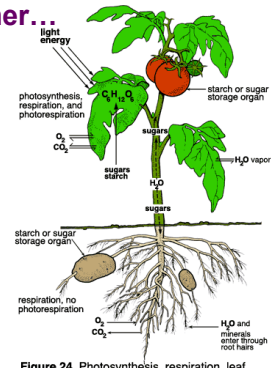
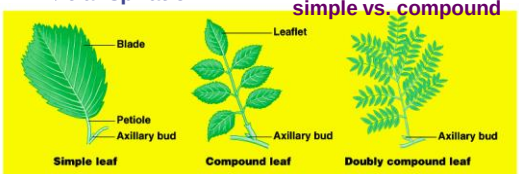


Figure 24. Photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant.

Leaves

- Function of leaves?
  - photosynthesis
    - energy production
    - CHO production
  - gas exchange
  - transpiration

simple vs. compound



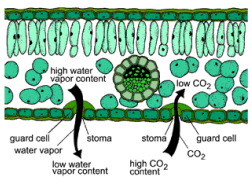
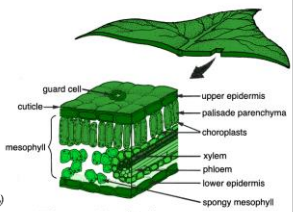
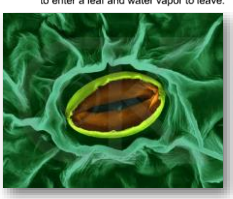
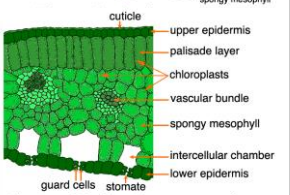


Figure 25. Stomata open to allow carbon dioxide (CO_2) to enter a leaf and water vapor to leave.

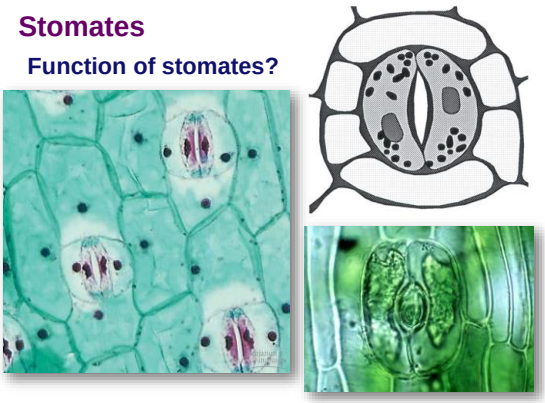






Stomates

Function of stomates?



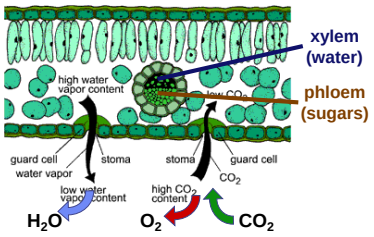
A look at stomates…

- Gas exchange
  - CO_2 in → for Calvin cycle
  - O_2 out → from light reactions
  - H_2O vapor out

photosynthesis

O_2 CO_2

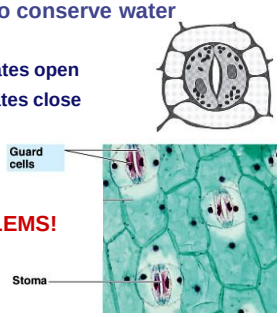
gas exchange
water loss



Controlling water loss from leaves

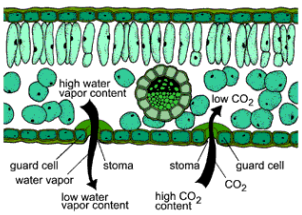
- Hot or dry days
  - stomates close to conserve water
  - guard cells
    - gain H_2O = stomates open
    - lose H_2O = stomates close
  - adaptation to living on land, but…

creates PROBLEMS!



Stomates

- closed stomates lead to…
  - O_2 builds up (from light reactions)
  - CO_2 is depleted (in Calvin cycle)
    - causes problems in Calvin Cycle



Inefficiency of Rubisco: CO_2 vs O_2

- Rubisco in Calvin cycle
  - carbon fixation enzyme
    - normally bonds C to RuBP
    - reduction of RuBP
    - building sugars

photosynthesis

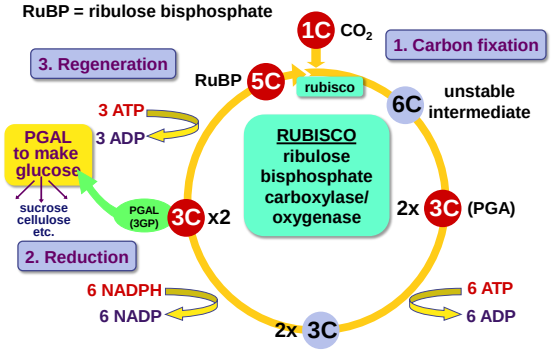
  - when O_2 concentration is high
    - Rubisco bonds O to RuBP
    - O_2 is alternative substrate
    - oxidation of RuBP
    - breakdown sugars

photorespiration

RUBISCO: ribulose bisphosphate carboxylase/oxygenase

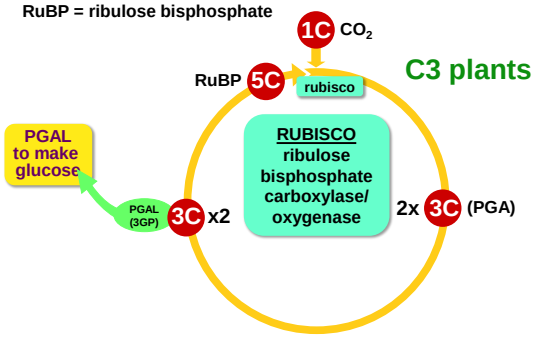
Calvin Cycle Review

RuBP = ribulose bisphosphate



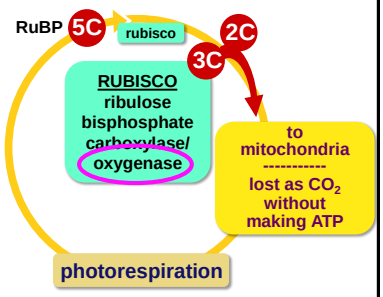
Calvin Cycle Review

RuBP = ribulose bisphosphate



Calvin Cycle—with ↑[O_2]

RuBP = ribulose bisphosphate



Impact of Photorespiration

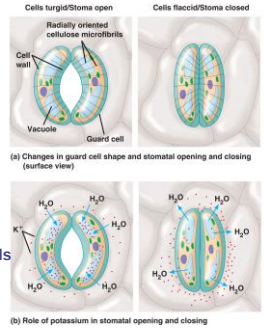
- Oxidation of RuBP
  - short circuit of Calvin cycle
  - decreases photosynthetic output by siphoning off carbons
    - no ATP (energy) produced
    - no $C_6H_{12}O_6$ (food) produced
  - loss of carbons to CO_2
    - can lose 50% of carbons fixed by Calvin cycle
  - if photorespiration could be reduced, plant would become 50% more efficient
    - strong selection pressure

Why the C3 problem?

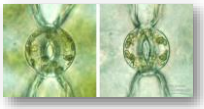
- Possibly evolutionary baggage
  - Rubisco evolved in high CO_2 atmosphere
    - there wasn't strong selection against active site of Rubisco accepting both CO_2 & O_2
- Today it makes a difference
  - 21% O_2 now vs. 0.03% O_2 then
  - photorespiration can drain away 50% of carbon fixed by Calvin cycle on a hot, dry day
  - strong selection pressure to evolve better way to fix carbon & minimize photorespiration

Regulation of Stomates

- Microfibril mechanism
  - guard cells attached at tips
  - microfibrils in cell walls
    - elongate causing cells to arch open = open stomate
    - shorten = close when water is lost
- Ion mechanism
  - uptake of K^+ ions by guard cells
    - ion pumps
    - water enters by osmosis
    - guard cells become turgid
  - loss of K^+ ions by guard cells
    - water leaves by osmosis
    - guard cells become flaccid



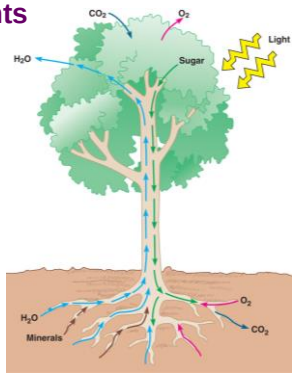
Regulation of Stomates



- Other cues
  - light trigger
    - blue-light receptor in plasma membrane of guard cells triggers ATP-powered proton pumps causing K^+ uptake
      - stomates open
  - abscisic acid
    - plant hormone released by mesophyll cells that cause the stomata to close if the mesophyll water potential is too negative (too dry)
  - depletion of CO_2
    - CO_2 is depleted during photosynthesis (Calvin cycle)
  - circadian rhythm = internal "clock"
    - automatic 24-hour cycle

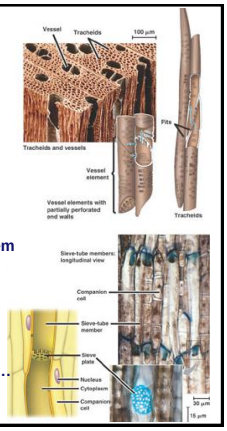
Transport in Plants

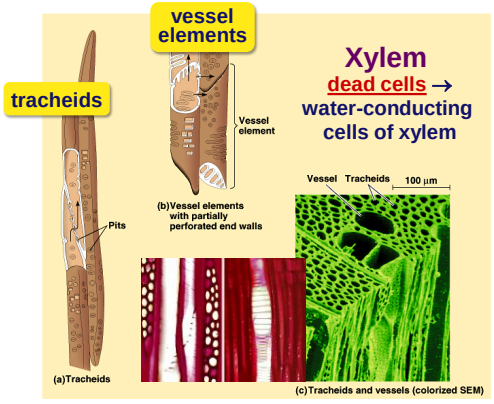
- H_2O & minerals
- Sugars
- Gas exchange



Vascular Tissue

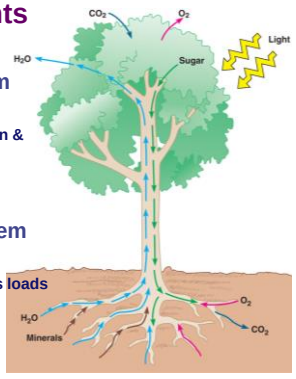
- Transports materials in roots, stems & leaves
- Xylem
  - carry water & minerals up from roots
  - tube-shaped dead cells
    - only their walls provide a system of microscopic water pipes
- Phloem
  - carry nutrients throughout plant
    - sugars (sucrose), amino acids…
  - tube-shaped living cells





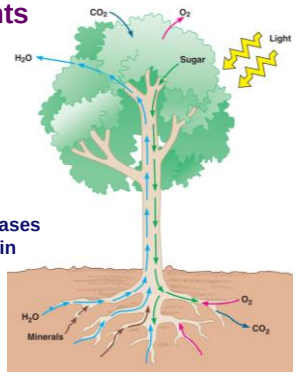
Transport in Plants

- H_2O & minerals
  - transport in xylem
  - transpiration
    - evaporation, adhesion & cohesion
    - negative pressure
- Sugars
  - transport in phloem
  - bulk flow
    - Calvin cycle in leaves loads sucrose into phloem
    - positive pressure



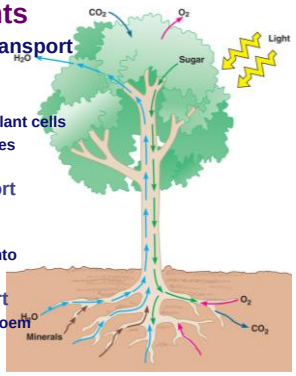
Transport in Plants

- Gas exchange
  - photosynthesis
    - CO_2 in; O_2 out
    - stomates
  - respiration
    - O_2 in; CO_2 out
    - roots exchange gases within air spaces in soil



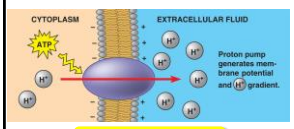
Transport in Plants

- Physical forces drive transport at different scales
  - cellular
    - from environment into plant cells
    - transport of H_2O & solutes into root hairs
  - short-distance transport
    - from cell to cell
    - loading of sugar from photosynthetic leaves into phloem sieve tubes
  - long-distance transport
    - transport in xylem & phloem throughout whole plant

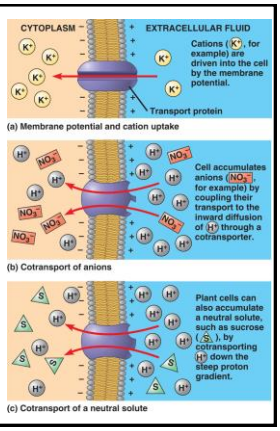


Cellular Transport

- Active transport
  - solutes are moved into plant cells via active transport
  - central role of proton pumps
    - chemiosmosis

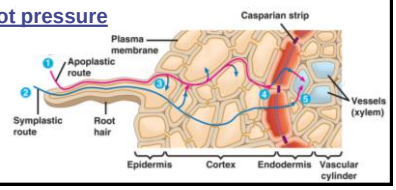


proton pumps



Water & Mineral Uptake by Roots

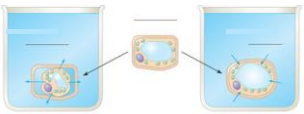
- Mineral uptake by root hairs…
  - dilute solution in soil
  - active transport pumps
    - this concentrates solutes (~100x) in root cells
- …followed by water uptake by root hairs
  - flow from high H_2O potential to low H_2O potential
  - creates root pressure



Movement of Water in Plants

cells are flaccid
plant is wilting

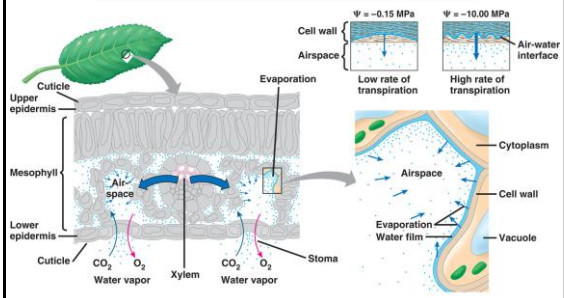
cells are turgid



- Water relations in plant cells is based on water potential
  - osmosis through aquaporins
    - transport proteins
  - water flows from high potential to low potential

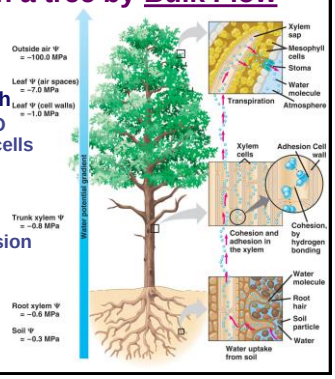
Ascent of Xylem "sap"

Transpiration pull generated by leaf



Rise of Water in a tree by Bulk Flow

- Water potential
  - high in soil → low in leaves
- Root pressure push
  - due to flow of H_2O from soil to root cells
  - upward push of xylem sap
- Transpiration pull
  - adhesion & cohesion
    - H bonding
  - brings water & minerals to shoot



Control of Transpiration

- Stomate function
  - always a compromise between photosynthesis & transpiration
    - leaf may transpire more than its weight in water in a day…this loss must be balanced with plant's need for CO_2 for photosynthesis
      - a corn plant transpires 125 L of water in a growing season