I. Biological Membrane

A plant cell is a unit composed of membrane system; the membrane is the center of plant physiological activity.

(I) Membrane property and chemical composition

1. Membrane property

The membrane is selectively permeable: its permeability to water is the highest; the substance that is easier to dissolve in lipids more easily permeates the membrane.

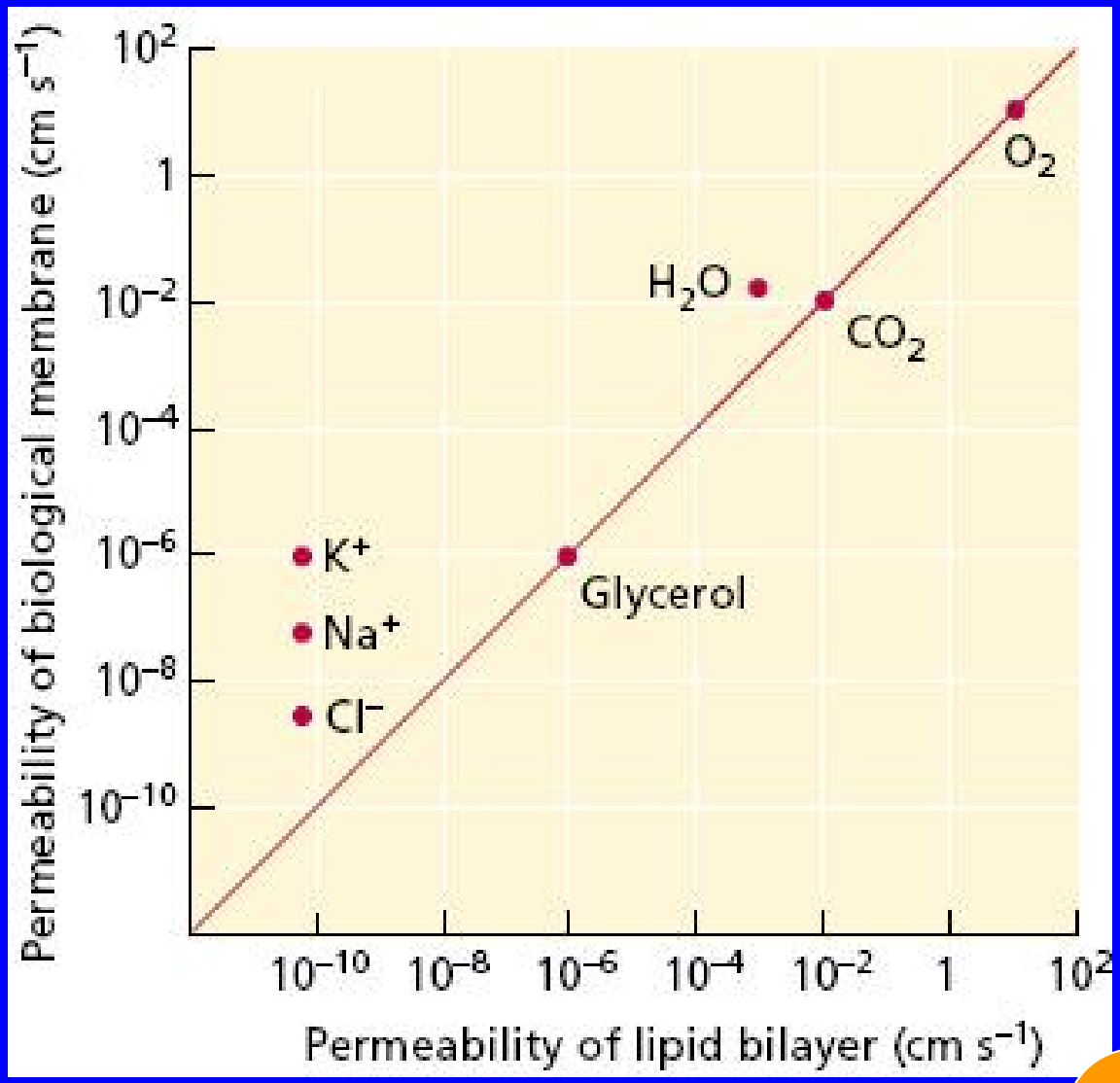
1.1.2 Chemical composition

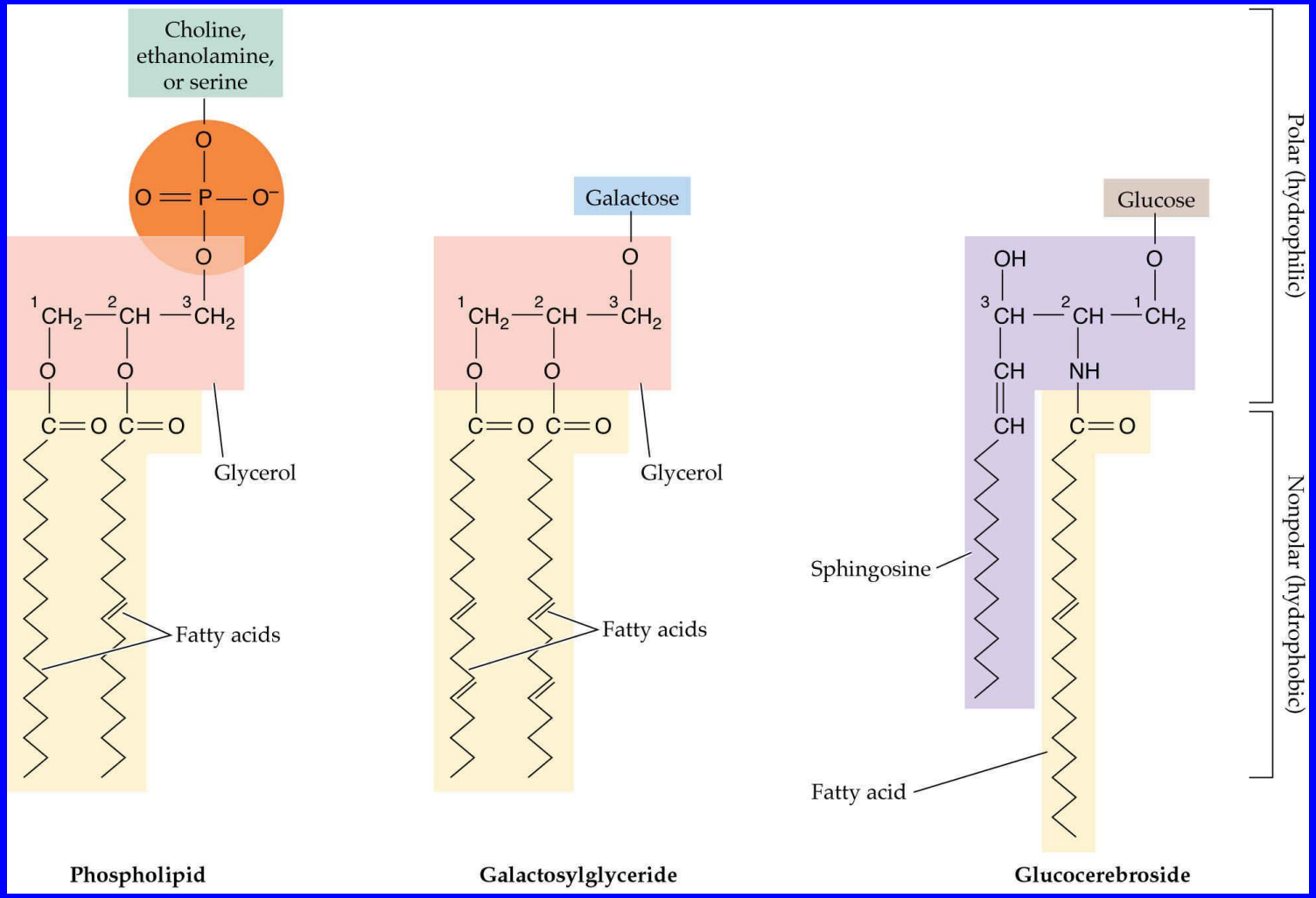
Proteins (glycoprotein and lipoprotein) — 30%-40%

Lipids (phospholipid, glycolipid and sterol) — 40%-60%

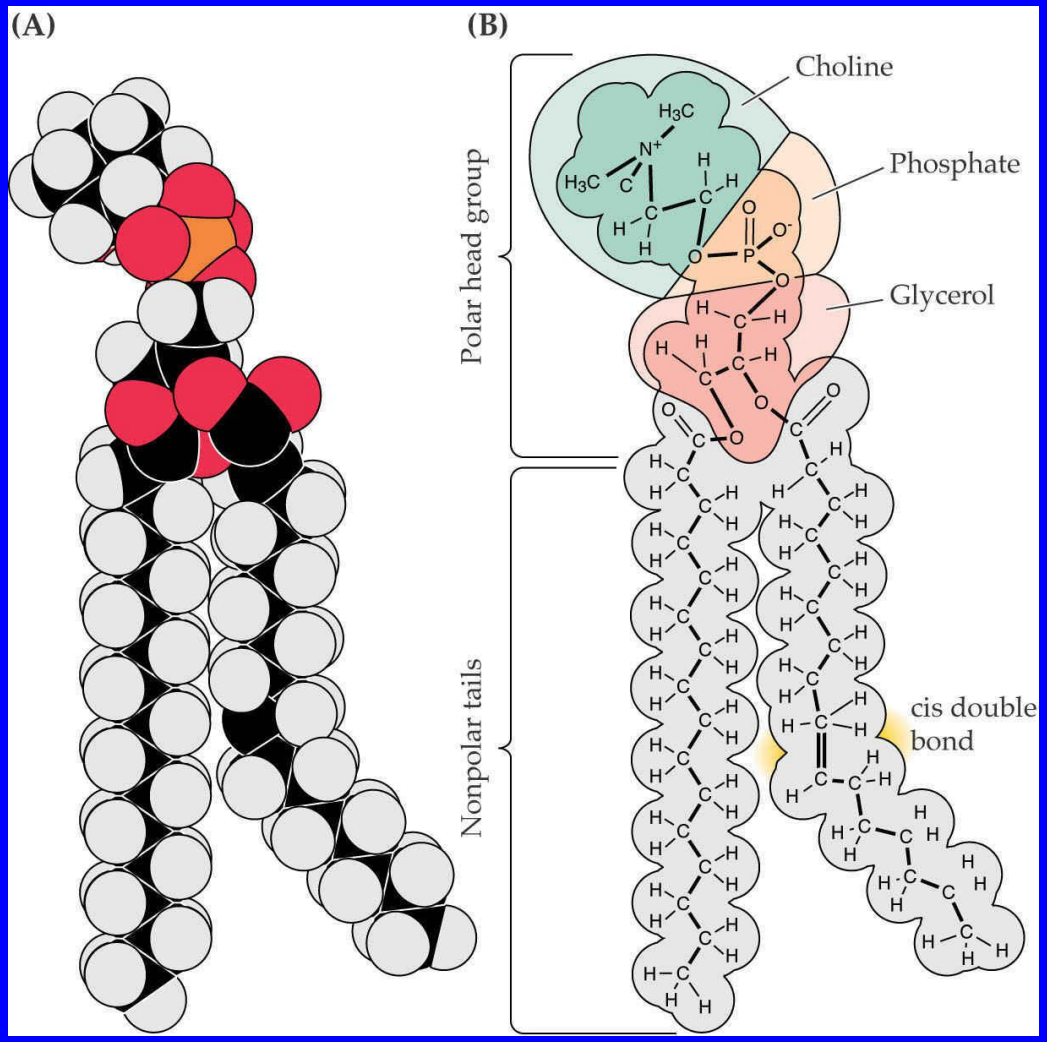
Carbohydrates — 10%-20%

Typical values for the permeability, *P*, of a biological membrane to various substances, compared with those for an artificial phospholipid bilayer.





Plant membrane lipids.



Space-filling model (A), and a diagram (B) defining the functional groups of a phosphatidyl-choline molecule.

(II) Membrane structure

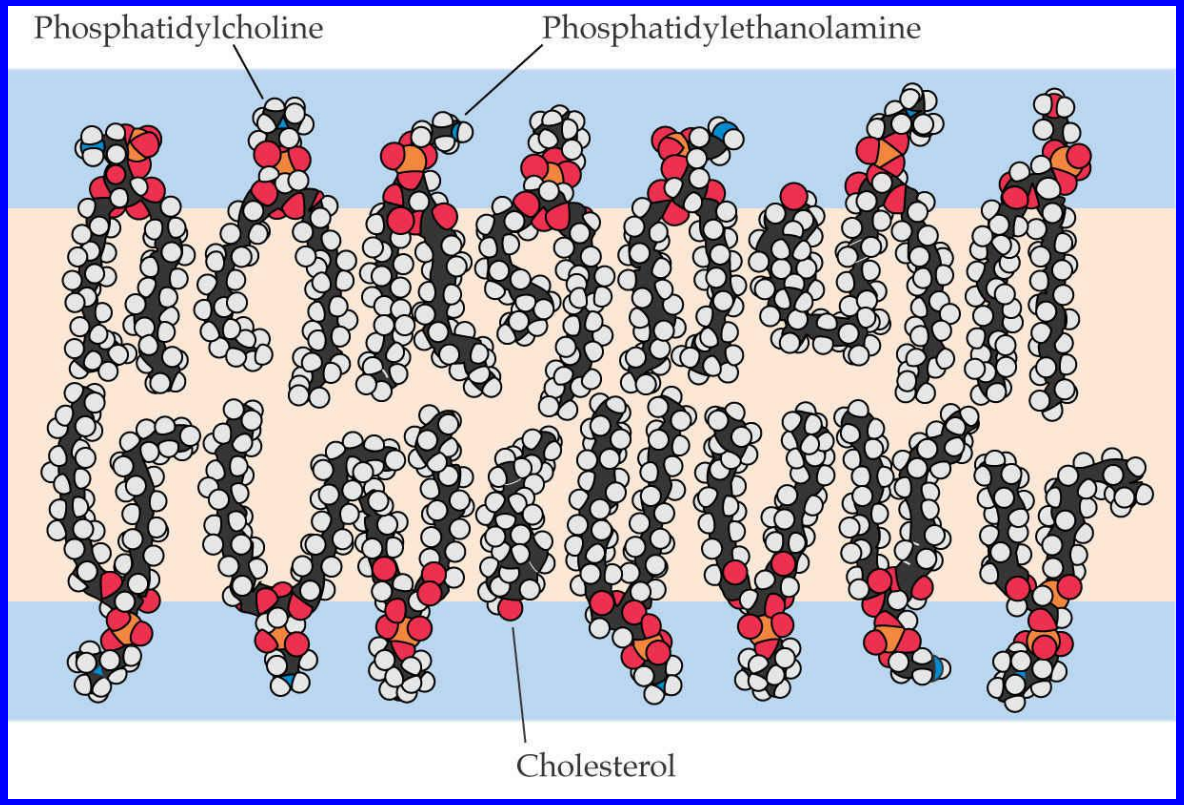
1.2.1 Structure features: the membrane is generally composed of phospholipid bilayer and mosaic protein.

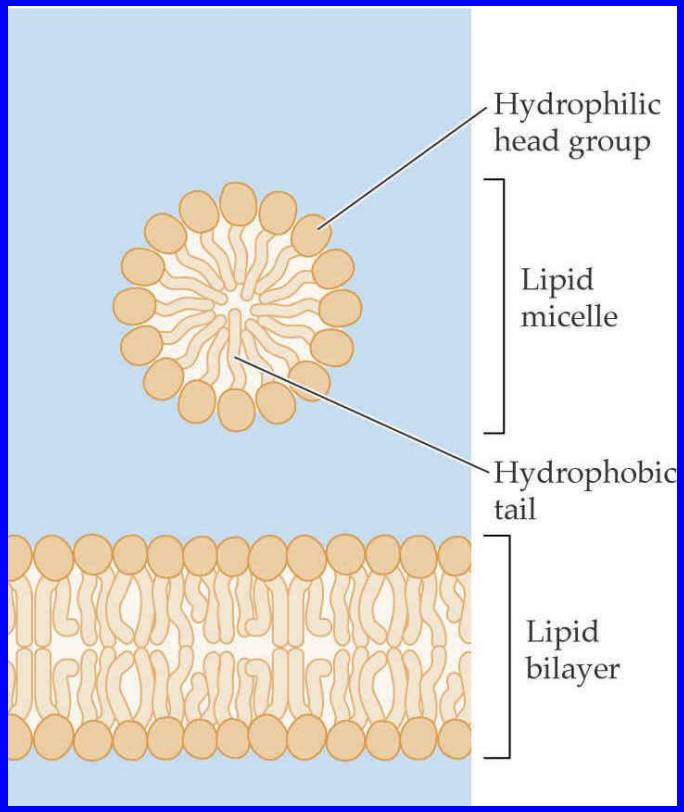
1.2.2 The hydrophilic head is on the surface of membrane and the hydrophobic tail is on the inner side of membrane.

1.2.3 Extrinsic protein: the protein on the membrane that is bound to the outer surface of membrane.

1.2.4 Intrinsic protein: the protein that is embedded between the phospholipids, and even penetrating the inner and outer membrane surfaces.

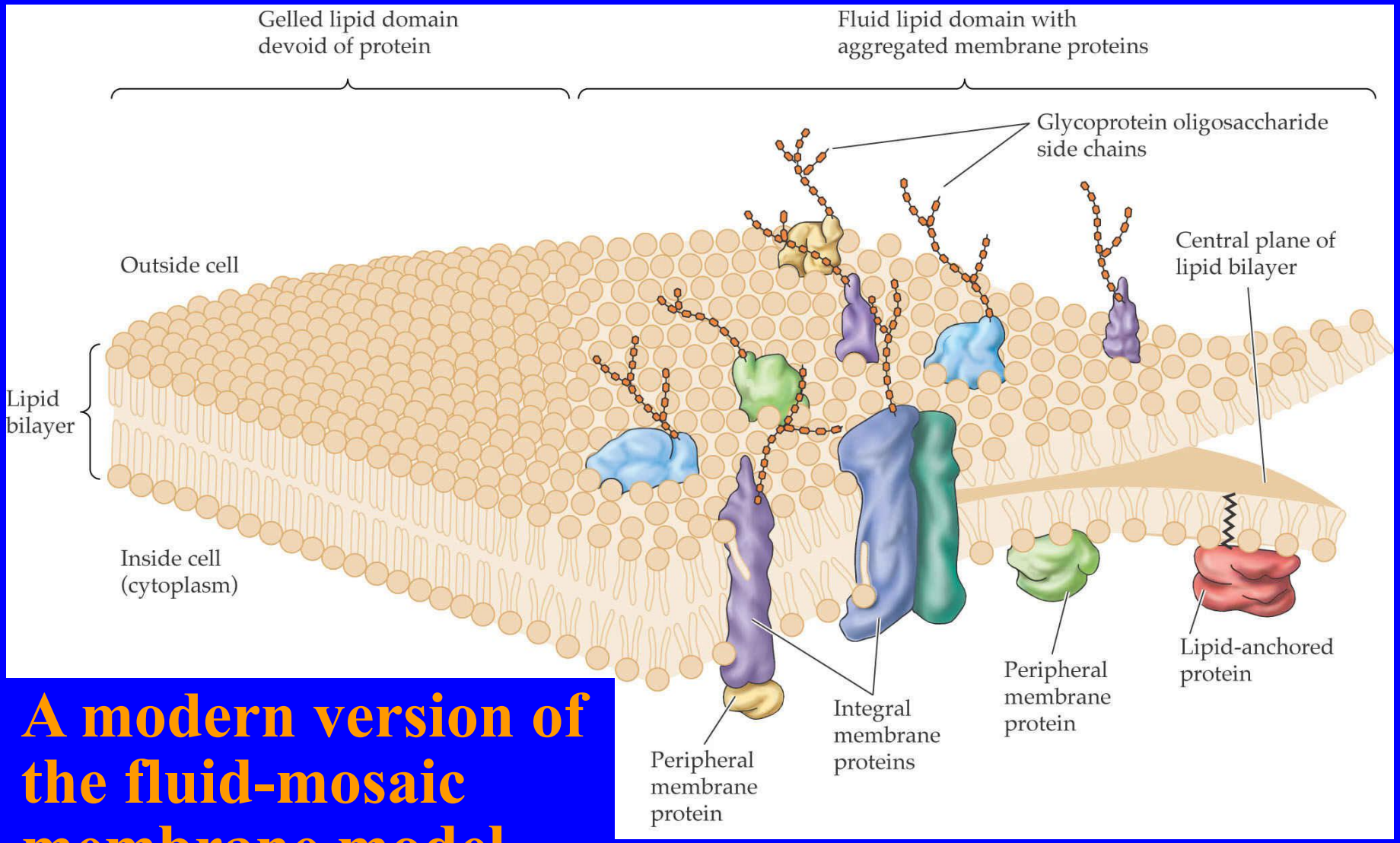
1.2.5 The membrane is of asymmetric structure with thickness of 7-10 nm, and the membrane lipids and proteins could move.



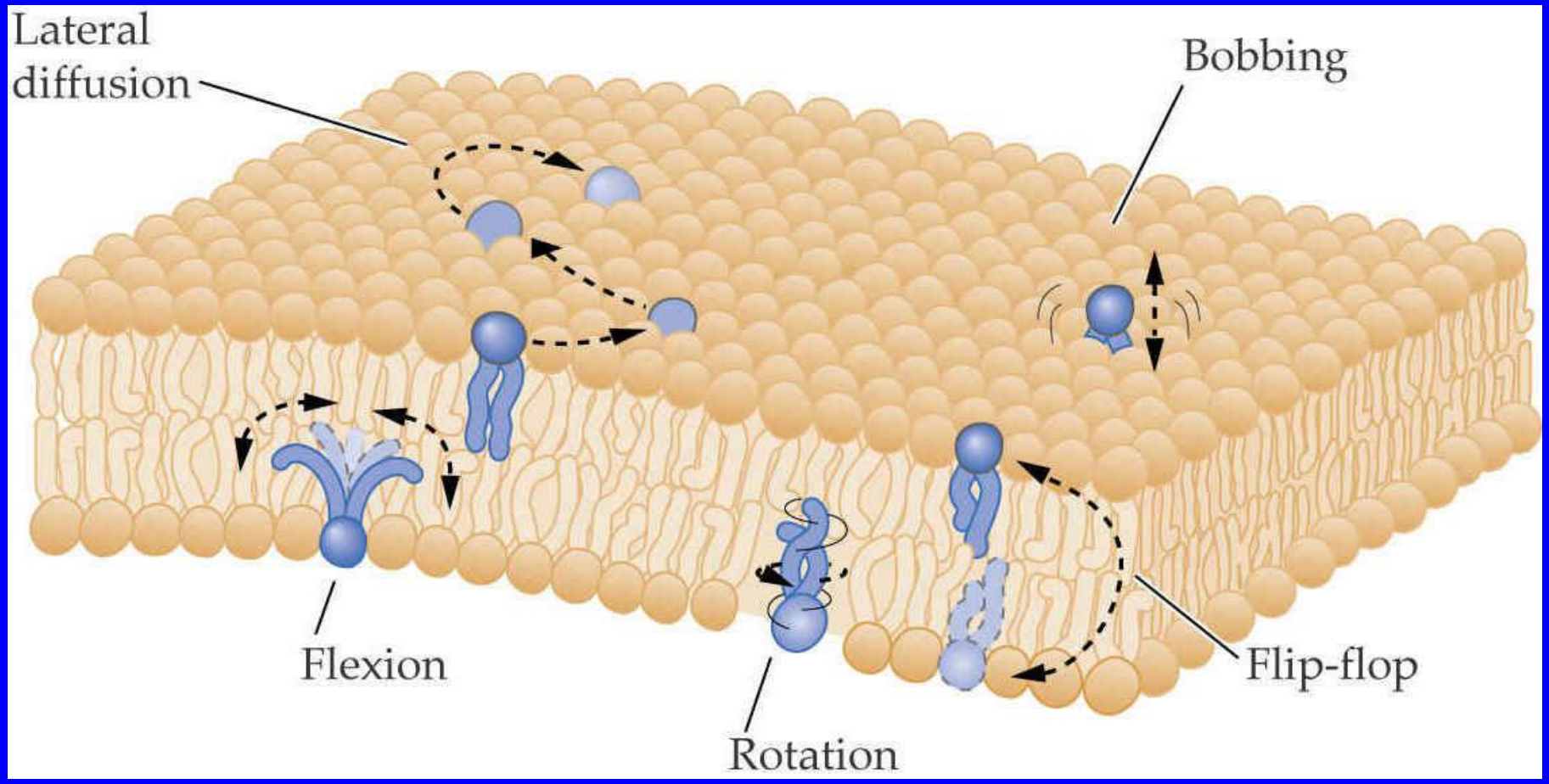


Organization of amphipathic lipid molecules in a bilayer.

Cross-sectional view of a lipid micelle and a lipid bilayer in aqueous solution.



A modern version of the fluid-mosaic membrane model.



Mobility of phospholipid molecules in a lipid bilayer.

II. Method and Mechanism of Cellular Absorption of Solutes

(I) Diffusion

Simple diffusion: the physical process whereby a solute moves passes through the phospholipid bilayer from an area of high concentration to that of lower concentration.

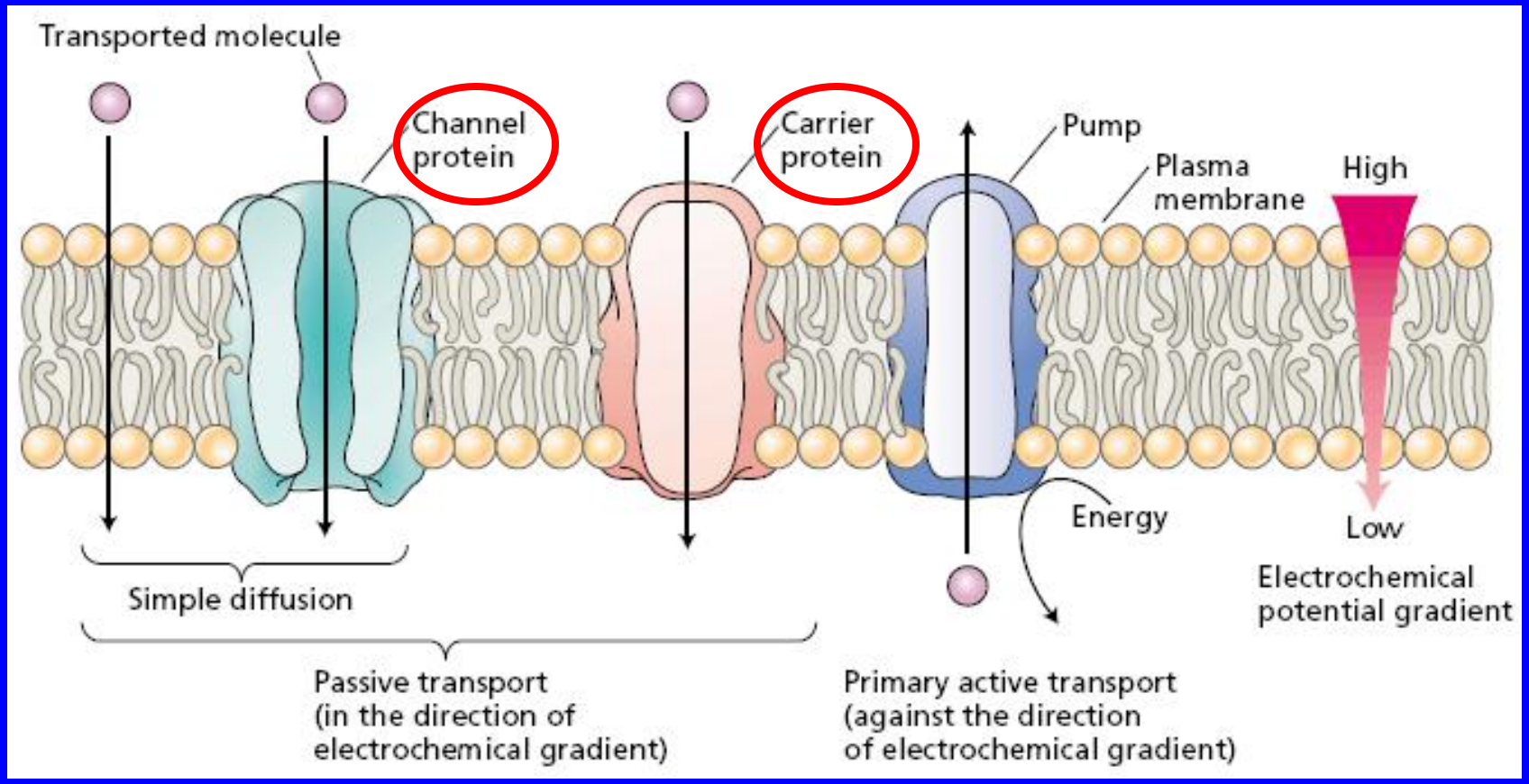
Facilitated (or assisted) diffusion: the transmembrane transport of some solutes down the concentration or electrochemical gradient mediated by membrane transport protein without requiring energy.

2.2 Ion channel

The channel formed across the cytomembrane by channel protein (internal protein across both sides of the membrane). It is activated chemically or electrochemically to control the ion transportation passively and laterally across the cytomembrane along concentration gradient and membrane potential difference. A certain channel only allow the passing of one or certain ions.

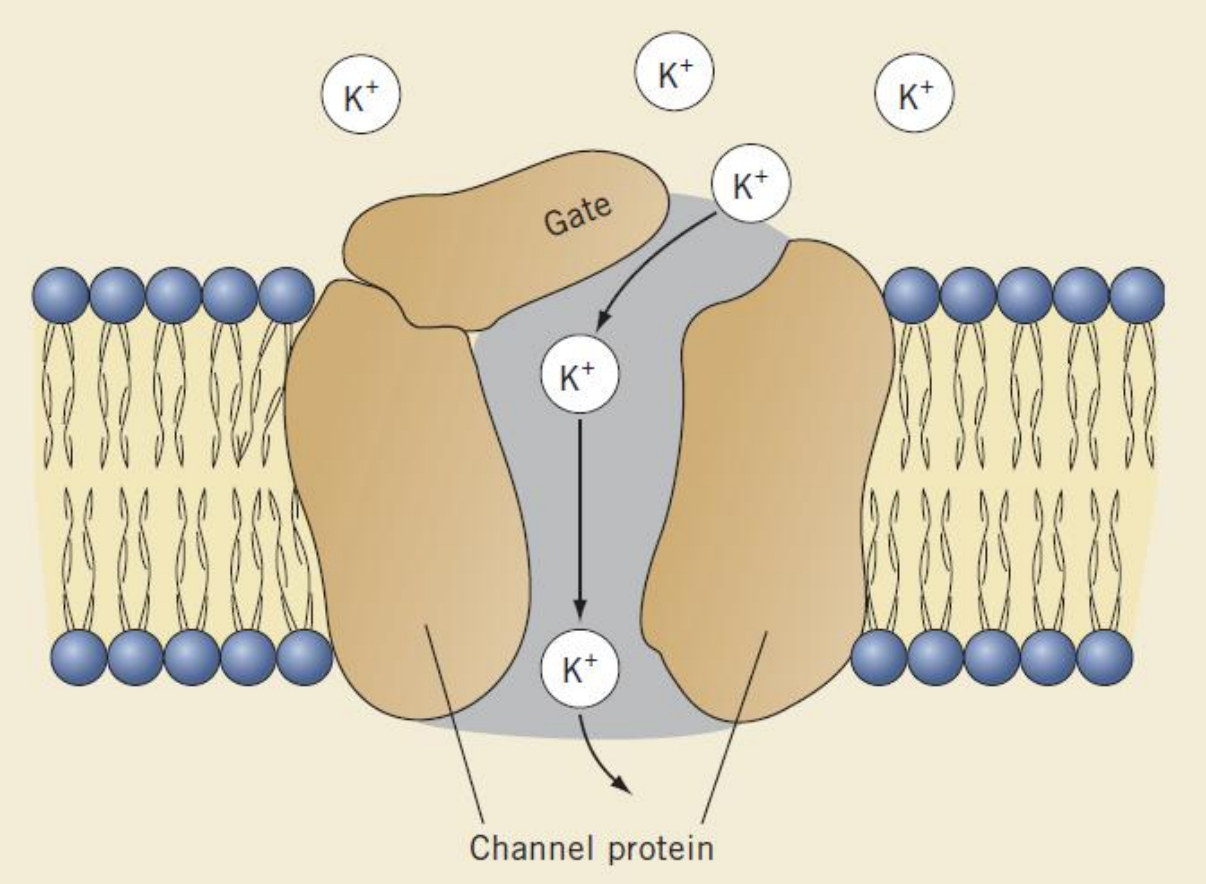
Known ion channel: K^+, Cl^-, H^+, Na^+, Ca^{2+}, NO_3^-, malic acid ion and water channel, etc.

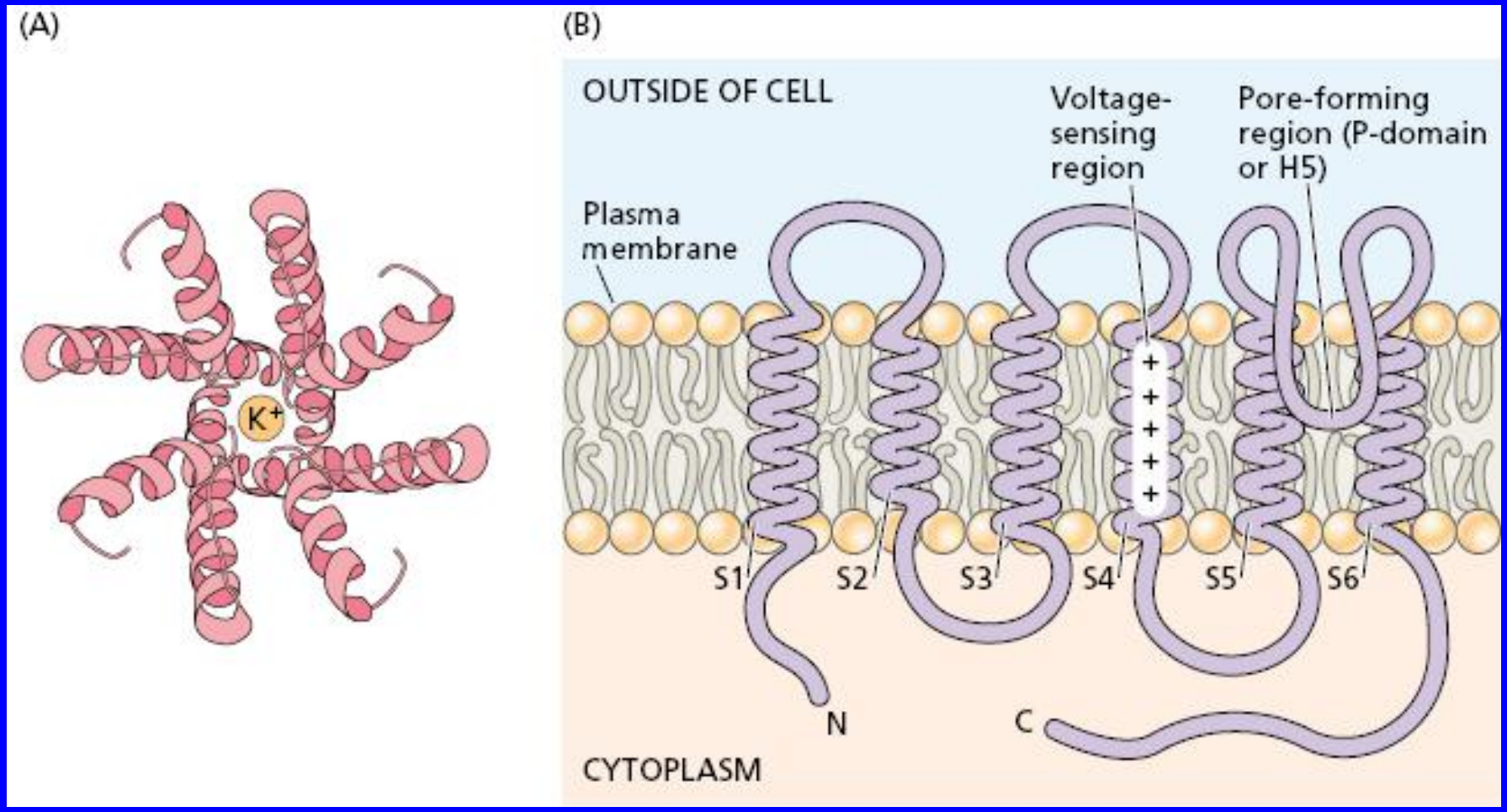
Transport rate: 10^7-10^8 ions/s, 1000 times faster than that of carrier protein.



Three classes of membrane transport proteins: channels, carriers, and pumps.

A gated membrane channel. Gated channels may be open, in which case ions are permitted to pass through the channel, or closed to ion flow. Opening may be stimulated by changes in membrane potential, the presence of hormones, or the ion itself.





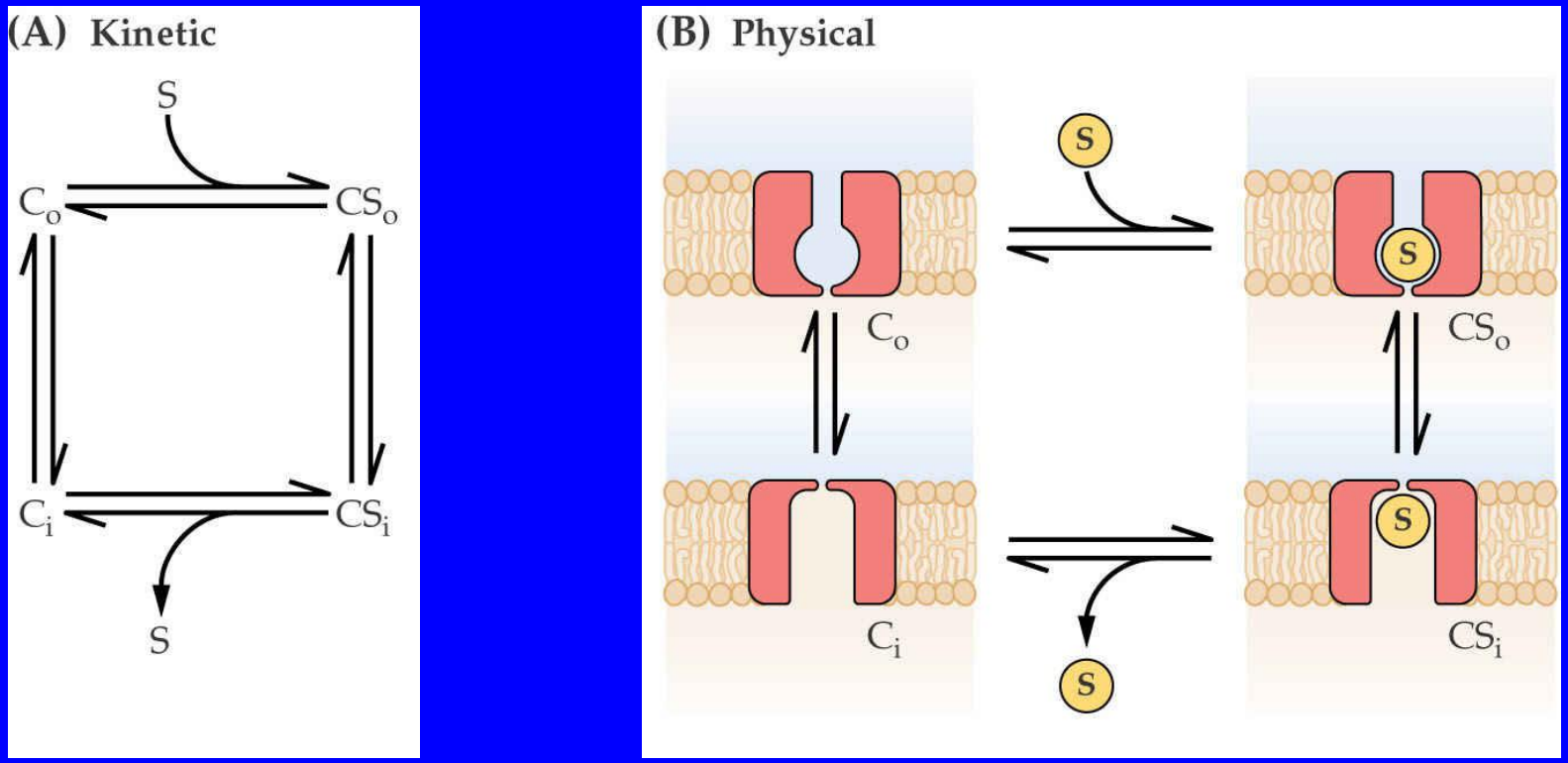
Models of K^+ channels in plants. (A) Top view of channel, looking through the pore of the protein. (B) Side view of the inward rectifying K^+ channel, showing a polypeptide chain of one subunit, with six membrane-spanning helices.

(III) Carrier protein

The carrier protein on the cytomembrane is an intrinsic protein without formation of obvious channel structure in transmembrane domain, and it selectively binds to the molecule or ion at one side of cytomembrane to form carrier-matter complex, and the transported matter is exposed to the other side of the cytomembrane by the conformational change of carrier protein and then released.

Feature: active or passive transport

Transport rate: 10^4~10^5 ions/s。



Kinetic (A) and cartoon (B) representations of the activity of carrier C, illustrating the transport of solute S from an extracytosolic compartment (outside, o) to the cell interior (inside, i).

1. Unidirectional transport carrier

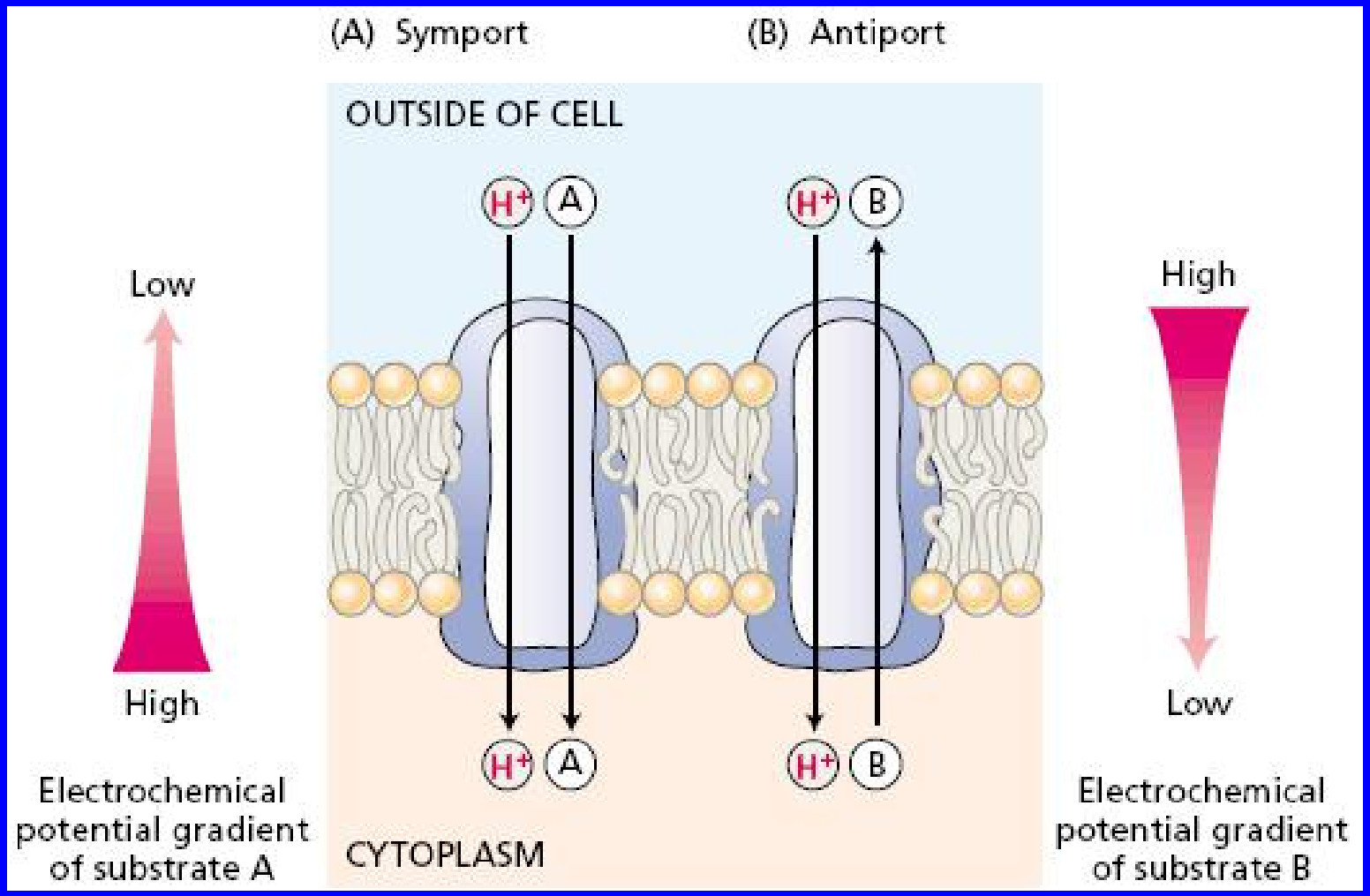
   The carrier to catalyze the molecule or ion to be transported across the cytomembrane along the electrochemical gradient; known carrier includes, Fe^{2+}, Zn^{2+}, Mn^{2+} and Cu^{2+}, etc.

2. Symporter

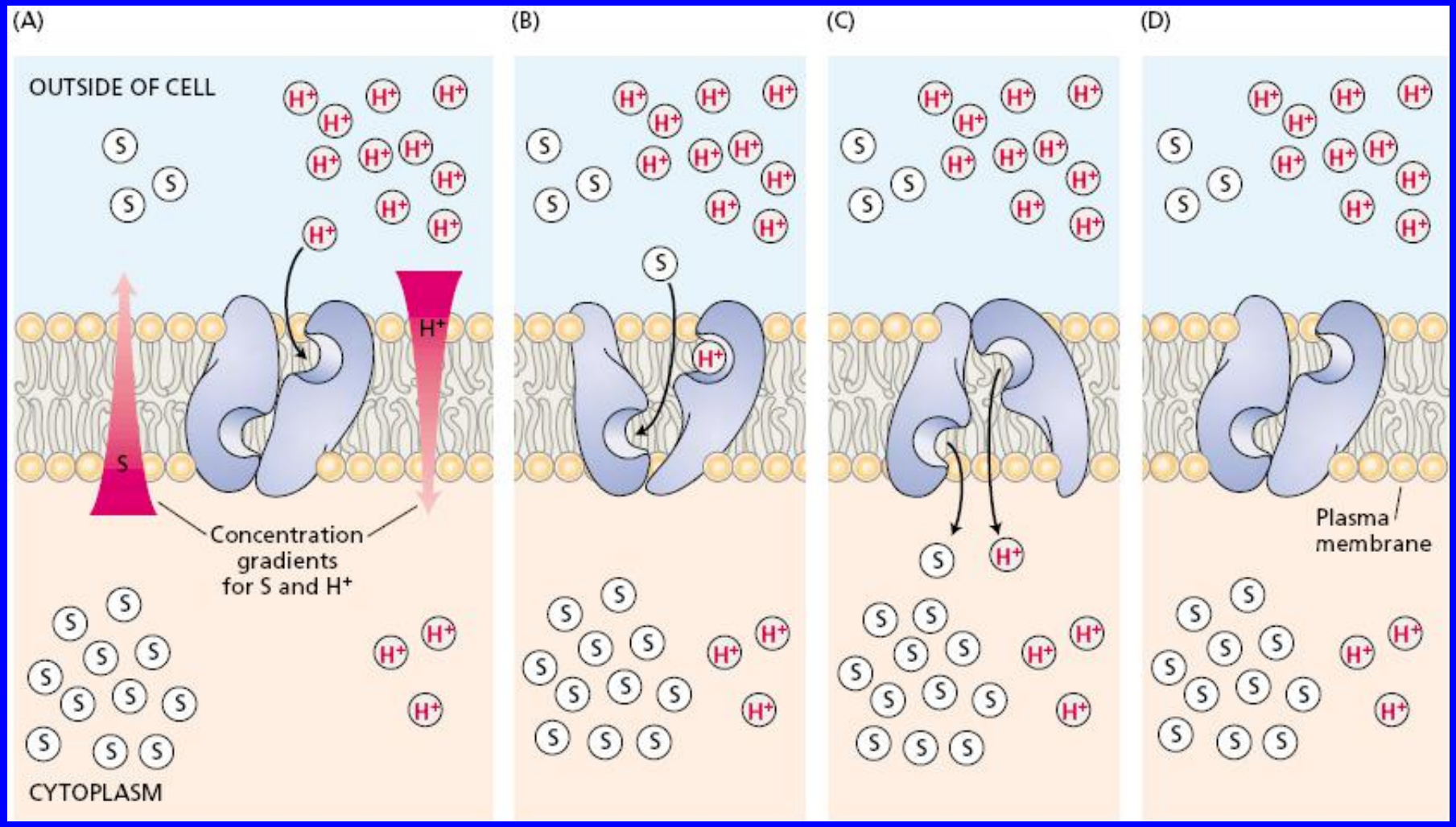
   The transporter binds to H^+ at the outside of cytomembrane and concurrently binds to another molecule or ion, and transport them at the same direction. The known matters of such transport method include Cl^-, K^+, NO_3^-, NH_4^+, PO_4^{3-}, SO_4^{2-}, amino acid, peptide, cane sugar and hexose, etc.

3. Antiporter

   The transporter binds to H^+ at the outside of cytomembrane and concurrently binds to another molecule or ion, and transport them at the opposite direction. The known matters of such transport method include Na^+ etc.



Two examples of secondary active transport coupled to a primary proton gradient.



Hypothetical model for secondary active transport.

(IV) Ion pump

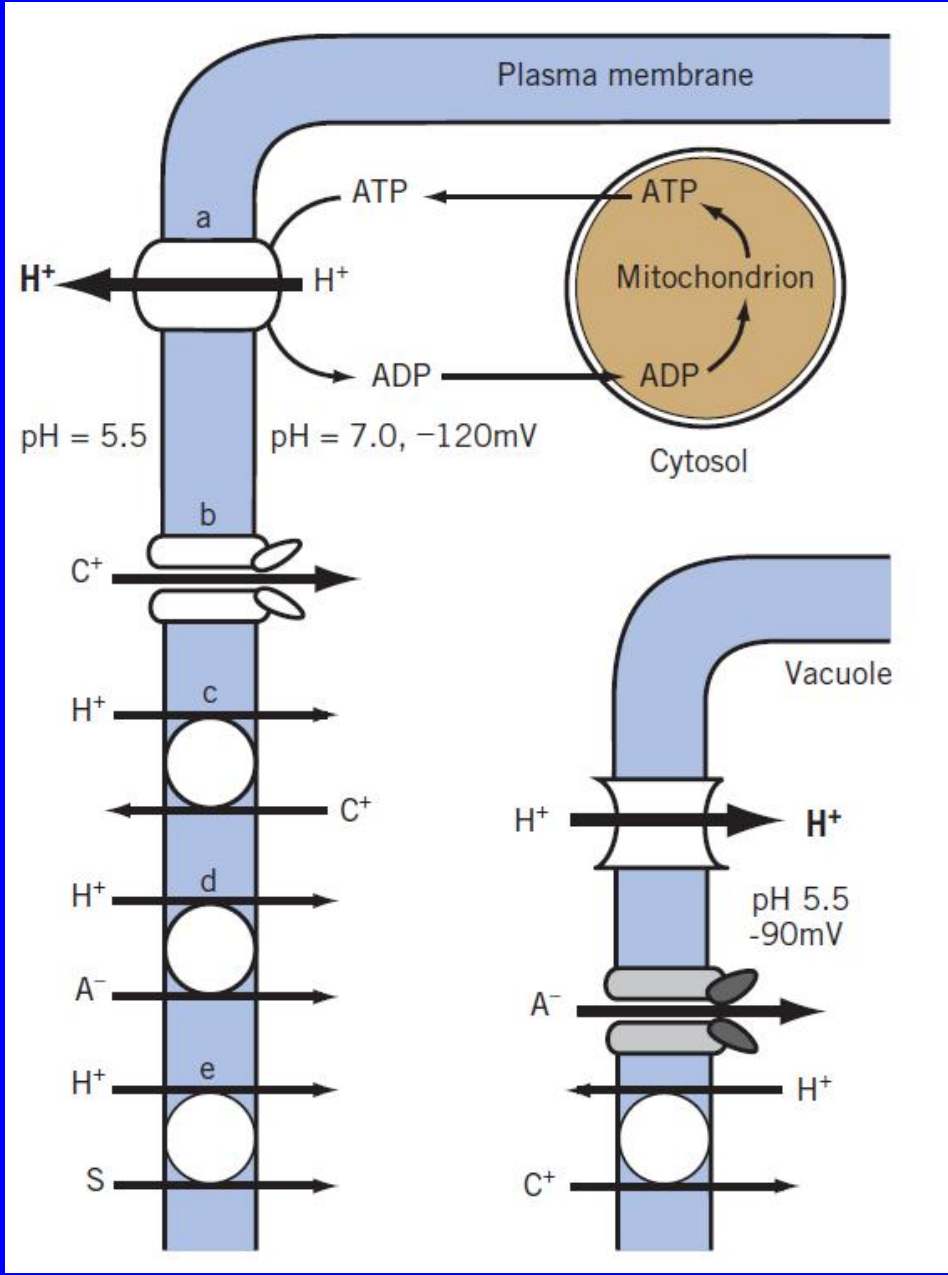
The ion pump on the cytomembrane is the ATP enzyme, and also intrinsic protein on the membrane; when small amount of K^+ and Na^+ enter the cytomembrane, the ATP enzyme is activated and hydrolyzed to release energy, which helps the ion to cross the membrane against the electrochemical potential.

1. H^+-ATP enzyme: it is catalyzed by ATP phosphohydrolase (ATP enzyme for short), and the ATP enzyme is an intrinsic protein on the cytomembrane.

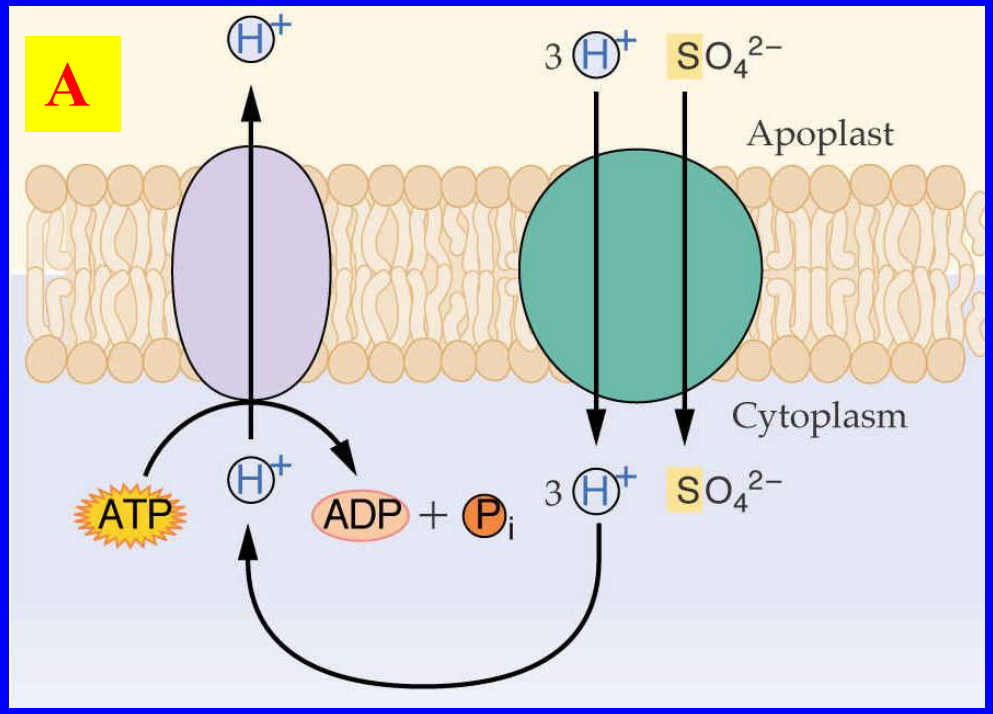
(1) ATP is hydrolyzed to release energy and pump the H^+ at inside of the cell to outside → $[H^+]\uparrow$ at the outside of the cell→ Proton gradient and membrane potential difference form between the 2 sides of cytomembrane→

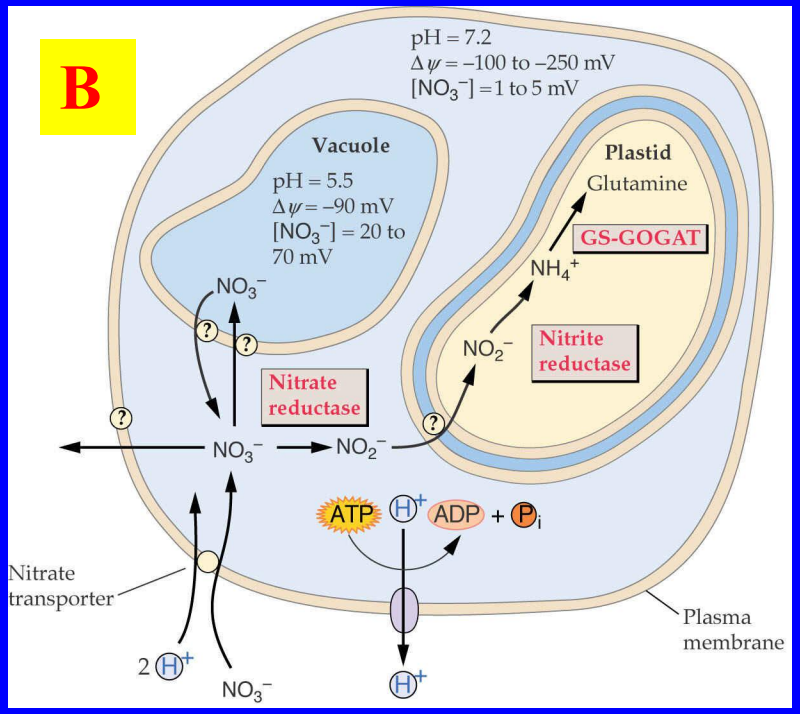
{ The positive ion enters the cell via channel protein
{ The negative ion enters the cell together with H^+ via symporter.

Schematic diagram relating the activity of a membrane ATPase-proton pump to solute exchange. The proton pump (*a*) uses the energy of ATP to establish both a proton gradient and a potential difference (negative inside) across the membrane. The energy of the proton gradient may activate an ion channel (*b*), or drive the removal of ions from the cell by an antiport carrier (*c*), or drive the uptake of ions or uncharged solute by a symport carrier (*d, e*). Similar pumps and carriers operate across the vacuolar membrane. C^+, cation; A^-, anion; S, uncharged solute.



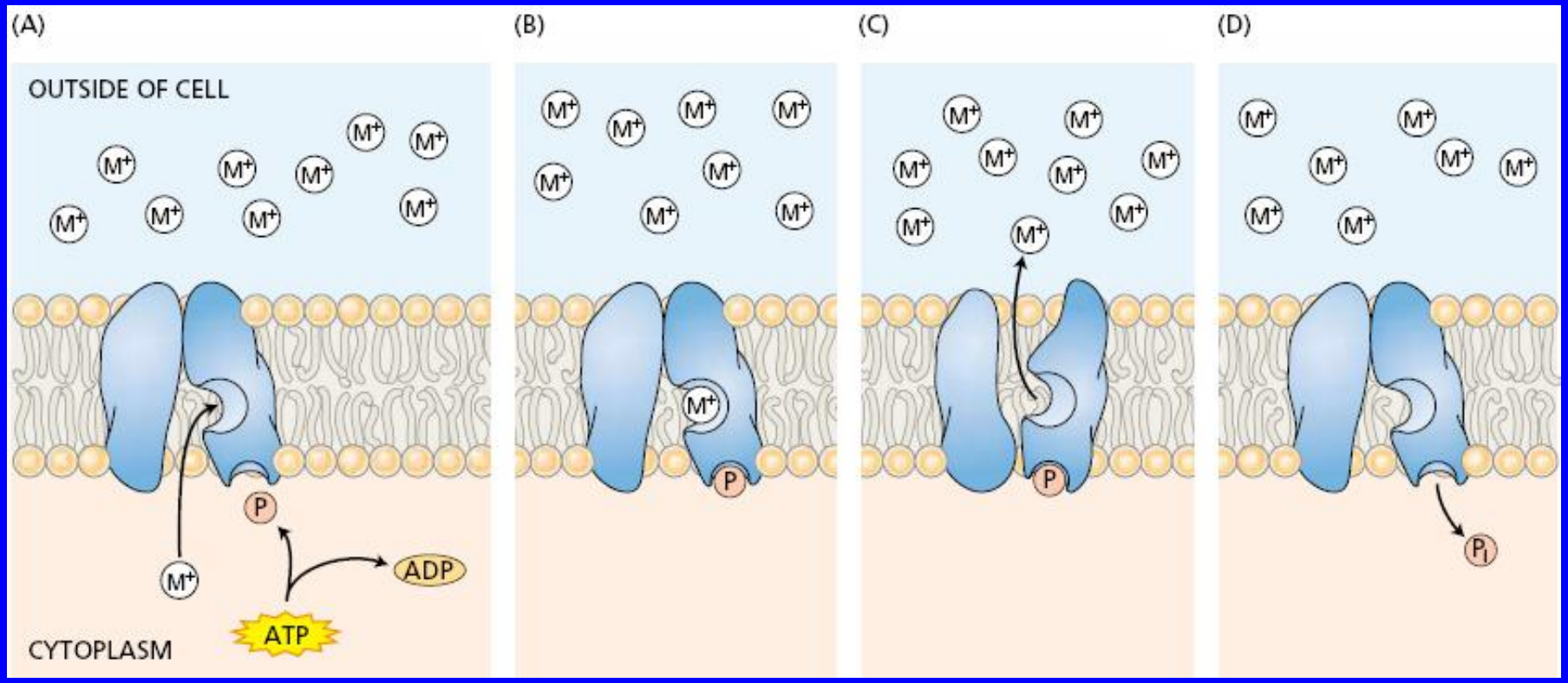
Model for sulfate (A) and nitrate (B) transport across the plasma membrane.



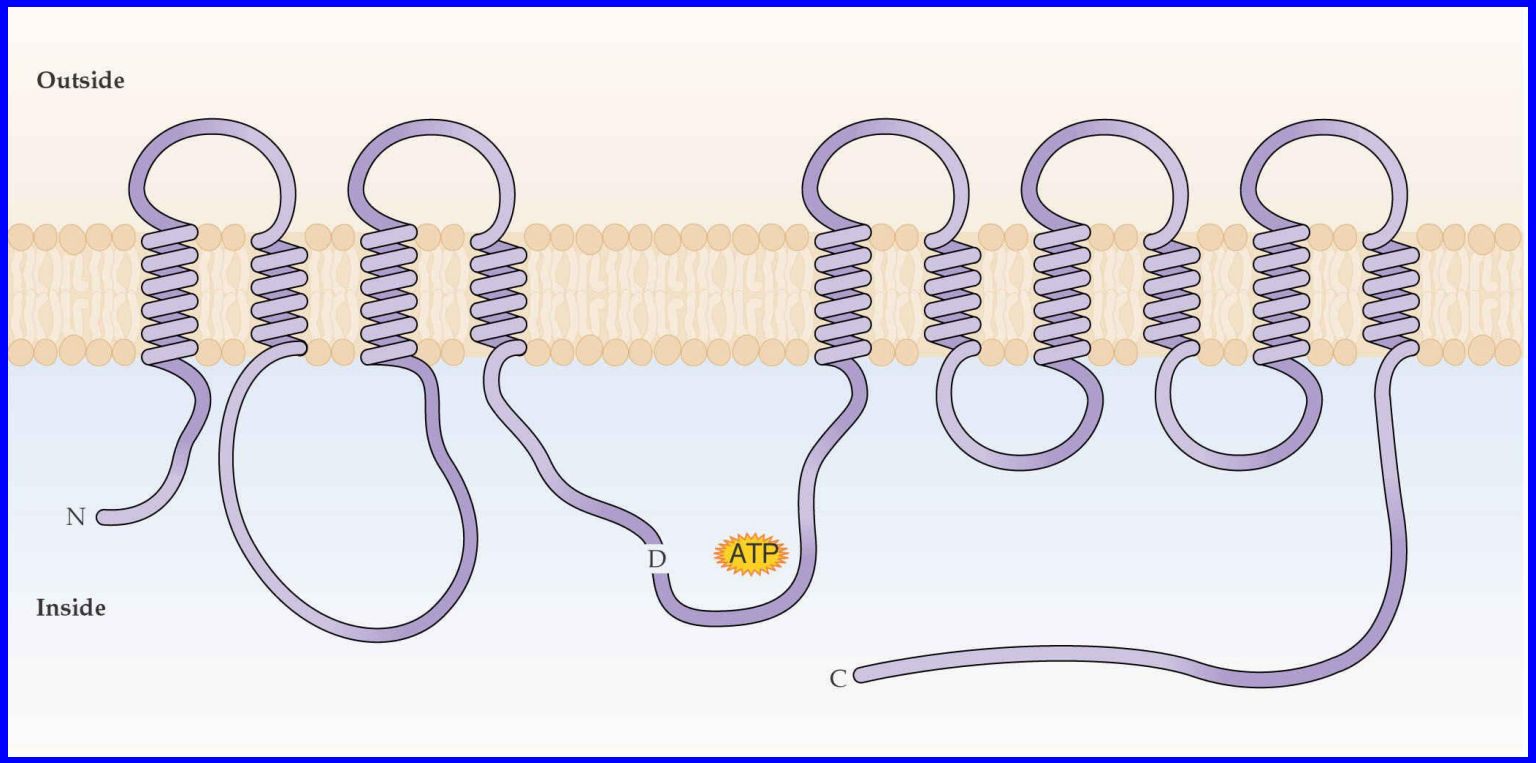


(2) Working principle of H^+-ATP enzyme: the proton pump to generate electricity on the cytomembrane forms channel, with opening at the inside of membrane, and the positive ion binds to ATP → The Asp of protein molecule is phosphorylated by ATP → Conformational change occurs→ The inside opening closes, and the outside one opens→ The positive ion is released to the outside → The confirmation returns to original state → The phosphate group is disconnected from the protein.

(3) Type: the P type H^+-ATP enzyme on the cytomembrane (inhibited by VO_3^-, insensitive to NO_3^-); the V type H^+-ATP enzyme on the tonoplast (insensitive to VO_3^-, and inhibited by NO_3^-); the F type H^+-ATP enzyme on the mitochondria and thylakoid membrane (involved in ATP synthesis, with features similar to that of the V type)



Hypothetical steps in the transport of a cation (the hypothetical M^+) against its chemical gradient by an electrogenic pump.



Membrane disposition of plasma membrane H^+-ATPase.

2. Calcium pump

It is also called Ca^{2+}-ATP enzyme, and it catalyzes, under the existence of Mg^{2+}, the ATP at the inside of cytomembrane to hydrolize and release energy, which drives the calcium ion inside the cell to be pumped outside, or pumps 2 H^+ ions into cytoplasm simultaneously

3. H^+- pyrophosphatase

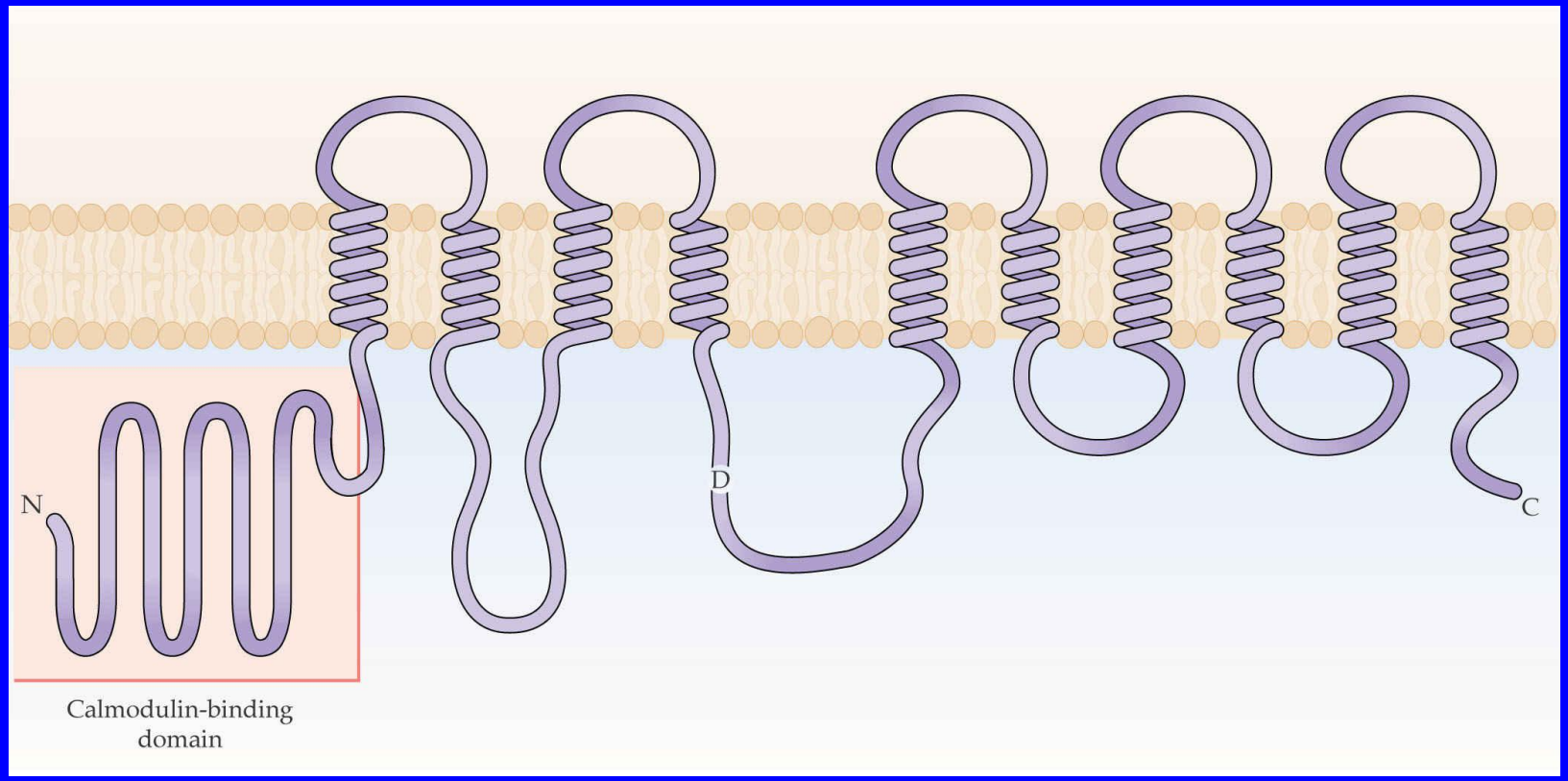
The H^+ pump on the tonoplast to pump H^+ inside the tonoplast with the free energy of pyrophosphoric acid, so as to produce electrochemical potential across the membrane, and induce nutrient active transmembrane transport.

(V) Pinocytosis

1. Definition: the process of the cell to directly take in external matter into the cell by means of membrane invagination. It is a non-selective absorption.

2. Process: the matter attaches to the cytomembrane → cytomembrane invagination → the liquid and matter enter → the cytomembrane infolding → the cytomembrane encompasses the liquid and matter → the vesicle forms → the vesicle moves inside the cell → the vesicle passes the matter to the cytoplasm.

Activity of the vacuolar Ca^{2+}-ATPase is regulated by the binding of calmodulin to the N terminal.



P type and V type need activation with calmodulin, but the ER type does not need.

III. Transport Protein on the Tonoplast

- Channel: includes rapid (Mal^{2-}, Cl^- , NO_3^-) and slow vacuole channel and Ca^{2+} outlet channel.
- Antiporter: includes Na^+-H^+, Ca^{2+}-H^+, Cd^{2+}-H^+, Mg^{2+}-H^+, hexose -H^+ and sucrose -H^+ (H^+ egresses, and solute enters)
- H^+ pump: includes H^+ import pump dependent on ATP and PPi effect
- ATP box domain transporter (ABC transporter): import anthocyanin and PC-Cd^{2+}

Chapter VI Mineral Nutrients – Cellular Absorption of Mineral Elements

Overview of the various transport processes on the plasma membrane and tonoplast of plant cells.