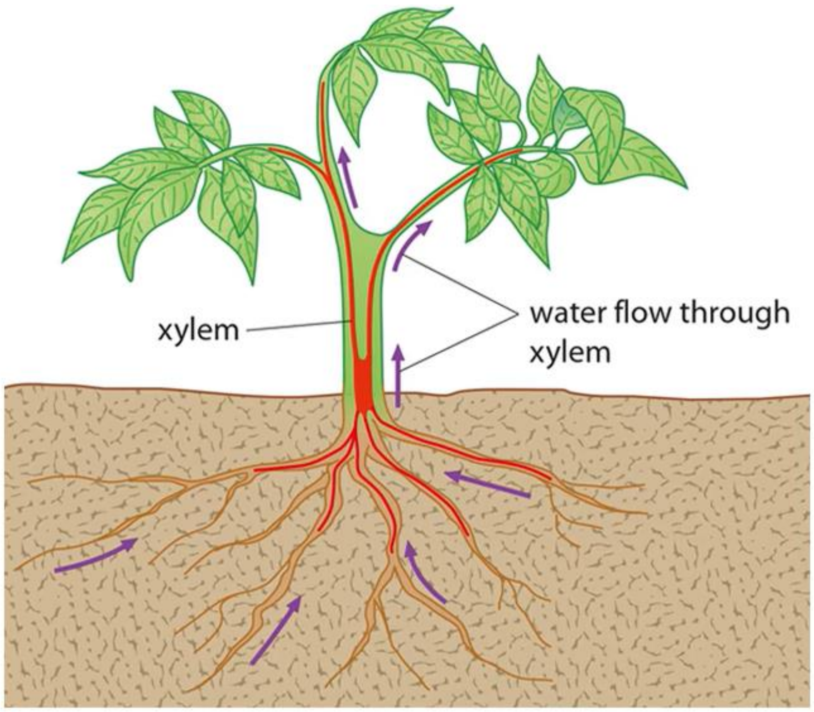
CONCEPT: WATER POTENTIAL

● ***Water potential*** (ψ) – potential energy of water between two environments, differences determine direction of flow

- □ $\psi = \psi_S + \psi_P$
- □ Water always flows from areas of higher potential to those of lower potential
- □ Measured in megapascals MPa (10^6 Pa), a unit of pressure
- □ Water potential gradient causes water to move from soil up through plant against gravity

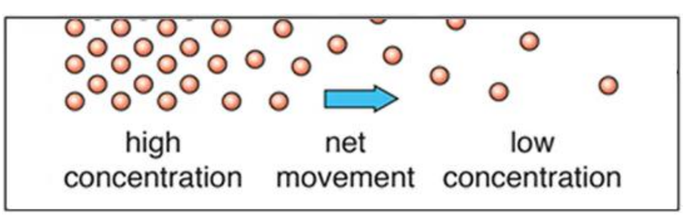
EXAMPLE:

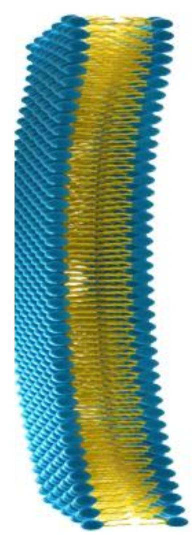


● ***Solute potential*** (ψ_S) – solute concentration relative to pure water, high concentration means low solute potential

- □ Water moves in response to differences in solute concentrations, from high to low solute potential
- □ Has negative pressure relative to pure water (pure water solute potential = 0 MPa)
- □ Cells always have dissolved solutes inside them

EXAMPLE:

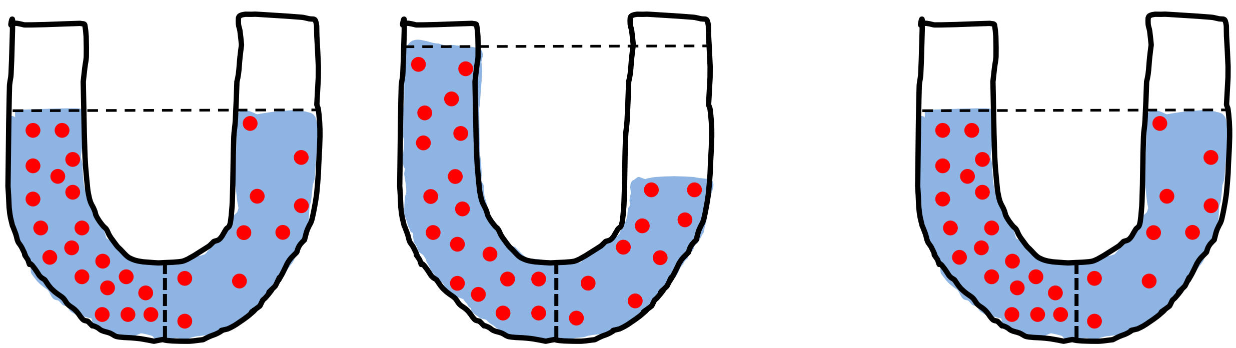




CONCEPT: WATER POTENTIAL

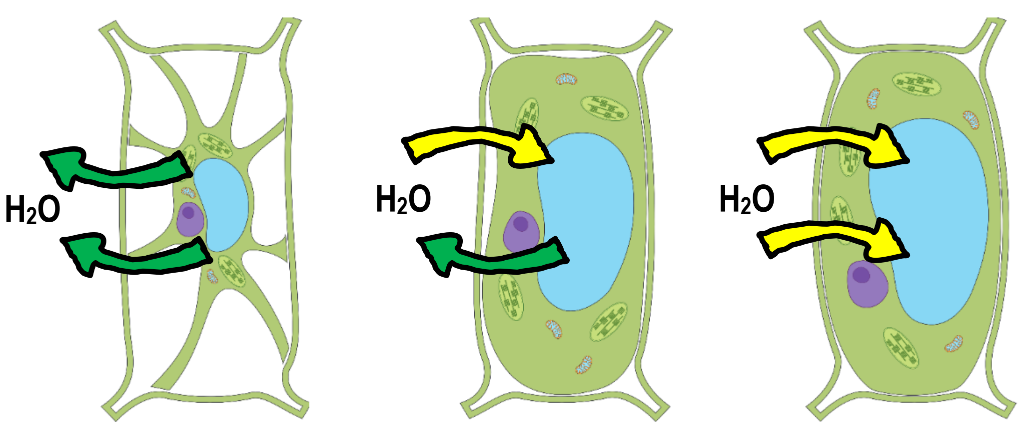
- ***Pressure potential*** (Ψ_P) – physical pressure on water, can be positive or negative (tension)
  - □ Living cells have positive pressure
- When membranes are present water moves from high to low solute potential
- When membranes are absent water moves from high to low pressure potential

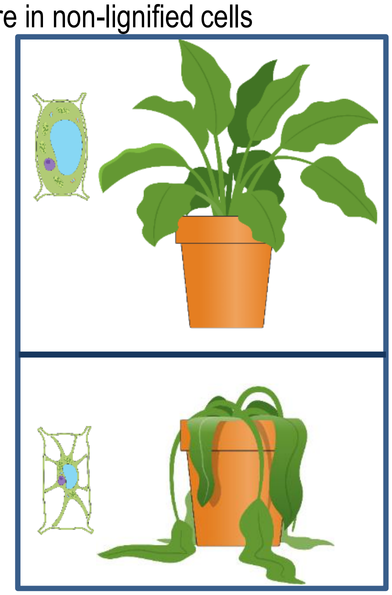
EXAMPLE:



- ***Turgor pressure*** – pressure inside the cell from the vacuole swelling, pushing against the cell wall
  - □ ***Protoplast*** – living content of a cell including the plasma membrane, does not include cell wall
- ***Wall pressure*** – force exerted by the cell wall on cell contents (equal and opposite to turgor pressure)
  - □ Turgidity increases until wall pressure is induced
  - □ Flaccid – no turgor pressure, meaning no pressure potential
    - Plasmolysis – shriveling of protoplast due to water loss
    - Wilting – loss of rigidity in non-woody plants due to a drop in turgor pressure in non-lignified cells

EXAMPLE:





<u>CONCEPT:</u> <u>WATER POTENTIAL</u>

● Water potential in soil varies depending on the conditions

  □ Dry soil has lower Ψ than plant roots

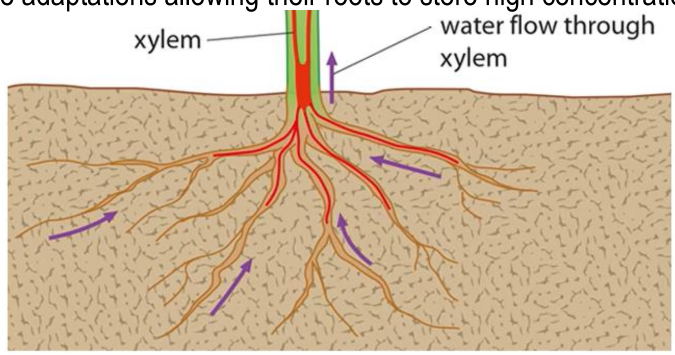
  □ Damp soil has higher Ψ than plant roots do because the water has few dissolved solutes

  □ Soil near the ocean has much lower water potential than roots due to all of the salt in the water

  □ If soil water potential is low enough, water can flow from the plant into the soil

    - Plants can have adaptations allowing their roots to store high concentrations of solutes,

EXAMPLE:



● Warm air and dry air have low water potential, so warm, dry air provides a very low water potential

● ***Transpiration*** – evaporation of water through plant leaves, pulls water up from roots

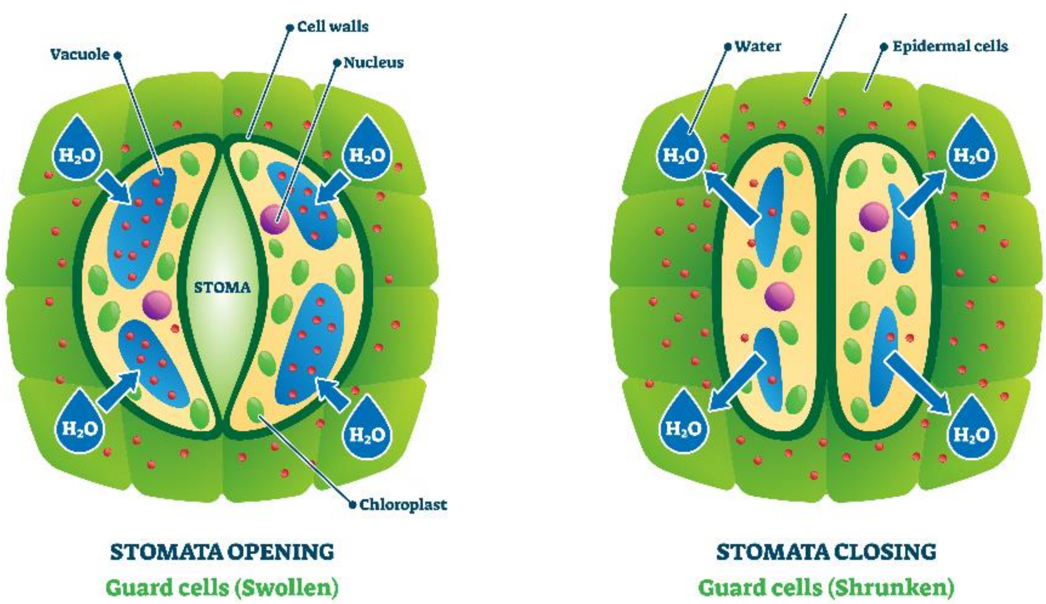
● ***Stomata*** – control gas exchange by opening and closing, if air outside is dry (<100% humidity) water will evaporate

  □ Opening: H^+-pumps concentrate H^+ outside the cell, depolarization causes K^+ to enter the cell and water follows

  □ Stomata open and close due to circadian rhythms, and close due to abscisic acid (ABA) hormone signal

    - ABA – produced in roots due to low soil water potential, induces stomata to close reducing transpiration

EXAMPLE:



● Photosynthesis-transpiration compromise – balance between conserving water and maximizing photosynthesis

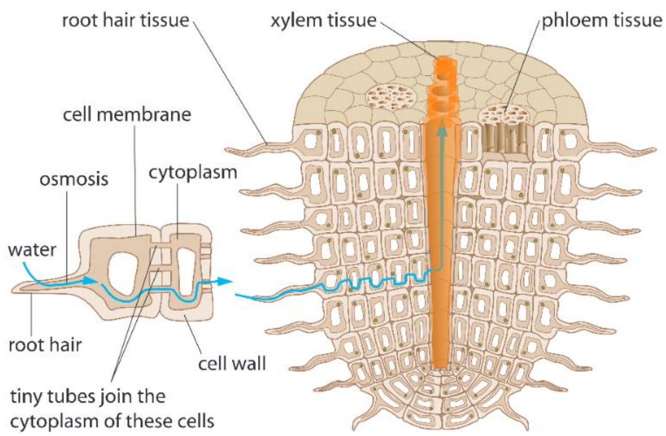
● Adaptations for water loss: cuticle, stomata in deep pits surrounded by trichromes, CAM and C4 photosynthesis

CONCEPT: XYLEM TRANSPORT

● Water flows from soil into the root hairs, and from there it moves to the xylem

□ Water moves into root hairs via osmosis

EXAMPLE:



● ***Transmembrane route*** – flow through aquaporins and directly through membrane

● ***Apoplastic route*** – flow outside the plasma membranes, in spaces between cells and porous cell walls

□ ***Apoplast*** – space outside of the plasma membrane, interrupted by the Casparian strip

□ ***Casparian strip*** – waxy layer made of suberin secreted by endodermis to block off xylem

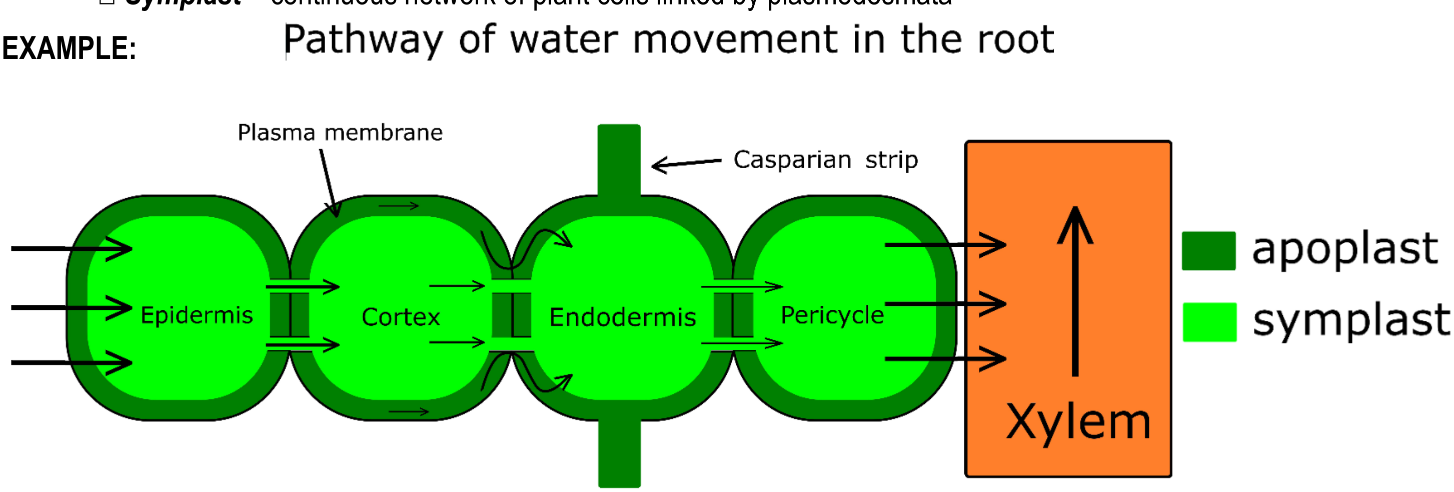
- Allows endodermal cells to acts as filters, controls ion flow and concentration gradients

- Water must eventually flow through endodermal cells to enter xylem due to Casparian strip

● ***Symplastic route*** – flow through cytosol of cells

□ ***Symplast*** – continuous network of plant cells linked by plasmodesmata

EXAMPLE:



● Water flows through xylem without crossing membranes, moves due to difference in pressure potential

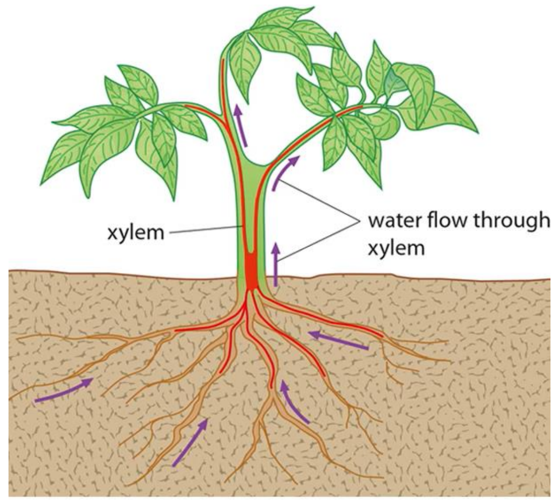
□ ***Bulk flow*** – mass movement of molecules along a pressure gradient

□ ***Xylem sap*** – water with some dissolved minerals, nutrients, and hormones

CONCEPT: XYLEM TRANSPORT

- Cohesion-tension is the most commonly accepted theory describing how water flows up xylem
- ***Root pressure theory*** – positive pressure builds in root xylem from increased absorption of water relative to transpiration
  - □ Ions are pumped into root xylem, creating negative water potential relative to soil
  - □ Water enters via osmosis due to solute concentrations, generating positive pressure
  - □ Stomata close at night, but roots continue to absorb ions and water from soil (root pressure highest in morning)
  - □ ***Guttation*** – water forced out of leaves due to pressure

EXAMPLE:

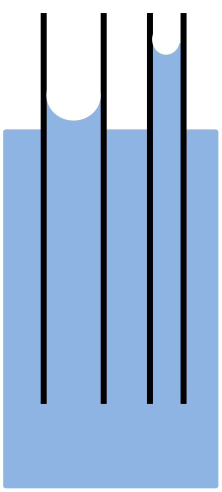


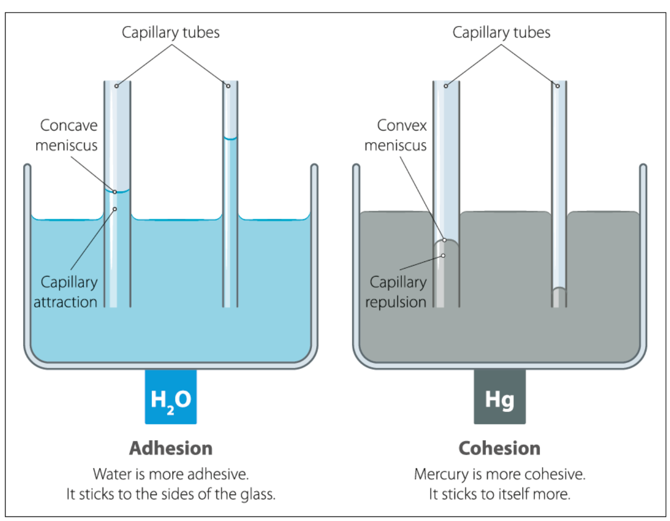
- ***Capillary action*** (capillarity) – ability of a liquid to move through narrow spaces
  - □ ***Adhesion*** – attraction between unlike molecules (water and the tube)
  - □ ***Cohesion*** – attraction between like molecules (water with itself)
    - Meniscus – concave surface boundary due to cohesion and adhesion

□ ***Surface tension*** – force between water molecules at the air-water interface

- Adhesion pulls up from container wall, surface tension pulls up from surface, cohesion transmits the pull

EXAMPLE:

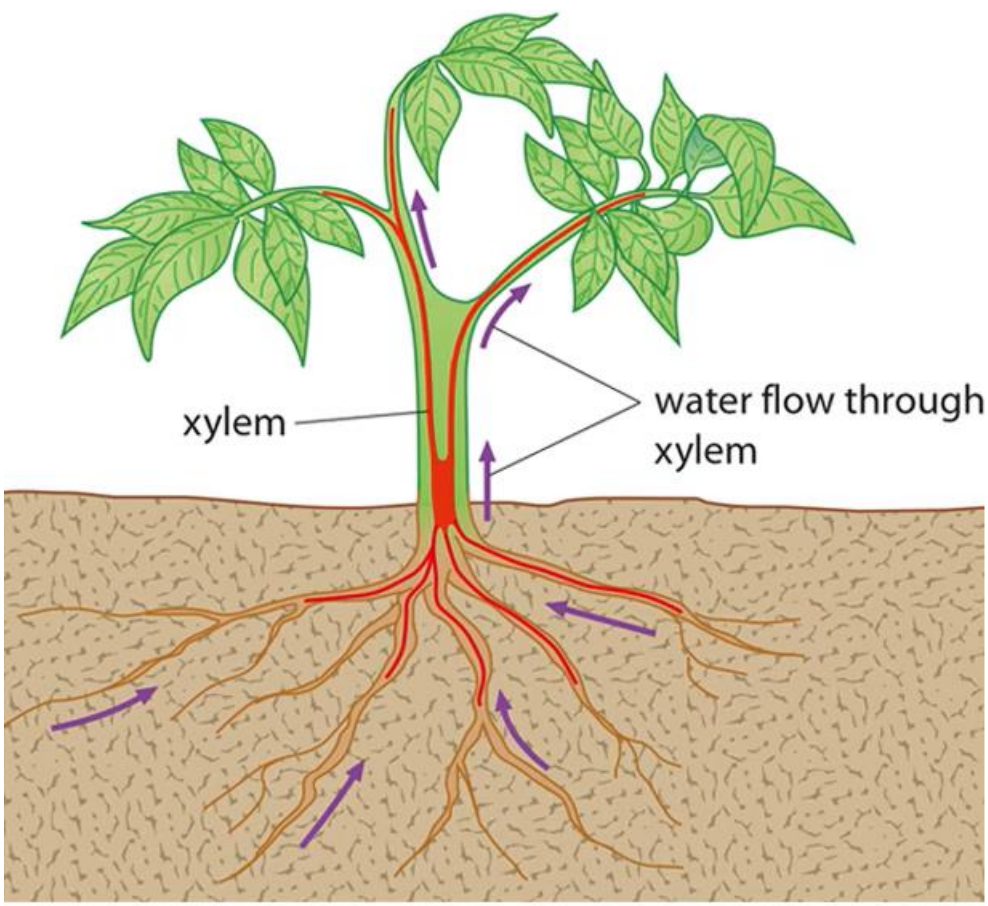




CONCEPT: XYLEM TRANSPORT

- ***Cohesion-tension theory*** – evaporation from leaves creates negative pressure, pulling water up from roots
    - □ Leaves contain humid air that evaporates water when stomata are open and humidity is <100%
    - □ Evaporation lowers humidity in mesophyll, causing water to enter into the space from parenchyma cells
        - Steep menisci form at air-water interface in leaf cell walls creating tension
        - Each meniscus is small, but all their forces added together are significant
    - □ Tension pulls water up into leaves from roots, assisted by cohesion and adhesion
    - □ This process is "solar-powered", plants do not expend energy to create the upward force
        - Plants expend energy to take up ions in the roots, which allows water to enter root hairs via osmosis
- Negative pressure can be powerful, lignified secondary cell walls allow vascular tissue to withstand it

EXAMPLE:



CONCEPT: PHLOEM TRANSPORT

● ***Translocation*** – movement of sugars via bulk flow from source to sink

□ Source – tissue where sugar enters the phloem

□ Sink – tissue where sugar exits the phloem

□ ***Phloem loading*** – sugars enter phloem via secondary active transport

- H^+-pumps concentrate H^+ outside cell, allowing proton-sucrose symporter to bring sugar into phloem

□ ***Phloem sap*** – mostly sucrose and other sugars dissolved in water, with some hormones and minerals

EXAMPLE:

● ***Pressure flow hypothesis*** – most commonly agreed upon theory for movement of sap through phloem

□ Sugar is more concentrated at the source, causing water from xylem to enter due to the concentration gradient

- Water from xylem increases turgor pressure in phloem

□ Sugar is less concentrated at the sink, causing water to leave the phloem and enter the xylem

- Water leaving phloem reduces turgor pressure

□ Bulk flow results from positive pressure due to differences in turgor pressure at the sink and the source

EXAMPLE: