I. Water and Solute 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
  - \( Osm \rightarrow |water| \)
  - \( Osm \rightarrow |water| \)
  - Osmosis can generate force (osmotic pressure)

II. Local Transport

III. Long Distance Transport

IV. Gas Exchange
Exchange & Transport in Plants

**Water and Solute Uptake by Cells**
- Hypotonic solution: Plant cells flaccid
- Isotonic solution: Normal
- Hypertonic solution: Plant cells turgid

**Water Potential (Ψ)**
- Osmotic pressure pulls water to the right:
- Osmotic potential (ΨS): solution on left has potential energy to push water to the right
- If ΨS & ΨP are equal but opposite → no net flow
  → Ψ = ΨS + ΨP = 0

**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 against concentration gradient

**Water and Solute Uptake by Cells**

- **Water and Solutes — Local Transport**
  - Tissue compartments & membranes

  - Cell wall
  - Cytosol
  - Vacuole
  - Plasmodesma
  - Tonoplast
  - Plasma membrane
**Water and Solutes — Local Transport**

- **Transmembrane Transport**: from cell-to-cell across plasma membranes (SLOW!)
- **Symplastic Transport**: from cell-to-cell through plasmodesmata
- **Apoplastic Transport**: around cells through porous cell walls

**Lateral transport routes**

<table>
<thead>
<tr>
<th>Transmembrane</th>
<th>Apoplastic</th>
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</table>

**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** — 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?

**Regulating Transpiration**

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

**Transpiration**: the loss of water vapor from the stomata of leaves.
**Water and Solutes — Phloem Transport**

- Movement of phloem sap — pushing only

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

![Image of phloem transport](image)

**Symplastic Flow**
- Solute [osmotic] potential ($\Psi_s$) creates pressure gradient
  - Source tissue
    - Photosynthesis or starch breakdown $\rightarrow \uparrow$ sucrose [solute] in phloem sap solution $\rightarrow \downarrow \Psi_s$ in phloem
  - Sink organ
    - Starch synthesis $\rightarrow \downarrow$ sucrose [solute] in phloem sap solution $\rightarrow \uparrow \Psi_s$ in phloem
- Bulk flow from $\uparrow \Psi_s$ to $\downarrow \Psi_s$ in phloem, from source to sink

**Gas Exchange**

**Why must plants do gas exchange?**

**Photosynthesis (chlorenchyma):**

$$\text{CO}_2 + \text{H}_2\text{O} + \text{energy} \rightarrow \text{CH}_2\text{O} + \text{O}_2$$

**Respiration (all tissues):**

$$\text{CH}_2\text{O} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{energy}$$

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

- epidermis
- mesophyll
- epidermis

**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\textsubscript{2}: 78%; P\textsubscript{N\textsubscript{2}} = 0.78 atm
- O\textsubscript{2}: 21%; P\textsubscript{O\textsubscript{2}} = 0.21 atm
- CO\textsubscript{2}: 0.03%; P\textsubscript{CO\textsubscript{2}} = 0.0003 atm

Other gases bring total up to 1 atmosphere.

Gas Exchange & Water Loss
- High demand for CO\textsubscript{2} in leaves in daylight; but water loss is a big problem.
- Cuticle limits water loss through epidermis.
  - (\uparrow \text{H}_2\text{O}/\downarrow \text{CO}_2): Stomata open to let air circulate.
  - (\downarrow \text{H}_2\text{O}/\uparrow \text{CO}_2): Stomata close to limit 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.

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

Gas Exchange & Water Loss
- No leaves!
  - Cactus
    - "Leaf" primordia → spines
    - Photosynthetic stem
  - Ocotillo
    - Leafless most of year
    - Small, short-lived leaves in rainy season

Heyer
Gas Exchange & Water Loss
- Some plants store CO₂ at night so they can keep stomata closed all day.

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

<table>
<thead>
<tr>
<th></th>
<th>5°C</th>
<th>35°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>% O₂ in air</td>
<td>21%</td>
<td>21%</td>
</tr>
<tr>
<td>% O₂ in water</td>
<td>0.9%*</td>
<td>0.5%*</td>
</tr>
<tr>
<td>O₂ in water/air</td>
<td>1/25 X</td>
<td>1/40 X</td>
</tr>
</tbody>
</table>

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

What about Oxygen?
Mangroves: Pneumatophores carry O₂ to roots in mud

What about Oxygen?
Aerenchyma Tissue

Some aquatic plants need special tricks for oxygen.