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</th>
<th>Internal concentration (mM) observed</th>
<th>Nernst (Predicted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mM</td>
<td>K⁺</td>
<td>75 mM</td>
<td>74</td>
</tr>
<tr>
<td>1 mM</td>
<td>Na⁺</td>
<td>8 mM</td>
<td>74</td>
</tr>
<tr>
<td>1 mM</td>
<td>Ca²⁺</td>
<td>2 mM</td>
<td>5,000</td>
</tr>
<tr>
<td>0.2 mM</td>
<td>Mg²⁺</td>
<td>3</td>
<td>1,340</td>
</tr>
<tr>
<td>2 mM</td>
<td>NO₃⁻</td>
<td>5 mM</td>
<td>0.02</td>
</tr>
<tr>
<td>1</td>
<td>Cl⁻</td>
<td>10 mM</td>
<td>0.01</td>
</tr>
<tr>
<td>1</td>
<td>H₂PO₄⁻</td>
<td>21</td>
<td>0.01</td>
</tr>
</tbody>
</table>

How can we determine whether an ion moves in or out by active or passive transport?

Nernst equation states that at equilibrium the difference in concentration of an ion between two compartments is balanced by the voltage difference. Thus it can predict the ion conc at equilibrium at a certain ΔE.

Very useful to predict active or passive transport of an ion.

Summary: In general
- Cation uptake: passive
- Cation efflux: active
- Anion uptake: active
- Anion release: passive
Proteins catalyze transport.

Channel, carrier, pump

Primary active transport

Electrochemical potential gradient

Secondary active transport

H+-coupled cotransport
Energy from H+ gradient is used to drive uphill movement of other nutrients. E.g. ions, sugars, amino-acids,

Channels allow rapid, passive transport of ions and metabolites.

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

ABC transporters pump organic molecules. E.g. auxins, Cd-X

Outline: Major Transport Proteins in Plants

1. Primary Pumps: H+-pumping ATPases are the major ion pumps in plants. Ca-pumps. Cu, Zn. Few ions moved by pumps.

2. Secondary active transport: H+-coupled cotransport

Energy from H+ gradient is used to drive uphill movement of other nutrients. E.g. ions, sugars, amino-acids,

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. E.g. auxins, Cd-X

H+ pumps generate a proton electrochemical gradient

3 H+ pumps:

PM H+-ATPase

Vac H+-ATPase

Vac H+-PPase

Why are H+ pumps important?
Evidence for H⁺ pumps

- Cell vac pH is acidic
- Isolated membrane vesicles-ATP generate pH gradient and electrical gradient
- Purify protein & reconstitute activity in liposomes
- Clone gene
- Express & show transport in yeast


Symport: H⁺ + A

Antiport: B + H⁺

How will uptake of A affect the membrane potential? differential gradient?
Active transport of many ions and metabolites is dependent on Secondary active transport: H⁺-coupled cotransport (Fig. 6-11)

Model of an antiporter

Channels allow rapid passive diffusion of ions. Fig. 6-15. K⁺ enters cells via a gated channel.

Taiz. Evidence that Glucose uptake depends on H⁺-coupled glucose symport

Channels are gated by
- voltage,
- Ligands: Ca, hormone, ATP, Glutamate

Web topic. Box 6-1 Taiz. Measuring ion fluxes via channels with patch clamp method. Measures current (movement of a + charge)

Voltage-gated current. Evidence for K⁺ conductance
Aquaporin: water channel

Proteins that conduct fast diffusion of water down its water potential gradient.

Experimental evidence.
How do you prove this?
1. Express a candidate gene in an animal cell.
2. Put cell in dilute solution.
3. Measure swelling...... Until boom!

Nobel Laureates in Chemistry 2003
"for discoveries concerning channels in cell membranes"

Agre
"for the discovery of water channels"

McKinnon
"for structural and mechanistic studies of ion channels"

Putting all the info. together
How is a nutrient transported into roots?
How do guard cells open and close?

How does a mineral nutrient move from root to leaf?
a. Movement into root.  
Consider the mode of transport at each stage.  
Passive, active, and type of transport protein?
b. Up the xylem in the stem to the leaf

c. Movement into mesophyll.

Solutes move through apoplast and symplast

Ion transport into roots

Xylem loading by xylem parenchyma cells.
18.8. Stomata. Open and closed state

What controls opening? How? Increase in turgor pressure

What controls closing?

18.9. Stomatal opening tracks photosynthetic active radiation at the leaf surface

Light stimulates stomatal opening

How?

Draw on board

18.13. Acidification of a suspension medium of guard cell protoplasts of *V. faba*

- Membrane potential hyperpolarize.
- K+ conc. Increase 100 mM → 400 mM
- Anions: Cl- and malate increase
- Water potential drops, water enters
- Guard cells increase their turgor pressure
- Stomata open.
**Closure**

- How?


Closing stomatal aperture: the long-term efflux of both anions and K+ from guard cells contributes to the loss of guard cell turgor, leading to stomatal closing.

**Lab. - guard cell movement**

1. Test effect of light versus dark on stomatal aperture
2. Determine which ion or solute is needed for stomatal opening: KCl, choline Cl, or mannitol
3. Determine the effect of a stress hormone, ABA, on stomatal aperture.

**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.