Cell Membrane

- Provides a boundary separating the internal structures from its external environment
- Selectively permeable, permitting the free passage of some materials, and restricting the passage of others
- Double layer (i.e., bilayer) of phospholipid molecules (그림)
- Lipid: water-insoluble, energy rich macromolecules, fats, waxes, oils
- Globular proteins in membrane: free to move within the layer
- Channels: protein-lined pores.
- Water-filled pores
- Intracellular and extracellular fluid: solution of dissolved salts (NaCl and KCl) which dissociate into Na+, K+, and Cl-
- Molecules transported across the cell membrane by passive and active processes

- Active process requires energy, ATP
- Passive process by inherent random movement of molecules
- Three passive processes
  - Osmosis: water transport
  - Diffusion: small molecules
  - Carrier-mediated diffusion: (그림)
- Active process
  - Against concentration gradient
  - Thus require energy
  - Na+-K+ pump
  - The pump uses energy stored in ATP to pump Na+ out of the cell and K+ in
  - Let’s look at the how membrane potential is caused by the movements of Na+ and K+

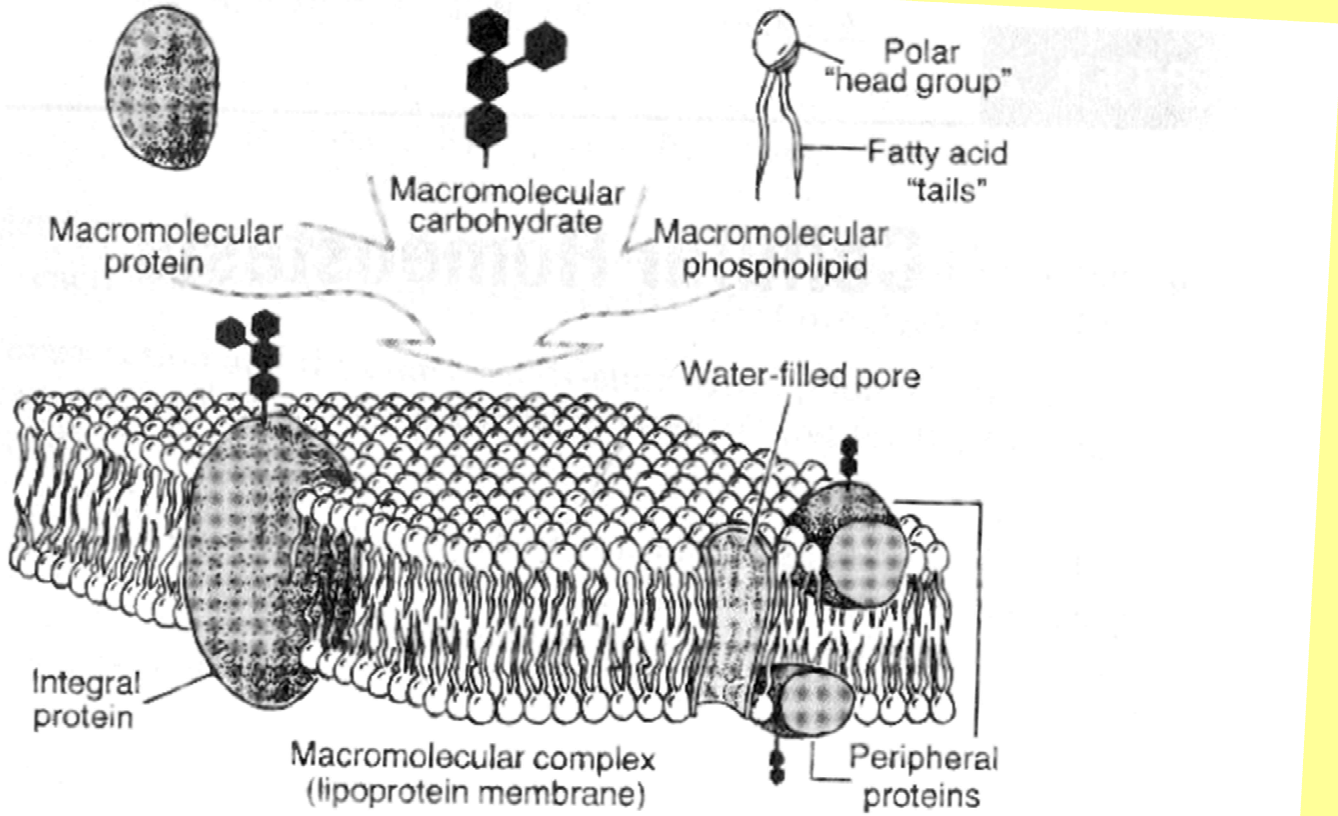
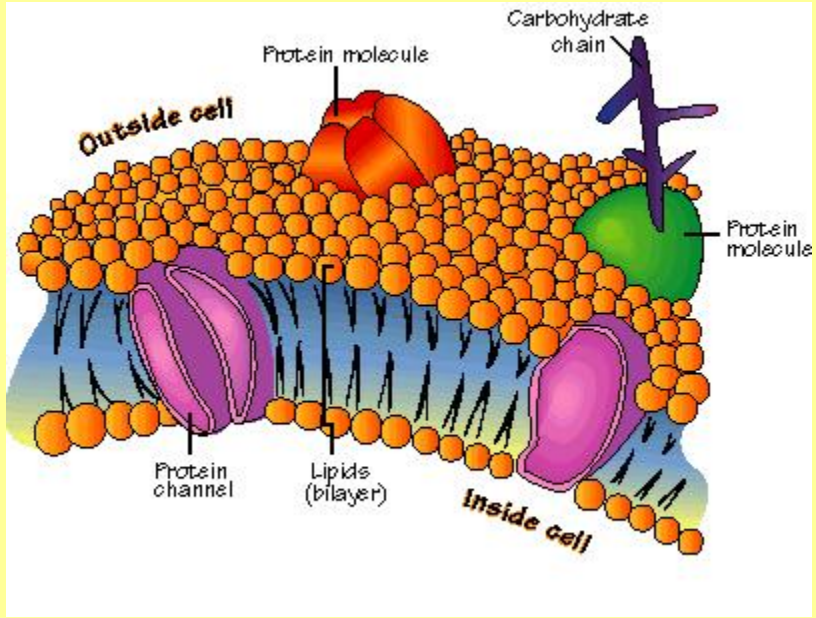


Figure 2.1 Schematic diagram of the cell membrane. (Davis et al., 1985, Fig. 3-1, p. 41.)


Carbohydrate chain
Protein molecule
Outside cell
Protein molecule
Protein channel
Lipids (bilayer)
Inside cell

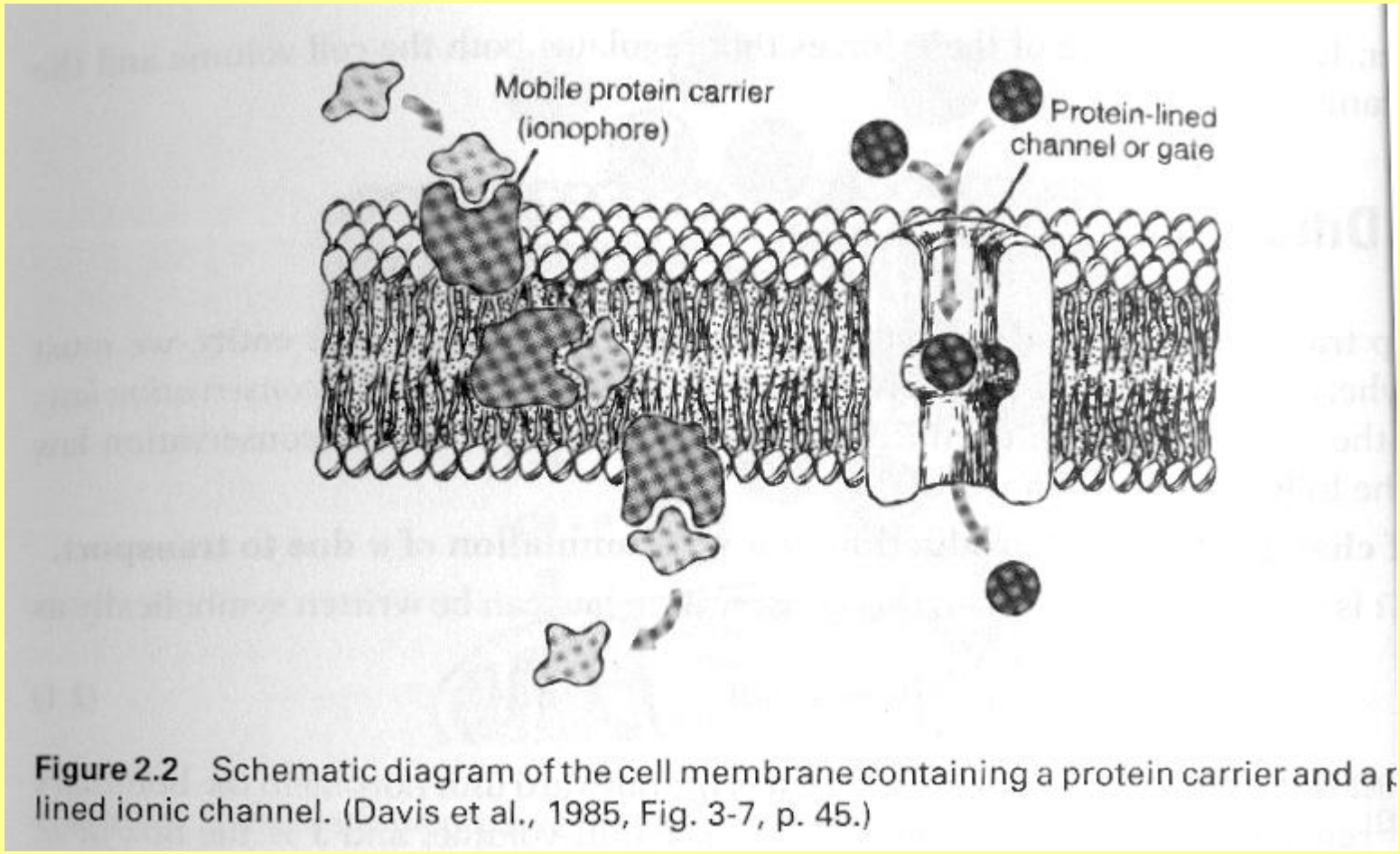


Figure 2.2 Schematic diagram of the cell membrane containing a protein carrier and a p
lined ionic channel. (Davis et al., 1985, Fig. 3-7, p. 45.)

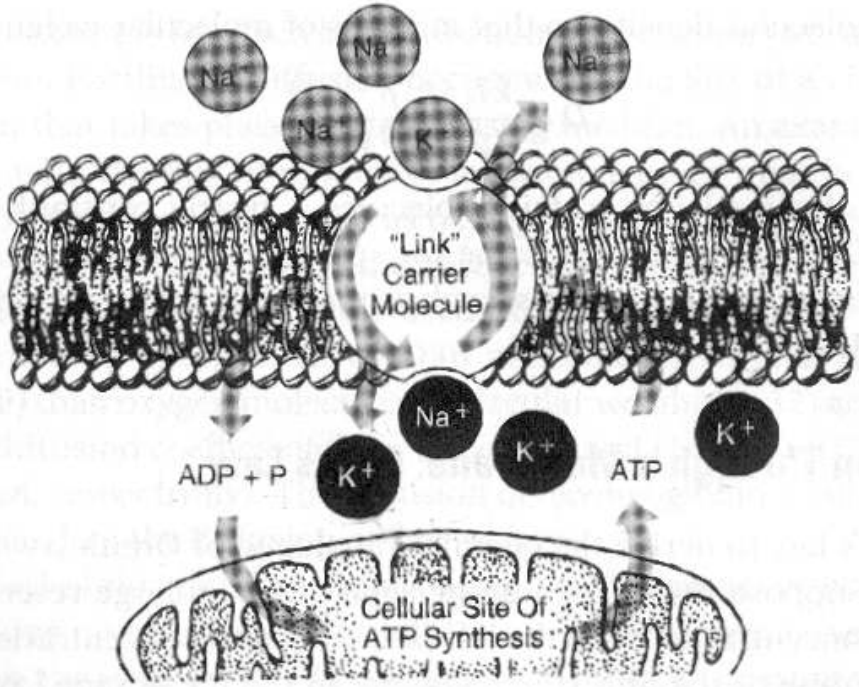
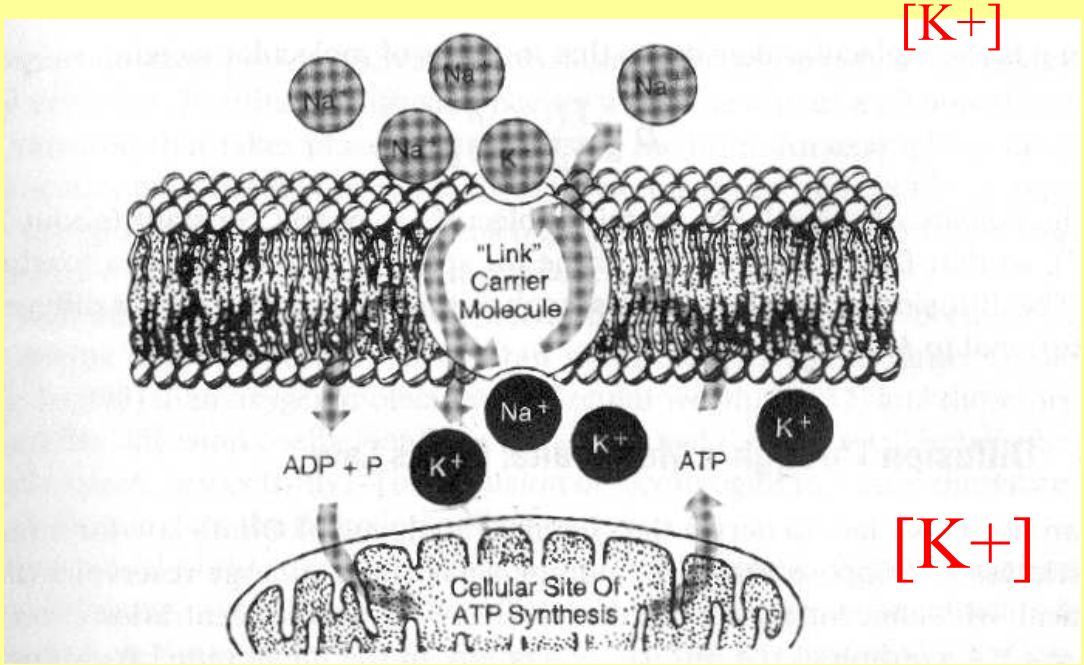


Figure 2.3 Schematic diagram of the cell membrane containing a $Na^+ - K^+$ pump. (Davis, et al., 1985, Fig. 3-11, p. 49.)

- The resting membrane potential is generated by (1) differential distribution of ions (2) selective permeability
- Differential distribution of Na+ and K+ maintained by Na+-K+ pump
- 2 opposing forces for ion flux thru an open channel (1) chemical concentration (2) electrical gradient
- Equilibrium potential for K+: two forces acting on K+ ions exactly oppose each other

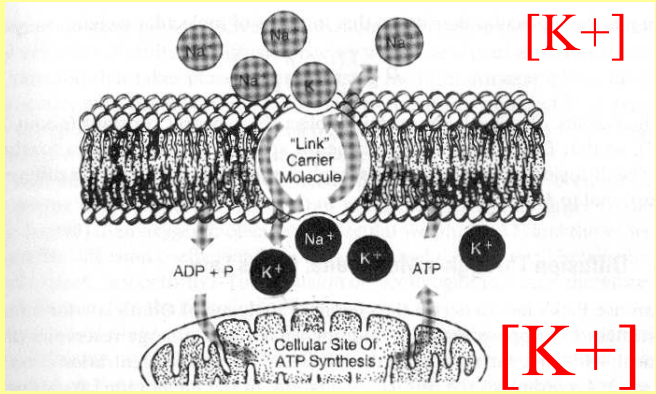


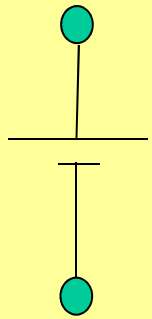
Nernst Equation

- In 1888, Walter Nernst, a German physical chemist derived an equation to calculate the equilibrium potential for an ionic battery
- Equilibrium potential = Nernst Potential
- For K+

$$E_{K+} = \frac{RT}{ZF} \ln \frac{[K+]_o}{[K+]_i}$$

  - R = Gas Constant
  - T = Temperature (degree Kelvin)
  - Z = Ionic Valence
  - F = Faraday Constant
  - [K+]o = K+ Concentration outside cell
  - [K+]i = K+ Concentration inside cell



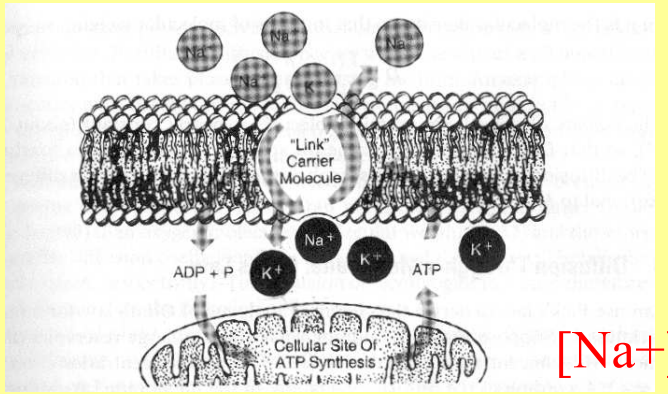


$E_{k+} \cong$ -75mV

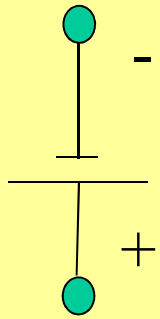
- The membrane potential (Vm) may not be at the equilibrium potential (E) of an ion, Thus, a net driving force exists
- For K+: Vm – E_{k+}

- Cell membranes are permeable to a number of ions. The ionic battery of each permeable ion contributes to the resting membrane potential

[Na+] out



[Na+] In



$E_{Na+} \cong +55mV$

Goldman Equation

- Goldman-Hodgkin-Katz Voltage Equation, simply Goldman Eq.
- The number of channels open for specific ions varies
- Thus, the permeability of the membrane for different ions varies
- P_{k+}:P_{Cl-}:P_{na+}=1.0:0.45:0.04
- The cell membrane is 25 times more permeable to K+ ions than Na+ ions
- The relative permeability of each ion determines its influence on the membrane potential
- Goldman equation is used to calculate Vm

$$V_m = \frac{RT}{F} \ln \frac{P_{K+}[K+]_o + P_{Na+}[Na+]_o + P_{Cl-}[Cl-]_i}{P_{K+}[K+]_i + P_{Na+}[Na+]_i + P_{Cl-}[Cl-]_o}$$

- The number of open channels can be changed by voltage-dependent or ligand-dependent gating
- This changes the relative permeability of the membrane.
- This is the basis for electrical signaling

Nernst Equation:

Relation of the diffusion potential to the concentration difference

&

Goldman Equation:

Diffusion potential when the membrane is permeable to several different ions