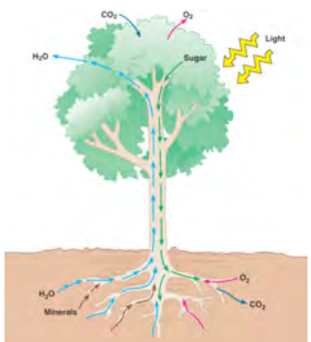
# Exchange & Transport in Vascular Plants

## Plant Exchange & Transport

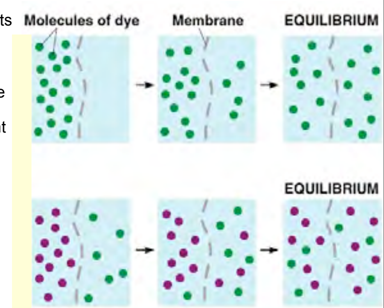
I. Water and Solute Uptake by Cells
II. Local Transport
III. Long Distance Transport
IV. Gas Exchange

## Water and Solutes - Uptake by Cells



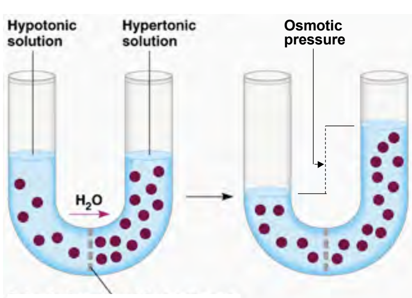

## Passive Transport (Diffusion)

- Net movement of molecules from a region of high concentration to a region of low concentration
  - ✓ Caused by random (Brownian) movements of molecules
  - ✓ (Increase entropy)
  - ✓ Each type of molecule follows its own concentration gradient
  - ✓ At equilibrium, movement is equal in both directions




## Osmosis: simple diffusion of the solvent (water)

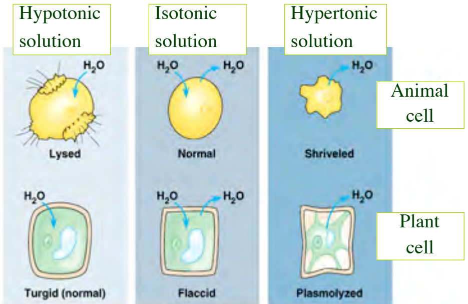
- Water diffuses according to its concentration gradient
- ↑Osm → ↓[water]
  ↓ Osm →↑[water]
- Osmosis can generate force (osmotic pressure)




## Water and Solute Uptake by Cells

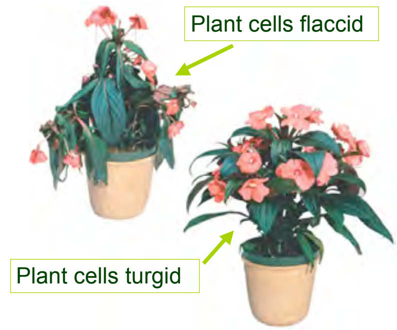
- ❖ Water moves across lipid bilayer and through aquaporins (membrane gate proteins)
- ❖ Move the water by moving the solutes!
  - Hypertonic solution: higher concentration of solutes
  - Hypotonic solution: lower concentration of solutes
  - Isotonic solution: equal solute concentrations

## Water and Solute Uptake by Cells

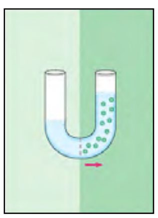


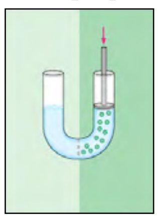

- **Turgor pressure**: pressure exerted on wall of turgid cell = 75–100psi

## Water and Solute Uptake by Cells




## Water Potential (Ψ)



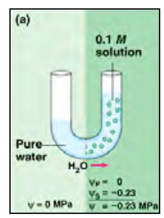


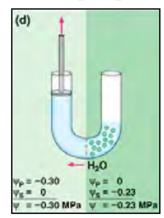
- Osmotic pressure pulls water to the right.
- Osmotic potential (=**solute potential [$\Psi_S$]**): solution on left has potential energy to push water to the right
- ↓Osm→↑ $\Psi_S$

- Physical pressure (= **pressure potential [$\Psi_P$]**): solution on right has potential energy to push water to the left
- **If $\Psi_S$ & $\Psi_P$ are equal but opposite→ no net flow**

  **⇒ $\Psi = \Psi_S + \Psi_P = 0$**

## Water Potential (Ψ)



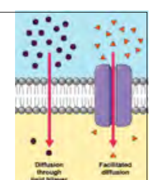

- **Pure water, $\Psi_S$ = 0 MPa.**
  - **1 MPa = 10 atm = ~160 psi**
- **solutes lower $\Psi_S$**
  - **0.1 Osm = –0.23 MPa**
- **Water moves from high Ψ to low Ψ.**

- **pressure potential [$\Psi_P$] could be negative**

## Water and Solute Uptake by Cells

- ❖Water moves across lipid bilayer and through aquaporins
- ❖Ions and small molecules use protein channels and pumps

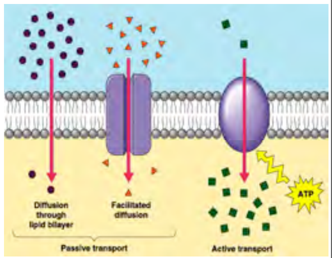
## Selective permeability



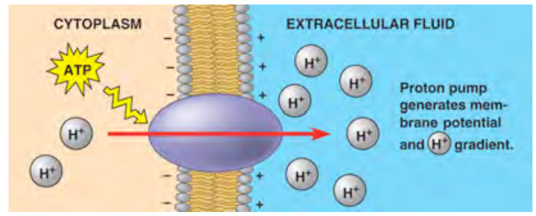
- Except for water and small nonpolar solutes, permeability of cell membranes is **selective** and **regulated**.
- Permeability determined by **transporter proteins**.
  - Channels and carriers are solute specific
  - If no transporter, than that solute cannot cross membrane
- *(Artificial membranes are only semipermeable —i.e., only discriminate based upon molecular size.)*

## Types of cellular transport

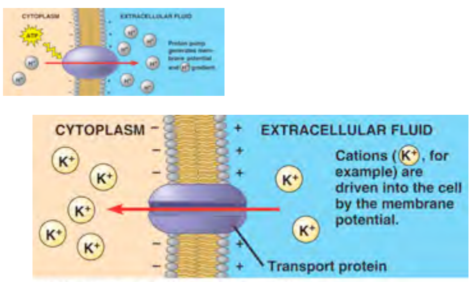
- **Passive transport**: driven by Brownian motion
  - Simple diffusion & osmosis
  - Facilitated diffusion (carrier mediated passive transport)
- **Active transport**: requires chemical energy (ATP)
  - Carrier mediated
  - Can transport <u>against</u> concentration gradient




## Water and Solute Uptake by Cells

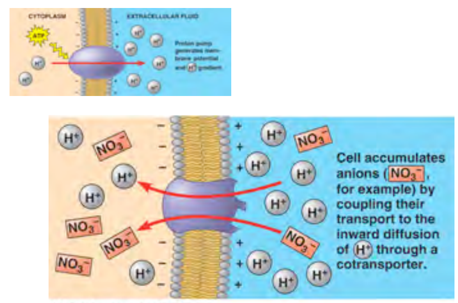



## Water and Solute Uptake by Cells



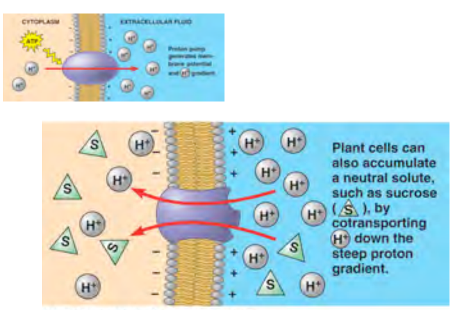

(a) Membrane potential and cation uptake

## Water and Solute Uptake by Cells




(b) Cotransport of anions

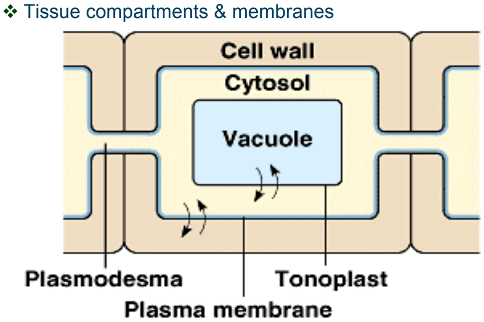
## Water and Solute Uptake by Cells




(c) Cotransport of a neutral solute

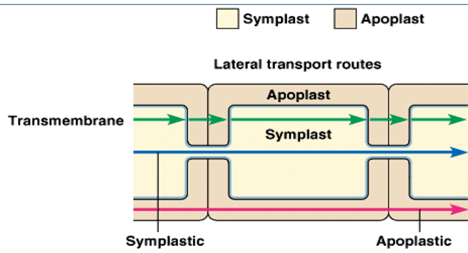
## Water and Solutes — Local Transport

- ❖ Tissue compartments & membranes

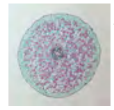


## Water and Solutes — Local Transport

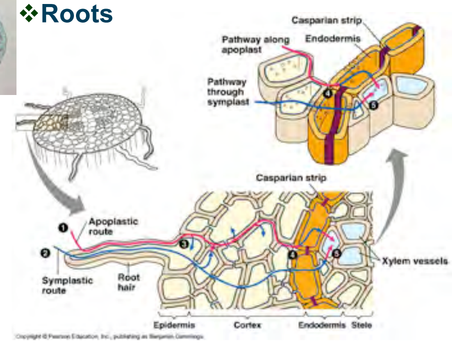
- ❖ **Transmembrane Transport**: from cell-to-cell across plasma membranes [SLOW!]
- ❖ **Symplastic Transport**: from cell-to-cell through plasmadesmata
- ❖ **Apoplastic Transport**: around cells through porous cell walls




## Water and Solutes — Local Transport

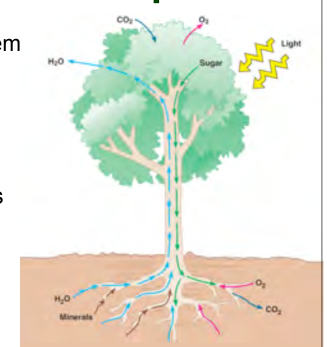


❖**Roots**




## Water and Solutes — Long Distance Transport

- ❖Via xylem and phloem
- ❖**Bulk Flow**: movement of fluids through vessels
- ❖Must generate big pressure differences
- ❖**Where's the pump?**




## Water and Solutes — Xylem Transport

❖Apoplastic movement of xylem sap—*pushing*

**Root Pressure**:

active transport in roots
→ minerals accumulate in xylem
→ water follows
→ ↑ pressure

Limited to 1–2 m, if at all

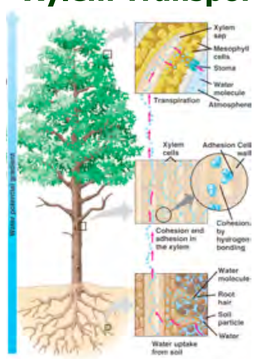
**Guttation**:

root pressure pushes water out leaves

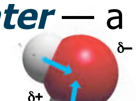
## Water and Solutes — Xylem Transport

❖Apoplastic movement of xylem sap —*pulling*

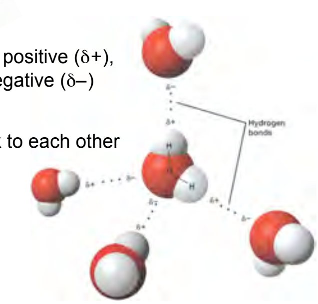
**Transpiration-Cohesion-Tension Mechanism**




## *Water* — a polar molecule

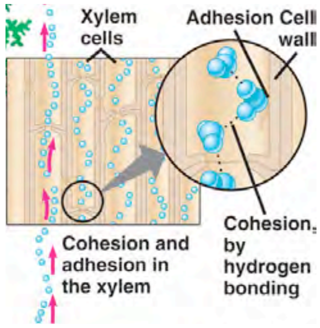



- **Polar:** one end slightly positive (δ+), the other end slightly negative (δ–)
- **Cohesion**:
  - – water molecules stick to each other

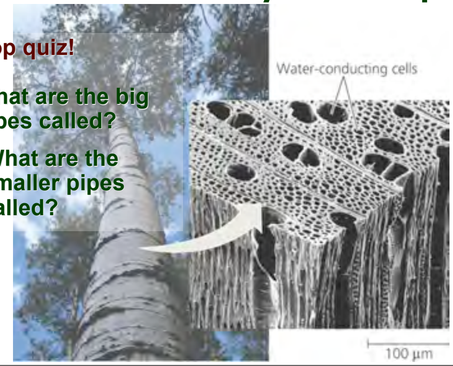


## ***Water*** — a polar molecule

- **Adhesion (wetting):**
  - water molecules are attracted to and stick to other polar molecules
  - Like the cellulose of xylem walls
- **Capillary action**
  - "lead" water molecules attracted to "dry" cellulose for adhesion
  - Pull rest of water along by cohesion




## Water and Solutes — Xylem Transport

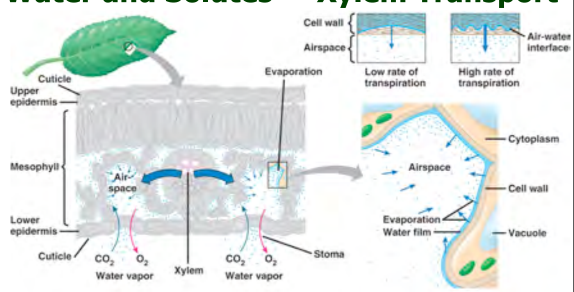



❖ Pop quiz!

What are the big pipes called?

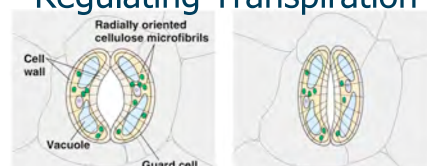
What are the smaller pipes called?

## Water and Solutes — Xylem Transport

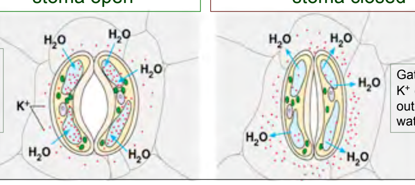



**Transpiration**: the loss of water vapor from the stomata of leaves

## Regulating Transpiration



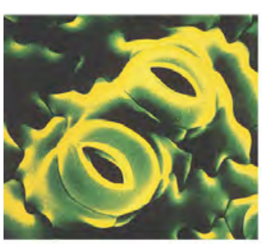

| Guard cells turgid: stoma open | Guard cells flaccid: stoma closed |
|---|---|

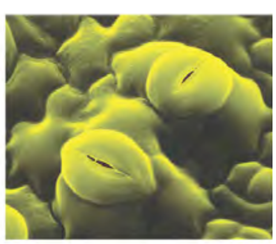



$K^+$ pumped into central vacuole; water follows

Gates allow $K^+$ diffusion out of cell; water follows

## Regulating Transpiration

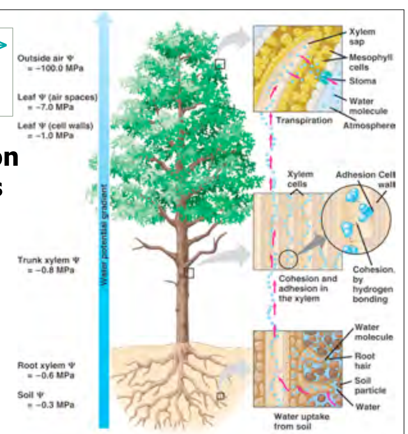




| Guard cells turgid: stoma open | Guard cells flaccid: stoma closed |
|---|---|

**Negative $\psi_p$ → negative $\psi$ in leaves**

**Transpiration pull moves xylem sap upward**



## Water and Solutes — Phloem Transport

❖Movement of phloem sap — *pushing only*

**Translocation:** moving sugar from **sources** to sinks

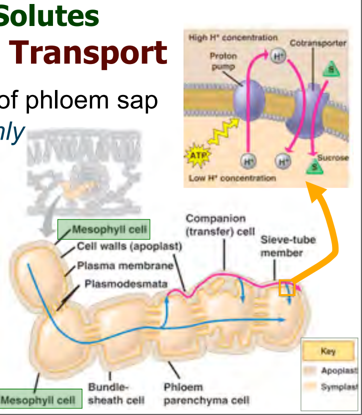



Fig. 36.19 **Leaf local transport: sucrose loading into phloem**

## Water and Solutes — Phloem Transport


**Symplastic Flow**

**Solute [osmotic] potential ($\Psi_s$) creates pressure gradient**

❖ **Source tissue**
- •Photosynthesis or starch breakdown → ↑sucrose [solute] in phloem sap solution → ↓$\Psi_s$
- → Absorb water from xylem → ↑$\Psi_P$ in phloem

❖ **Sink organ**
- •Starch synthesis → ↓sucrose [solute] in phloem sap solution → ↑$\Psi_s$
- →phloem loses water to xylem → ↓$\Psi_P$ in phloem

❖ Bulk flow from ↑$\Psi_P$ to ↓$\Psi_P$ in phloem, from source to sink

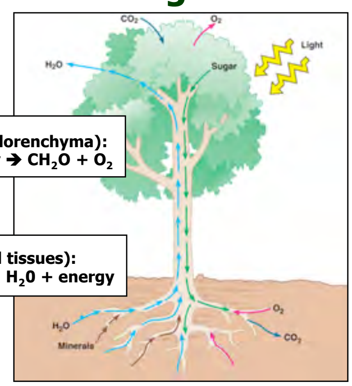
## Gas Exchange

### Why must plants do gas exchange?

**Photosynthesis (chlorenchyma):**
$CO_2 + H_20 + \text{energy} \rightarrow CH_2O + O_2$

**Respiration (all tissues):**
$CH_2O + O_2 \rightarrow CO_2 + H_20 + \text{energy}$

## Gas Exchange

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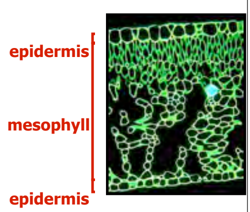
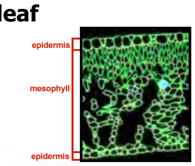
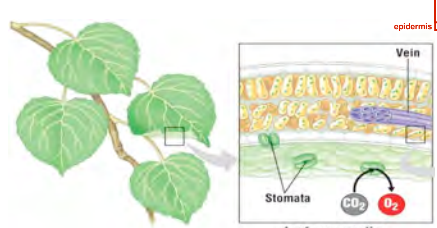
### Photosynthetic mesophyll (chlorenchyma): cells are inside the leaf




### Photosynthetic mesophyll (chlorenchyma): cells are inside the leaf

- Need to deliver adequate $CO_2$ from air to chlorenchyma
- But exposure to dry air causes water loss



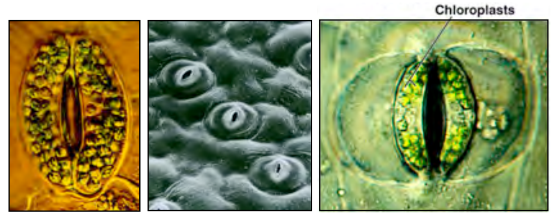
## Air: composition & partial pressures

- $N_2$: 78%; $P_{N_2}$ = 0.78 atm
- $O_2$: 21%; $P_{O_2}$ = 0.21 atm
- $CO_2$: 0.03%; $P_{CO_2}$ = 0.0003 atm

**Other gases bring total up to 1 atmosphere.**

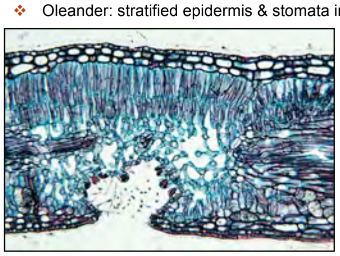
## Gas Exchange & Water Loss

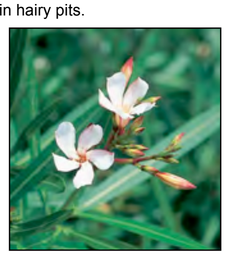
- **High demand for $CO_2$ in leaves in daylight; but water loss is a big problem.**
- **Cuticle limits water loss through epidermis.**
  - **(↑$H_2O$/↓$CO_2$): Stomata open to let air circulate.**
  - **(↓$H_2O$/↑$CO_2$): Stomata close to limit water loss.**




## Gas Exchange & Water Loss

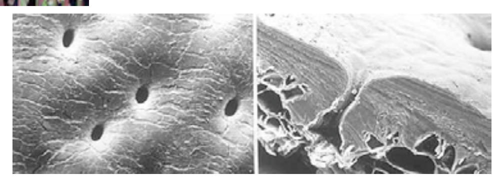
- Plants have tricks to balance gas exchange & water loss.
- **Xerophytes**: plants adapted for low-moisture habitats
  - Desert, windy, seashore
- Oleander: stratified epidermis & stomata in hairy pits.





## Gas Exchange & Water Loss

- Shoot epidermis of the epiphytic cactus *Rhipsalis*
  - Surface view: The crater-shaped depressions with a guard cell each at their base can be recognized.
  - Cross-section: The guard cells are deeply countersunk, the cuticle is extremely thick.

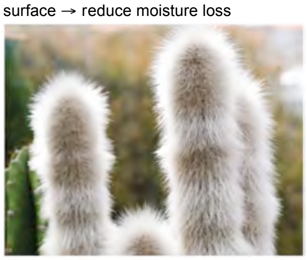


Surface view Cross-section

## Gas Exchange & Water Loss

- Layer of dead, air-filled cells in epidermis
  - Air-pockets are silvery and insulating → keep leaves cool
  - Living tissues displaced from surface → reduce moisture loss
- Trichomes make hairy surface
  - Dense hairs trap humid air

Maui silversword



Old man cactus

## Gas Exchange & Water Loss

- No leaves!

Cactus

- "leaf" primordia → spines
- Photosynthetic stem

Ocotillo

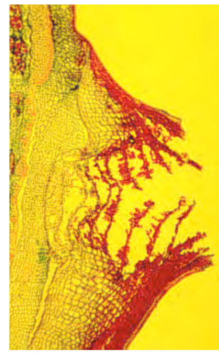
- Leafless most of year
- Small, short-lived leaves in rainy season

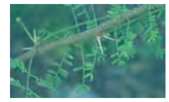
## Gas Exchange & Water Loss

- Some plants store $CO_2$ at night so they can keep stomata closed all day.

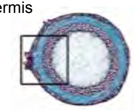
*This is covered in 6B!*

## What about Oxygen?





- **Lenticels**: elongated parenchyma creating air gaps in the peridermal cork
  - permit gas-exchange between the atmosphere and the metabolically active cells below the bark
  - Often develop under site of stoma in primary epidermis



## What about Oxygen?

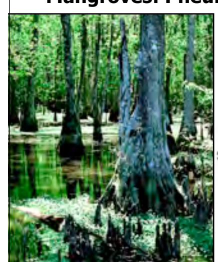
Special issues for submerged plants

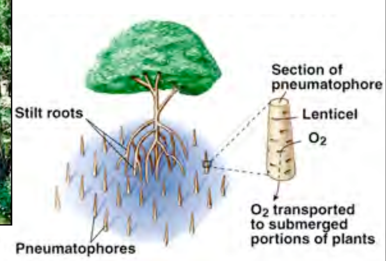
| | 5°C | 35°C |
|---|---|---|
| % $O_2$ in air | 21% | 21% |
| % $O_2$ in water | 0.9%* | 0.5%* |
| $O_2$ in water/air | $^1/_{25}$ x | $^1/_{40}$ x |

* At equillibrium with air. Stagnation may decrease to 0.

## What about Oxygen?

**Mangroves: Pneumatophores carry $O_2$ to roots in mud**



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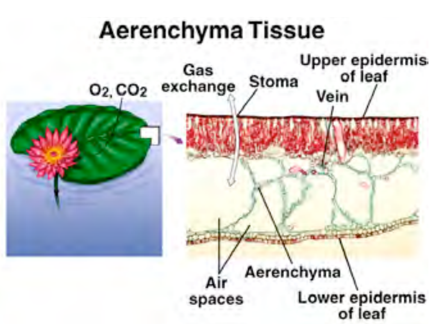


**Some aquatic plants need special tricks for oxygen.**