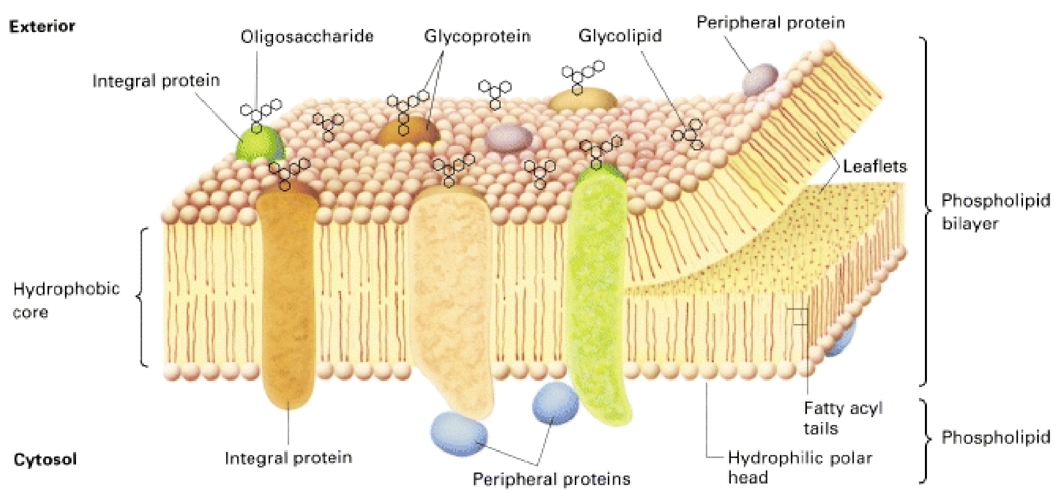
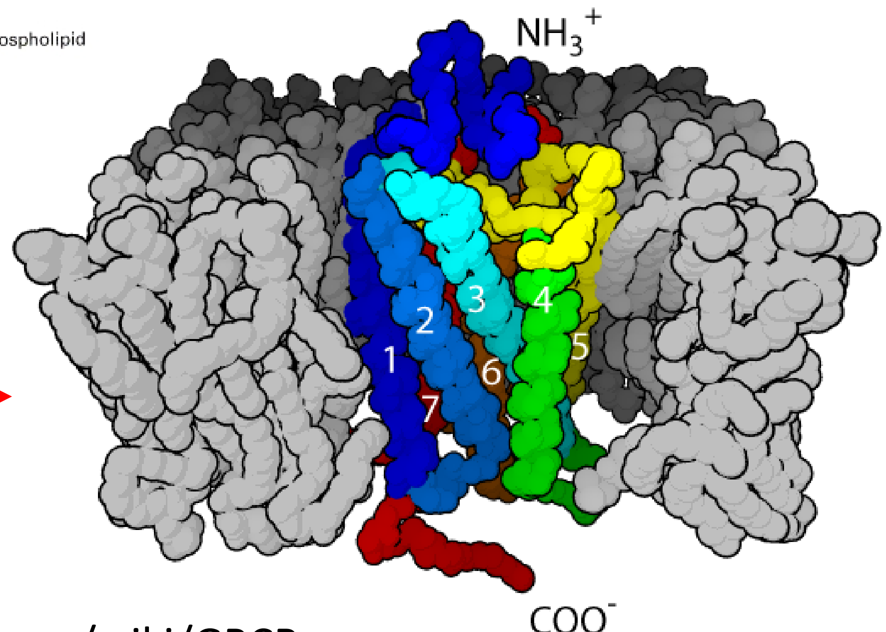
Membrane Proteins



Review of Membrane Proteins

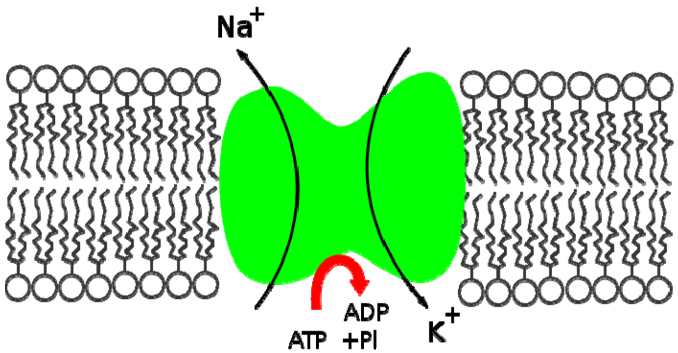
G Protein-Coupled Receptor

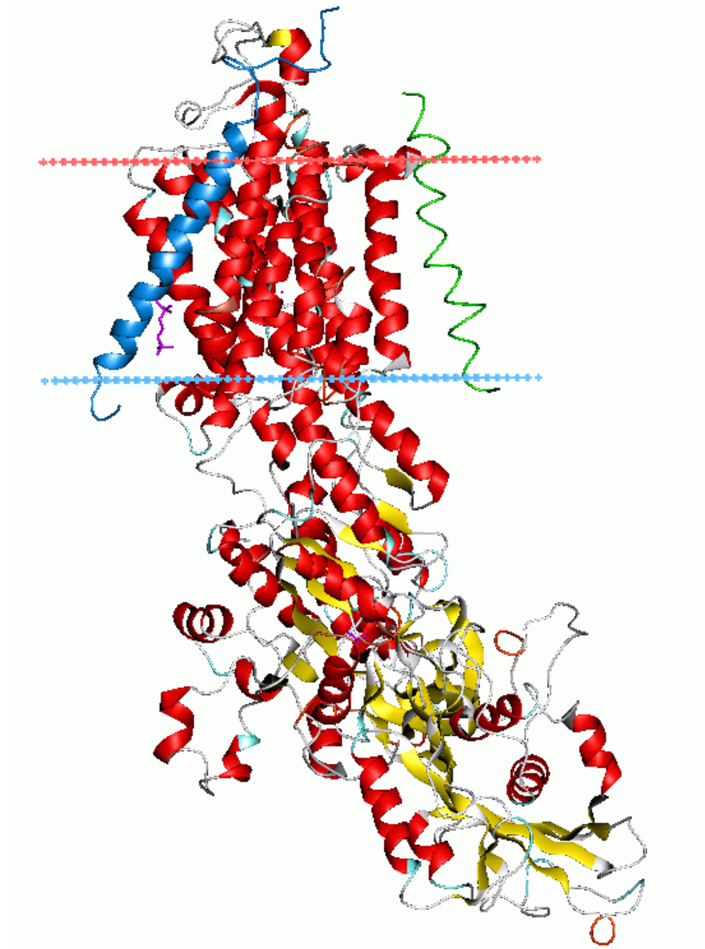


Target of 40% of drugs!

Lodish, Mol. Cel. Biol. 4th ed.; http://en.Wikipedia.org/wiki/GPCR

Another Example: Na-K ATPase





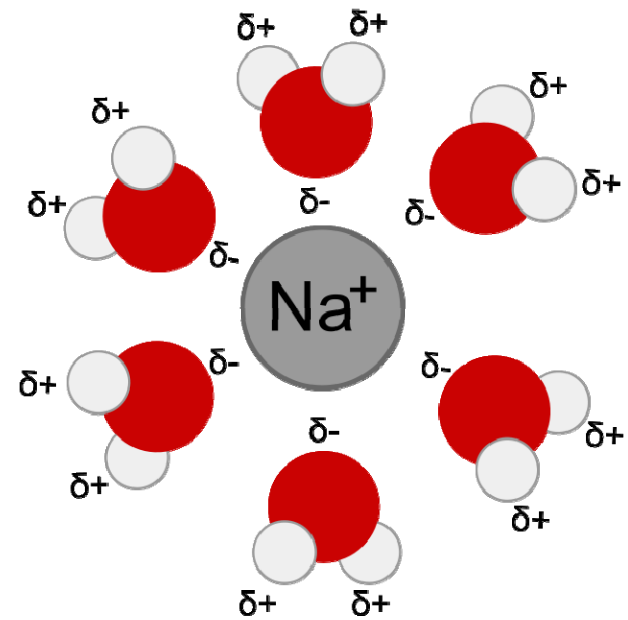
- Chemical potential: $\mu \propto RT \ln[\mathrm{Na}^+]$
  - Chemical work (hydrolysis of ATP)
  - Coupled reaction: transport of Na^+, K^+ ions ($\Delta\mu = \mu_{out} - \mu_{in}$)

- What about charge?
  - Ions will move (current)
  - Different # of ions in and out (voltage)

Source: *Wikipedia*

Review: Charges

- Unit of charge: 1 Coulomb (C)
  - Electron (e^-) has charge of -1.6022×10^{-19} C
  - Proton (H^+) has charge of $+1.6022 \times 10^{-19}$ C



- **Faraday constant:** Charge of a mole of ions

$$F = 9.64853 \times 10^4 \text{ C mol}^{-1}$$

http://en.wikipedia.org/wiki/Solvation_shell

Review: Electricity

- **Current (I):** Flow of electrons through a wire (charge per unit time)
  - Unit is Ampere ($C\ s^{-1}$)

- **Voltage (V):** Energy stored in an electric field for a given amount of charge (also called potential)
  - Unit is Volt ($J\ C^{-1}$)

- **Power (P):** Energy dissipated per unit time ($P = I \cdot V$)
  - Unit is Watt ($J\ s^{-1}$)

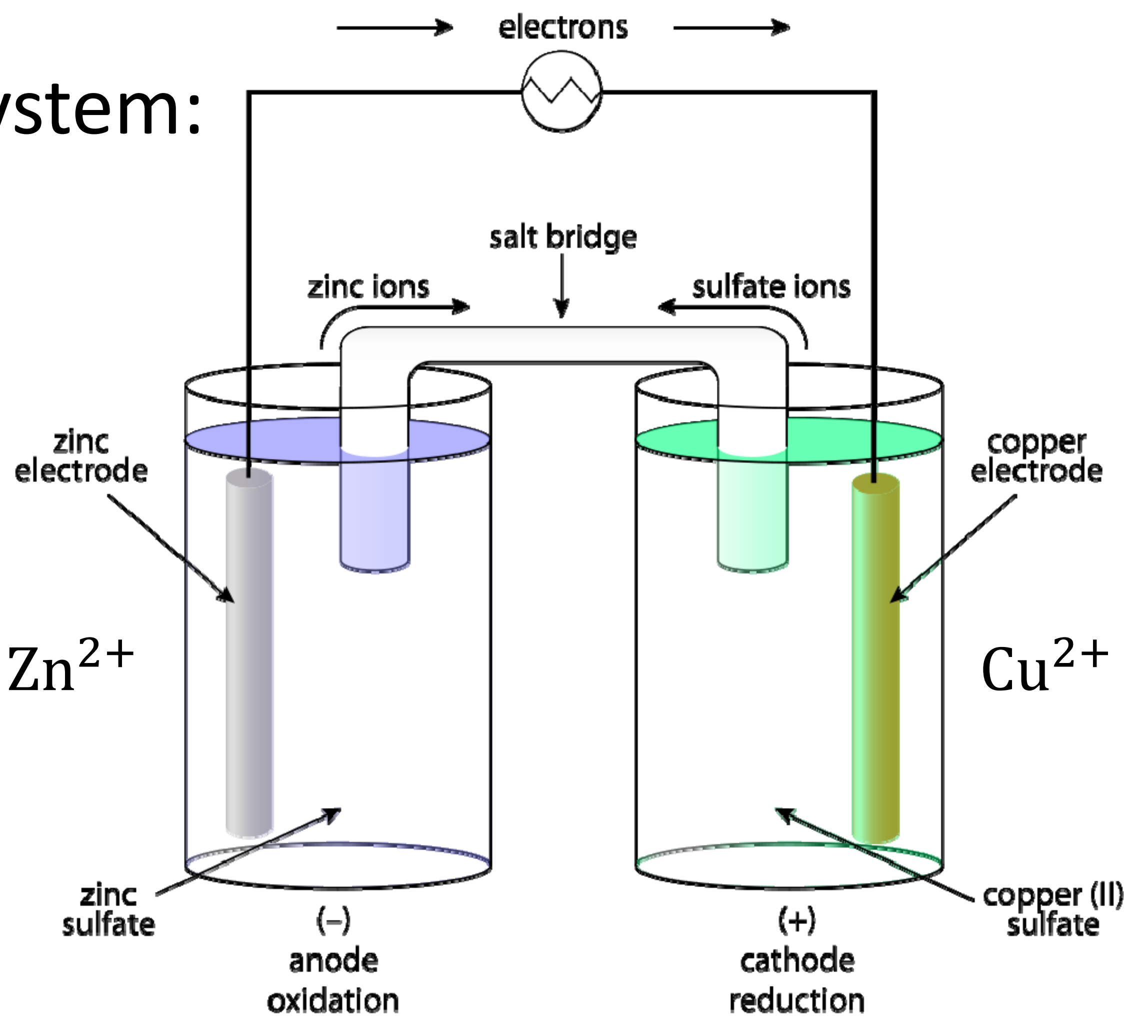
Electrochemistry and Galvanic Cells

- Certain chemical reactions result in transfer of electrons from one compound to another (oxidation-reduction)
- **What if:** What if we could couple electron transfer to current going through a wire?
- **We could measure chemical work (dw^* and ΔG) by measuring the electrical work!**
  - Doesn't work for all reactions, even all redox reactions

Electrochemistry and Galvanic Cells

- The system:

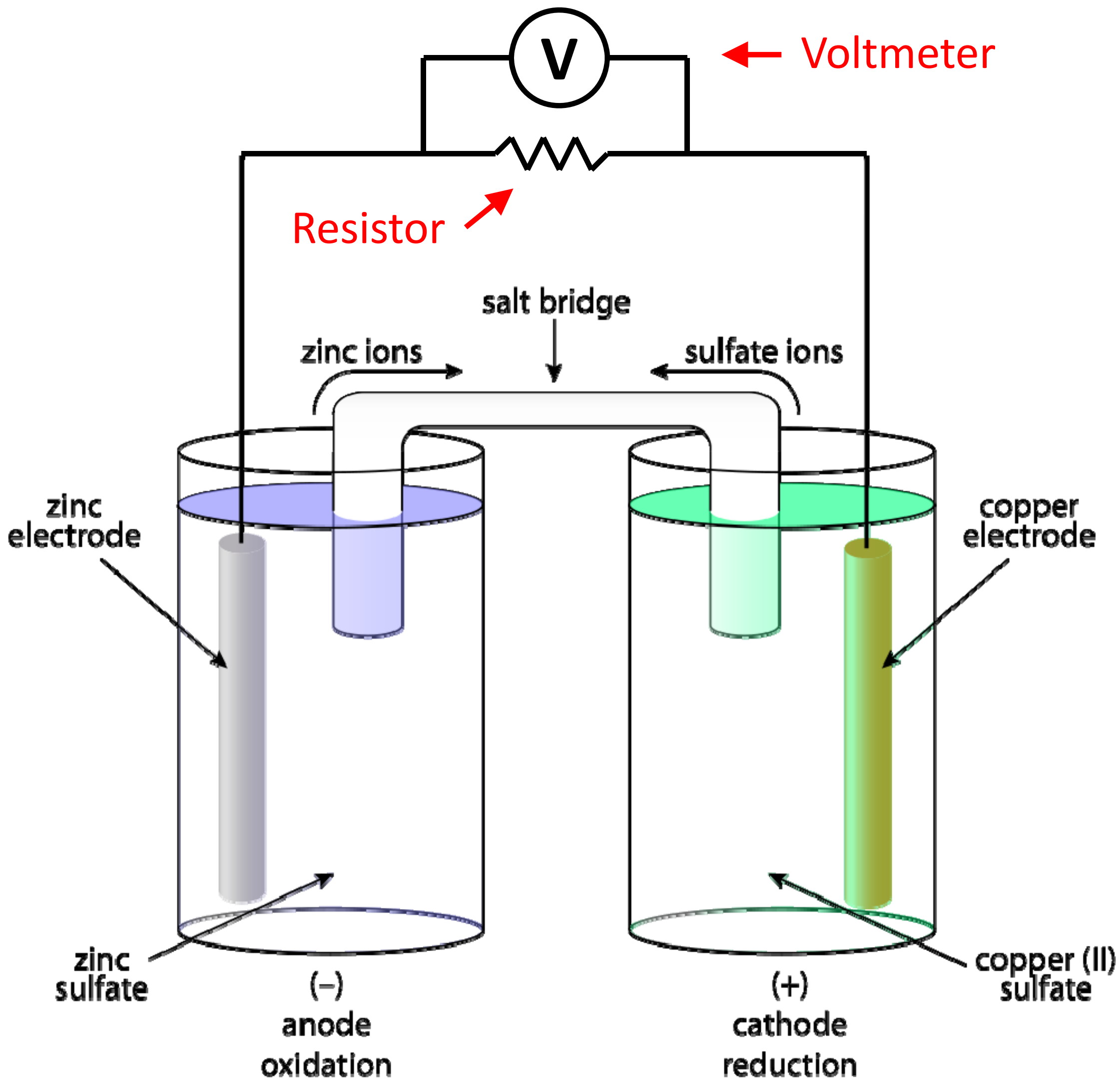
$$\mathrm{Zn} \rightarrow 2\mathrm{e}^{-} + \mathrm{Zn}^{2+}$$



$$\mathrm{Cu}^{2+} + 2\mathrm{e}^{-} \rightarrow \mathrm{Cu}$$

http://en.wikipidia.com/wiki/Galvanic_cell

Non-PV Work in Galvanic Cells



- For a voltage ξ, if n electrons transferred from anode to cathode:
  $$dw^* = -nF\xi$$
- At const T and P, remember:
  $$\Delta\bar{G} = dw^*$$

http://en.wikipidia.com/wiki/Galvanic_cell

Convention: Galvanic Cells

Phase Boundaries

Salt Bridge

$$Zn(s)\ |\ ZnSO_4\,(1M)\,||\,CuSO_4\,(1M)\ |\ Cu(s)$$

Anode
(where oxidation occurs,
net electron loss)

Electrolyte solutions
(with concentrations)

Cathode
(where reduction occurs,
net electron gain)

Reaction and Equilibrium

- Overall Reaction is:

$$\mathrm{Zn(s)} + \mathrm{Cu^{2+}(aq)} \rightarrow \mathrm{Zn^{2+}(aq)} + \mathrm{Cu(s)}$$

- Equilibrium constant (at equlibrium):

Pure Substance

$$K_{eq} = \left(\frac{[\mathrm{Zn^{2+}}][\mathrm{Cu}]}{[\mathrm{Zn}][\mathrm{Cu^{2+}}]}\right)_{\mathrm{eq}}$$

Pure Substance

- Reaction quotient (not at equilibrium):

$$Q = \frac{[\mathrm{Zn^{2+}}]}{[\mathrm{Cu^{2+}}]}$$

Relating ΔG and $\mathcal{E}$

- As before, we know (at const T, P):

$$\Delta\bar{G} = \Delta\bar{G}^0 + RT\ln Q$$

- Remember previous result:

$$\Delta\bar{\mathrm{G}} = -nF\mathcal{E}$$

Electrochemistry and Galvanic Cells

- Converting our "Gibbs equation" to volts:

$$\mathcal{E} = \mathcal{E}^0 - \frac{RT}{nF} \ln Q$$

- Special notes:
  - This is called the "Nernst Equation"
  - F is "Faraday's number," or 96,485 C mol^{-1}
  - *n* is the **total # of moles of electron per mole of reaction** (remember $d\alpha$ reaction variable)
  - Positive voltage is a spontaneous process

Electrochemistry Example

- Copper/Silver Galvanic Cell:

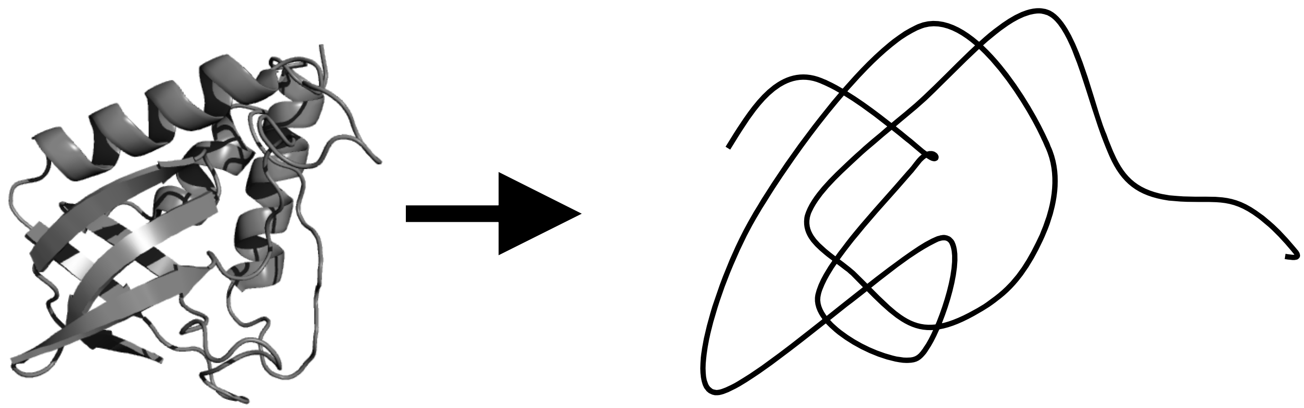
$$Ag^{+} + e^{-} \rightarrow Ag \qquad \mathcal{E}^{0} = 0.799\ \mathrm{V}$$

$$Cu^{2+} + 2e^{-} \rightarrow Cu \qquad \mathcal{E}^{0} = 0.337\ \mathrm{V}$$

- What is the standard state free energy for a Cu/Ag galvanic cell? Is Ag the cathode or the anode?

Probabilities: Moving toward statistical thermodynamics

- Protein folding:



- What does $\Delta\bar{G}^0$ tell us about this system *at equilibrium?*

Folding vs. ΔG^0

$\Delta\overline{G}^0$ (kcal mol^{-1})	$\Delta\overline{G}^0$ (kJ mol^{-1})	K (at 298 K)	% Folded
15	63	1×10^{-11}	~100
10	42	5×10^{-8}	99.999995
5	21	2×10^{-4}	99.98
0	0	1	50
-5	-21	5×10^{3}	0.02

- What does it mean if a protein is 50% folded?