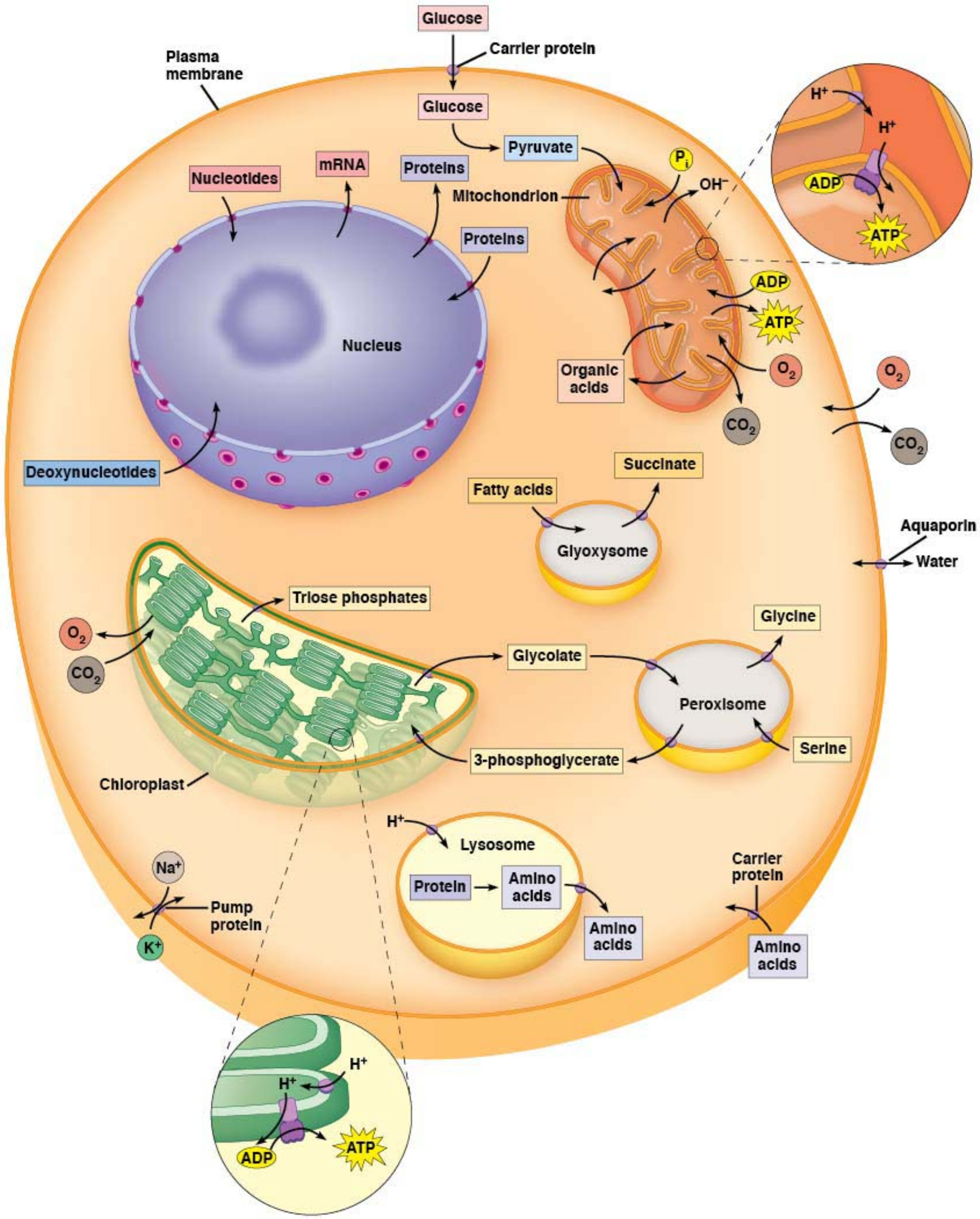
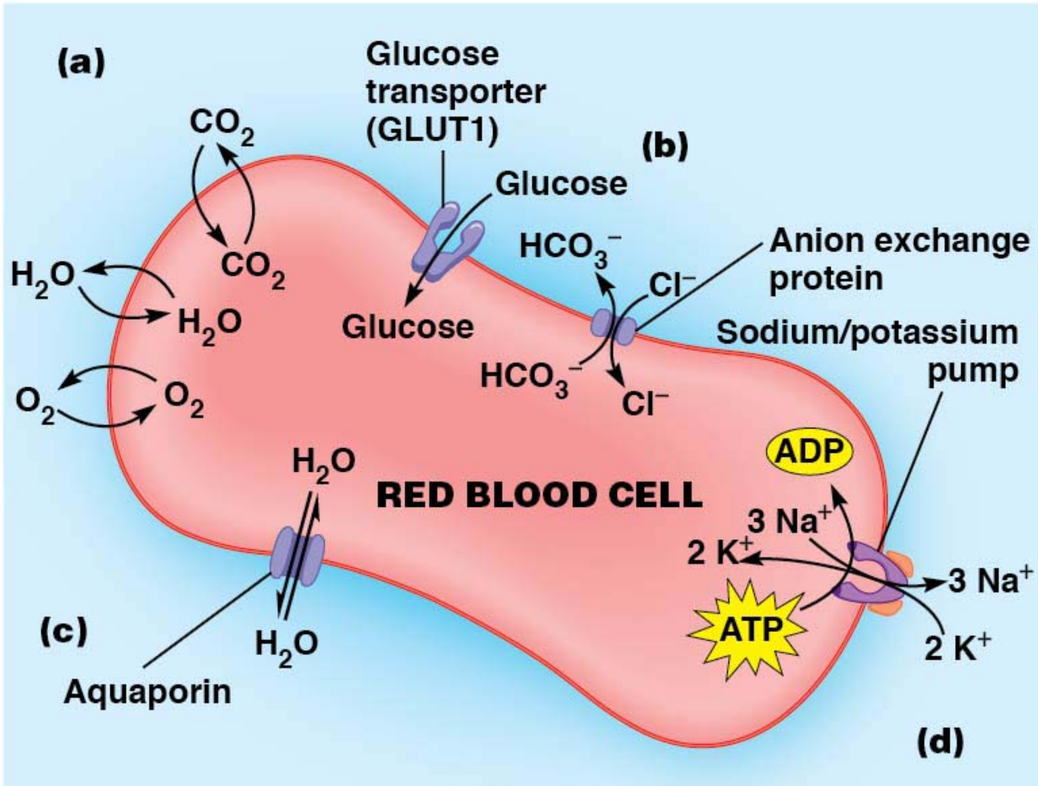

Glucose
Carrier protein
Plasma membrane
Glucose
Pyruvate
Nucleotides
mRNA
Proteins
Mitochondrion
Proteins
Nucleus
Deoxynucleotides
H+
H+
ADP
ATP
OH−
ADP
ATP
Organic acids
O2
CO2
O2
CO2
Succinate
Fatty acids
Glyoxysome
Aquaporin
Water
Triose phosphates
O2
CO2
Glycolate
Glycine
Peroxisome
Serine
3-phosphoglycerate
Chloroplast
H+
Lysosome
Protein
Amino acids
Amino acids
Carrier protein
Amino acids
Na+
Pump protein
K+
H+
H+
ADP
ATP

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

Properties	Simple Diffusion	Facilitated Diffusion	Active Transport
Solutes transported			
	Small polar (H_2O, glycerol)	Small polar (H_2O, glycerol)	
	Small nonpolar (O_2, CO_2)	Large polar (glucose)	Large polar (glucose)
	Large nonpolar (oils, steroids)	Ions (Na^+, K^+, Ca^{2+})	Ions (Na^+, K^+, Ca^{2+})
Thermodynamic properties			
Direction relative to electrochemical gradient	Down	Down	Up
Metabolic energy required	No	No	Yes
Intrinsic directionality	No	No	Yes
Kinetic properties			
Membrane protein required	No	Yes	Yes
Saturation kinetics	No	Yes	Yes
Competitive inhibition	No	Yes	Yes

(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. No transport protein is required.

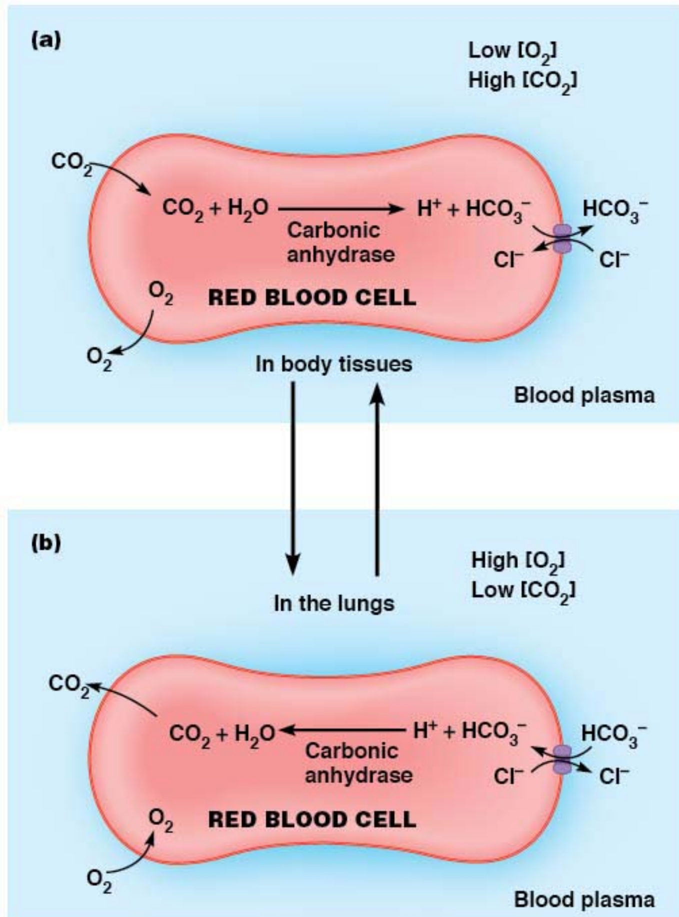
(b) Facilitated diffusion using carrier proteins.
GLUT1 transports glucose into the erythrocyte, where the glucose concentration is lower. An anion exchange protein transports chloride (Cl^-) and bicarbonate (HCO_3^-) in opposite directions.



(c) Facilitated diffusion using channel proteins.
Aquaporin channel proteins can facilitate the rapid inward or outward movement of water depending on the relative solute concentration on opposite sides of the membrane.

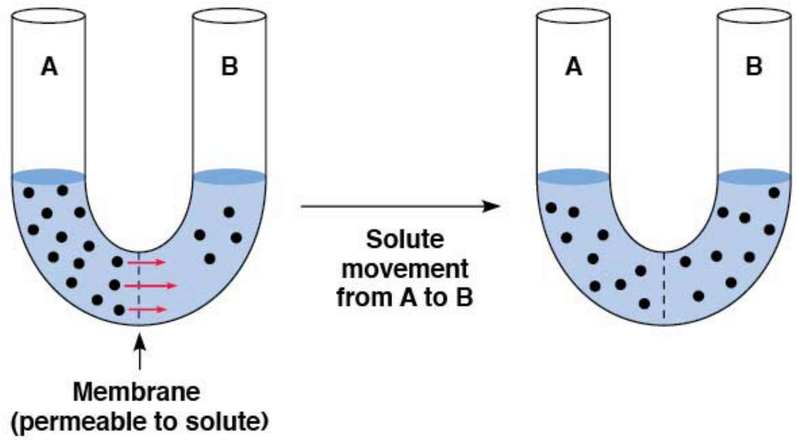
(d) Active transport using ATP-requiring pumps.
Driven by the hydrolysis of ATP, the Na^+/K^+ pump moves sodium ions outward and potassium ions inward, establishing an electro-chemical potential across the plasma membrane for both ions.

(a) In the capillaries of body tissues (low [O_2] and high [CO_2] relative to the erythrocytes), O_2 is released by hemoglobin within the erythrocytes and diffuses outward to meet tissue needs. CO_2 diffuses inward and is converted to bicarbonate by carbonic anhydrase in the cytosol. Bicarbonate ions are transported outward by the anion exchange protein, accompanied by the inward movement of chloride ions to maintain charge balance. Carbon dioxide therefore returns to the lungs as bicarbonate ions.

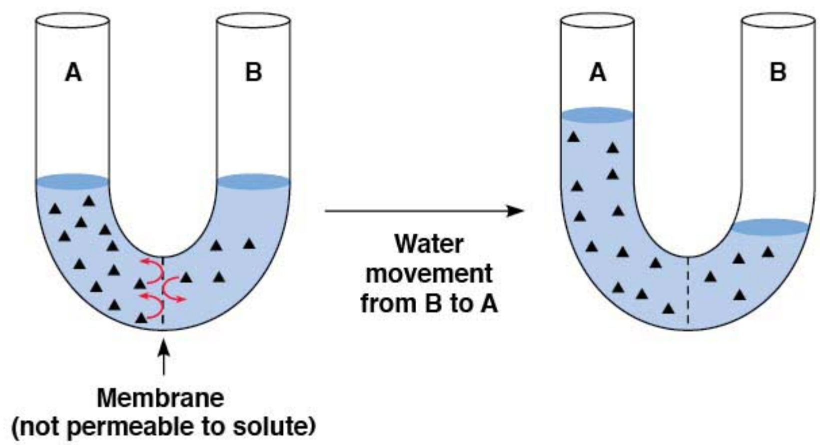


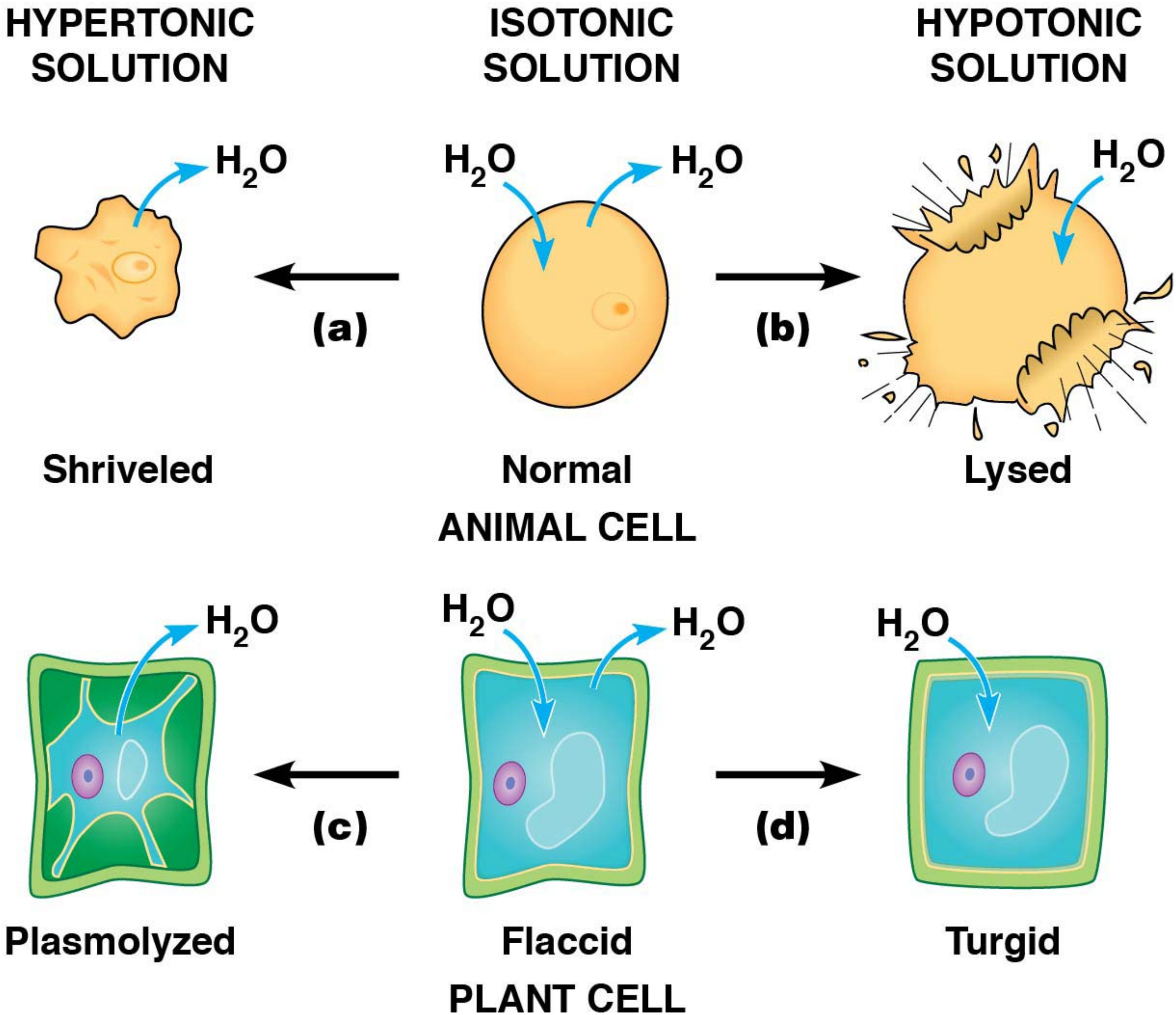
(b) In the capillaries of the lungs (high [O_2] and low [CO_2] relative to the erythrocytes), O_2 diffuses inward and binds to hemoglobin. Bicarbonate moves inward from the blood plasma, accompanied by an outward movement of chloride ions. Incoming bicarbonate is converted into CO_2, which diffuses out of the erythrocytes and into the cells lining the capillaries of the lungs. The CO_2 is now ready to be expelled from the body.

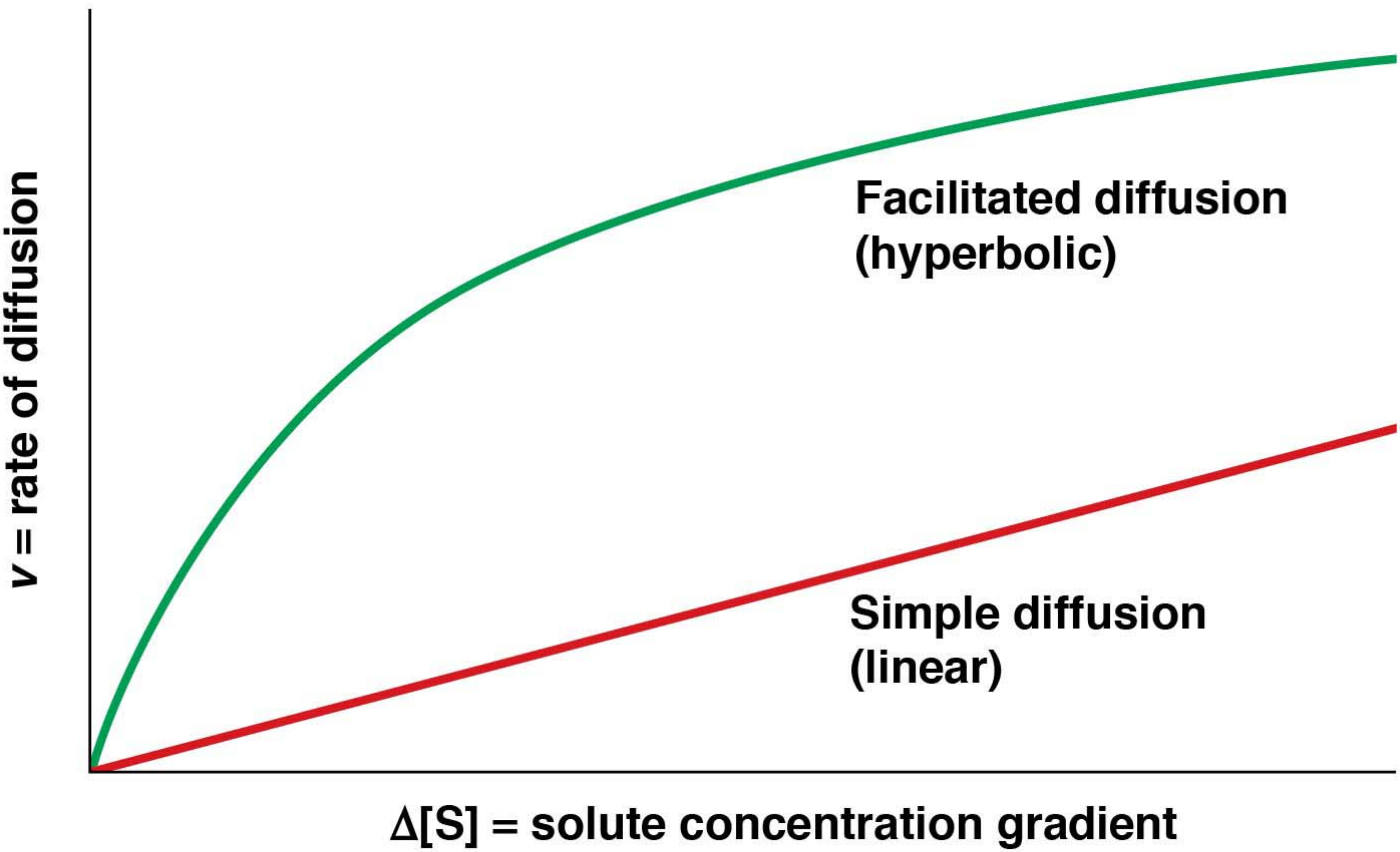
(a) Simple diffusion takes place when the membrane separating chambers A and B is permeable to molecules of dissolved solute, represented by the black dots. Net movement of solute molecules across the membrane is from chamber A to B (high to low solute concentration). Equilibrium is reached when the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

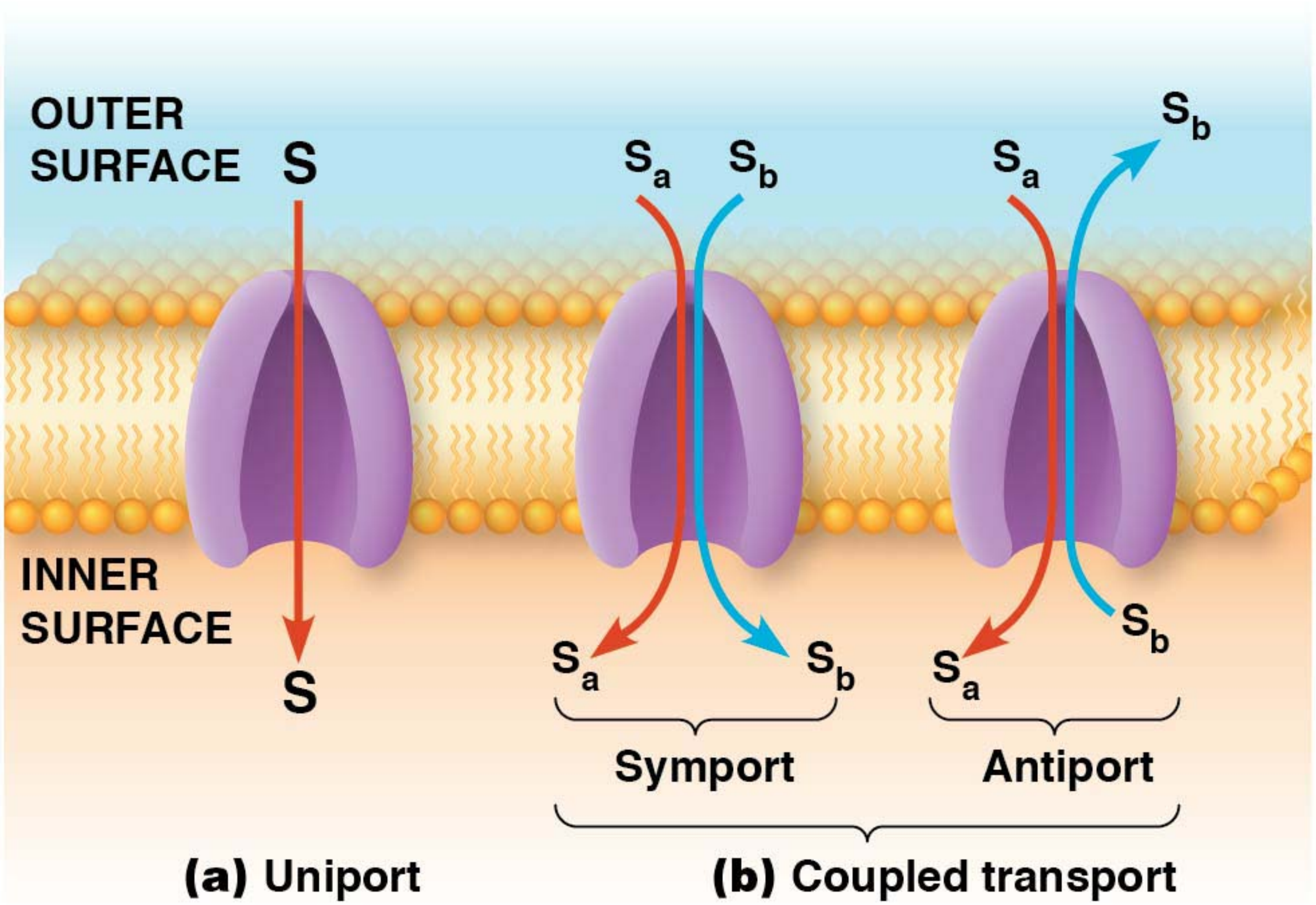


(b) Osmosis occurs when the membrane between the two chambers is not permeable to the dissoved solute, represented by the black triangles. Because solute cannot cross the membrane, water diffuses from chamber B, where the solute concentration is lower (more water), to chamber A, where the solute concentration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




HYPERTONIC SOLUTION
ISOTONIC SOLUTION
HYPOTONIC SOLUTION
H2O
H2O
H2O
H2O
(a)
(b)
Shriveled
Normal
Lysed
ANIMAL CELL
H2O
H2O
H2O
H2O
(c)
(d)
Plasmolyzed
Flaccid
Turgid
PLANT CELL


v = rate of diffusion
Facilitated diffusion
(hyperbolic)
Simple diffusion
(linear)
Δ[S] = solute concentration gradient

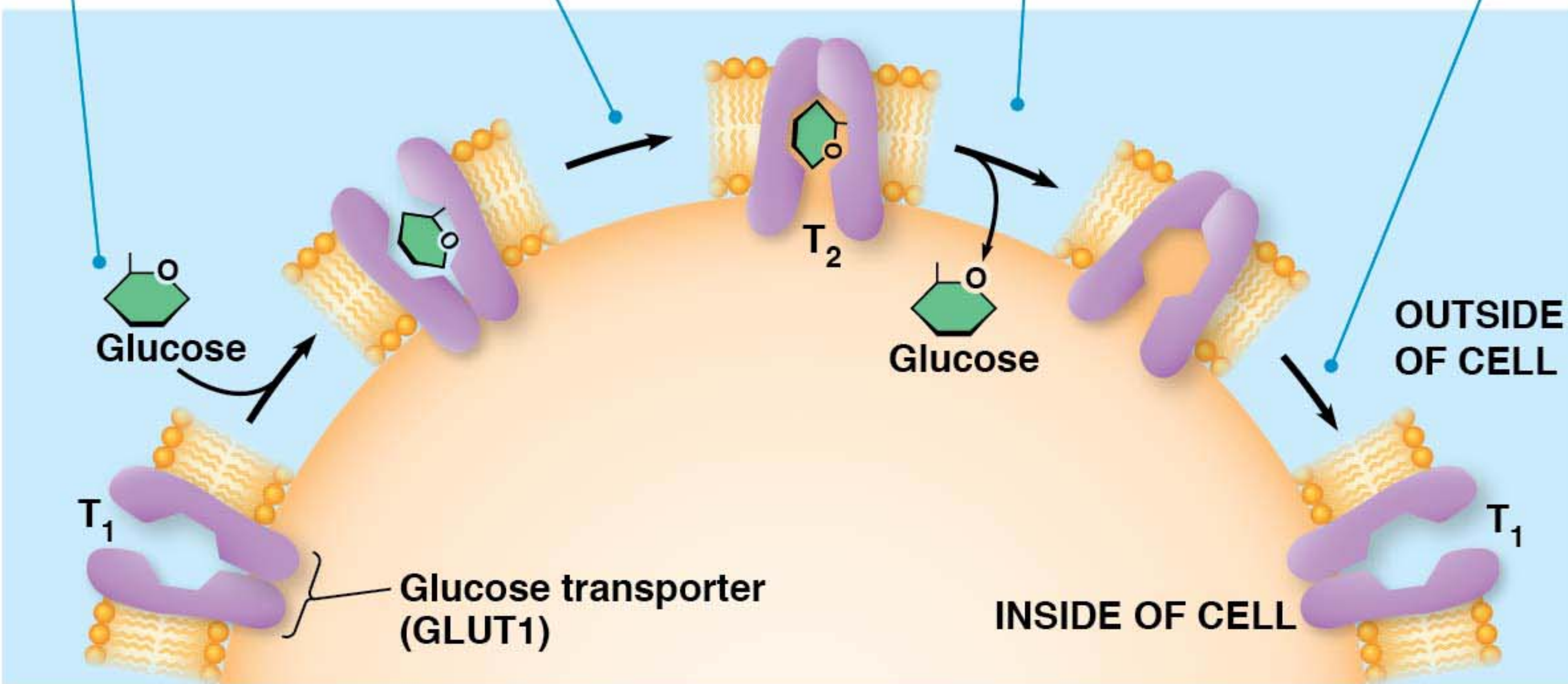

OUTER SURFACE
S
S
INNER SURFACE
Sa
Sb
Sa
Sb
Sa
Sb
Sa
Sb
Symport
Antiport
(a) Uniport
(b) Coupled transport

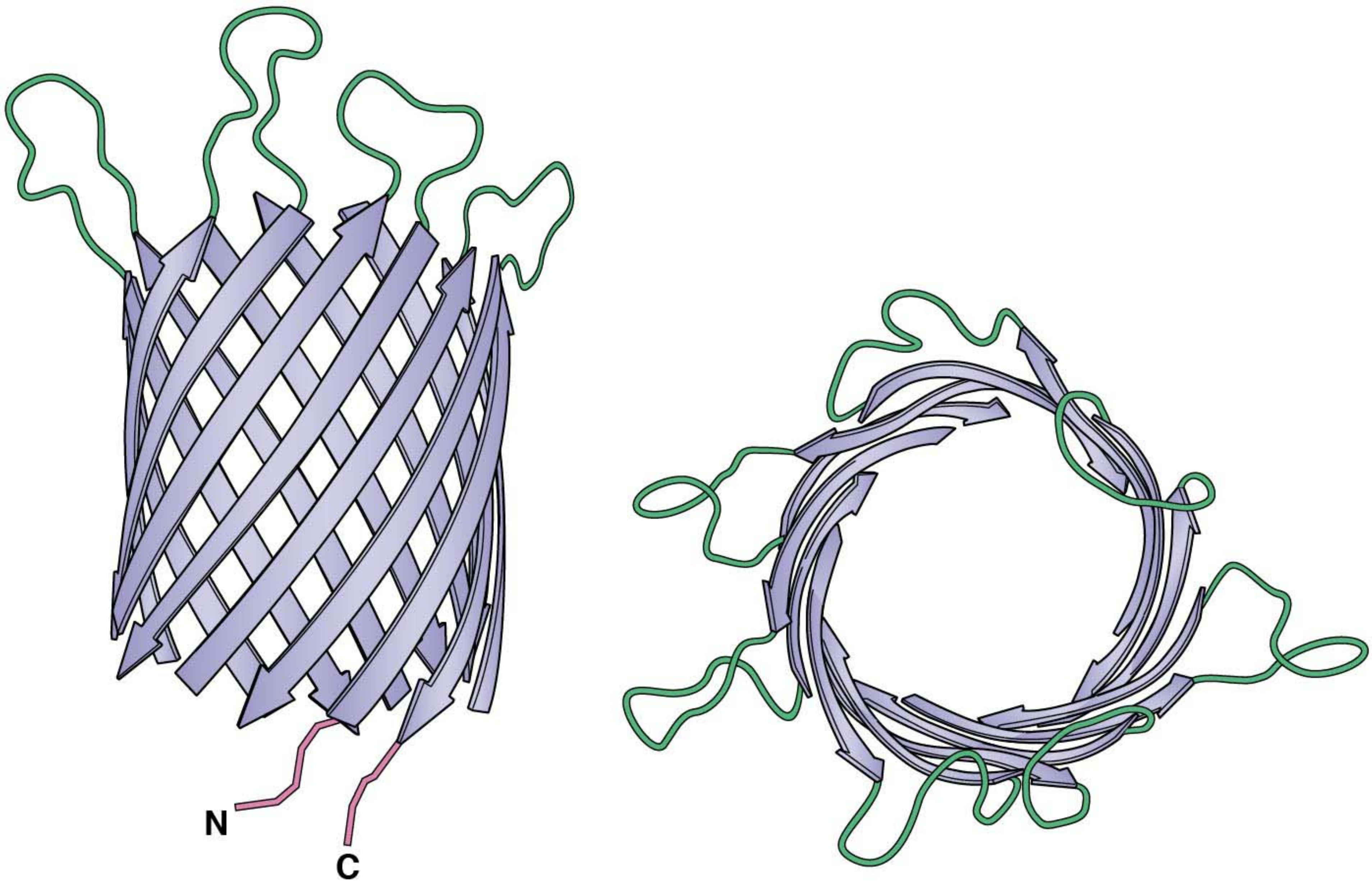
1 Glucose binds to a GLUT1 transporter protein that has its binding site open to the outside of the cell (T_1 conformation).

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.

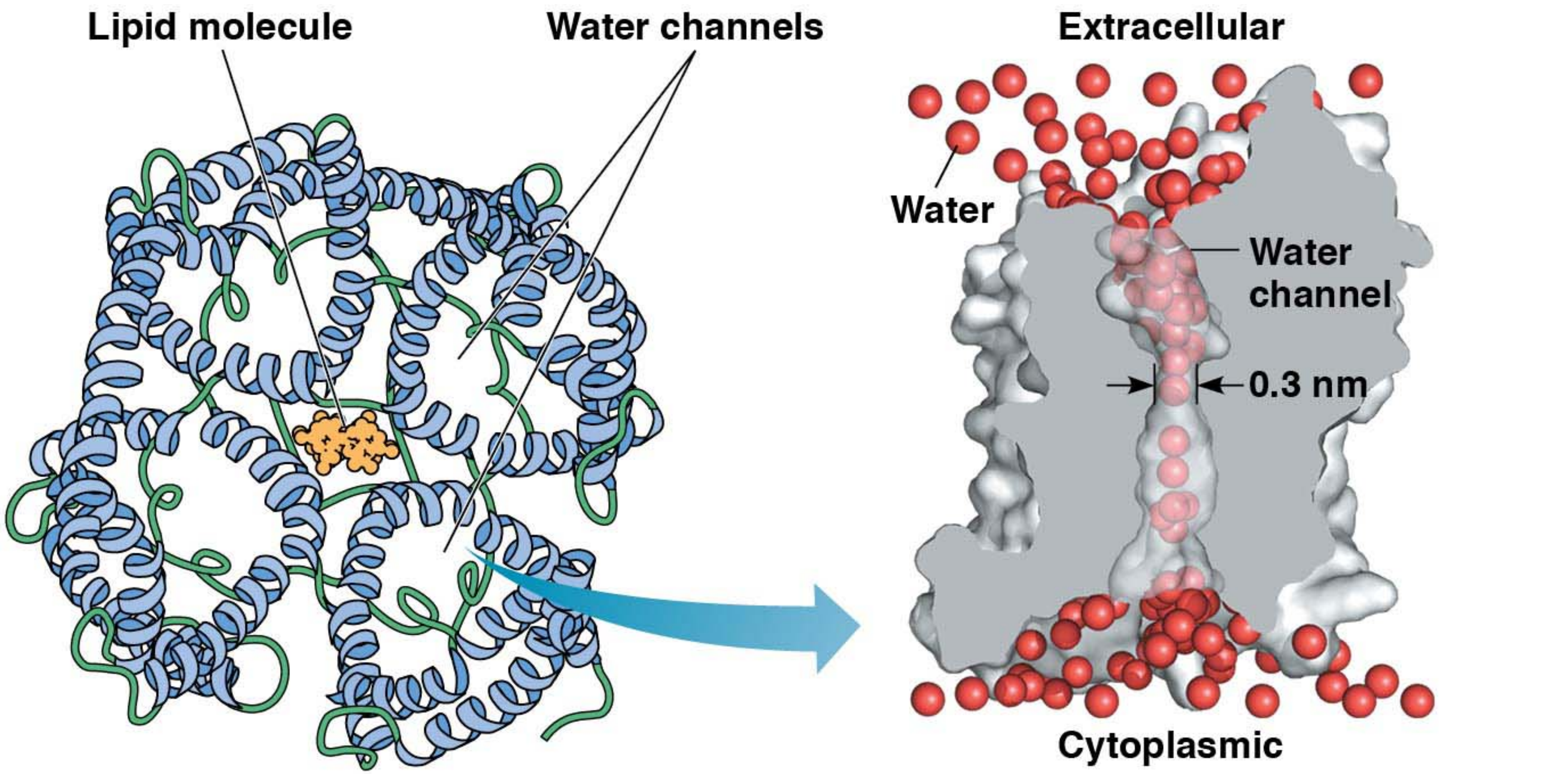
3 Glucose is released to the interior of the cell, initiating a second conformational change in GLUT1.

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





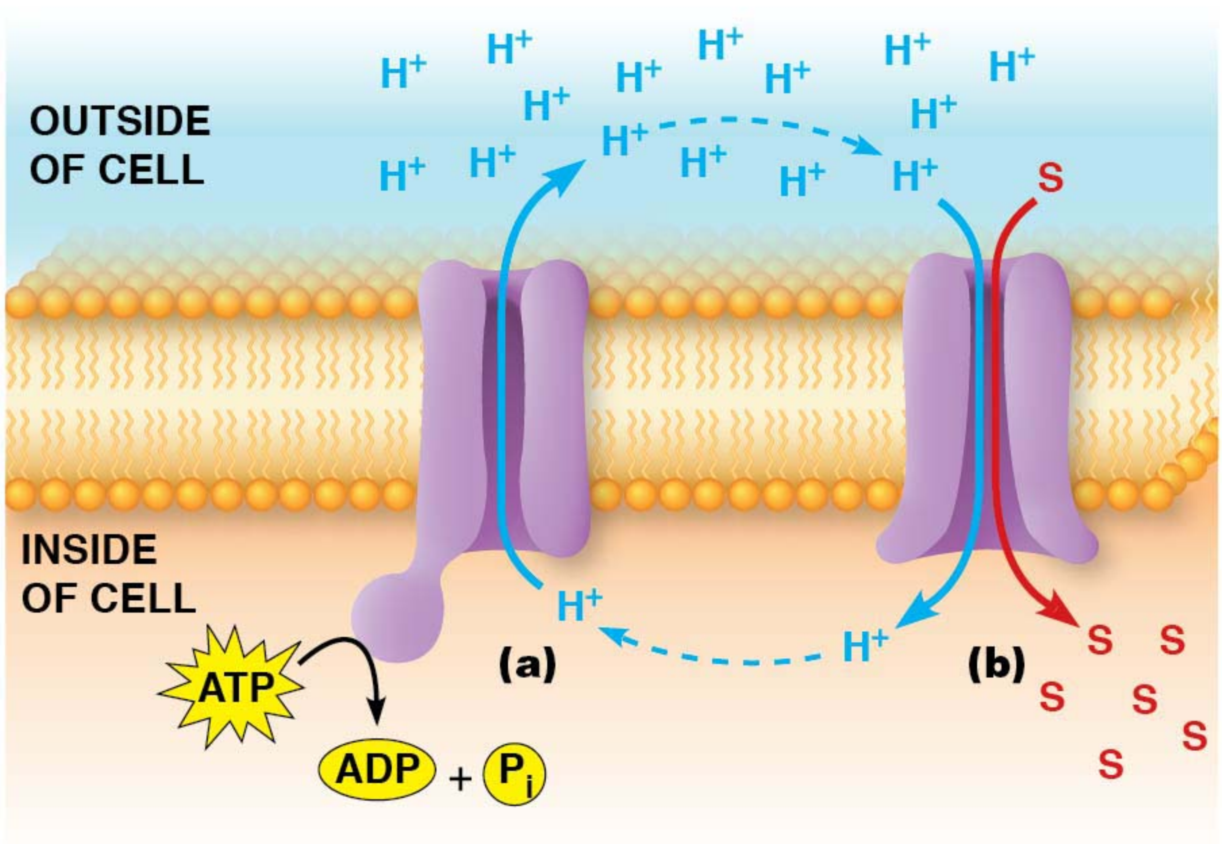
(a) Porin side view **(b)** Porin end view

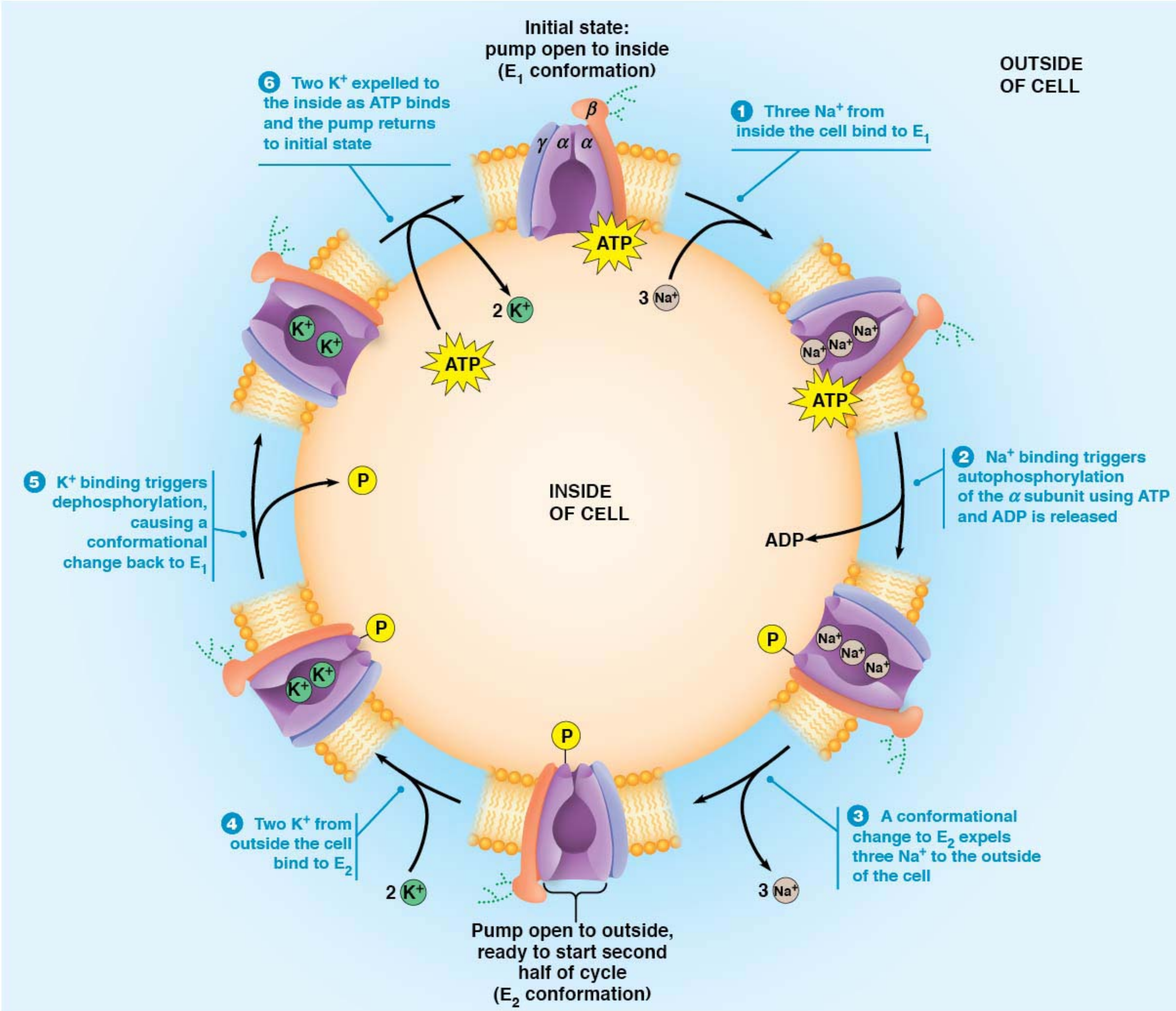


(a) Aquaporin tetramer (end view) **(b)** Aquaporin monomer (side view)

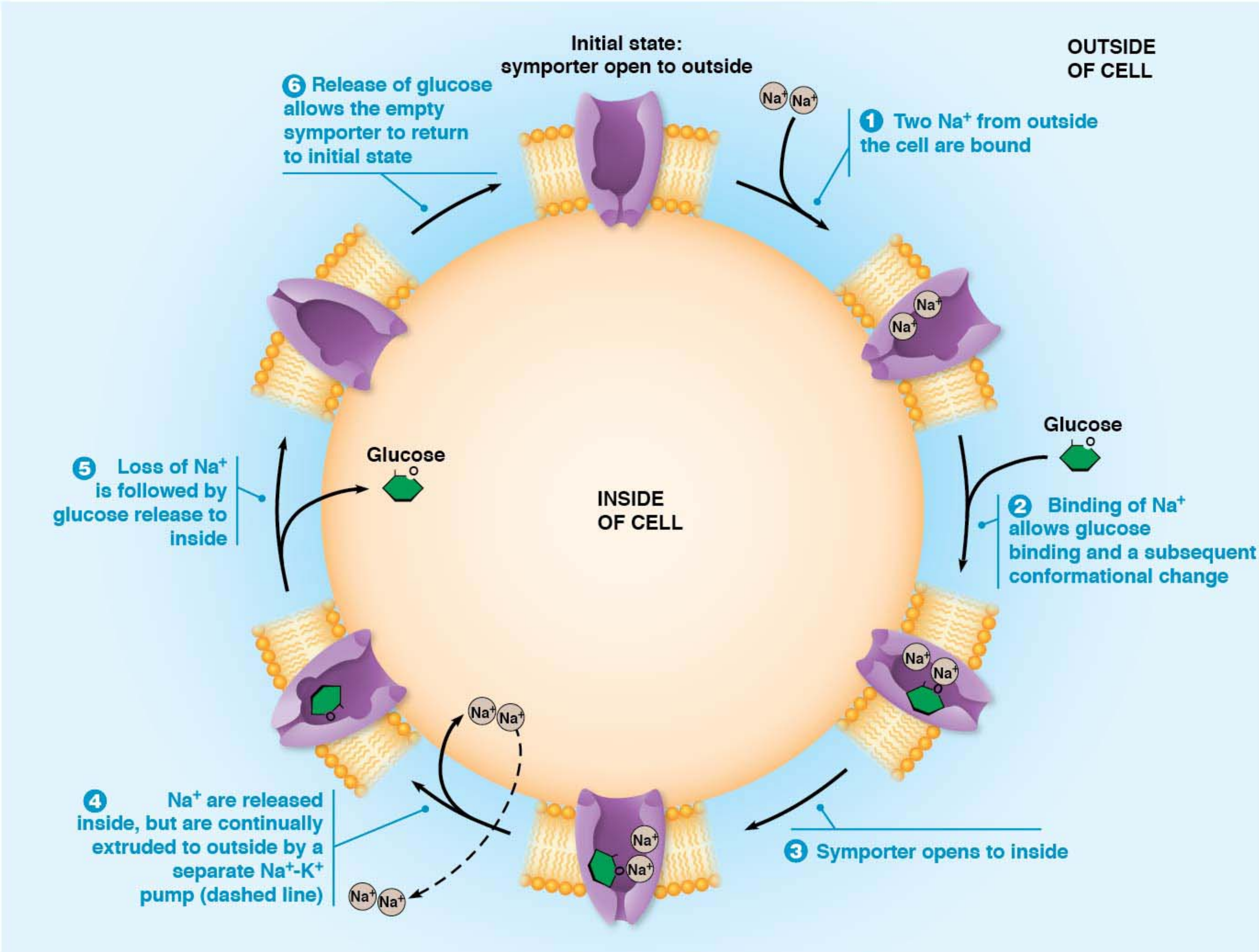
(a) Direct active transport involves a transport system coupled to an exergonic chemical reaction, most commonly the hydrolysis of ATP. As shown here, ATP hydrolysis drives the outward transport of protons, thereby establishing an electro-chemical potential for protons across the membrane.

(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.

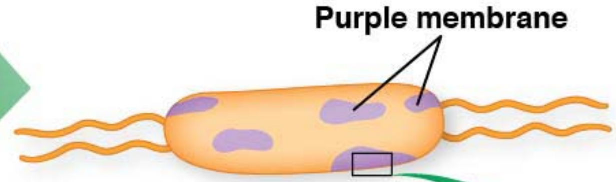




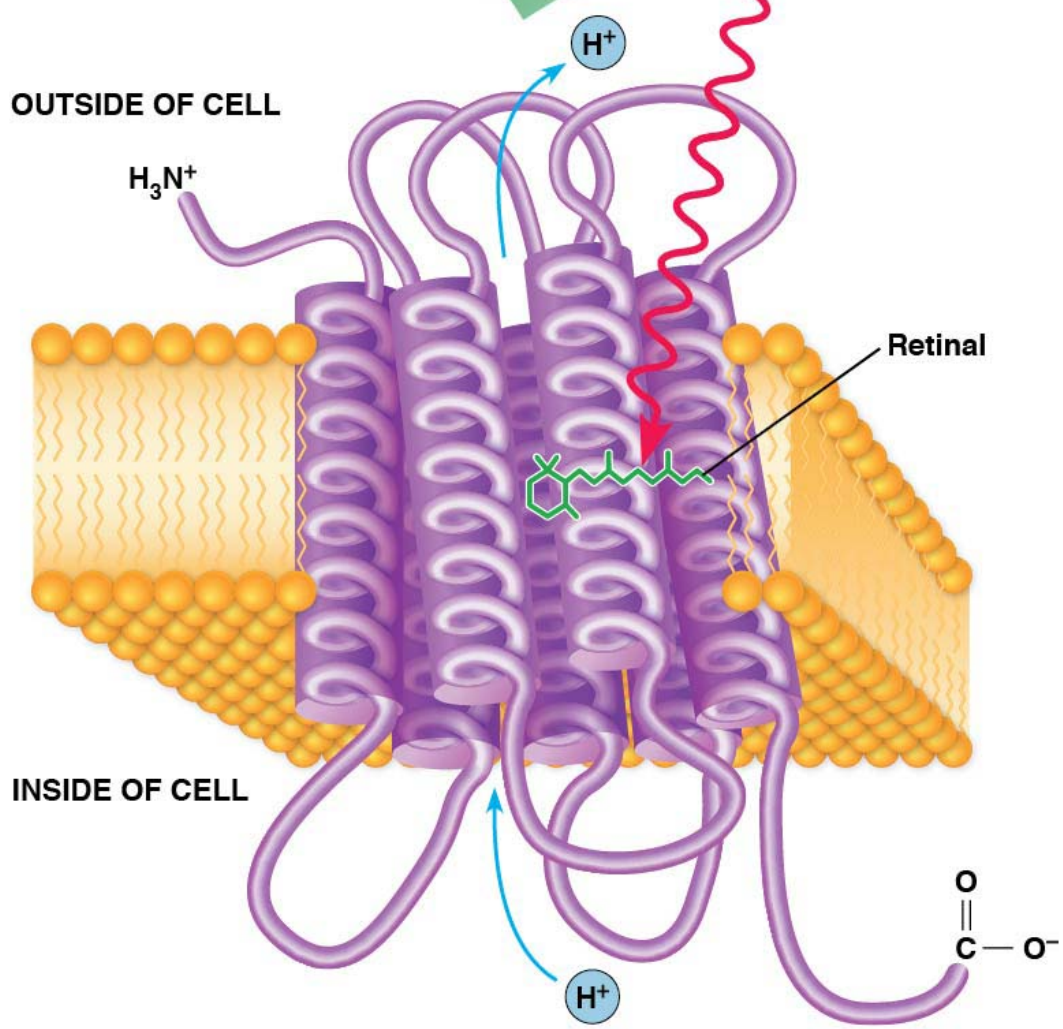
Initial state:
pump open to inside
(E_1 conformation)
OUTSIDE
OF CELL
6 Two K^+ expelled to the inside as ATP binds and the pump returns to initial state
γ α α
β
1 Three Na^+ from inside the cell bind to E_1
ATP
2 K^+
3 Na^+
K^+
Na^+
ATP
2 Na^+ binding triggers autophosphorylation of the α subunit using ATP and ADP is released
INSIDE
OF CELL
ADP
5 K^+ binding triggers dephosphorylation, causing a conformational change back to E_1
P
3 A conformational change to E_2 expels three Na^+ to the outside of the cell
4 Two K^+ from outside the cell bind to E_2
2 K^+
3 Na^+
Pump open to outside,
ready to start second
half of cycle
(E_2 conformation)


Initial state:
symporter open to outside
OUTSIDE
OF CELL
6 Release of glucose allows the empty symporter to return to initial state
Na+
Na+
1 Two Na+ from outside the cell are bound
Glucose
2 Binding of Na+ allows glucose binding and a subsequent conformational change
INSIDE
OF CELL
Glucose
5 Loss of Na+ is followed by glucose release to inside
3 Symporter opens to inside
4 Na+ are released inside, but are continually extruded to outside by a separate Na+-K+ pump (dashed line)

(a) *Halobacterium* (purple color) grows in the high-salt concentration of solar evaporation ponds used for manufacturing salt around San Francisco Bay



(b) *Halobacterium* cell with patches of purple membrane



(c) Bacteriorhodopsin molecule embedded in the plasma membrane