

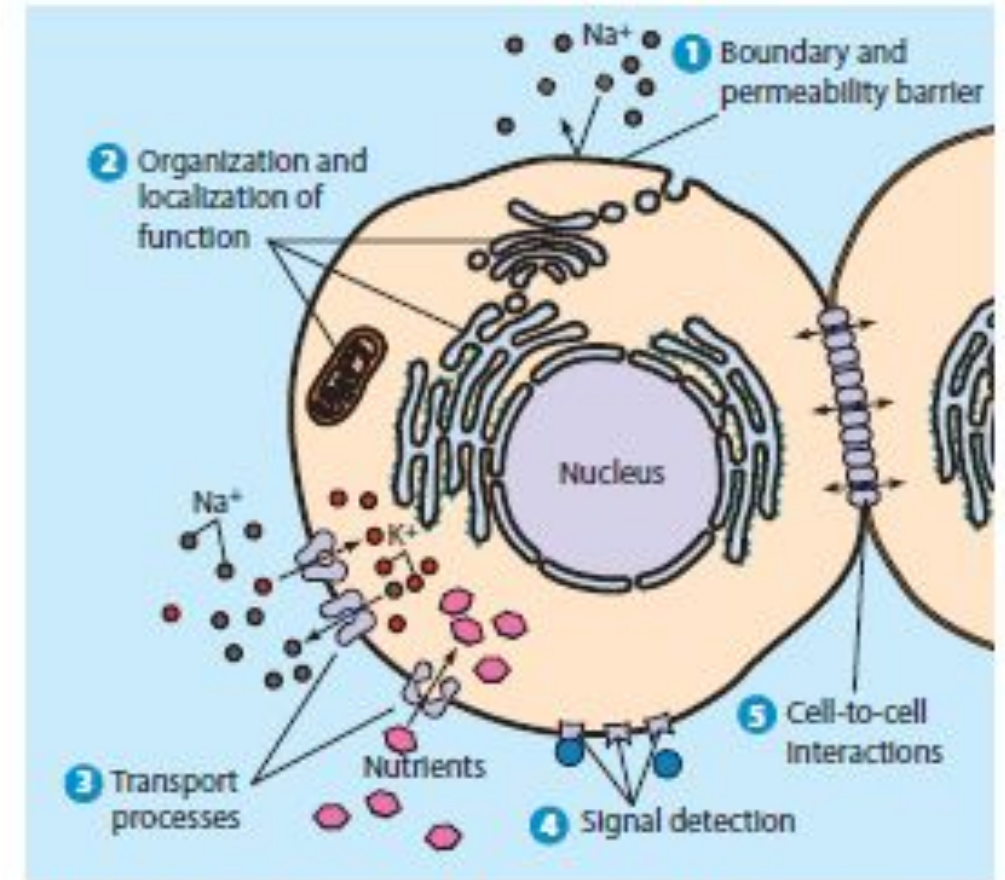
**Biological Membranes: membrane permeability: pumps and channels, action potential.**

# Introduction

**Membranes** define the boundaries of the cell and its various internal compartments.

Their functions include:

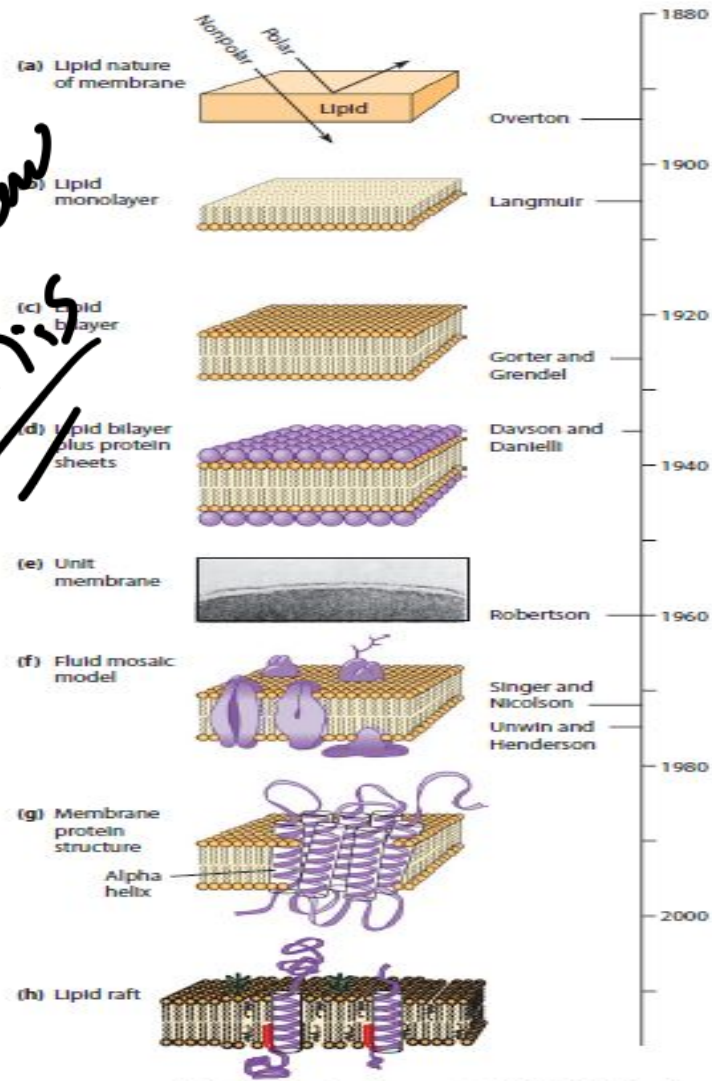
- Define the boundaries of the cell and its organelles and act as permeability barriers.
- Sites for specific biochemical functions, such as electron transport during mitochondrial respiration or protein processing in the ER.
- Allow transport and have transport proteins that regulate the movement of substances into and out of the cell and its organelles.
- They provide mechanisms for cell-to-cell contact, adhesion, and communication.



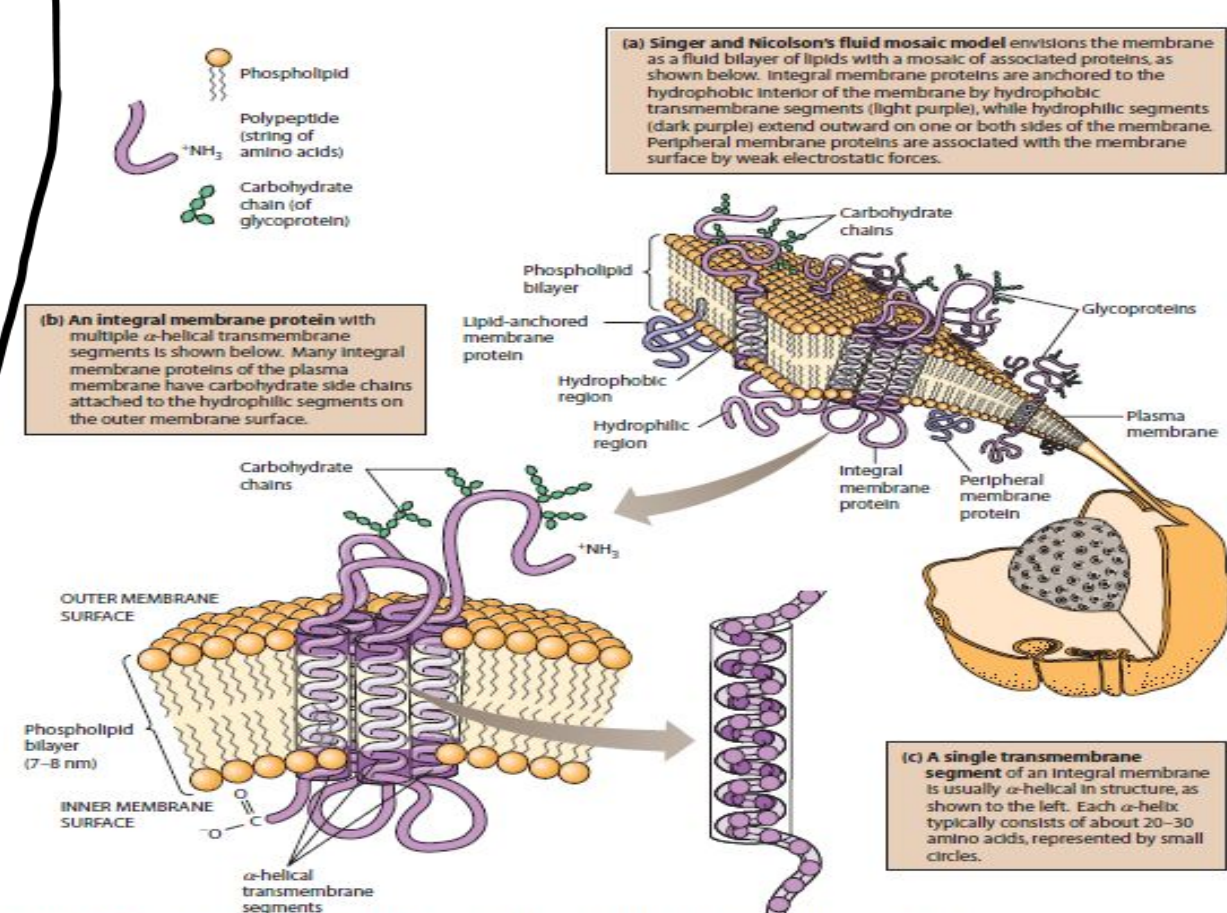
**FIGURE 7-2 Functions of Membranes.** Membranes not only define the cell and its organelles but also have a number of important functions, including transport, signaling, and adhesion.

# What are membranes made up of ?

*Draw this*



Timeline of experiments carried out for understanding the membrane structure



**FIGURE 7-5 The Fluid Mosaic Model of Membrane Structure.** These drawings show (a) representative phospholipids and proteins in a typical plasma membrane, with closeups of (b) an integral membrane protein and (c) one of its transmembrane segments.

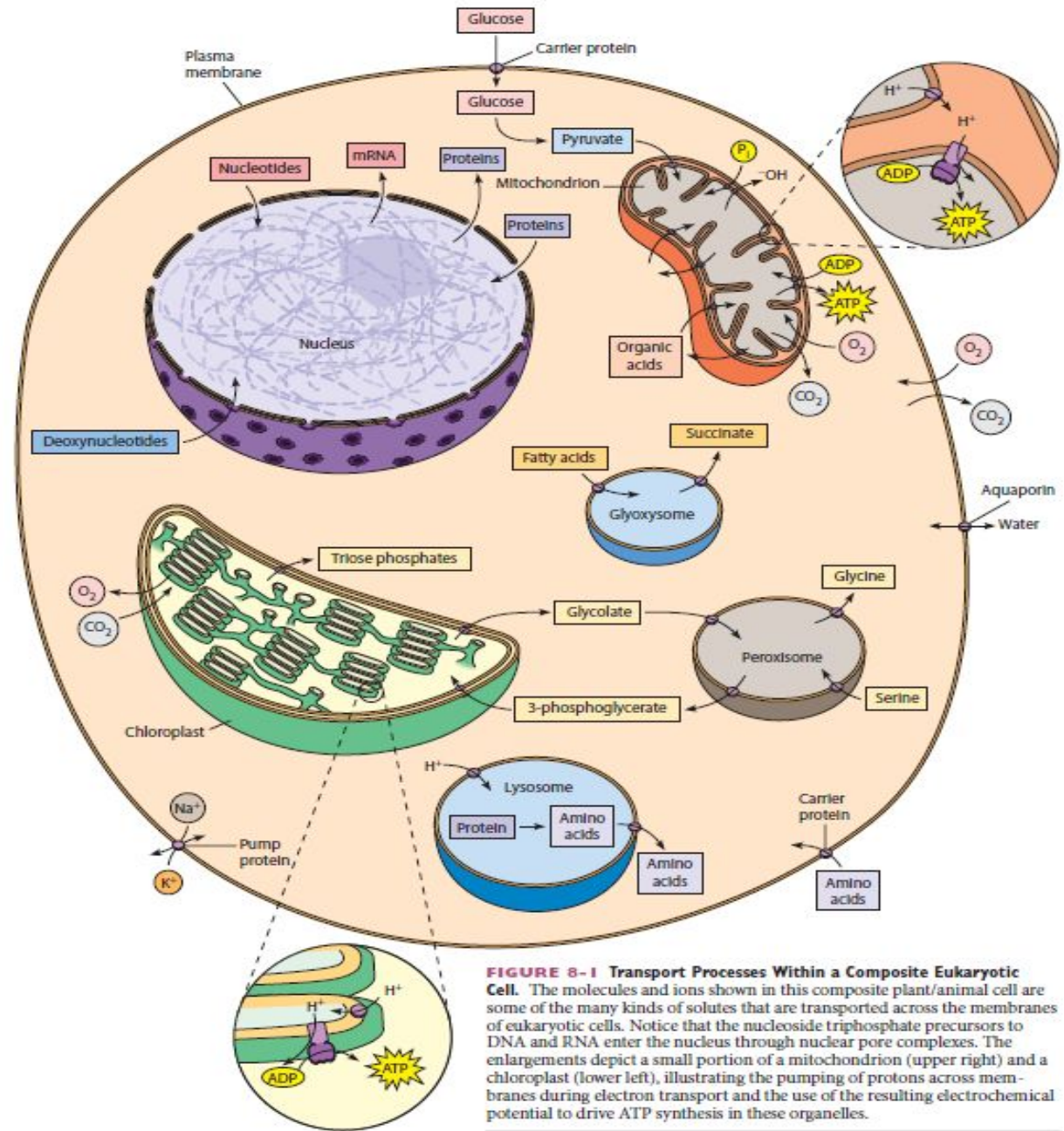
**ACTIVITIES** [www.thecellplace.com](http://www.thecellplace.com) Membrane structure

Membranes are made up of a lipid bilayer, trans membrane proteins, integral membrane proteins and carbohydrates: all of which contributes to membrane permeability



# Transport across membranes

- **Simple diffusion:** direct, unaided transport of small molecules
- **Facilitated diffusion:** Movement with help of channel proteins and carrier proteins
- **Active transport:** Energy driven transport

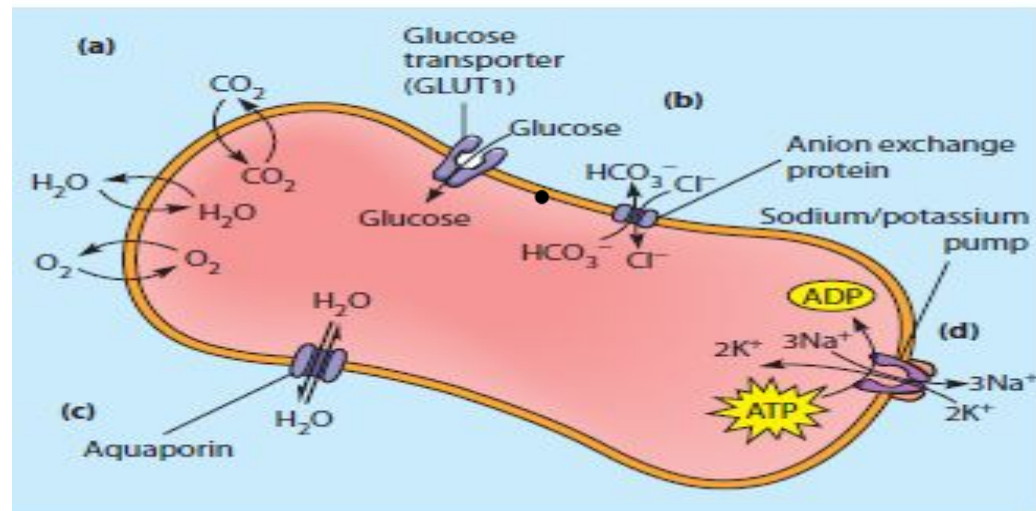


**(a) Simple diffusion.**

Oxygen, carbon dioxide, and water diffuse directly across the plasma membrane in response to their relative concentrations inside and outside the cell.

**(b) Facilitated diffusion mediated by carrier proteins.**

The movement of glucose across the plasma membrane is facilitated by a specific glucose transporter called GLUT1. An anion exchange protein facilitates the reciprocal transport of chloride ( $\text{Cl}^-$ ) and bicarbonate ( $\text{HCO}_3^-$ ).



**(c) Facilitated diffusion mediated by channel proteins.**

Aquaporin channel proteins can facilitate the rapid inward or outward movement of water molecules.

**(d) Active transport.**

Driven by the hydrolysis of ATP, the  $\text{Na}^+/\text{K}^+$  pump moves three sodium ions outward for every two potassium ions moved inward, establishing an electrochemical potential across the plasma membrane for both ions.

## Important Transport Processes of the Erythrocyte

**Table 8-1****Comparison of Simple Diffusion, Facilitated Diffusion, and Active Transport**

Properties	Simple Diffusion	Facilitated Diffusion	Active Transport
<b>Solutes transported</b>			
	Small polar (H <sub>2</sub> O, glycerol)	Small polar (H <sub>2</sub> O, glycerol)	
	Small nonpolar (O <sub>2</sub> , CO <sub>2</sub> )	Large polar (glucose)	Large polar (glucose)
	Large nonpolar (oils, steroids)	Ions (Na <sup>+</sup> , K <sup>+</sup> , Ca <sup>2+</sup> )	Ions (Na <sup>+</sup> , K <sup>+</sup> , Ca <sup>2+</sup> )
<b>Thermodynamic properties</b>			
Direction relative to electrochemical gradient	Down	Down	Up
Metabolic energy required	No	No	Yes
Intrinsic directionality	No	No	Yes
<b>Kinetic properties</b>			
Membrane protein required	No	Yes	Yes
Saturation kinetics	No	Yes	Yes
Competitive inhibition	No	Yes	Yes



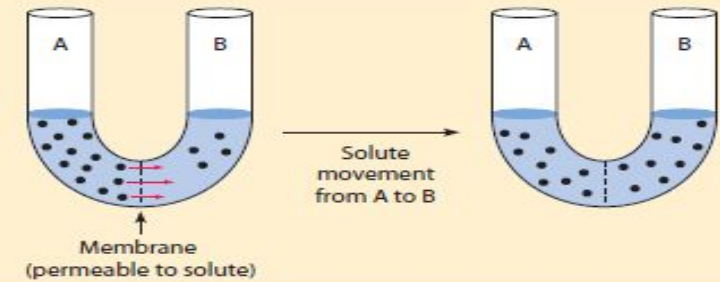
## Simple diffusion

- Simple diffusion is that the net rate of transport for a specific substance is directly proportional to the concentration difference for that substance across the membrane over a broad concentration range.
- For the diffusion of solute S from the outside to the inside of a cell, the expression for the rate, or velocity, of inward diffusion through the membrane:

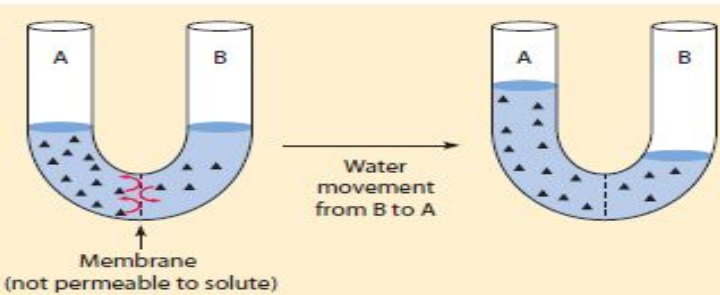
$$v_{\text{inward}} = P \Delta [S]$$

where  $v_{\text{inward}}$  is the rate of inward diffusion (in moles/square cm second of membrane surface), and  $\Delta[S]$  is the concentration gradient of the solute across the membrane and  $P$  is the permeability coefficient

(a) Simple diffusion takes place when the membrane separating chambers A and B is permeable to molecules of dissolved solute, represented by the black dots. Net movement of solute molecules across the membrane is from chamber A to B (high to low solute concentration). Equilibrium is reached when the solute concentration is the same in both chambers.



(b) Osmosis occurs when the membrane between the two chambers is not permeable to the dissolved solute, represented by the black triangles. Because solute cannot cross the membrane, water diffuses from chamber B where the solute concentration is lower (more water) to chamber A where the solute concentration is higher (less water). At equilibrium, the solute concentration will be equal on both sides of the membrane.



**FIGURE 8-4 Comparison of Simple Diffusion and Osmosis.** In both examples shown, there is initially more solute in chamber A than in chamber B. The membrane in example (a) is permeable to the solute and the membrane in example (b), like a typical cell membrane, is not.

## Facilitated diffusion

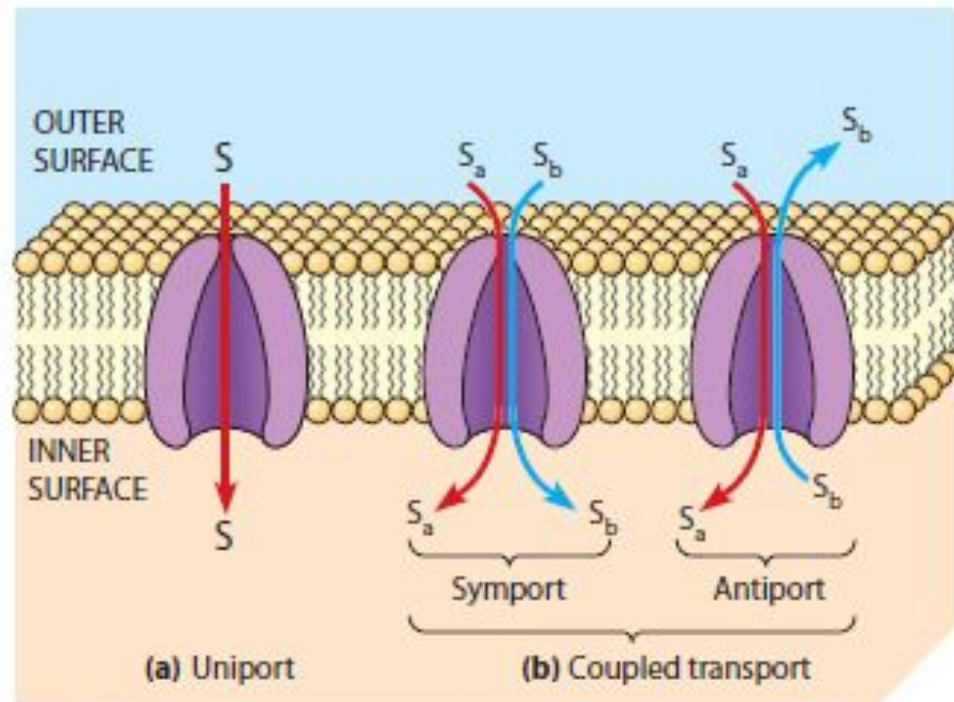
**Facilitated diffusion** involves the movement of molecules in the direction determined by their relative concentrations inside and outside of the cell. **No external source of energy** is provided, so molecules travel across the membrane in the direction determined by their concentration gradients and, in the case of charged molecules, by the electrical potential across the membrane

Two classes of proteins that mediate facilitated diffusion have generally been distinguished: **carrier proteins** and **channel proteins**.

**Carrier proteins** bind specific molecules to be transported on one side of the membrane. They then undergo conformational changes that allow the molecule to pass through the membrane and be released on the other side.

In contrast, **channel proteins** form open pores through the membrane, allowing the free diffusion of any molecule of the appropriate size and charge.





**FIGURE 8-6 Comparison of Uniport, Symport, and Antiport Transport by Carrier Proteins.** (a) In uniport, a membrane transport protein moves a single solute across a membrane. (b) Coupled transport involves the simultaneous transport of two solutes,  $S_a$  and  $S_b$ . Coupled transport may be either symport (both solutes moved in the same direction) or antiport (the two solutes moved in opposite directions). Note that transporters are not simply open channels, as depicted in this simplified illustration, but alternate between two conformations as solutes are transported.

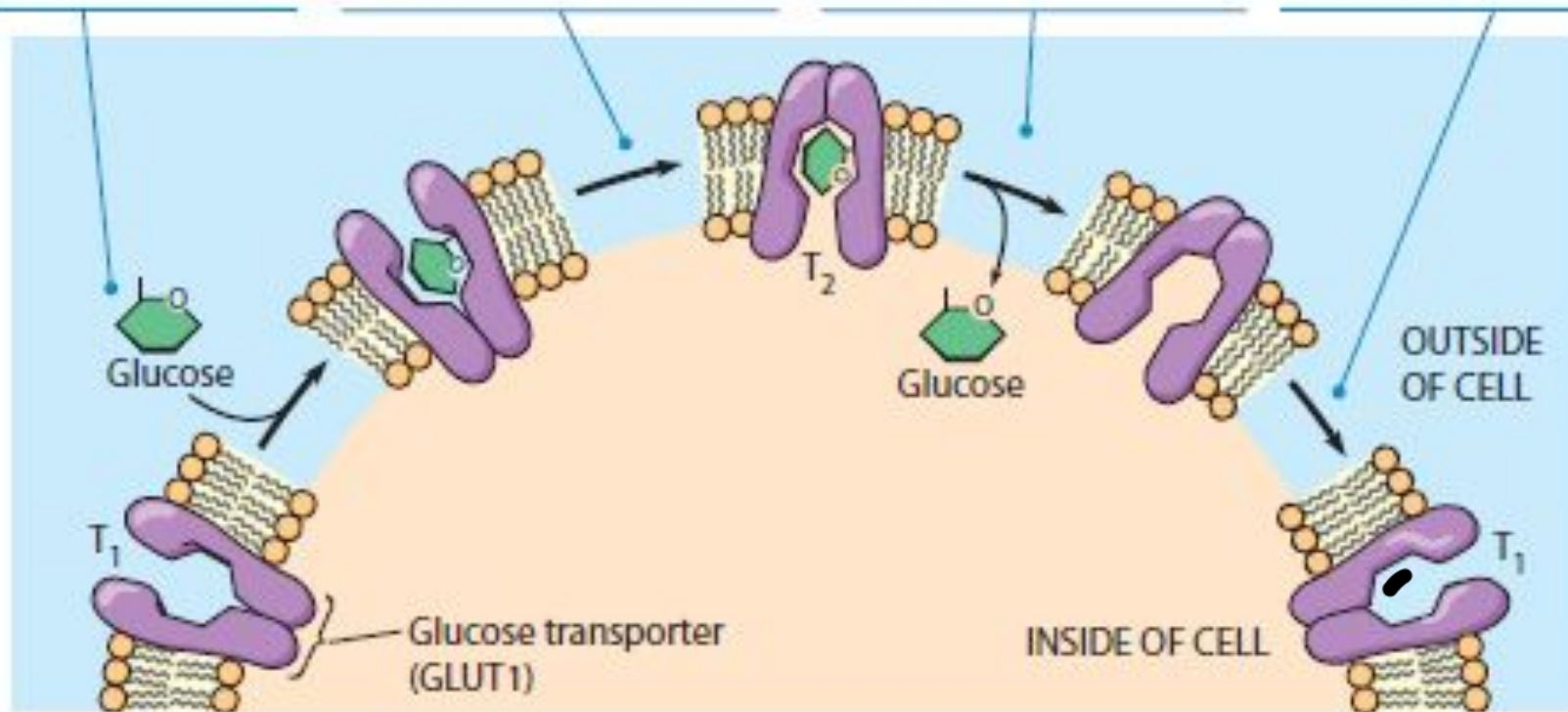
caricature

**1** Glucose binds to a GLUT1 transporter protein that has its binding site open to the outside of the cell ( $T_1$  conformation).

**2** Glucose binding causes the GLUT1 transporter to shift to its  $T_2$  conformation with the binding site open to the inside of the cell.

**3** Glucose is released to the interior of the cell, initiating a second conformational change in GLUT1.

**4** Loss of bound glucose causes GLUT1 to return to its original ( $T_1$ ) conformation, ready for a further transport cycle.



**FIGURE 8-7** The Alternating Conformation Model for Facilitated Diffusion of Glucose by the Glucose Transporter GLUT1 in the Erythrocyte Membrane. The inward transport of glucose by GLUT1 is shown here in four steps, arranged at the periphery of a cell.

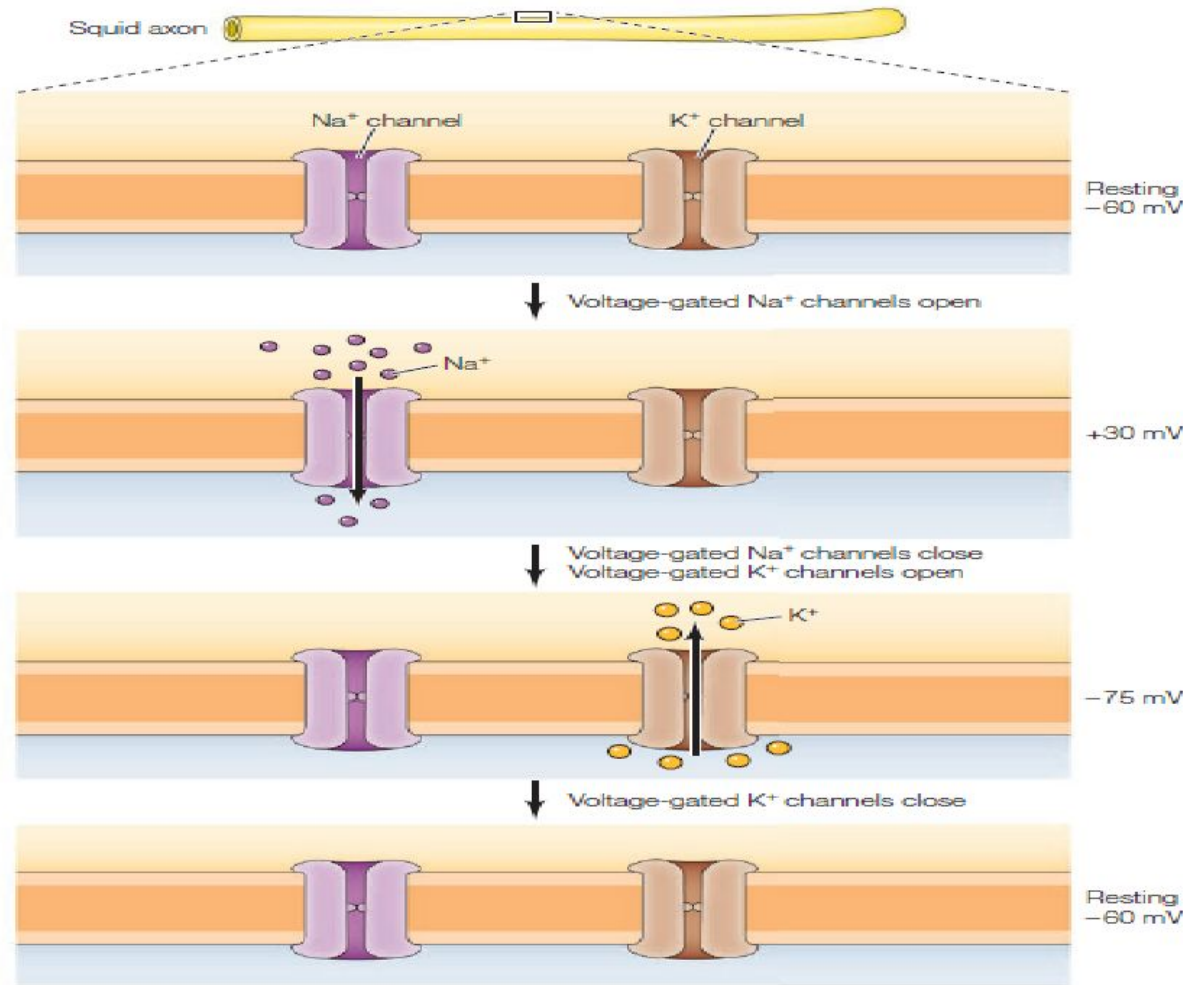
## Channel proteins

One group of **channel proteins** discussed earlier is the **porins**, which permit the free passage of ions and small polar molecules through the outer membranes of bacteria, mitochondria, and chloroplasts. **Gap junctions**, contain channel proteins that permit the passage of molecules between connected cells.

The best-characterized channel proteins are the **ion channels**, which mediate the passage of ions across plasma membranes. Three properties of ion channels are central to their function:

- ❖ Transport through channels is **extremely rapid**.
- ❖ Ion channels are **highly selective** because narrow pores in the channel restrict passage to ions of the appropriate size and charge
- ❖ Most ion channels are **not permanently open**. Instead, the opening of ion channels is regulated by “gates” that transiently open in response to specific stimuli. Some channels (called ligand-gated channels) open in response to the binding of neurotransmitters or other signaling molecules; others (voltage-gated channels) open in response to changes in electric potential across the plasma membrane.



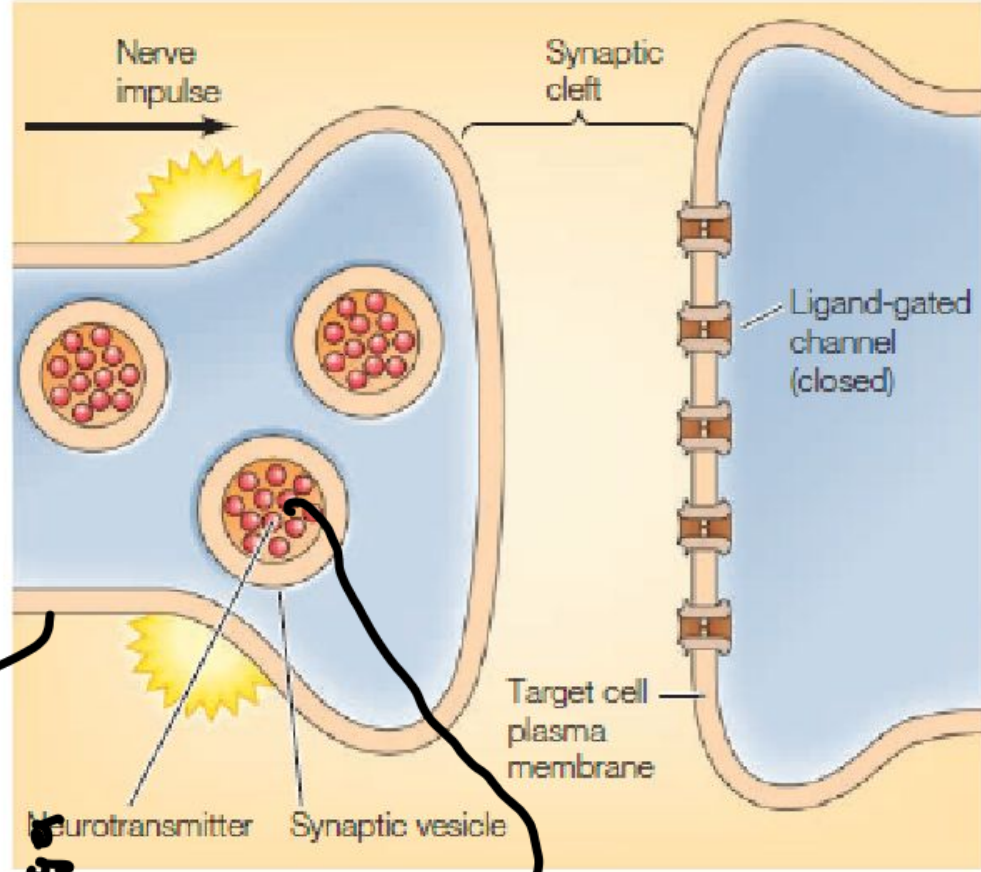


**Figure 15.18 Membrane potential and ion channels during an action potential** The membrane potential first increases as voltage-gated Na<sup>+</sup> channels open. The membrane potential then falls below its resting value as the Na<sup>+</sup> channels are inactivated and voltage-gated K<sup>+</sup> channels open. The voltage-gated K<sup>+</sup> channels are then inactivated, and the membrane potential returns to its resting value.

Channel Protein working.  
Bio electricity → used for impulses.

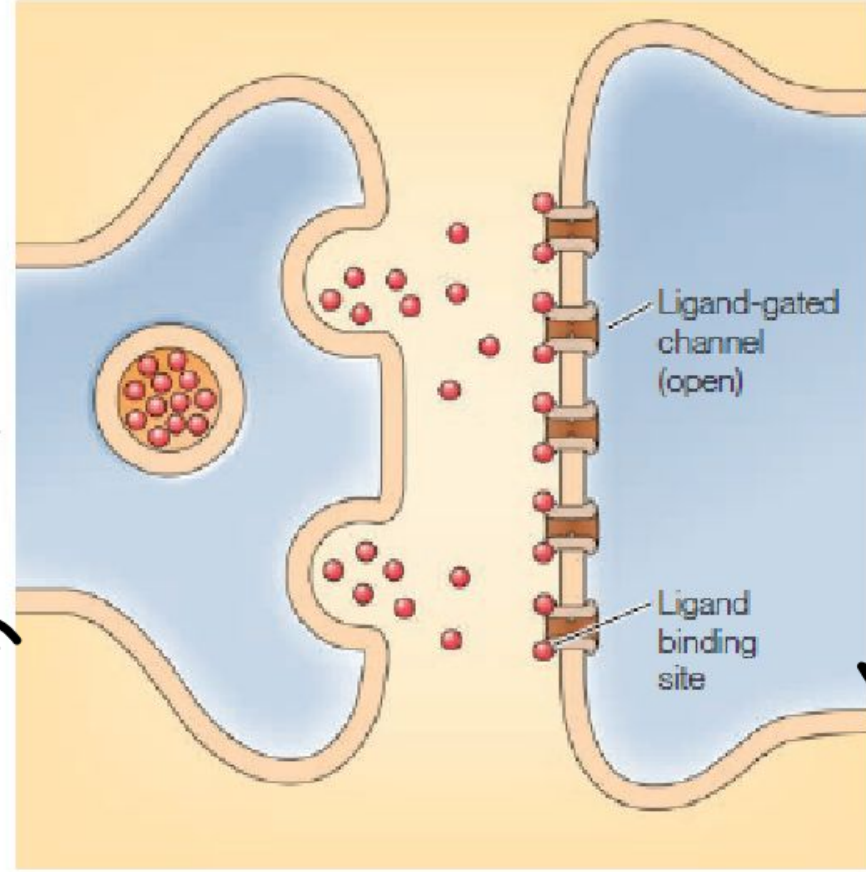


Hormonal  
 Acetylcholine  
 carry message  
 to neuron  
 → the synaptic cleft



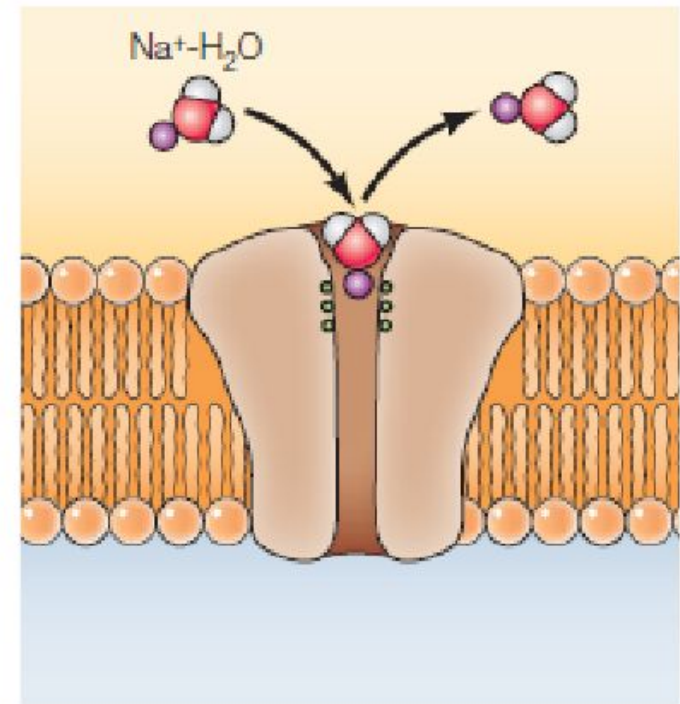
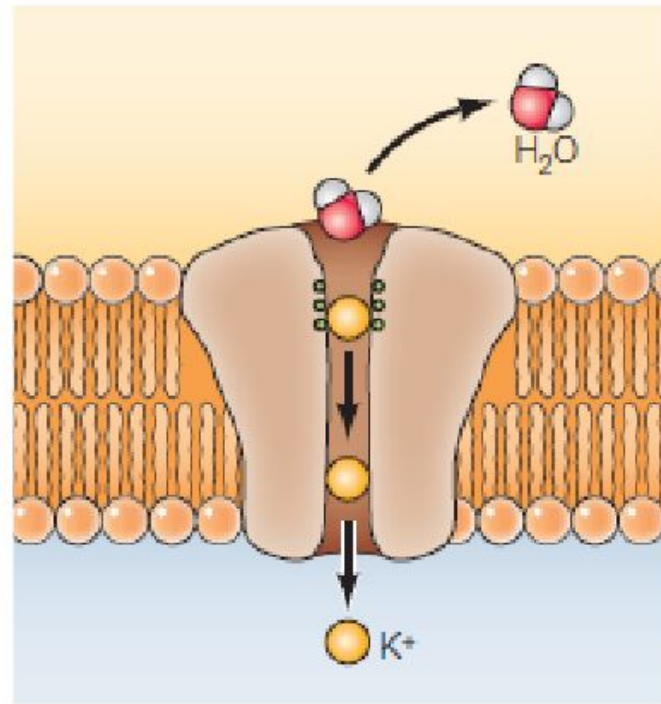
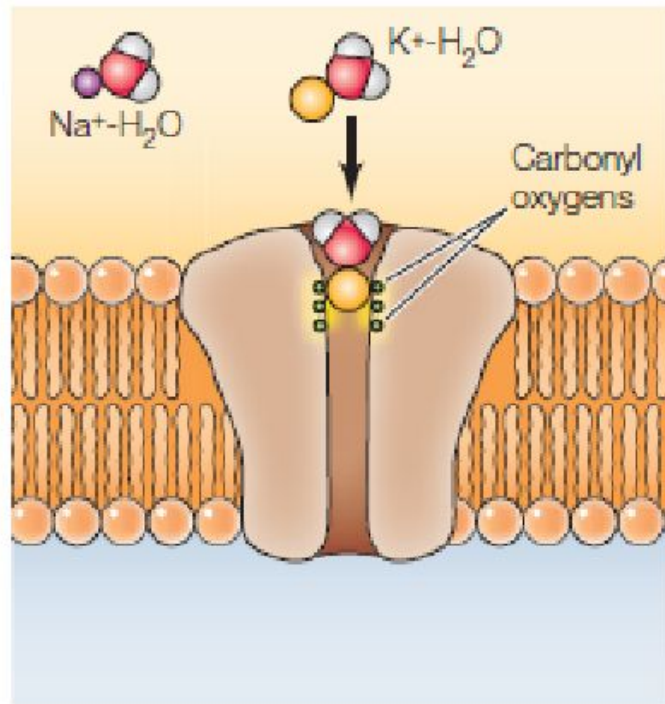
acetylcholine  
 coline

neuron



**Figure 15.19 Signaling by neurotransmitter release at a synapse**  
 The arrival of a nerve impulse at the terminus of the neuron signals the fusion of synaptic vesicles with the plasma membrane, resulting in the release of neurotransmitters from the presynaptic cell into the synaptic cleft. The neurotransmitter binds to receptors and opens ligand-gated ion channels in the target cell plasma membrane.

will come for description!



**Figure 15.22 Selectivity of  $K^+$  channels** The  $K^+$  channel contains a narrow selectivity filter lined with carbonyl oxygen ( $C=O$ ) atoms. The pore is just wide enough to allow the passage of dehydrated  $K^+$  from which all associated water molecules have been displaced as a result of interactions between  $K^+$  and these carbonyl oxygens.  $Na^+$  is too small to interact with the carbonyl oxygens of the selectivity filter, so it remains bound to water in a complex that is too large to pass through the channel pore.

*Not very important*

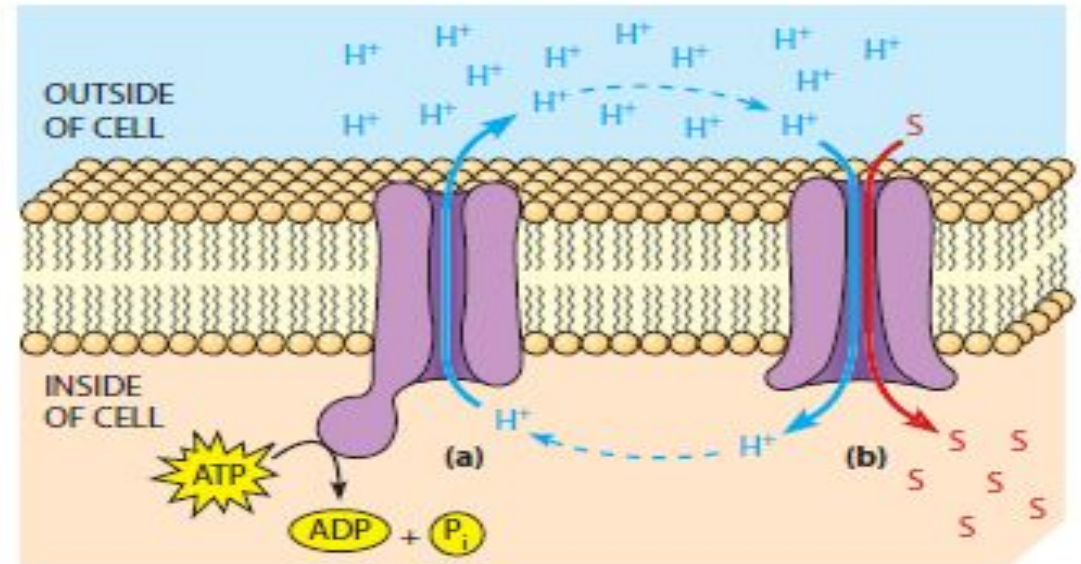


# Active transport driven by ATP hydrolysis

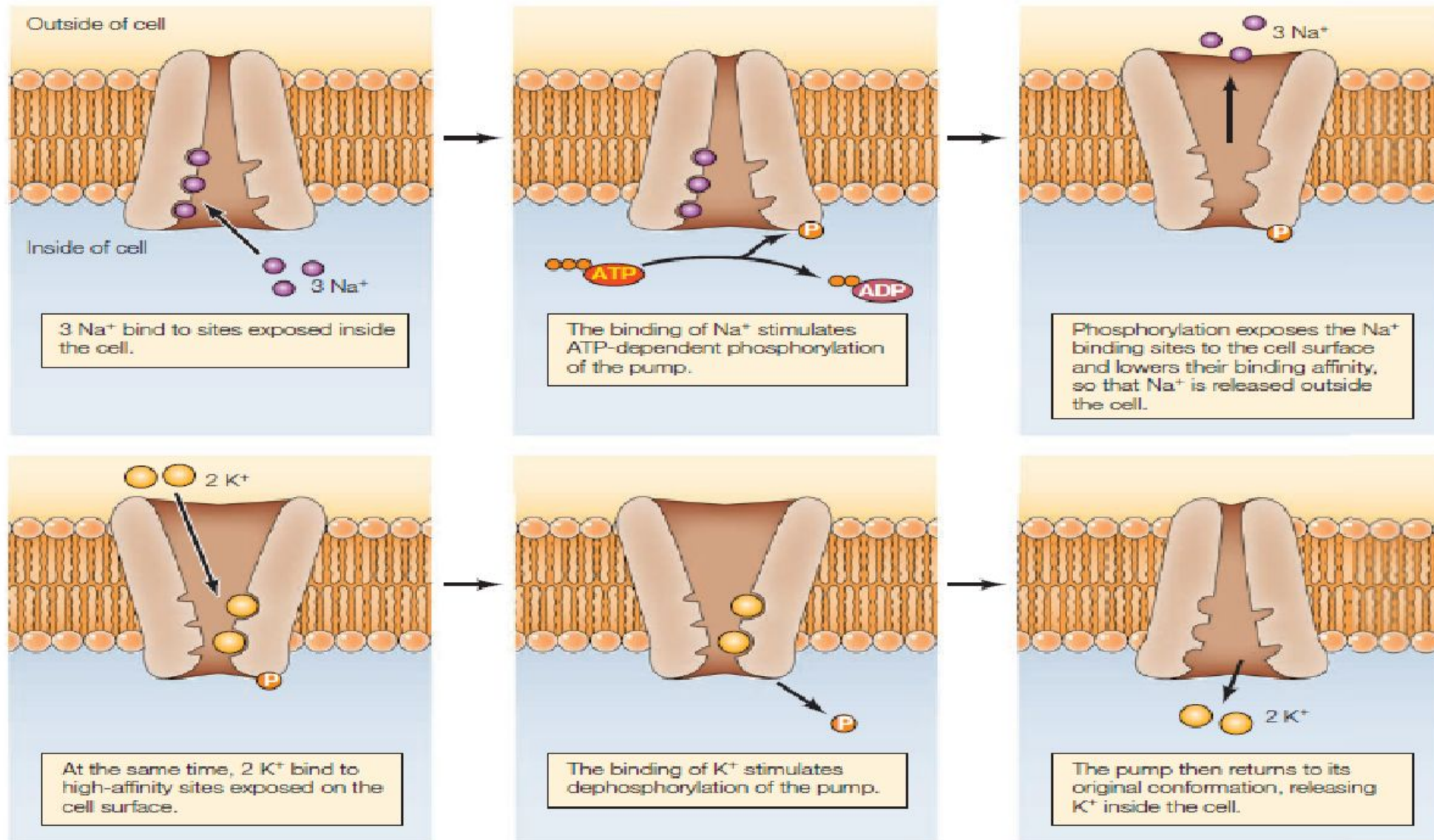
- ❖ In active transport, energy provided by another coupled reaction (such as the hydrolysis of ATP) is used to drive the uphill transport of molecules in the energetically unfavorable direction.
- ❖ The ion pumps responsible for maintaining gradients of ions across the plasma membrane provide important examples of active transport driven directly by ATP hydrolysis.
- ❖ These ion gradients are maintained by the  $\text{Na}^+$ - $\text{K}^+$  pump (also called the  $\text{Na}^+$ - $\text{K}^+$  ATPase), which uses energy derived from ATP hydrolysis to transport  $\text{Na}^+$  and  $\text{K}^+$  against their electrochemical gradients.
- ❖ This process is a result of **ATP-driven conformational changes in the pump**

**(a) Direct active transport** involves a transport system coupled to an exergonic chemical reaction, most commonly the hydrolysis of ATP. As shown here, ATP hydrolysis drives the outward transport of protons, thereby establishing an electrochemical potential for protons across the membrane.

**(b) Indirect active transport** involves the coupled transport of a solute S and ions—protons, in this case. The exergonic inward movement of protons provides the energy to move the transported solute, S, against its concentration gradient or electrochemical potential.

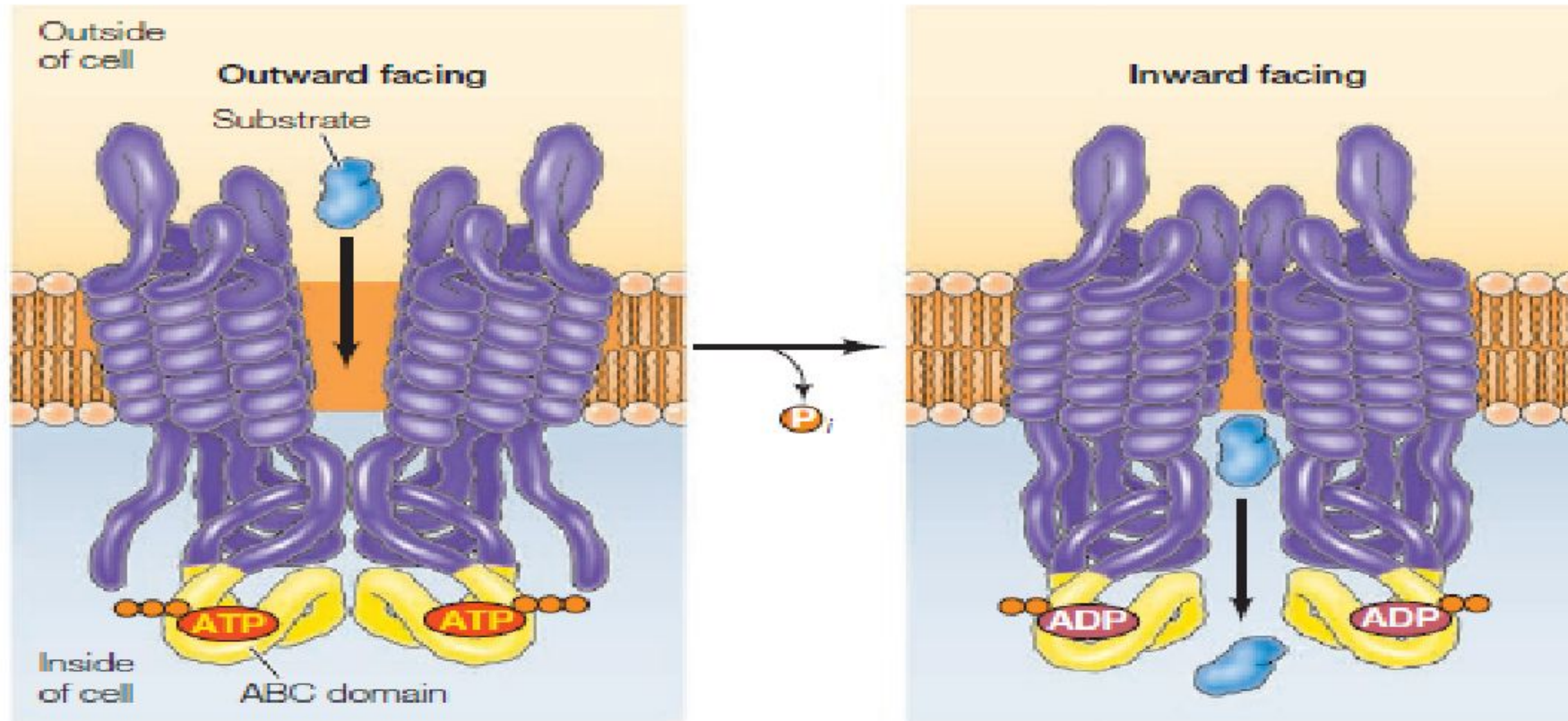


**FIGURE 8-9 Comparison of Direct and Indirect Active Transport.** Note the circulation of protons across the membrane that results from the coupling of direct and indirect mechanisms of active transport. Note also that transporters are not simply open channels, as depicted in the simplified illustration.



**Figure 15.24** Model for operation of the  $\text{Na}^+\text{-K}^+$  pump





**Figure 15.26 Model of active transport by an ABC transporter** The transporter consists of two transmembrane domains (each containing six membrane-spanning  $\alpha$  helices) and two cytosolic ATP-binding domains (ABC domains). The transporter illustrated is an importer, with its substrate-binding site facing outward with ATP bound to the ABC domain. Hydrolysis of ATP to ADP changes the conformation of the transporter, releasing its substrate inside the cell.

Table 8-2

Main Types of Transport ATPases (Pumps)

Solutes Transported	Kind of Membrane	Kind of Organisms	Example of ATPase function
<b>P-type ATPases (P for “phosphorylation”)</b>			
<b>P<sub>1</sub></b> K <sup>+</sup> , Cu <sup>+</sup> , Zn <sup>2+</sup> , Cd <sup>2+</sup> , Pb <sup>2+</sup>	Plasma membrane	Bacteria, archaea, plants, fungi, animals	Transport of potassium or heavy metal ions
<b>P<sub>2</sub></b> Ca <sup>2+</sup> /H <sup>+</sup> Na <sup>+</sup> /K <sup>+</sup> H <sup>+</sup> /K <sup>+</sup>	SR <sup>*</sup> or plasma membrane Plasma membrane Plasma membrane	Eukaryotes Animals Animals	Keeps [Ca <sup>2+</sup> ] low in cytosol Maintains membrane potential (−60 mV) Pumps H <sup>+</sup> to acidify stomach
<b>P<sub>3</sub></b> H <sup>+</sup>	Plasma membrane	Plants, fungi	Pumps protons out of cell to generate membrane potential (−180 mV)
<b>P<sub>4</sub></b> Phospholipids	Plasma membrane	Eukaryotes	Flippases that maintain asymmetry in the lipid bilayer
<b>P<sub>5</sub></b> Various cations	ER, vacuole, lysosome	Eukaryotes	Not well characterized
<b>V-type ATPases (V for “vacuole”)</b>			
H <sup>+</sup>	Lysosomes, secretory vesicles Vacuolar membrane	Animals Plants, fungi	Keeps pH of compartment low, which activates hydrolytic enzymes
<b>F-type ATPases (F for “factor”); also called ATP synthases</b>			
H <sup>+</sup>	Inner mitochondrial membrane Plasma membrane Thylakoid membrane	Eukaryotes Bacteria Plants	Uses H <sup>+</sup> gradient to drive ATP synthesis
<b>ABC-type ATPases (ABC for “ATP-binding cassette”)</b>			
Importers A variety of solutes**	Plasma membrane, organellar membranes	Bacteria	Nutrients such as vitamin B <sub>12</sub>
Exporters Antitumor drugs, toxins, antibiotics, lipids	Plasma membrane	Bacteria, archaea, eukaryotes	Multidrug resistance transporter removes drugs and antibiotics from cell