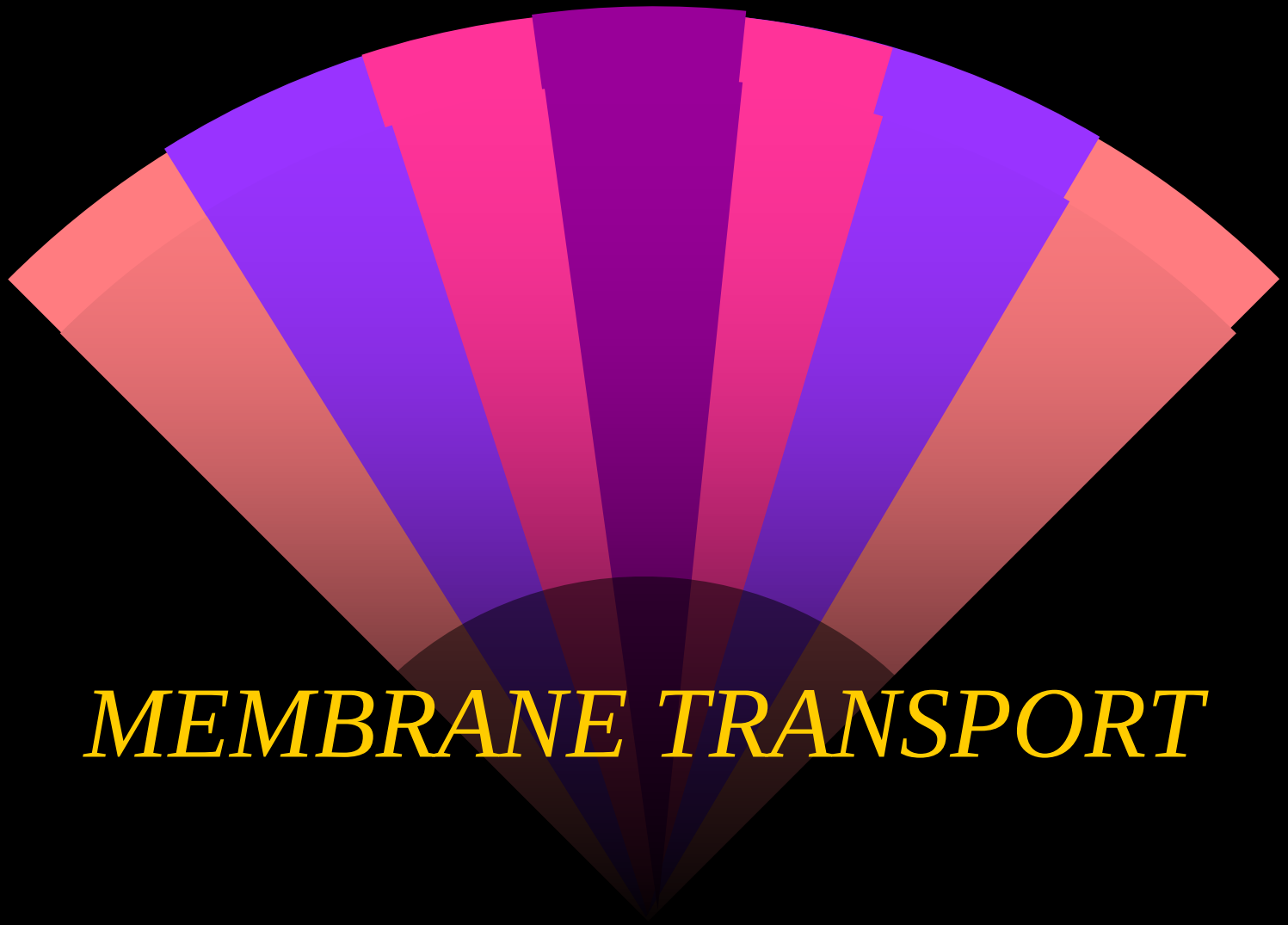


MEMBRANE TRANSPORT

Membrane Transport

- I. Relevance
- II. Plasma Membrane (cell membrane)
- III. Membrane Transport
  - diffusion
    - free diffusion
    - facilitated diffusion
    - Donnan equilibrium
  - active transport

Membrane Transport

- IV. Osmosis

Membrane Transport

- **<u>Your body is 60-70% water</u>**
  - 99% water
  - 0.83% ions
  - 0.17% organics
- Balance between water and ions-regulated precisely
- 20-25% loss of fluid outside cells=circulatory shock

Membrane Transport

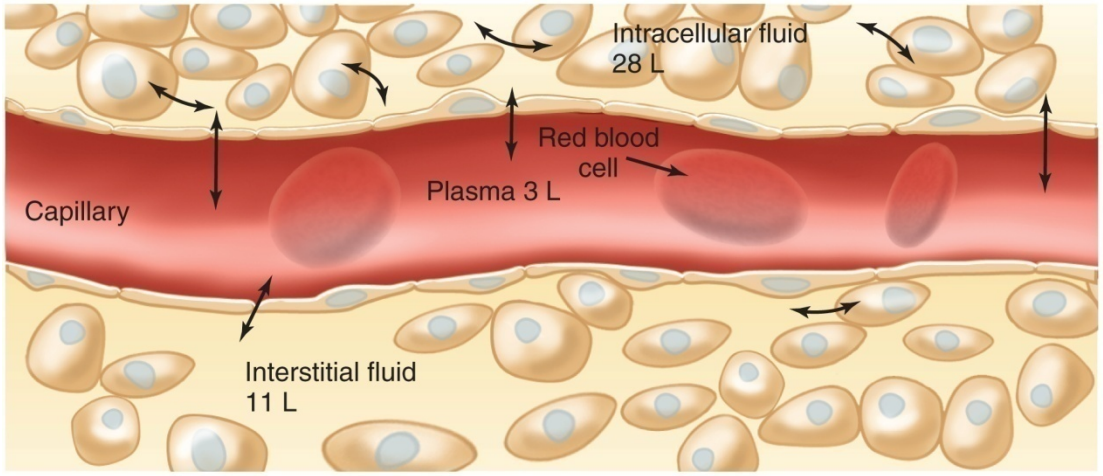
- hyperkalemia=extracellular K+ rises 60-100%, cardiac toxicity
- hypokalemia=muscle weakness

Membrane Transport

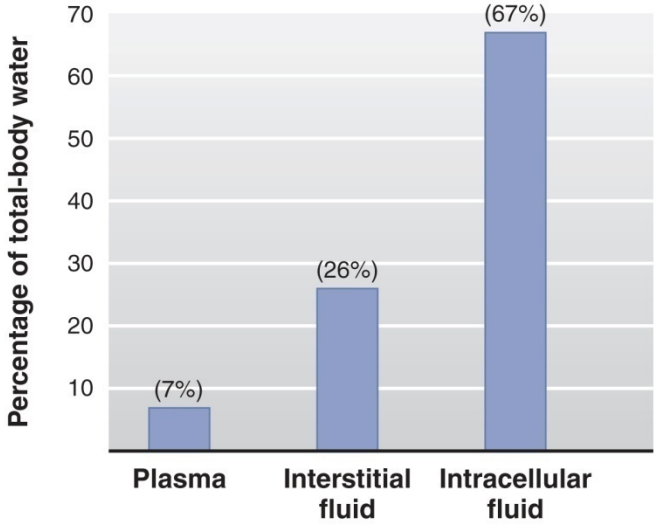
- If all body fluids were identical in composition, it would be easy to maintain body fluids. But, intracellular and extracellular fluids are very different.

- Differences are maintained by
  - "pumps" in plasma membrane
  - selective permeability of plasma membrane.

Fig. 1.3



(a)



(b)

Membrane Transport

Compartment	Volume
ICF	
ECF	
TOTAL	

ICF, Intracellular fluid compartment
ECF, Extracellular fluid compartment

Membrane Transport

Compartment	Volume
ICF	25 L
ECF	
TOTAL	

ICF, Intracellular fluid compartment
ECF, Extracellular fluid compartment

Membrane Transport

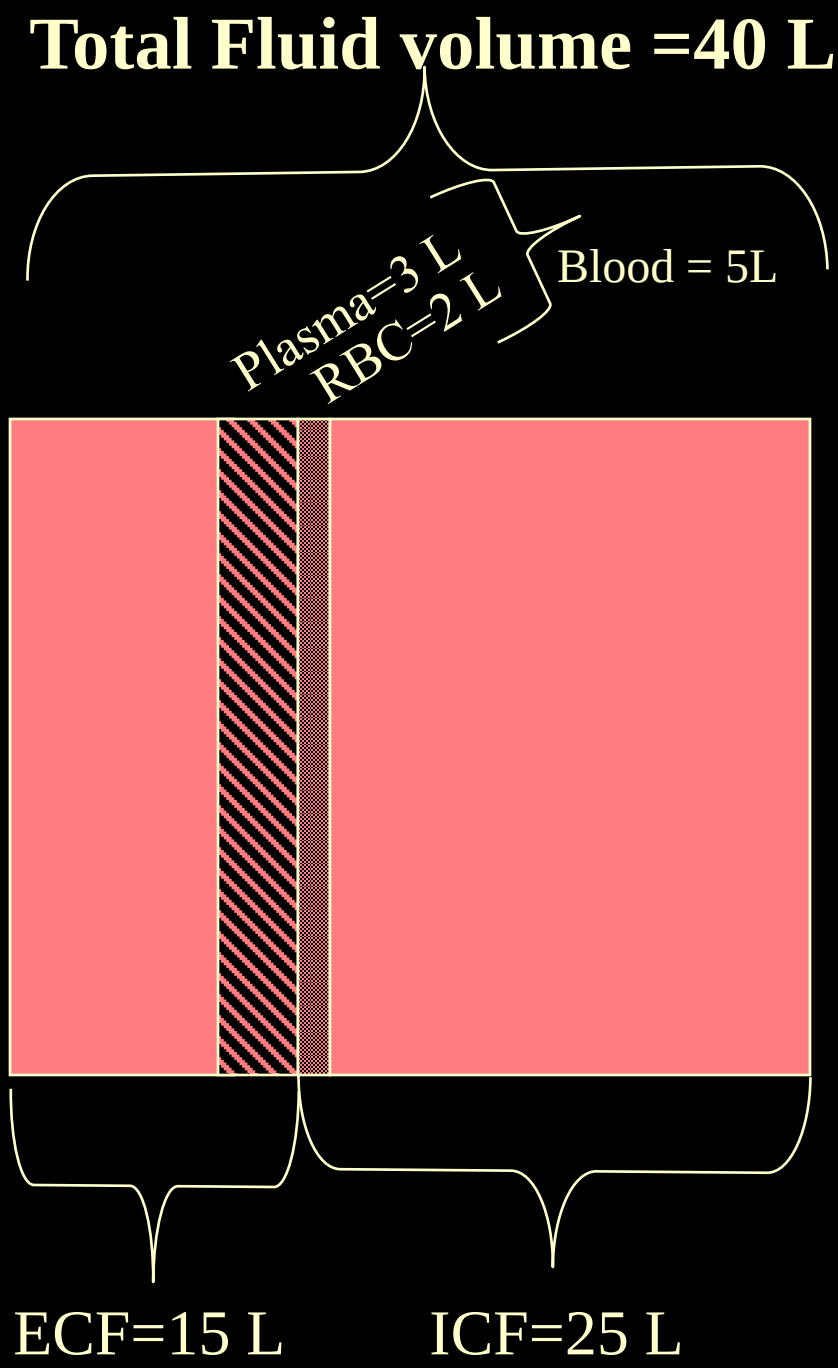
Compartment	Volume
ICF	25 L
ECF	15 L

ICF, Intracellular fluid compartment
ECF, Extracellular fluid compartment

Membrane Transport

Compartment	Volume
ICF	25 L
ECF	15 L
TOTAL	**40 L**

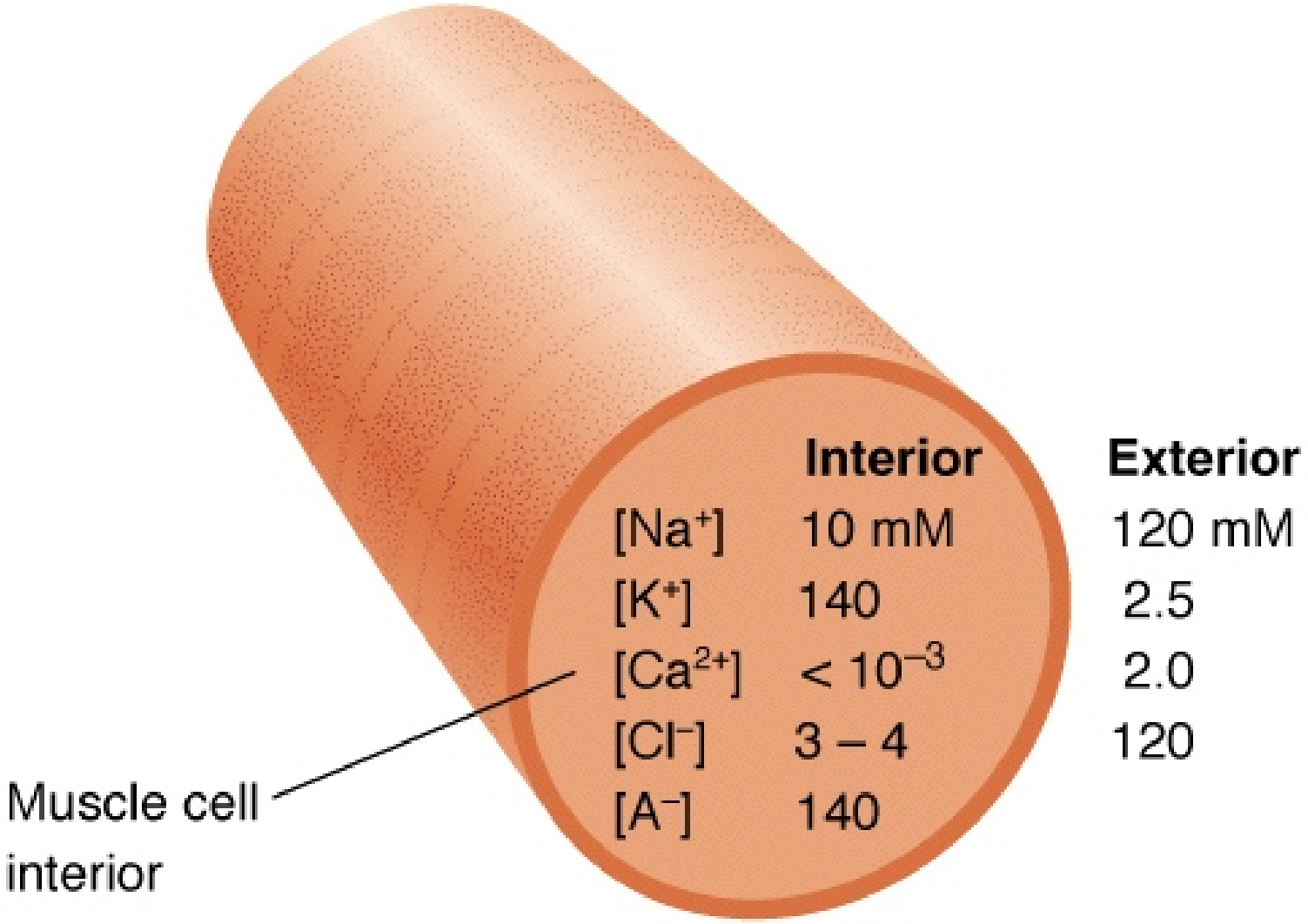
ICF, Intracellular fluid
ECF, Extracellular fluid



Blood = 5 L

plasma = 3 L

RBC = 2 L



[A^-] = molar equivalent of negative charges carried by other molecules and ions.

Ionic Composition of ECF and ICF (mM)

Ion	ICF	ECF	Permeabiliy
Na^+	10	**120**	-

Ionic Composition of ECF and ICF (mM)

Ion	ICF	ECF	Permeabiliy
Na^+	10	120	-
K^+	140	2.5	+

Ionic Composition of ECF and ICF (mM)

Ion	ICF	ECF	Permeabiliy
Na^+	10	120	-
K^+	140	2.5	+
Cl^-	5	120	+

Ionic Composition of ECF and ICF (mM)

Ion	ICF	ECF	Permeabiliy
Na^{+}	10	120	-
K^{+}	140	2.5	+
Cl^{-}	5	120	+
A^{-n}	126-140	0	-

Ionic Composition of ECF and ICF (mM)

Ion	ICF	ECF	Permeability
Na^{+}	10	120	-
K^{+}	140	2.5	+
Cl^{-}	5	120	+
A^{-n}	126-140	0	-
Water	***55,000***	***55,000***	+

Hyponatremia

- can occur as a result of excess water intake

- decreased water excretion

- deficient Na+ intake or excess loss of the cation.

abcNEWS

Radio Station Faces Criminal Probe, Lawsuit

Sacramento Detectives Investigating Death After Woman Drinks Too Much Water in Contest Stunt

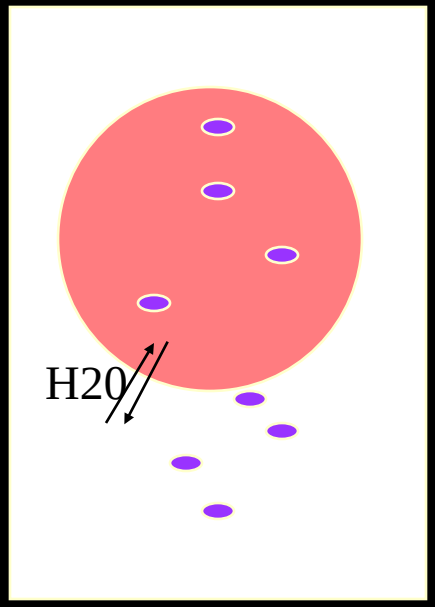
Summary

- $K+_{in} > K+_{out}$
- $Na+_{in} < Na+_{out}$
- Total solute in = 300 mM = total solute out
- **Water in = water out**
- the plasma membrane is permeable to some things and not others
- G_{K+} is 30-70 times greater than G_{Na+}
- G=conductance, = permeability

if water in = water out, cell is happy

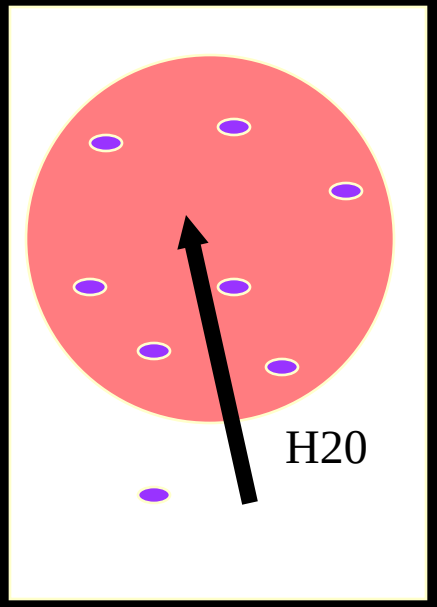
Effects of solute [ ] on water movement

$[S]_{icf} = [S]_{ecf}$



Cell maintains equilibrium

$[S]_{icf} > [S]_{ecf}$



Cell swells and bursts

- Animal cells prevent water gain by maintaining equal concentrations of water in and out of cell

- They don’t do this by
  - pumping water in or out
  - using water channels

- They maintain [solute] equal inside and outside of cell, thereby eliminating gradient for water movement

- $[S]_{ICF=300\ mM} = [S]_{ECF}$

Definitions

- Anion-negatively charged ion
- Cation- positively charged ion
- Electrolyte-a compound that dissolves in water
- Molarity-moles/liter, M
- Molality-moles/kg water
- Mole-6.022 x 10^{23} atoms

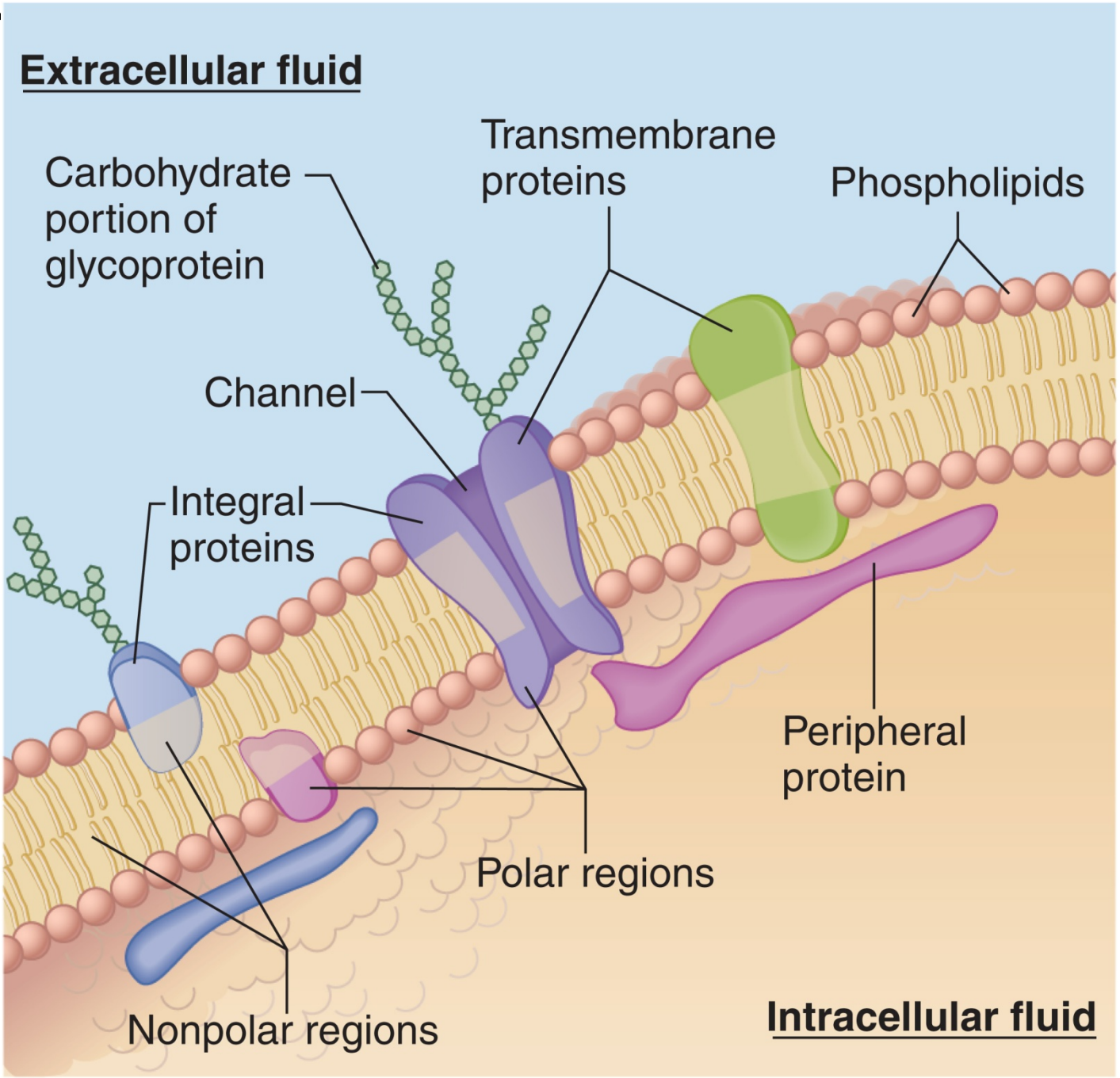
Plasma Membrane

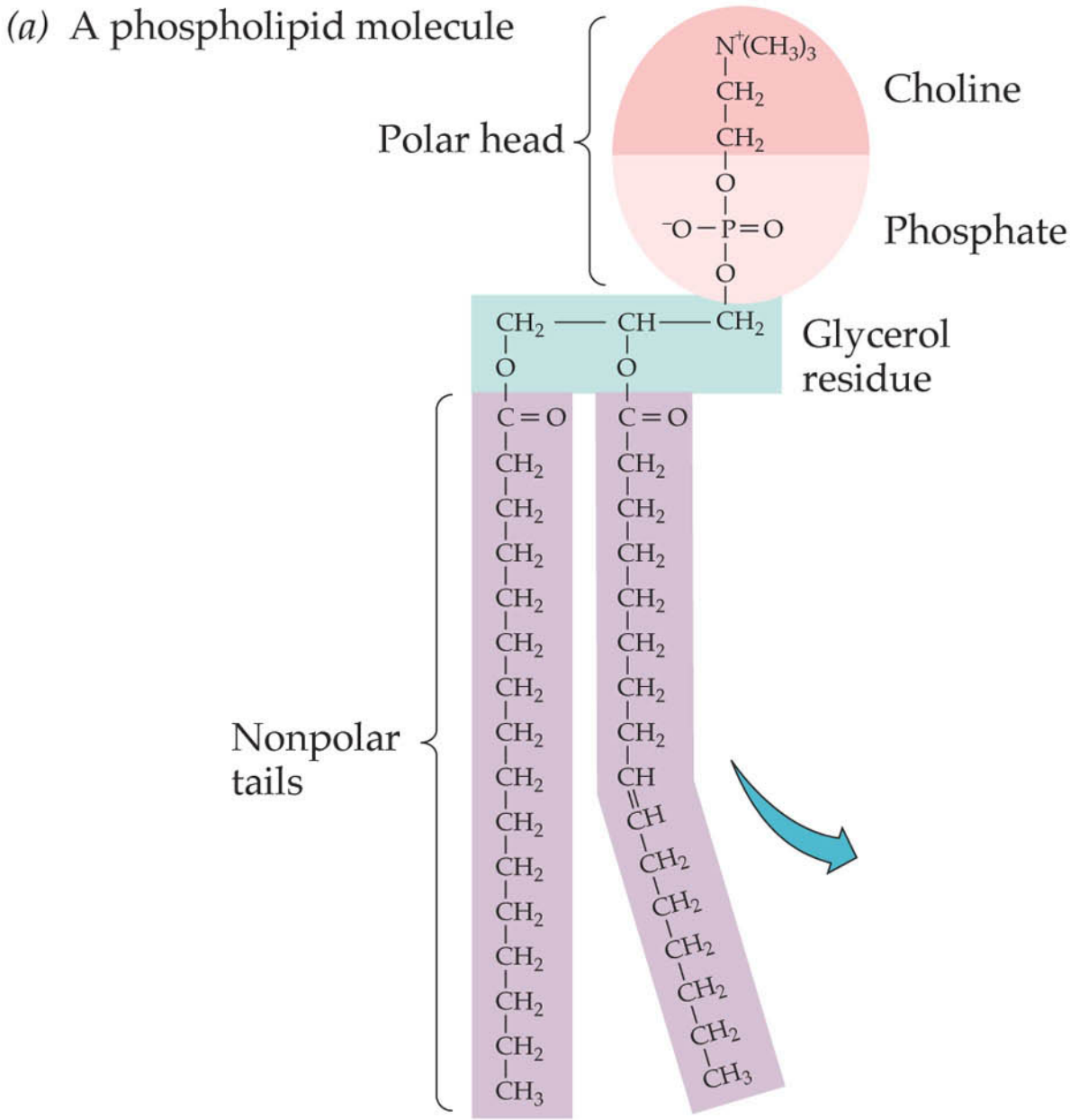
- Lipids
  - phospholipids- amphipathic, hydrophilic at one end, hydrophobic at the other

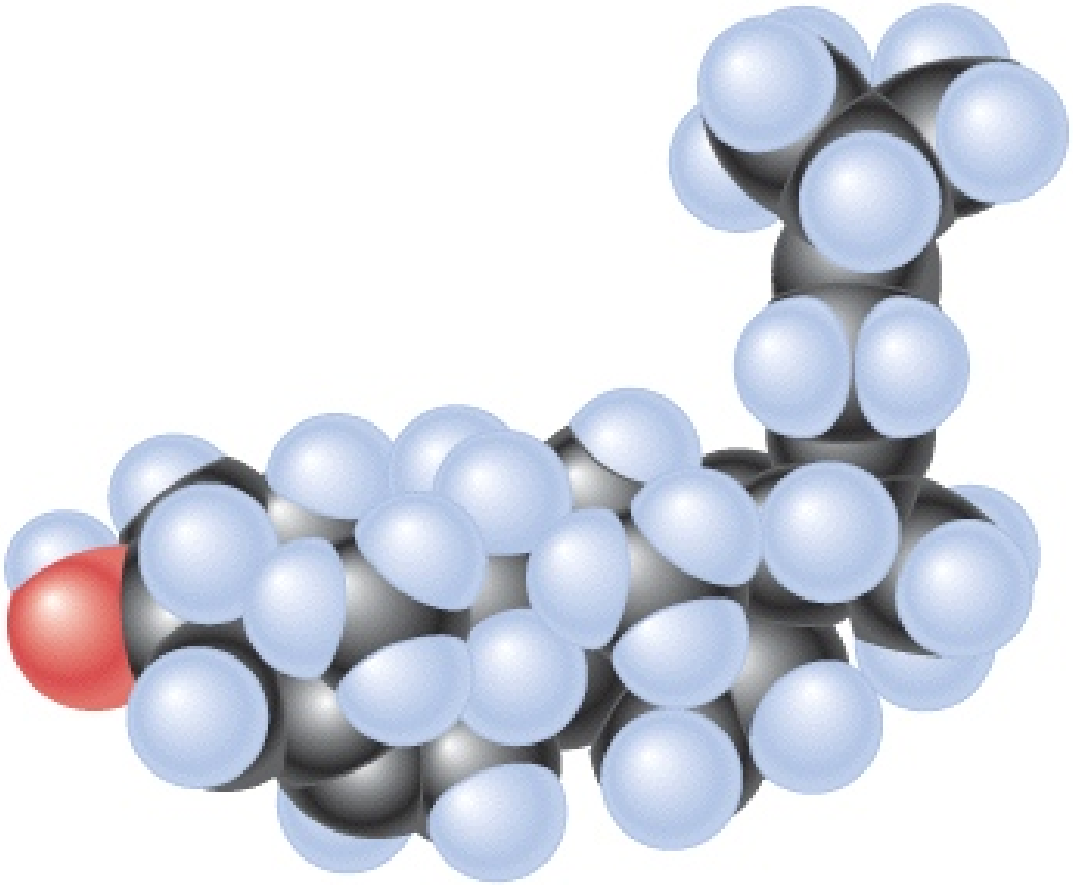
Membrane Lipids

- Membrane phospholipids are permeable to:
  - CO2, O2, steroids, thyroid hormones, lipids, **water**
- Membrane phospholipids are *not* permeable to:
  - ions
  - amino acids
  - sugars

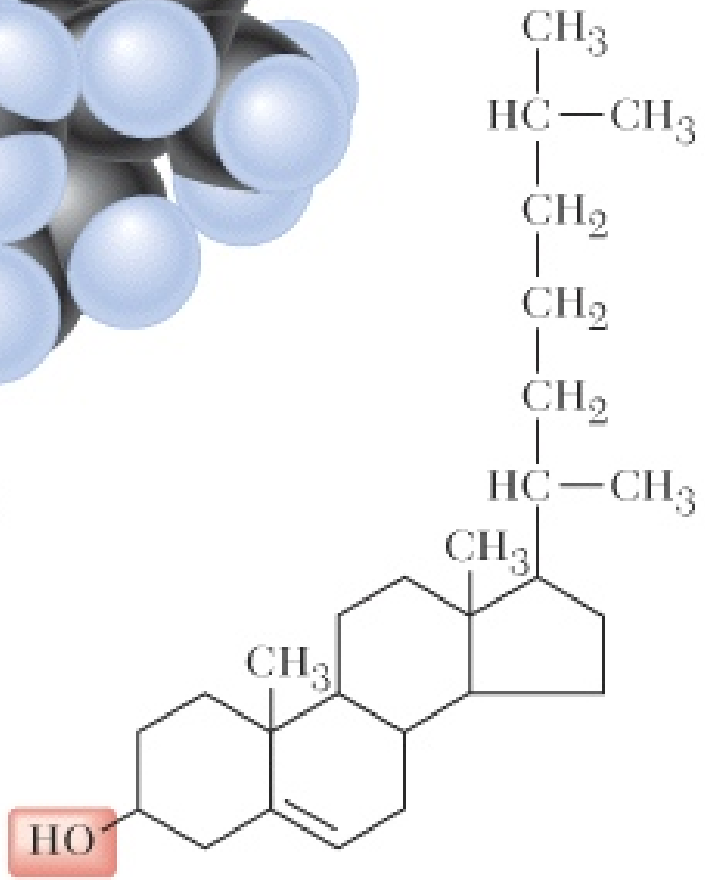
Fig. 3.6

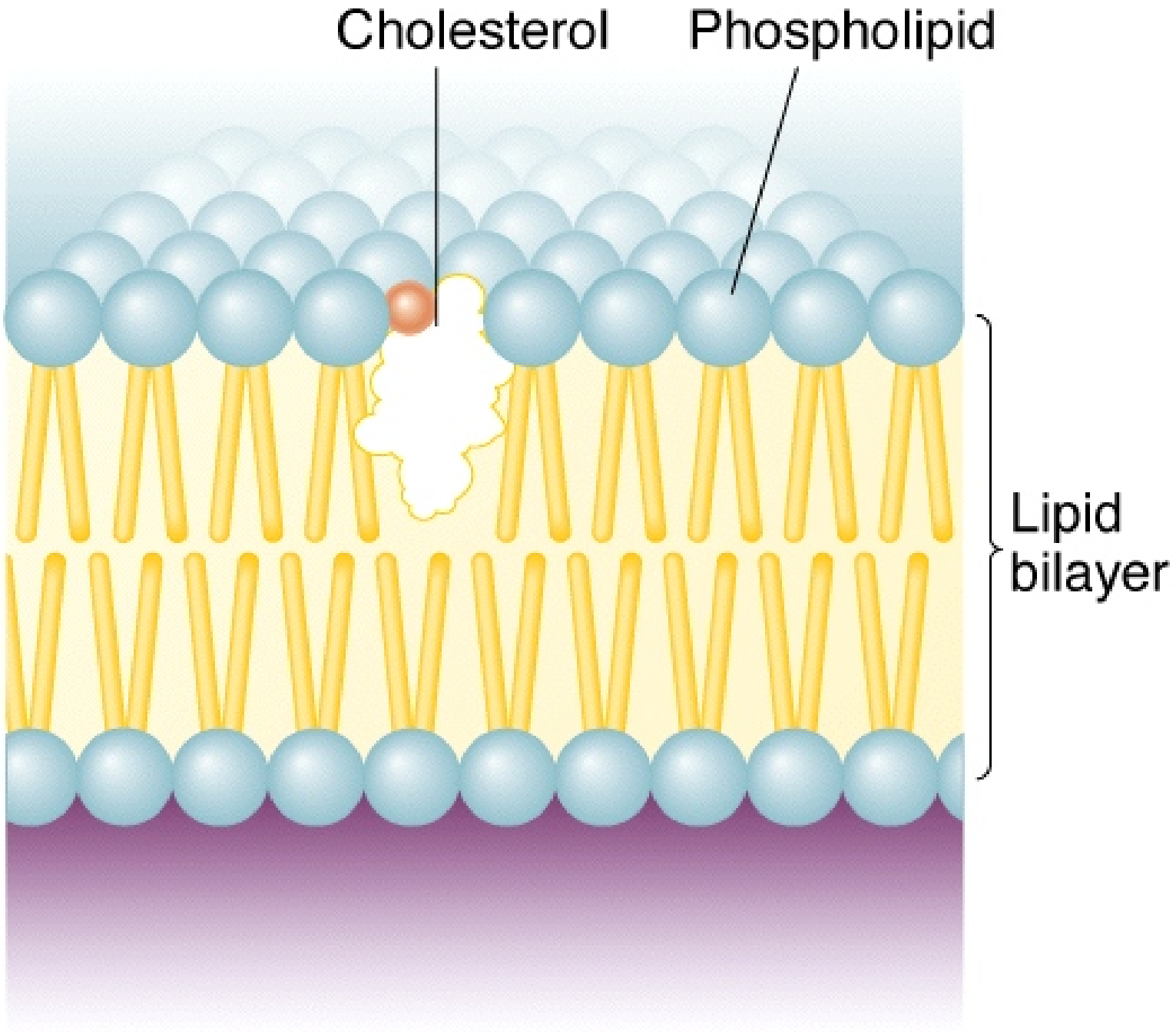




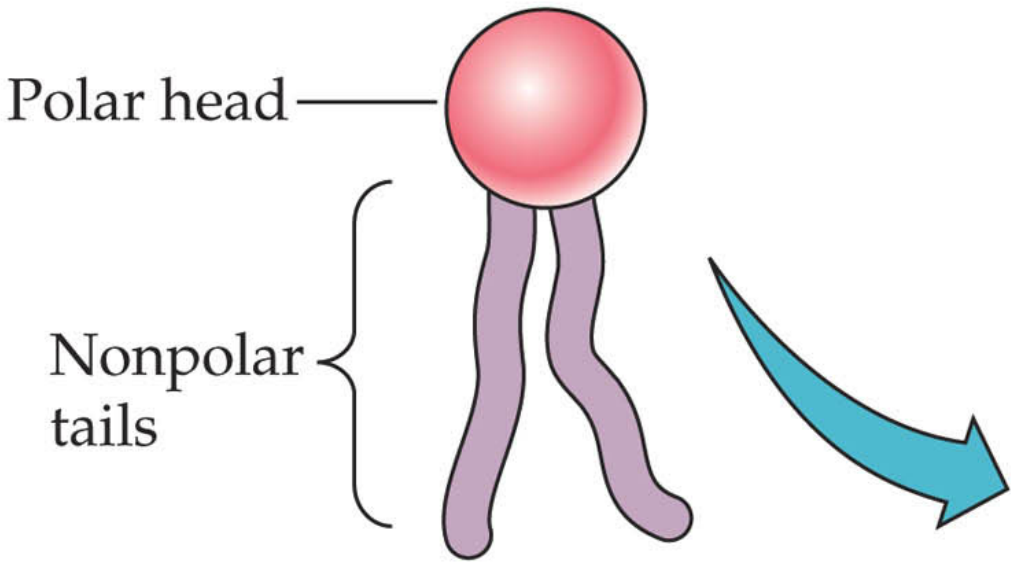


Cholesterol

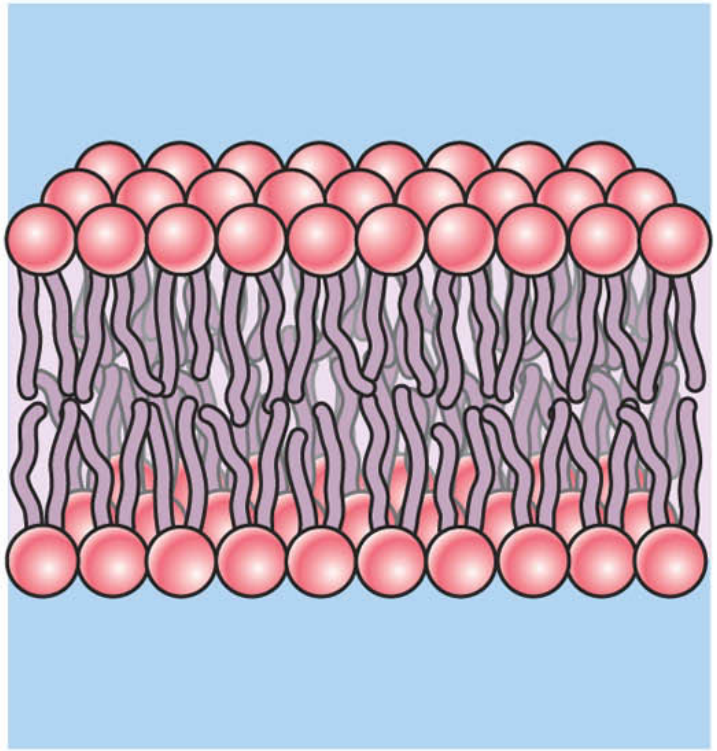


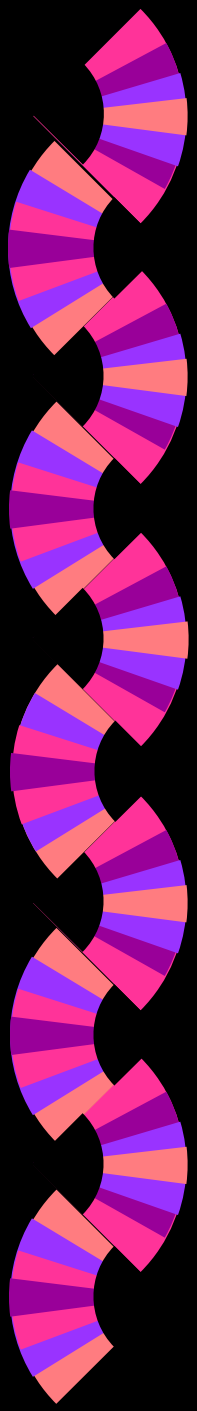

Cholesterol
Phospholipid
Lipid bilayer

(*b*) Model of a phospholipid molecule



(*c*) Phospholipid molecules assembled into a bilayer with water on either side





Membrane proteins

- Proteins are long chains of amino acids with important 3 dimensional structure

Membrane proteins

- Integral proteins-span the width of the plasma membrane

- Transporters, channels, receptors, or pores for trans-membrane passage

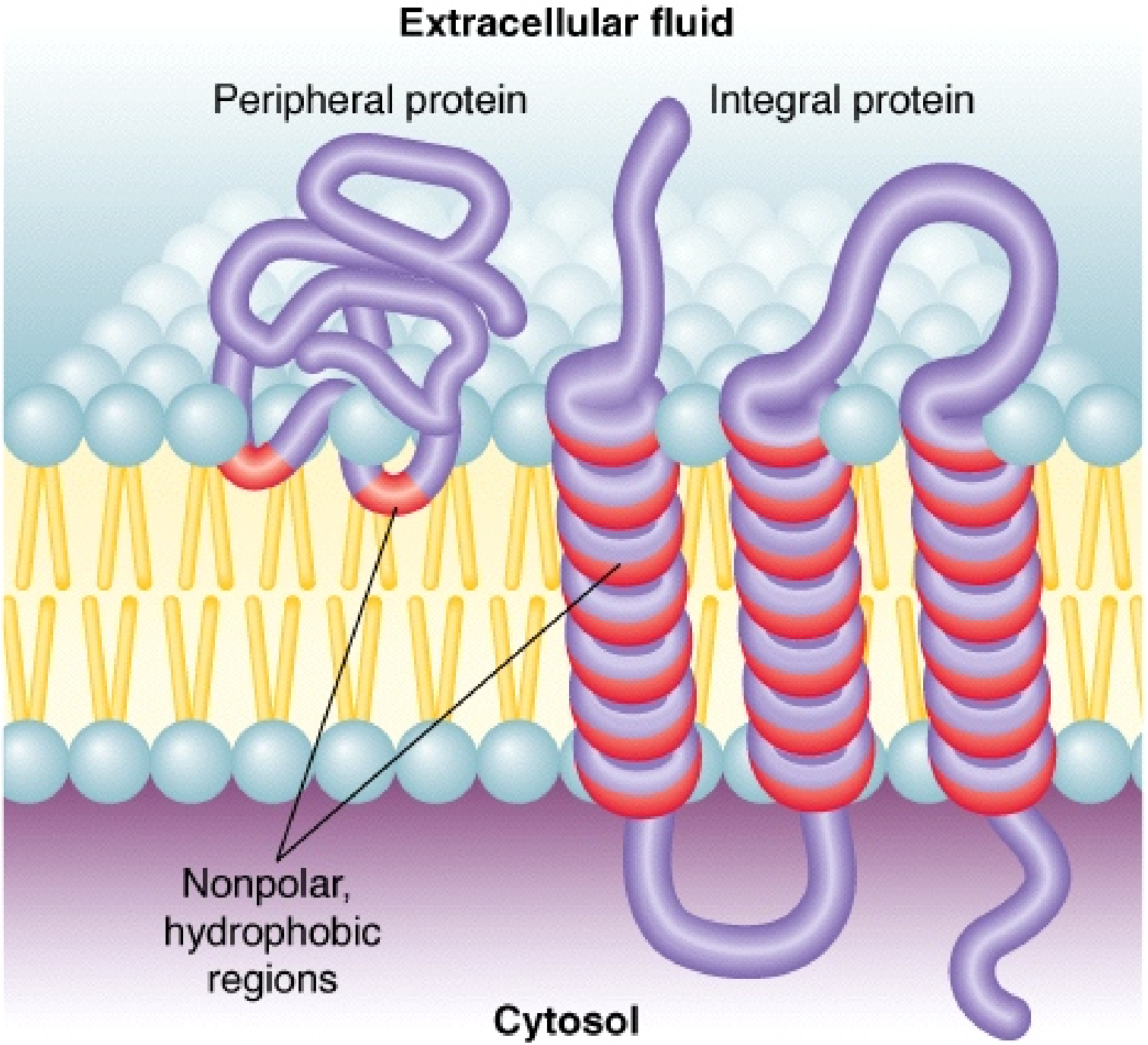

Extracellular fluid
Peripheral protein
Integral protein
Nonpolar, hydrophobic regions
Cytosol

Fig. 2.15

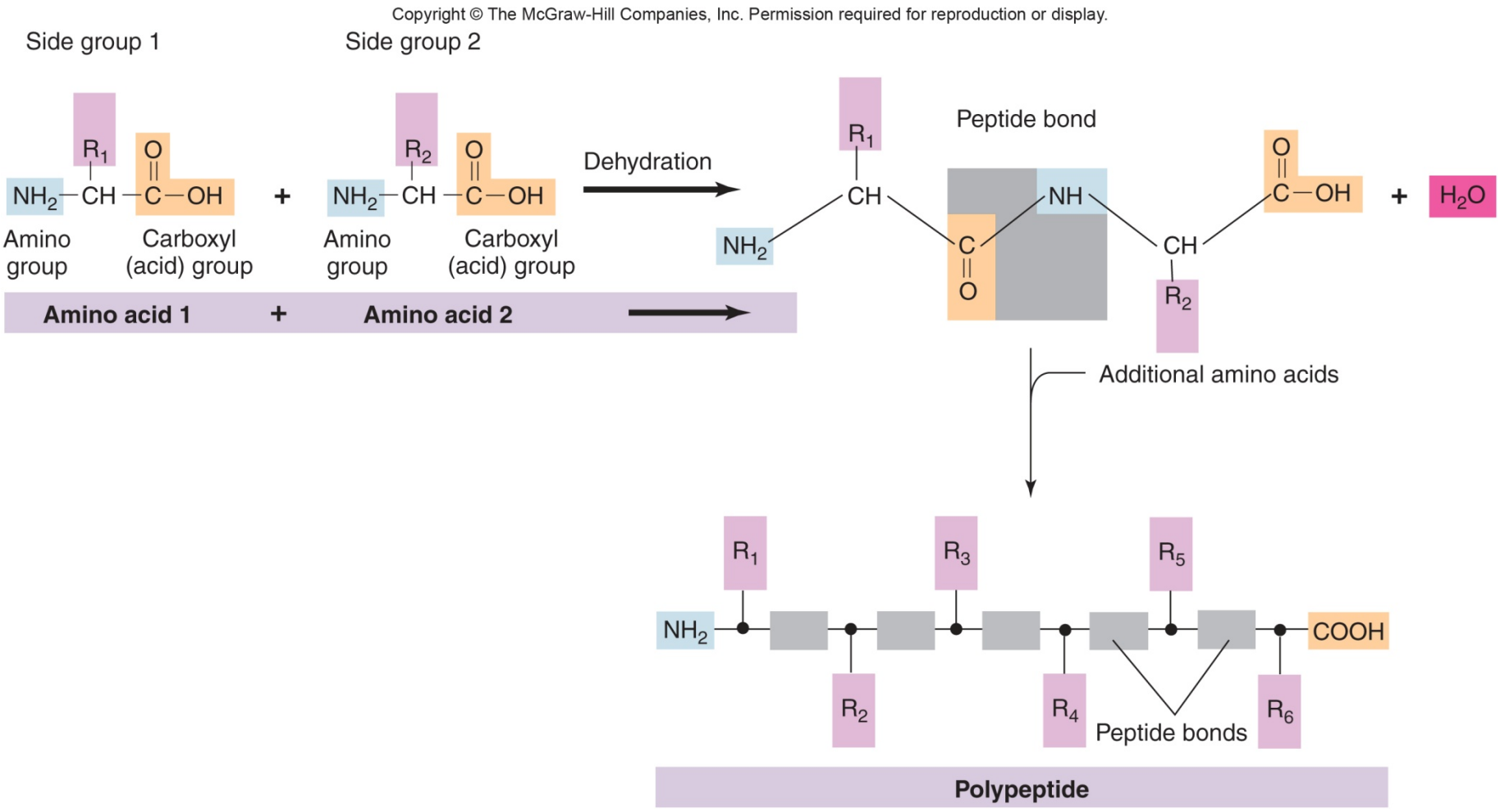
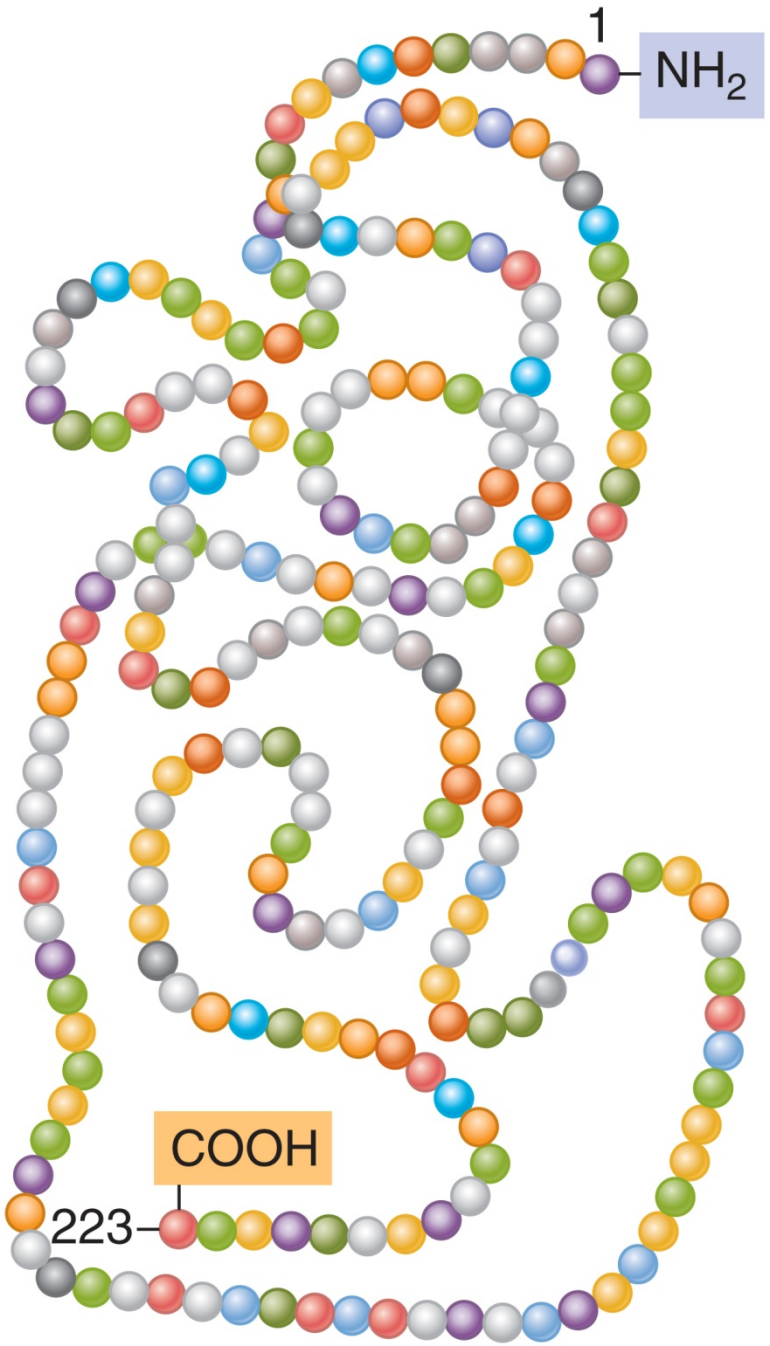


Fig. 2.16



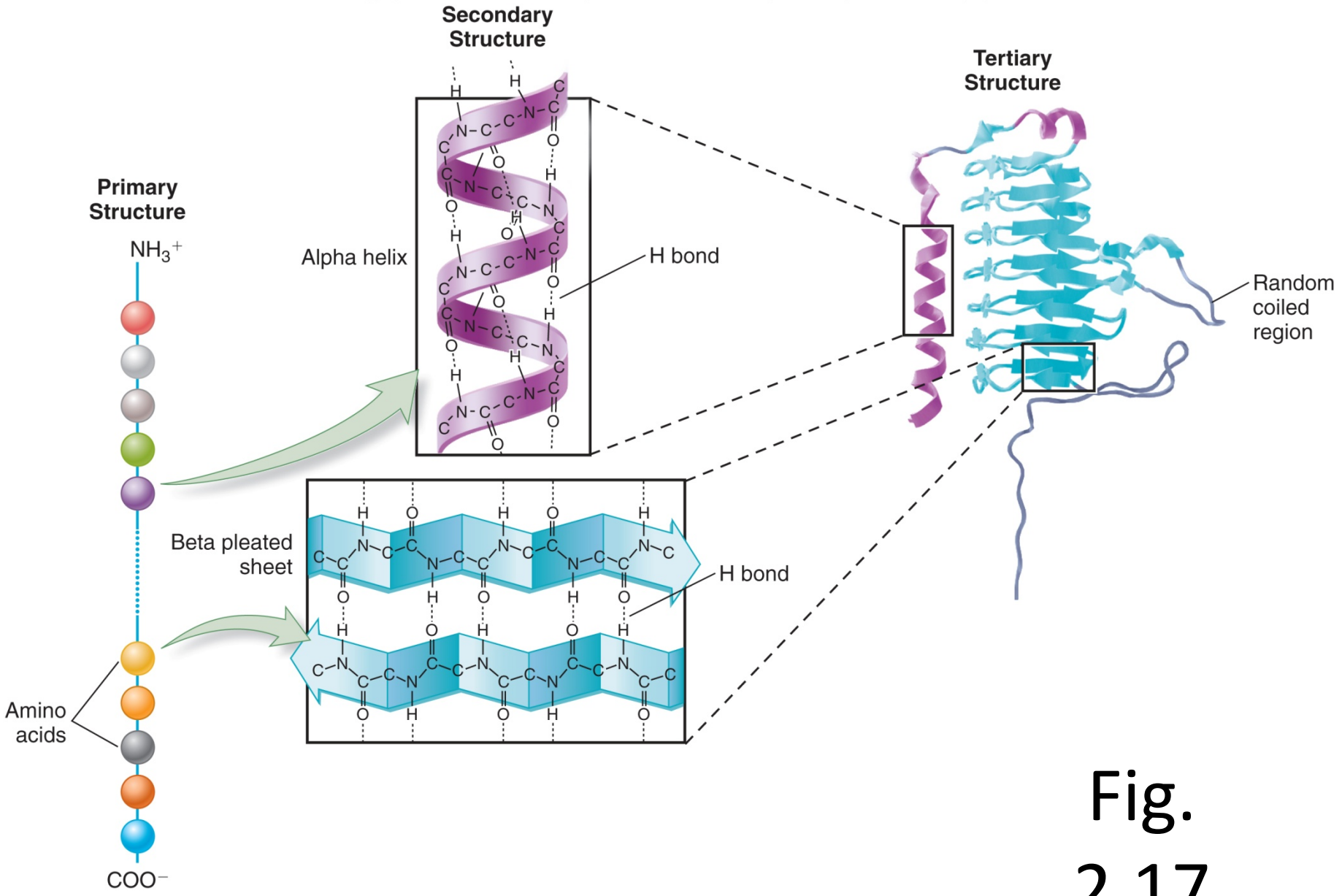
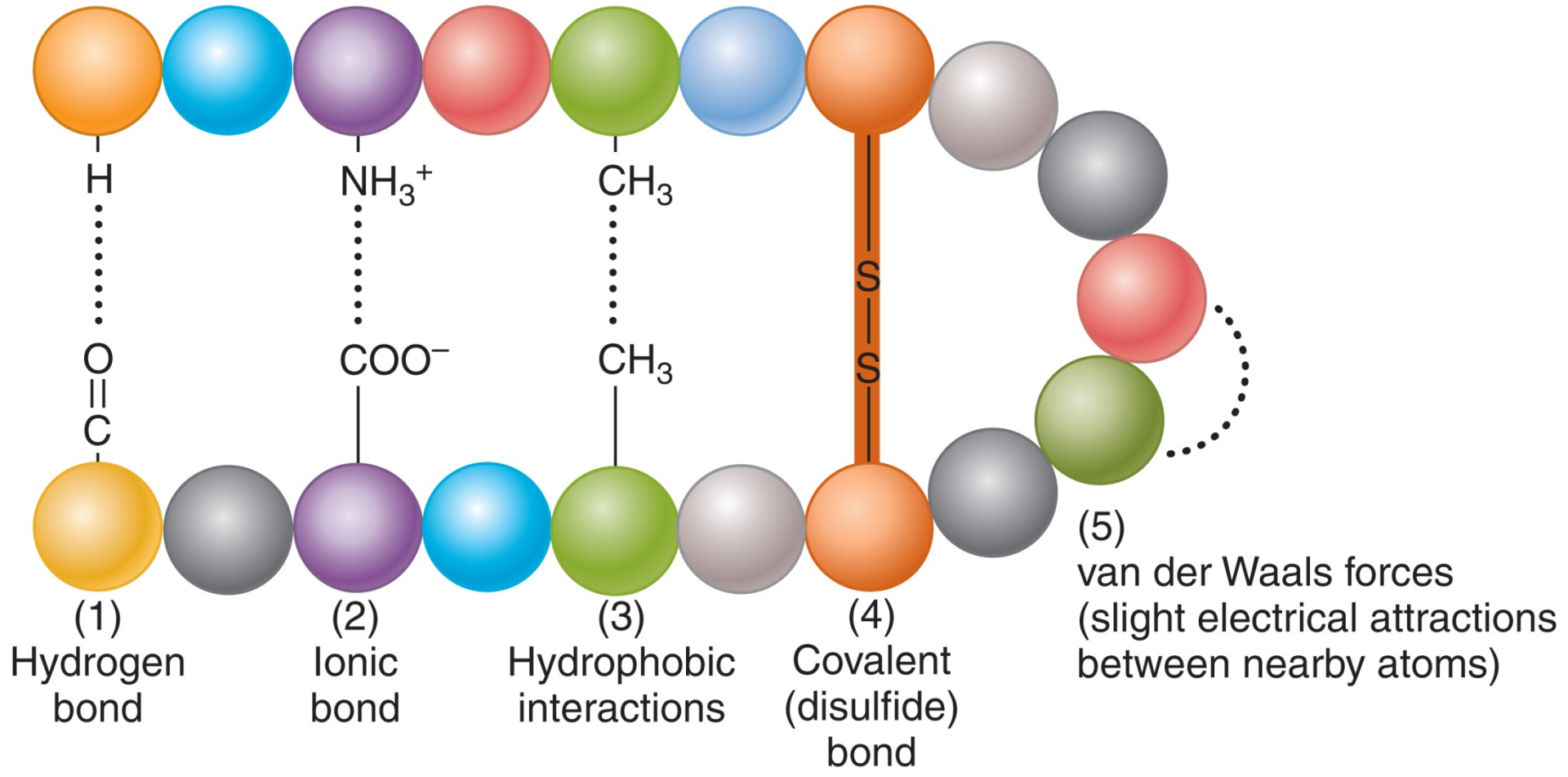
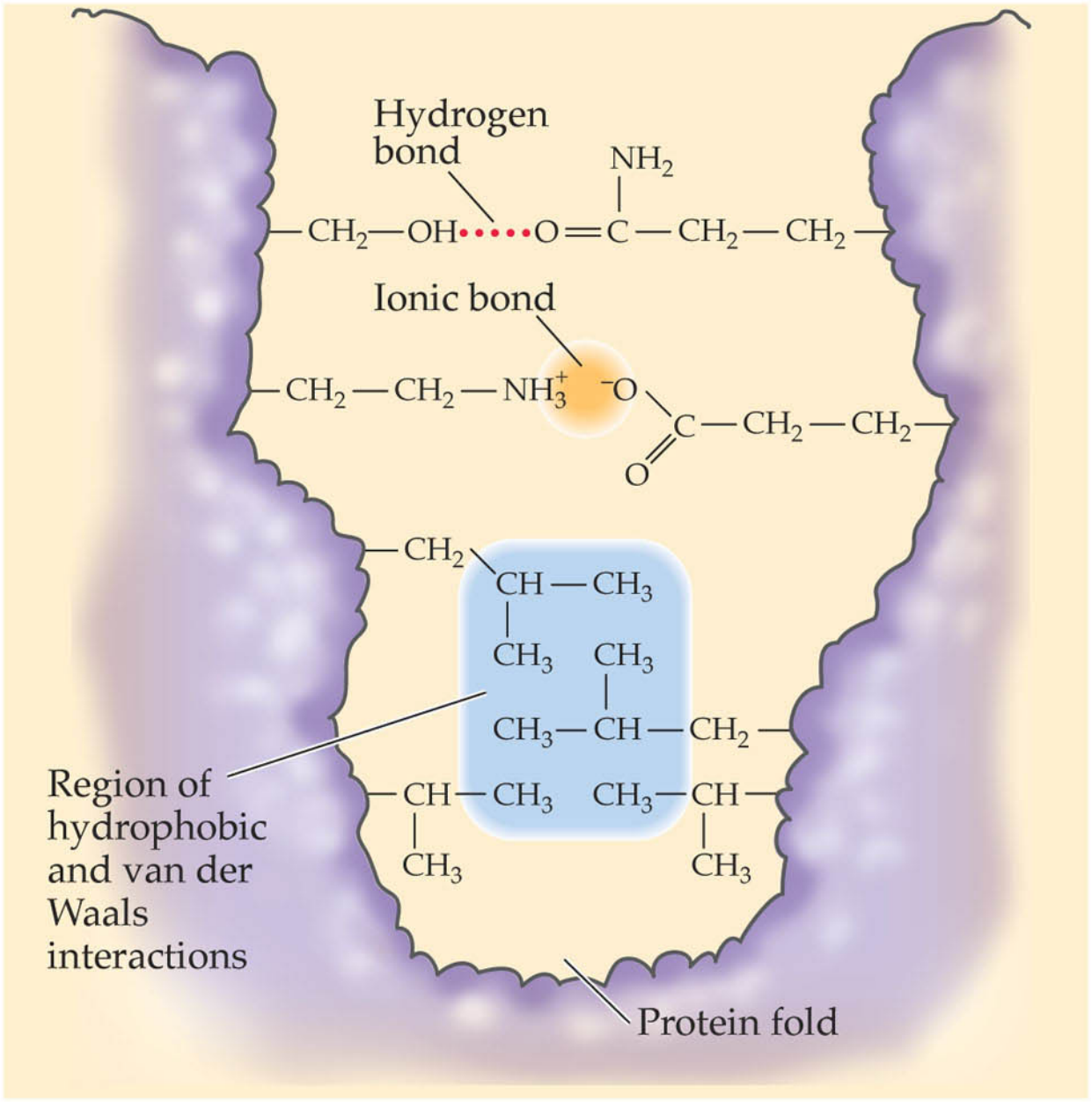


Fig. 2.17

Fig. 2.18





ANIMAL PHYSIOLOGY, **Box 2.1, Figure C**

II. Transport

- A. Diffusion- free (no NRG required) movement of a compound in a random fashion caused by kinetic energy.

- B. Active transport- movement against concentration gradient that requires energy.

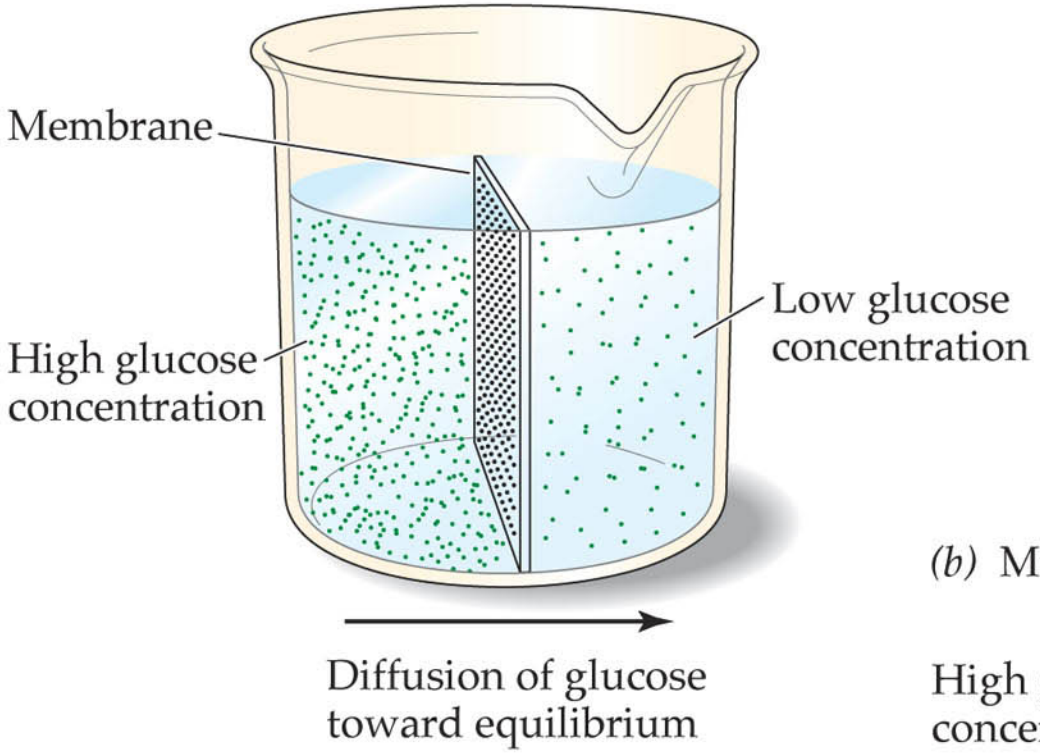
1. Free Diffusion

- A. Non-channel mediated
  - lipids, gasses (O2, CO2), water
- B. Channel mediated
  - ions, charged molecules

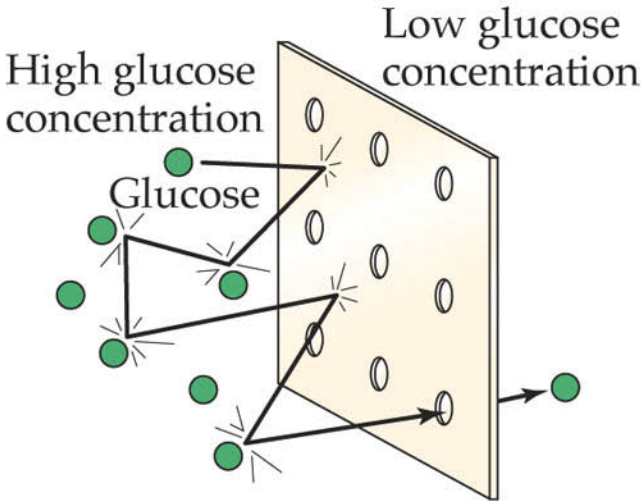
2. Facilitated diffusion

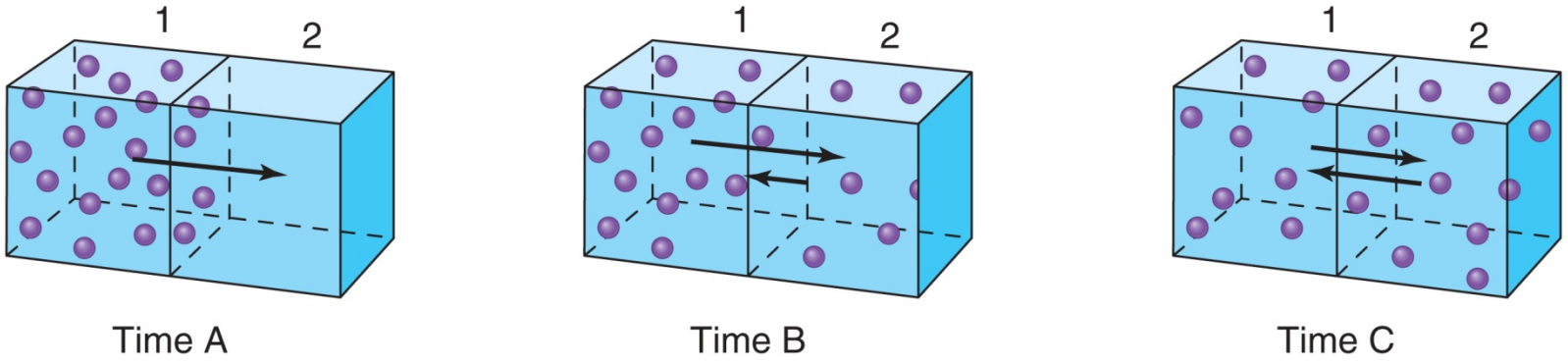
- Carrier mediated
  - glucose, amino acids

(a) Macroscopic view of simple diffusion



(b) Microscopic view of simple diffusion





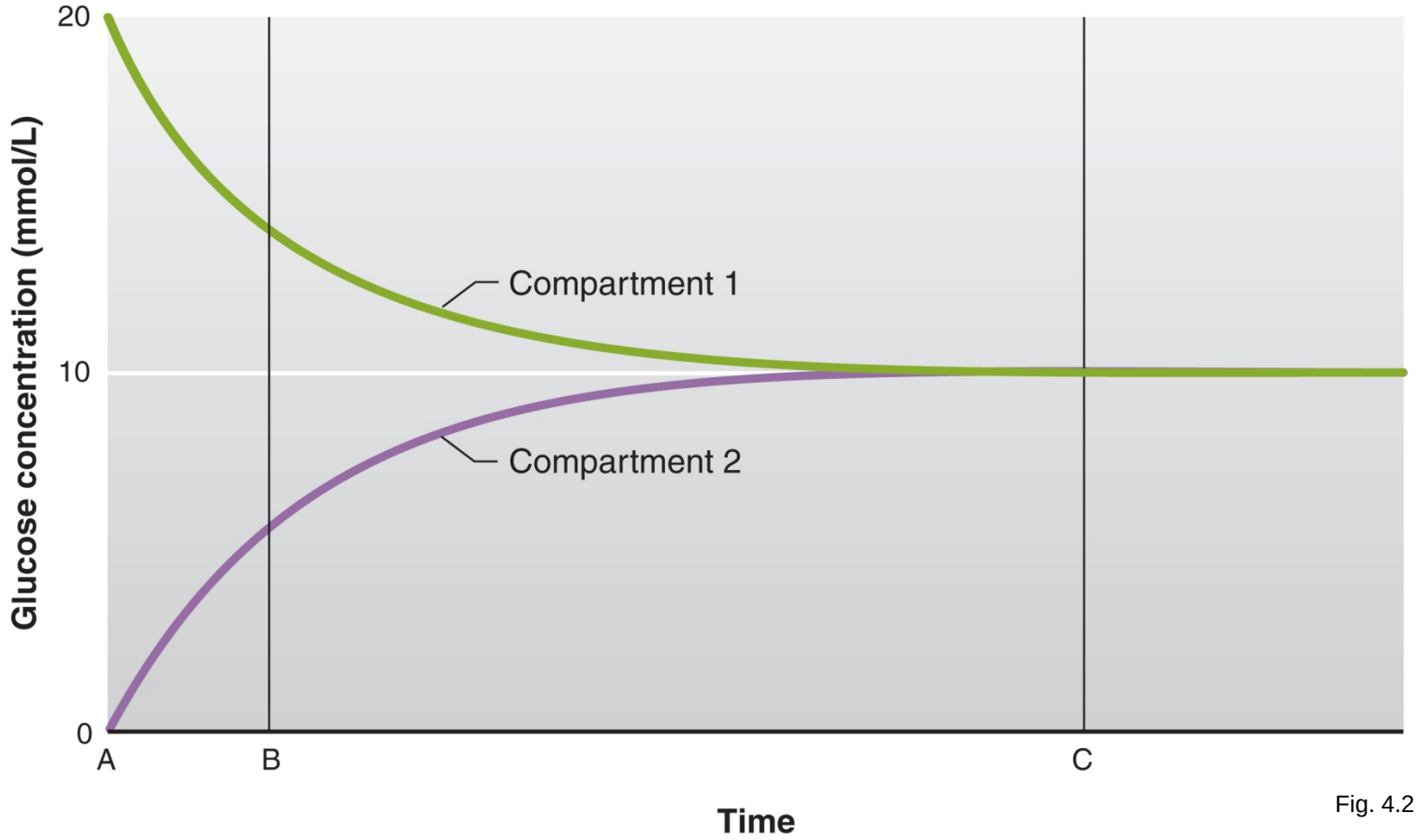


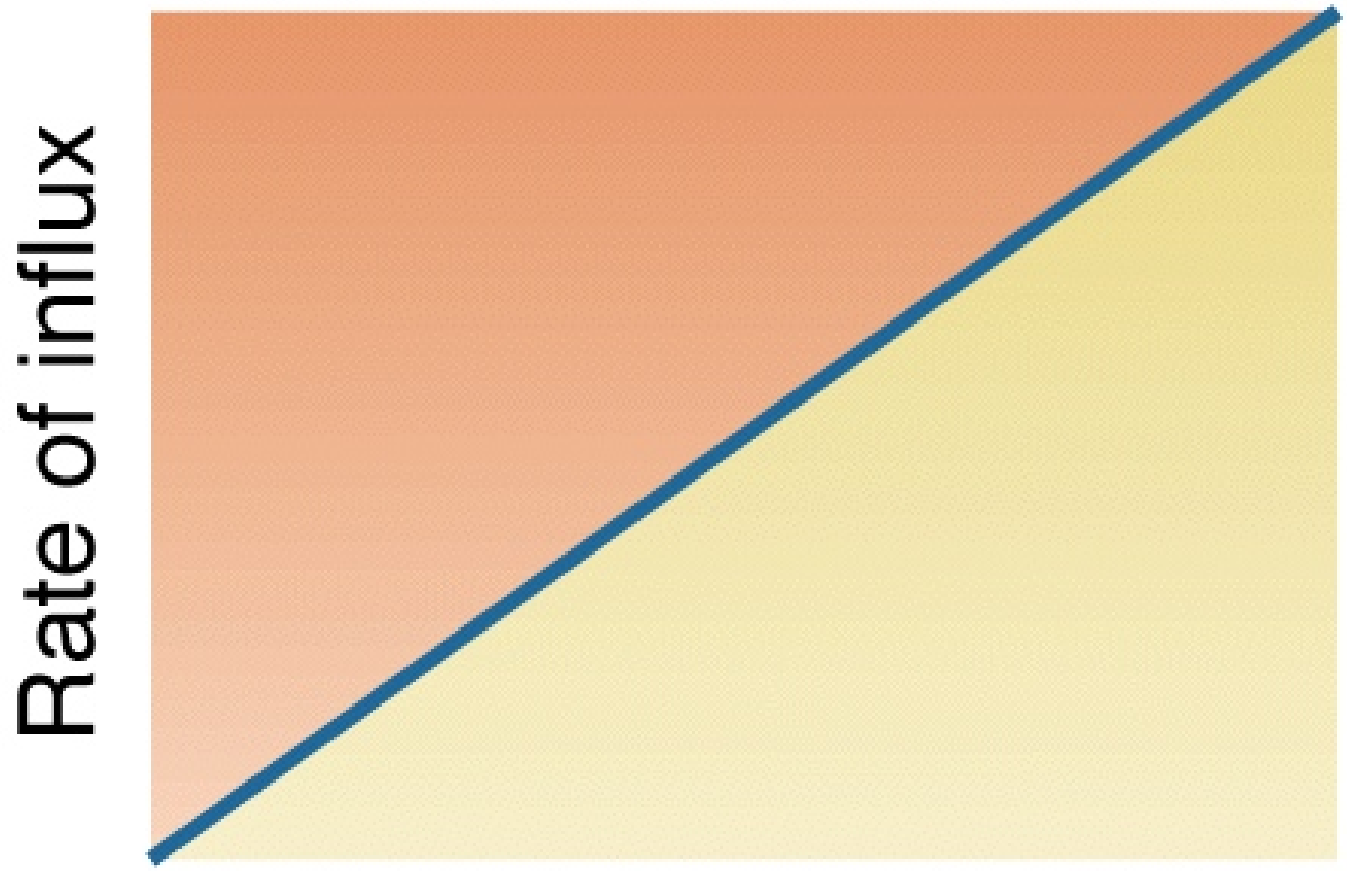
Fig. 4.2

Plethodontid salamanders

- Lungless
- Breathe through skin
- Small body size
- Very thin integument

http://www.dnr.state.oh.us/wildlife/Resources/amphibians/lungless.htm

(a) Passive diffusion through membrane



(b) Passive transport through channels

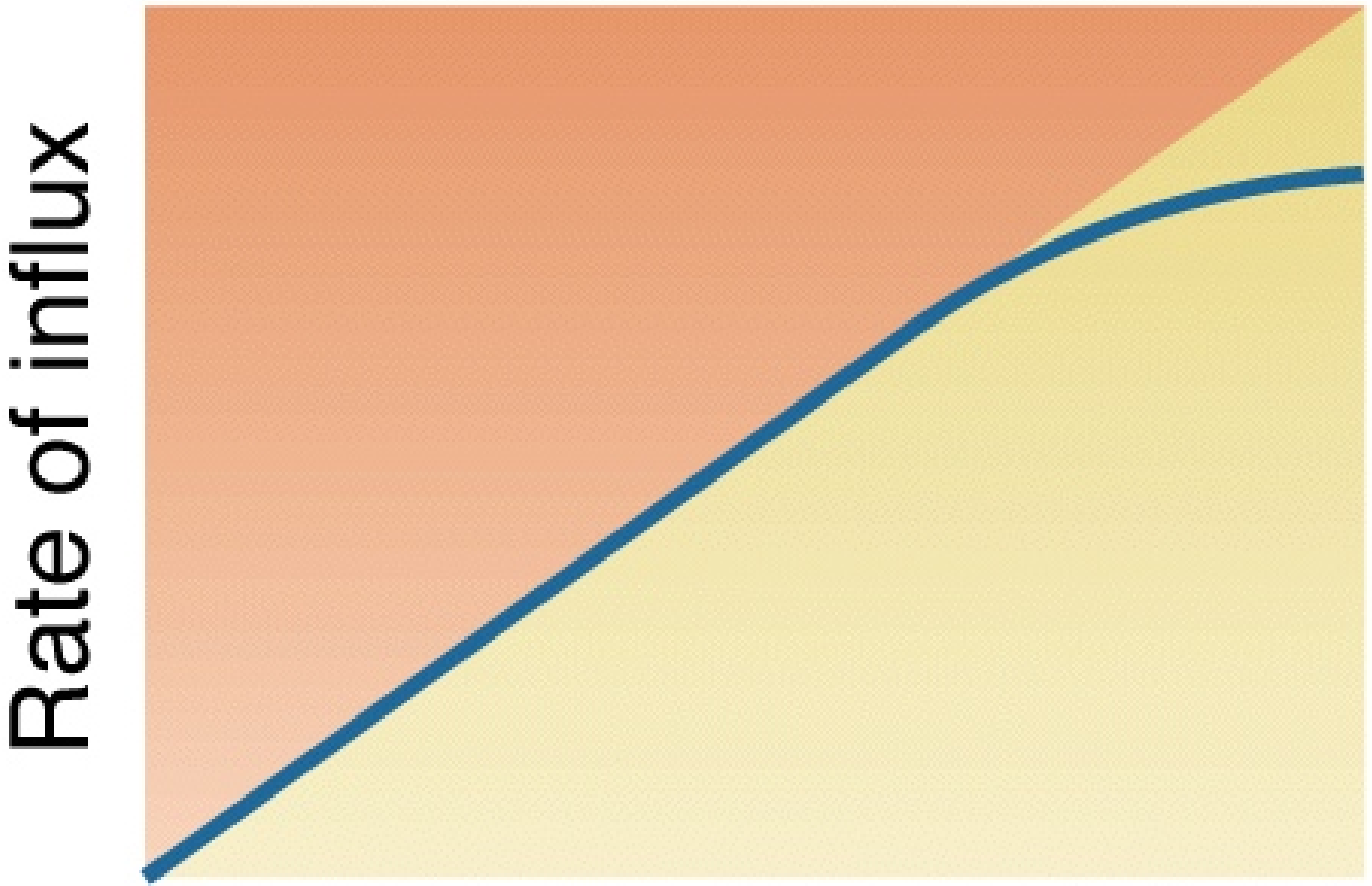
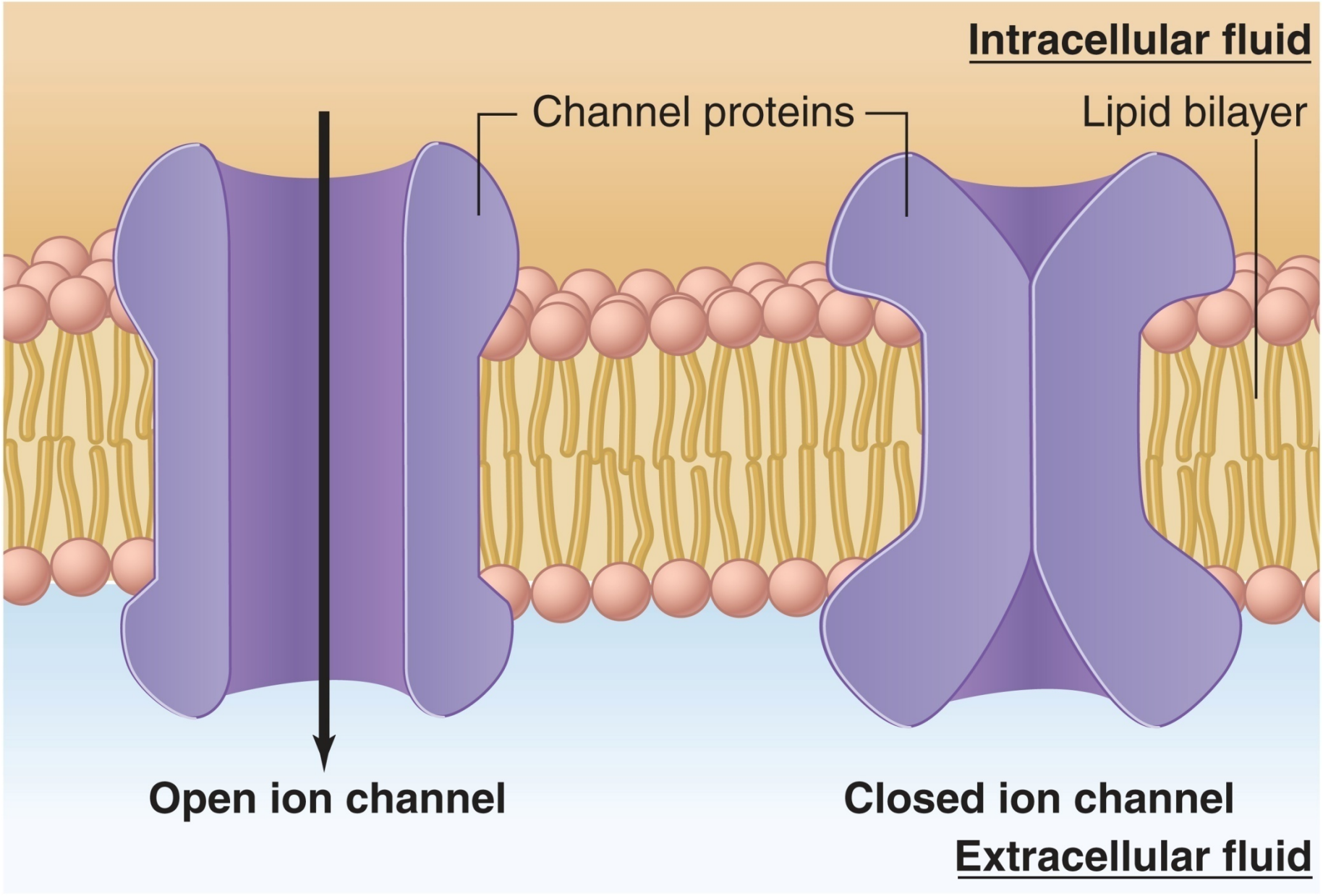


Fig. 4.7



(c) Carrier-mediated transport (passive or active)

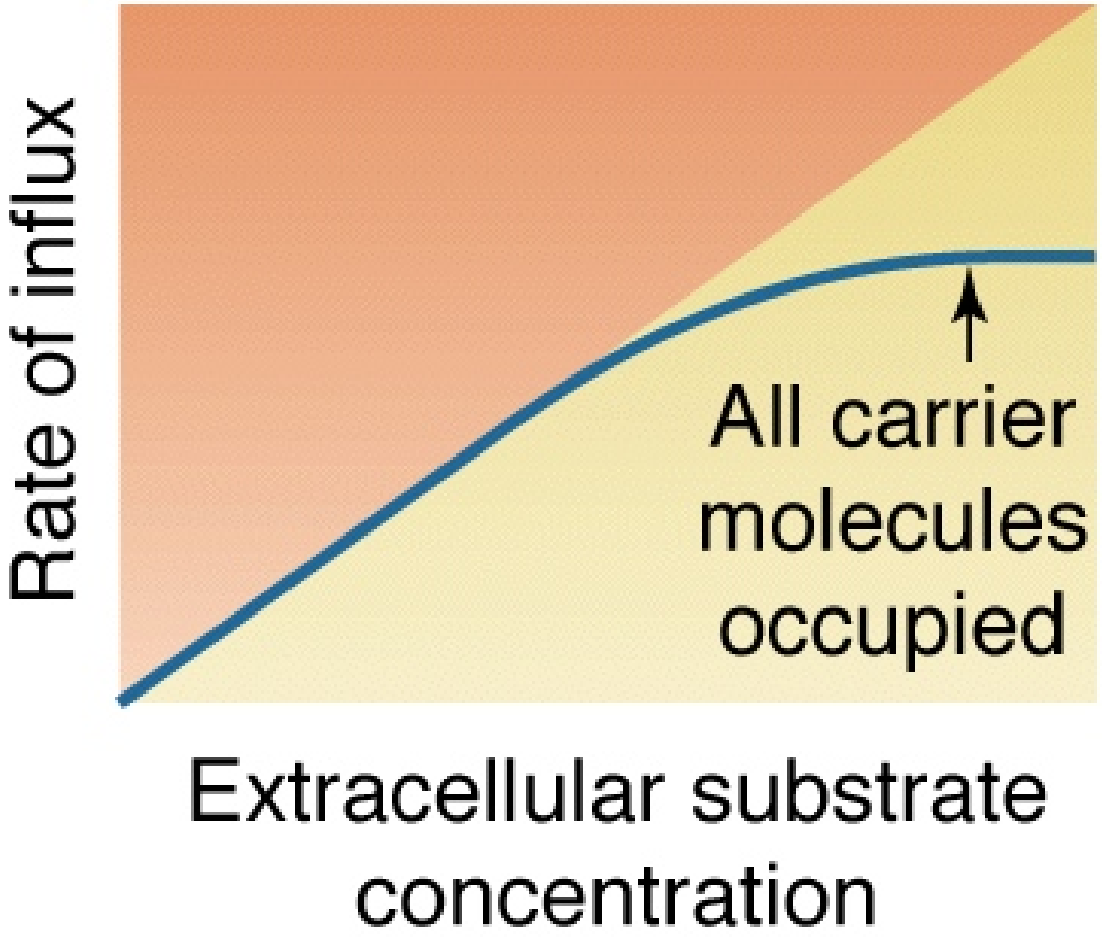
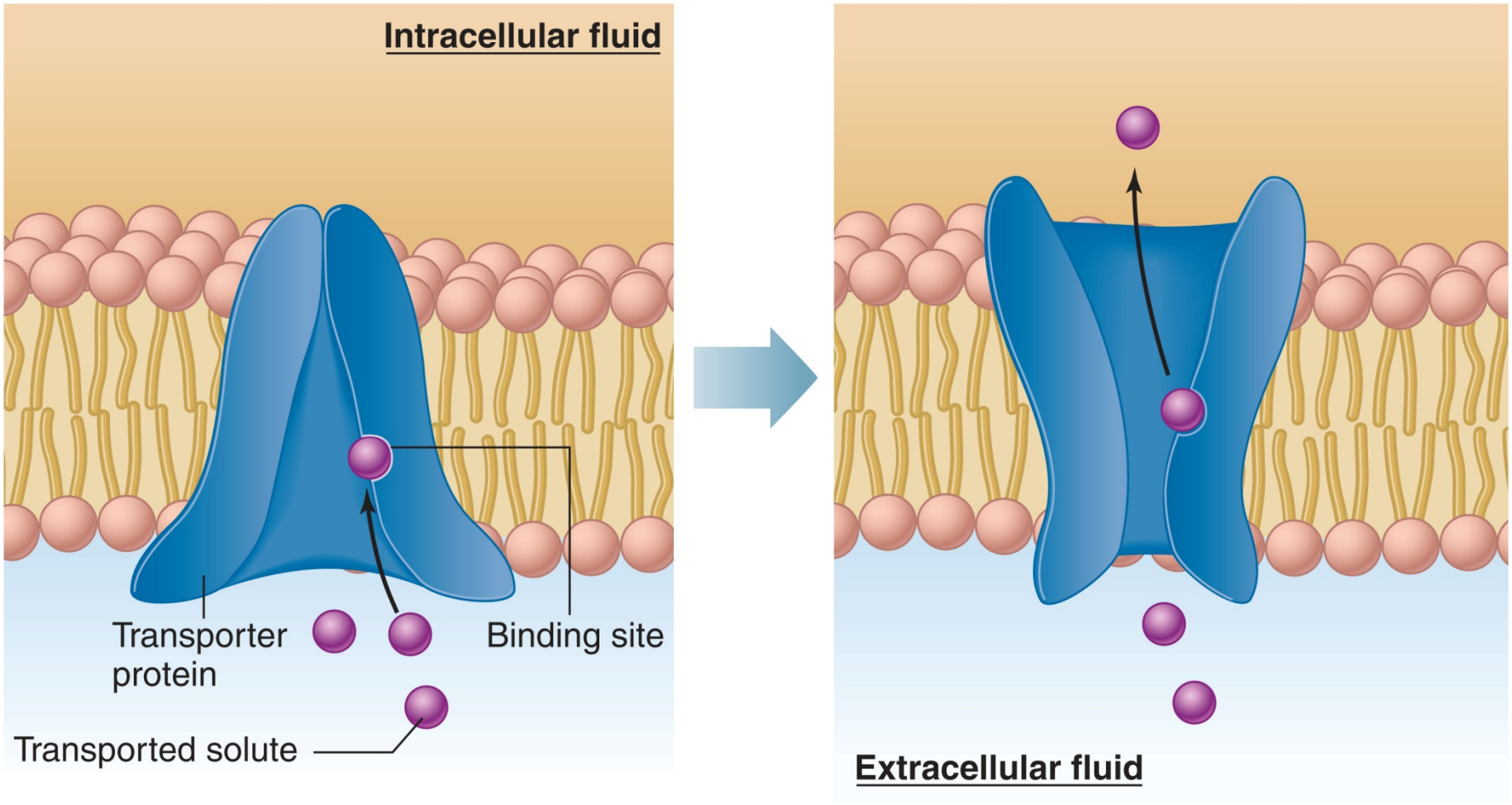


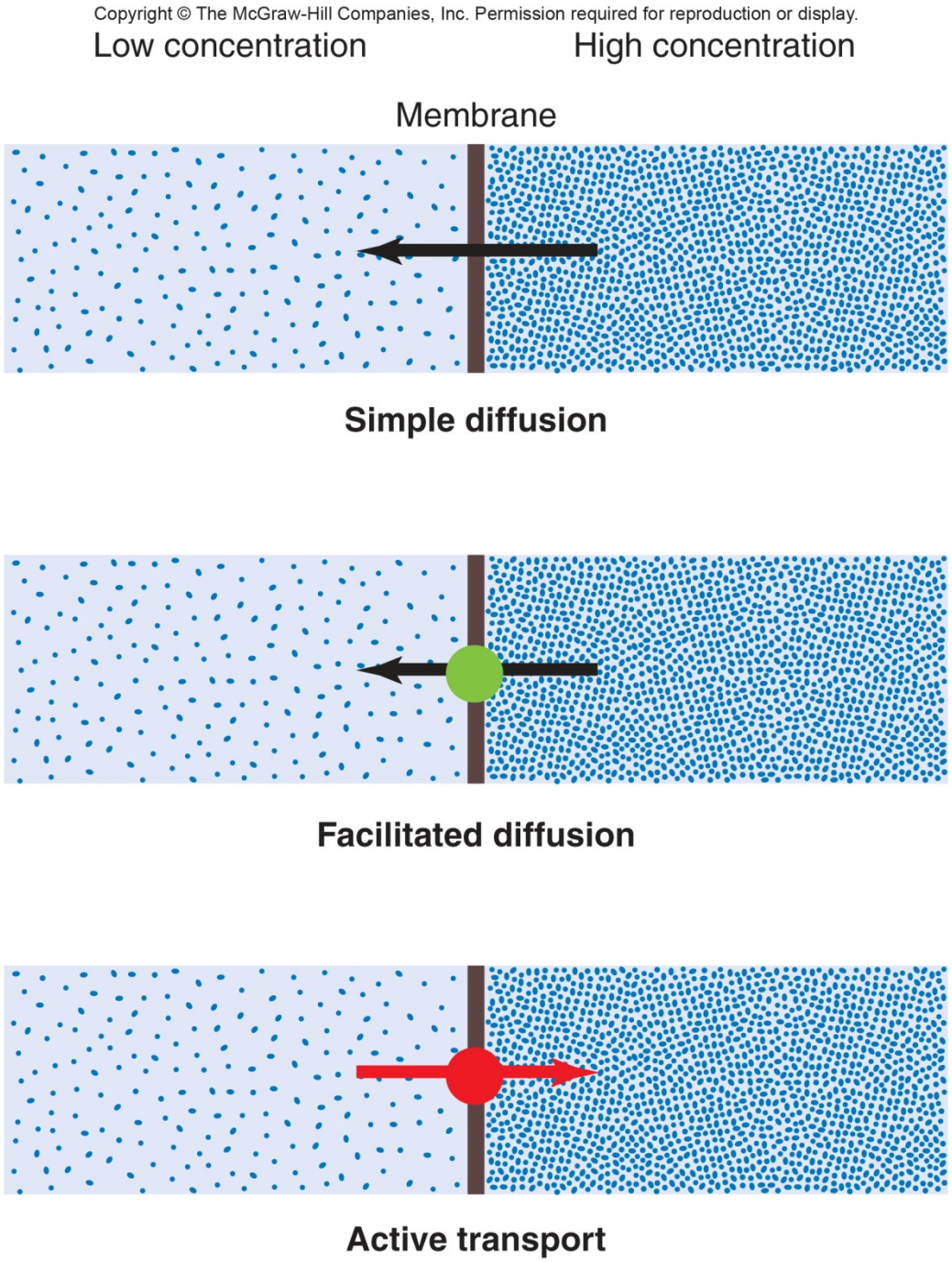
Fig. 4.8



Facilitated Diffusion

- Rate of diffusion is determined by:
- concentration gradient
- amount of carrier protein
- rate of association/dissociation

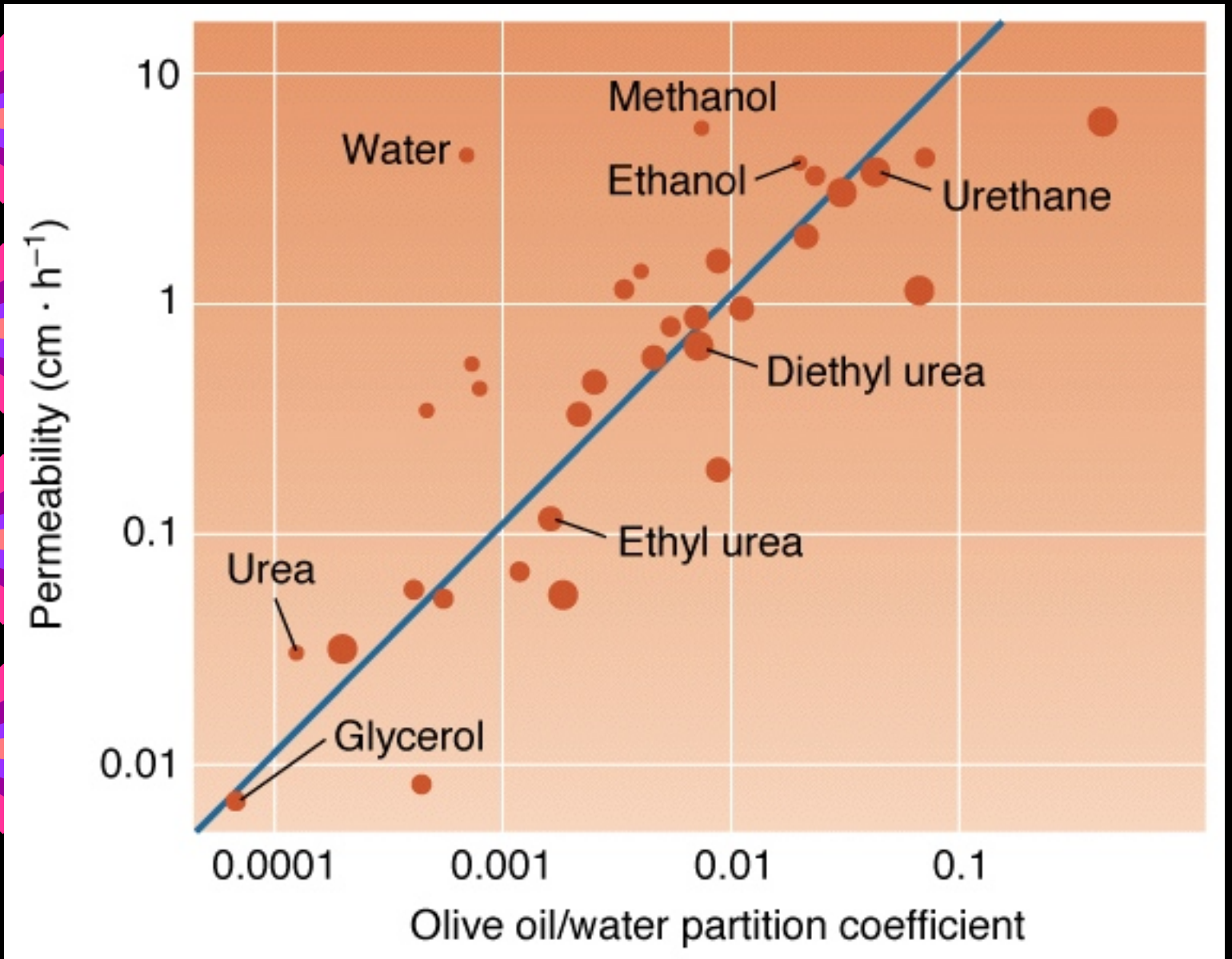
Fig. 4.10



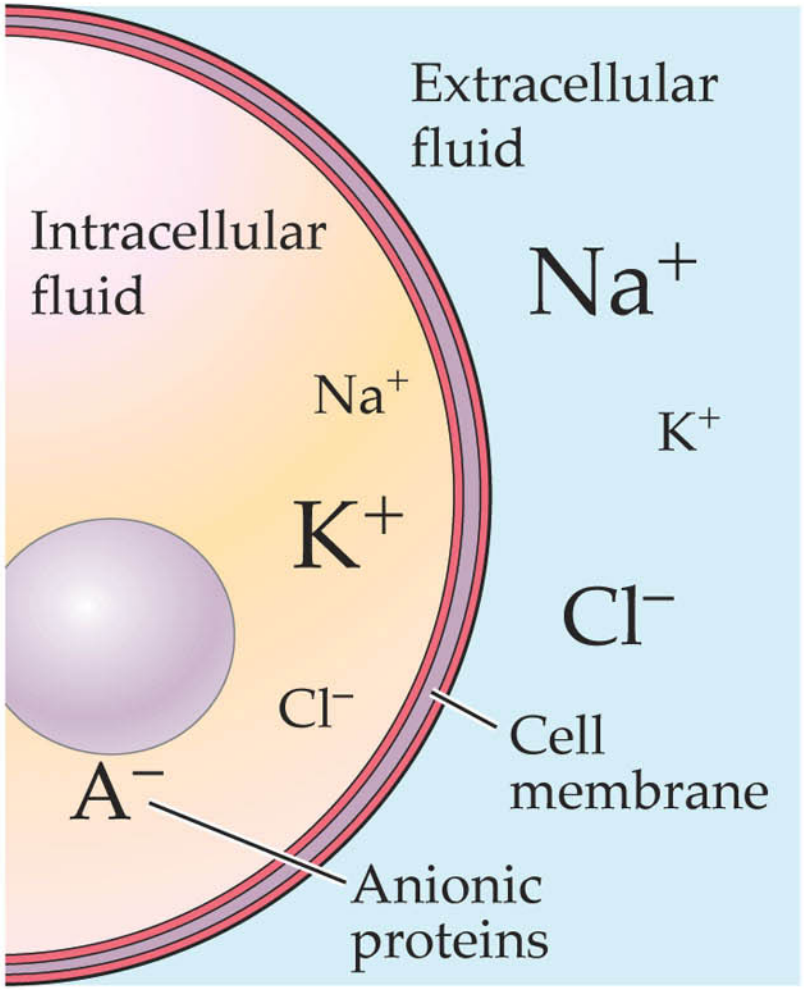
General Nature of Diffusion

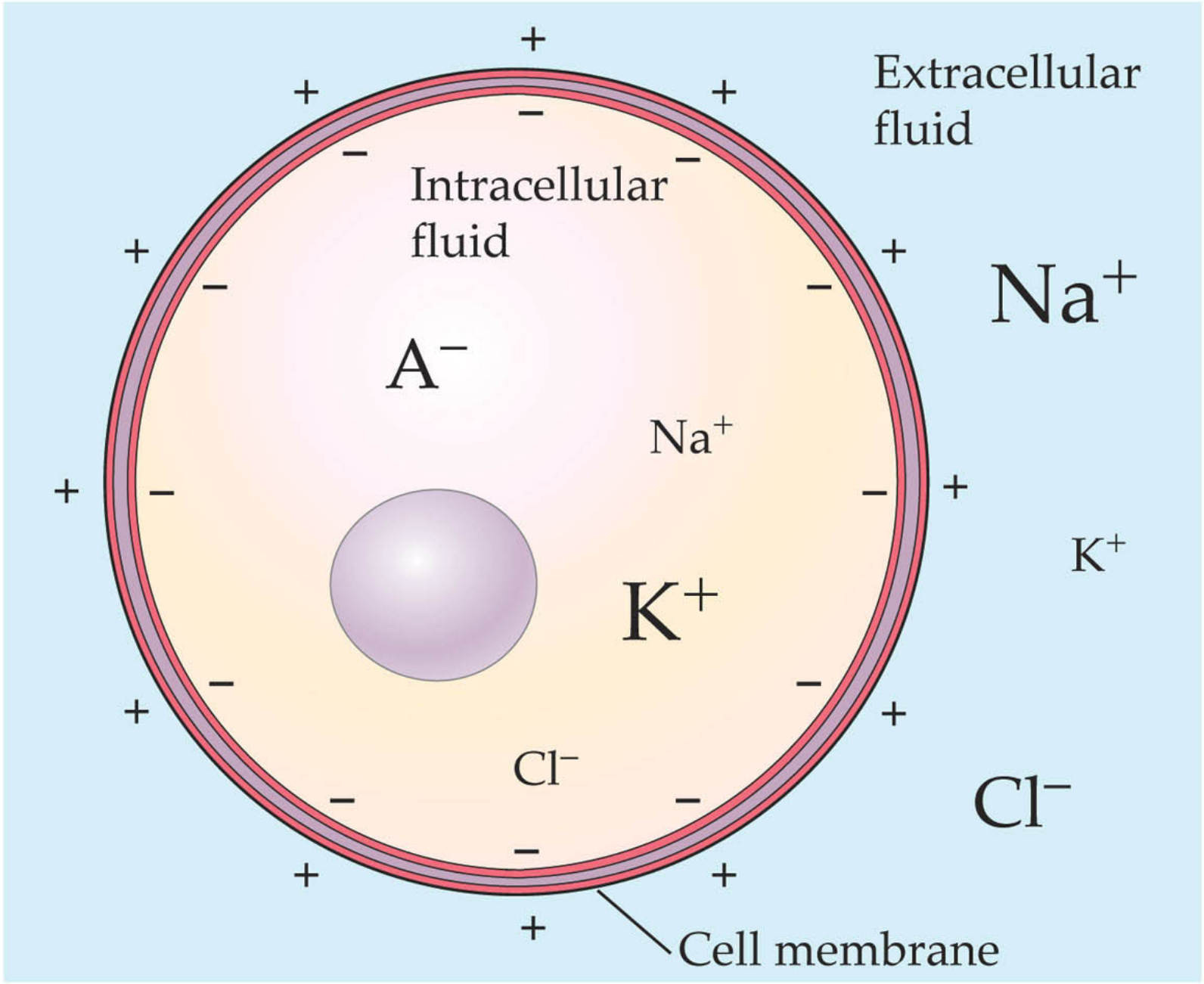
- Diffusion rate is proportional to the concentration gradient.
- Net movement inward and outward can only occur until inside [ ] = outside [ ].
  - Anything that moves in can move out.
- For lipid soluble molecules the partition coefficient is important.
- For electrolytes, electrical charge can influence diffusion.

Partition Coefficient

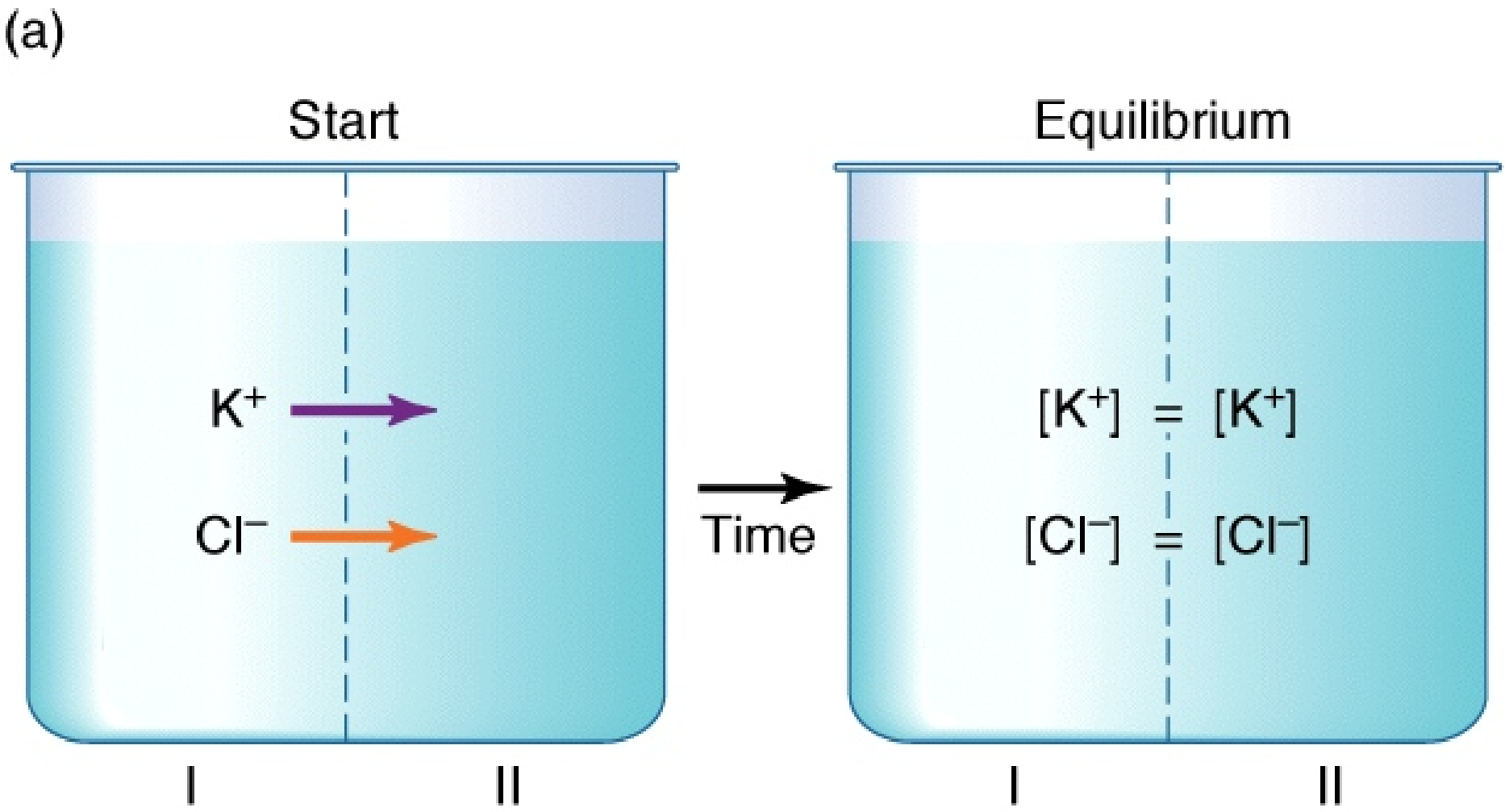


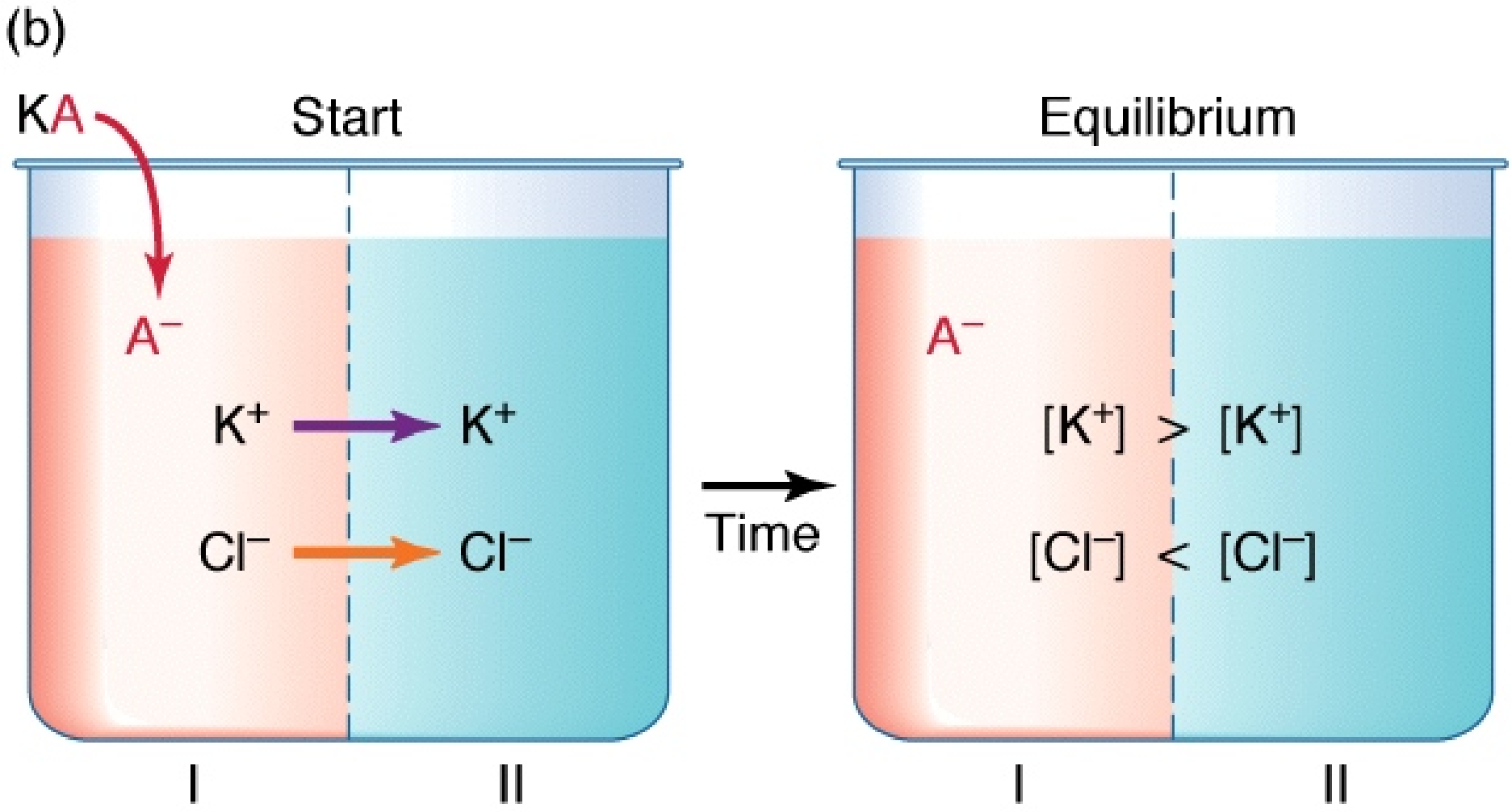
(*a*) Relative ion concentrations inside and outside a single animal cell





Donnan Equilibrium




(b)
KA
Start
Equilibrium
A⁻
K⁺
K⁺
Cl⁻
Cl⁻
Time
A⁻
[K⁺] > [K⁺]
[Cl⁻] < [Cl⁻]
I
II
I
II

Electrochemical equilibrium

- for ions there are two major forces that affect diffusion:

1. concentration gradient
2. electrochemical gradient

Electrical forces are more powerful than concentration gradients

Principle of electroneutrality

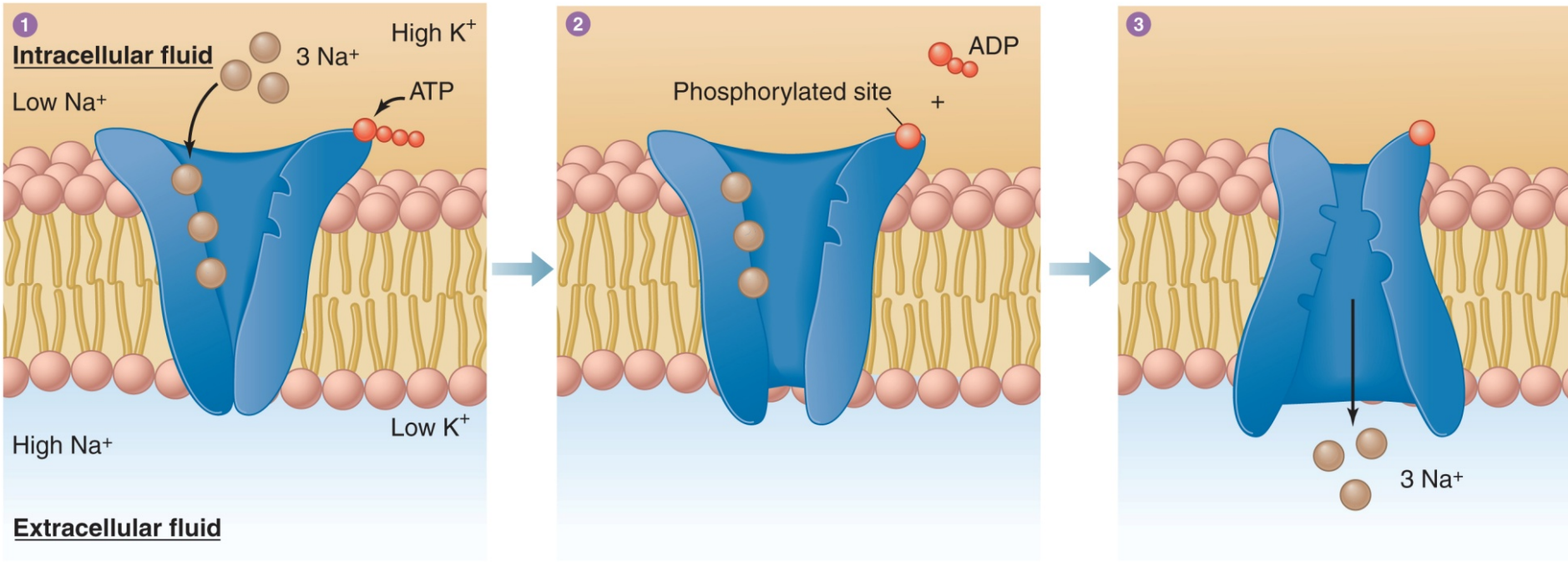
- (-) and (+) charges tend to balance each other out
- Donnan equilibrium:

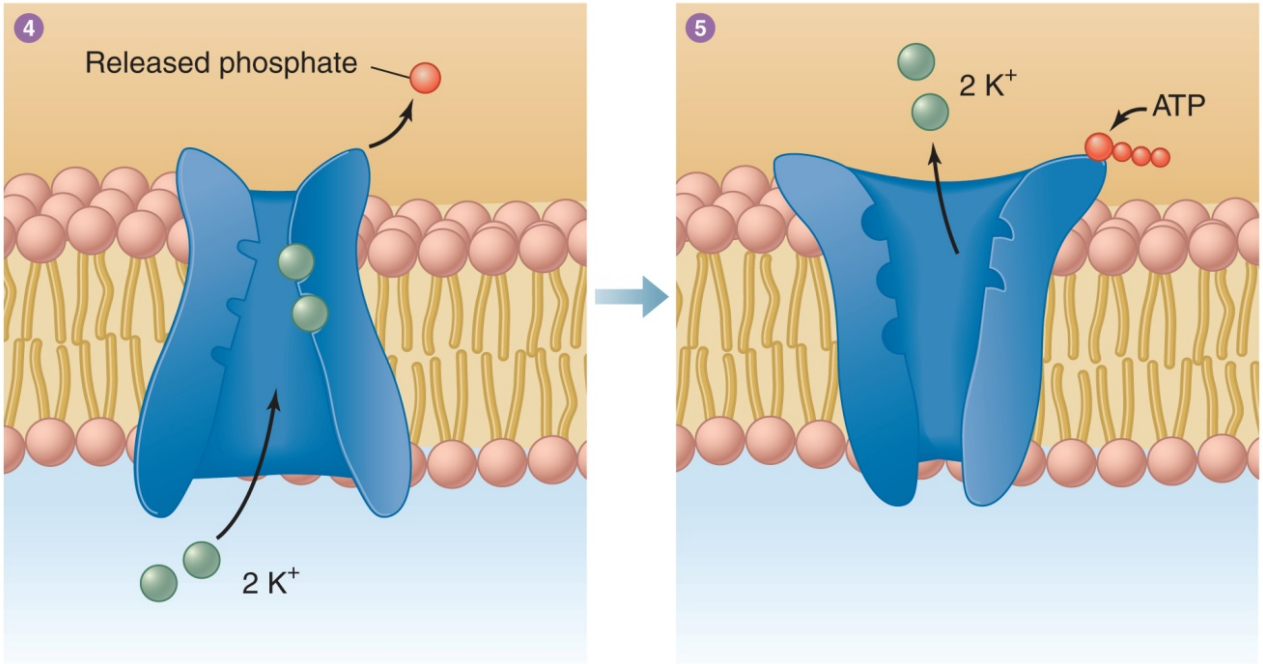
$[K+]_{in} \times [Cl-]_{in} = [K+]_{out} \times [Cl-]_{out}$

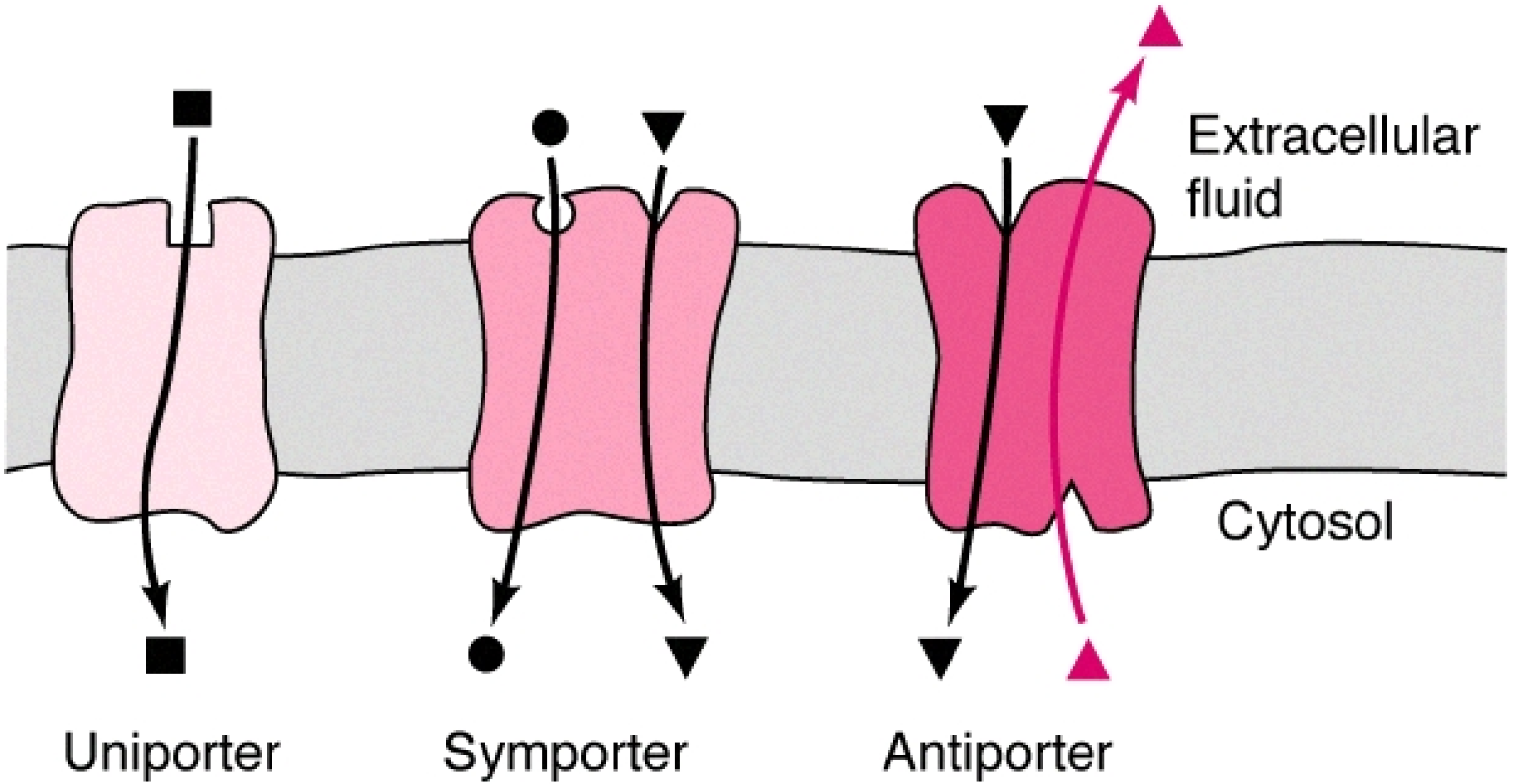
Applies to membrane permeable ions, K+ and Cl- for our purposes

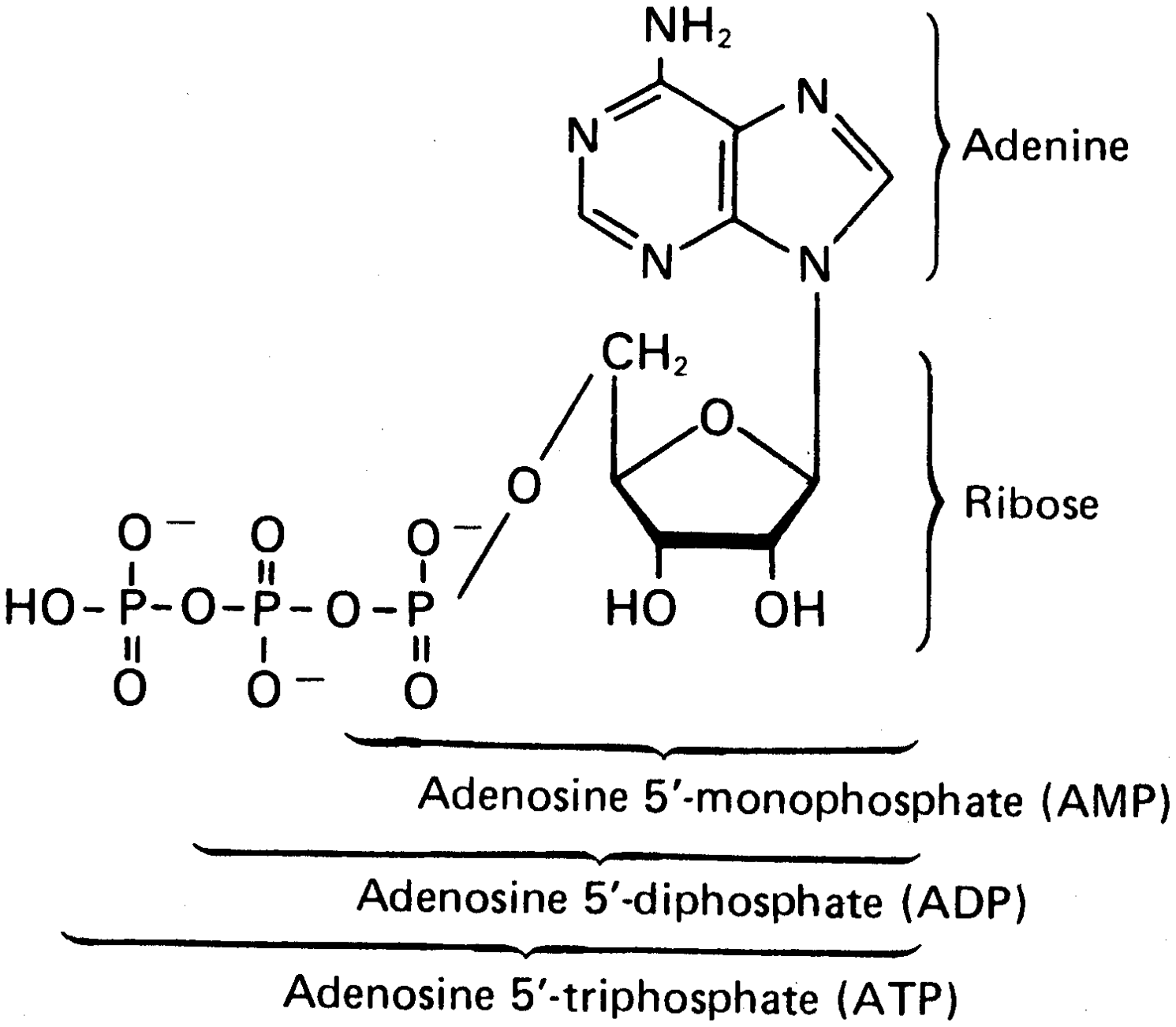
Active Transport

- Moves from low to high concentration
- requires NRG in the form of ATP
- highly selective
- exchange one ion for another
- primary active transport
  - Na+/K+ ATPase
- secondary active transport
  - Na+-dependent glucose transporter



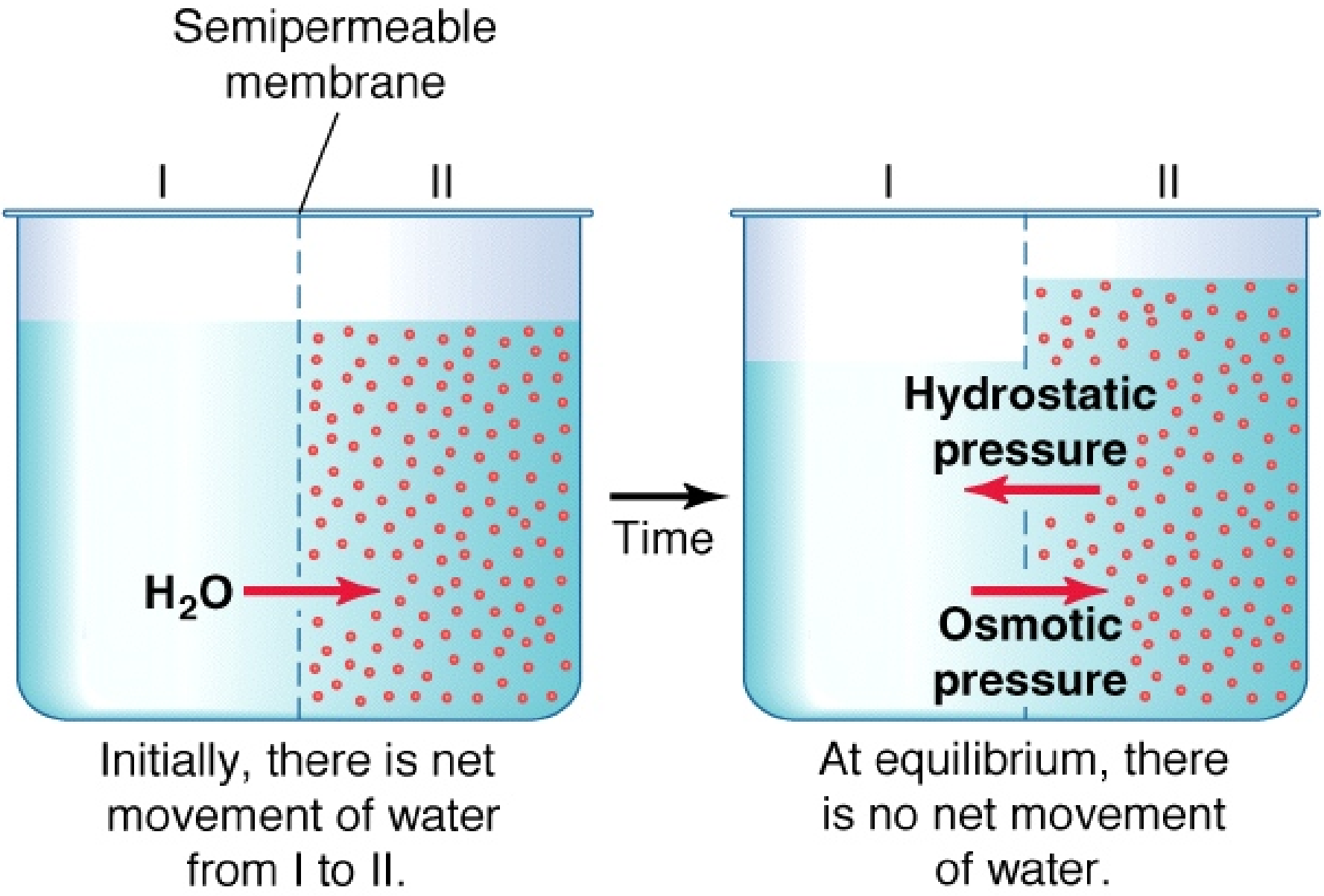



Extracellular fluid
Cytosol
Uniporter
Symporter
Antiporter


NH2
N
N
N
N
Adenine
CH2
O
O
HO
OH
Ribose
O−
O
O−
HO-P-O-P-O-P
O
O−
O
Adenosine 5′-monophosphate (AMP)
Adenosine 5′-diphosphate (ADP)
Adenosine 5′-triphosphate (ATP)

IV. Osmosis

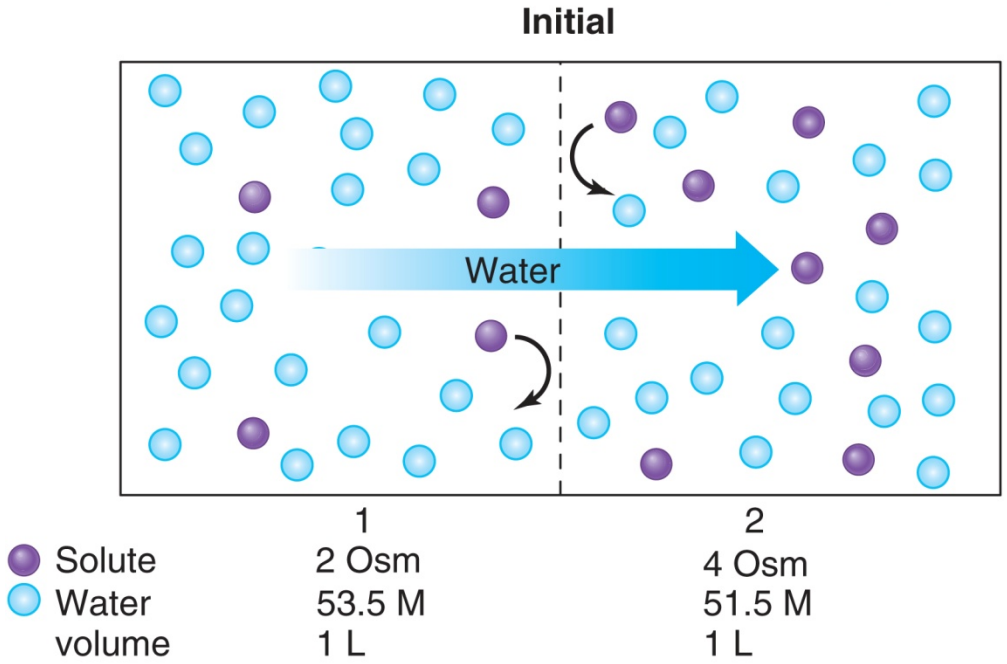
- Osmosis is the diffusion of water.
- Occurs thru transient pores between hydrocarbon tails.
- Small passive protein pores = aquaporins. Eg. Collecting duct of renal nephron.



Initially, there is net movement of water from I to II.

At equilibrium, there is no net movement of water.

4.18



Definitions

- Osmolarity- the total solute concentration.
- Osmoles of solutes per liter
- Ideal non-electrolyte 1 mM = 1 mOsM.
- osmole = one mole of osmotically active particle regardless of its chemical identity.
- Osmosis is a colligative property of solutions.

Definitions and terms

- Osmotic pressure is proportional to
- number of solute particles dissolved in solution
- temperature.

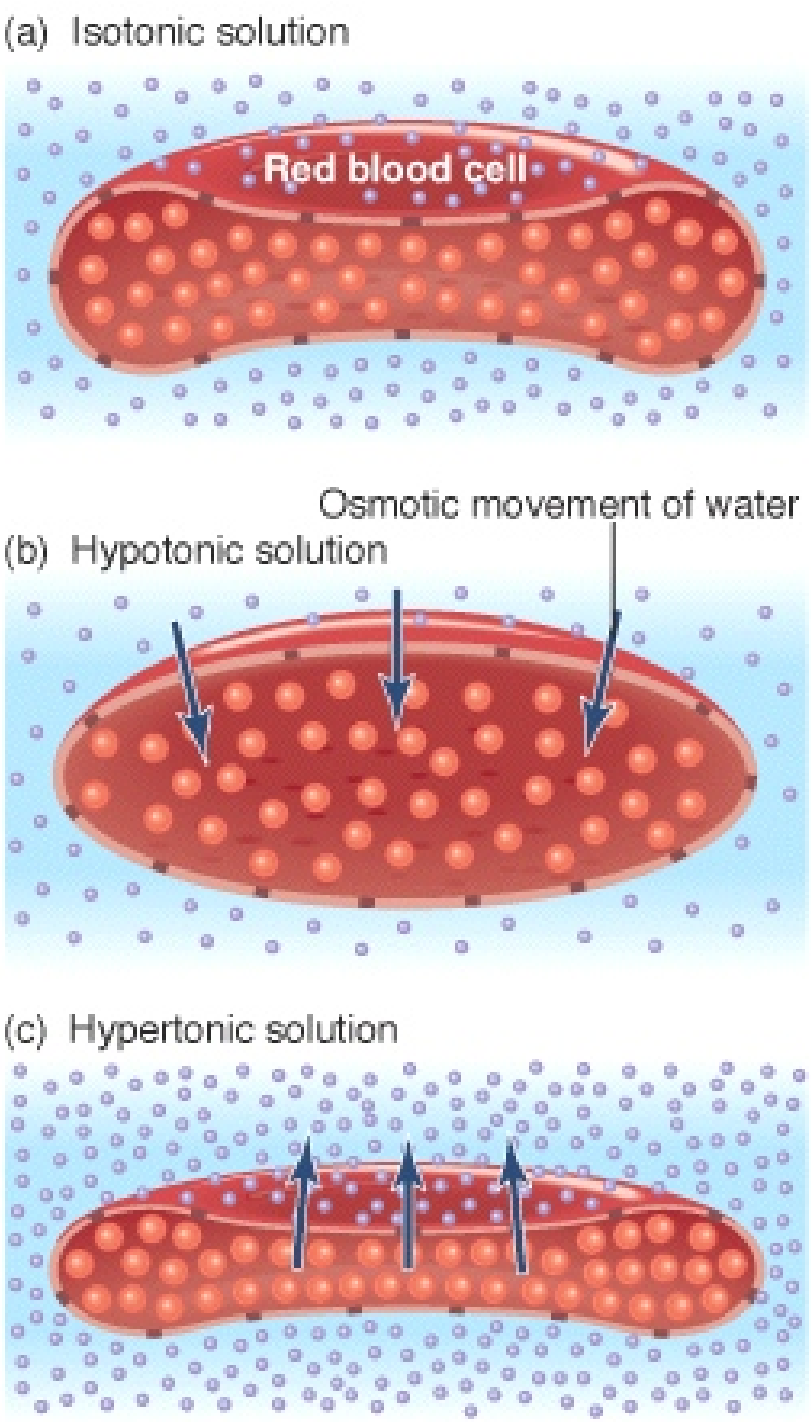
- The greater the osmolarity, the lower the water concentration and the greater the diffusion of water into that solution.

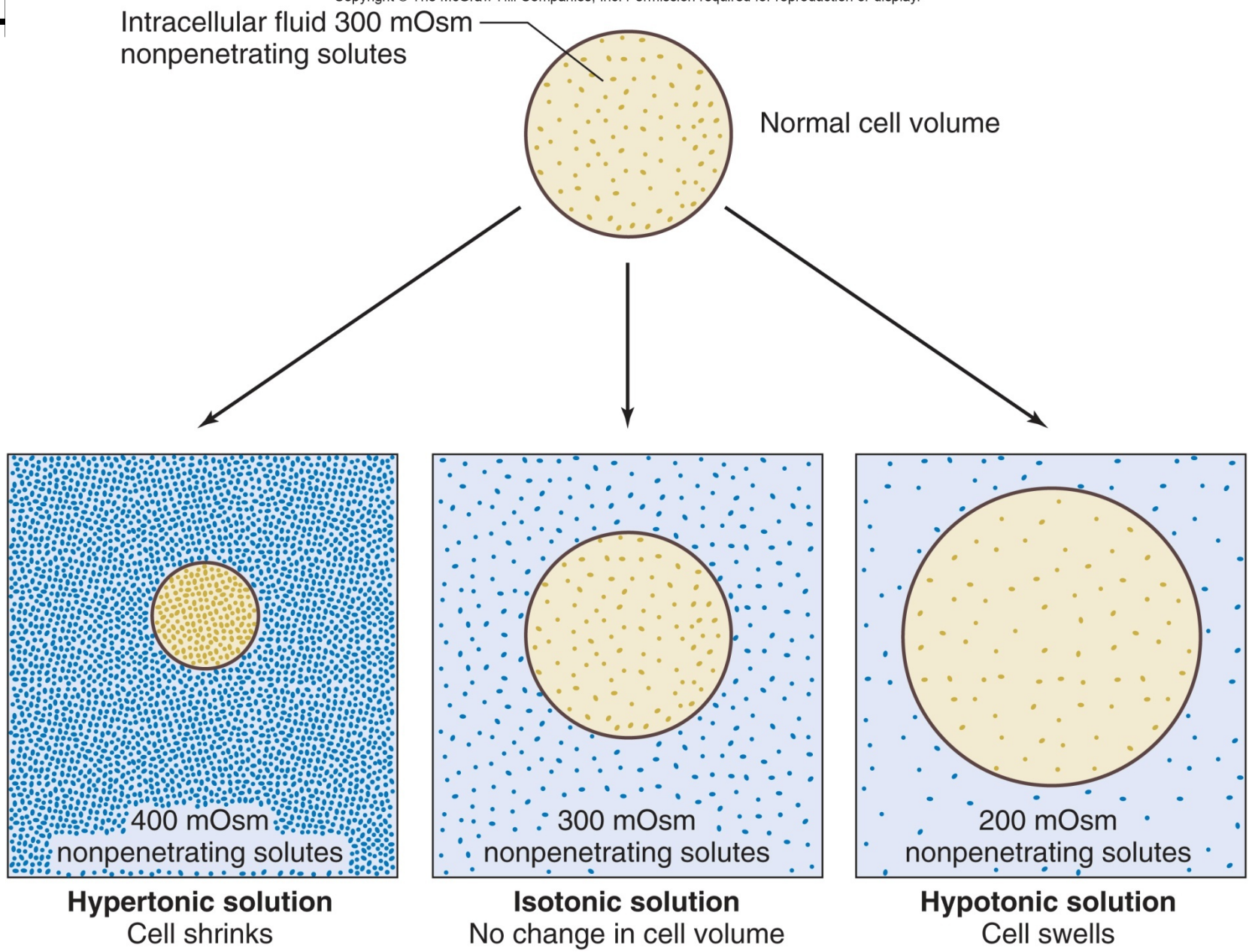
Definitions and terms

- Non-ideal electrolytes
  - 1 M NaCl = 2 OsM
  - 1 M CaCl2 = 3 OsM
- osmolarity of body fluids = 300 mOsM = blood = intracellular body fluids
- IN ORDER FOR CELL TO BALANCE WATER # OSMOTICALLY ACTIVE PARTICLES IN MUST EQUAL # OSMOTICALLY ACTIVE PARTICLES OUT!

TONICITY

- hypertonic = cell shrinks
- hypotonic = cell swells
- isotonic = no change in cell volume


(a) Isotonic solution
Red blood cell
Osmotic movement of water
(b) Hypotonic solution
(c) Hypertonic solution



OSMOLARITY

- hyperosmotic = more solute outside than inside cell
- hypoosmotic = less solute outside than inside cell
- isosmotic = same solute concentration inside and outside