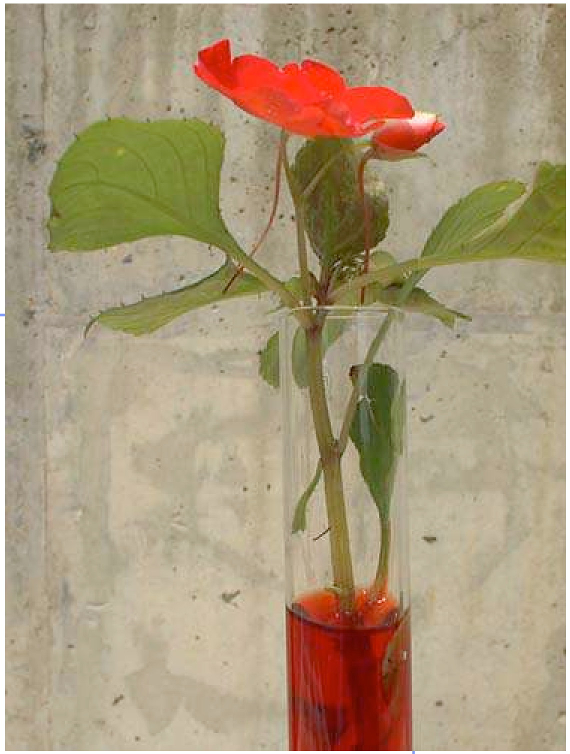


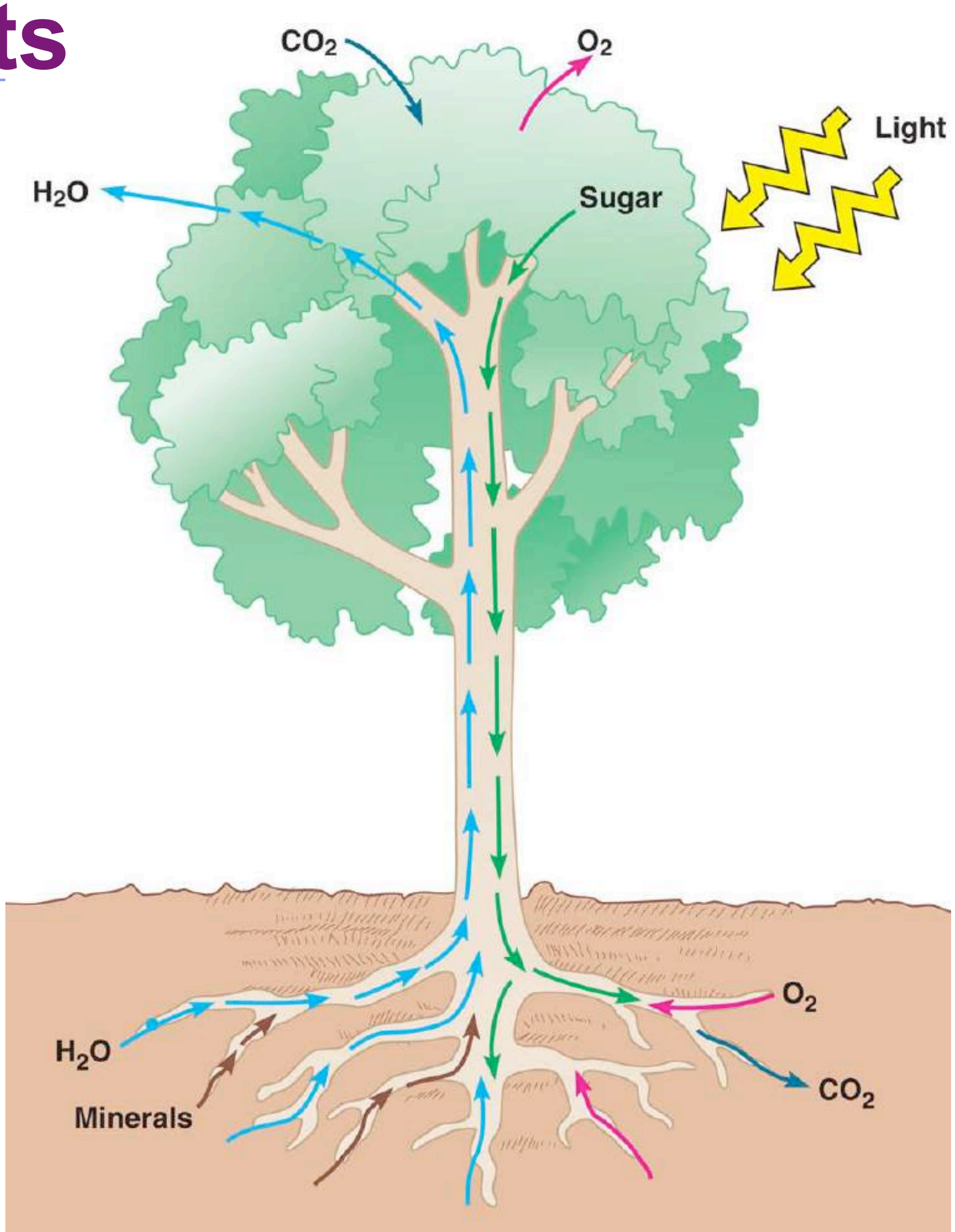
Chapter 36.

Transport in Plants

2005-2006

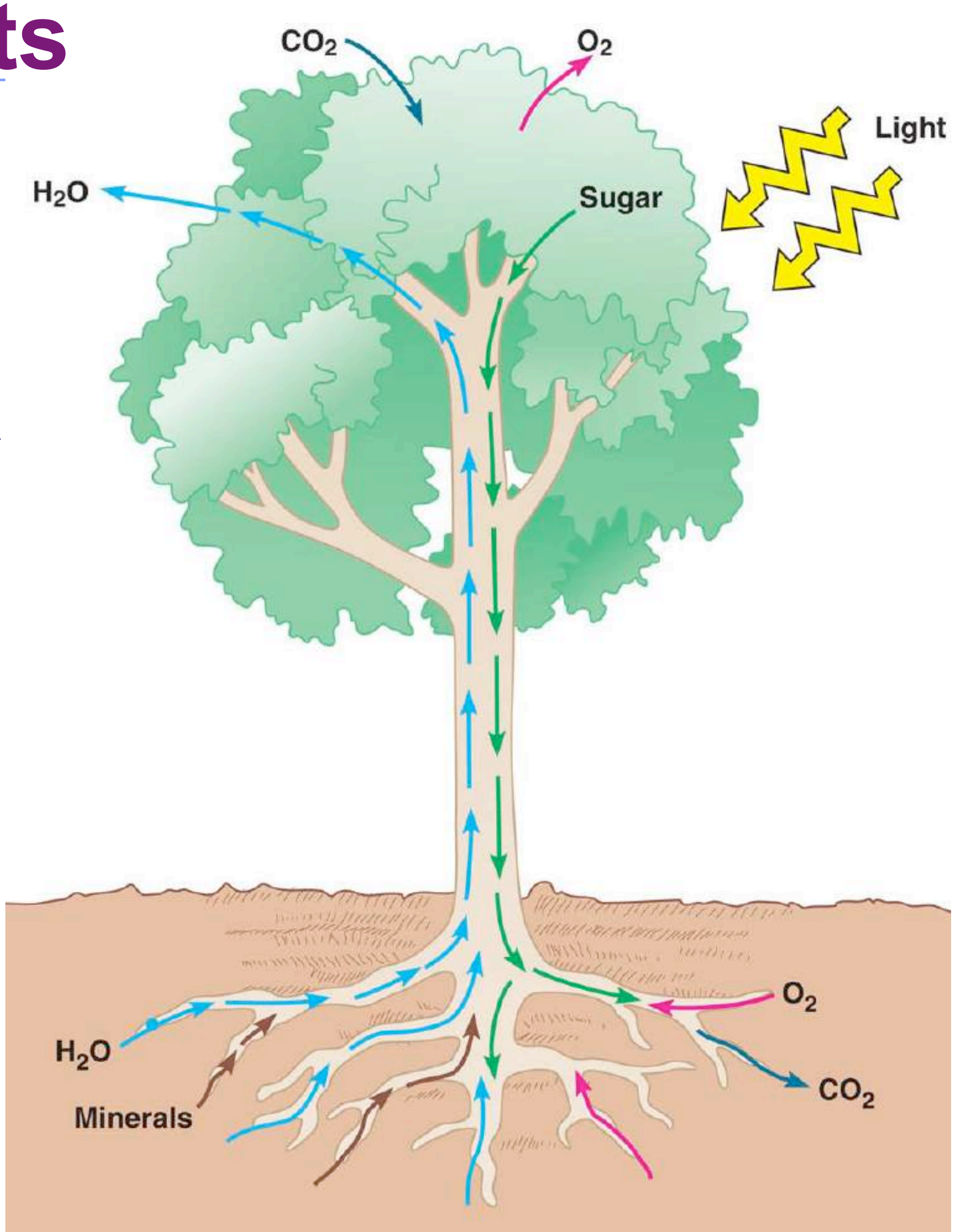
Transport in plants

- H_2O & minerals
- Sugars
- Gas exchange



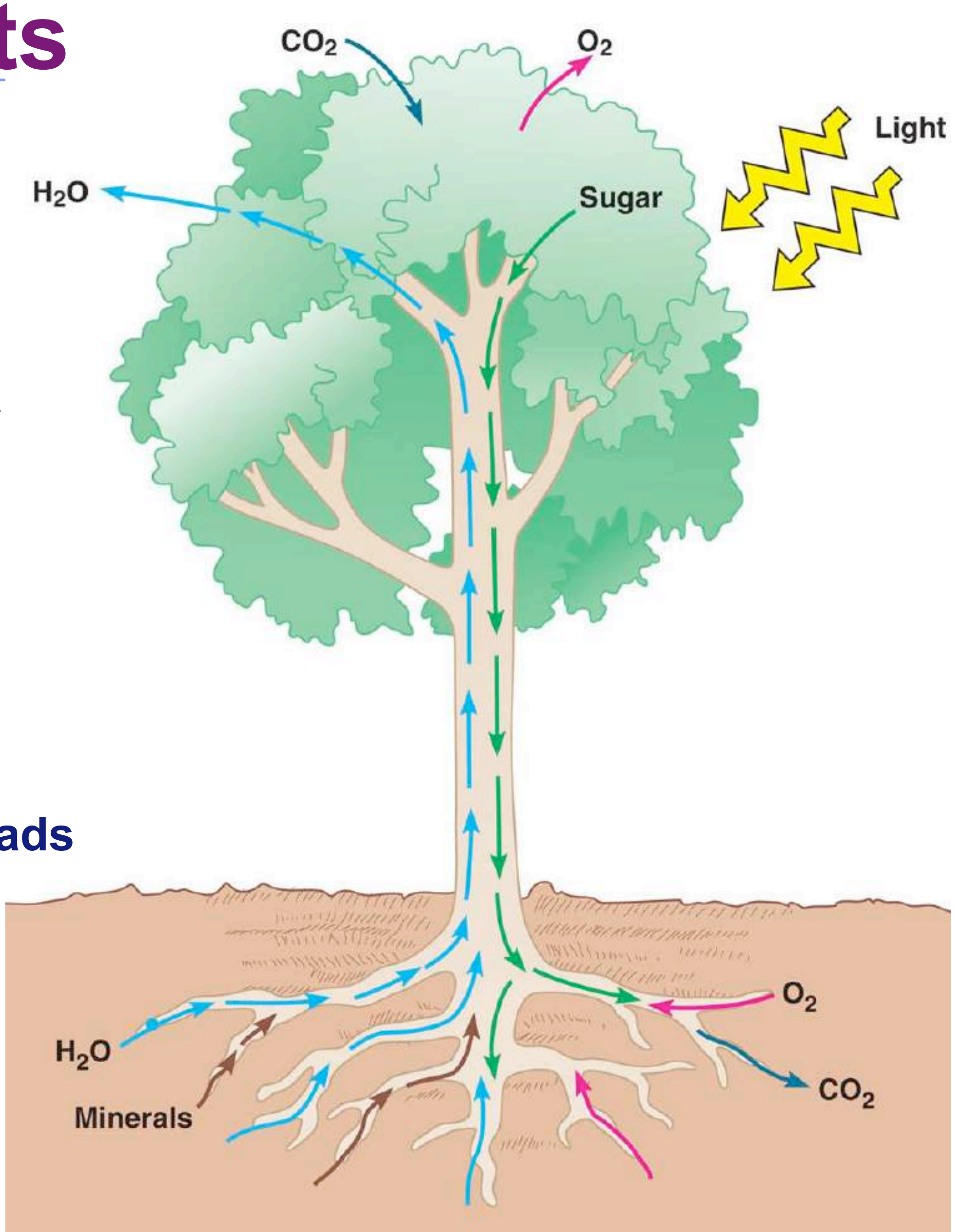
Transport in plants

- H_2O & minerals
  - transport in xylem
  - transpiration
    - evaporation, adhesion & cohesion
    - negative pressure
- Sugars
- Gas exchange



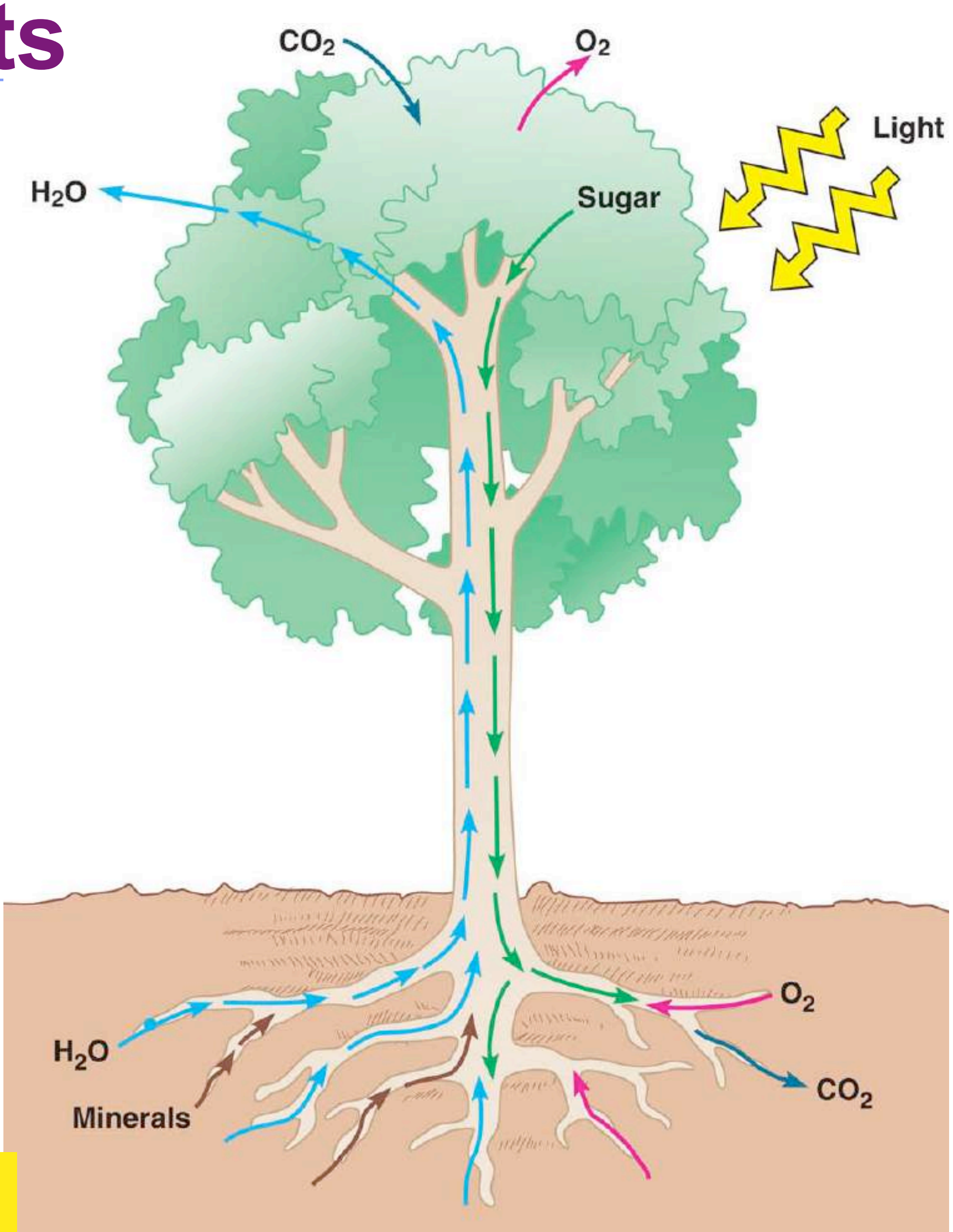
Transport in plants

- 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
- Gas exchange



Transport in plants

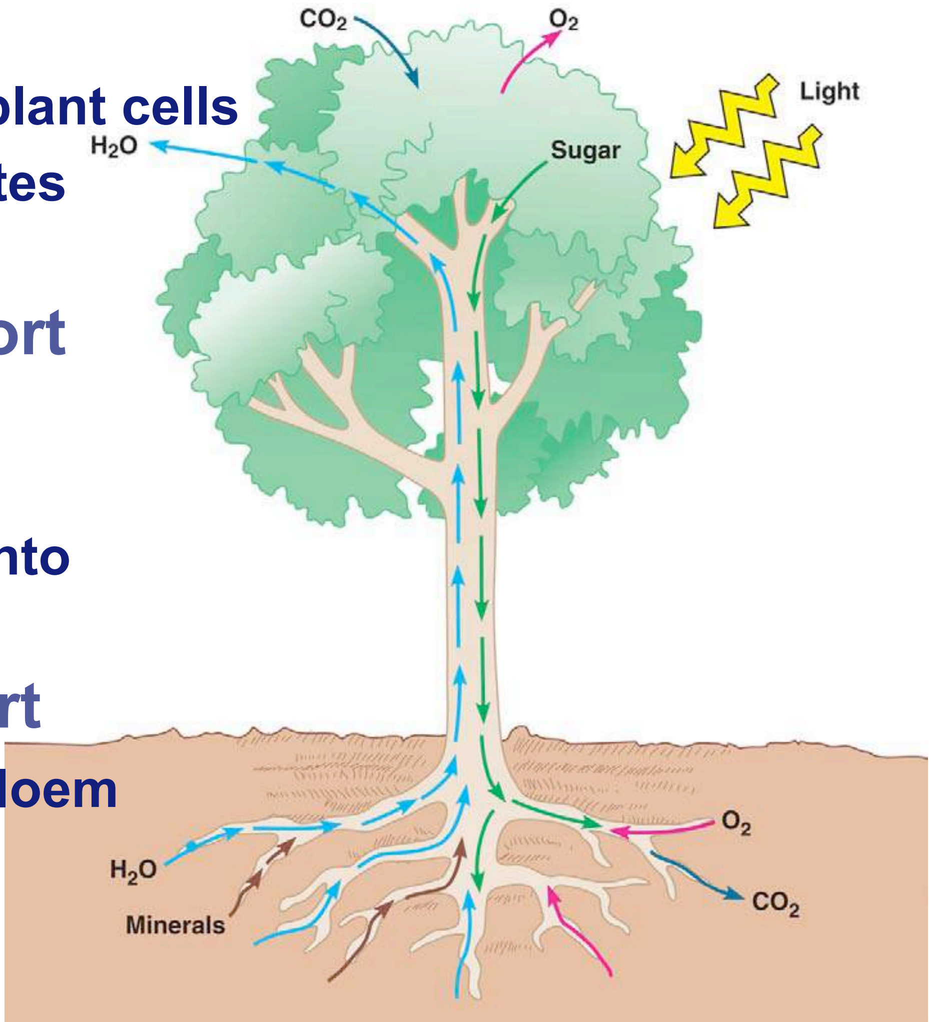
- H_2O & minerals
  - transport in xylem
  - transpiration
- Sugars
  - transport in phloem
  - bulk flow
- Gas exchange
  - photosynthesis
    - CO_2 in; O_2 out
    - stomates
  - respiration
    - O_2 in; CO_2 out
    - roots exchange gases within air spaces in soil



Why does over-watering kill a plant?

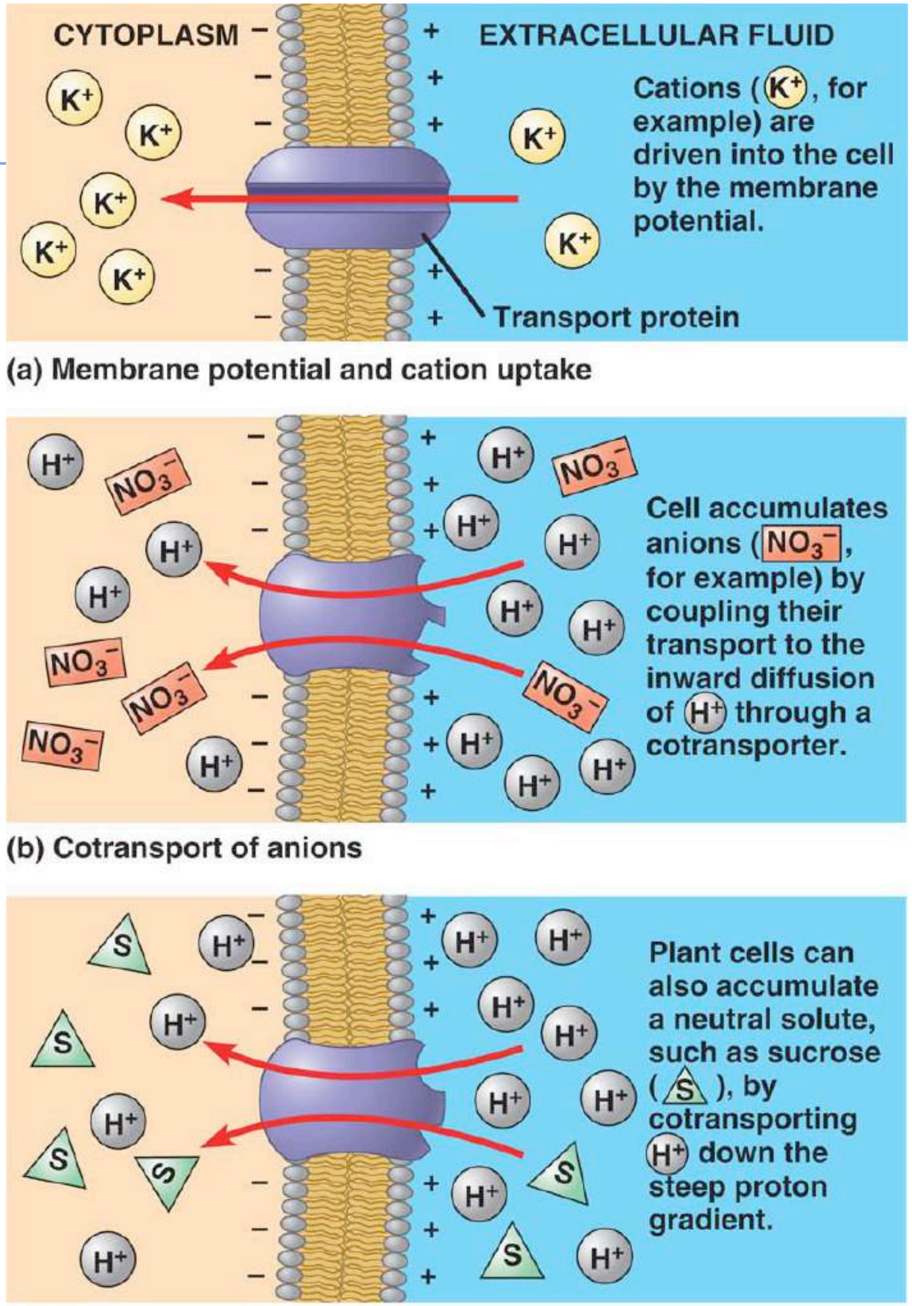
Transport in plants

- 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

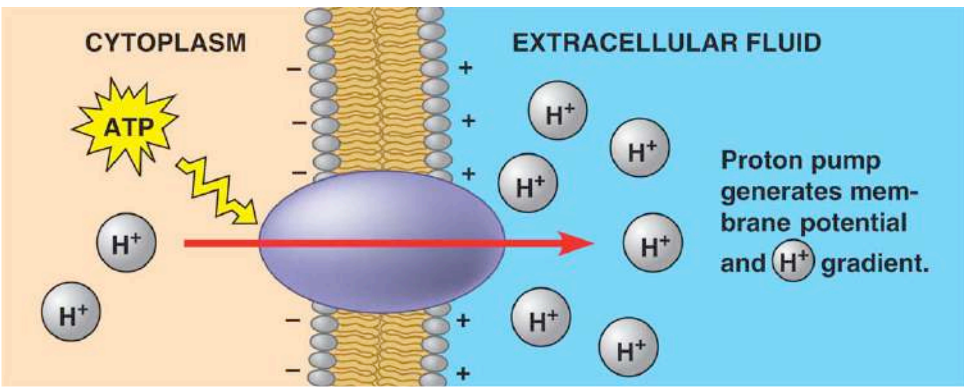


(a) Membrane potential and cation uptake

(b) Cotransport of anions

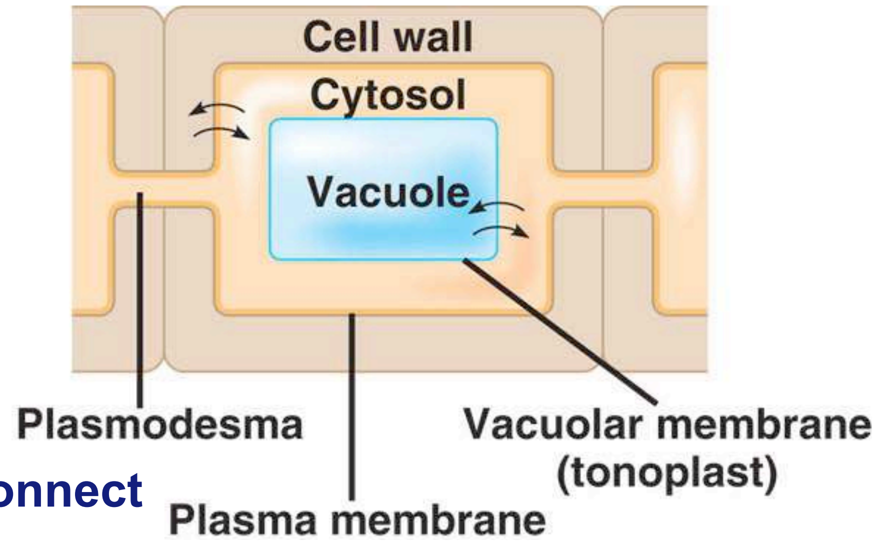
(c) Cotransport of a neutral solute

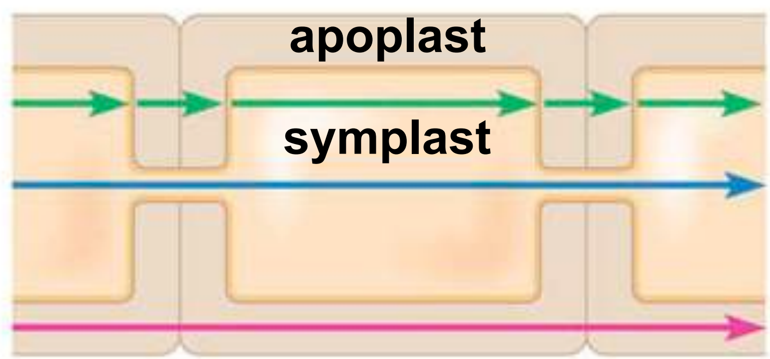
proton pumps



Short distance (cell-to-cell) transport

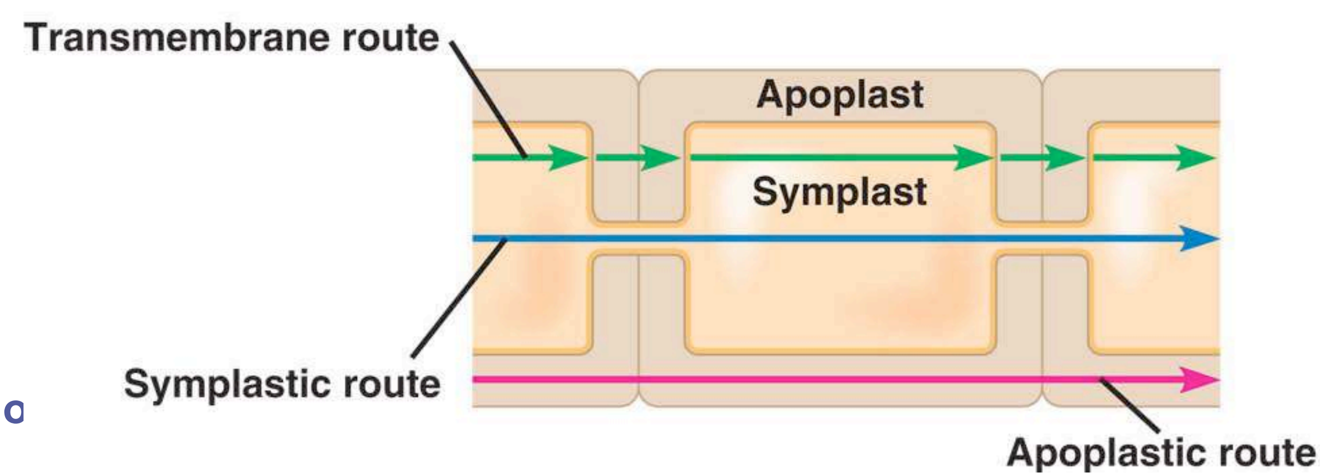
- Compartmentalized plant cells
  - cell wall
  - cell membrane
    - cytosol
  - vacuole
- Movement from cell to cell
  - move through cytosol
    - plasmodesmata junctions connect cytosol of neighboring cells
    - symplast
  - move through cell wall
    - continuum of cell wall connecting cell to cell
    - apoplast





Routes from cell to cell

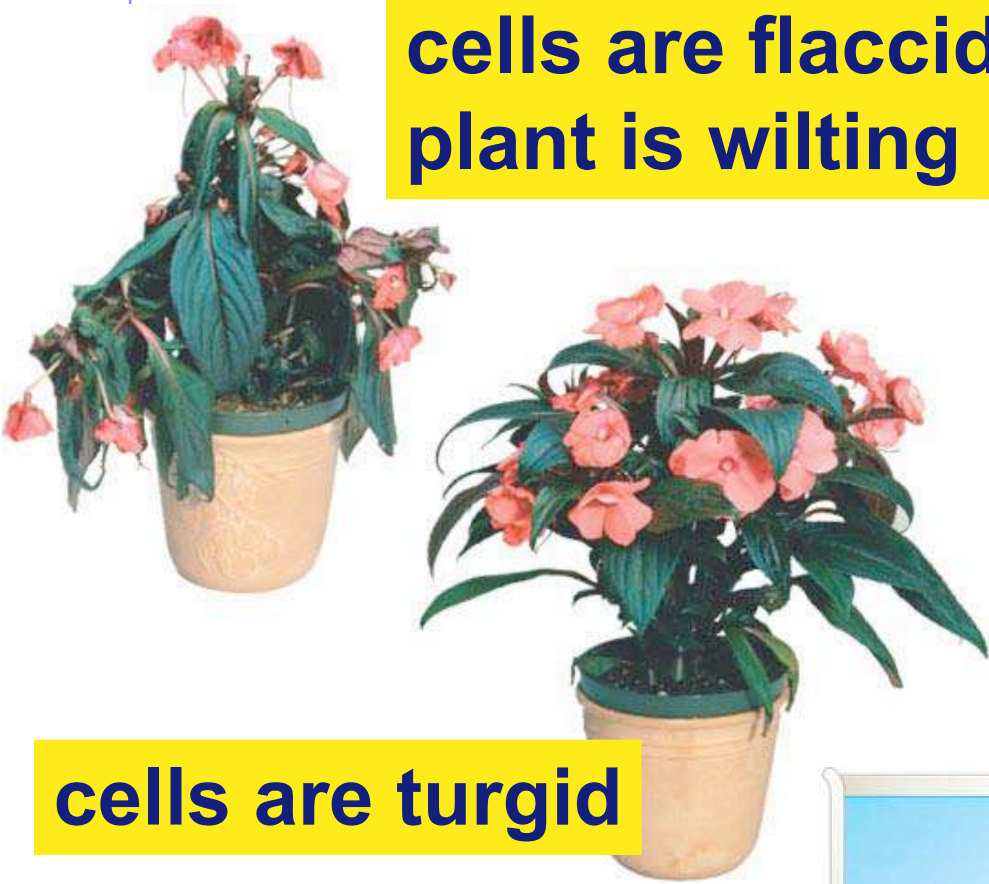
- **Moving water & solutes between cells**
  - transmembrane route
    - repeated crossing of plasma membranes
    - slowest route but offers more control
  - symplast route
    - move from cell to cell within cytosol
  - apoplast route
    - move through connected cell wall without crossing cell membrane
    - fastest route but never enter cell



Long distance transport

- Bulk flow
  - movement of fluid driven by pressure
    - flow in xylem tracheids & vessels
      - negative pressure
      - transpiration creates negative pressure pulling xylem sap upwards from roots
    - flow in phloem sieve tubes
      - positive pressure
      - loading of sugar from photosynthetic leaf cells generates high positive pressure pushing phloem sap through tube

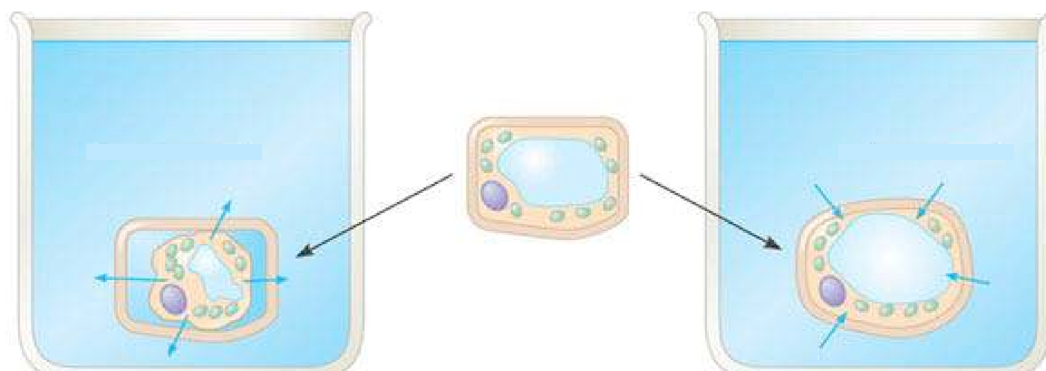
Movement of water in plants



cells are flaccid
plant is wilting

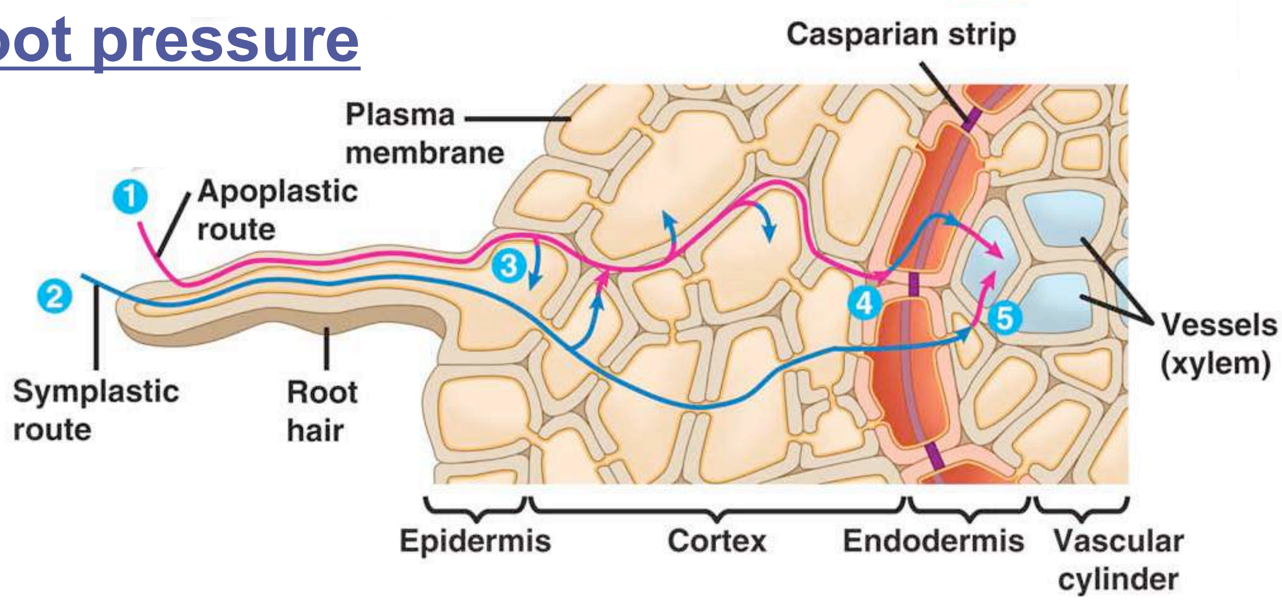
cells are turgid

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

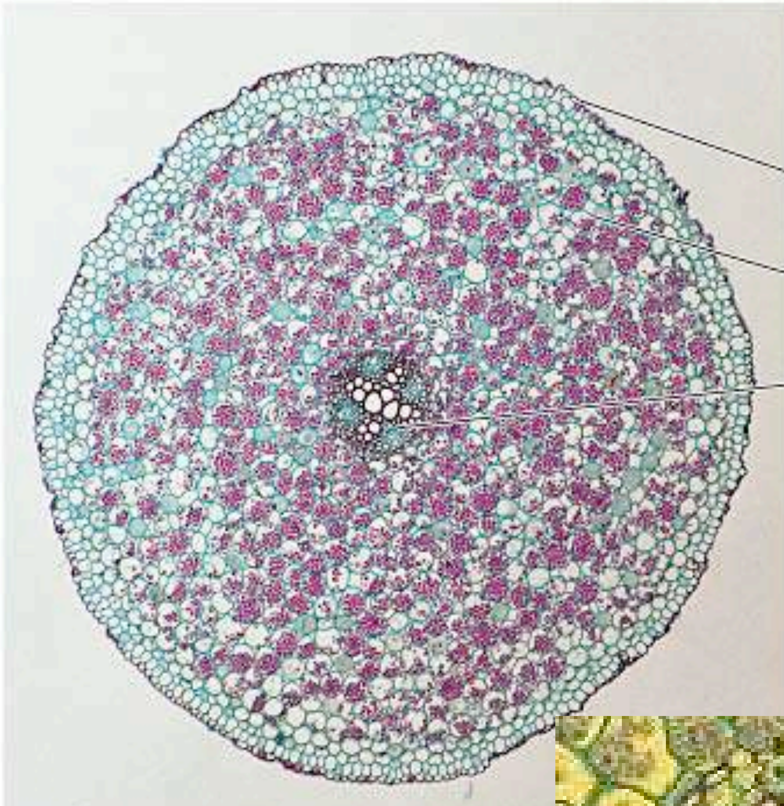


Water & mineral uptake by roots

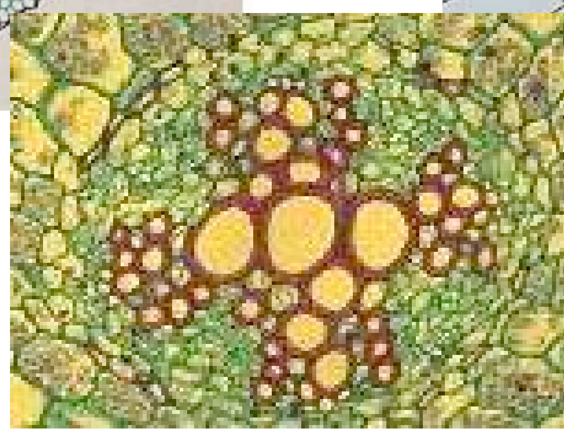
- **Mineral uptake by root hairs**
  - dilute solution in soil
  - active transport pumps
    - **this concentrates solutes (~100x) in root cells**
- **Water uptake by root hairs**
  - flow from high H_2O potential to low H_2O potential
  - creates root pressure

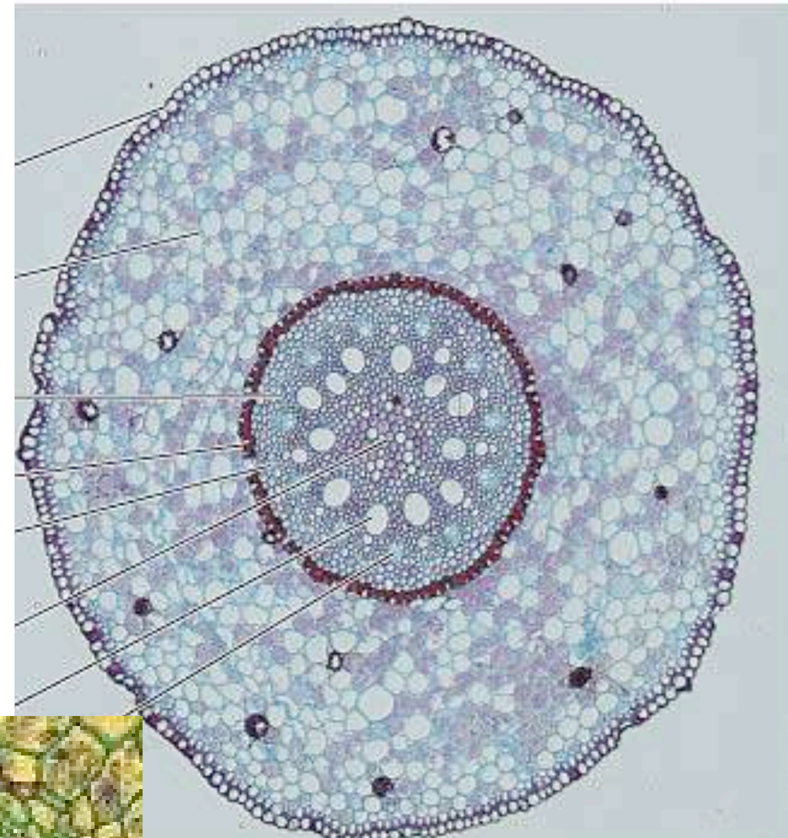


Root anatomy

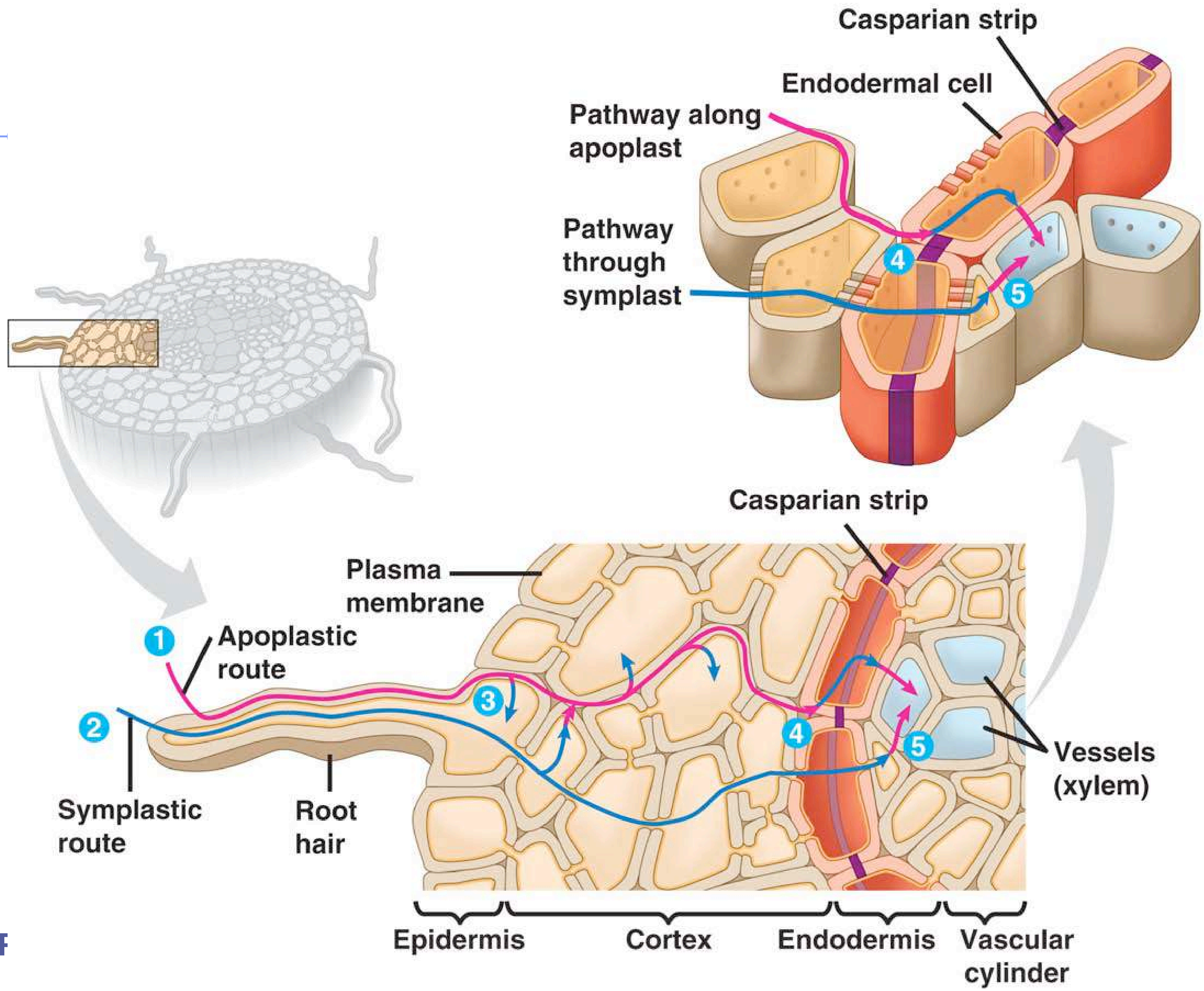


dicot



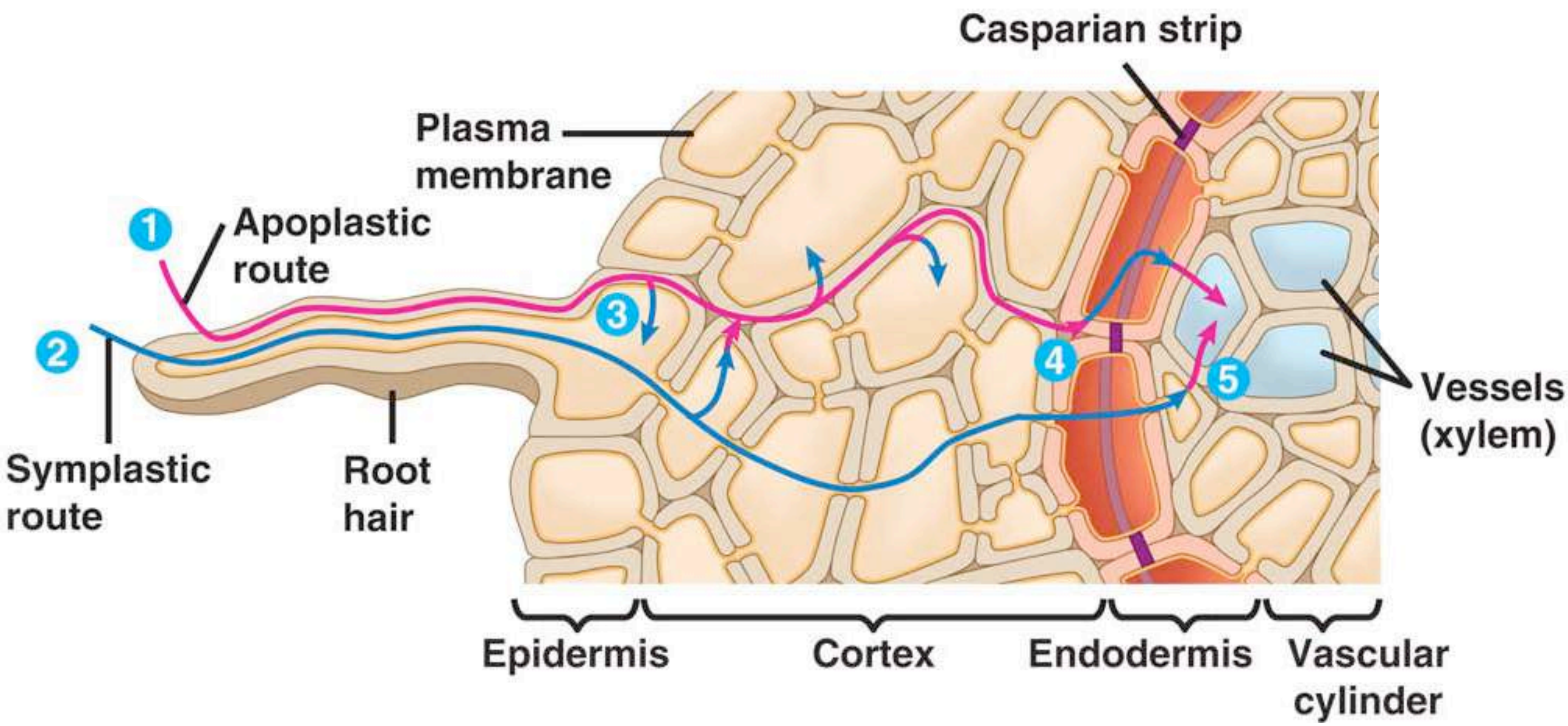


monocot


Casparian strip
Endodermal cell
Pathway along apoplast
Pathway through symplast
4
5
Casparian strip
Plasma membrane
1
Apoplastic route
2
3
4
5
Symplastic route
Root hair
Vessels (xylem)
Epidermis
Cortex
Endodermis
Vascular cylinder

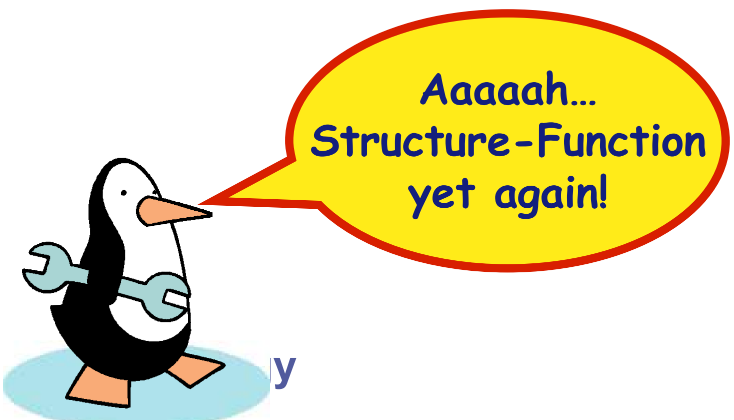
Route water takes through root

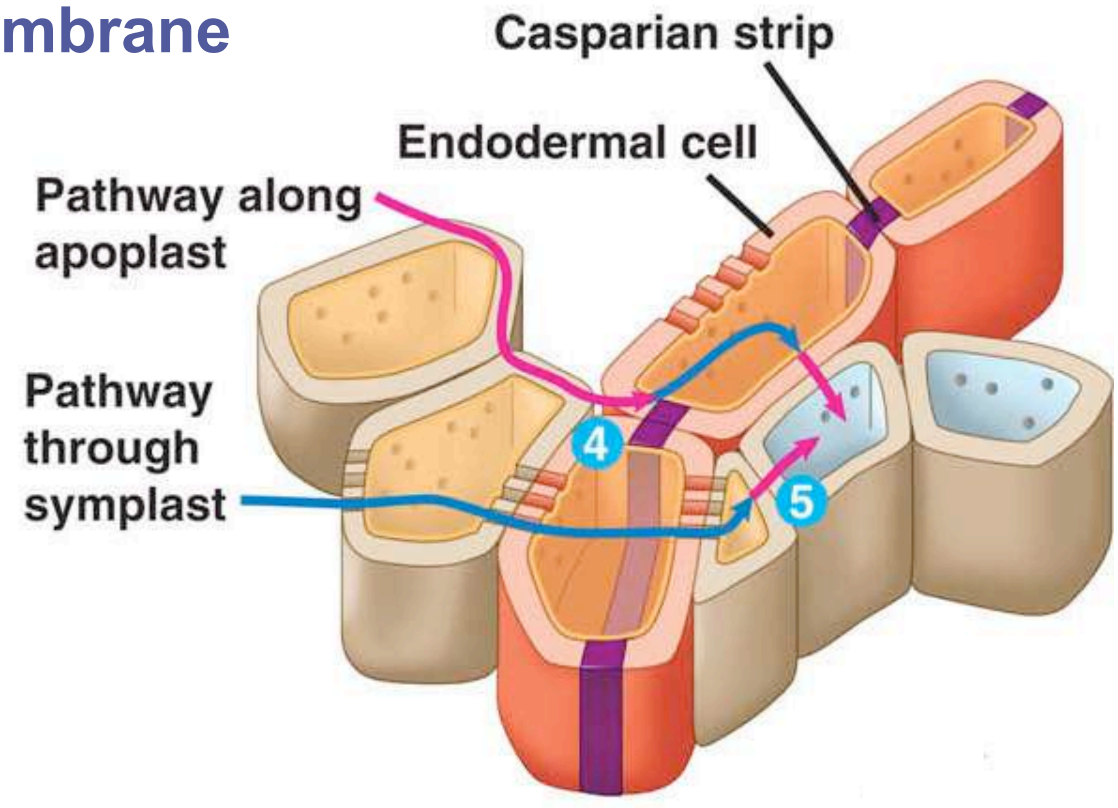
- Water uptake by root hairs
  - a lot of flow can be through cell wall route
  - apoplasty



Controlling the route of water in root

- **Endodermis**
  - cell layer surrounding vascular cylinder of root
  - lined with impervious <u>Casparian strip</u>
  - forces fluid through selective cell membrane & into symplast
    - filtered & forced into xylem vessels

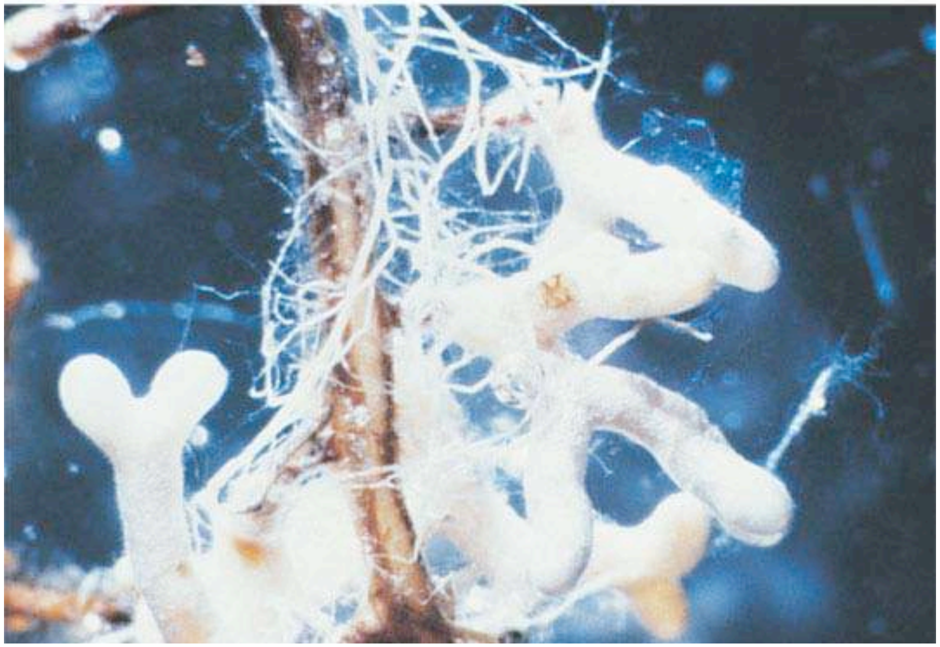




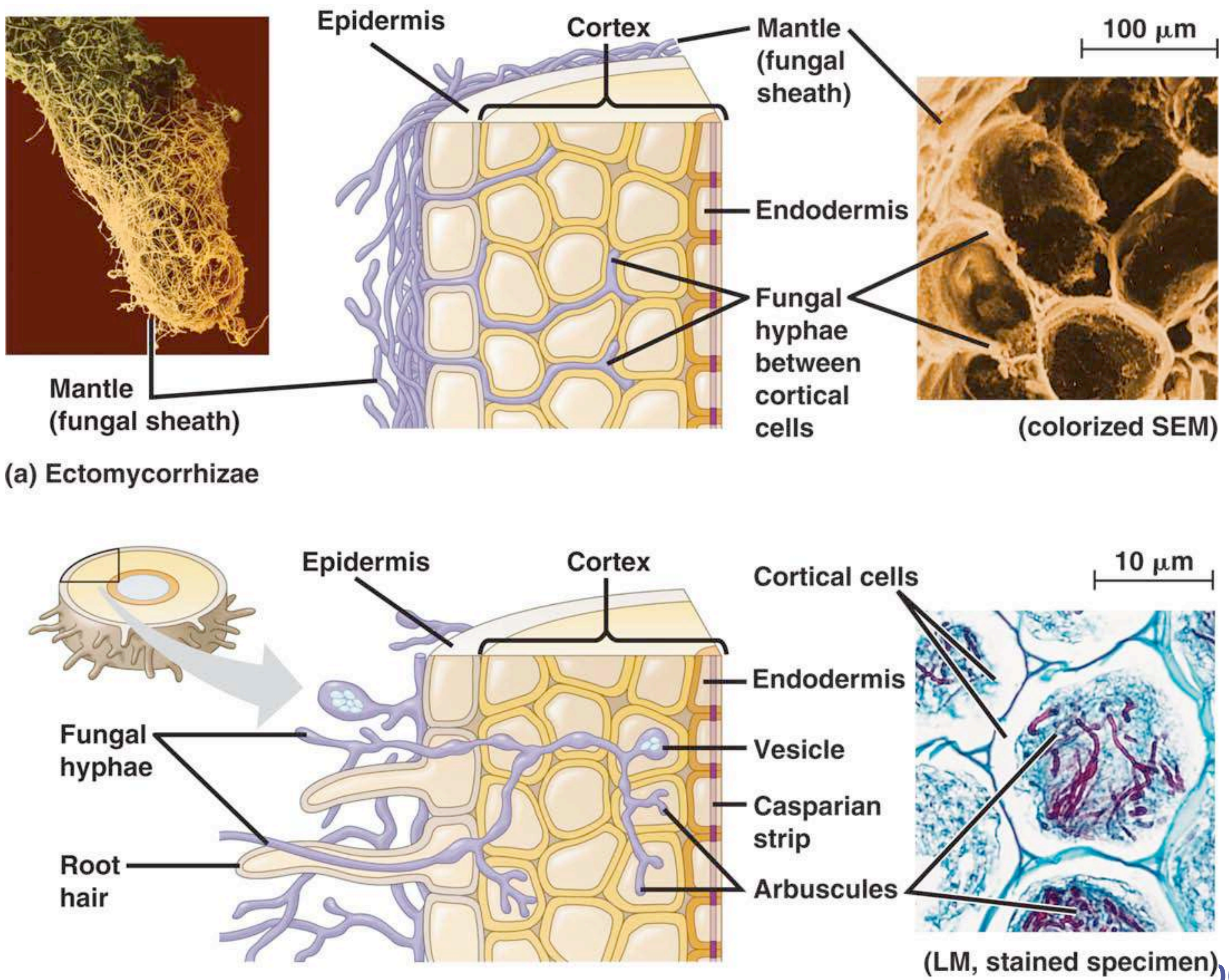
Mycorrhizae increase absorption

- Symbiotic relationship between fungi & plant
  - symbiotic fungi greatly increases surface area for absorption of water & minerals
  - increases volume of soil reached by plant
  - increases transport to host plant

2.5 mm



Mycorrhizae



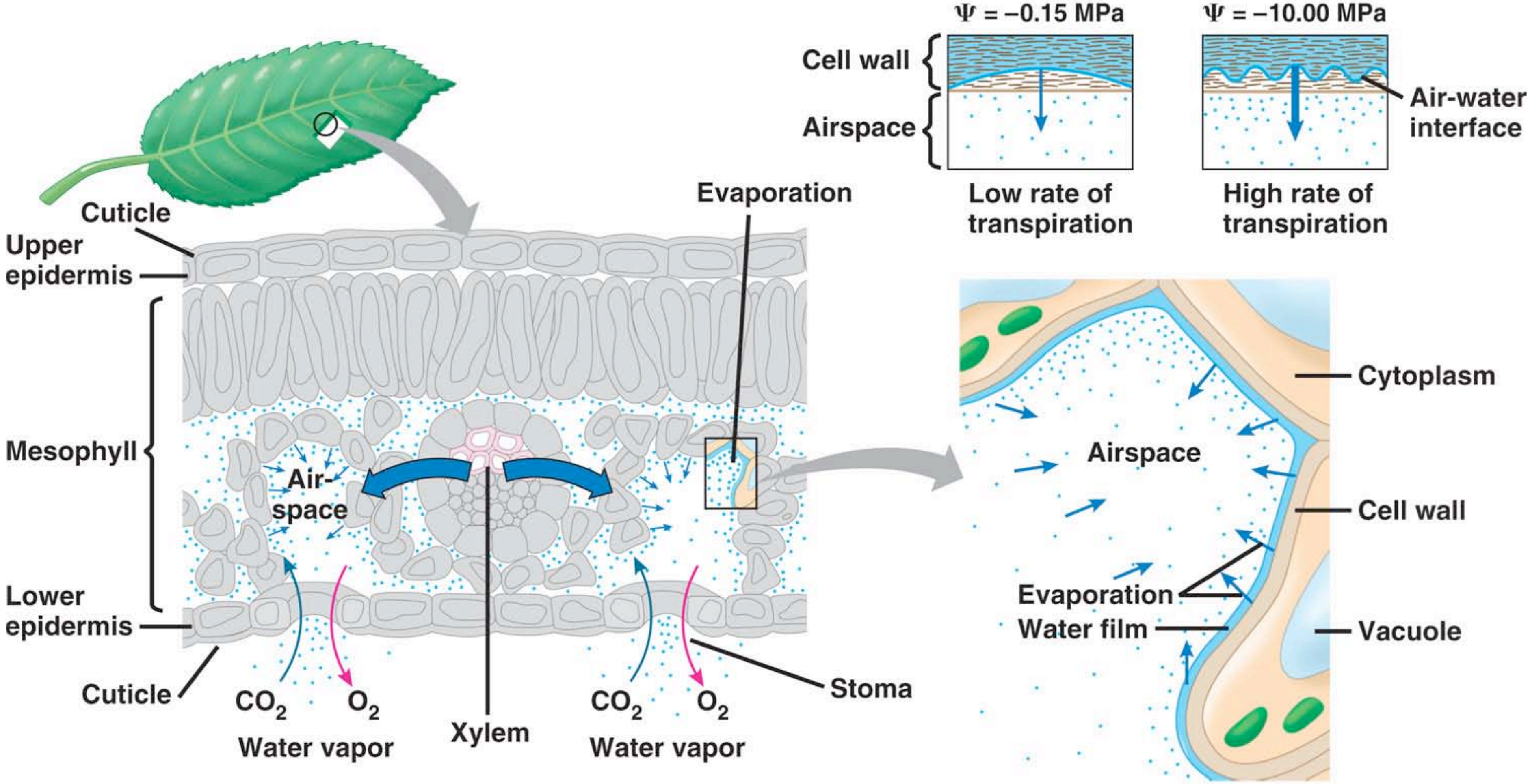
(a) Ectomycorrhizae

(b) Endomycorrhizae

May apples and Mycorrhizae

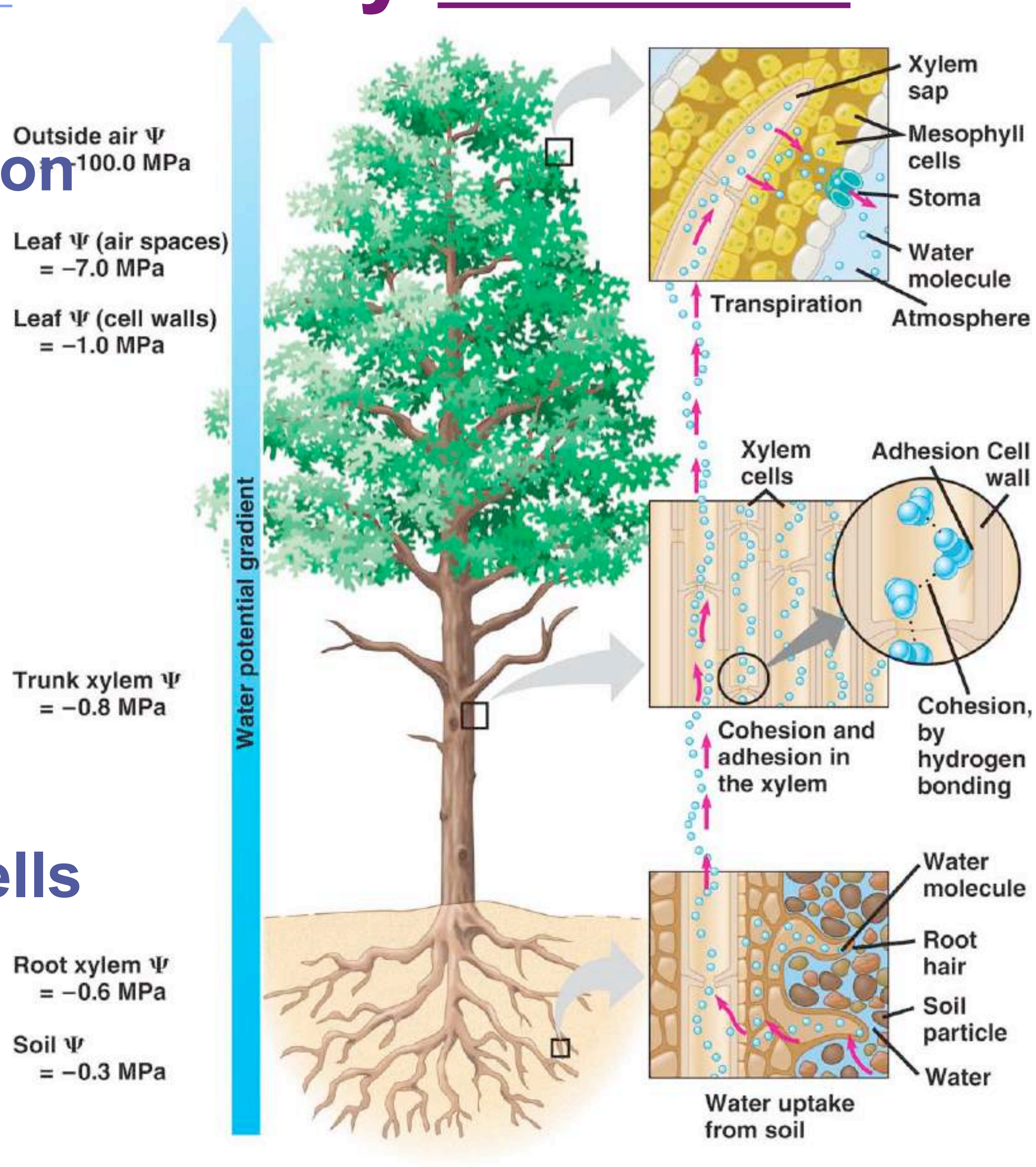
Ascent of xylem “sap”

Transpiration pull generated by leaf



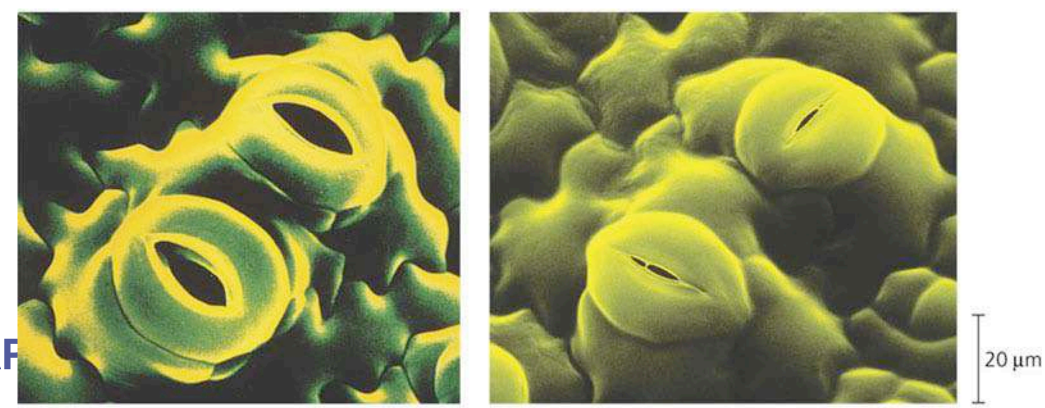
Rise of water in a tree by bulk flow

- Transpiration pull
  - adhesion & cohesion
    - H bonding
  - brings water & minerals to shoot
- 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



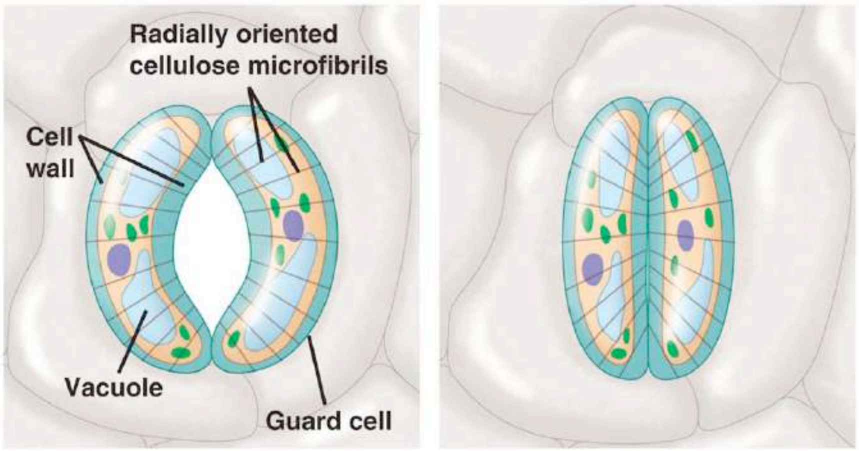
Control of transpiration

- **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

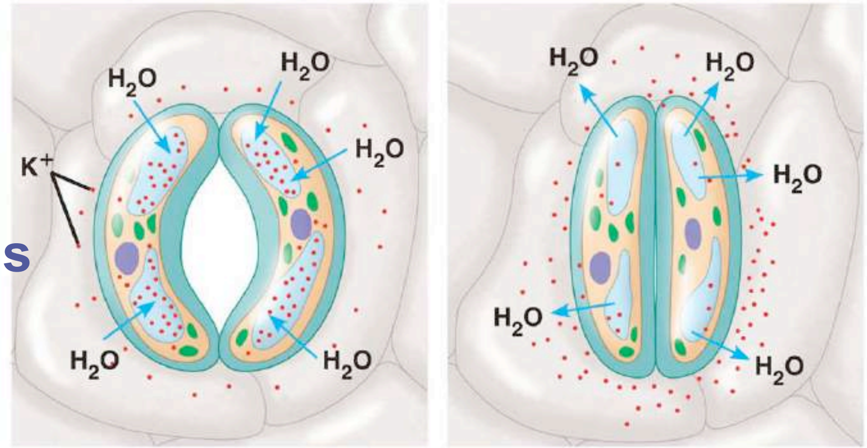


Regulation of stomates

- 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
    - proton pumps
    - water enters by osmosis
    - guard cells become turgid
  - loss of K^+ ions by guard cells
    - water leaves by osmosis
    - guard cells become flaccid

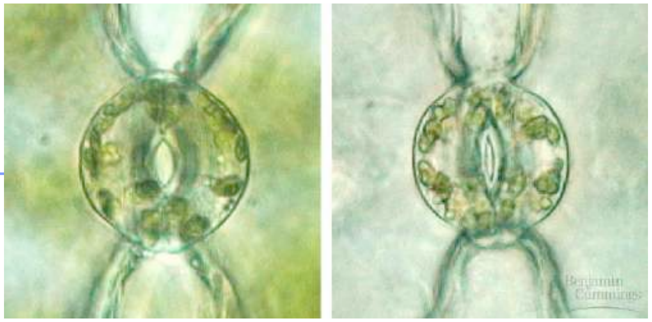


(a) Changes in guard cell shape and stomatal opening and closing (surface view)

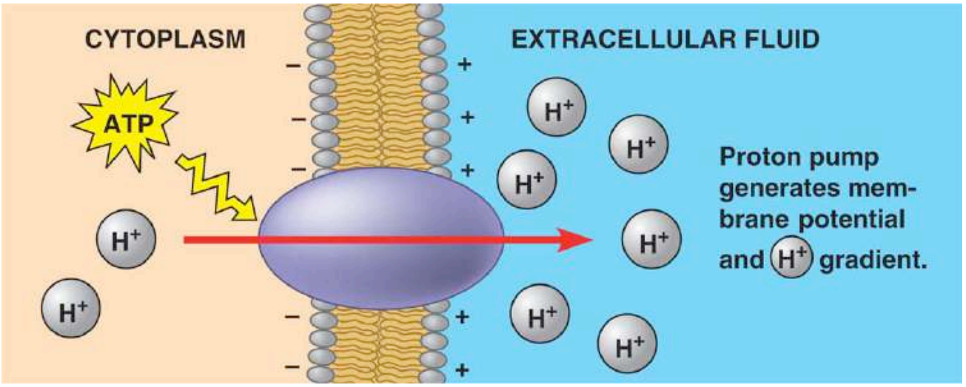


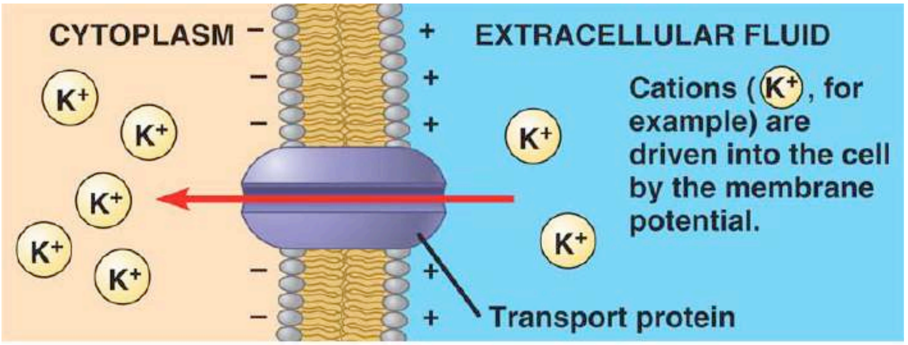
(b) Role of potassium in stomatal opening and closing

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
  - depletion of CO_2
    - CO_2 is depleted during photosynthesis (Calvin cycle)
  - circadian rhythm = internal "clock"
    - automatic 24-hour cycle

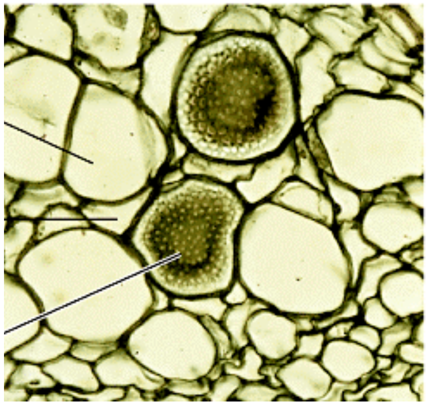


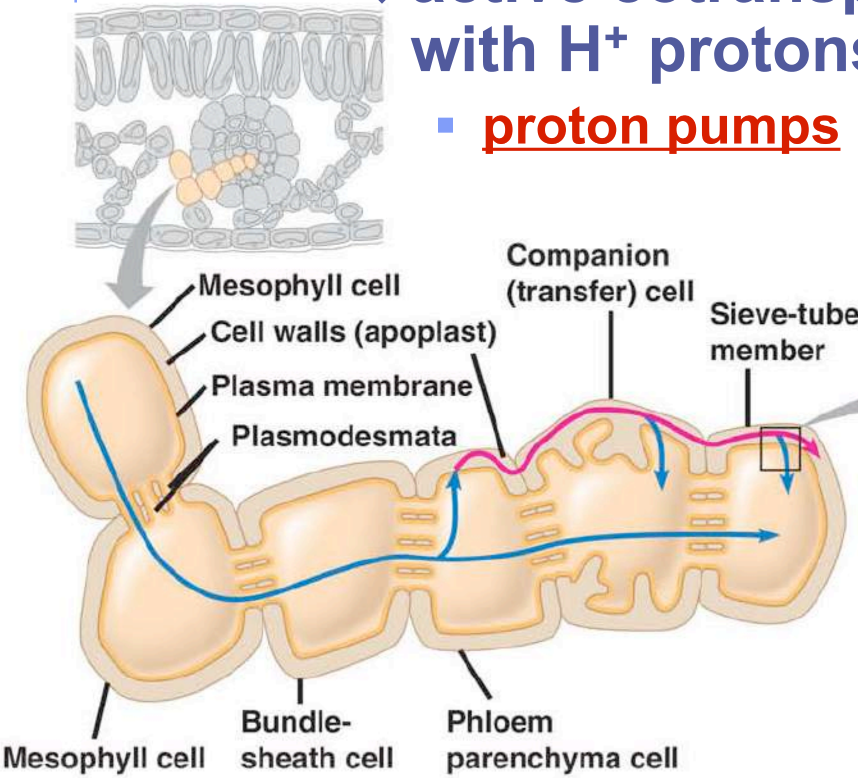


(a) Membrane potential and cation uptake

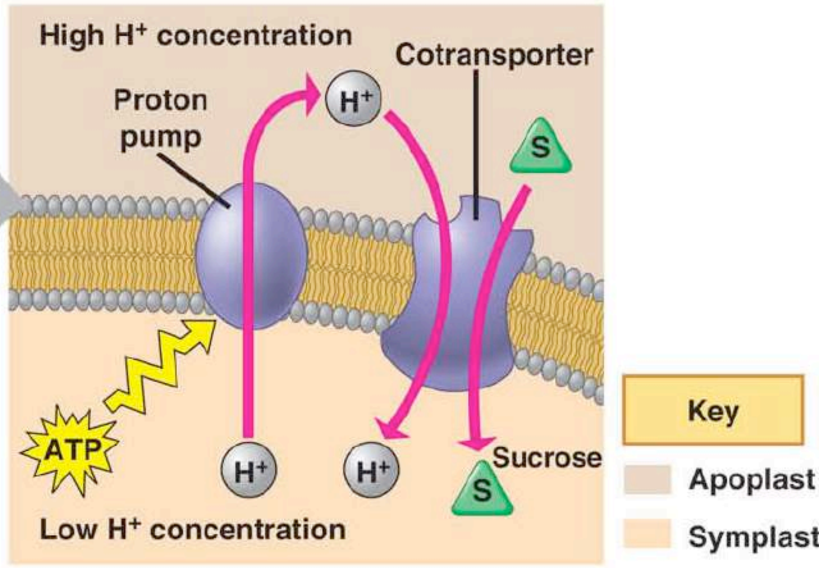
Transport of sugars in phloem

- **Loading of sucrose into phloem**
  - flow through symplast via plasmodesmata
  - active cotransport of sucrose with H^+ protons
    - proton pumps





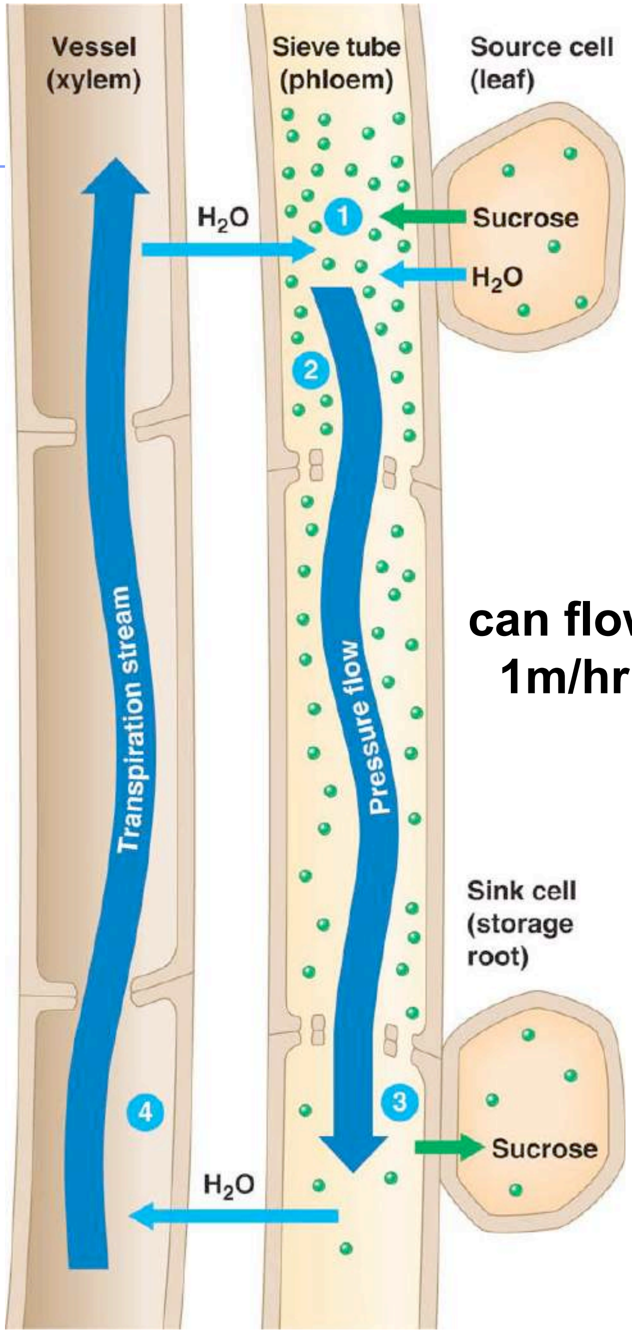
(a)



(b)

Pressure flow in sieve tubes

- Water potential gradient
  - “source to sink” flow
    - direction of transport in phloem is variable
  - sucrose flows into phloem sieve tube decreasing H_2O potential
  - water flows in from xylem vessels
    - increase in pressure due to increase in H_2O causes flow



can flow 1m/hr

What plant structures are sources & sinks?

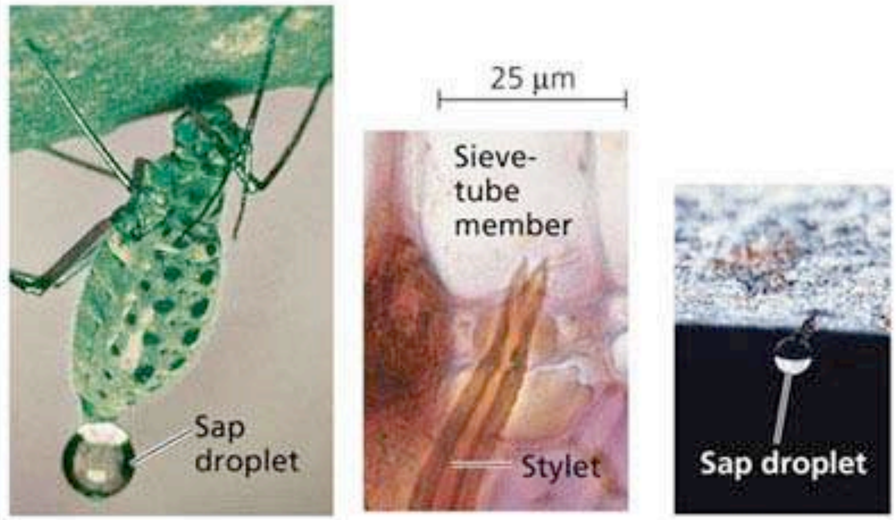
Experimentation

- Testing pressure flow hypothesis
  - using aphids to measure sap flow & sugar concentration along plant stem

Figure 36.19

Inquiry What causes phloem sap to flow from source to sink?

EXPERIMENT To test the pressure flow hypothesis, researchers used aphids that feed on phloem sap. An aphid probes with a hypodermic-like mouthpart called a stylet that penetrates a sieve-tube member. As sieve-tube pressure force-feeds aphids, they can be severed from their stylets, which serve as taps exuding sap for hours. Researchers measured the flow and sugar concentration of sap from stylets at different points between a source and sink.



Aphid feeding | Stylet in sieve-tube member | Severed stylet exuding sap

RESULTS The closer the stylet was to a sugar source, the faster the sap flowed and the higher was its sugar concentration.

CONCLUSION The results of such experiments support the pressure flow hypothesis.

Maple sugaring

Any Questions??