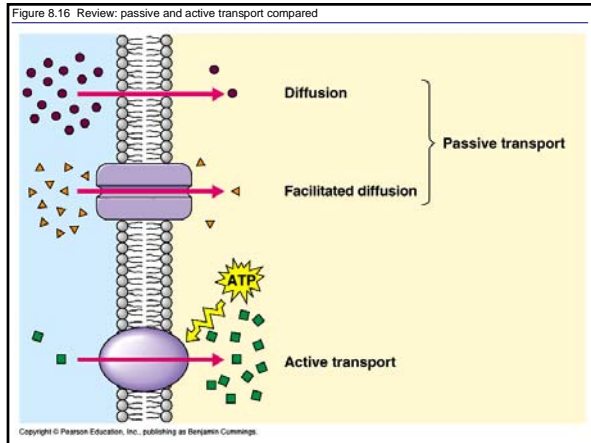


Three levels of transport in plants

- Into and out of single cells;
- Cell to cell in tissues and organs;
- Long distance (e.g., root to shoot)

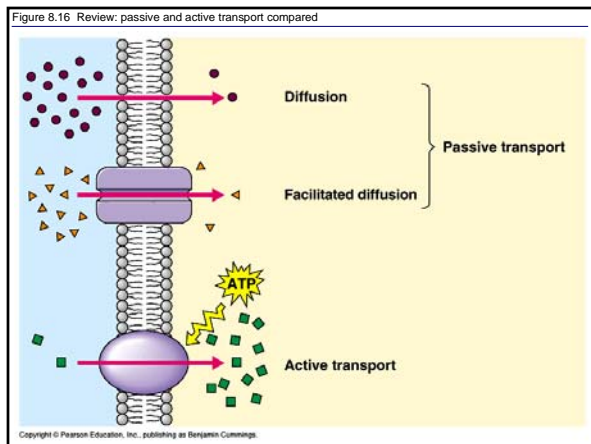
Transport into and out of single cells

- Solution = solvent + solute
- Membranes are “selectively permeable”
- Passive transport does not require metabolic energy; solutes move from where they are more concentrated to where they are less concentrated
- Active transport requires metabolic energy; solutes move from where they are less concentrated to where they are already more concentrated



Passive transport mechanisms

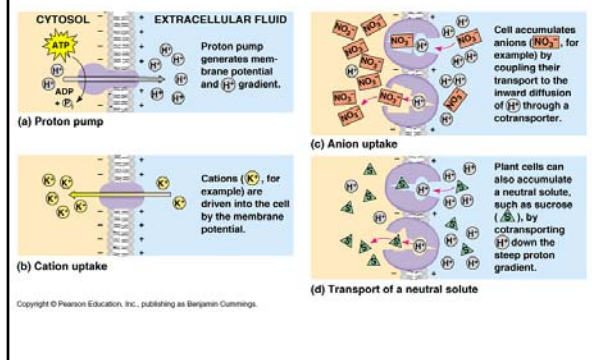
- Move substances with their concentration gradients
- Simple diffusion is one mechanism; few things move across membranes by diffusion
- NOTE: Charged substances do not move across membranes by simple diffusion.
- Facilitated diffusion using a membrane transport protein = “carrier” is more efficient than simple diffusion



Passive transport mechanisms (cont.)

- Charged substances may enter or exit cells through protein “channels”
- Charged substances move along concentration and electrochemical gradients
- Channels are usually selective for a particular ion (e.g., potassium ion channels)

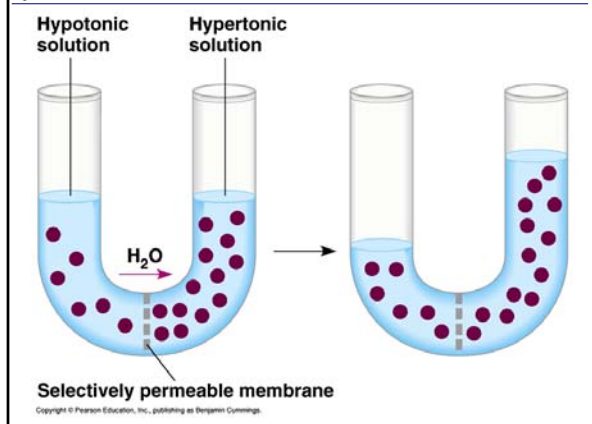
Figure 36.2 A chemiosmotic model of solute transport in plant cells



Osmosis = passive transport of water across membranes

- Energy comes from differences in solute concentrations on the two sides of the membrane
- Water moves through channels called aquaporin channels
- Osmosis IS NOT driven by water diffusion!!!!!!!!!!!!!!!!!!!!!!

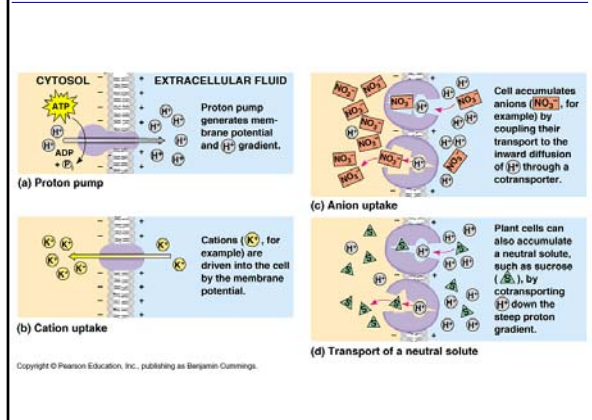
Figure 8.11 Osmosis



Active transport mechanisms

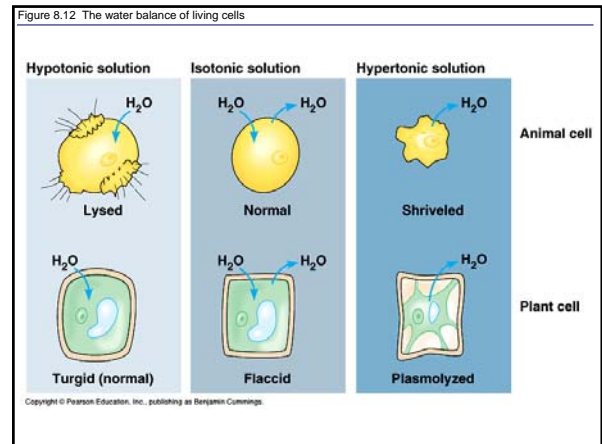
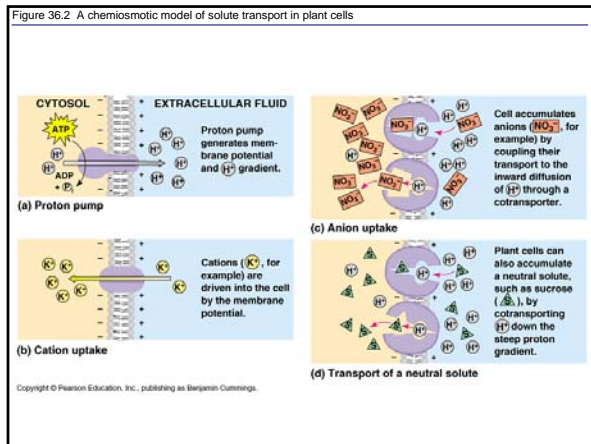
- Move substances against their concentration gradients
- Energy usually comes from ATP hydrolysis
- Proton pumps = proton-translocating ATPases are involved in many active transport processes
- May be coupled to passive transport mechanisms (e.g., potassium ion transport coupled to proton pumping)

Figure 36.2 A chemiosmotic model of solute transport in plant cells

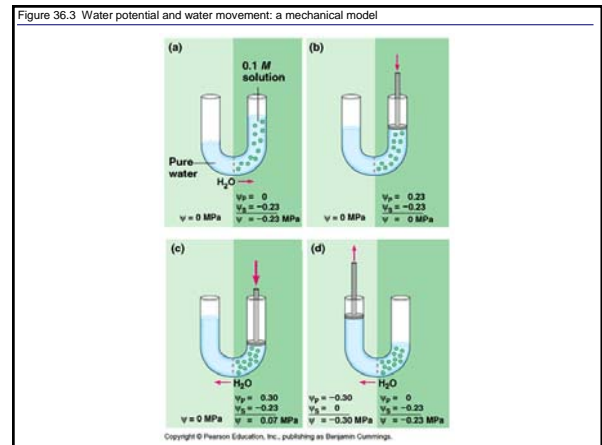


Co-transport mechanisms

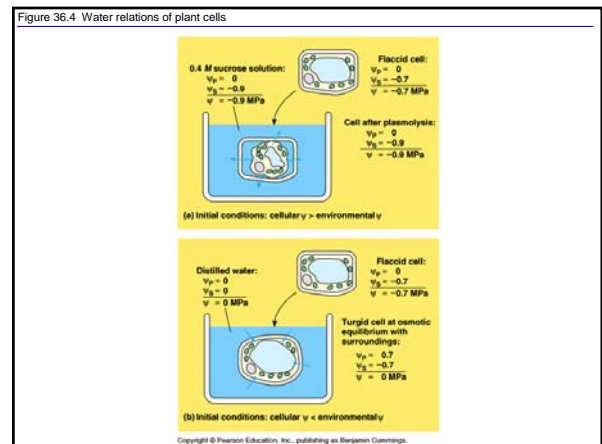
- Movement of one substance down its concentration gradient is “coupled” to movement of another substance against its concentration gradient using a protein that carries both substances
- Examples: proton-sucrose co-transporters and proton-nitrate co-transporters in plants



- Water potential drives water transport among cells, tissue, and organs in plants
- Plant cells tend to swell due to osmosis;
 - The pressure causing swelling is called osmotic pressure or osmotic potential = $\Psi\pi$ (also Ψ_s for solute pressure/potential)
 - Swelling is opposed by physical pressure of the cell wall = turgor pressure/potential = Ψ_p
 - Water potential, Ψ , is the net suction force acting to move water into a cell, tissue, or organ
 - $\Psi = \Psi_p + \Psi_s$



- Water potential facts
- Units are megapascals (MPa) = units of pressure
 - A 0.1M (molar) solution of any solute has a water potential of about -0.23 MPa
 - Ψ is always negative in sign; Ψ_p is always 0 or positive in sign; Ψ_s is 0 for pure water and otherwise negative in sign ($\pi = -cRT$)
 - Plant cells adjust to the same water potential as the external solution in which they are bathed



Plasmolyzed vs turgid cells

- Plasmolysis = Ψ of external solution more negative than Ψ of cell
- Turgid = Ψ s of cell $>$ Ψ s of external solution

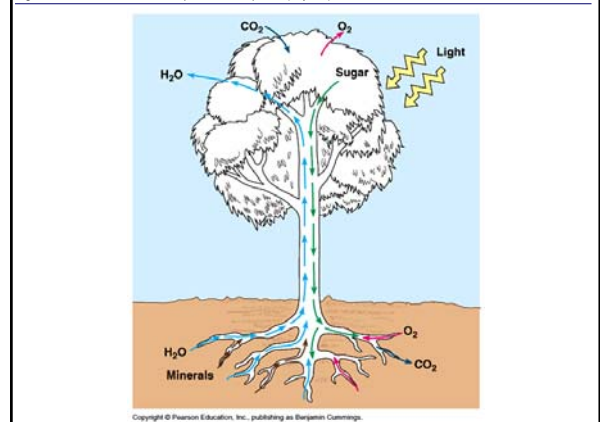
Figure 36.5 A watered tomato plant regains its turgor



Adjustments to water potential may occur by...

- A change in Ψ_s
- A change in Ψ_p
- Changes in both Ψ_s and Ψ_p
- Short-term adjustments to water potential are usually achieved by changes in Ψ_p
- Long-term adjustments to water potential are usually achieved by changes in Ψ_s

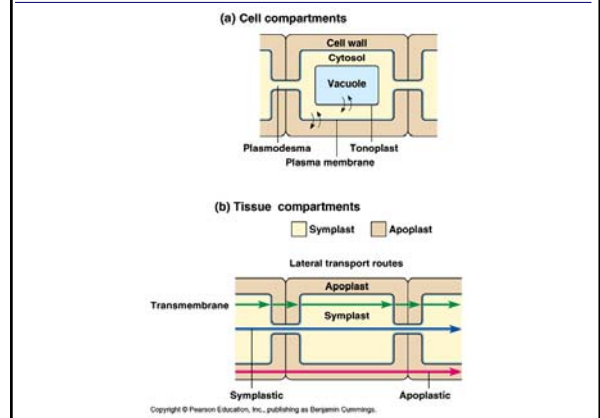
Figure 36.1 An overview of transport in whole plants (Layer 4)



Three compartments of plant cells involved in water transport

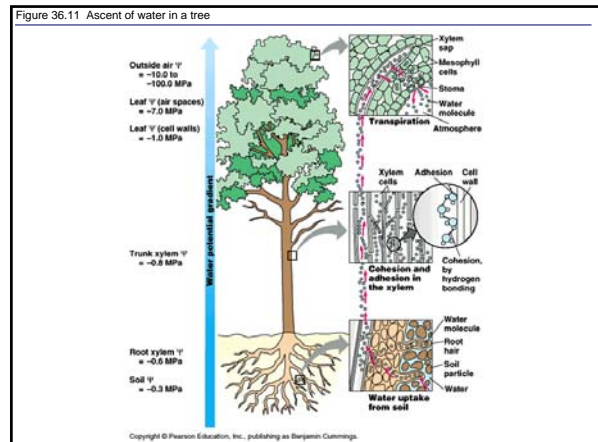
- Vacuoles exclusive to each cell
- Apoplast = Walls of adjoining cells
- Symplast = cytosols of protoplasts (protoplast = plasma membrane and everything inside) joined by plasmodesmata (sing. = plasmodesma)
- Water and solutes may travel through the apoplast, through the symplast, or through both

Figure 36.6 Compartments of plant cells and tissues and routes for lateral transport



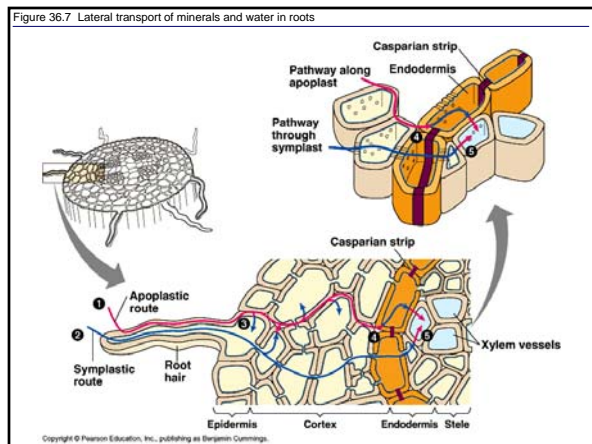
Movement of water and minerals in plants

- Water moves from soil-to-root-shoot-leaf-air
- Water moves along a gradient toward more negative tissue, organ, and atmospheric water potentials



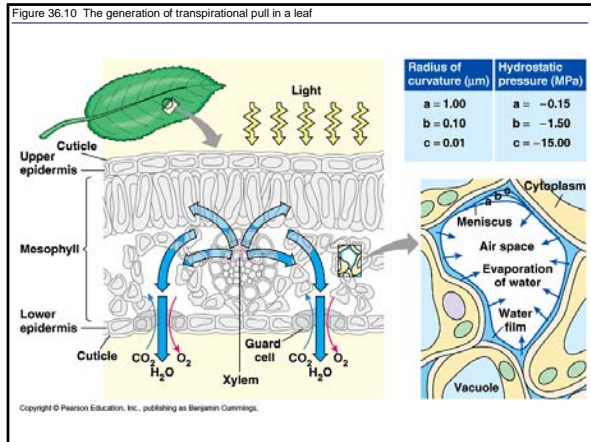
At the root:

- Root hairs and mycorrhizae increase surface area
- Root cells can accumulate minerals to hundreds of times their soil concentrations (sometimes good for “bioremediation”)
- Water can enter initially by apoplast, symplast, or both
- Water can only enter the xylem in the stele through the symplast of the endodermis: the endodermis is covered with a layer of wax called the Casparian strip
- Water and minerals enter the xylem from the endodermis by both active and passive transport



At the leaf:

- Water loss from plants is called “transpiration”
- External air is drier than air in the spaces between leaf cells
- Most water is transpired through stomata on leaf surfaces
- A maple tree can transpire 200 liters/hour



Between root and leaf:

- Water moves unidirectionally upward
- Water is “pulled” due to cohesion-tension
- Water is under “negative” tension because it is cohesive
- Water lost from leaves is replaced with xylem water
- Xylem water enters the apoplast and symplast of drying mesophyll tissue

Miscellaneous stuff about water in plants

- Water can rise to more than 100 meters in trees
- Cavitation and air embolism can inactivate xylem vessels (e.g., during freezing)
- The degree of stomatal opening regulates rates of transpiration, thereby determining water use efficiency = WUE
- $\text{WUE} = \frac{\text{mol CO}_2 \text{ fixed by photosynthesis}}{\text{mol H}_2\text{O lost by transpiration}}$
- Xerophytes have adaptations to improve WUE: small thick leaves; thick cuticles; stomata on lower leaf surfaces only; stomata in “crypts”; leaf shedding; Crassulacean acid metabolism

Figure 36.12 An open (left) and closed (right) stoma of a spider plant (*Chlorophytum colosum*) leaf

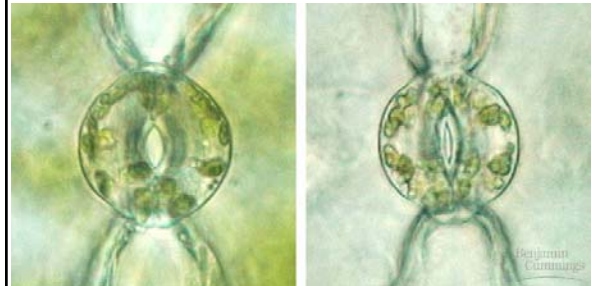


Figure 36.12x Stomata on the underside of a leaf

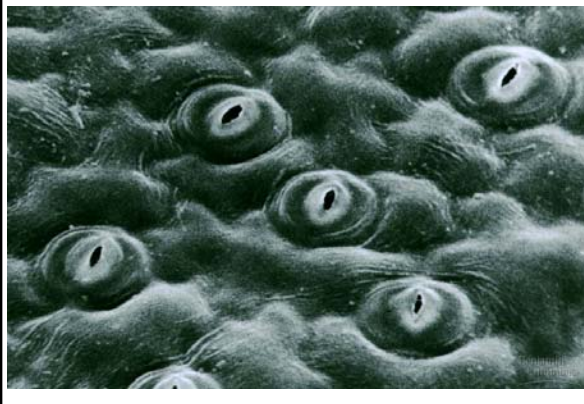
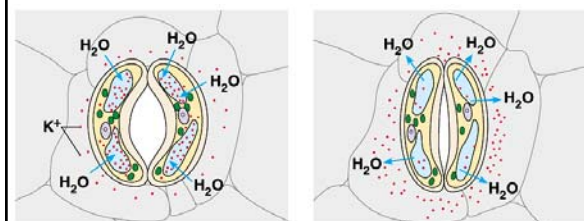


Figure 36.13b The mechanism of stomatal opening and closing



(b) Role of potassium in stomatal opening and closing
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Figure 36.15x Structural adaptations of a xerophyte leaf

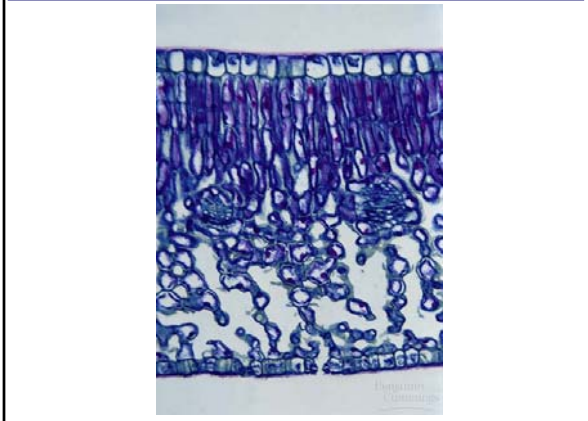
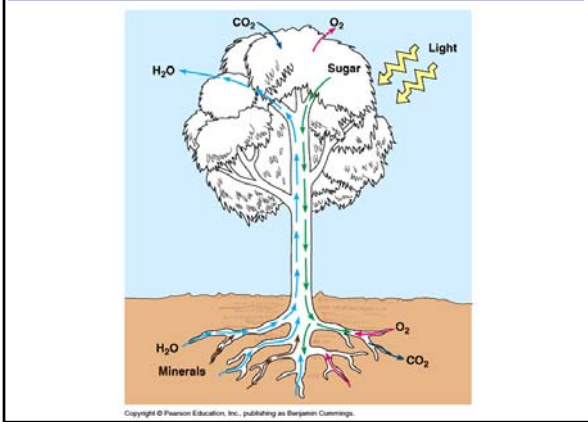


Figure 36.15 Structural adaptations of a xerophyte leaf



Figure 36.1 An overview of transport in whole plants (Layer 4)



Transport of “photosynthate”

- Photosynthate moves by “translocation”
- Photosynthate moves through sieve tube members of phloem
- Sieve tube members are arranged end-to-end to make sieve tubes
- Phloem “sap” contains sugars (mainly sucrose), minerals, amino acids, and hormones

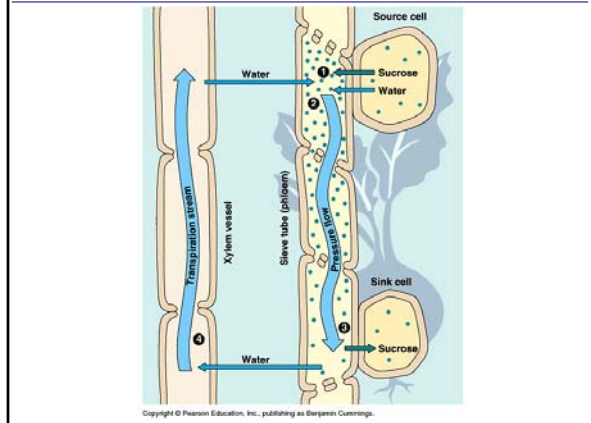
Figure 36.18 Tapping phloem sap with the help of an aphid



The “pressure-flow” hypothesis may explain movements of phloem sap in angiosperms

- Phloem transport is variable in direction
- Flow is from “source” to “sink”
- Leaves are the primary source
- Growing tissues are the main sinks (roots, tips of shoots, fruits, etc.)
- Phloem is loaded at the source and unloaded at the sink
- Sap moves along pressure gradients by “bulk flow”

Figure 36.17 Pressure flow in a sieve tube



Phloem loading

- In some plants, loading is entirely symplastic
- In other plants, loading involves symplast and apoplast
- Companion (transfer) cells facilitate loading in some plants
- Proton pumps may aid in sucrose loading

Figure 36.16 Loading of sucrose into phloem

