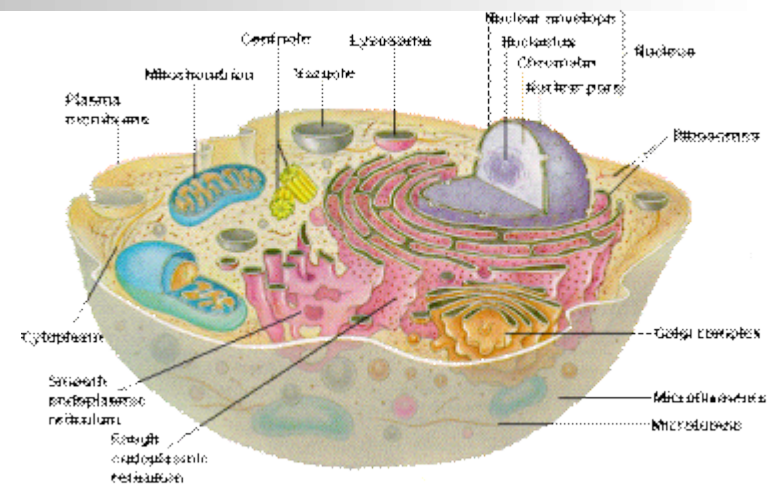


Chapter 2

Basic Functions of Cells

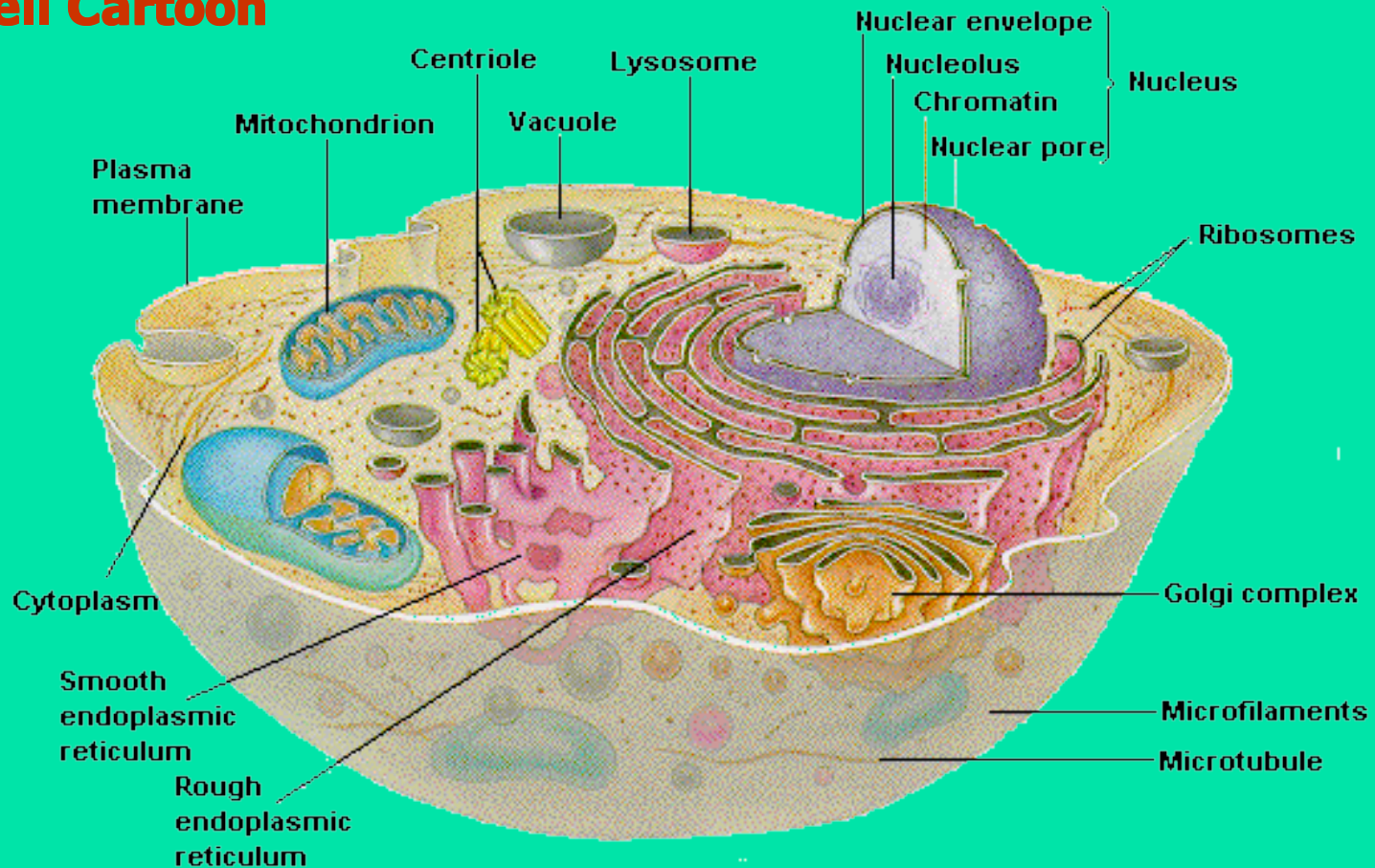
Lei CHEN (陈蕾)

Email: chenleiqd@163.com



Cell— Basic structural and functional unit

Cell Cartoon



(Taken from *Human Biology* by Daniel Chiras)



Basic Functions of Cells

- **Transport of molecules across cell membranes**
- **Cellular signal transduction**
- **Bioelectrical phenomena of cells**
- **Mechanisms of muscular excitation and contraction**

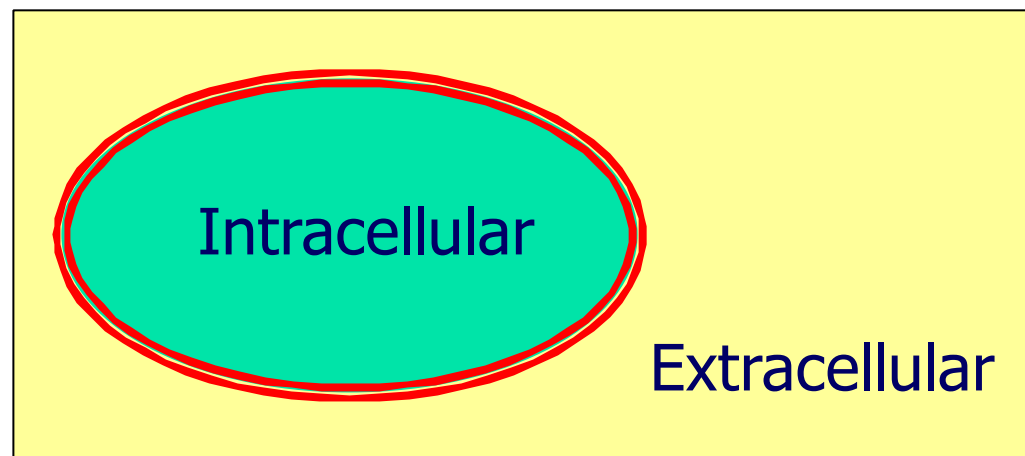


Section 1

Transport Across Cell Membranes

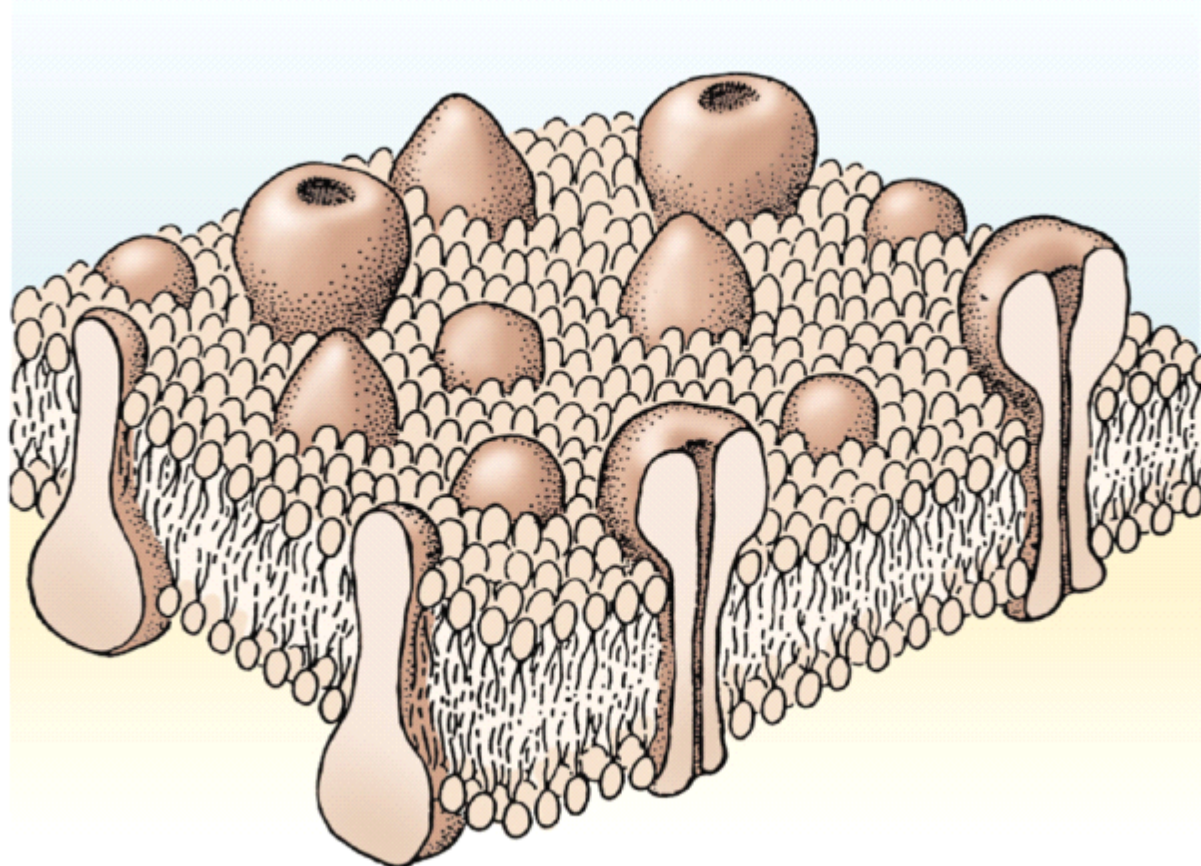
Basic function of cell membrane

- Acting as a selective barrier
- Regulating the passage of substances into and out of the cell
- Detecting chemical signals from other cells



The structure of the cellular membrane

1972 Singer and Nicholson **Fluid mosaic model**

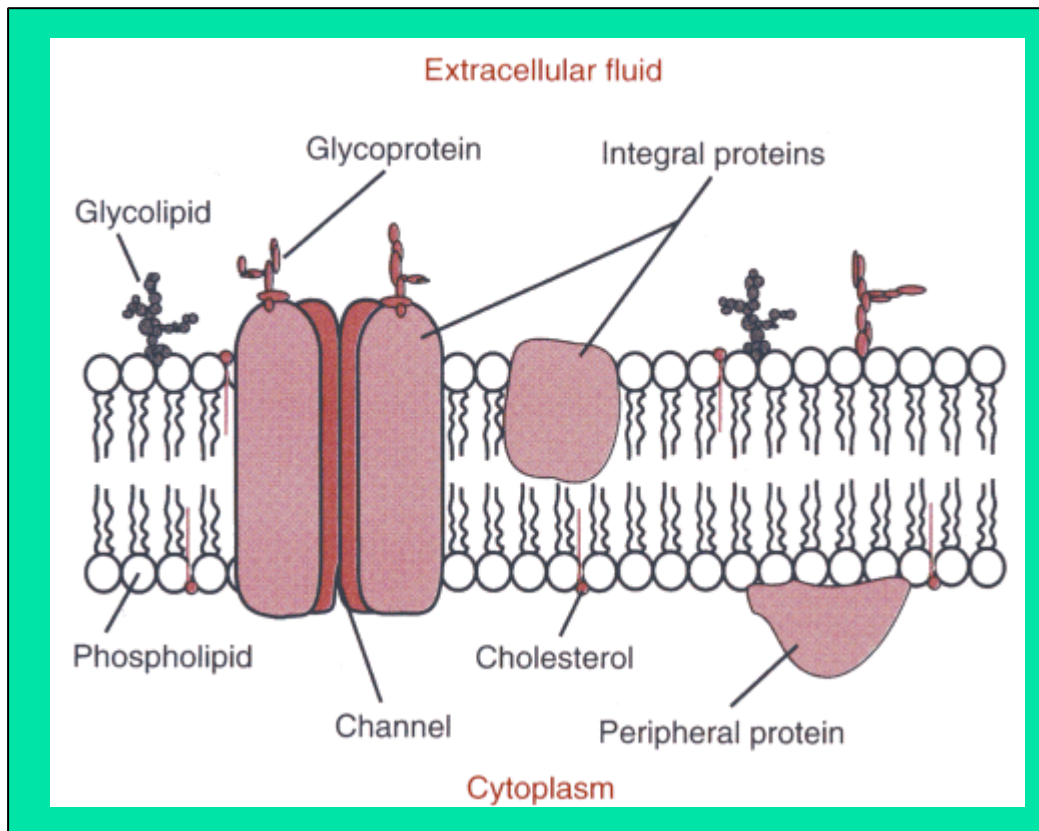




The structure of the cellular membrane

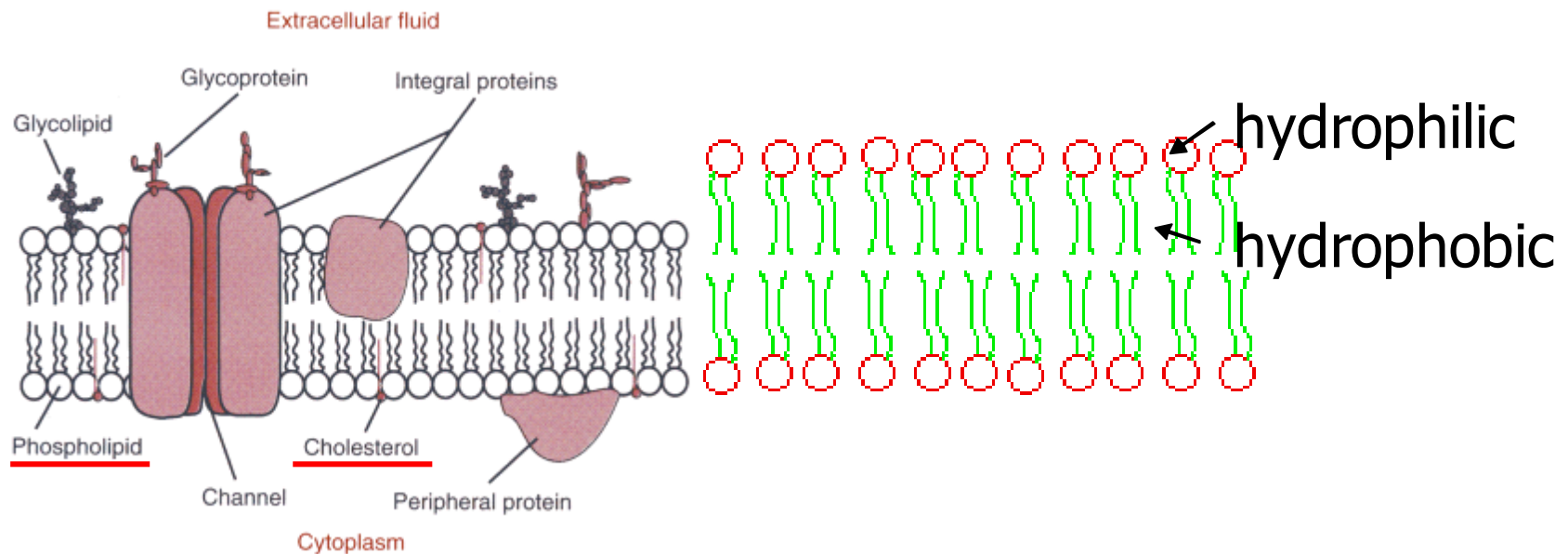
Fluid mosaic model: cell membranes consist of proteins embedded in lipid bilayer that has the physical properties of a fluid, allowing membrane proteins to move laterally within it.

The structure of the cellular membrane



- Protein: 55%
- Phospholipids: 25%
- Cholesterol: 13%
- Other lipid: 4%
- Carbohydrates: 3%

Lipid bilayer

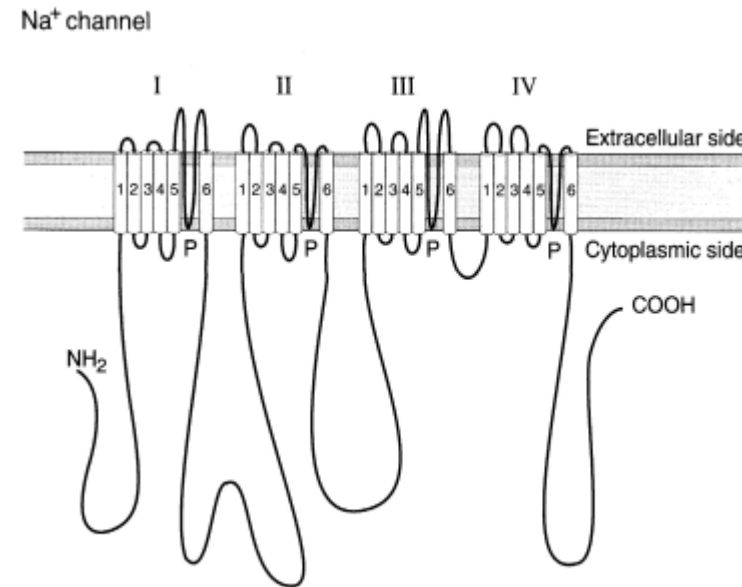
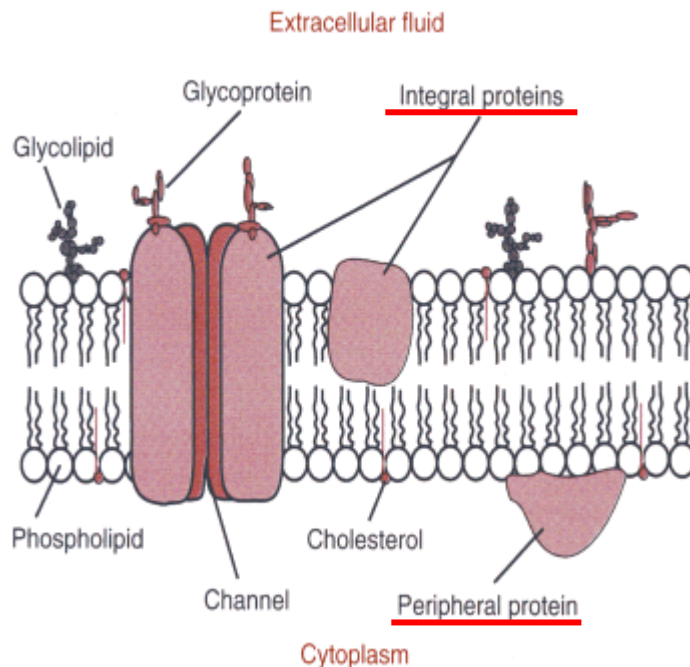


Phospholipid
cholesterol

} **amphiphilic molecule**

Membrane proteins

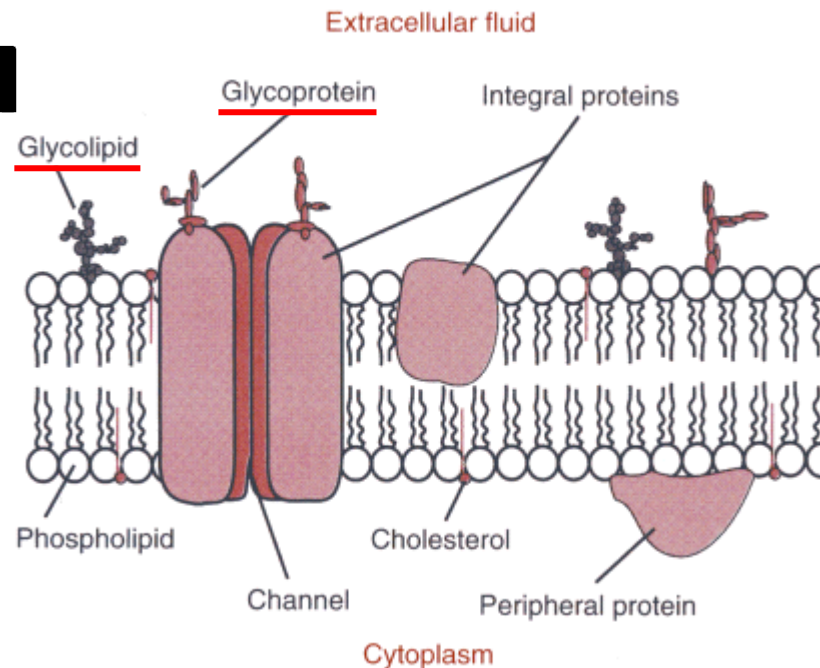
- **Integral proteins : 70~80%. Carrier, channel, ion pump, transporter.**
- **Peripheral proteins : 20~30%. Enzymes**



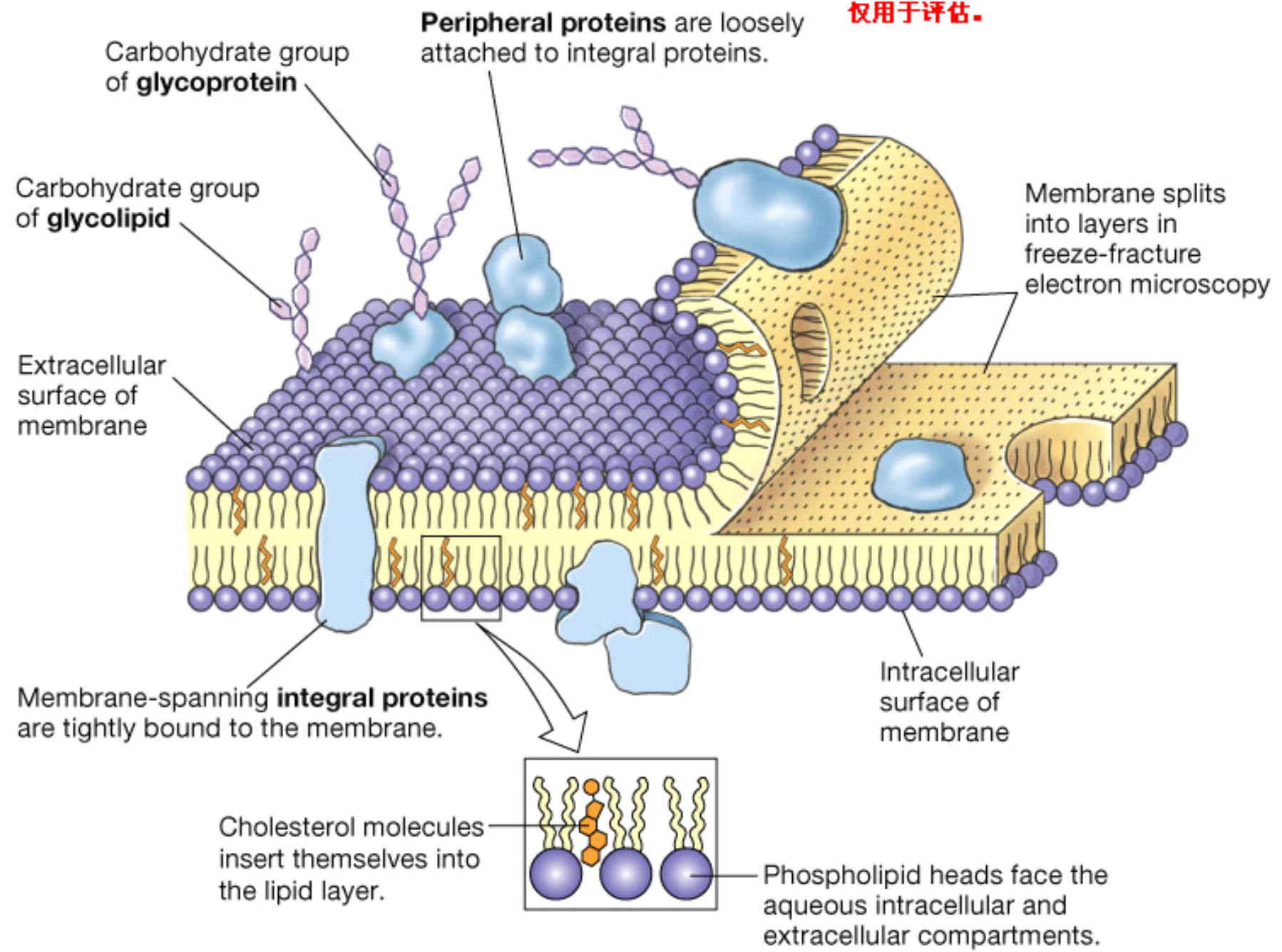
α -helical conformation

Membrane carbohydrates

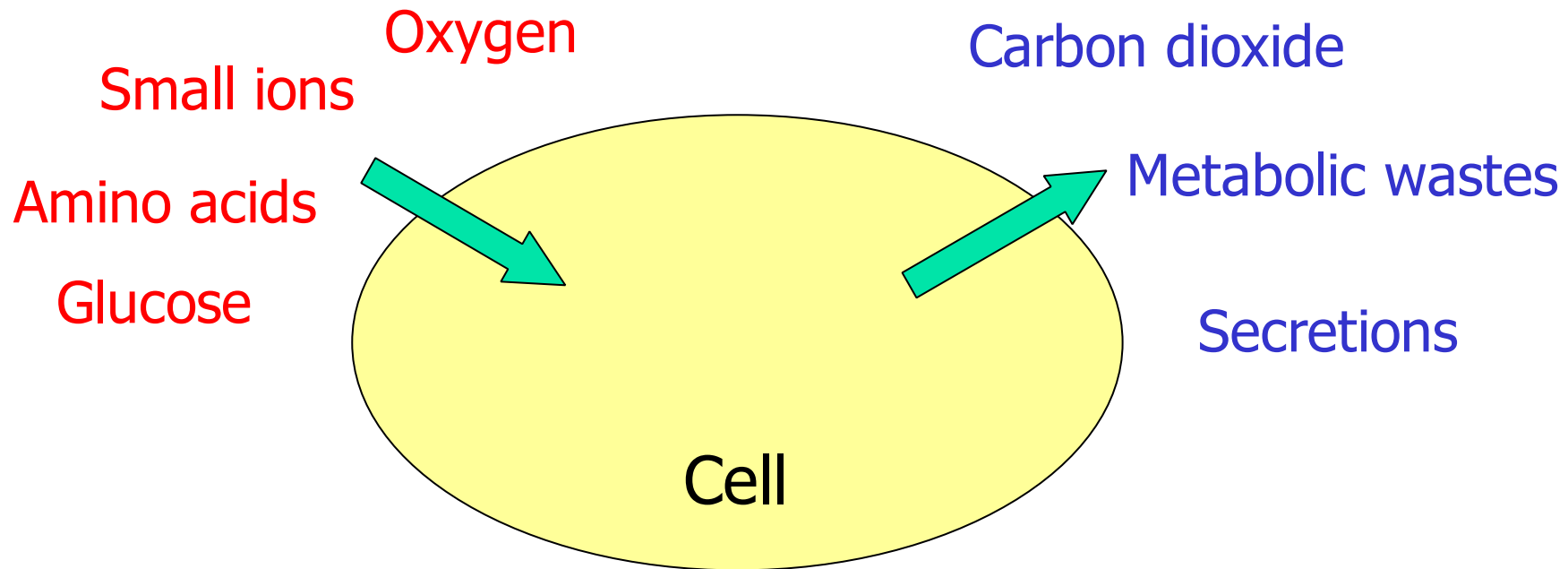
- **Glycoprotein**
- **Glycolipid**



Expose to the extracellular fluid, serve as highly specific recognition sites.



Transport of substances through the cell membrane

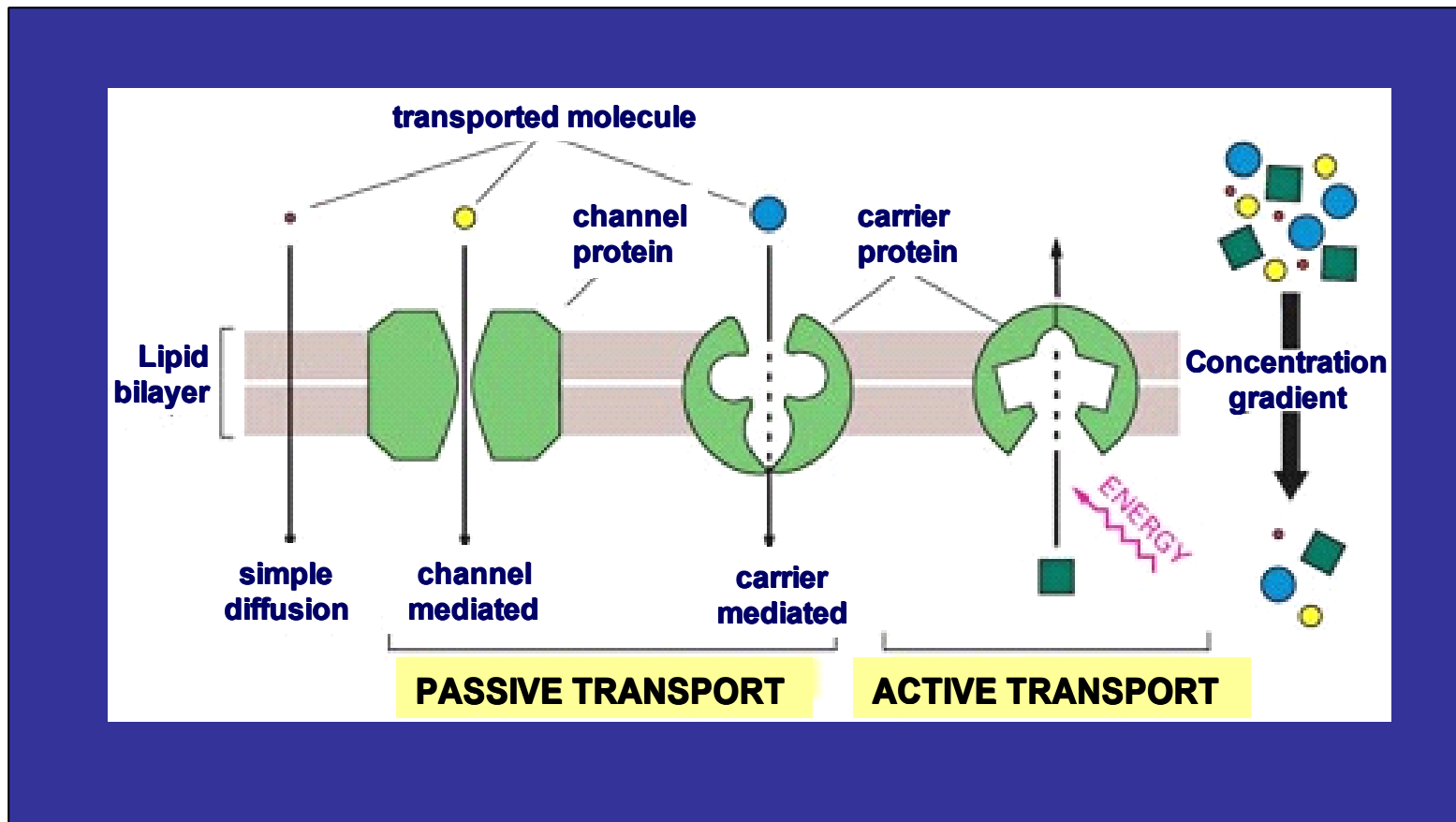




Forms of transmembrane transport

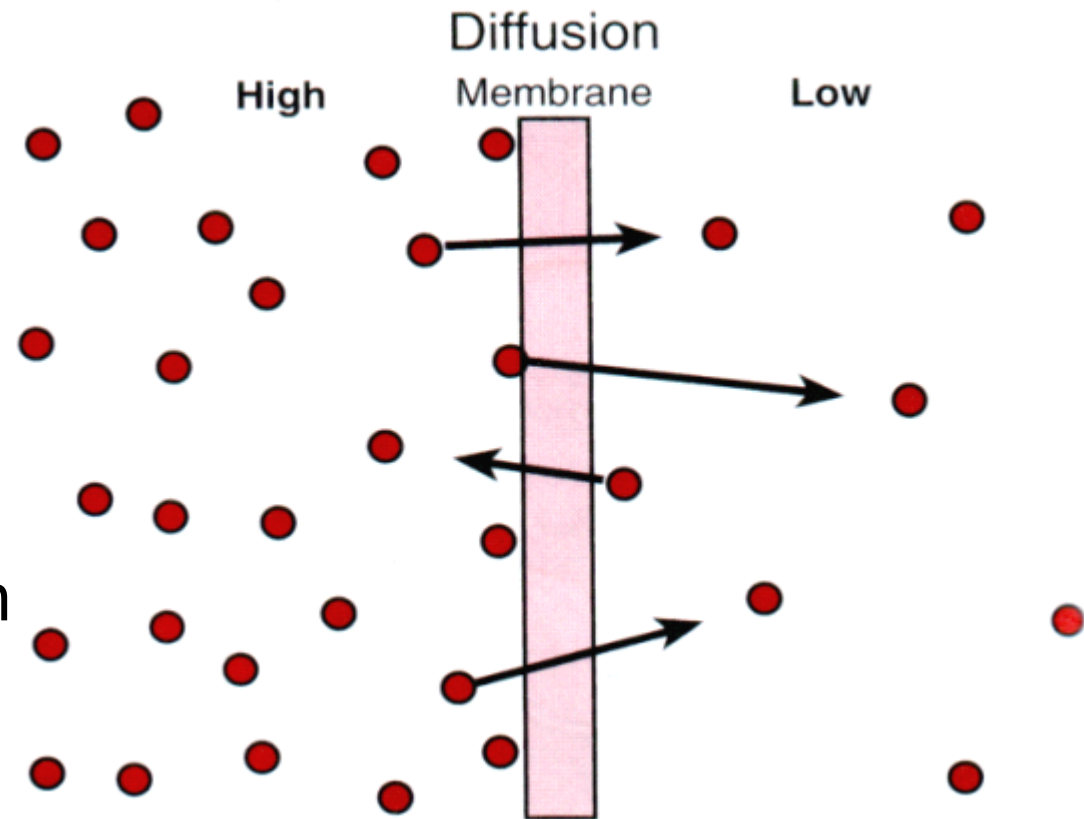
- **Simple diffusion**
- **Protein-mediated membrane transport**
- ❖ **Facilitated diffusion**
 - **Facilitated diffusion via carrier**
 - **Facilitated diffusion via ion channel**
- ❖ **Active transport**
 - **Primary active transport**
 - **Secondary active transport**
- **Exocytosis and endocytosis**

Forms of transmembrane transport



Simple diffusion

Diffusion: with a solution, a solute will move from regions of higher concentration to regions of lower concentration until the solute reaches a uniform concentration throughout the solution.





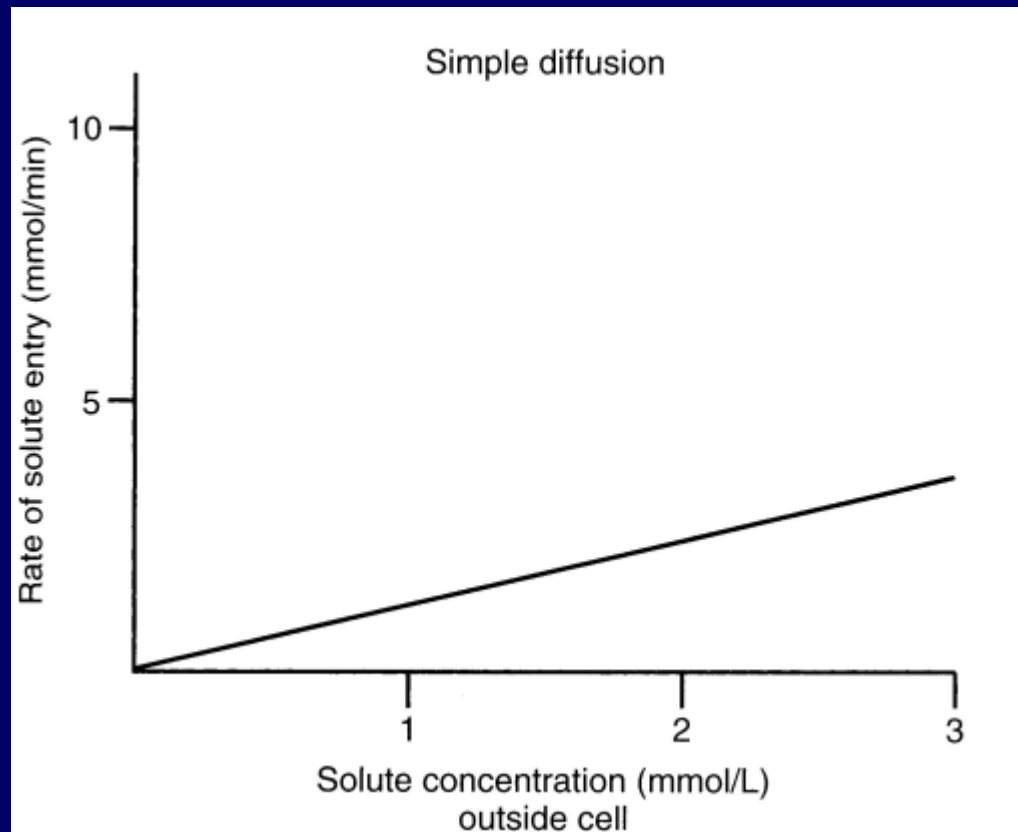
Simple diffusion

Simple diffusion: gases and lipid-soluble molecules move from regions of high concentration to regions of low concentration.

The magnitude depends on

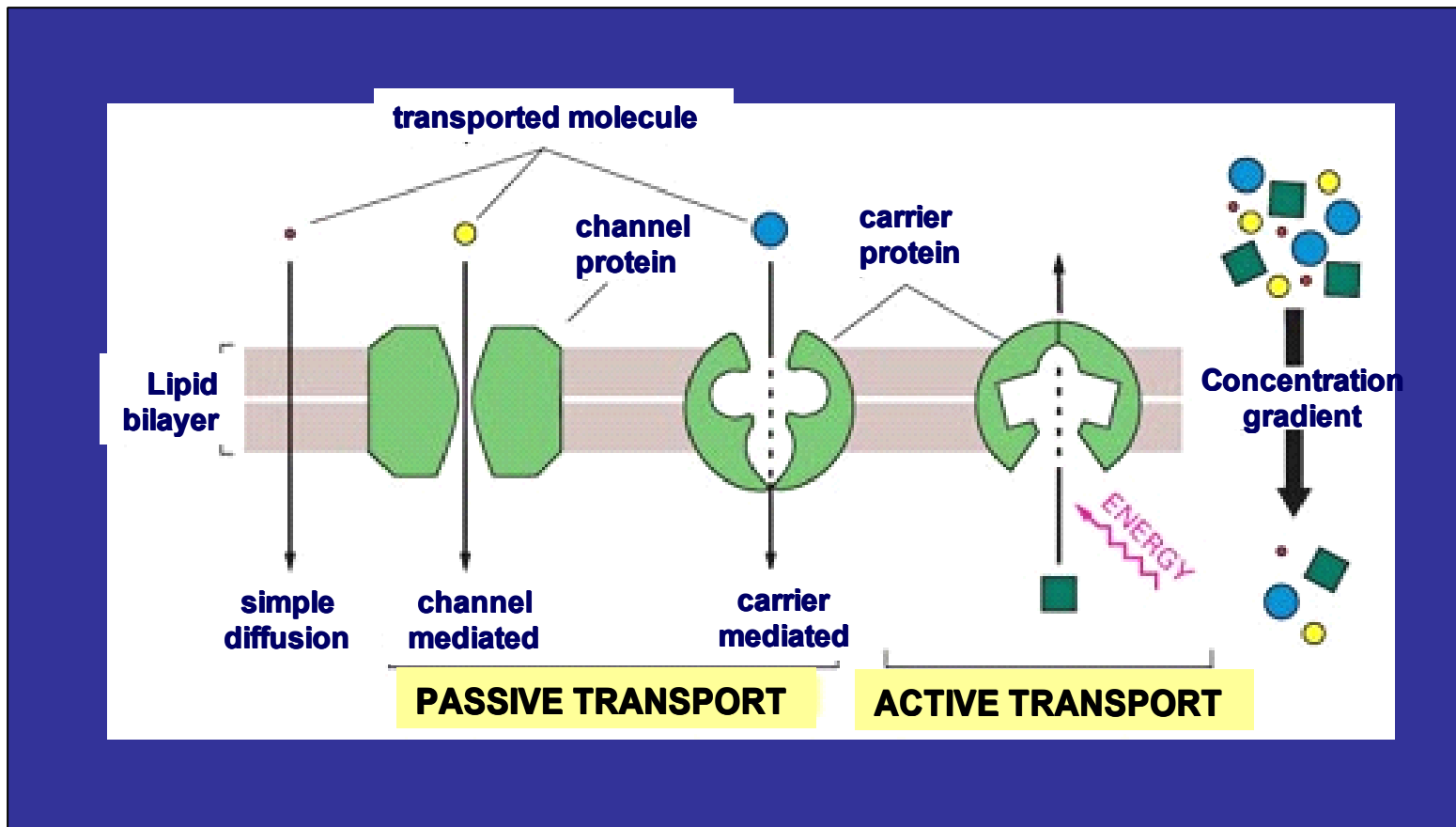
Concentration difference
Lipid solubility
Size of molecules
Surface area

Simple diffusion



The higher the difference in concentration, the greater the amount of substance crossing the membrane.

Protein-mediated transport

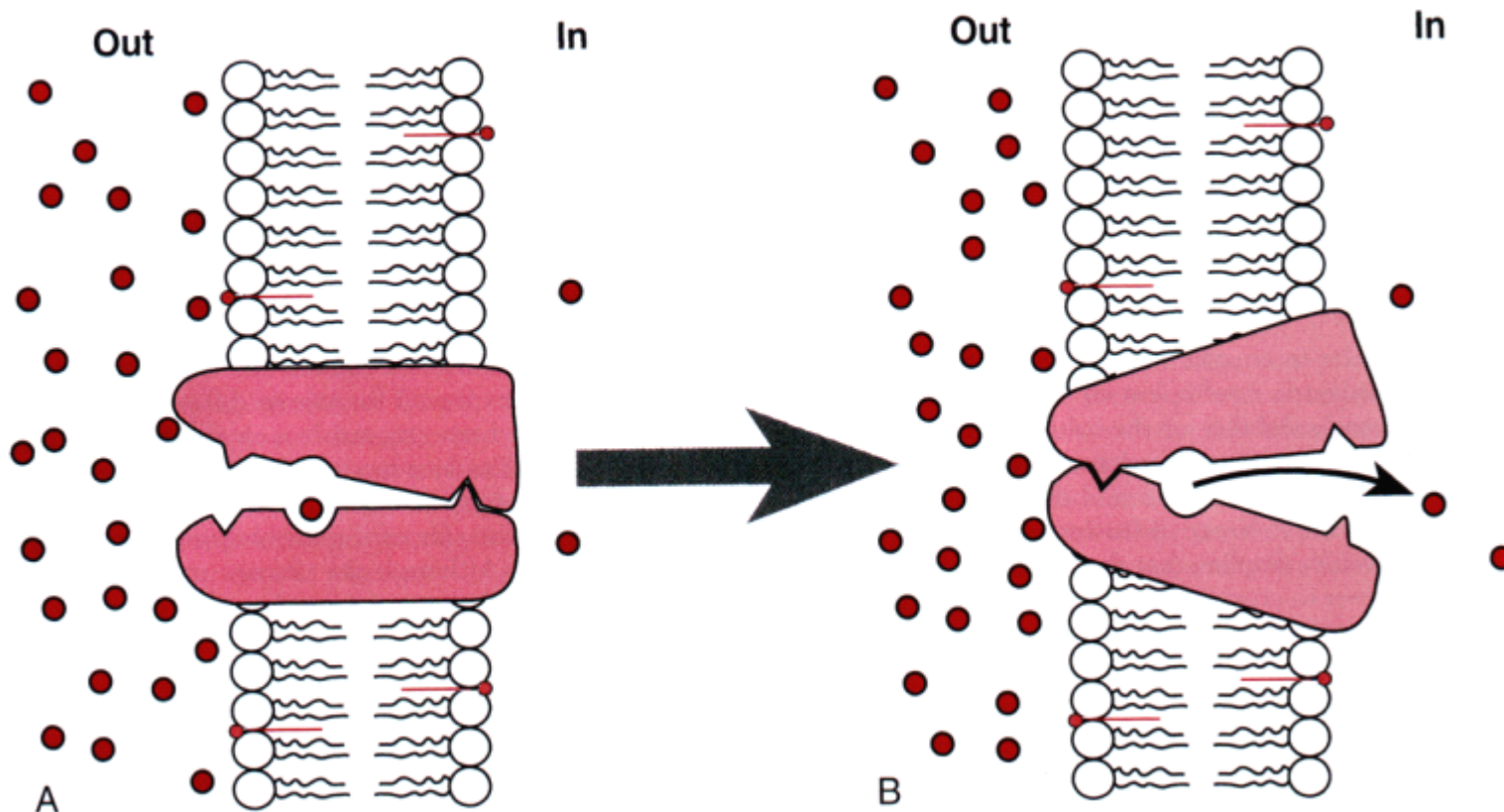




Protein-mediated transport

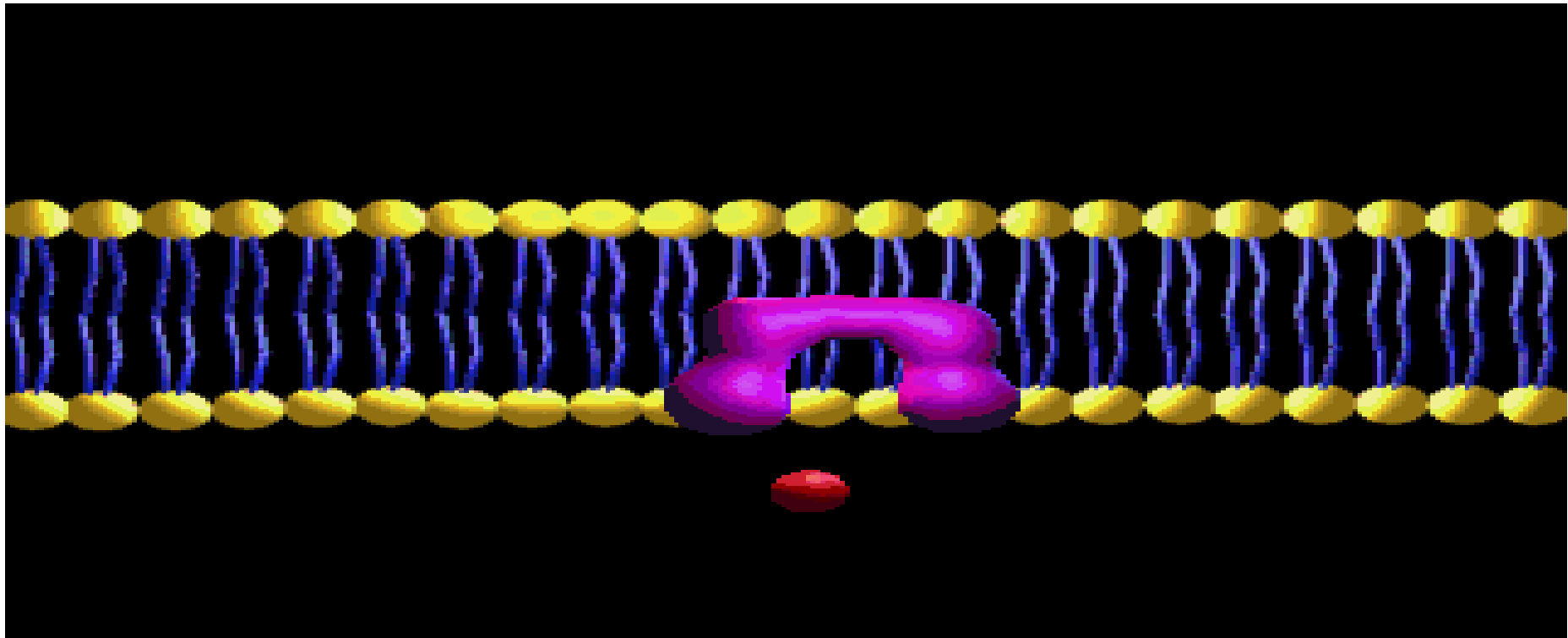
- **Facilitated diffusion:** uses a transport called a channel or a carrier to move solute “downhill” from a higher to a lower concentration across a membrane.
- **Active transport:** uses a transporter that is coupled to an energy source to move solute “uphill” across a membrane against its electro-chemical gradient.

Facilitated diffusion via carrier

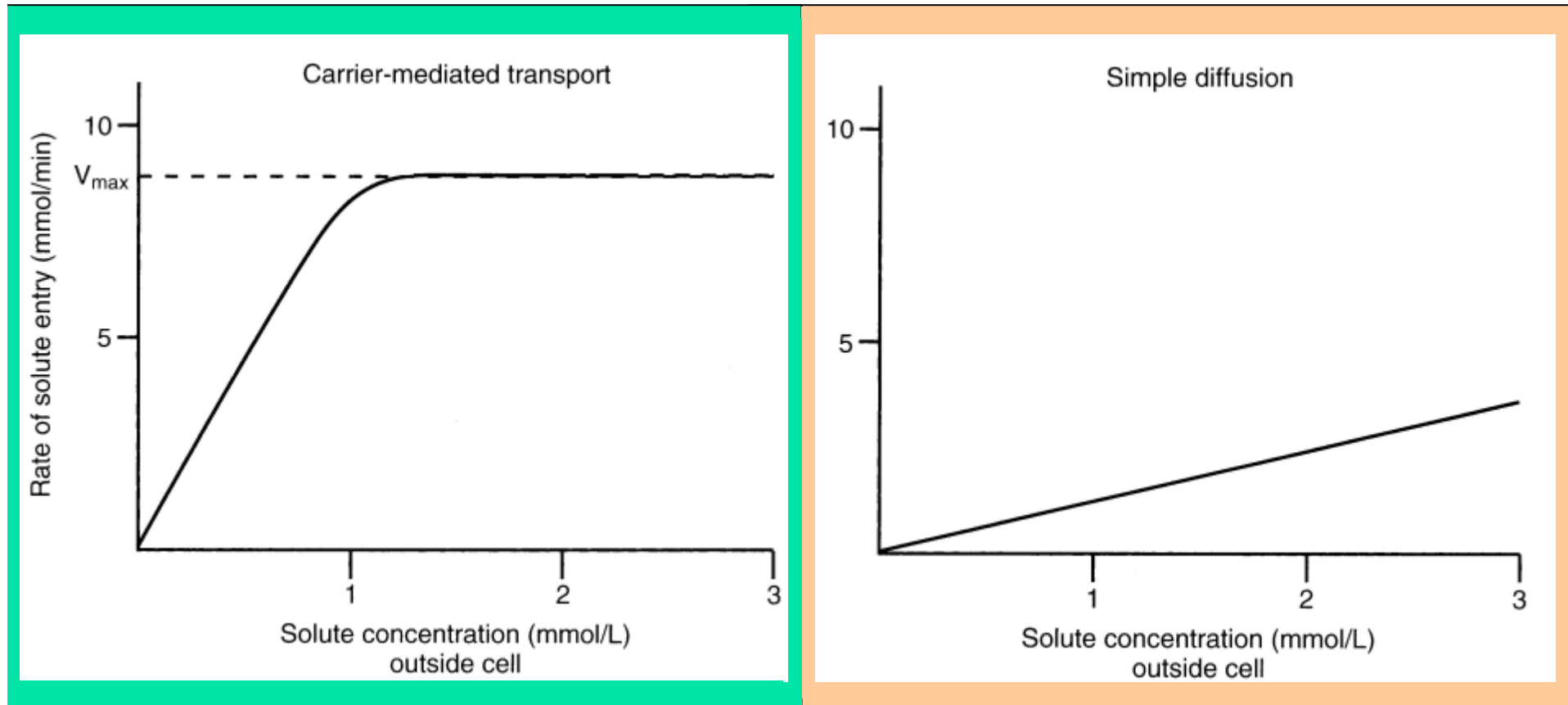


➤ In the body, glucose and amino acid are transported via carrier in the manner of facilitated diffusion

Facilitated diffusion via carrier



Facilitated diffusion via carrier



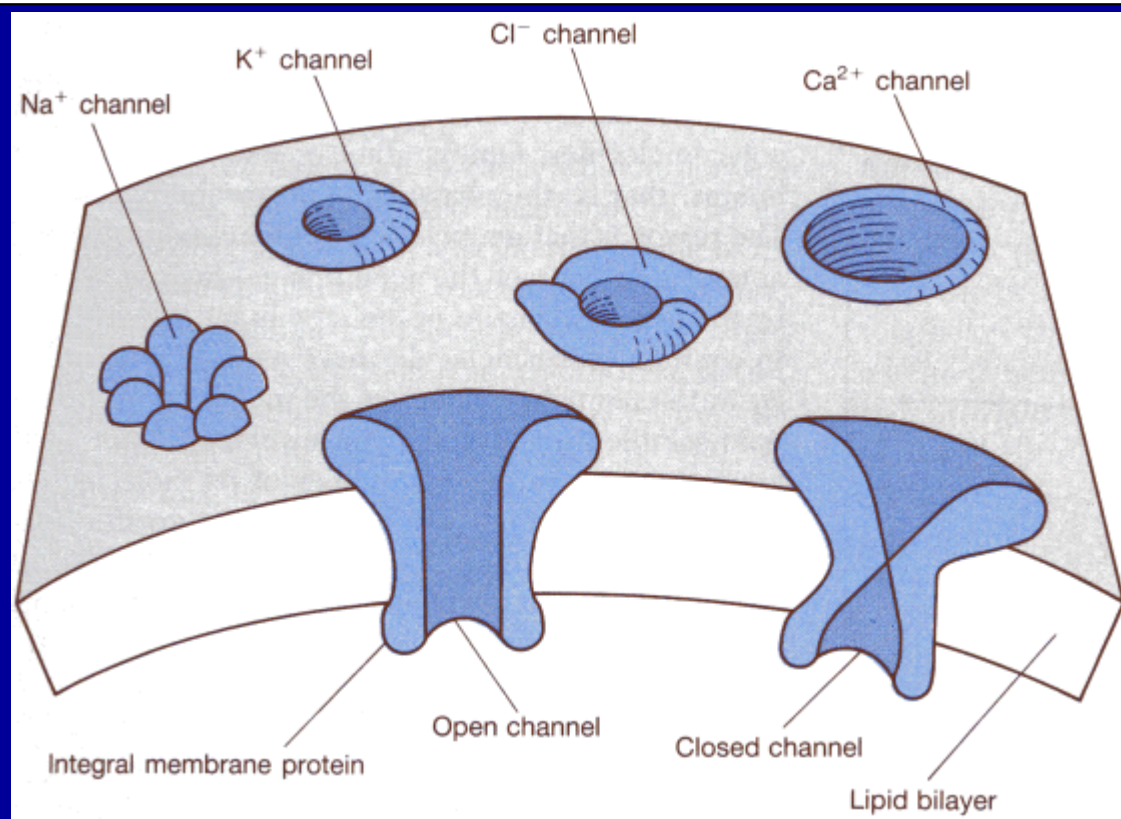


Facilitated diffusion via carrier

Characteristics

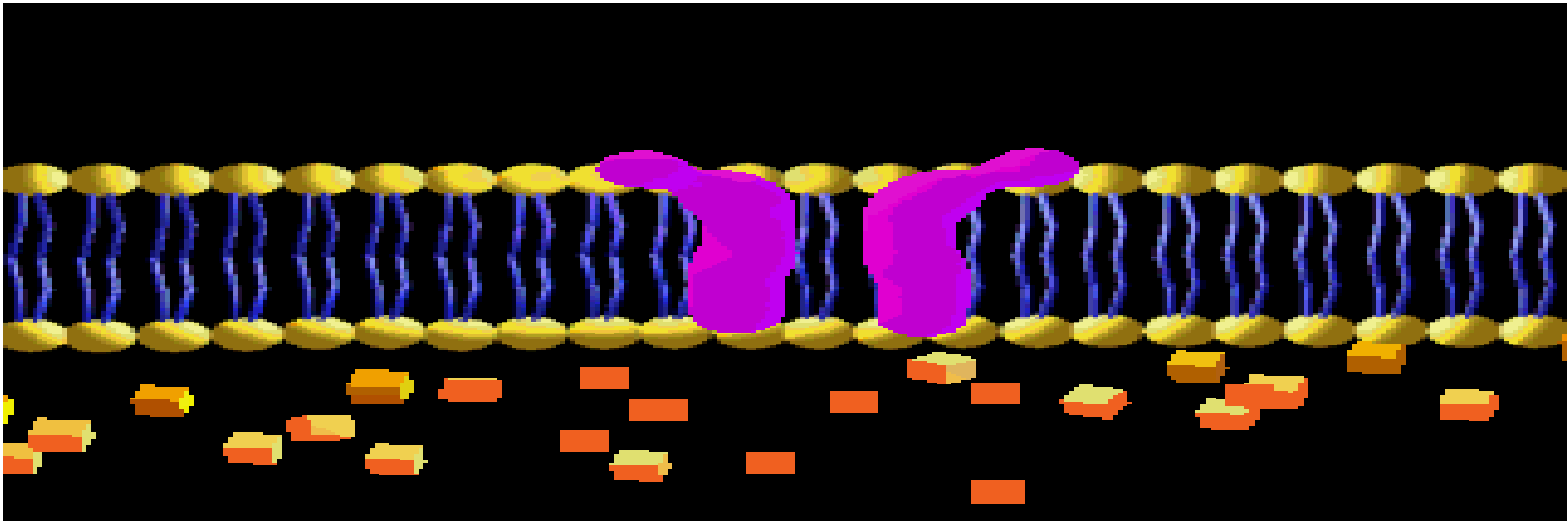
- **Much faster than expected for simple diffusion**
- **Saturation:** as the concentration of the solute reaches a high level, the rate of solute transport reaches maximal.
- **Structural specificity:** the binding sites on each type of carriers are specific for a particular solute.
- **Competitive inhibition:** a type of carrier may transport two different solutes with similar molecular structure may result in competitive inhibition.

Facilitated diffusion via **ion channel**



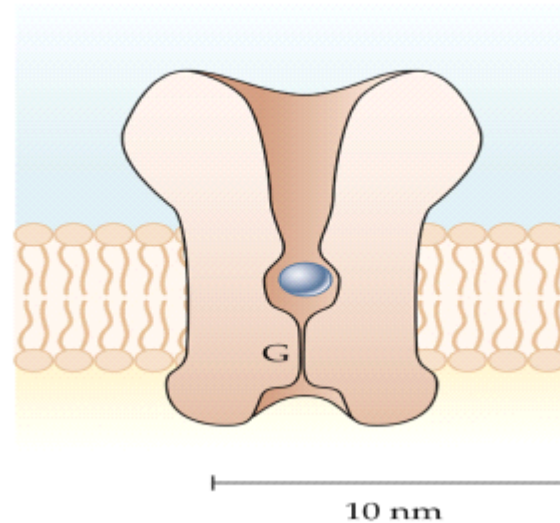
One kind of channel has a conformation specific to one kind of ion, with a hole in the middle allowing the ions to move.

Facilitated diffusion via **ion** **channel**



Facilitated diffusion via **ion channel**

- **High speed:** $10^6 \sim 10^8$ ions/sec (carrier: $10^3 \sim 10^5$ ions/sec)
- **Ionic selectivity**
- **Gating:**
 - resting closed
 - activation open
 - inactivation closed



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Ion channels

- **Voltage-gated ion channels**
- **Ligand-gated ion channels**
- **Mechanically-gated ion channels**

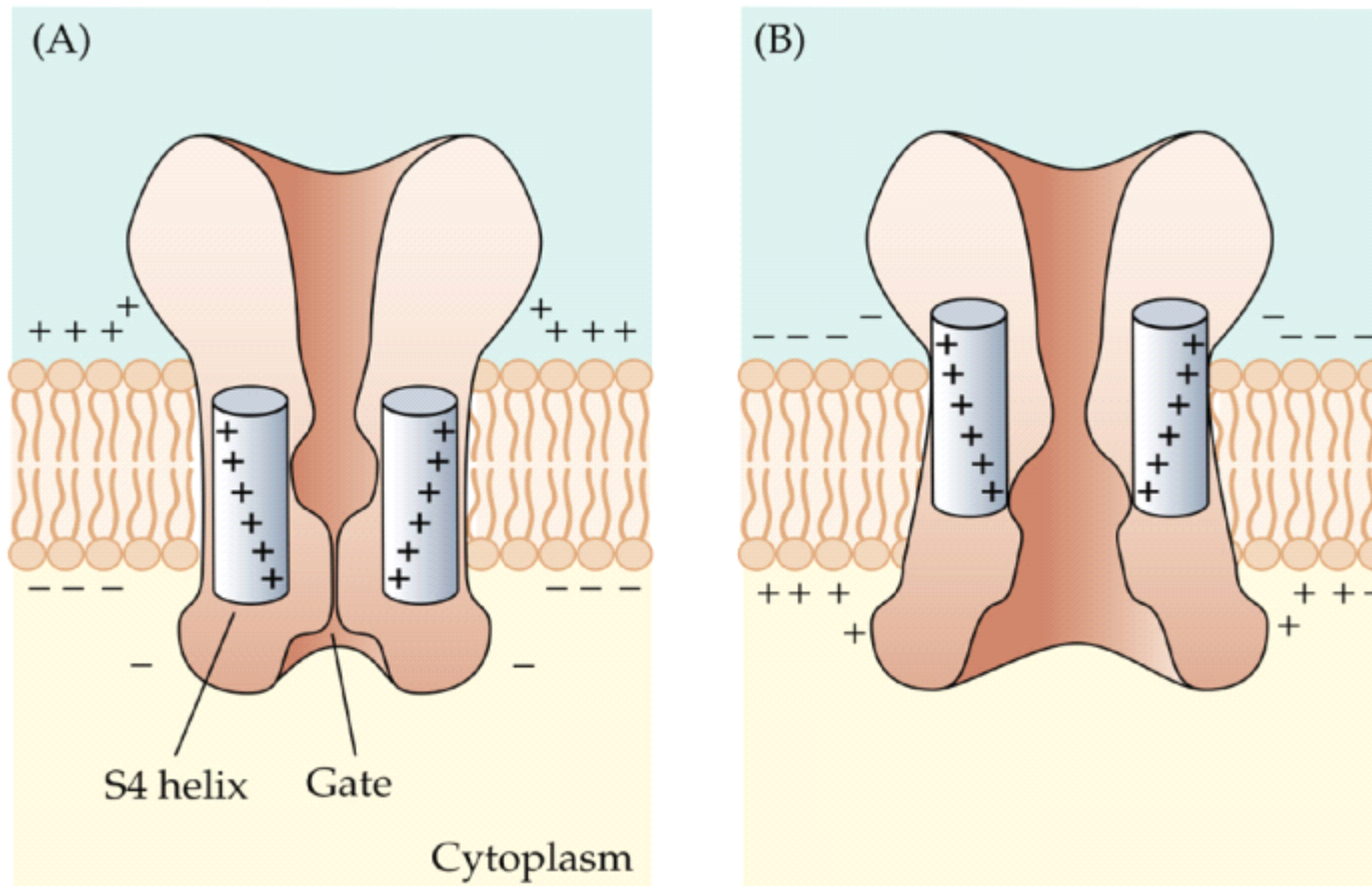


Voltage-gated ion channel

- **Voltage-gated ion channels open when the membrane potential changes beyond a certain threshold value.**

Voltage-gated ion channel

■ Activation

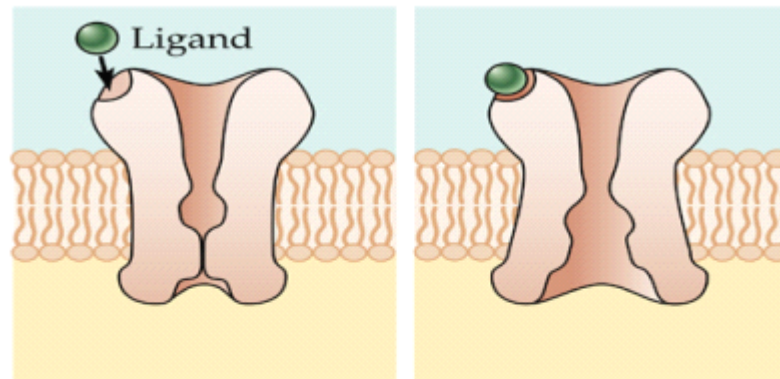




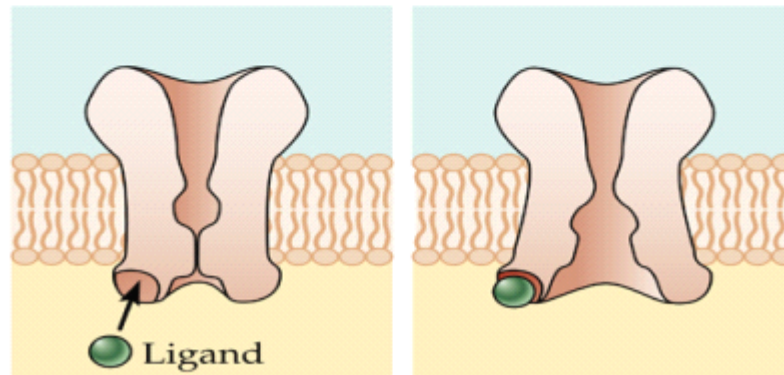
Chemically-gated ion channel

- **Ligand-gated ion channels**
open by a conformational
change in the protein
induced by the ligand
binding.

Ligand-gated ion channel



Extracellular activation



Intracellular activation

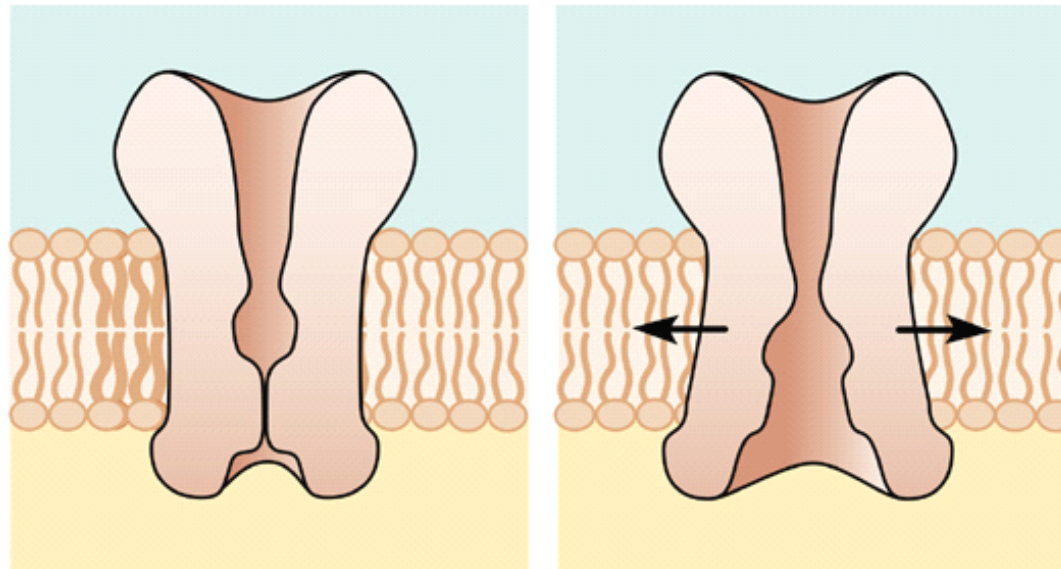
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Ligand

- neurotransmitter
- intracellular second messenger

Mechanically-gated ion channel

- **Mechanically-gated channels** – open and close in response to physical deformation of channels



Stretch-activated



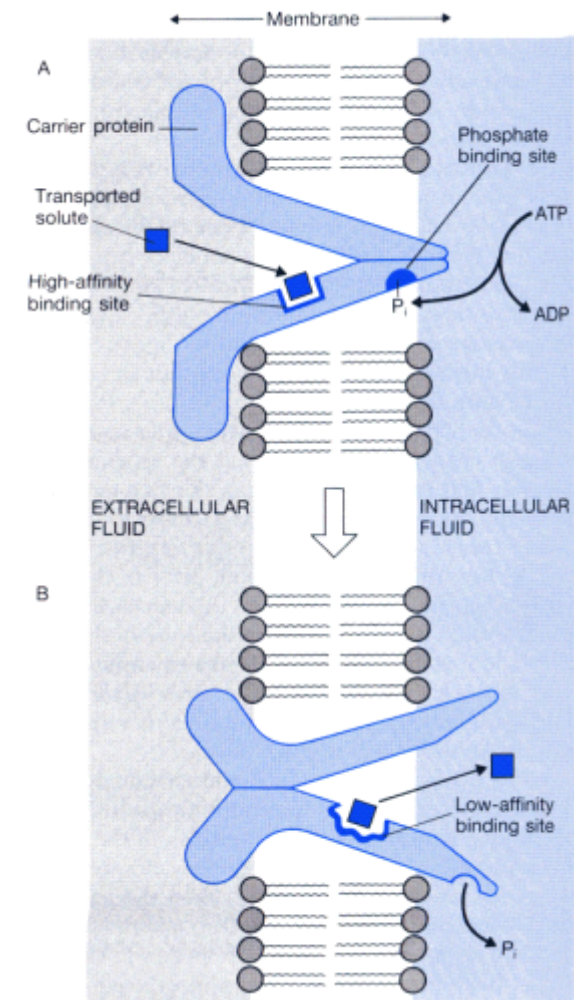
Active transport

- **Active transport:** uses energy to move solute “uphill” across a membrane against its electro-chemical gradient.
- **Primary active transport**
- **Secondary active transport**

Primary active transport

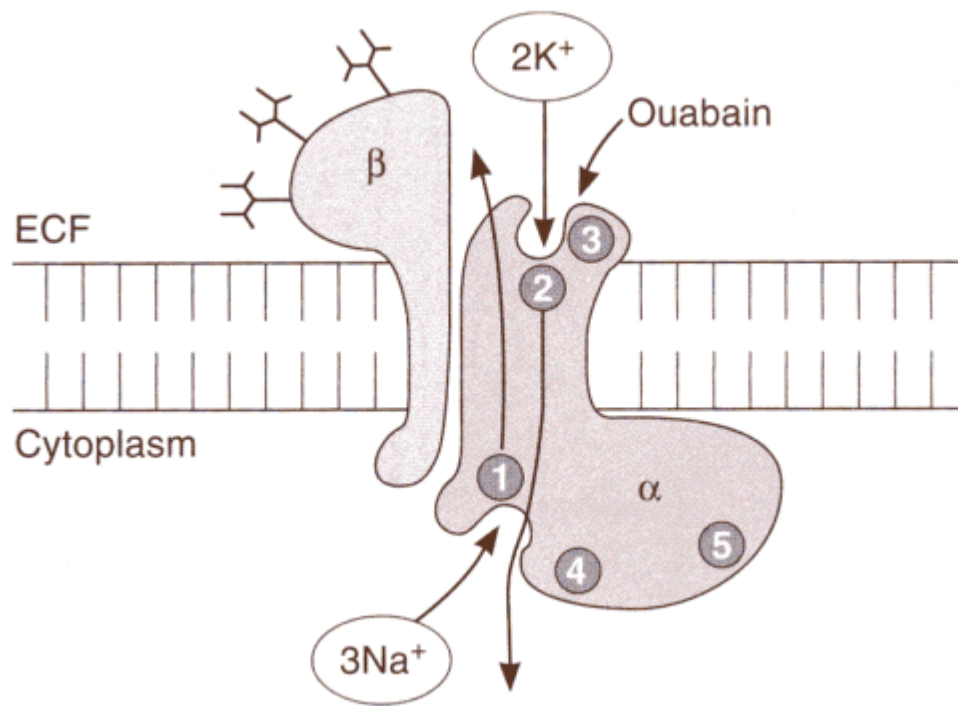
- **Primary active transport:** active transport in which chemical energy is transferred directly from ATP to carrier protein.

Ion pump



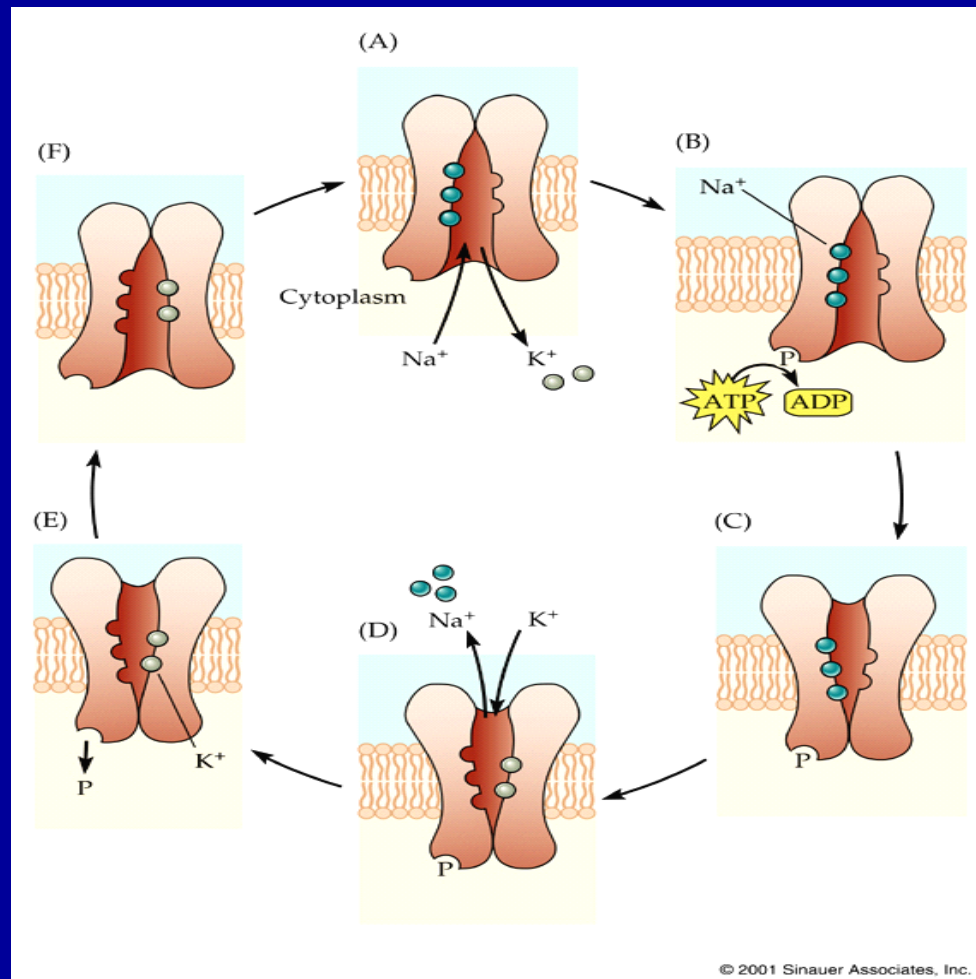
Sodium-potassium pump

- Sodium-potassium pump
(sodium pump; Na^+ - K^+ -ATPase)



- α , β subunits
- Binding sites for Na^+ , K^+ and ATP are located in α subunits
- Hydrolyze 1 ATP—transport 3 Na^+ out and 2 K^+ in

Sodium-potassium pump



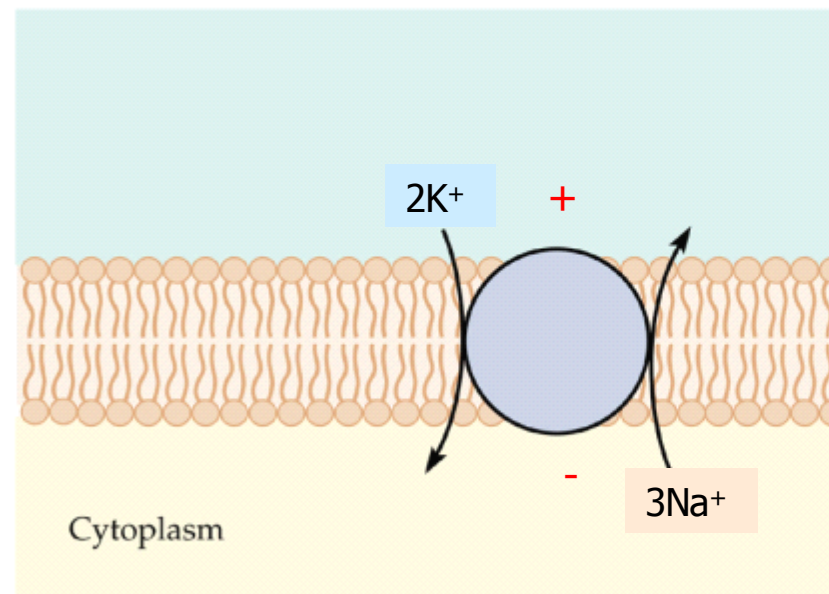


Significance of sodium pump

- **High level of intracellular K^+ and extracellular Na^+ is the basis for the generation of bioelectricity.**
- **Maintain the intracellular osmotic pressure and cellular volume.**

Significance of sodium pump

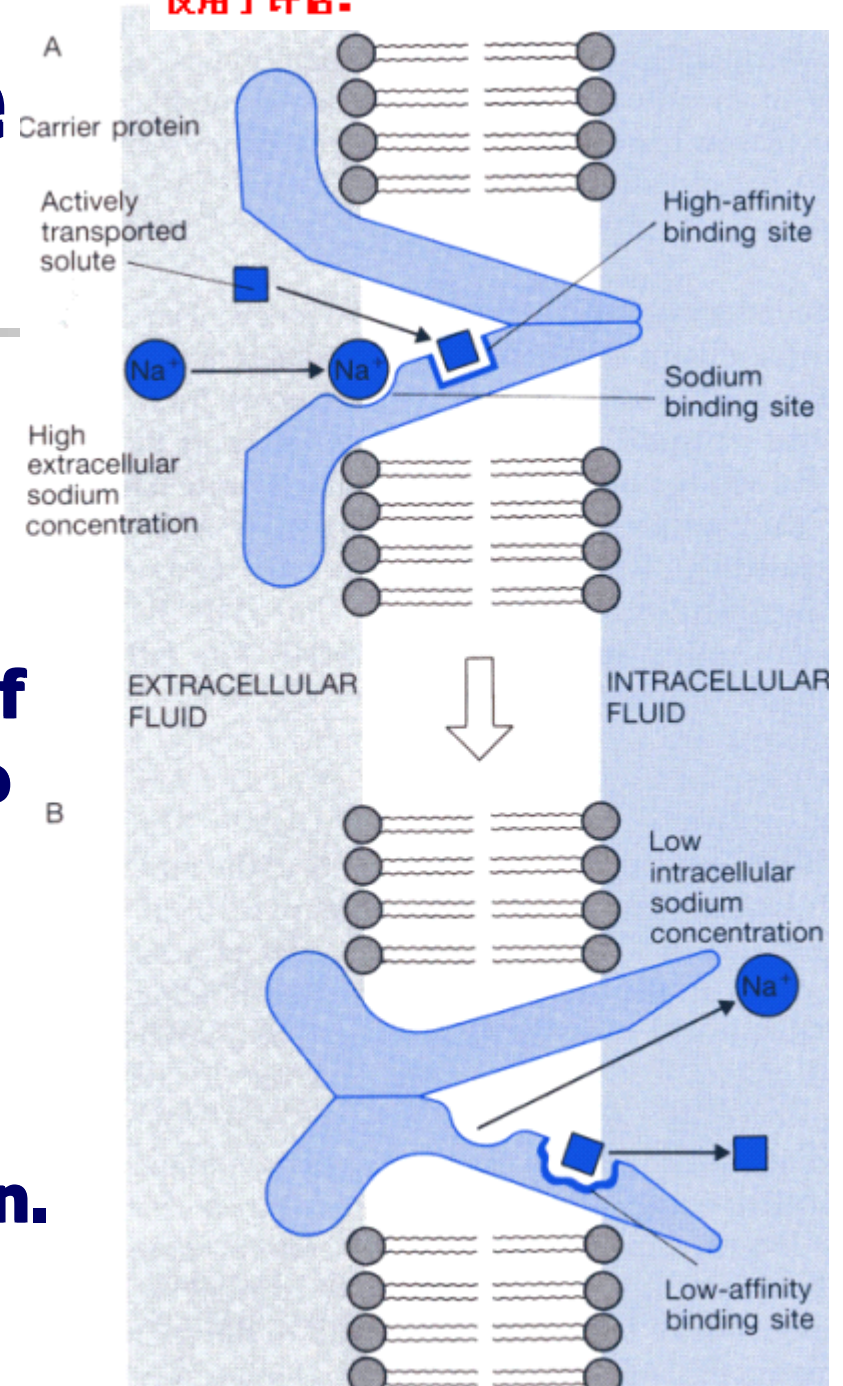
- **Sodium pump is electrogenic, and in turn is involved in the generation of resting potential**



Secondary active transport

- **Secondary active transport:** active transport in which energy released during transmembrane movement of one substance from higher to lower concentration is transferred to the simultaneous movement of another substance from lower to higher concentration.

Transporter



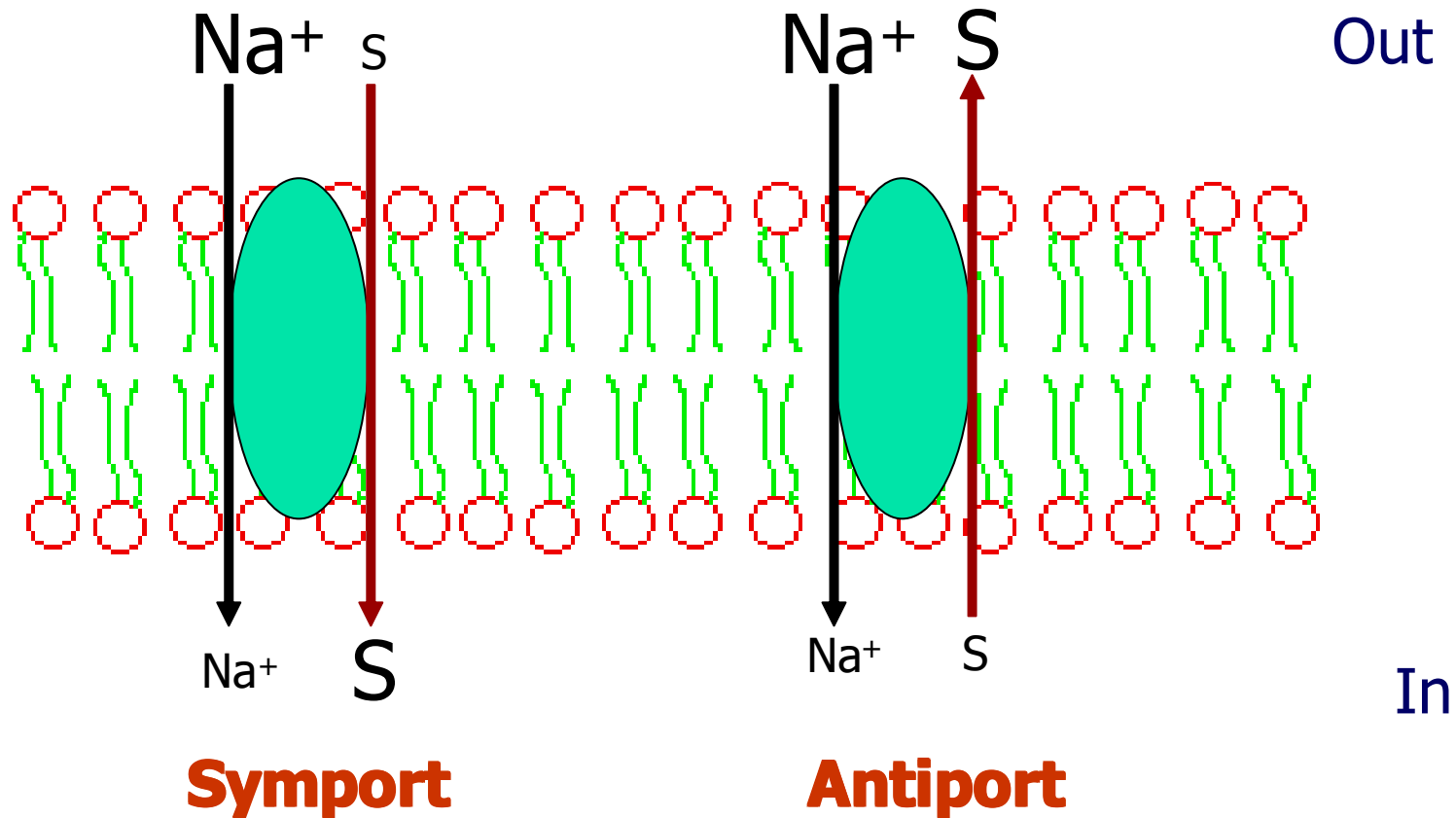


Secondary active transport

Transport

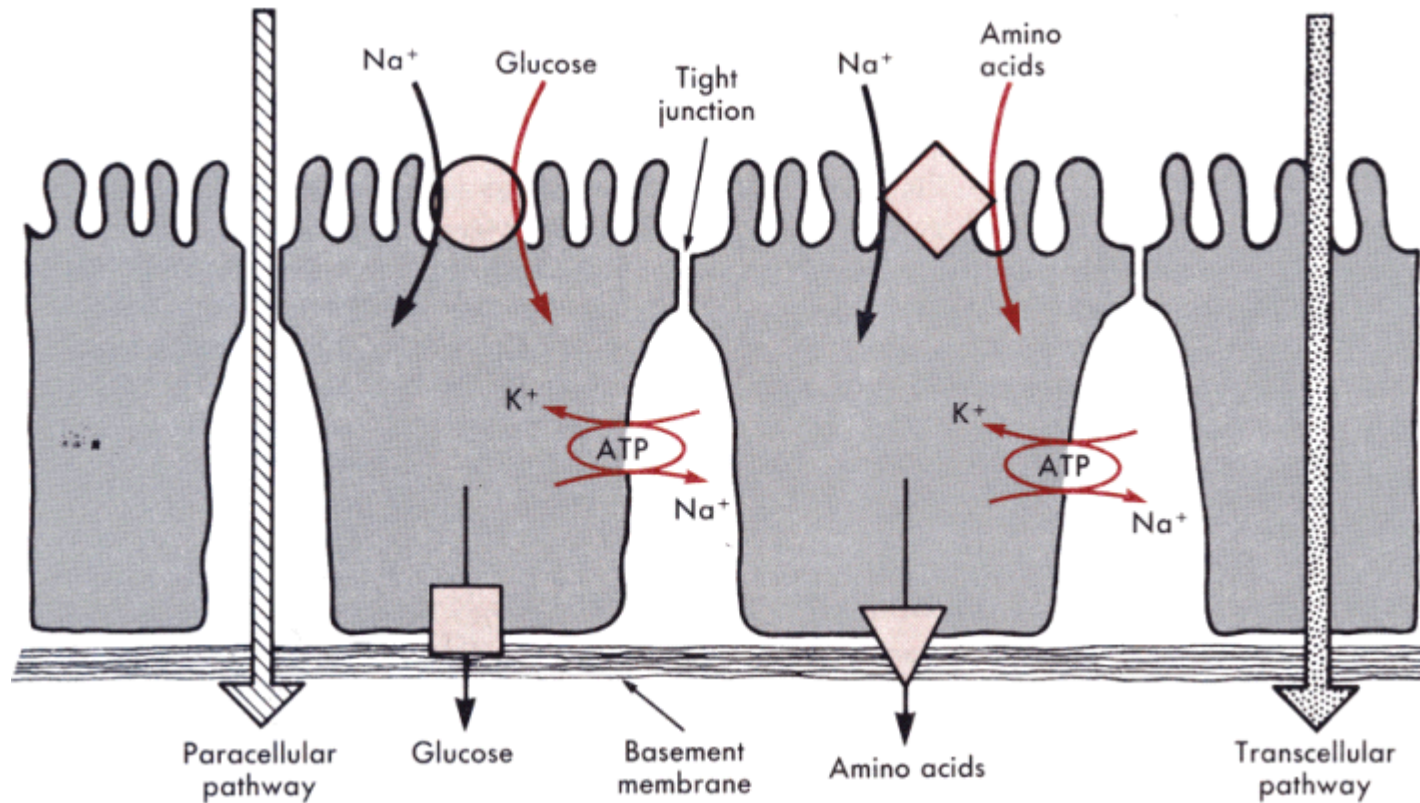
- **Symport**, in which the solute being transported moves in the same direction as the sodium ion.
- **Antiport (exchange)**, in which sodium moves in one direction and the solute moves in the opposite direction.

Secondary active transport

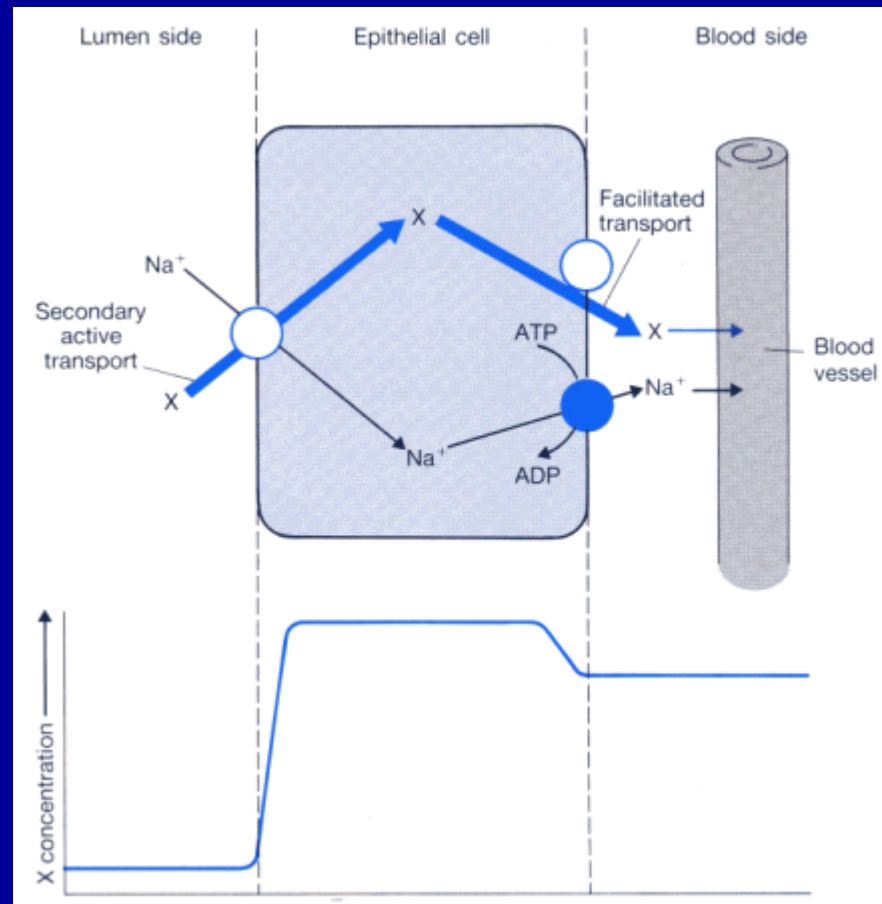


Secondary active transport

- Na^+ -glucose symporter
- Na^+ -amino acid symporter

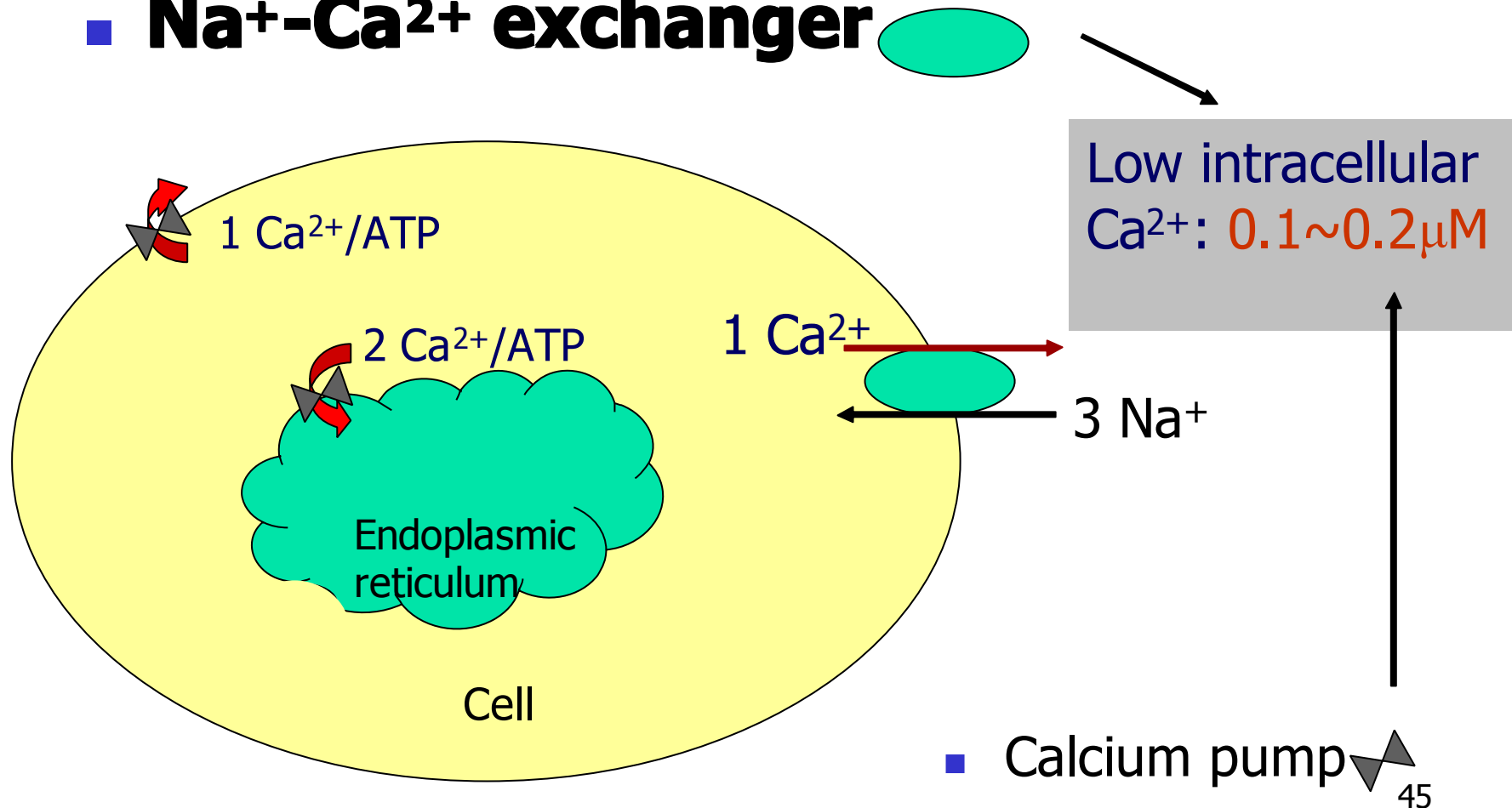


Secondary active transport



Secondary active transport

■ $\text{Na}^+-\text{Ca}^{2+}$ exchanger





Endocytosis and exocytosis

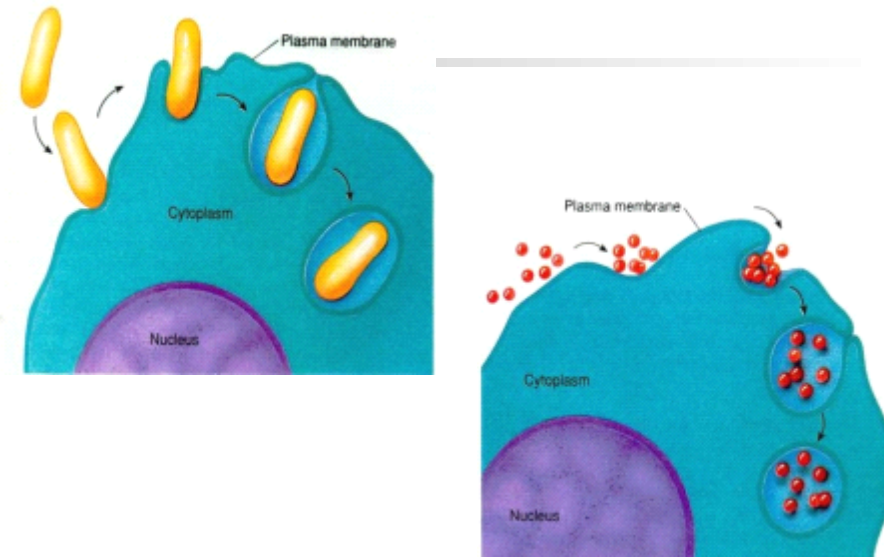
- **Endocytosis:** process in which plasma membrane folds into the cell forming small pockets that pinch off to produce intracellular, membrane-bound vesicles.

Endocytosis

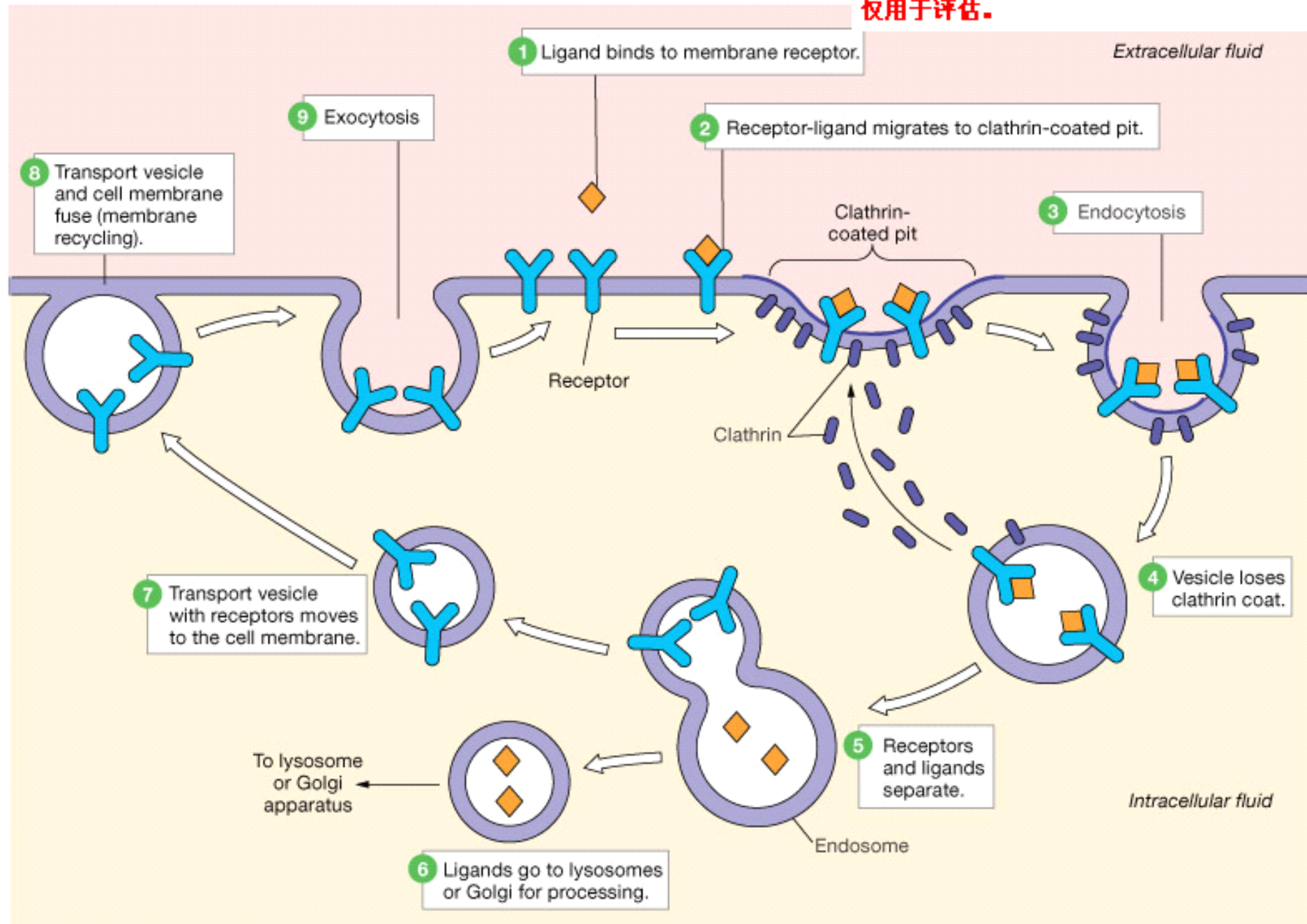
■ Endocytosis

{
phagocytosis
pinocytosis

{
fluid-phase endocytosis
receptor-mediated endocytosis



LDL (low-density lipoprotein)

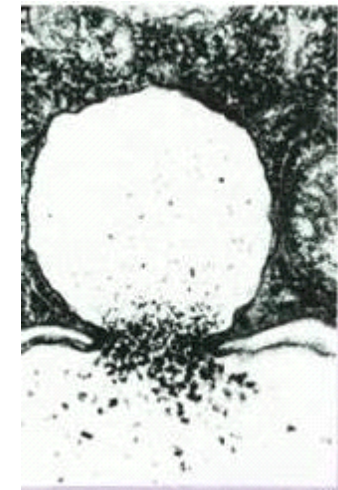
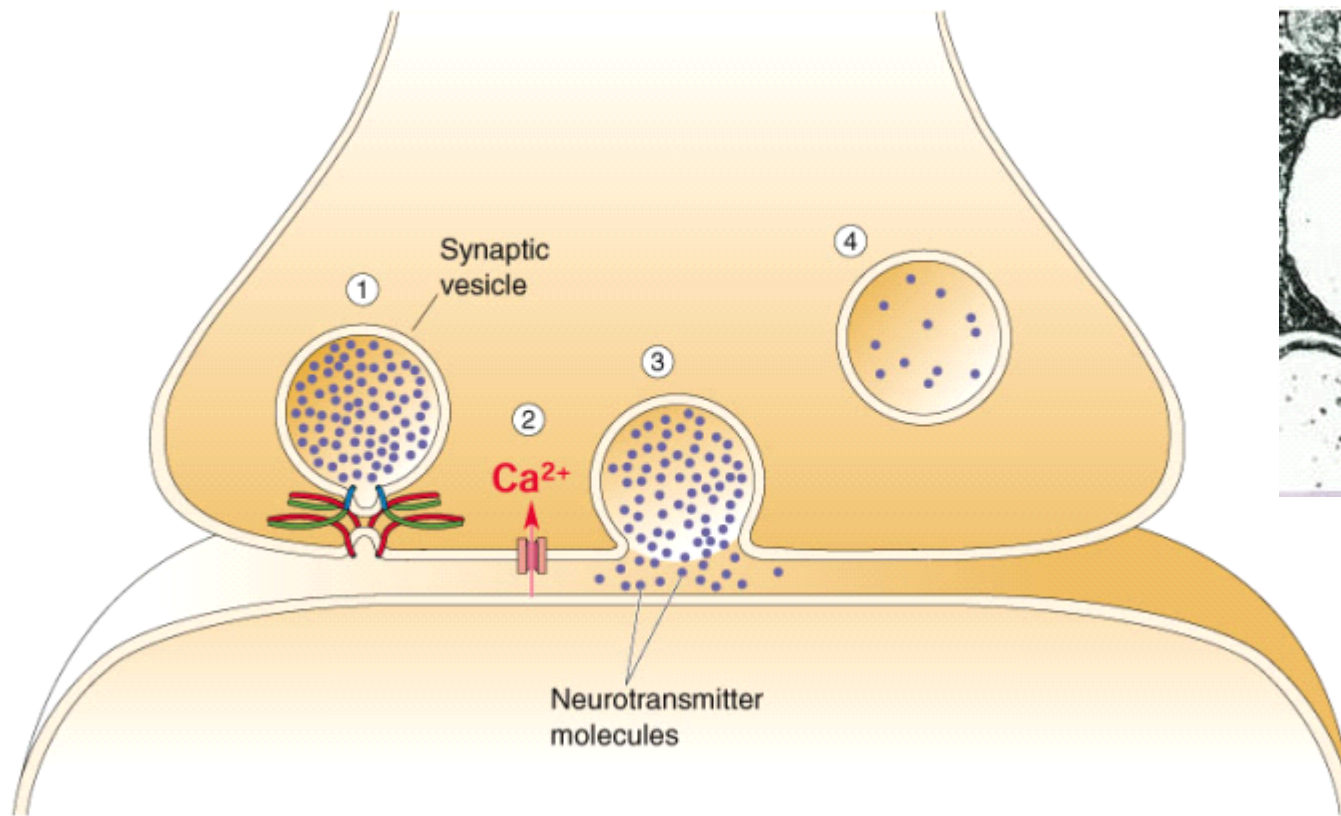




Exocytosis

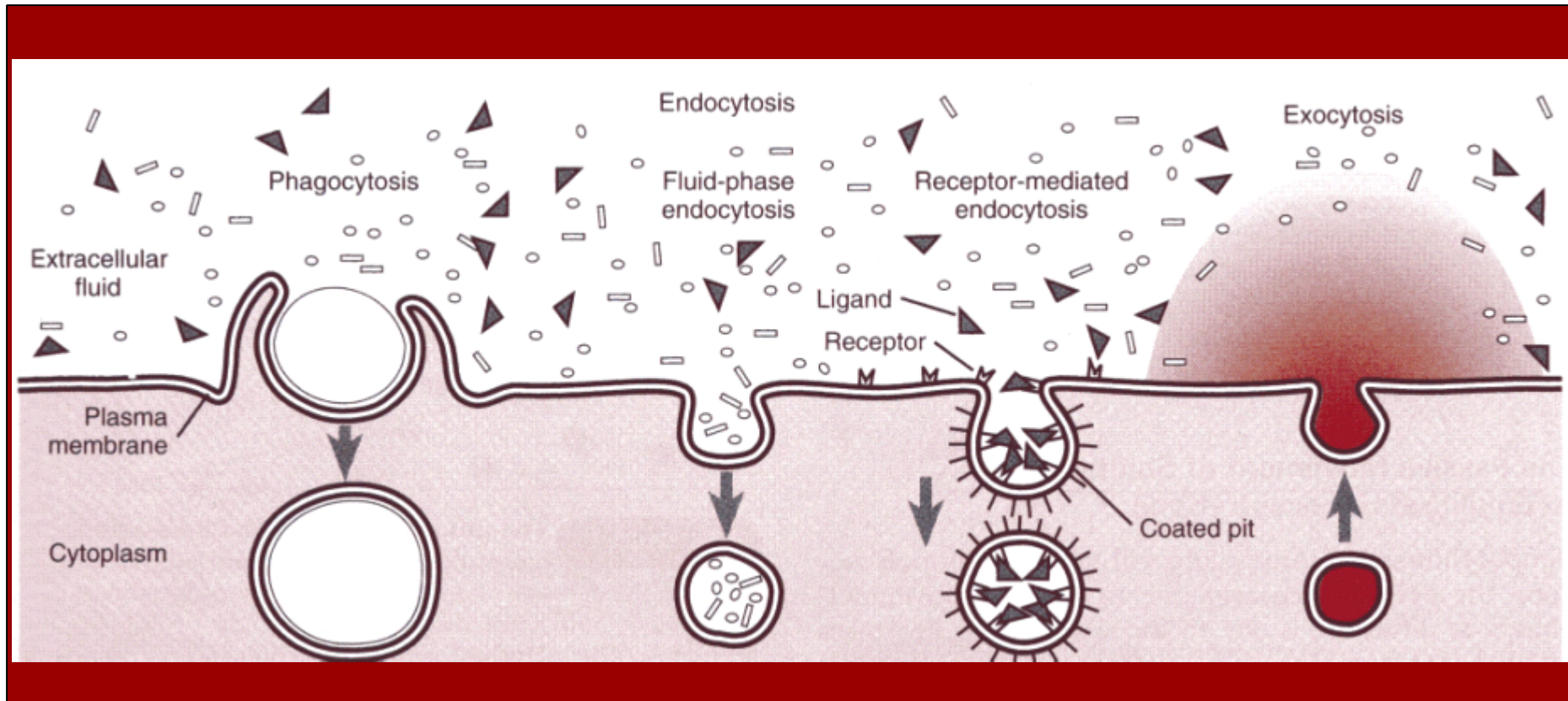
- **Exocytosis:** process in which intracellular vesicle fuses with plasma membrane, the vesicle opens, and its contents are liberated into the extracellular fluid.

Exocytosis



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Exocytosis and endocytosis





Summary

- **Liquid mosaic model**
- **Simple diffusion**
- **Facilitated diffusion via carrier**
- **Facilitated diffusion through ion channel**
- **Voltage-gated ion channel**
- **Ligand-gated ion channel**
- **Mechanically-gated ion channel**
- **Primary active transport**
- **Secondary active transport**
- **Endocytosis and exocytosis**



Questions

- **Define each term:**
 - Fluid mosaic model
 - Simple diffusion
 - Facilitated diffusion
 - Active transport
 - Symport
 - Antiport



Questions

- **Answer the following question**
 - Describe the significance of sodium pump
 - Characteristics of simple diffusion, facilitated diffusion via carrier and facilitated diffusion via channel
 - Describe the major types of channels