3. Transport can be active or passive.
   - Passive transport is movement down an electrochemical gradient.
   - Active transport is movement against an electrochemical gradient.

What is an electrochemical gradient?
How is it formed?
Passive and active transport of ions result in electric potential difference across membranes.
- Movement of an uncharged mol is dependent on conc. gradient alone.
- Movement of an ion depends on the electric gradient and the conc. gradient.

Diffusion potential
Pump potential

How do you know if an ion is moving uphill or downhill?

Nernst Eq

What is the driving force for uphill movement?
A) ATP; b) H⁺ gradient

6-5. Pump potential and diffusion potential.

<table>
<thead>
<tr>
<th>Ext Conc.</th>
<th>Ion Internal concentration (mM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>observed</td>
</tr>
<tr>
<td>1 mM</td>
<td>K⁺</td>
</tr>
<tr>
<td>1 mM</td>
<td>Na⁺</td>
</tr>
<tr>
<td>1 mM</td>
<td>Ca²⁺</td>
</tr>
<tr>
<td>0.2 mM</td>
<td>Mg²⁺</td>
</tr>
<tr>
<td>2 mM</td>
<td>NO₃⁻</td>
</tr>
<tr>
<td>1</td>
<td>Cl⁻</td>
</tr>
<tr>
<td>1</td>
<td>H₂PO₄⁻</td>
</tr>
</tbody>
</table>

Summary: In general
- Cation uptake: passive
- Cation efflux: active
- Anion uptake: active
- Anion release: passive
Outline: Major Transport Proteins in Plants

1. **Primary Pumps:**
   \[ H^+ \text{-pumping ATPases} \] are the major ion pumps in plants

2. **Secondary active transport:** 
   \[ H^+ \text{-coupled cotransport} \]
   Energy from \[ H^+ \] gradient is used to drive uphill movement of other nutrients.

3. **Channels** allow rapid, passive transport of ions and metabolites.

4. **Water Channels** or **AQUAPORINS** in membranes that conduct large volumes of water rapidly.

5. **ABC transporters** pump organic molecules.

---

45 P-type ion ATPases in Arabidopsis

3 \( H^+ \) pumps:
- **PM \( H^+ \text{-ATPase} \)**
- **Vac \( H^+ \text{-ATPase} \)**
- **Vac \( H^+ \text{-PPase} \)**

\[ pH \ 5.5 \]
\[ pH \ 7.3 \]
6-15. Taiz. PM-H+-ATPase acidify the cell exterior

- Transmembrane
- 100 kDa
- Arabidopsis:
- 12 genes

From Wilkins et al. 1999. JBC; Sagerman et al 2001. PNAS


From Wilkins et al. 1999. JBC; Sagerman et al 2001. PNAS

6-10 Taiz. Secondary active transport: H+-coupled cotransport

(A) Symport  (B) Antiport
6-11 Taiz. Evidence that glucose uptake depends on H⁺-coupled glucose symport.

**Fig. 6-8.** K⁺ enters cells via a gated channel.

18-8 Stomata. Open and closed state

What controls opening? How?

What controls closing?

18-9 Stomatal Apertures

ABC transporters

ATP-driven transport of organic molecules, heavy metal-conjugates
6-18. How do ions move from exterior to xylem?

Ions are actively taken up into root cells

Xylem loading

---

**Ion Pumps in Arabidopsis**

3 H+ pumps:

- PM H+-ATPase
- Vac H+-ATPase
- Vac H+-PPase

Energy from proton gradient is used for secondary active transport.

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**Box 6-3 Taiz. Measuring H+ pumping in isolated vesicles**

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**Box 6-1 Taiz. Measuring ion flux via channels with patch clamp method**

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