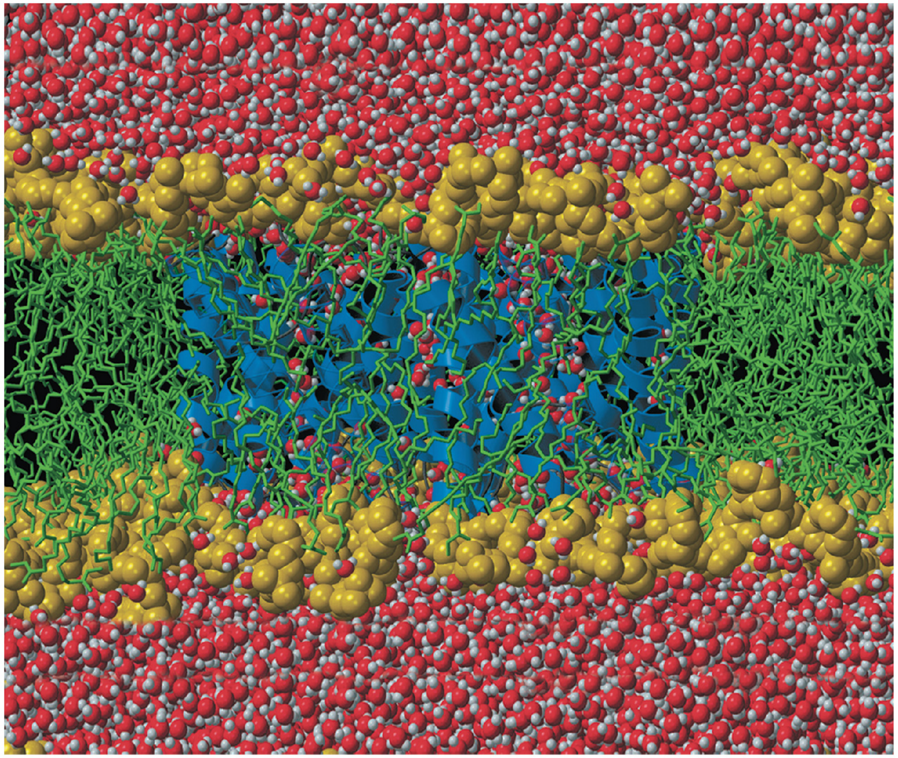
Chapter 5

Membrane Structure and Function



What You Must Know:

- Why membranes are selectively permeable.
- The role of phospholipids, proteins, and carbohydrates in membranes.
- How water will move if a cell is placed in an isotonic, hypertonic, or hypotonic solution and be able to predict the effect of different environments on the organism.
- How electrochemical gradients and proton gradients are formed and function in cells.

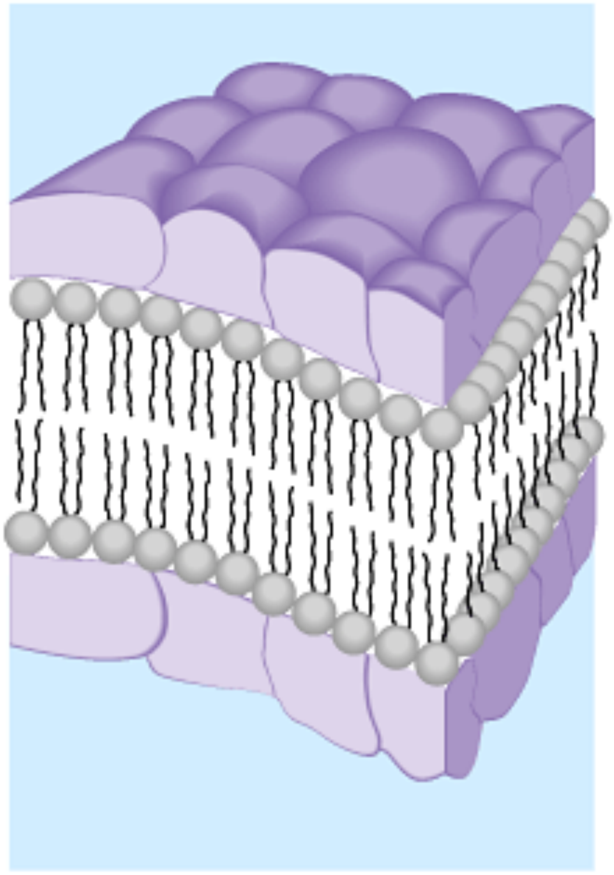
Cell Membrane

A. Plasma membrane is **selectively permeable**
   - Allows some substances to cross more easily than others

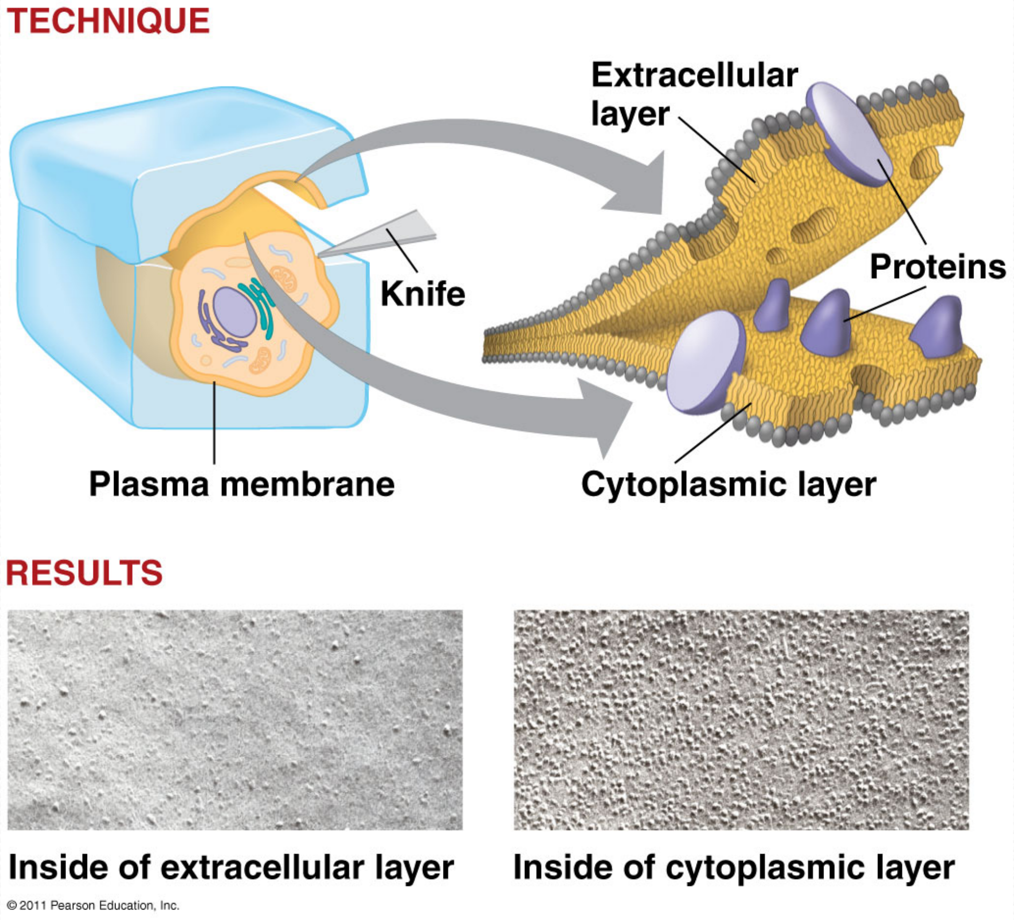
B. **Fluid Mosaic Model**
   - **Fluid**: membrane held together by weak interactions
   - **Mosaic**: phospholipids, proteins, carbs

Early membrane model

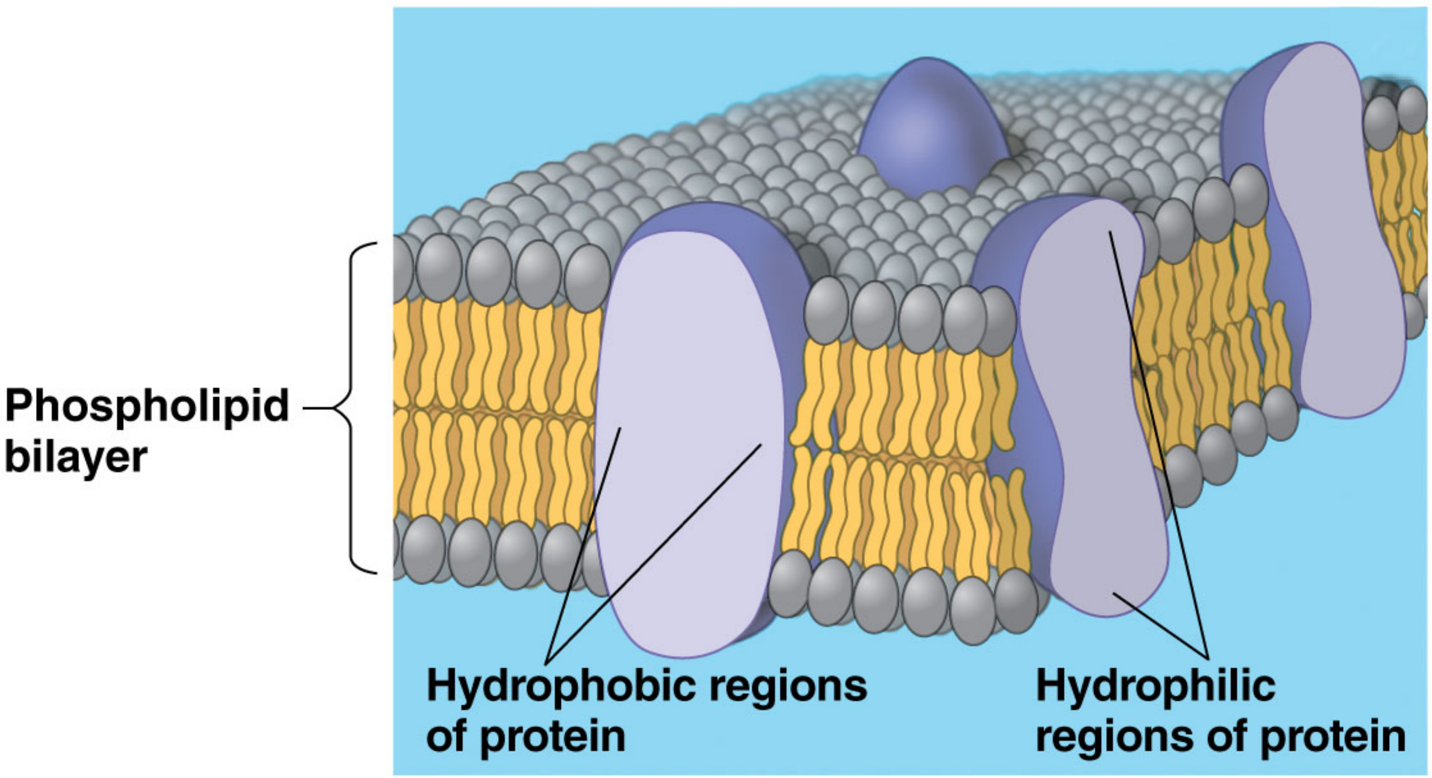
- (1935) Davson/Danielli – Sandwich model
- phospholipid bilayer between 2 protein layers
- Problems: varying chemical composition of membrane, hydrophobic protein parts

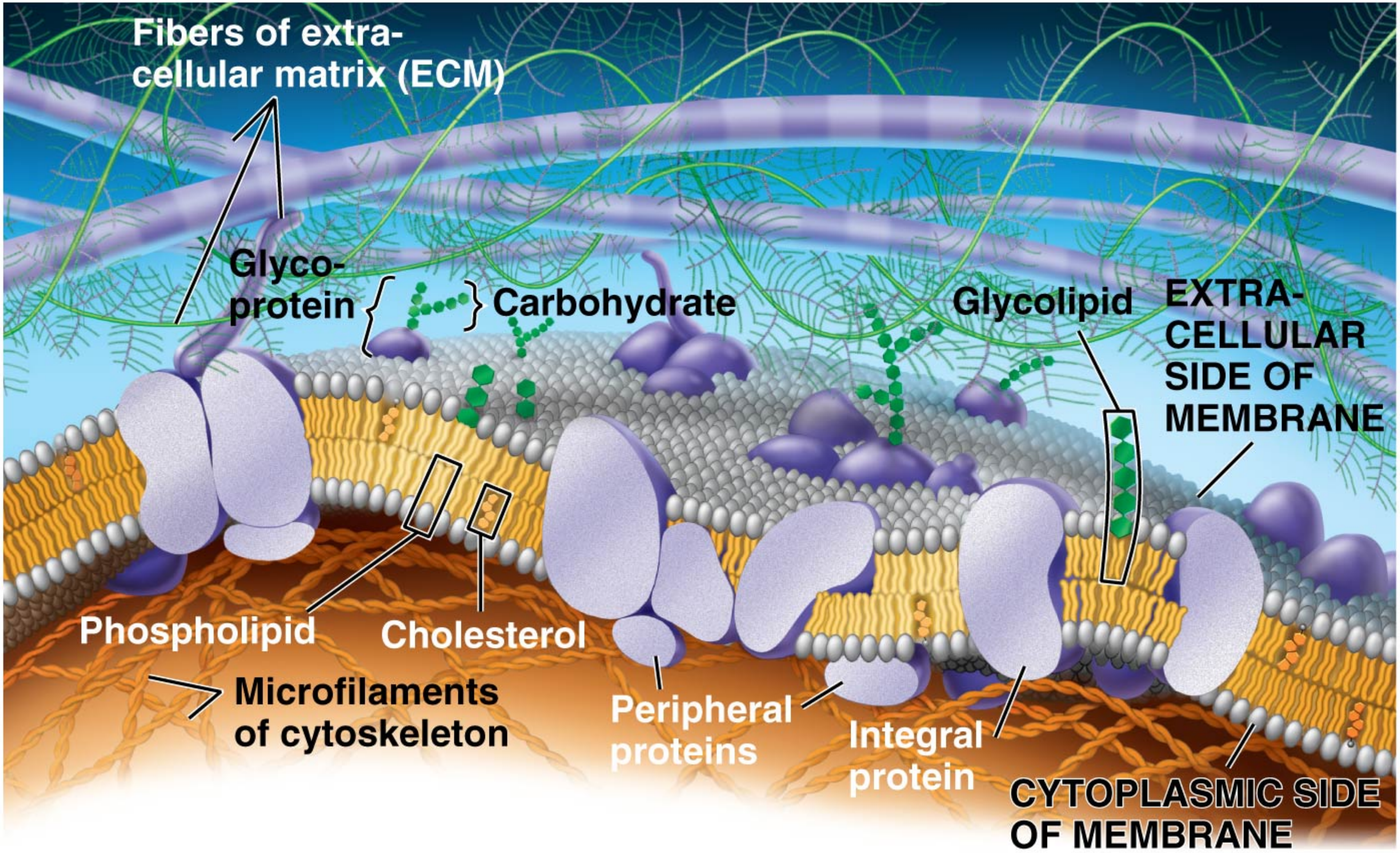


The freeze-fracture method: revealed the structure of membrane's interior



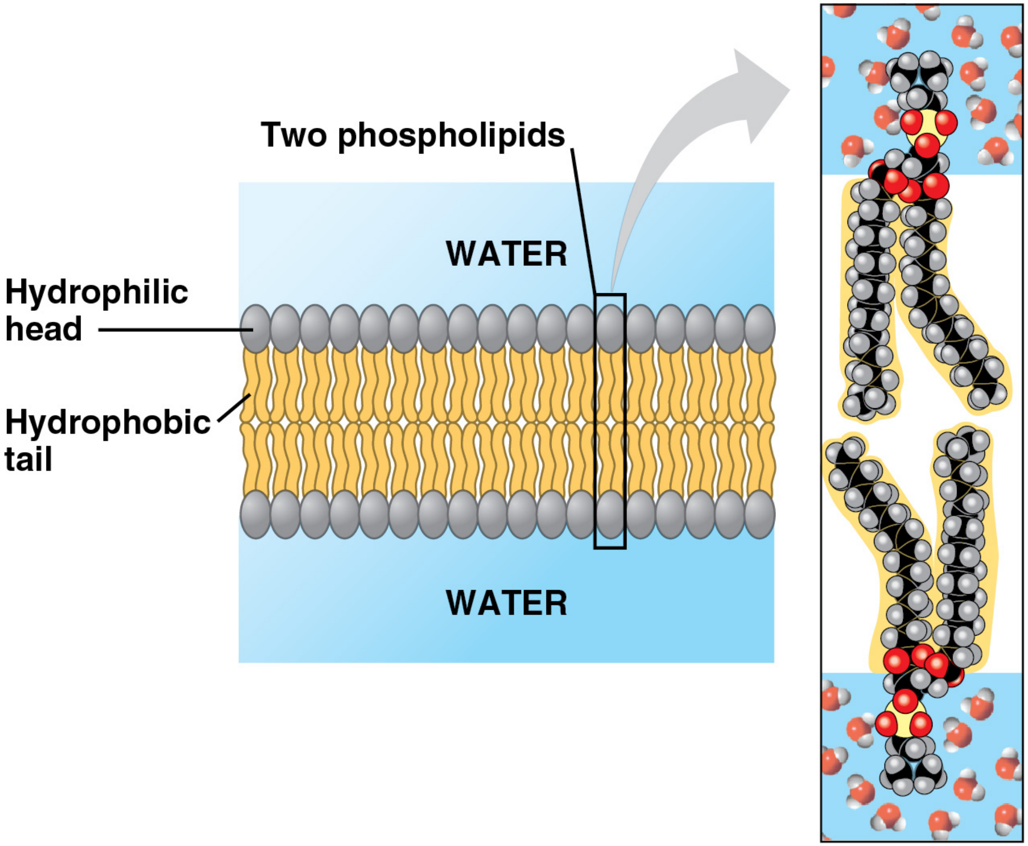
Fluid Mosaic Model




Fibers of extracellular matrix (ECM)
Glycoprotein
Carbohydrate
Glycolipid
EXTRACELLULAR SIDE OF MEMBRANE
Phospholipid
Cholesterol
Microfilaments of cytoskeleton
Peripheral proteins
Integral protein
CYTOPLASMIC SIDE OF MEMBRANE

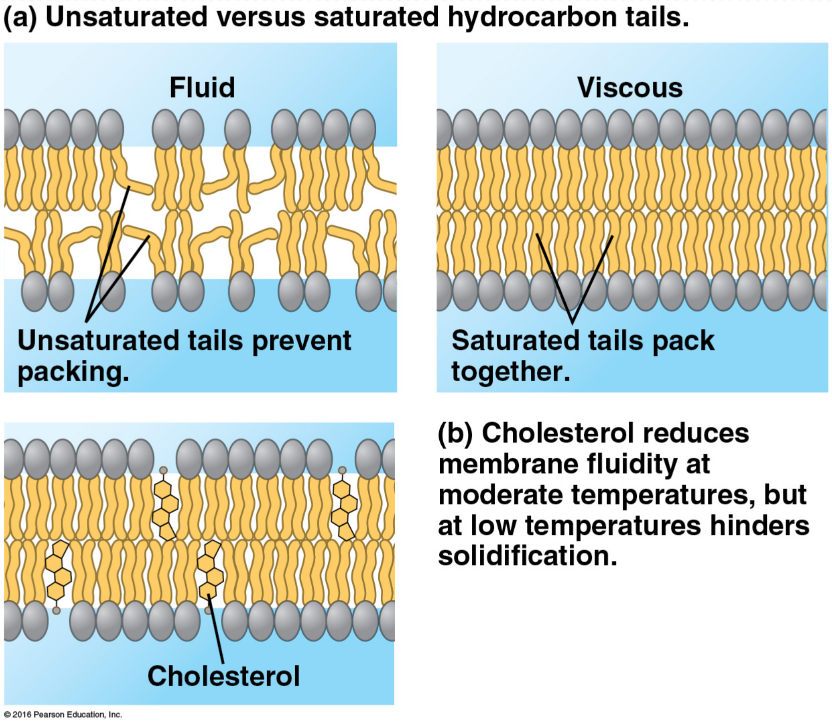
Phospholipids

- Bilayer
- **Amphipathic** = hydrophilic head, hydrophobic tail
- Hydrophobic barrier: keeps hydrophilic molecules out



Membrane fluidity

- **Low temps**: phospholipids w/ unsaturated tails (kinks prevent close packing)
- **Cholesterol** resists changes by:
  - limit fluidity at high temps
  - hinder close packing at low temps



(a) Unsaturated versus saturated hydrocarbon tails.

(b) Cholesterol reduces membrane fluidity at moderate temperatures, but at low temperatures hinders solidification.

- Adaptations: bacteria in hot springs (unusual lipids); winter wheat (↑ unsaturated phospholipids)

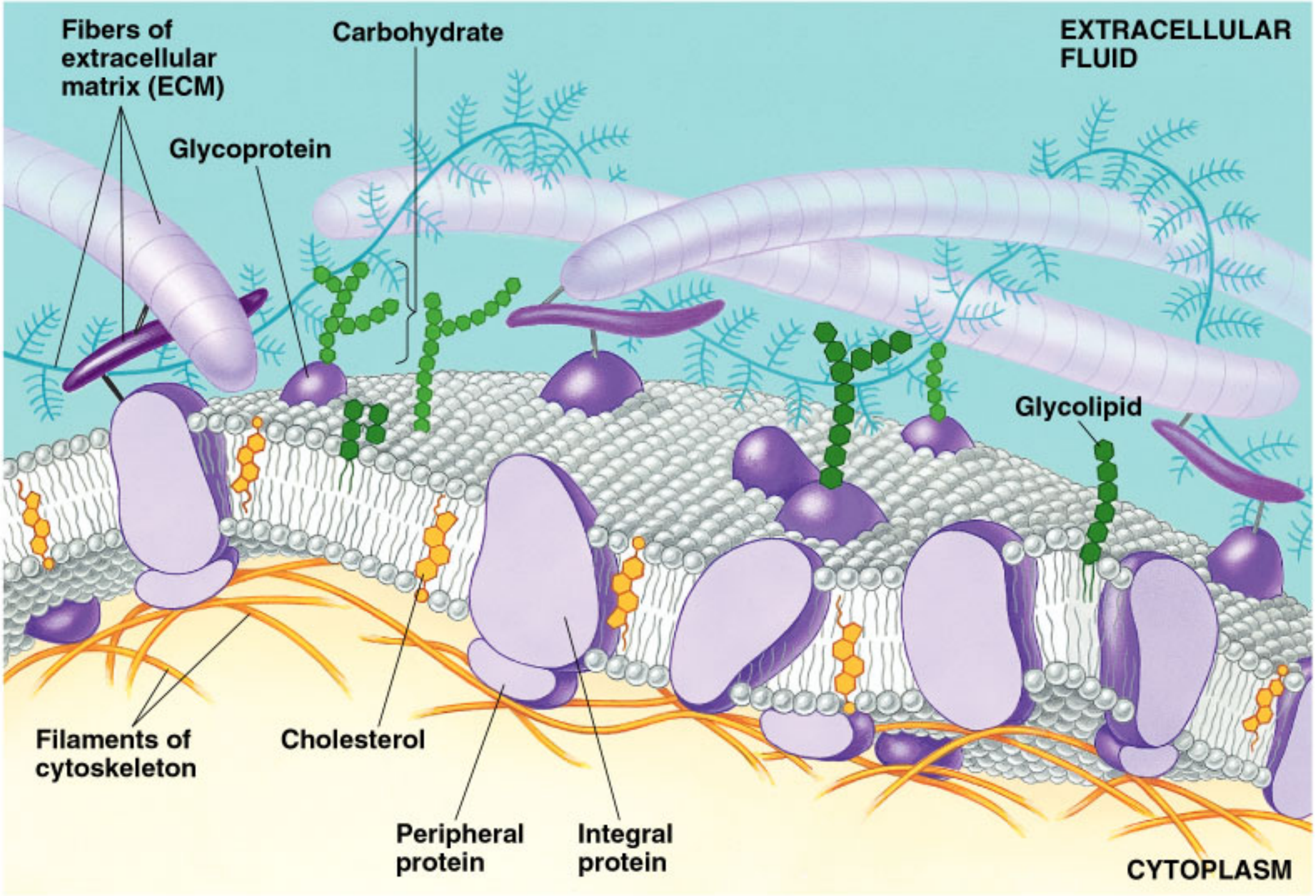
Membrane Proteins

Integral Proteins

- Embedded in membrane
- Determined by freeze fracture
- Transmembrane with hydrophilic heads/tails and hydrophobic middles

Peripheral Proteins

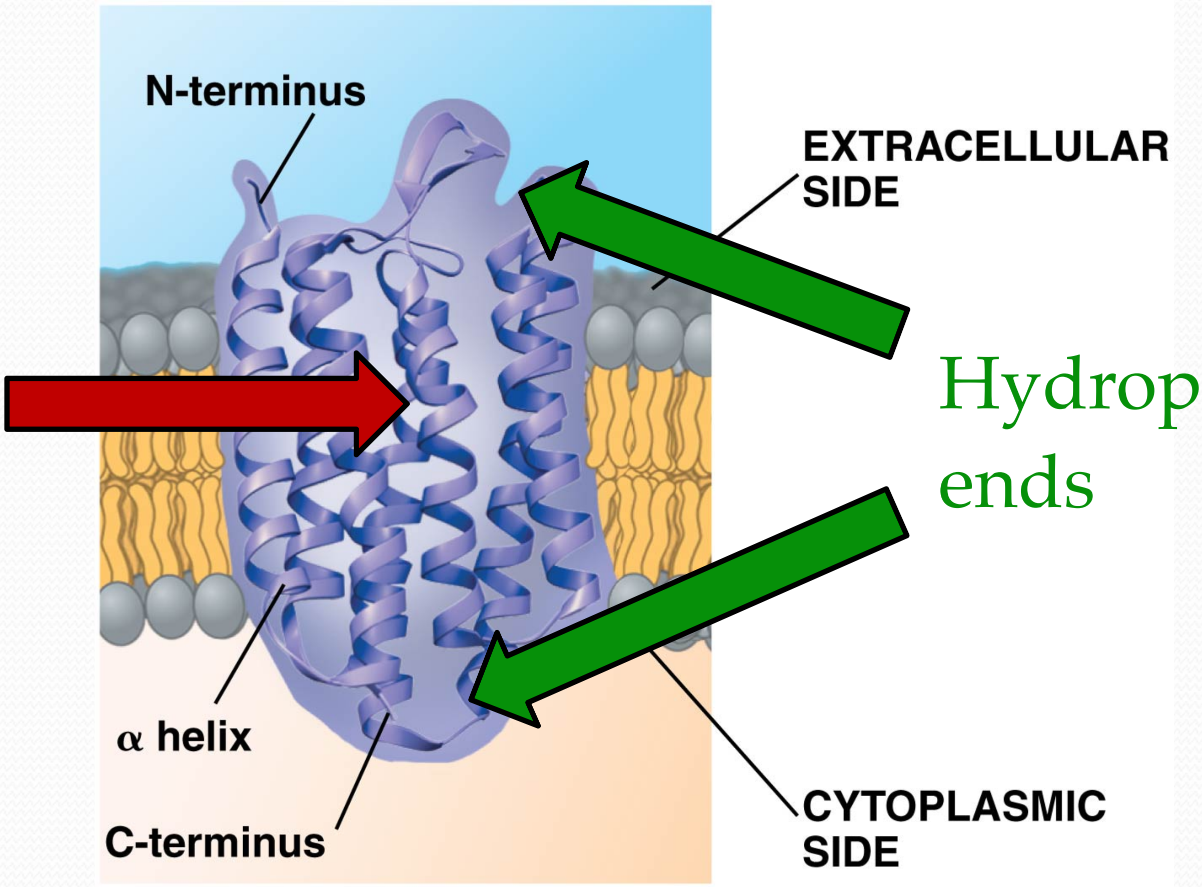
- Extracellular or cytoplasmic sides of membrane
- NOT embedded
- Held in place by the cytoskeleton or ECM
- Provides stronger framework



Integral & Peripheral proteins

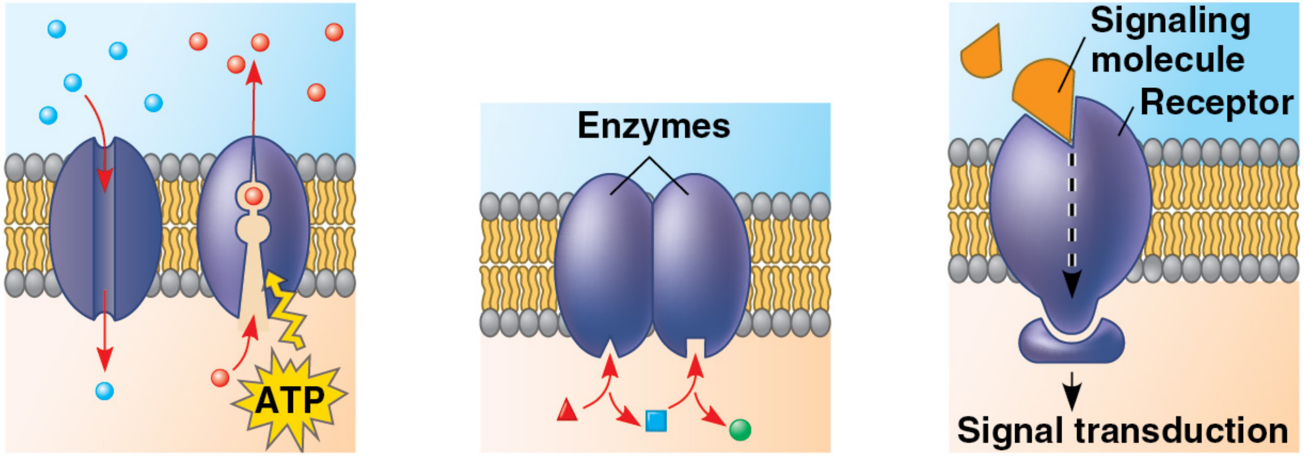
Transmembrane protein structure

Hydrophobic interior

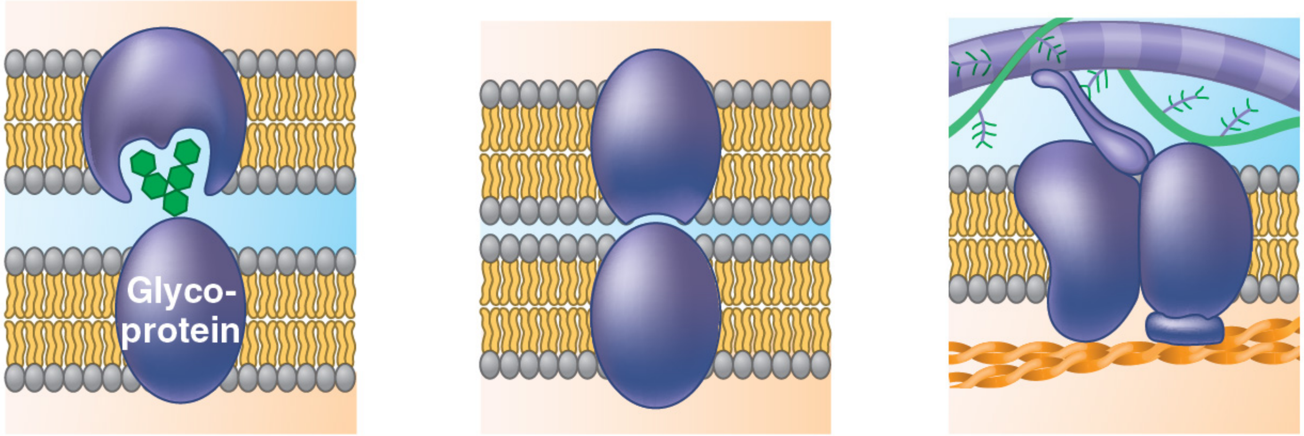


Hydrophilic ends

Some functions of membrane proteins



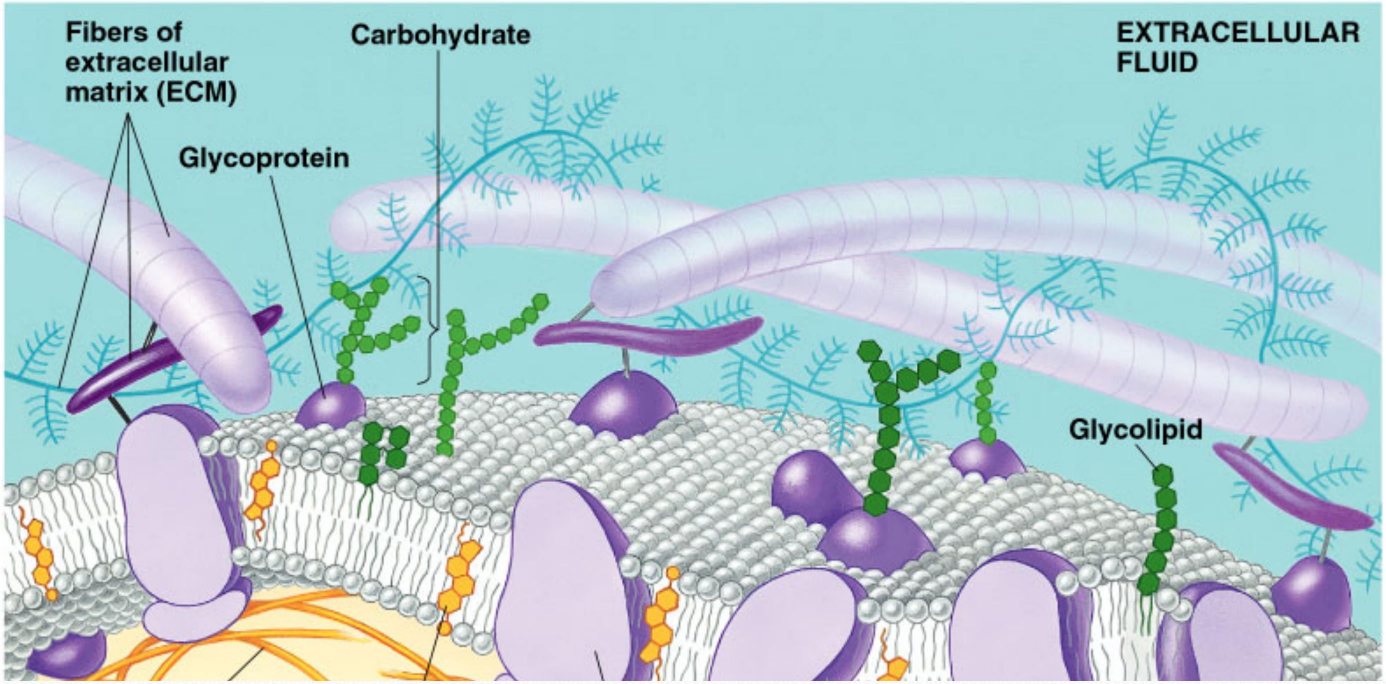
(a) Transport (b) Enzymatic activity (c) Signal transduction



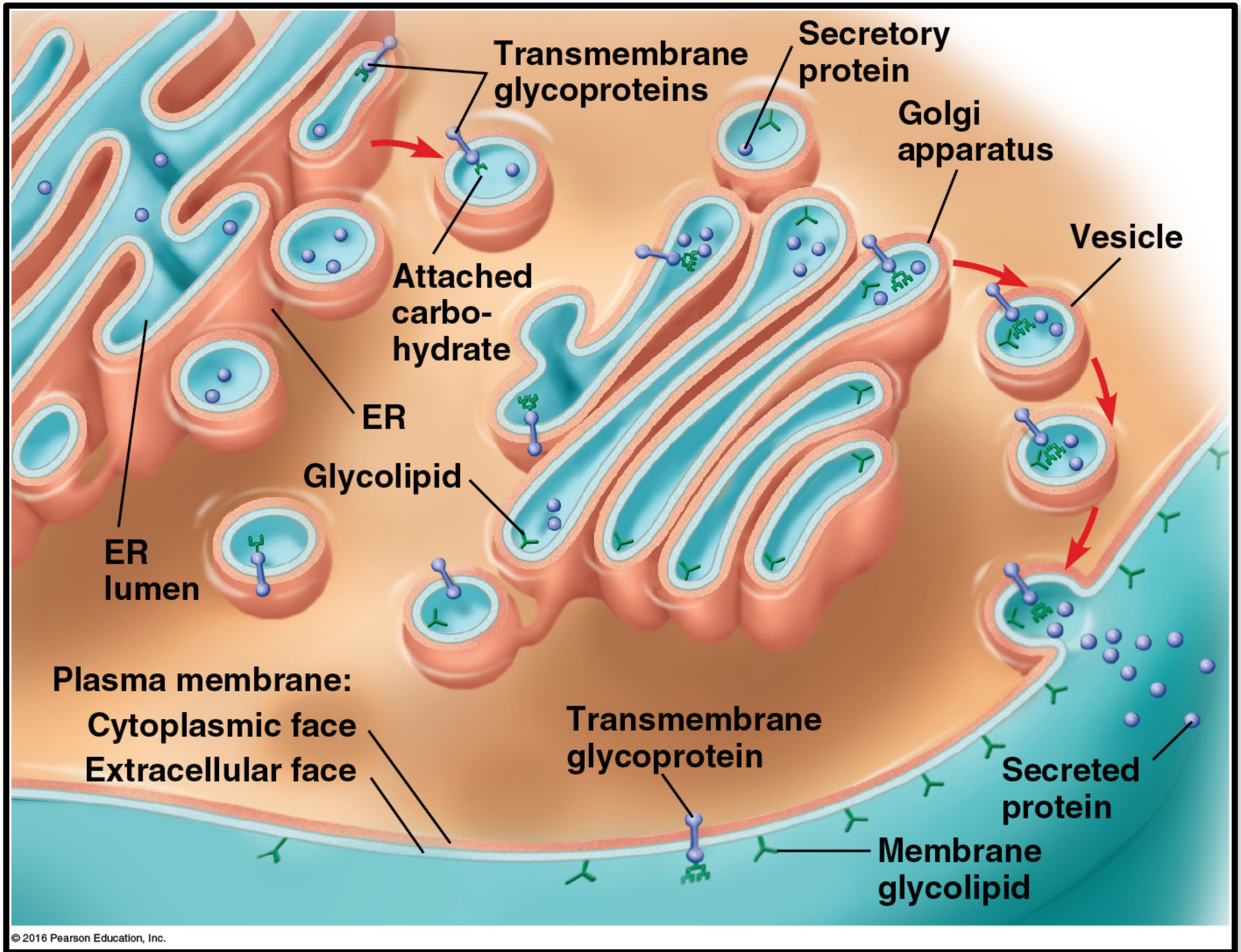
(d) Cell-cell recognition (e) Intercellular joining (f) Attachment to the cytoskeleton and extracellular matrix (ECM)

Carbohydrates

- **Function**: cell-cell recognition; developing organisms
- Glycolipids, glycoproteins
- Eg. blood transfusions are type-specific



Synthesis and sidedness of membranes

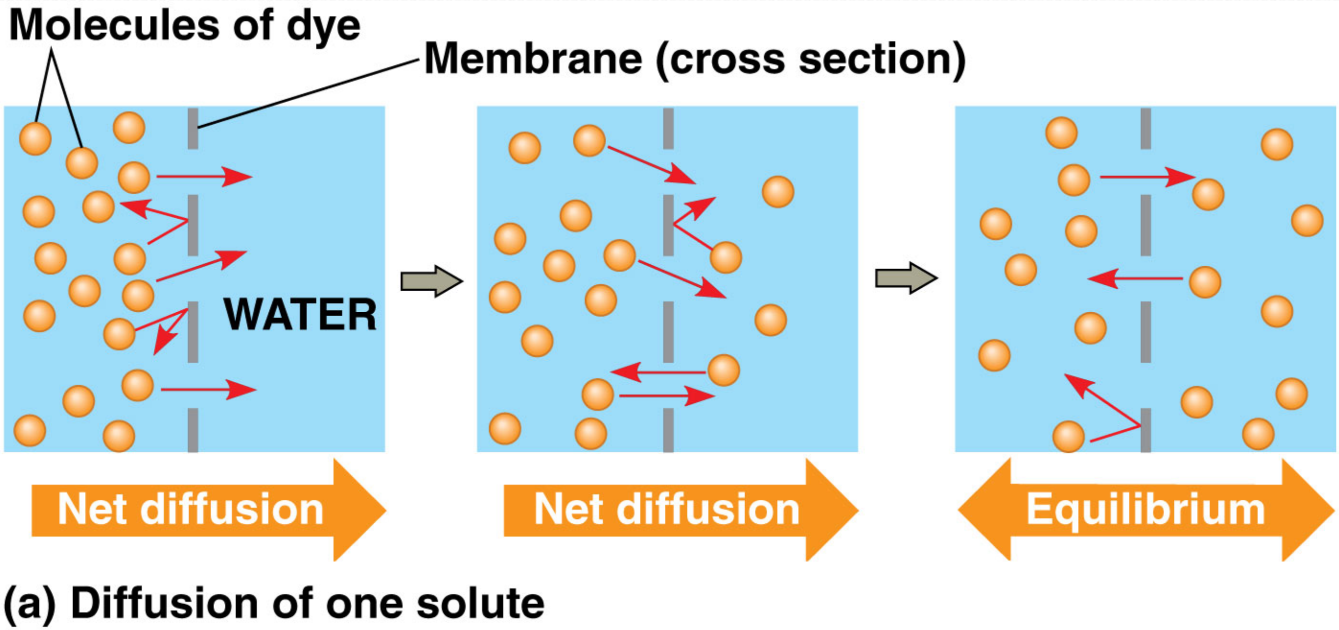


Selective Permeability

- **Small nonpolar molecules** cross easily: hydrocarbons, hydrophobic molecules, CO_2, O_2, N_2
- **Polar uncharged molecules**, including H2O – pass in small amounts
- Hydrophobic core ***prevents*** passage of **ions, large polar molecules – movement through embedded channel and transport proteins**

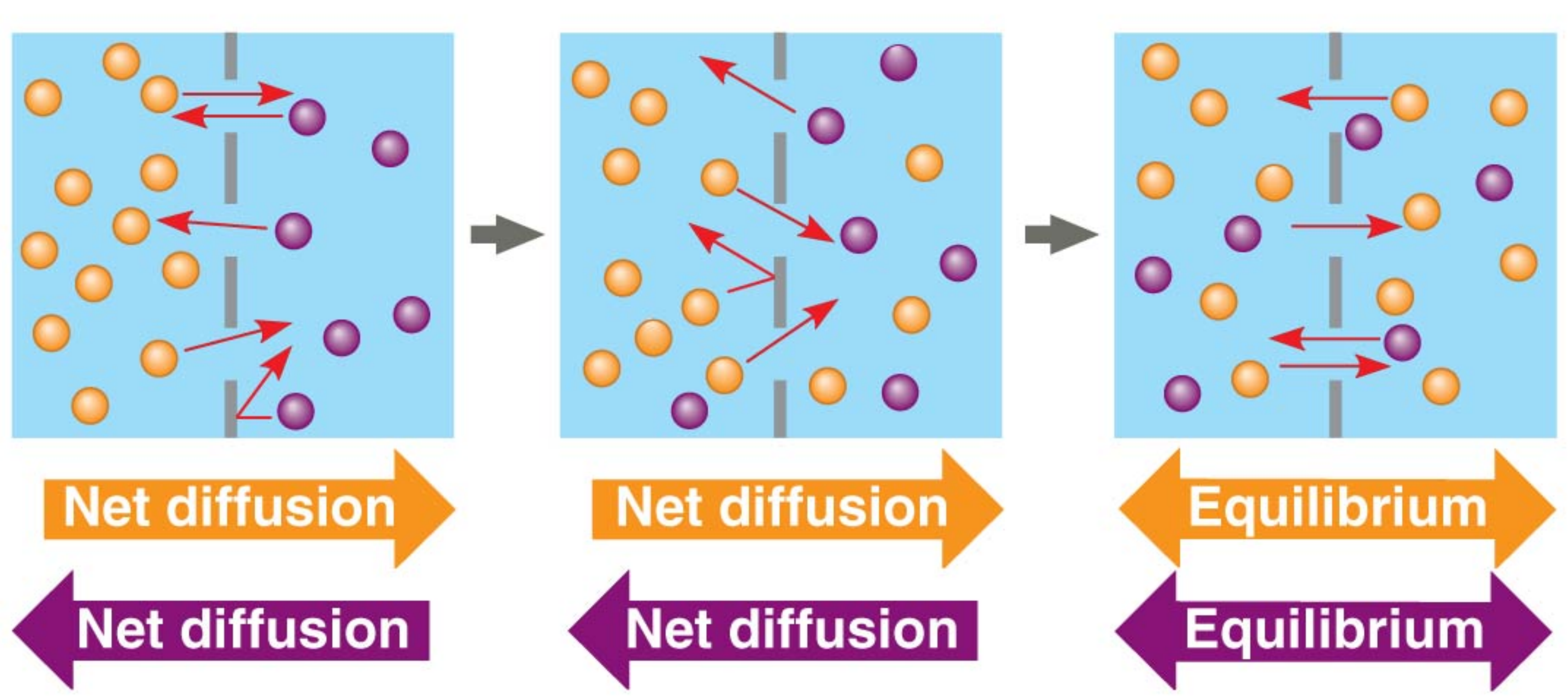
Passive Transport

- NO ENERGY (ATP) needed!
- **Diffusion** *down* concentration gradient (high → low concentration)
- Eg. hydrocarbons, CO_2, O_2, H_2O



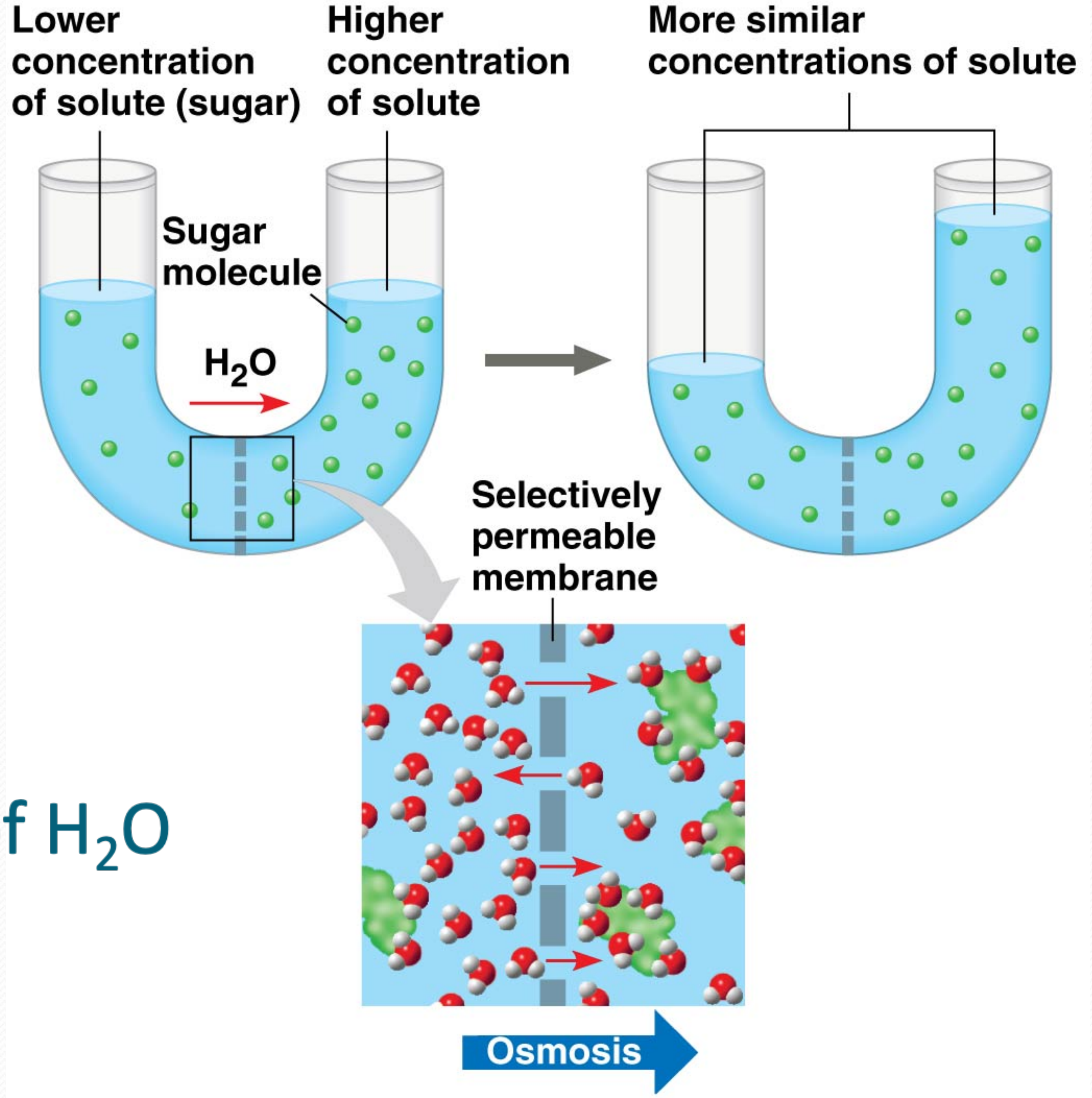
(a) Diffusion of one solute

Diffusion

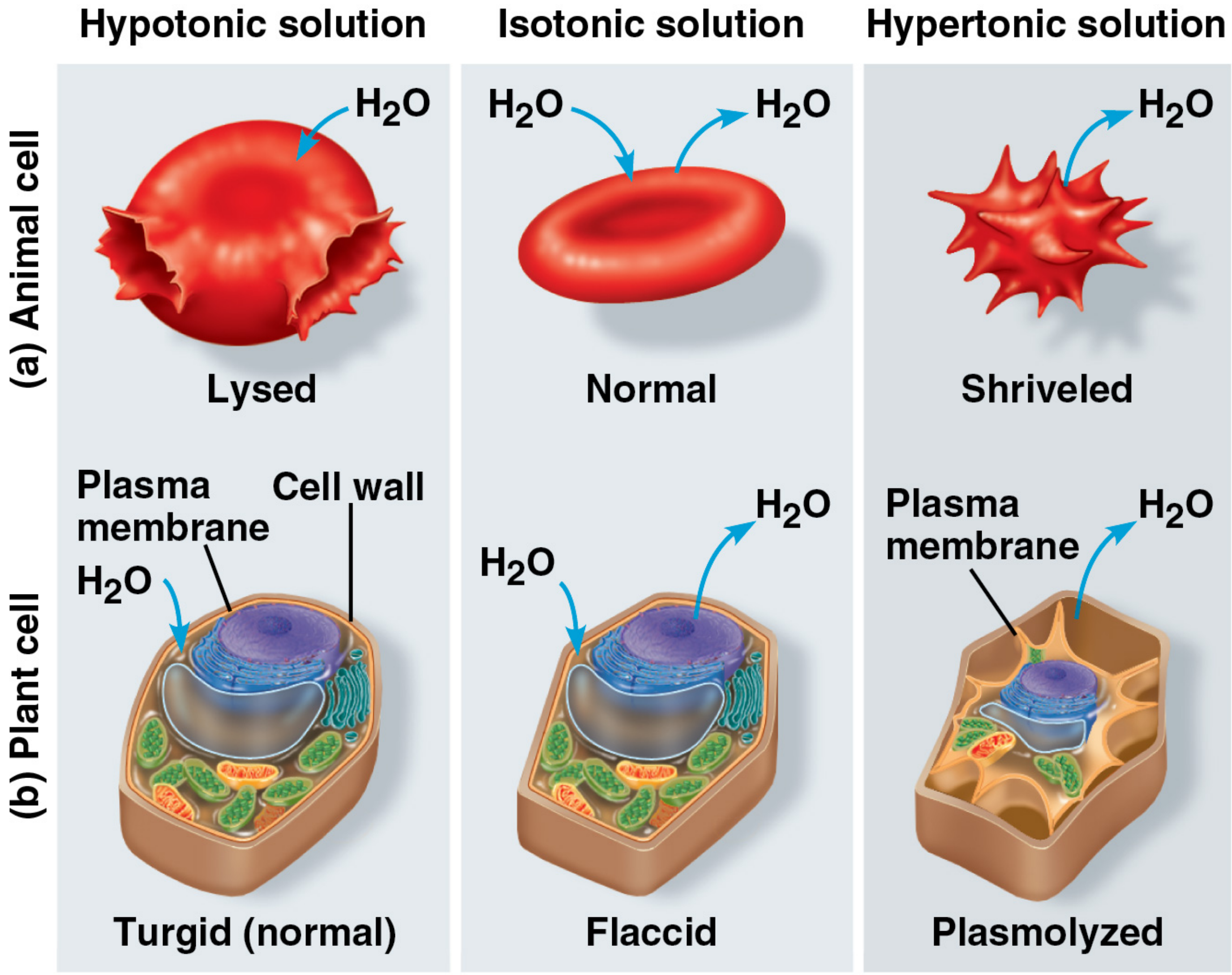


(b) Diffusion of two solutes

Osmosis: diffusion of H_2O



External environments can be hypotonic, isotonic or hypertonic to internal environments of cell



Understanding Water Potential

Water Potential

Water potential (ψ): H_2O moves from high ψ → low ψ potential

Water potential equation:

$$\psi = \psi_S + \psi_P$$

- Water potential (ψ) = free energy of water
- Solute potential (ψ_S) = solute concentration (osmotic potential)
- Pressure potential (ψ_P) = physical pressure on solution; ***turgor pressure (plants)***
  - Pure water: $\psi_P = 0$ MPa
  - Plant cells: $\psi_P = 1$ MPa

Calculating Solute Potential (ψ_S)

$$\psi_S = -iCRT$$

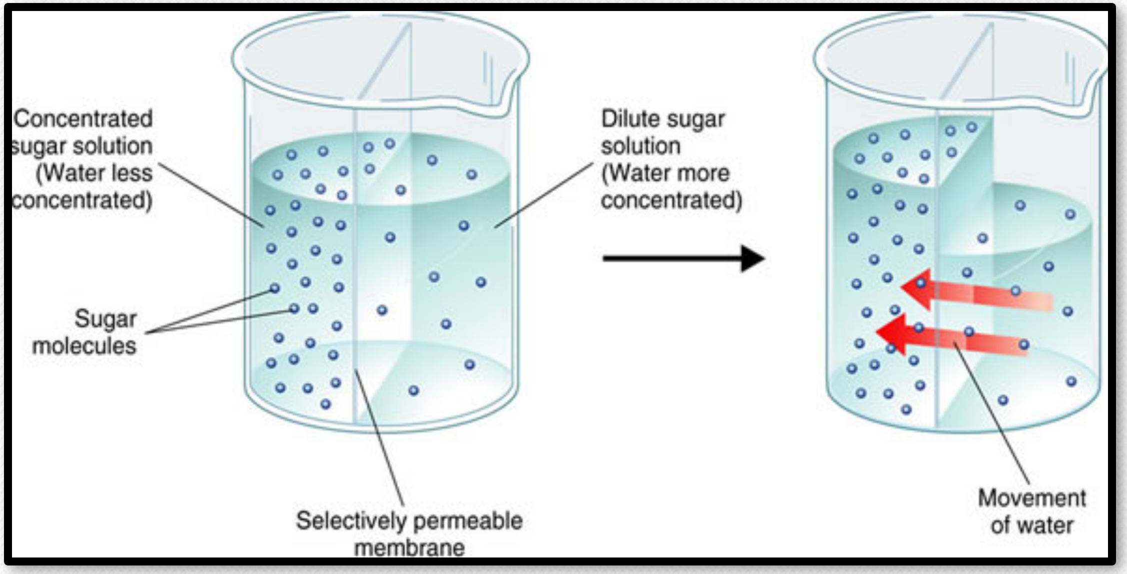
- i = ionization constant (# particles made in water)
- C = molar concentration
- R = pressure constant (0.0831 liter bars/mole-K)
- T = temperature in K ($273 + {}^{0}C$)

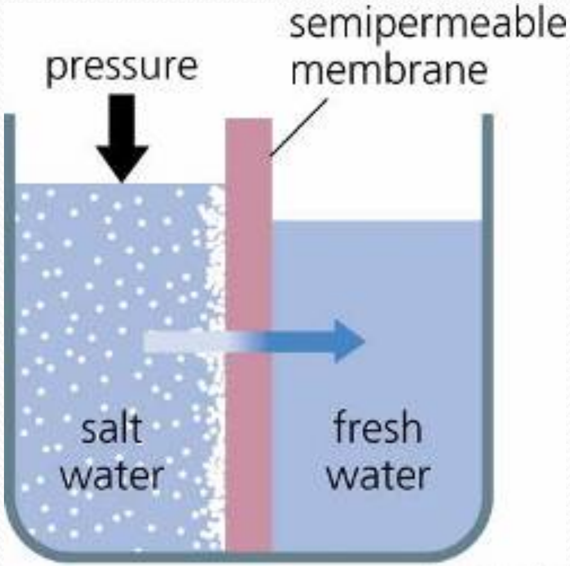
- The **addition of solute** to water ***lowers*** the solute potential (more **negative**) and therefore ***decreases*** the water potential.

Where will WATER move?

From an area of:

- higher ψ → lower ψ (more negative ψ)
- low solute concentration → high solute concentration
- high pressure → low pressure





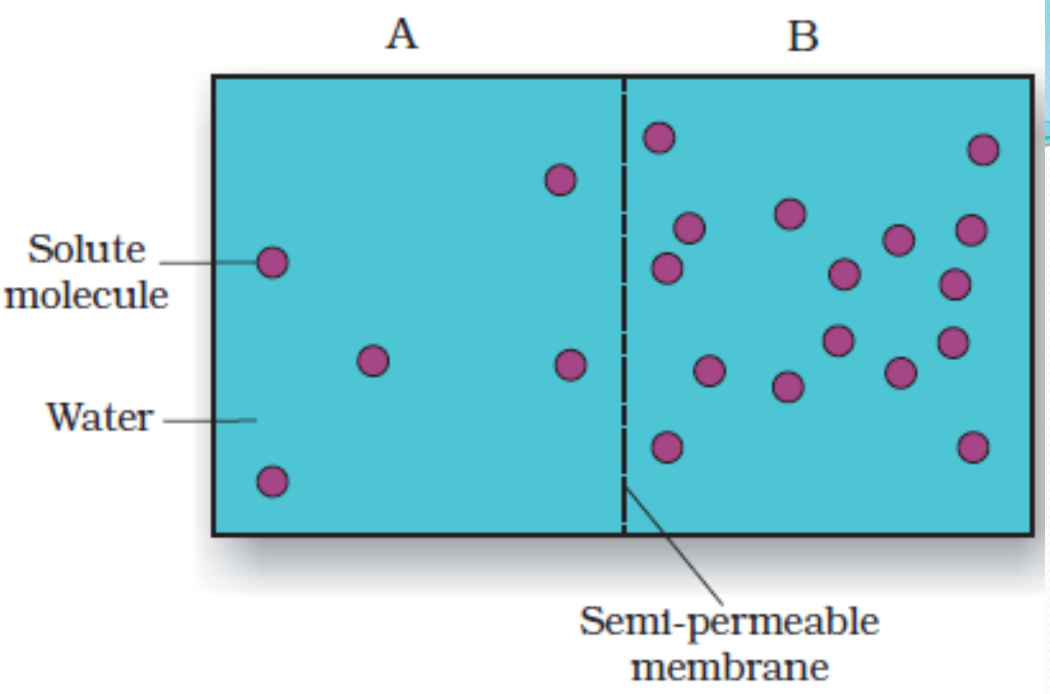


Figure 11.3

1. Which chamber has a lower water potential?
2. Which chamber has a lower solute potential?
3. In which direction will osmosis occur?
4. If one chamber has a Ψ of -2000 kPa, and the other -1000 kPa, which is the chamber that has the higher Ψ?

Low water potential

Atmosphere ψ: –95.2 MPa
(Changes with humidity;
usually very low)

Leaf ψ: –0.8 MPa
(Depends on transpiration rate;
low when stomata are open)

Root ψ: –0.6 MPa
(Medium–high)

Soil ψ: –0.3 MPa
(High if moist;
low if extremely dry)

High water potential

Figure 36-3 Biological Science, 2/e

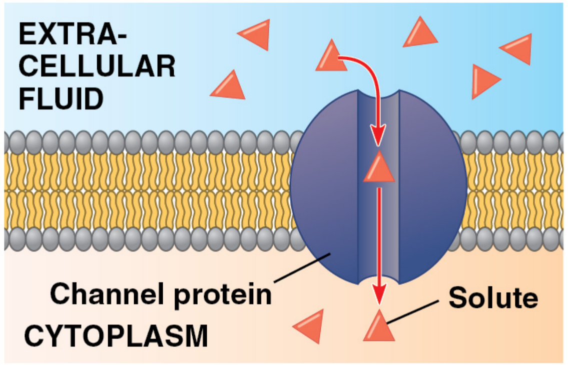
Sample Problem

1. Calculate the solute potential of a 0.1M NaCl solution at 25°C.
2. If the concentration of NaCl inside the plant cell is 0.15M, which way will the water diffuse if the cell is placed in the 0.1M NaCl solution?

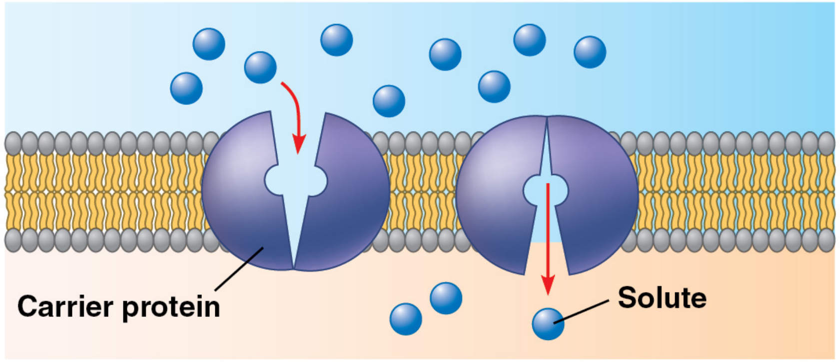
Facilitated Diffusion

Transport proteins (channel or carrier proteins) help hydrophilic substances cross

- Two ways:
  - Provide hydrophilic channel
  - Loosely bind / carry molecule across
- Eg. ions, polar molecules (H_2O, glucose)

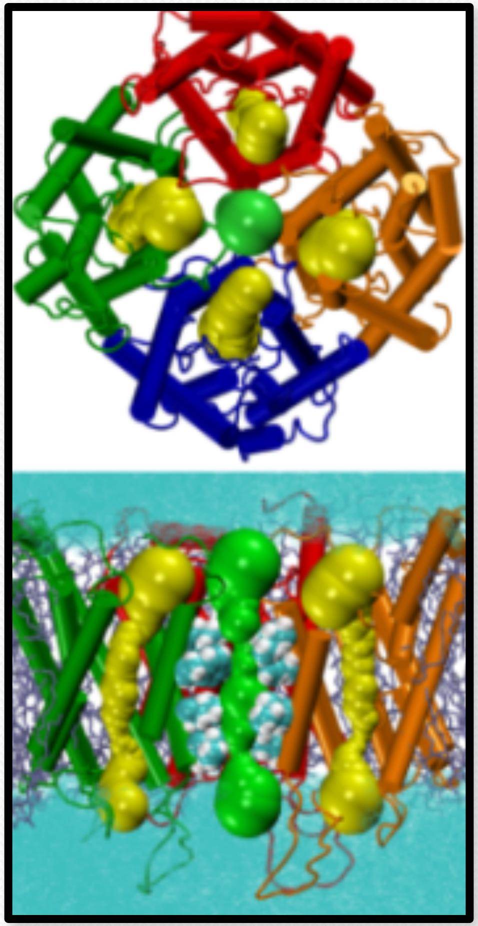


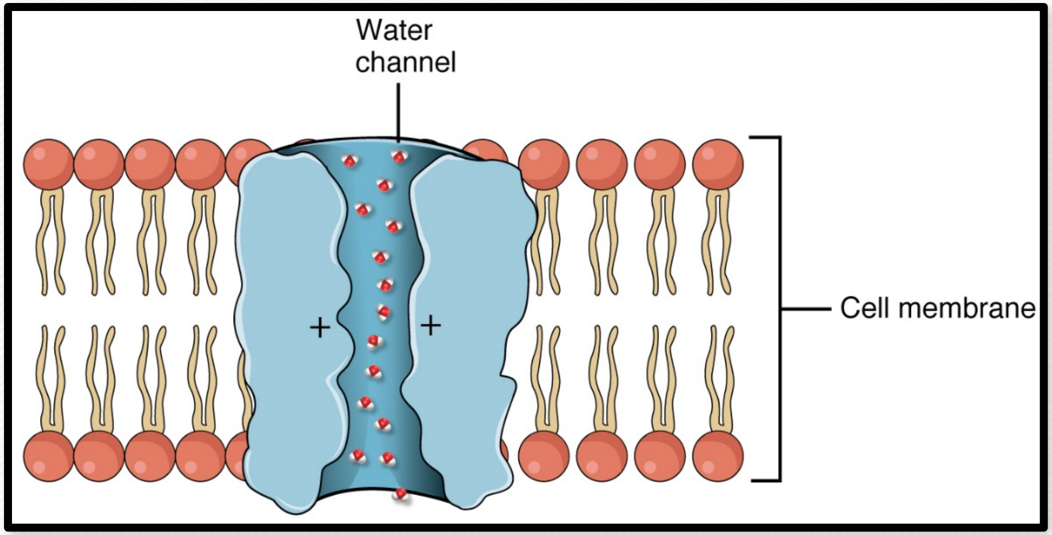
(a) A channel protein

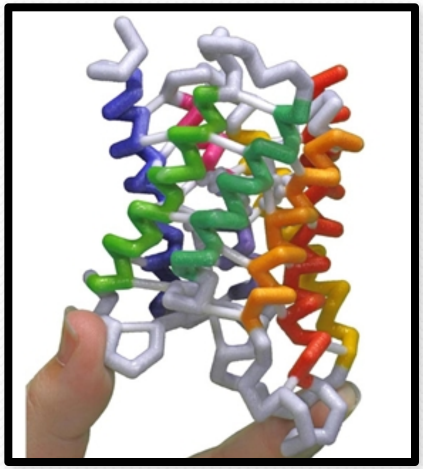


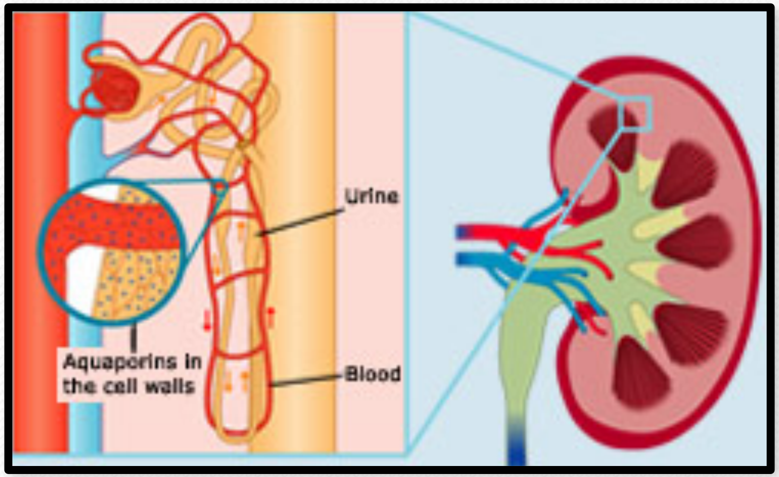
(b) A carrier protein

Aquaporin: channel protein that allows passage of H_2O

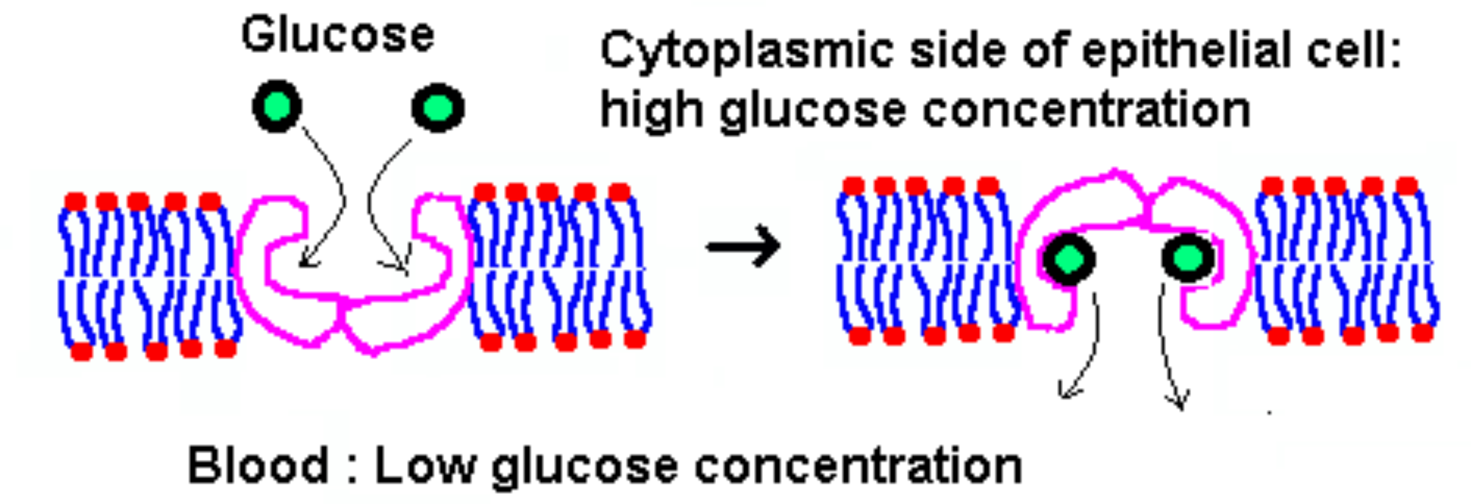


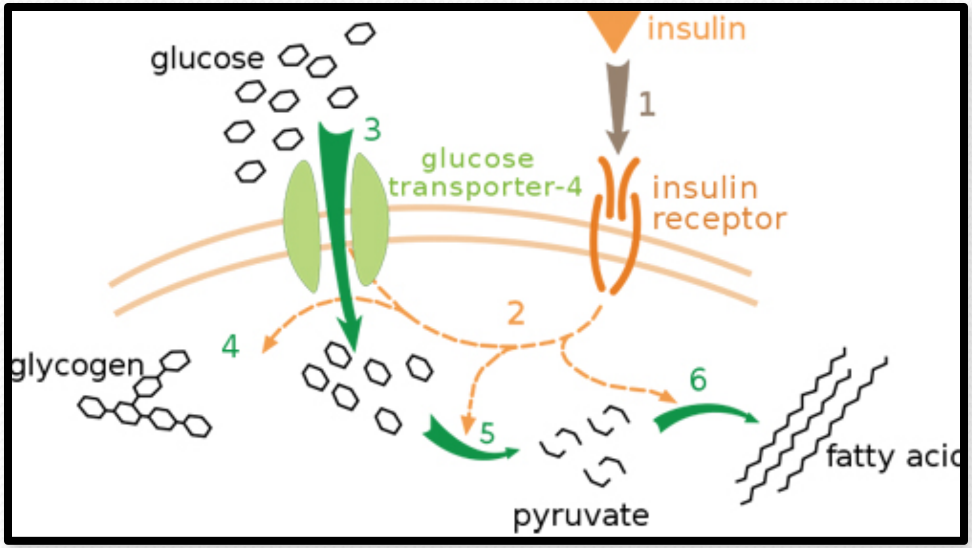






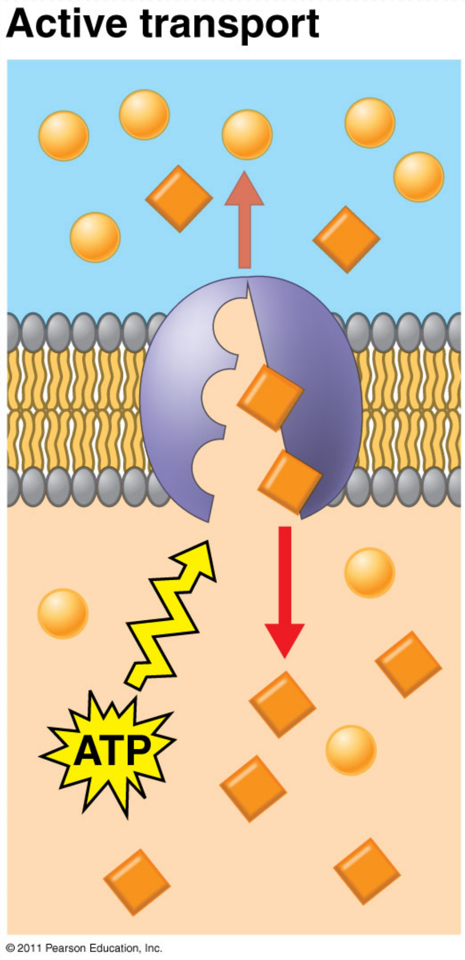
Glucose Transport Protein (carrier protein)





Active Transport

- Requires **ENERGY** (ATP)
- Proteins transport substances ***against*** **concentration gradient** (low → high conc.)
- Eg. Na^+/K^+ pump, proton pump



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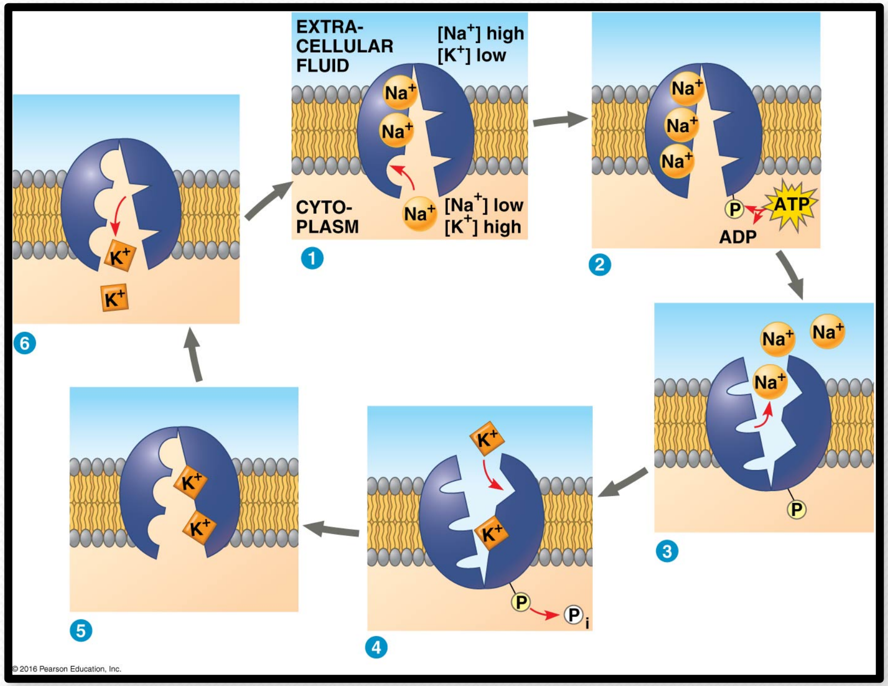
Electrogenic Pumps: generate voltage across membrane

Na+/K+ Pump



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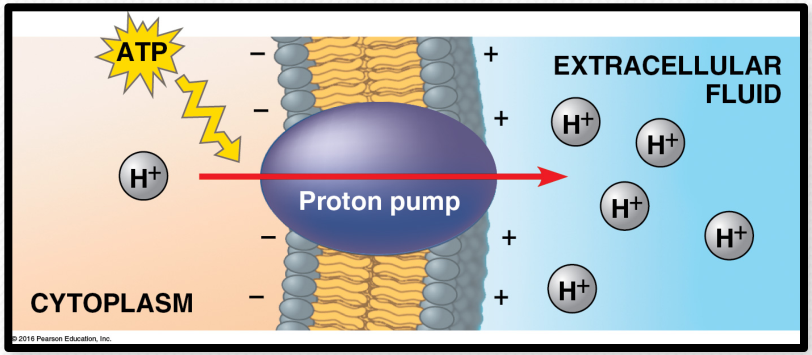
- Pump Na+ out, K+ into cell
- Nerve transmission

Proton Pump



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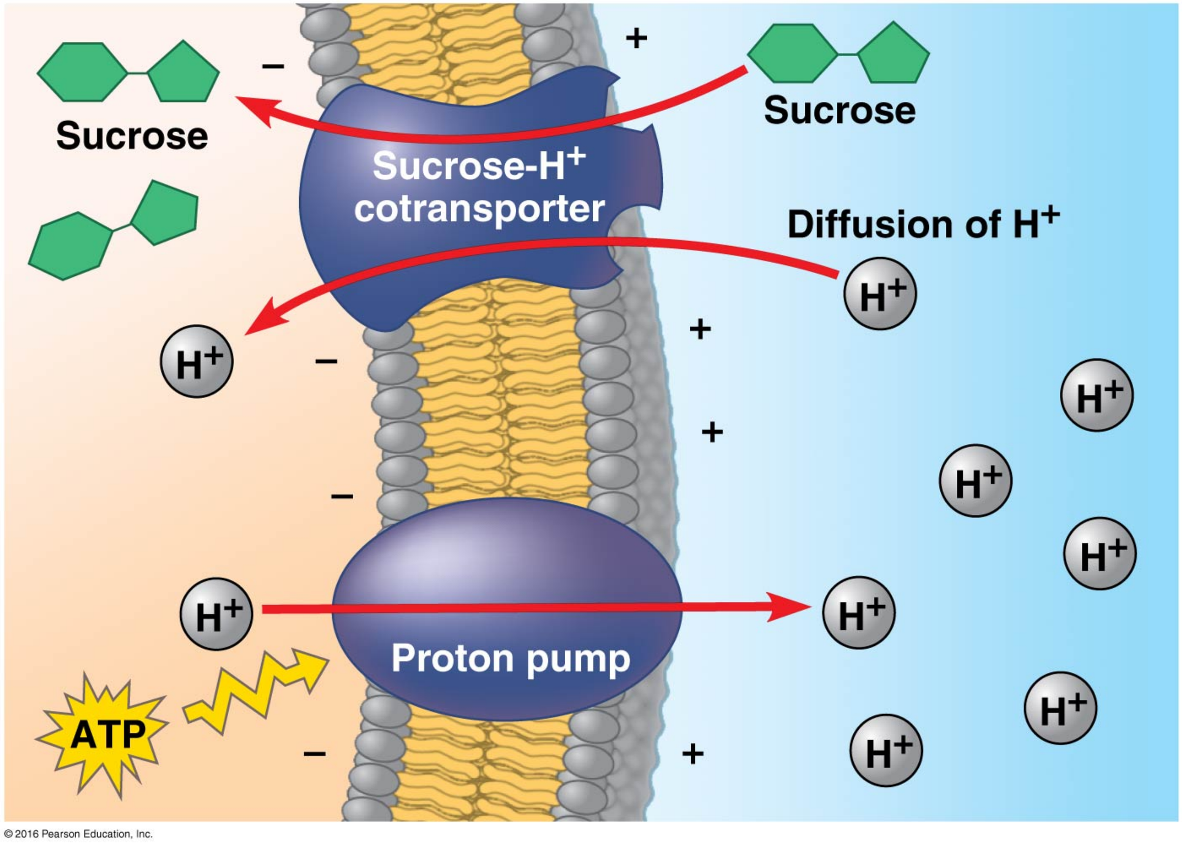
- Push protons (H+) across membrane
- Eg. mitochondria (ATP production)

Cotransport: membrane protein enables "downhill" diffusion of one solute to drive "uphill" transport of other

Eg. sucrose-H^+ cotransporter (sugar-loading in plants)



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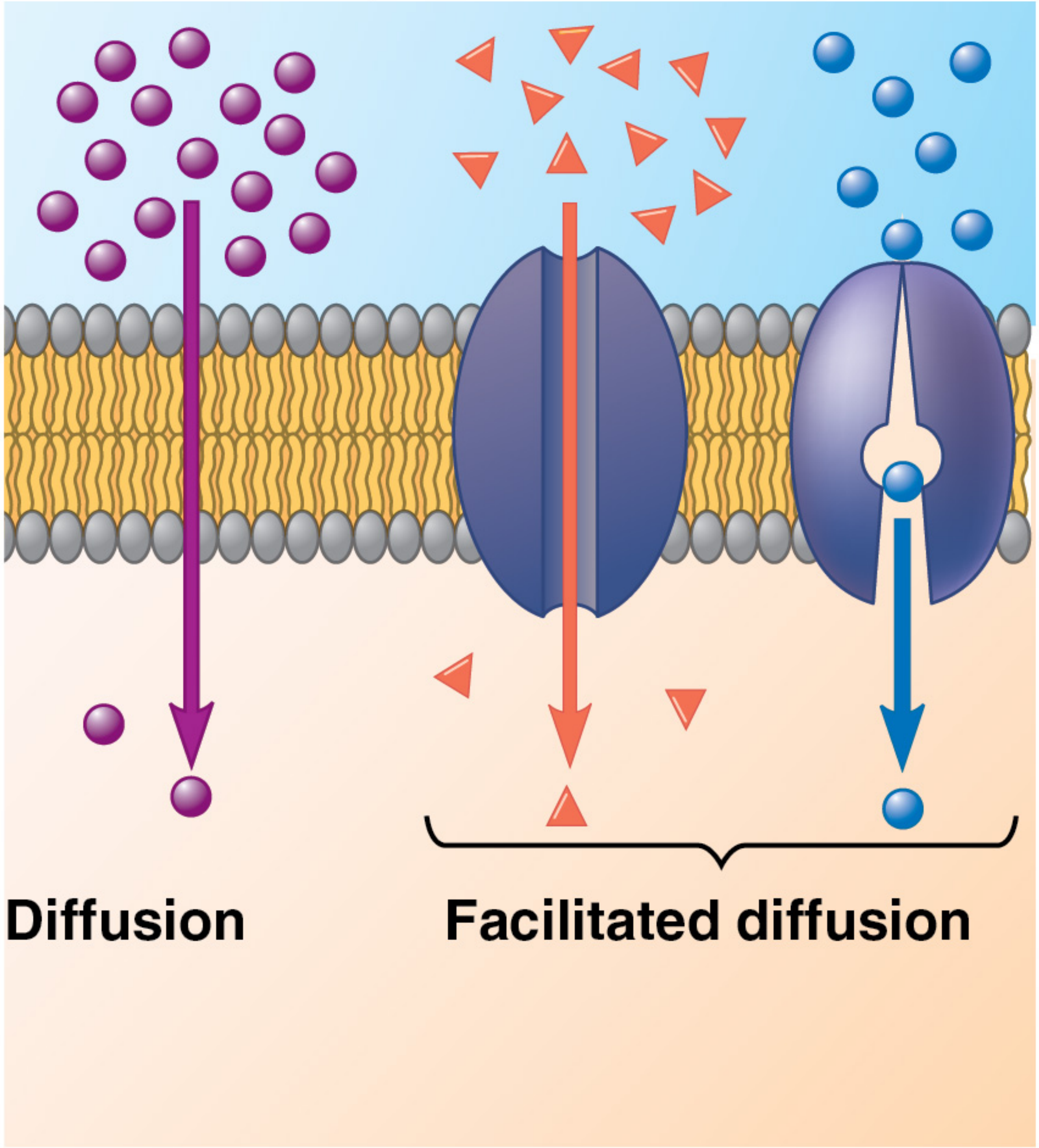
Passive vs. Active Transport

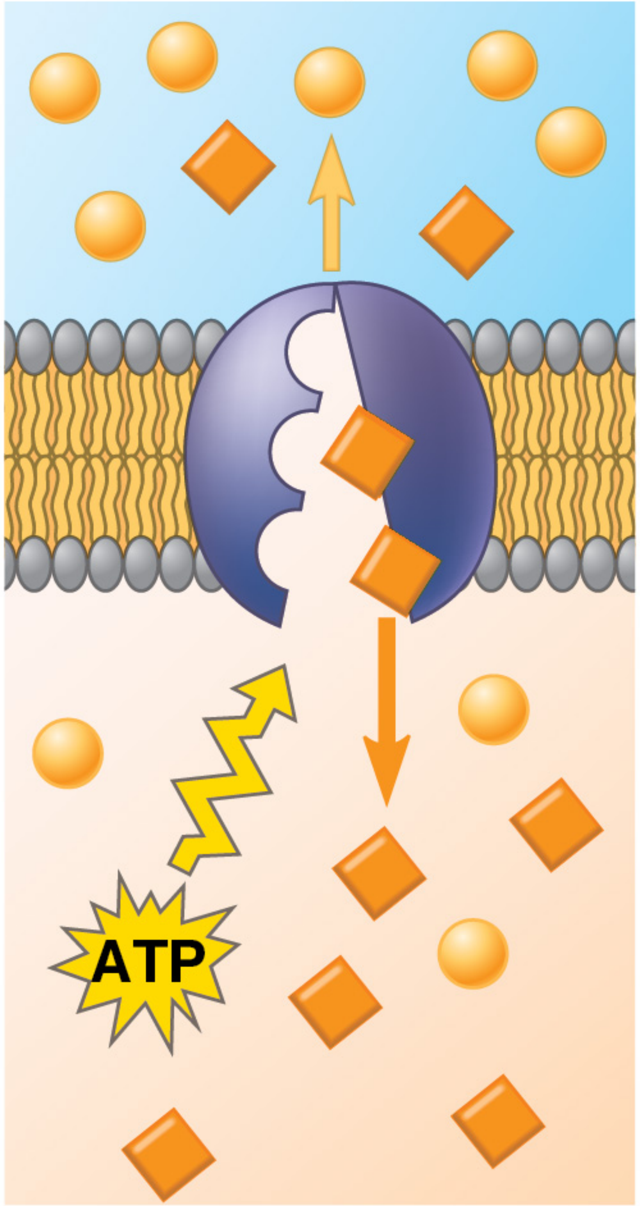
- Little or no Energy
- High → low concentrations
- **DOWN** the concentration gradient
- eg. diffusion, osmosis, facilitated diffusion (w/ transport protein)

- Requires Energy (ATP)
- Low → high concentrations
- **AGAINST** the concentration gradient
- eg. pumps, exo/ endocytosis

Passive transport

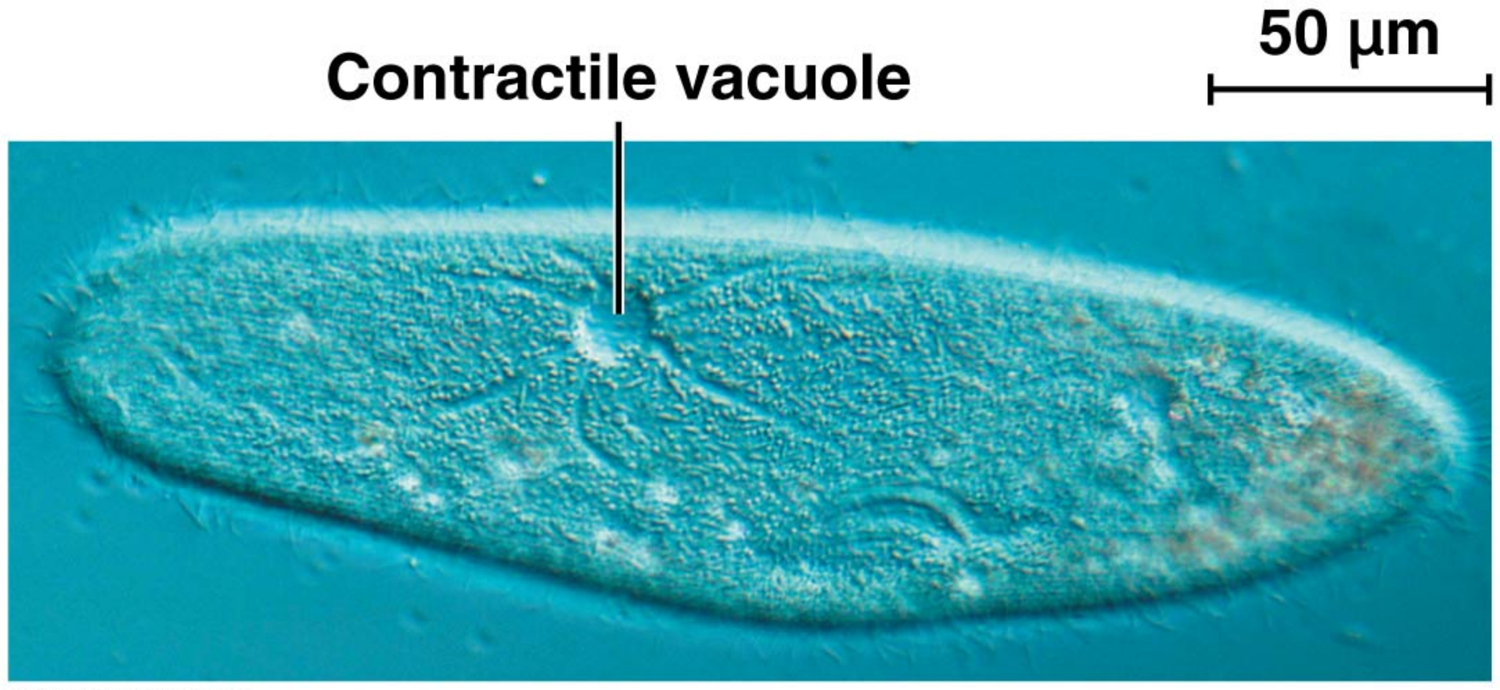


Active transport



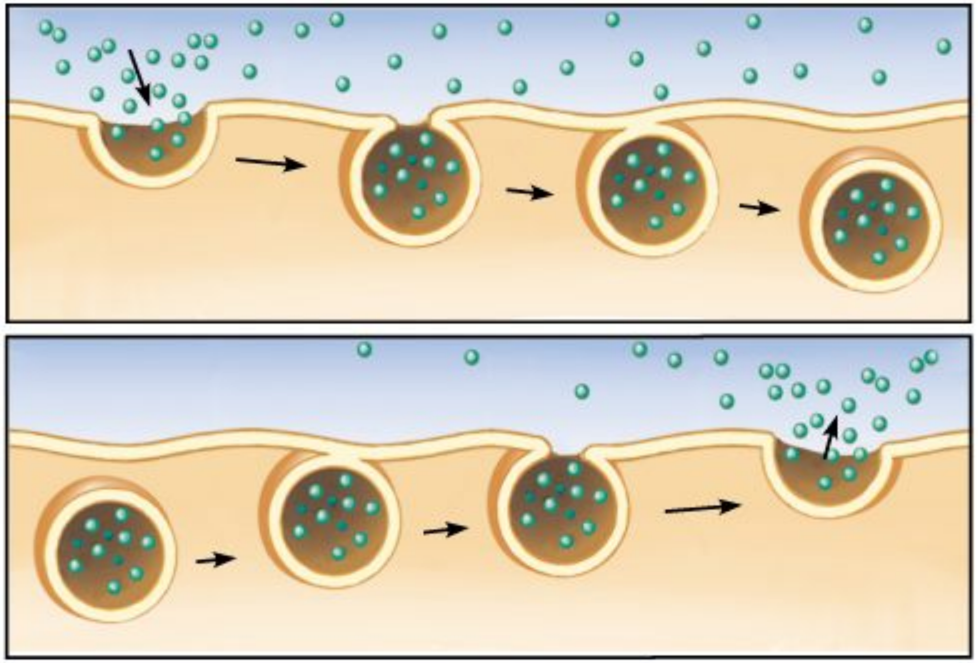
Osmoregulation

- Control solute & water balance
- **Contractile vacuole**: "bilge pump" forces out fresh water as it enters by osmosis
- Eg. paramecium caudatum – freshwater protist



Bulk Transport

- Transport of proteins, polysaccharides, large molecules



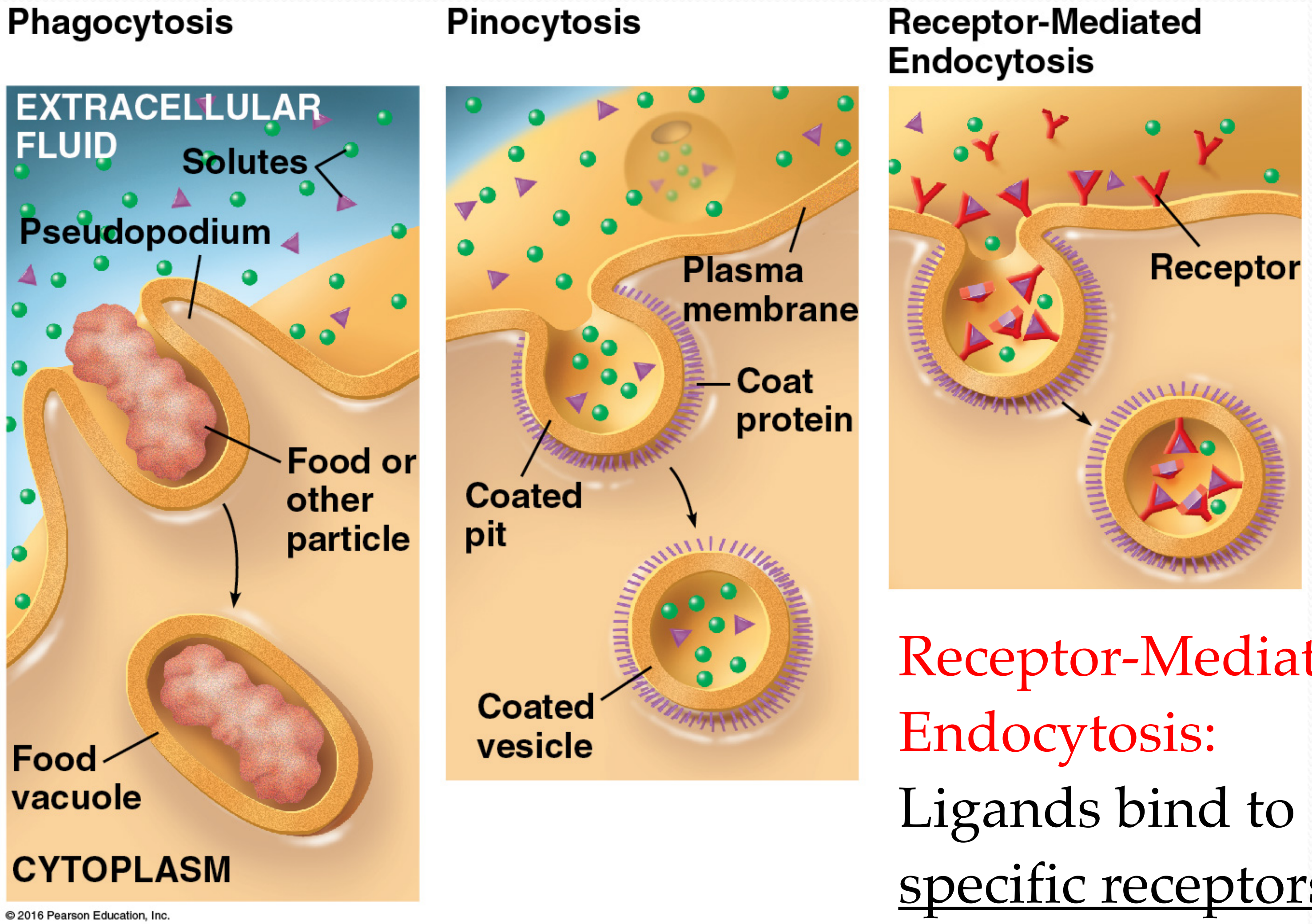
Endocytosis: take in macromolecules and particulate matter, form new vesicles from plasma membrane

Exocytosis: vesicles fuse with plasma membrane, secrete contents out of cell

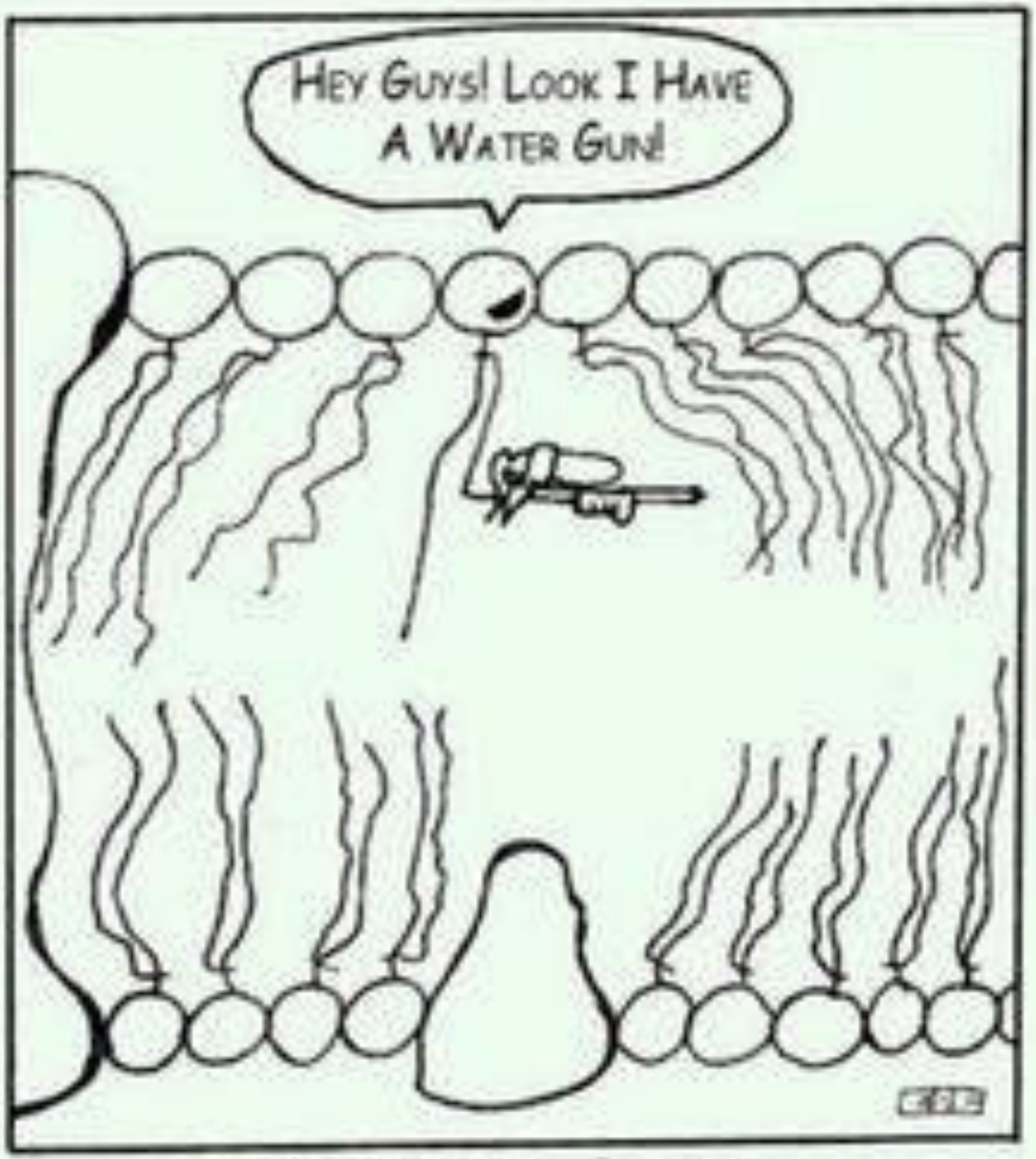
Types of Endocytosis

Phagocytosis:
"cellular eating" - solids

Pinocytosis:
"cellular drinking" - fluids



Receptor-Mediated Endocytosis:
Ligands bind to specific receptors on



MEMBRANE PRANKS