

CELLULAR EXCHANGE

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Question: Explain how the plasma membrane is adapted to allow the substances which a cell needs to pass through.

•**Answer:** A plasma membrane consists of a **double layer of phospholipid molecules** arranged with their hydrocarbon chains inwards.

Fat-soluble and small molecules such as oxygen can diffuse through this bilayer.

- These molecules can pass through the gaps between the phospholipids.
- Water soluble molecules and ions make use of membrane proteins.
- Some of these proteins have pores in them. Ions often pass through these pores.
- Gates open and close regulating the passage of the ions.
- Facilitated diffusion and active transport make use of protein carriers. These carriers have specific shapes which only allow certain molecules to fit them. A cell that needs to take up a lot of a particular substance will have a lot of one sort of carrier protein. Another cell which does not need so much may not have so much of that carrier. Active transport also uses the protein carriers but it allows substances to be taken up against the concentration gradient and is particularly useful when a cell needs a lot of a substance which is only present in small amounts in the surroundings. Active transport needs energy.

Movement Across Membranes

1 - Passive processes - require no expenditure of energy by a cell:

Simple diffusion = net movement of a substance from an area of high concentration to an area of low concentration.

The rate of diffusion is influenced by:

- **Concentration gradient**
- **Cross-sectional area through which diffusion occurs**
- **Temperature**
- **Molecular weight of a substance**
- **Distance through which diffusion occurs**

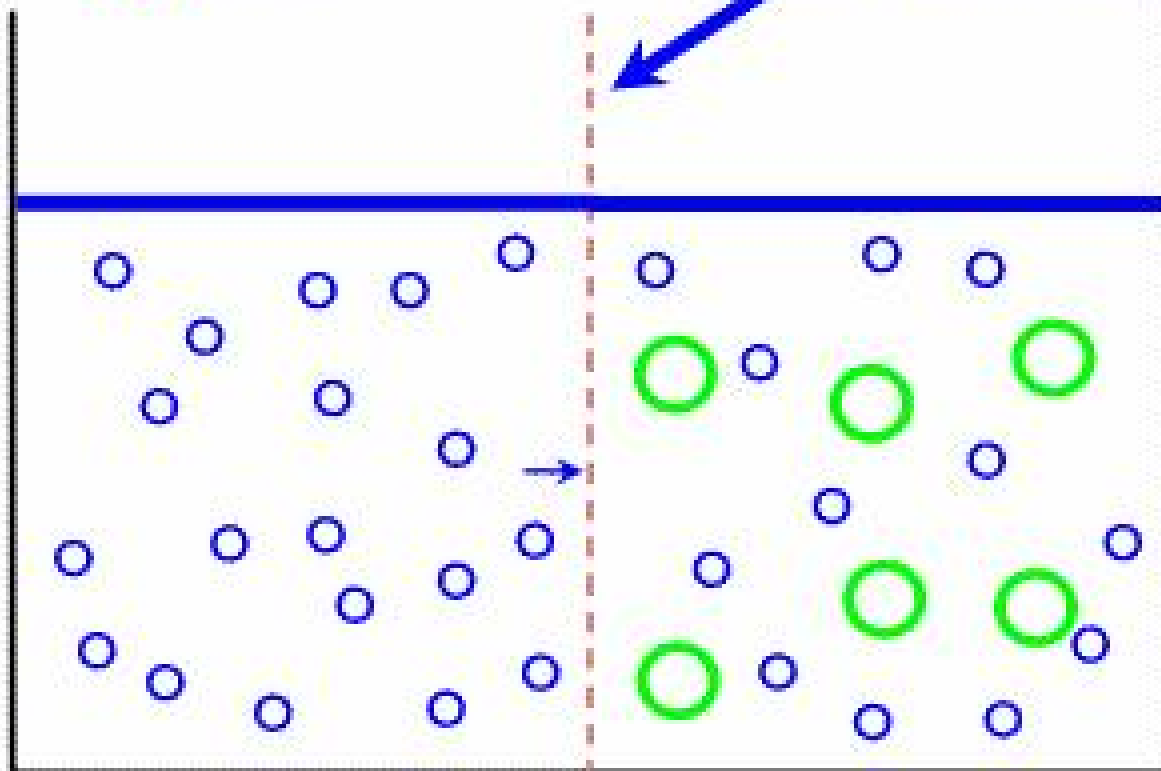
Osmosis = diffusion of water across a semipermeable membrane (like a cell membrane) from an area of low solute concentration to an area of high solute concentration

Facilitated diffusion = movement of a substance across a cell membrane from an area of high concentration to an area of low concentration. This process requires the use of 'carriers' (membrane proteins). In the example below, a ligand molecule (e.g., acetylcholine) binds to the membrane protein. This causes a conformational change or, in other words, an 'opening' in the protein through which a substance (e.g., sodium ions) can pass.

Osmosis

○ - Water
○ - Sugar

Selectively Permeable Membrane



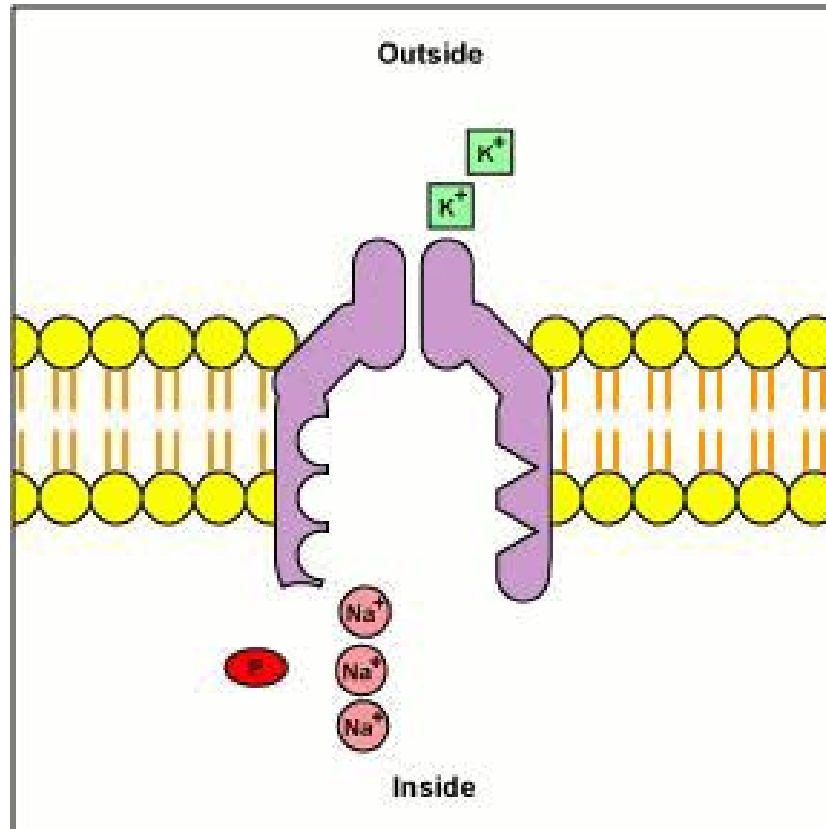
Low Sugar Concentration

High Water Concentration

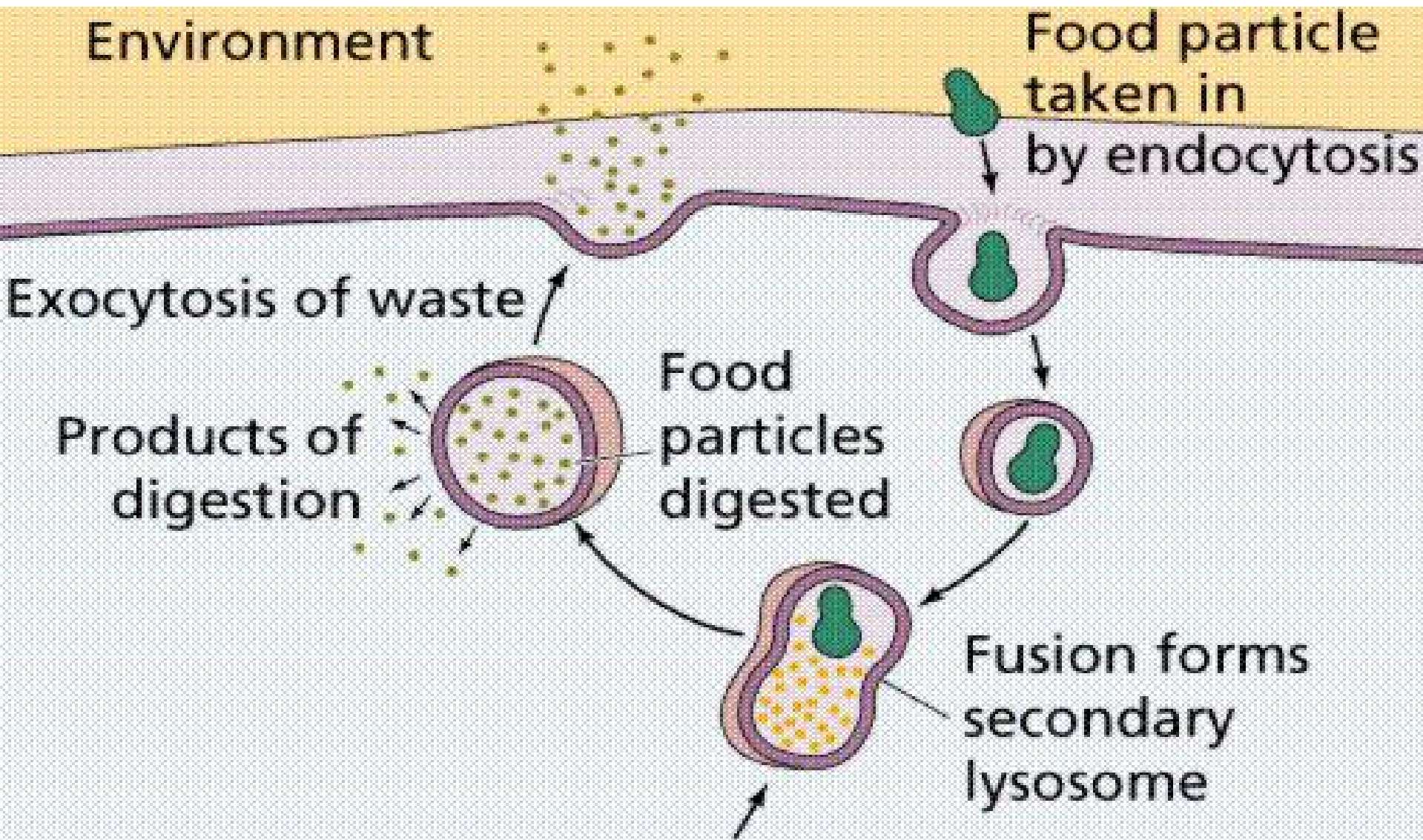
High Sugar Concentration

Low Water Concentration

2 - Active processes - require the expenditure of energy by cells:
Active transport = movement of a substance across a cell membrane from an area of low concentration to an area of high concentration using a carrier molecule



Endo- & exocytosis - moving material into (endo-) or out of (exo-) cell in bulk form



Passive Membrane Transport: Diffusion

- Simple diffusion – nonpolar and lipid-soluble substances
 - Diffuse directly through the lipid bilayer
 - Diffuse through channel proteins

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Diffusion

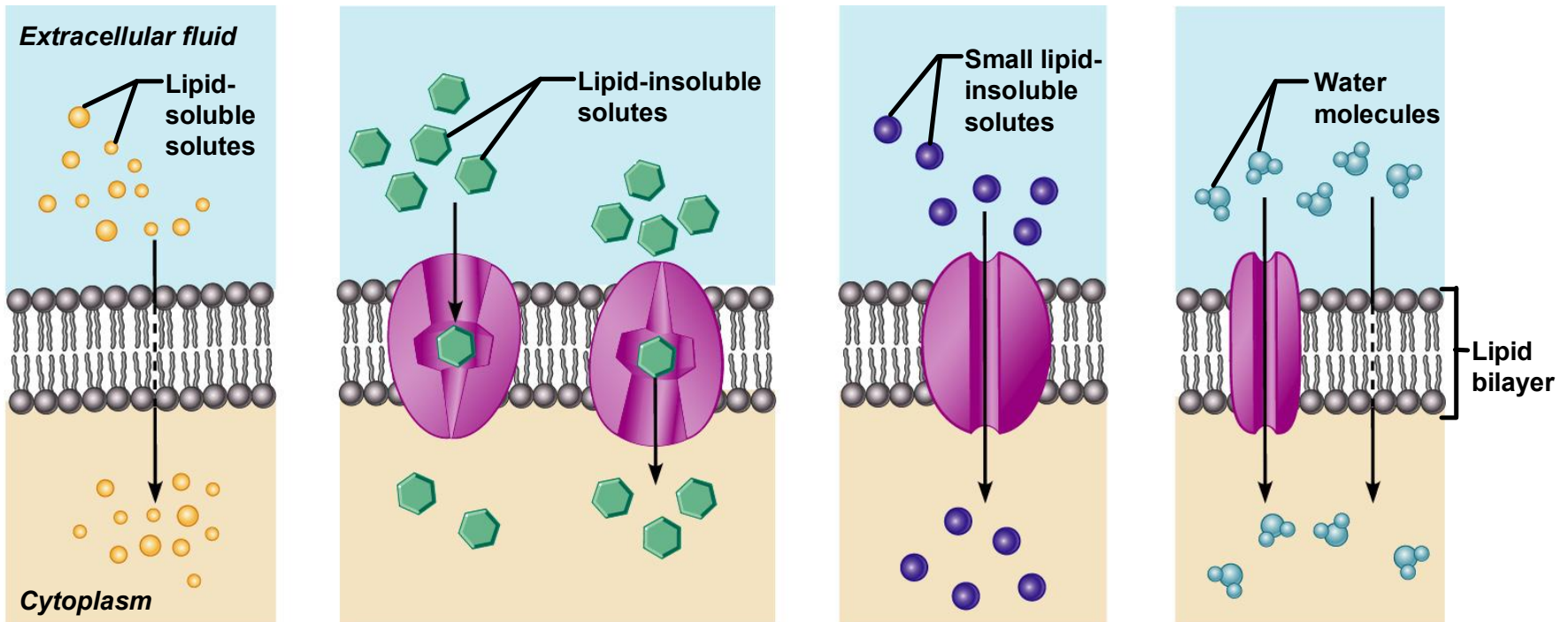
Passive Membrane Transport: Diffusion

- Facilitated diffusion
 - Transport of glucose, amino acids, and ions
 - Transported substances bind carrier proteins or pass through protein channels

Carrier Proteins

- Are integral transmembrane proteins
- Show specificity for certain polar molecules including sugars and amino acids

Diffusion Through the Plasma Membrane



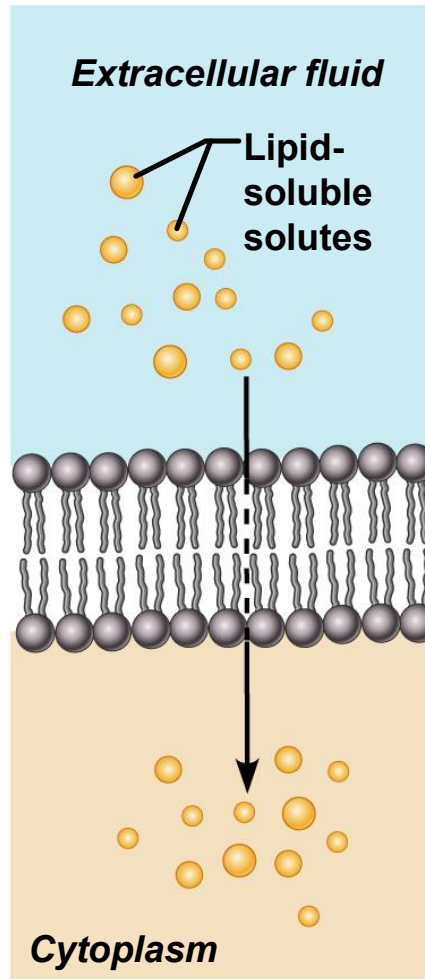
(a) Simple diffusion directly through the phospholipid bilayer

(b) Carrier-mediated facilitated diffusion via protein carrier specific for one chemical; binding of substrate causes shape change in transport protein

(c) Channel-mediated facilitated diffusion through a channel protein; mostly ions selected on basis of size and charge

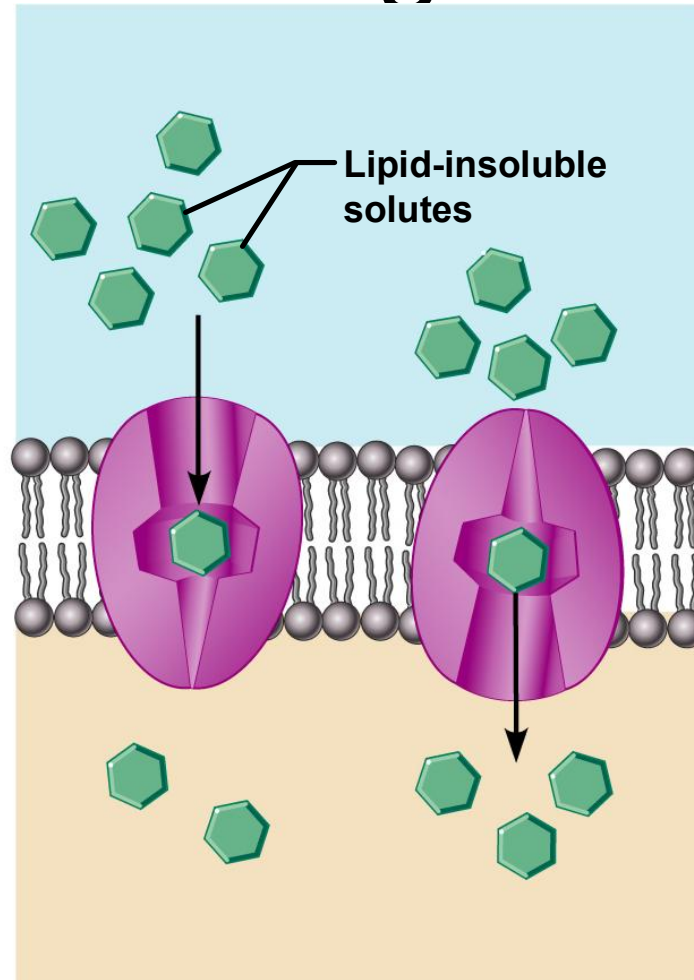
(d) Osmosis, diffusion through a specific channel protein (aquaporin) or through the lipid bilayer

Diffusion Through the Plasma Membrane



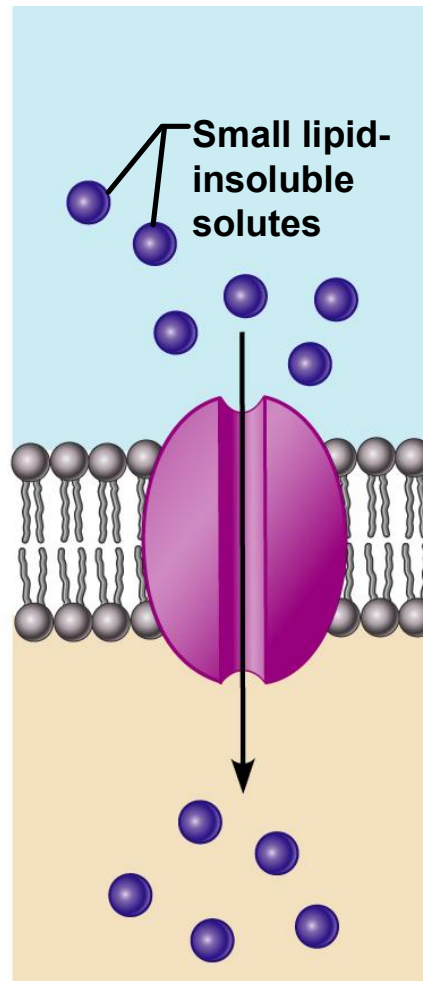
(a) Simple diffusion directly through the phospholipid bilayer

Diffusion Through the Plasma



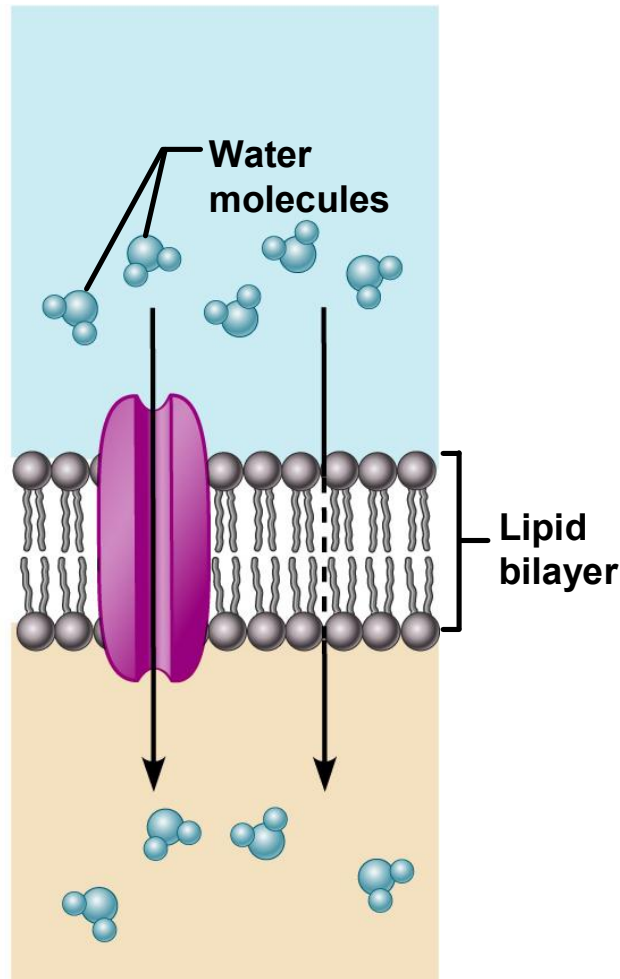
(b) Carrier-mediated facilitated diffusion via protein carrier specific for one chemical; binding of substrate causes shape change in transport protein

Diffusion Through the Plasma Membrane



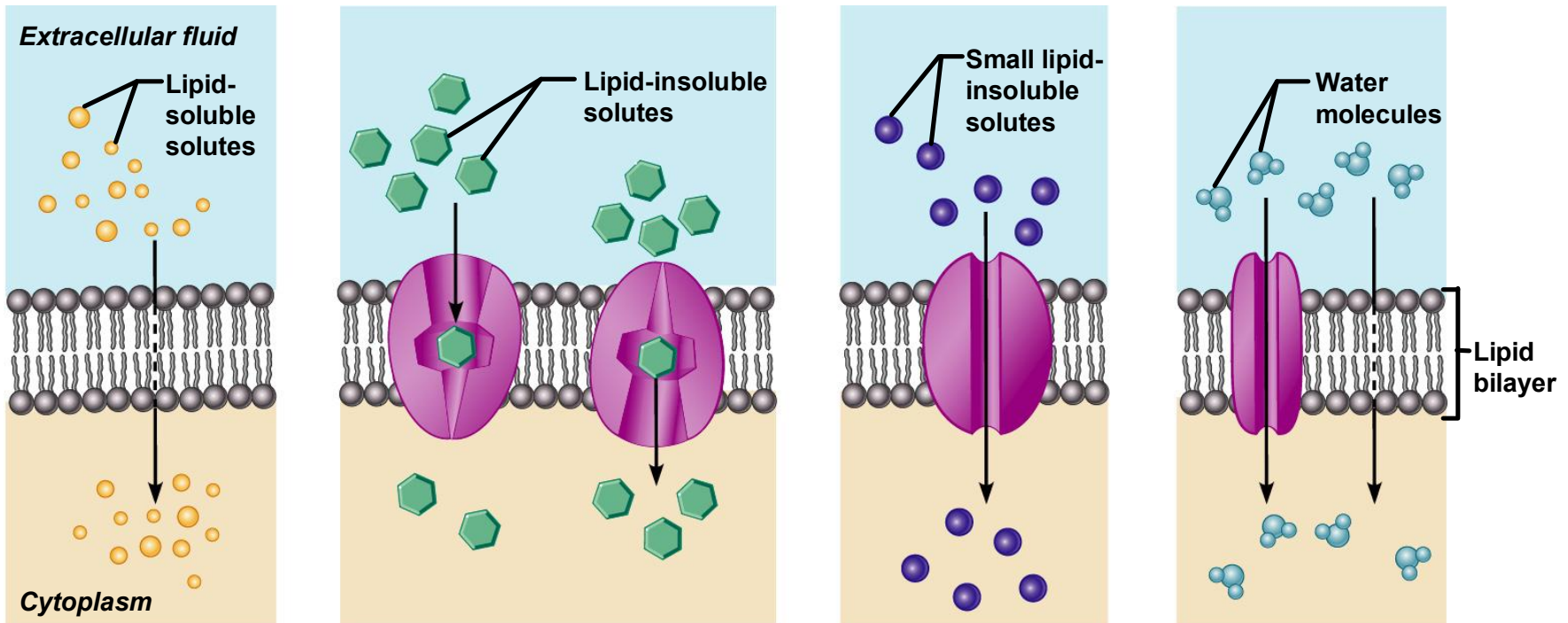
(c) Channel-mediated facilitated diffusion through a channel protein; mostly ions selected on basis of size and charge

Diffusion Through the Plasma Membrane



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Diffusion Through the Plasma Membrane



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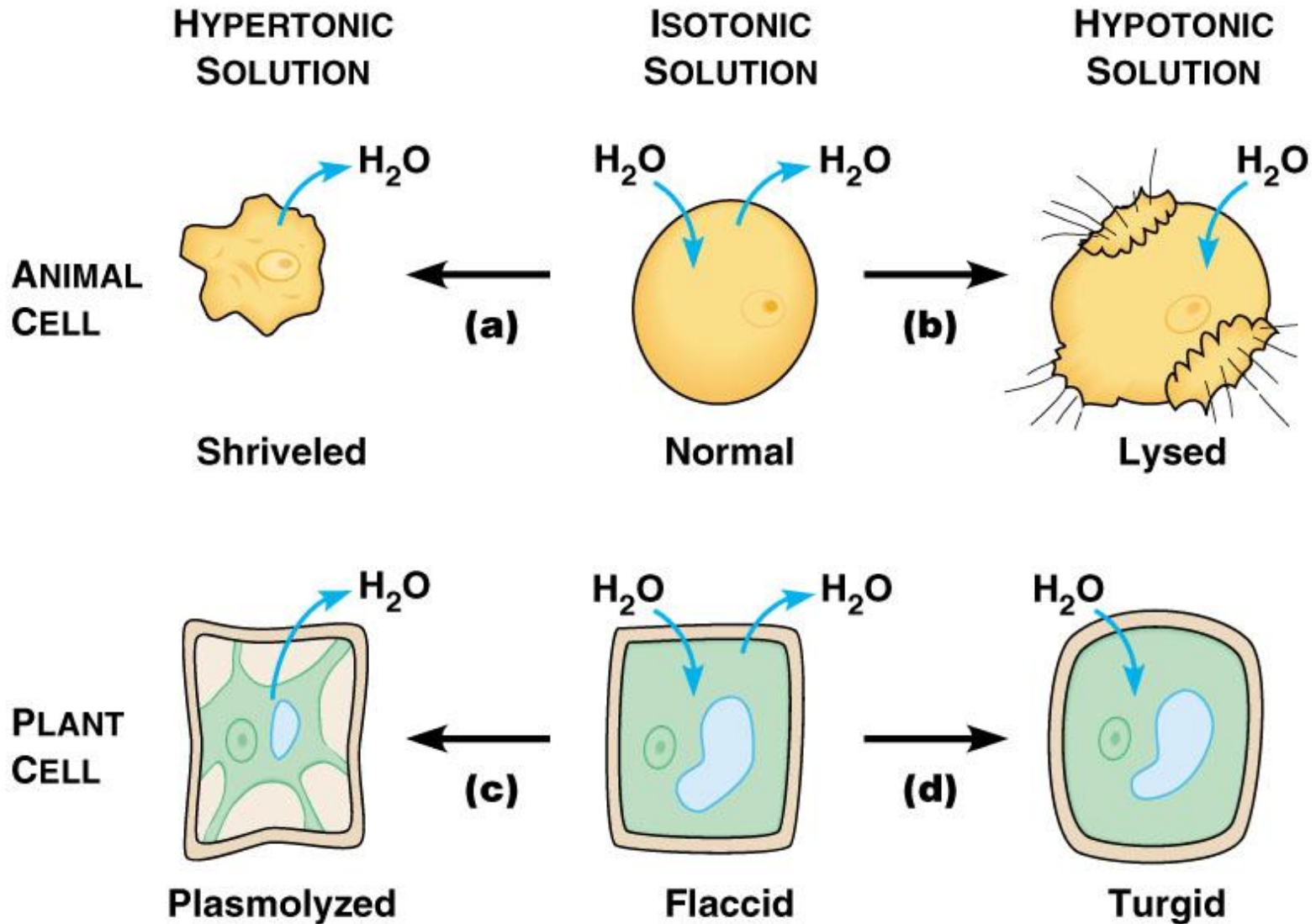
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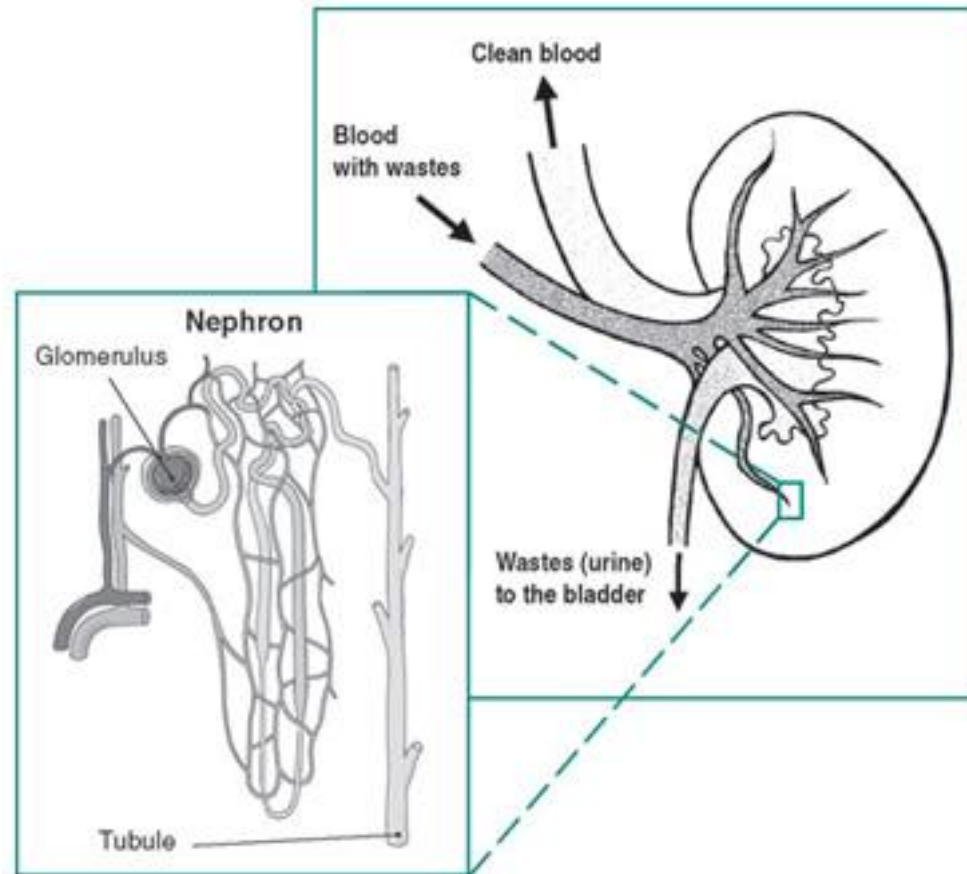
Passive Membrane Transport: Osmosis

- Occurs when the concentration of a solvent is different on opposite sides of a membrane
- Diffusion of water across a semipermeable membrane
- Osmolarity – total concentration of solute particles in a solution
- Tonicity – how a solution affects cell volume

Osmotic pressure affects cell shape and life



Why this is important biologically



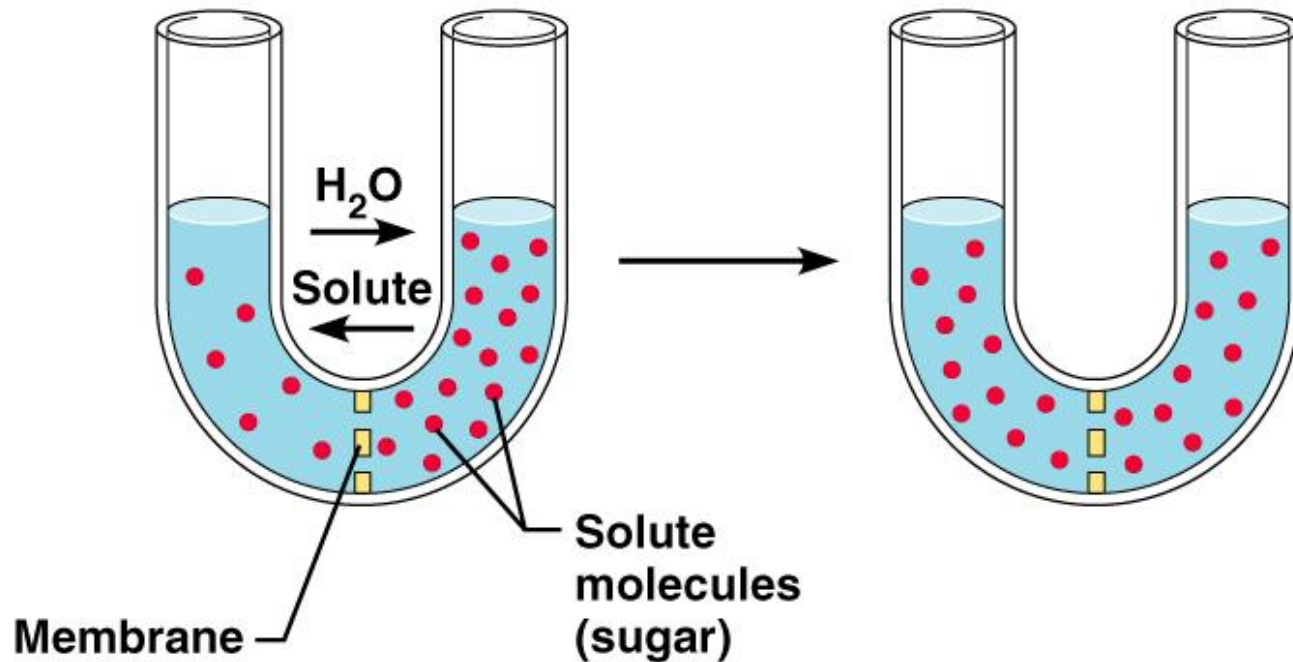
Kidney function is dependent upon ion and water transport

Effect of Membrane Permeability on Diffusion and Osmosis

Left compartment:
Solution with lower osmolarity

Right compartment:
Solution with greater osmolarity

Both solutions have the same osmolarity:
volume unchanged

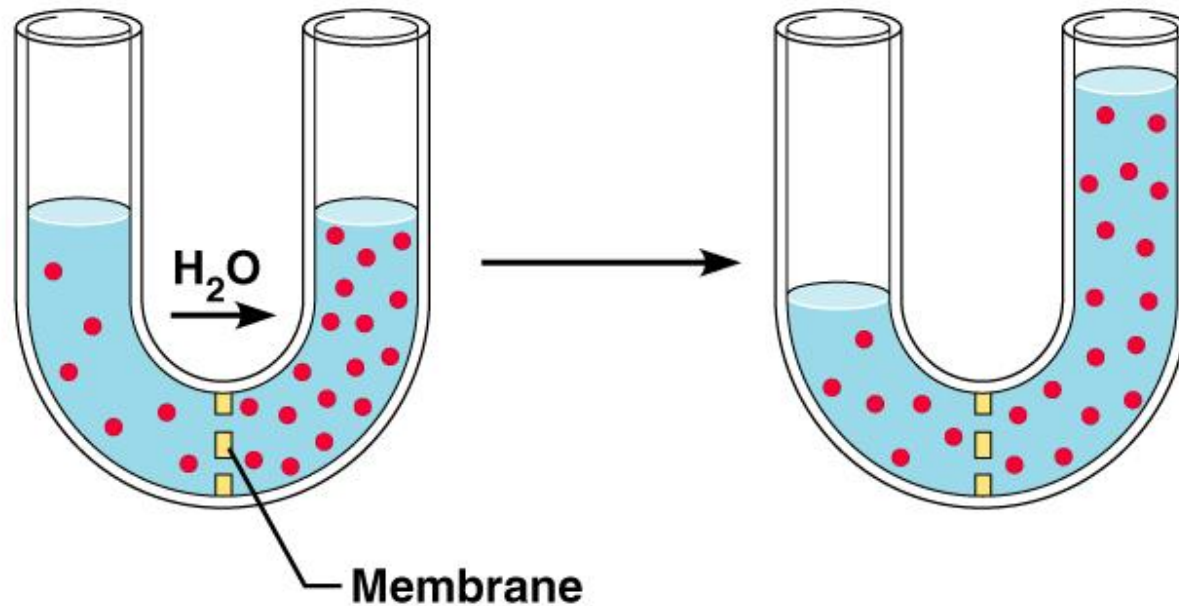


(a) Membrane permeable to both solute molecules and water

Effect of Membrane Permeability on Diffusion and

Both solutions have identical osmolarity, but volume of the solution on the right is greater because only water is free to move

Left compartment Right compartment



(b) Membrane impermeable to solute molecules, permeable to water

Passive Membrane Transport: Filtration

- The passage of water and solutes through a membrane by hydrostatic pressure
- Pressure gradient pushes solute-containing fluid from a higher-pressure area to a lower-pressure area

Effects of Solutions of Varying Tonicity

- Isotonic – solutions with the same solute concentration as that of the cytosol
- Hypertonic – solutions having greater solute concentration than that of the cytosol
- Hypotonic – solutions having lesser solute concentration than that of the cytosol

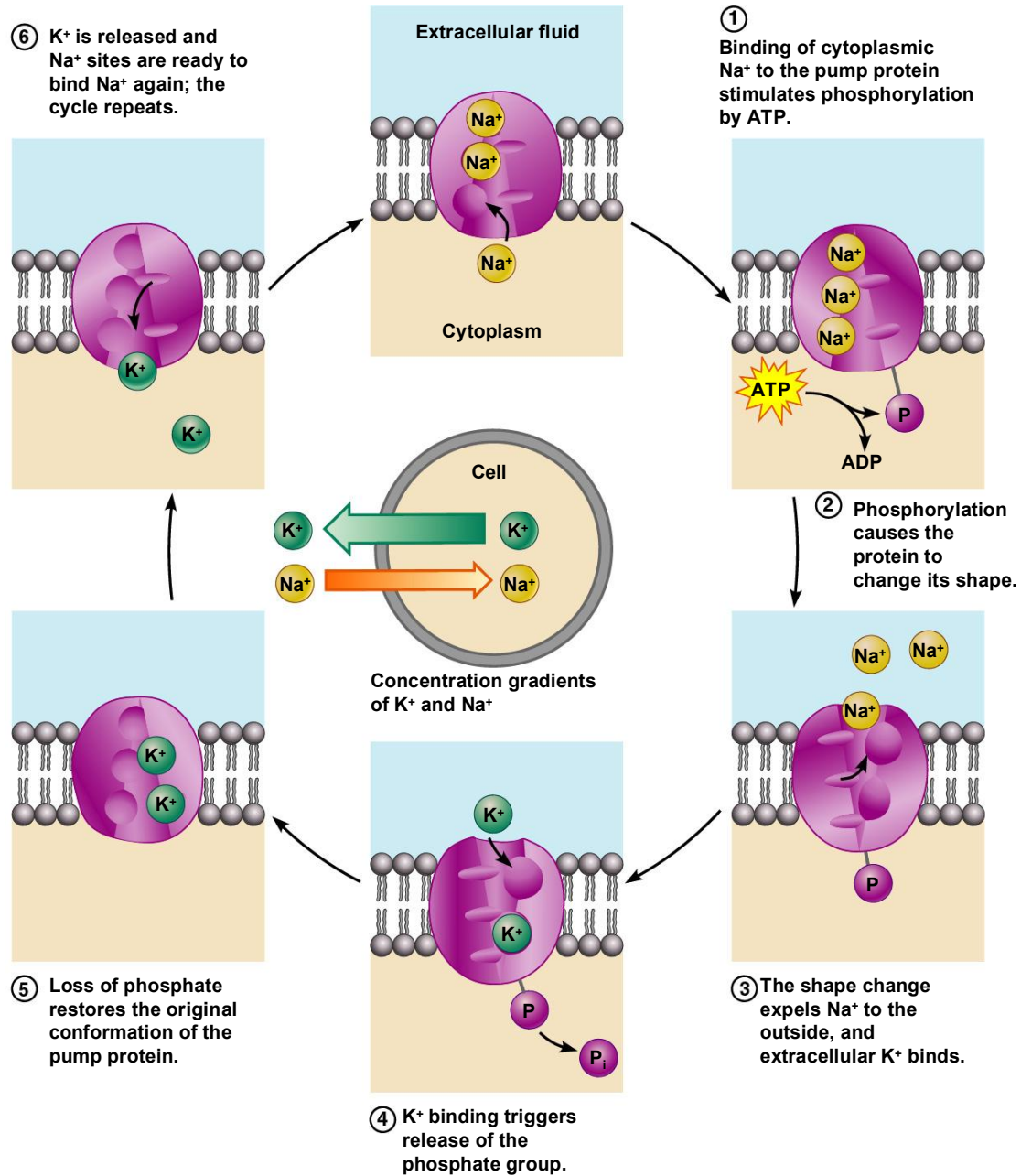


Figure 3.10

Active Transport

- Uses ATP to move solutes across a membrane
- Requires carrier proteins

Types of Active Transport

- Symport system – two substances are moved across a membrane in the same direction
- Antiport system – two substances are moved across a membrane in opposite directions

Types of Active Transport

- Primary active transport – hydrolysis of ATP phosphorylates the transport protein causing conformational change
- Secondary active transport – use of an exchange pump (such as the Na^+ - K^+ pump) indirectly to drive the transport of other solutes

Types of Active Transport

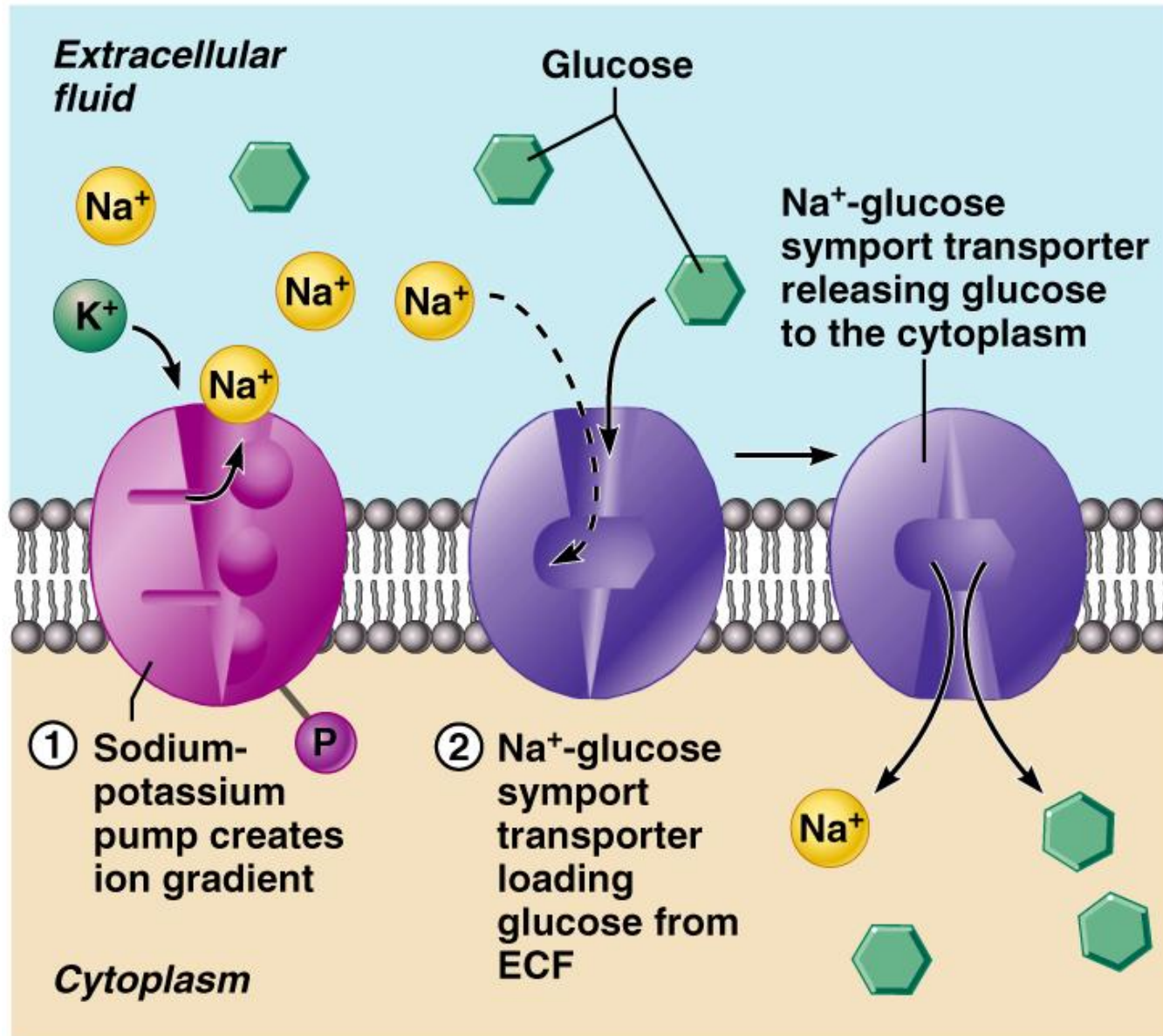


Figure 3.11

Vesicular Transport

- Transport of large particles and macromolecules across plasma membranes
 - Exocytosis – moves substance from the cell interior to the extracellular space
 - Endocytosis – enables large particles and macromolecules to enter the cell

Vesicular Transport

- Transcytosis – moving substances into, across, and then out of a cell
- Vesicular trafficking – moving substances from one area in the cell to another
- Phagocytosis – pseudopods engulf solids and bring them into the cell's interior

Vesicular Transport

- Fluid-phase endocytosis – the plasma membrane infolds, bringing extracellular fluid and solutes into the interior of the cell
- Receptor-mediated endocytosis – clathrin-coated pits provide the main route for endocytosis and transcytosis
- Non-clathrin-coated vesicles – caveolae that are platforms for a variety of signaling molecules

Exocytosis

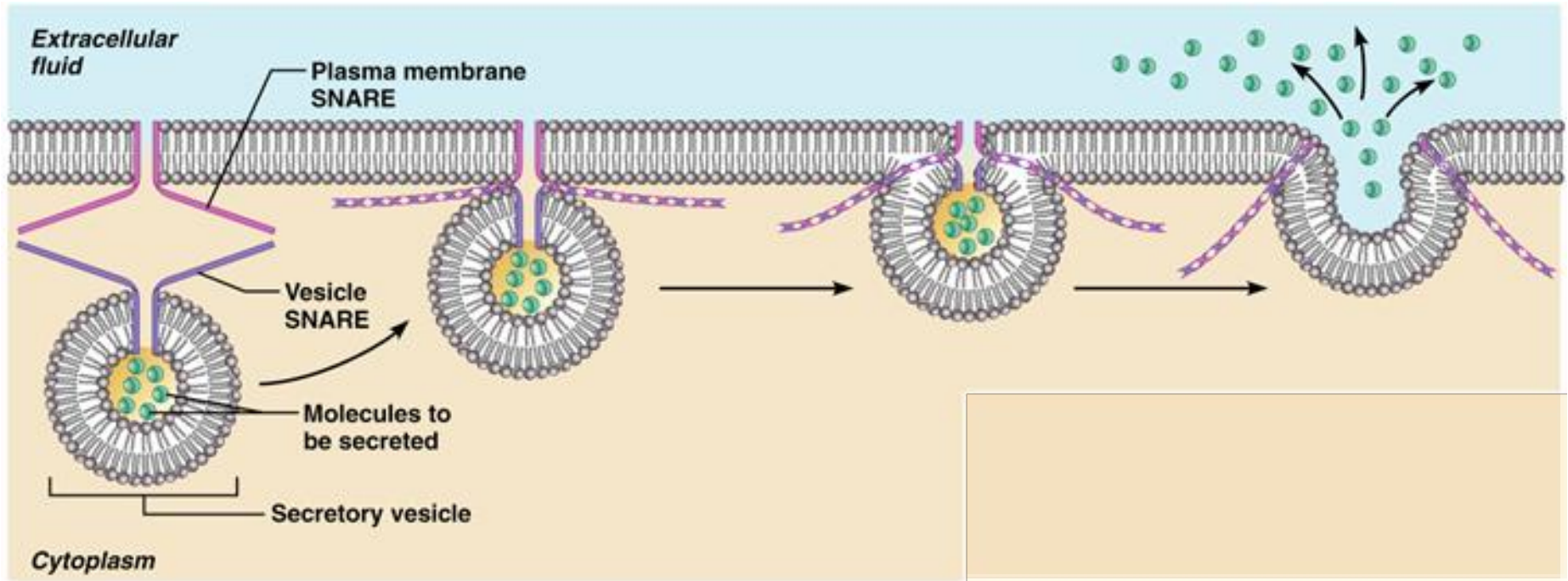
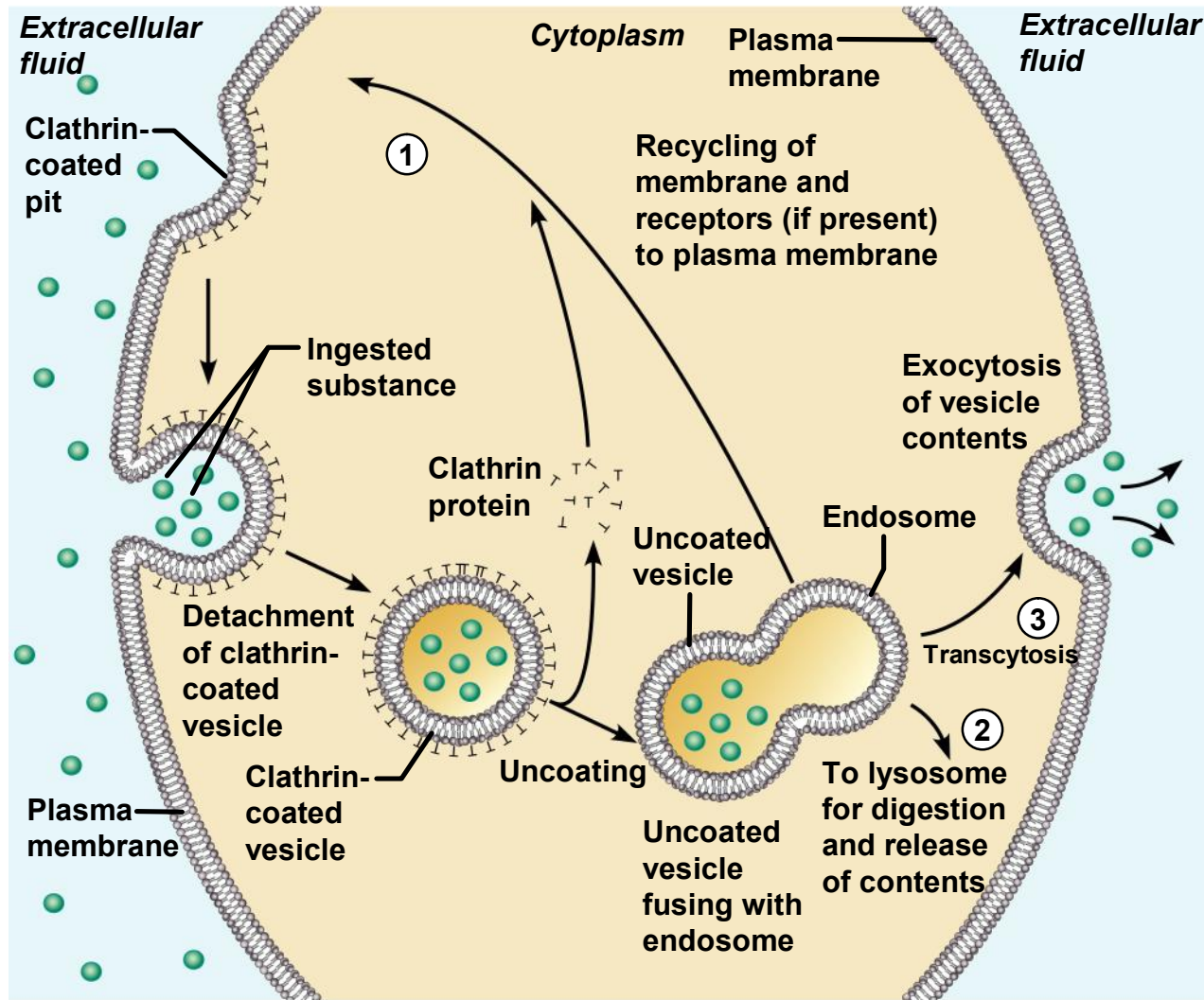


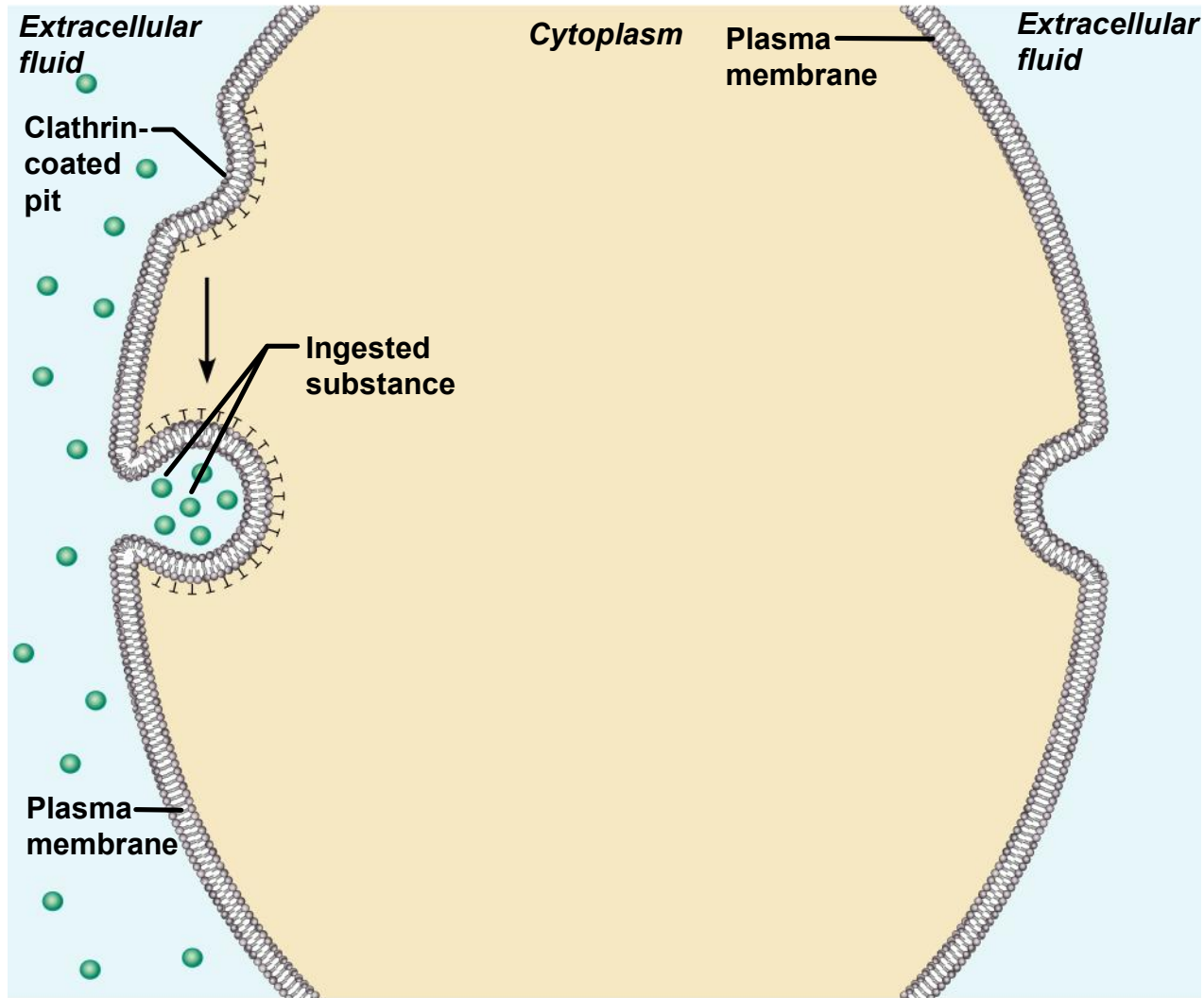
Figure 3.12a

Clathrin-Mediated Endocytosis



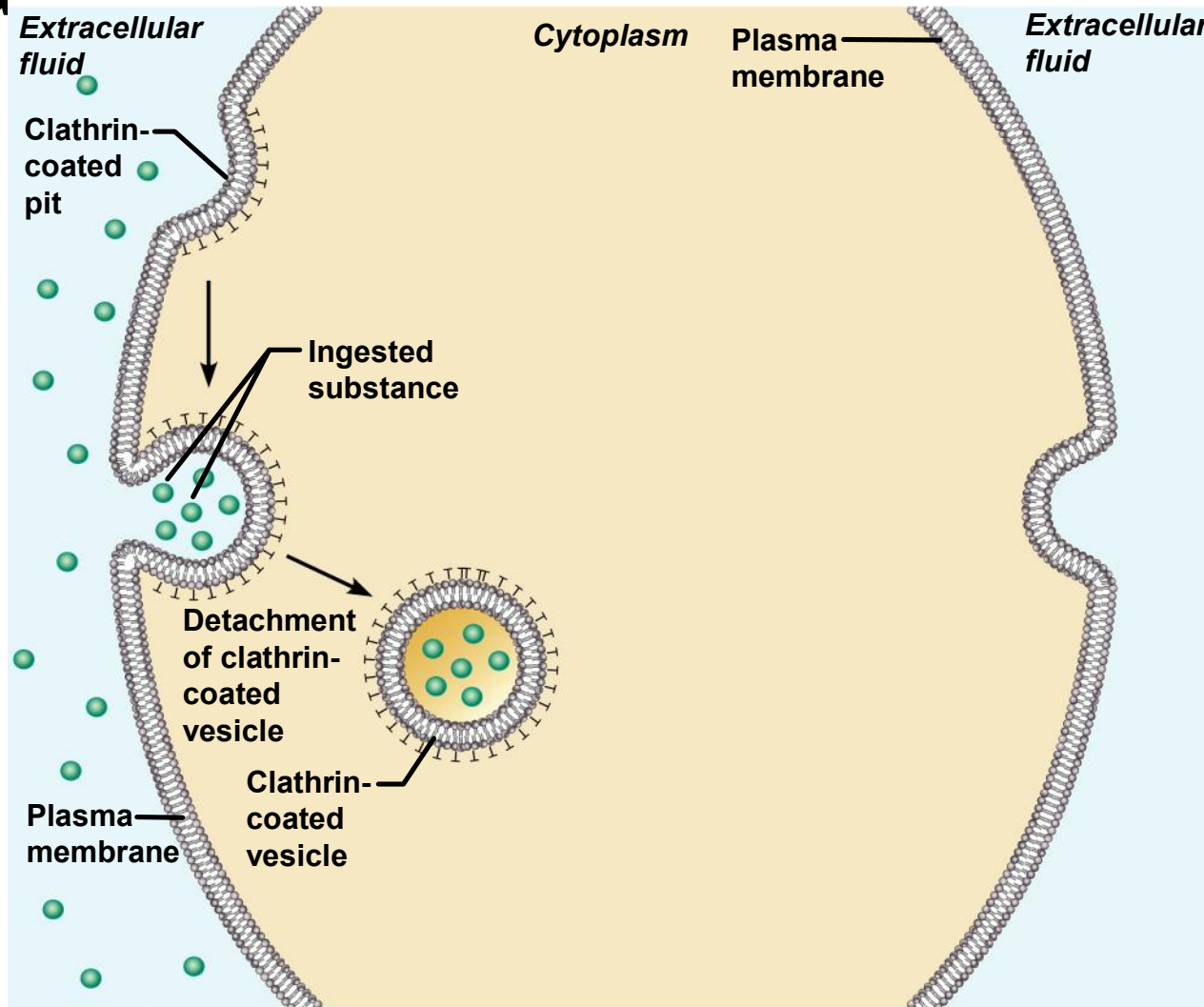
(a) Clathrin-mediated endocytosis

Clathrin-Mediated Endocytosis



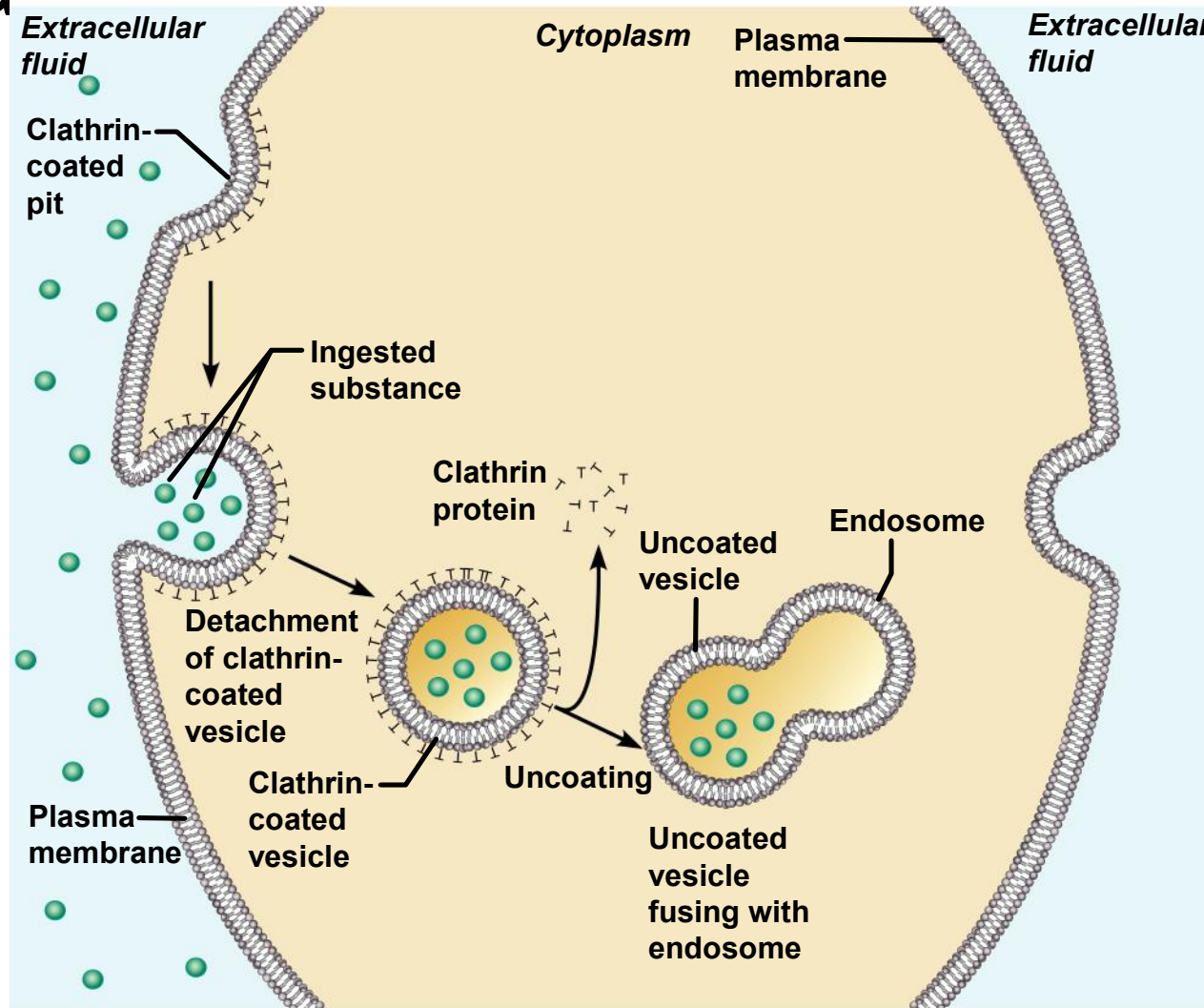
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Clathrin-Mediated Endocytosis



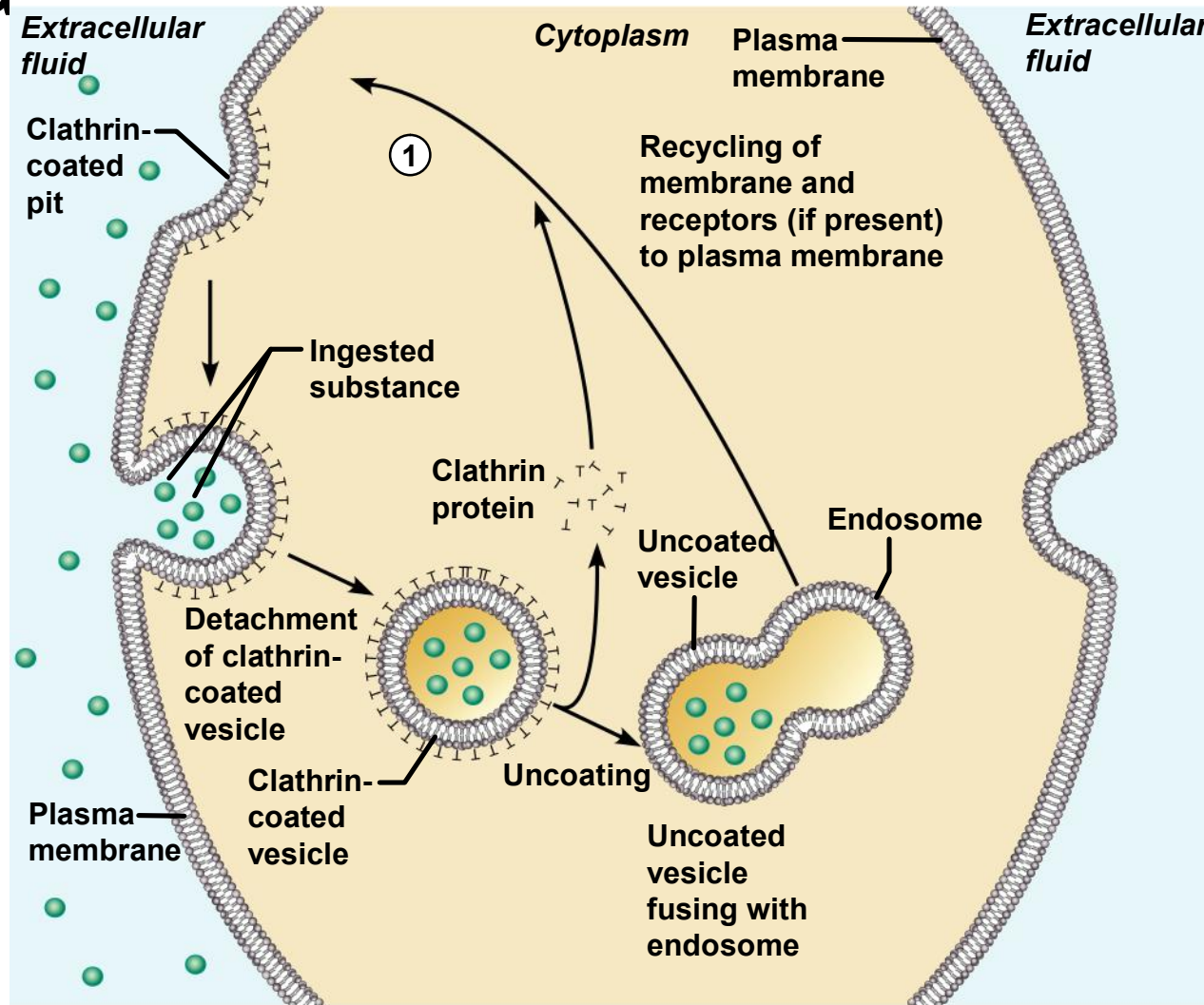
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Clathrin-Mediated Endocytosis



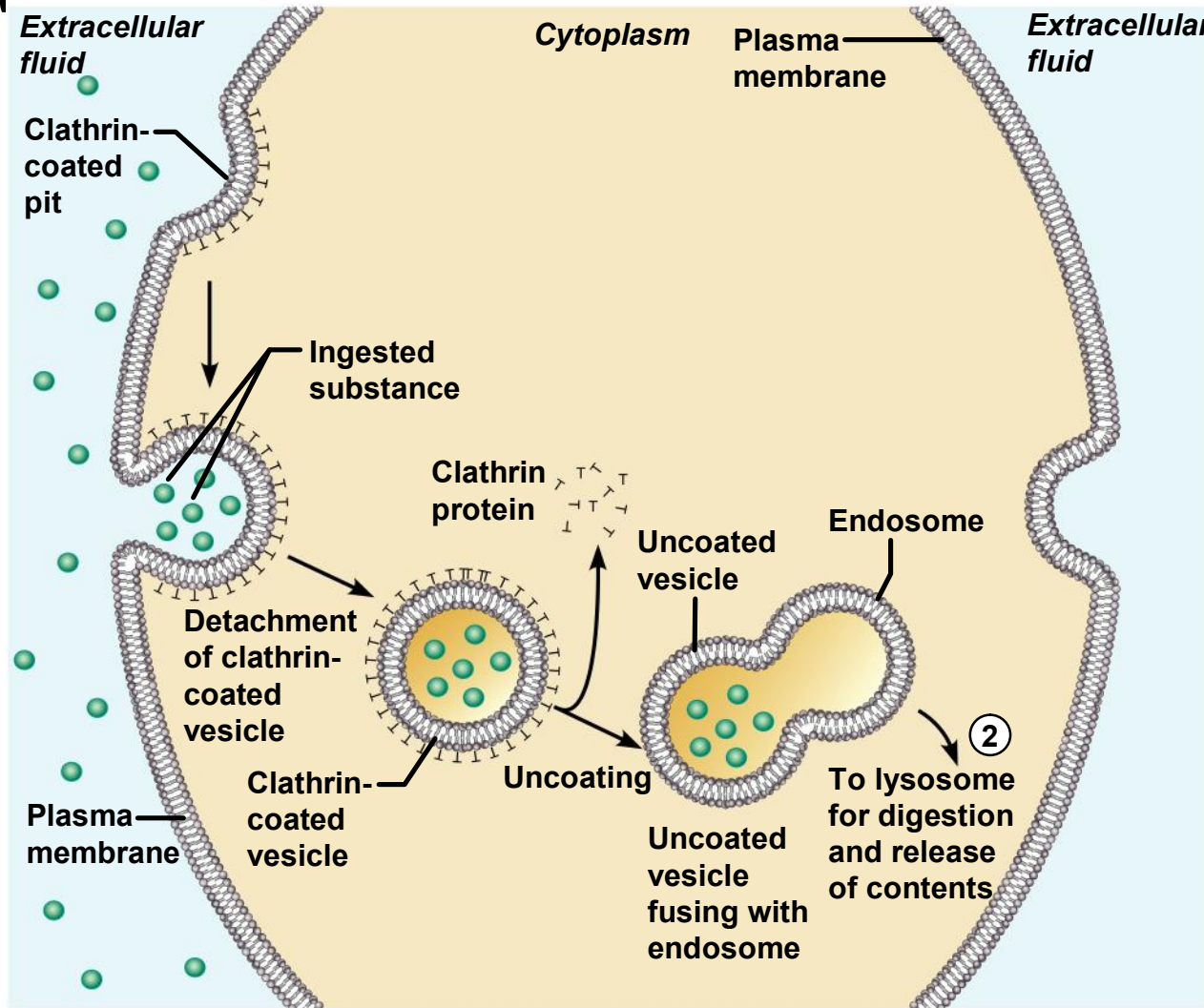
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Clathrin-Mediated Endocytosis



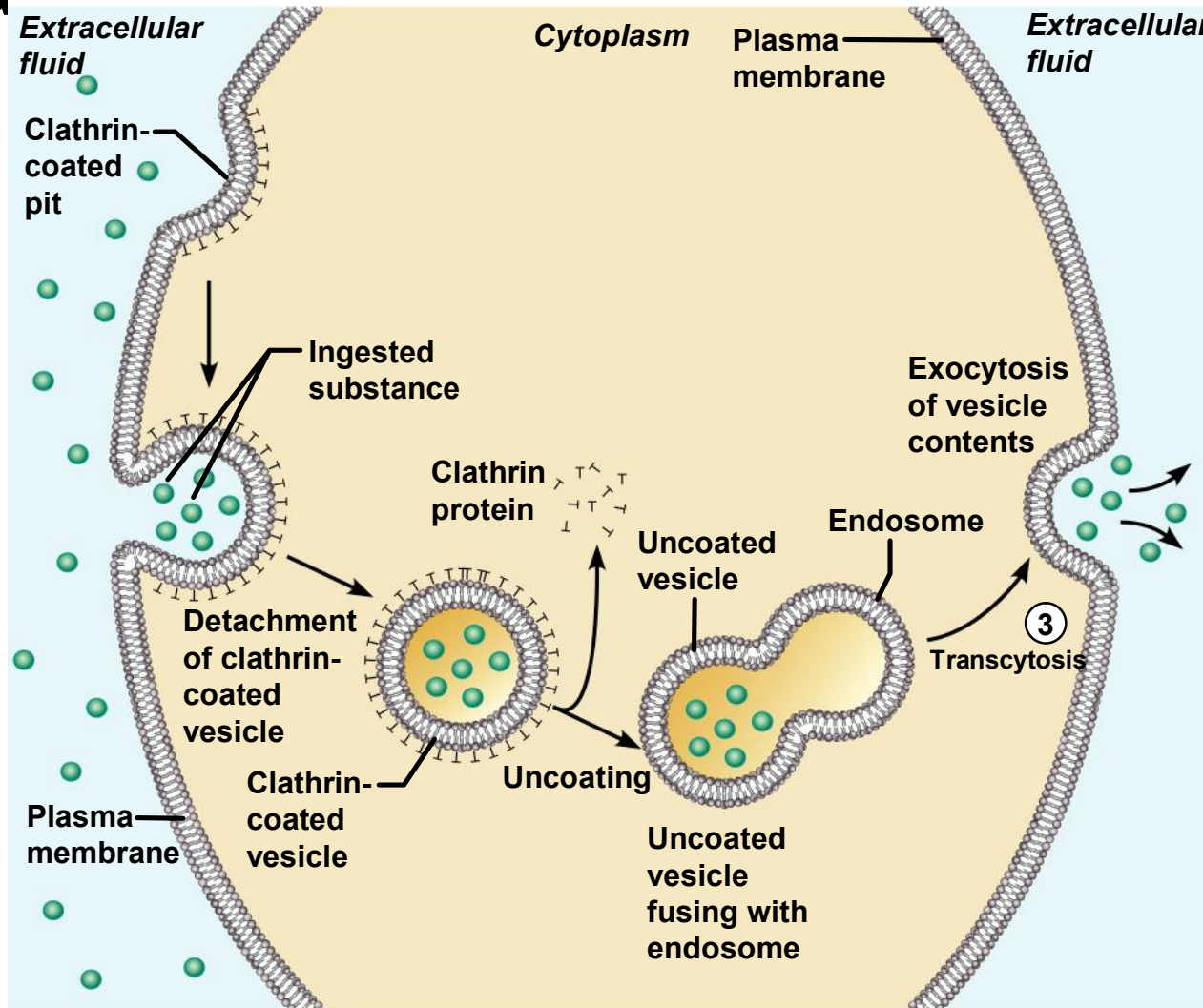
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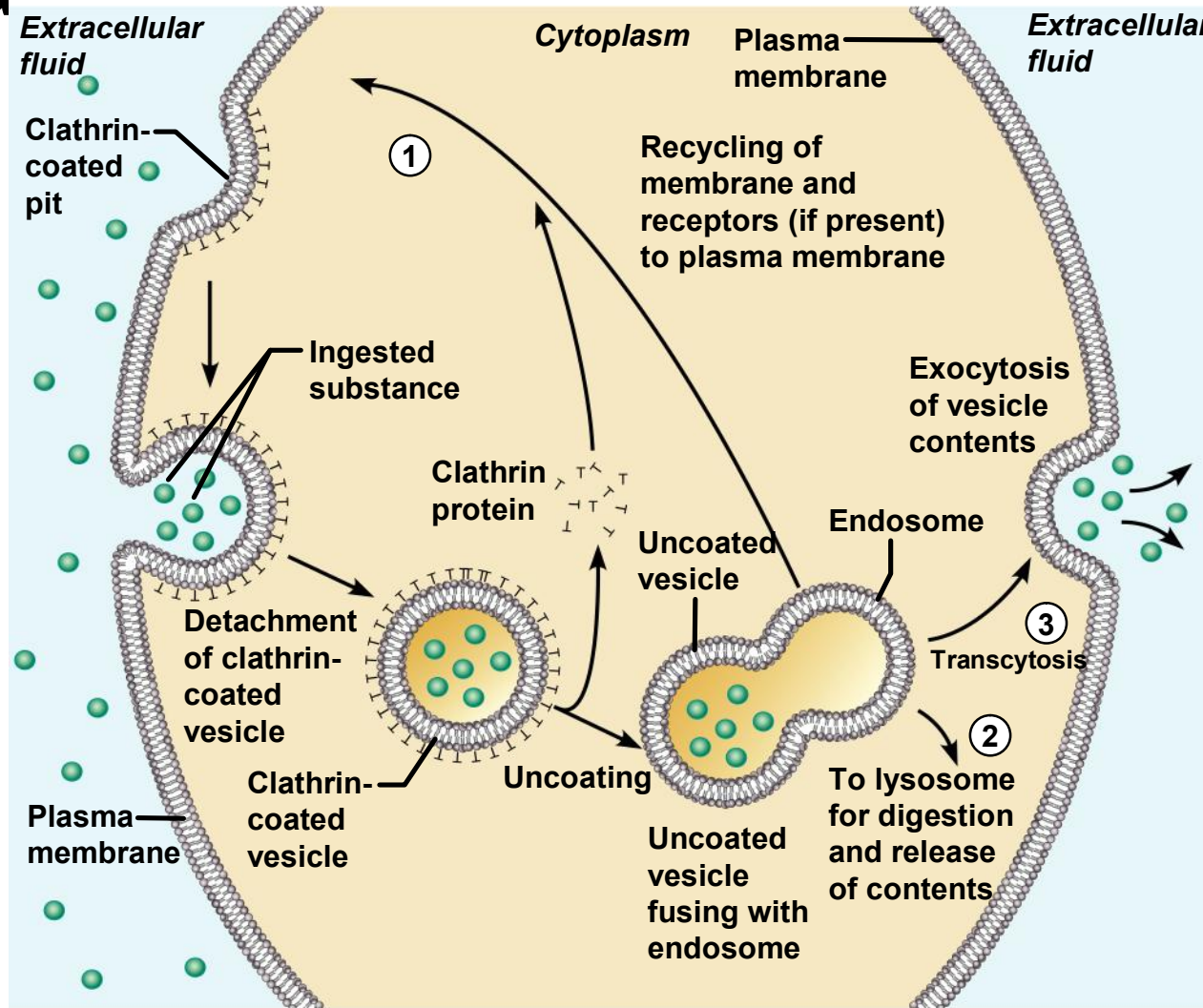
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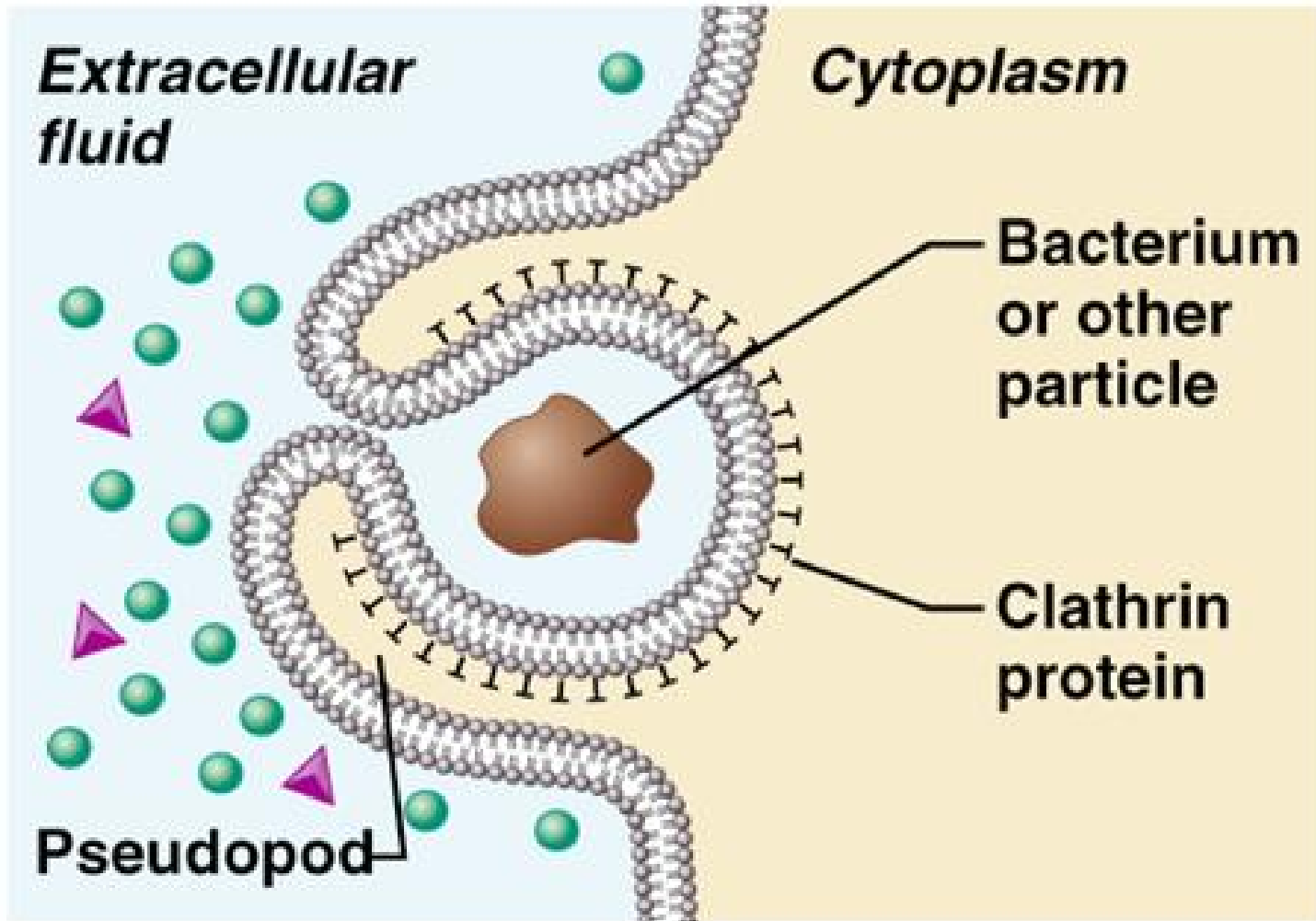
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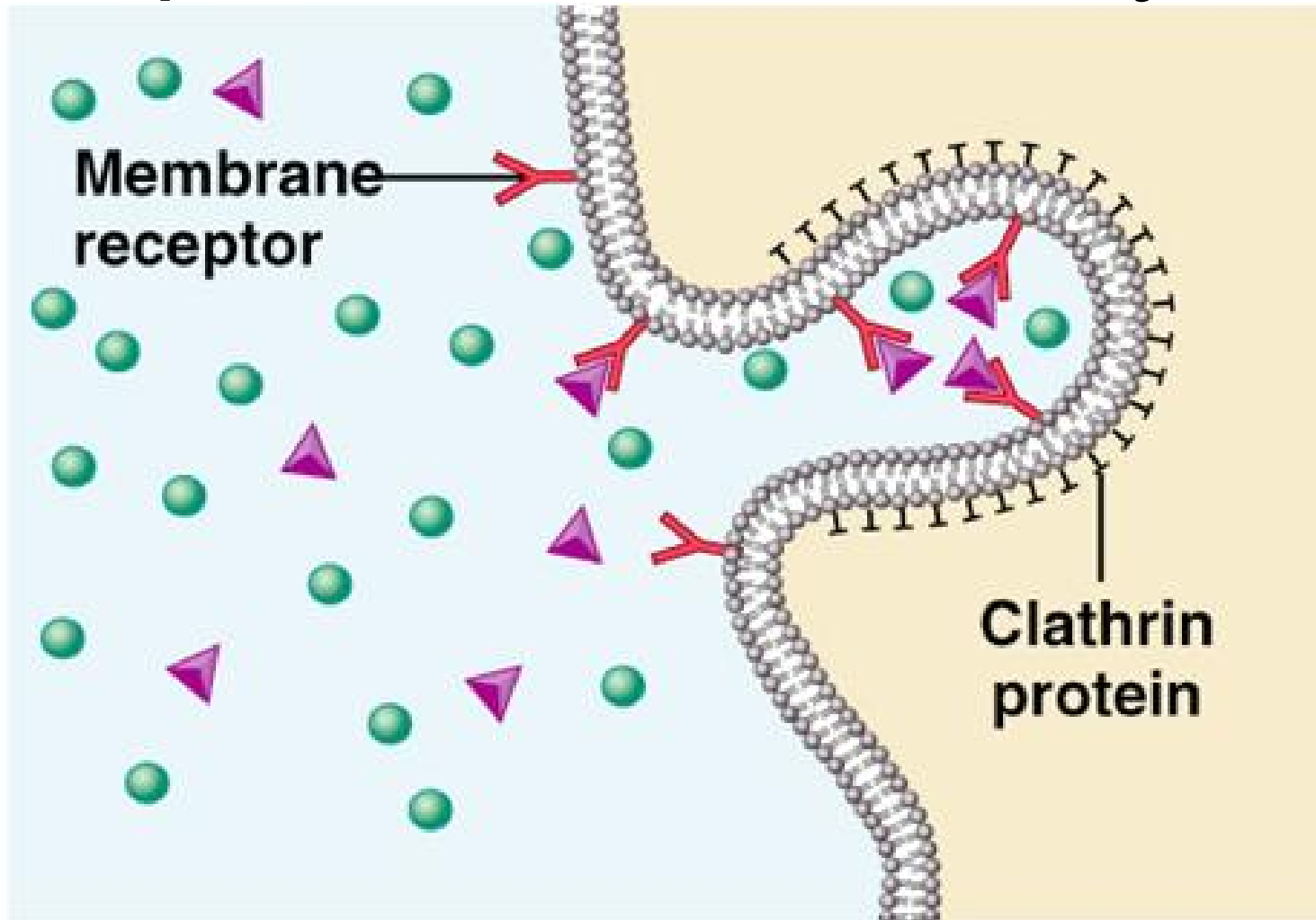
(a) Clathrin-mediated endocytosis

Phagocytosis



(b) Phagocytosis

Receptor Mediated Endocytosis



(c) Receptor-mediated endocytosis

Passive Membrane Transport – Review

Process	Energy Source	Example
Simple diffusion	Kinetic energy	Movement of O ₂ through membrane
Facilitated diffusion	Kinetic energy	Movement of glucose into cells
Osmosis	Kinetic energy	Movement of H ₂ O in & out of cells
Filtration	Hydrostatic pressure	Formation of kidney filtrate

Active Membrane Transport – Review

Process	Energy Source	Example
Active transport of solutes	ATP	Movement of ions across membranes
Exocytosis	ATP	Neurotransmitter secretion
Endocytosis	ATP	White blood cell phagocytosis
Fluid-phase endocytosis	ATP	Absorption by intestinal cells
Receptor-mediated endocytosis	ATP	Hormone and cholesterol uptake
Endocytosis via caveoli	ATP	Cholesterol regulation
Endocytosis via coatomer vesicles	ATP	Intracellular trafficking of molecules

Membrane Potential

- Voltage across a membrane
- Resting membrane potential – the point where K^+ potential is balanced by the membrane potential
 - Ranges from -20 to -200 mV
 - Results from Na^+ and K^+ concentration gradients across the membrane
 - Differential permeability of the plasma membrane to Na^+ and K^+
- Steady state – potential maintained by active transport of ions

Generation and Maintenance of Membrane Potential

InterActive Physiology®:
Nervous System I: The Membrane Potential

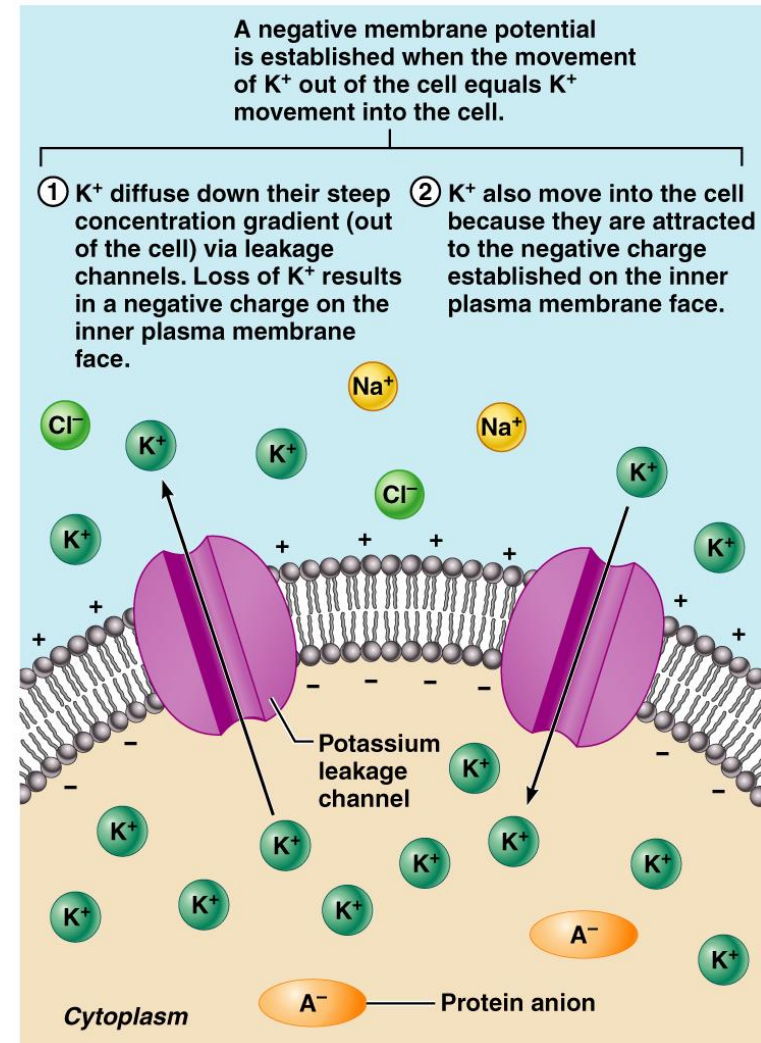


Figure 3.15