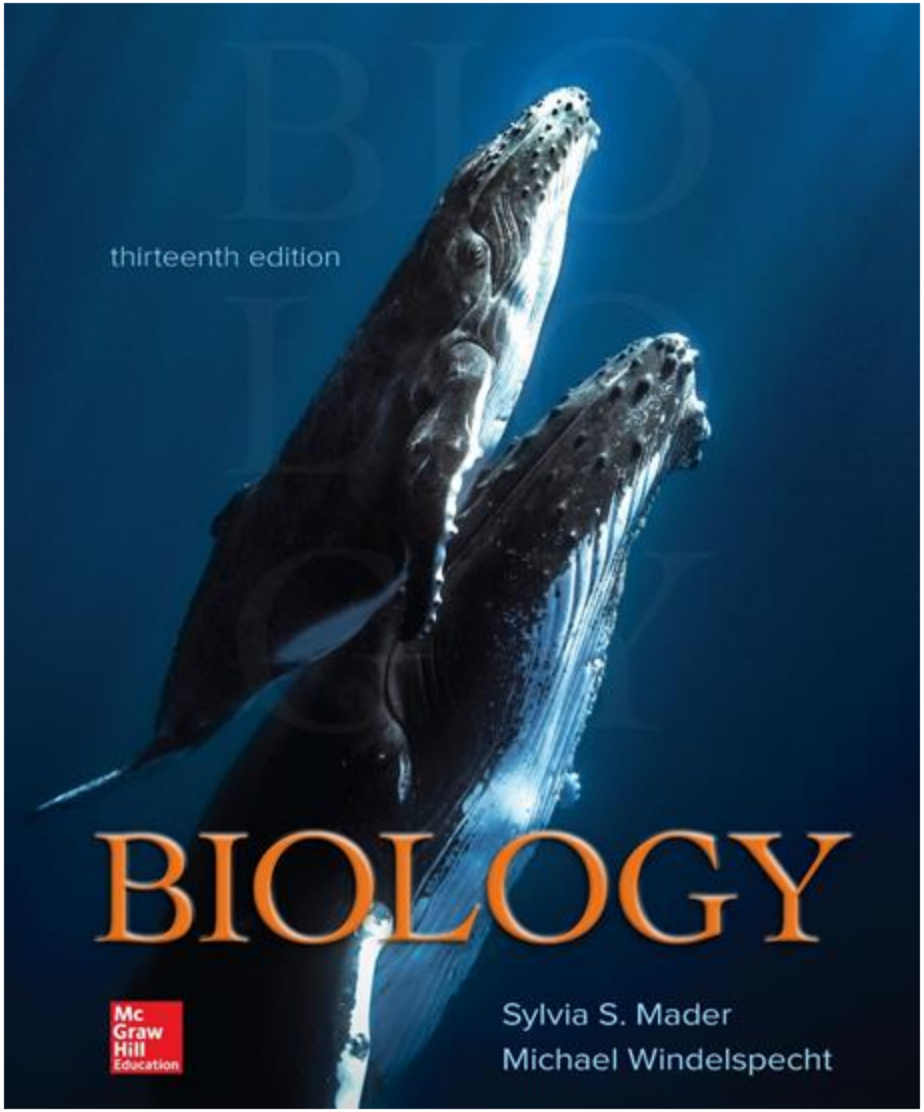


Biology

Sylvia S. Mader
Michael Windelspecht

Chapter 5
Membrane Structure and Function
Lecture Outline

See separate FlexArt PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.

Outline

5.1 Plasma Membrane Structure and Function

5.2 Passive Transport Across a Membrane

5.3 Active Transport Across a Membrane

5.4 Modification of Cell Surfaces

Introduction—What Is Capsaicin?

A hot pepper contains the substance capsaicin, which makes your mouth feel like it is on fire.

Capsaicin binds to a protein in the plasma membrane of pain receptors in your mouth.

When bound, these receptors open and calcium ions move through them into the cell.

The movement of calcium ions causes the pain receptor to send a signal to the brain, which the brain interprets as pain.

5.1 Plasma Membrane Structure and Function

The **plasma membrane** is common to all cells.

Separates:

- Internal cytoplasm from the external environment of the cell
- Allows sometimes incompatible chemical reactions to occur simultaneously
- Fluid mosaic model accounts for the structure

Phospholipid bilayer:

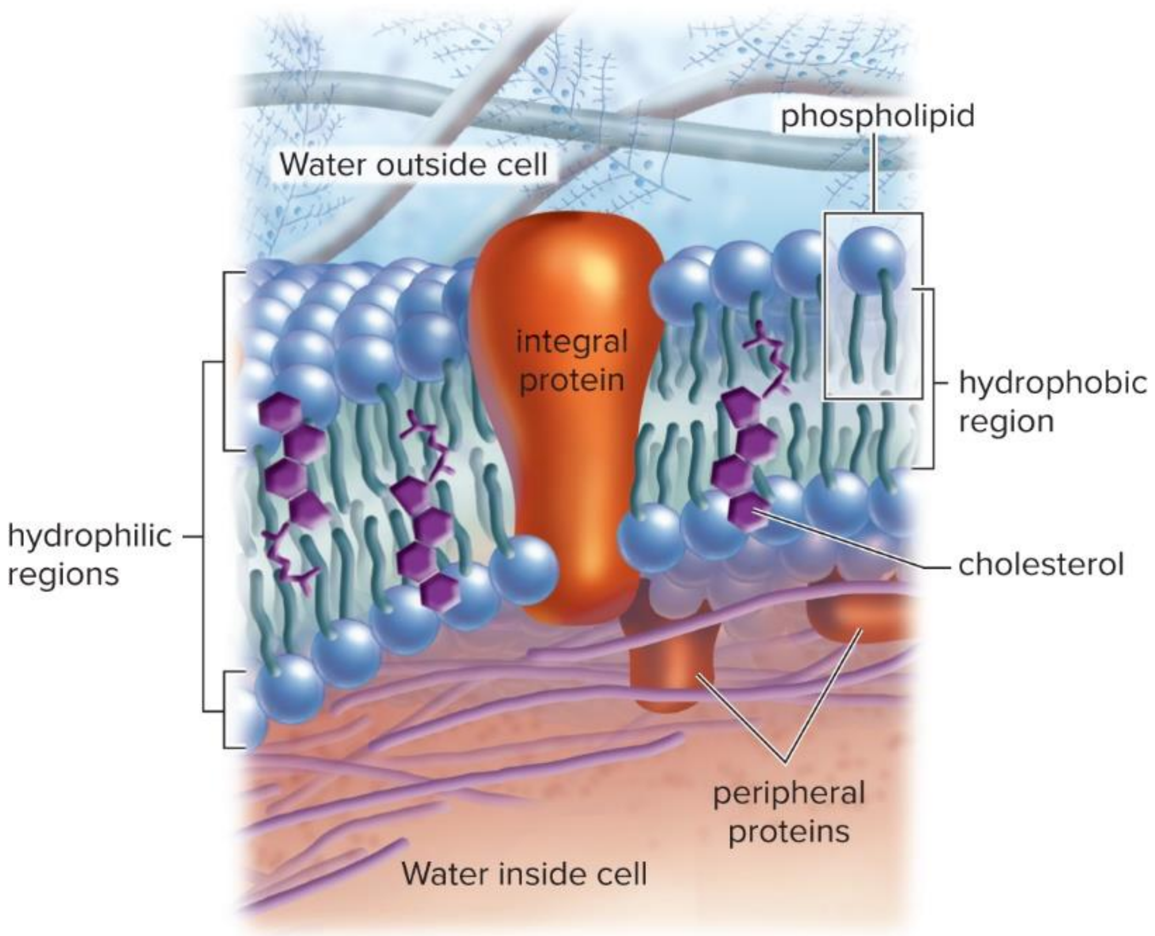
- External surface lined with hydrophilic polar heads
- Cytoplasmic surface lined with hydrophilic polar heads
- Nonpolar, hydrophobic, fatty-acid tails sandwiched in between

Plasma Membrane Structure and Function (1)

Components of the Plasma Membrane

- Three components:
  - Lipid component referred to as phospholipid bilayer
  - Protein molecules
    - Float around like icebergs on a sea
    - Membrane proteins may be peripheral or integral.
      - Peripheral proteins are found on the inner membrane surface.
      - Integral proteins are partially or wholly embedded (transmembrane) in the membrane.
  - **Cholesterol** affects the fluidity of the membrane.

Membrane Proteins



Plasma Membrane Structure and Function (2)

Carbohydrate Chains

- Contribute to cell's "fingerprint"
- The two "Gs" play a role in cellular identification.
  - Important in tissue transplantation and blood transfusions

Glycoproteins

- Proteins with attached carbohydrate chains

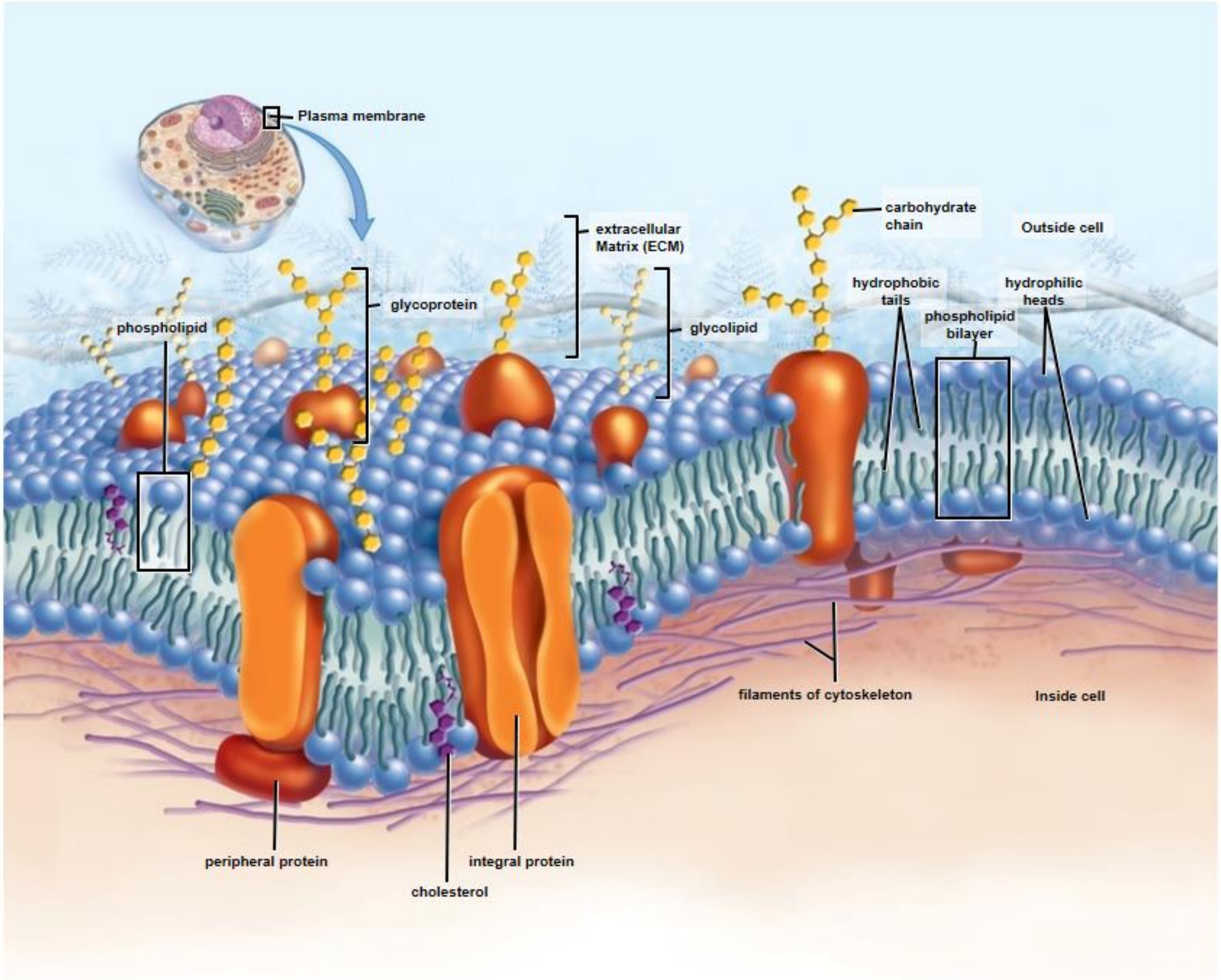
Glycolipids

- Lipids with attached carbohydrate chains

These carbohydrate chains exist only on the outside of the membrane.

- Makes the membrane asymmetrical

Fluid Mosaic Model of the Plasma Membrane



[Jump to Fluid Mosaic Model of the Plasma Membrane Long Description]

Plasma Membrane Structure and Function (3)

Functions of Membrane Proteins

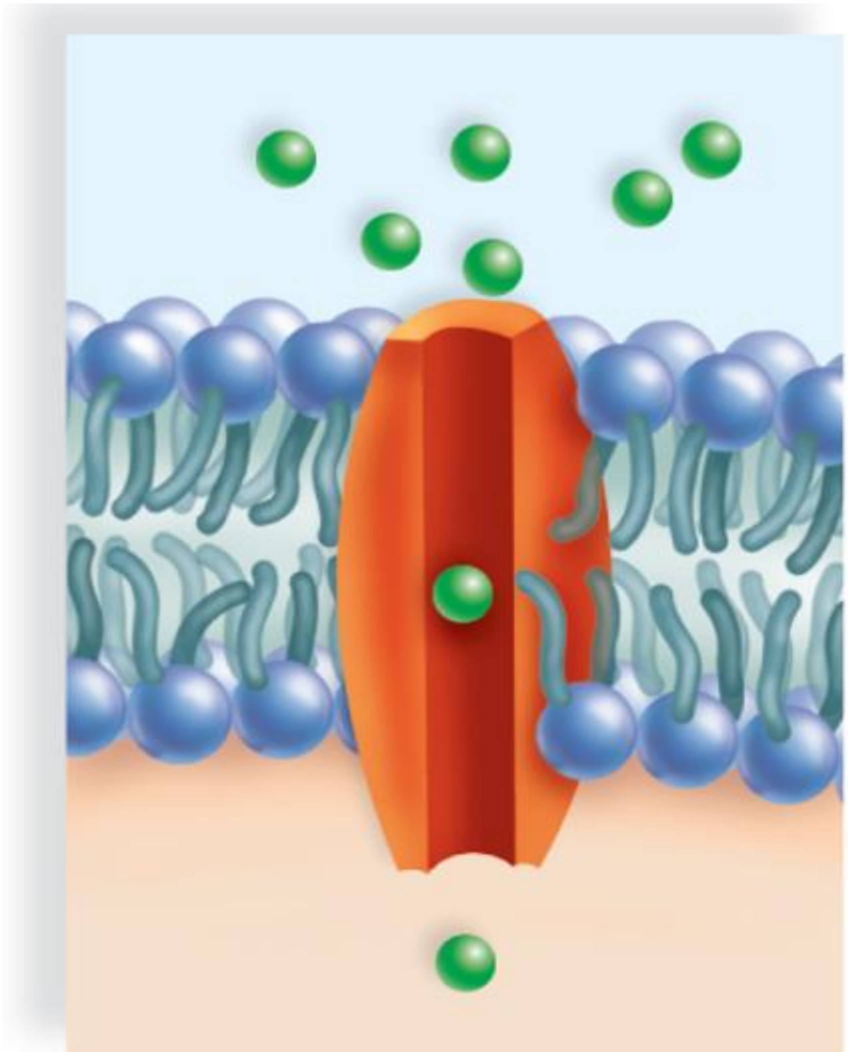
- **Channel Proteins**:
  - Allow passage of molecules through membrane via a channel in the protein
- **Carrier Proteins**:
  - Combine with the substance to be transported
  - Assist passage of molecules through membrane
- **Cell Recognition Proteins**:
  - Glycoproteins
  - Help the body recognize foreign substances

Plasma Membrane Structure and Function (4)

Functions of Membrane Proteins

- **Receptor Proteins**:
  - Bind with specific molecules
  - Allow a cell to respond to signals from other cells
- **Enzymatic Proteins**:
  - Carry out metabolic reactions directly
- **Junction Proteins**:
  - Attach adjacent cells

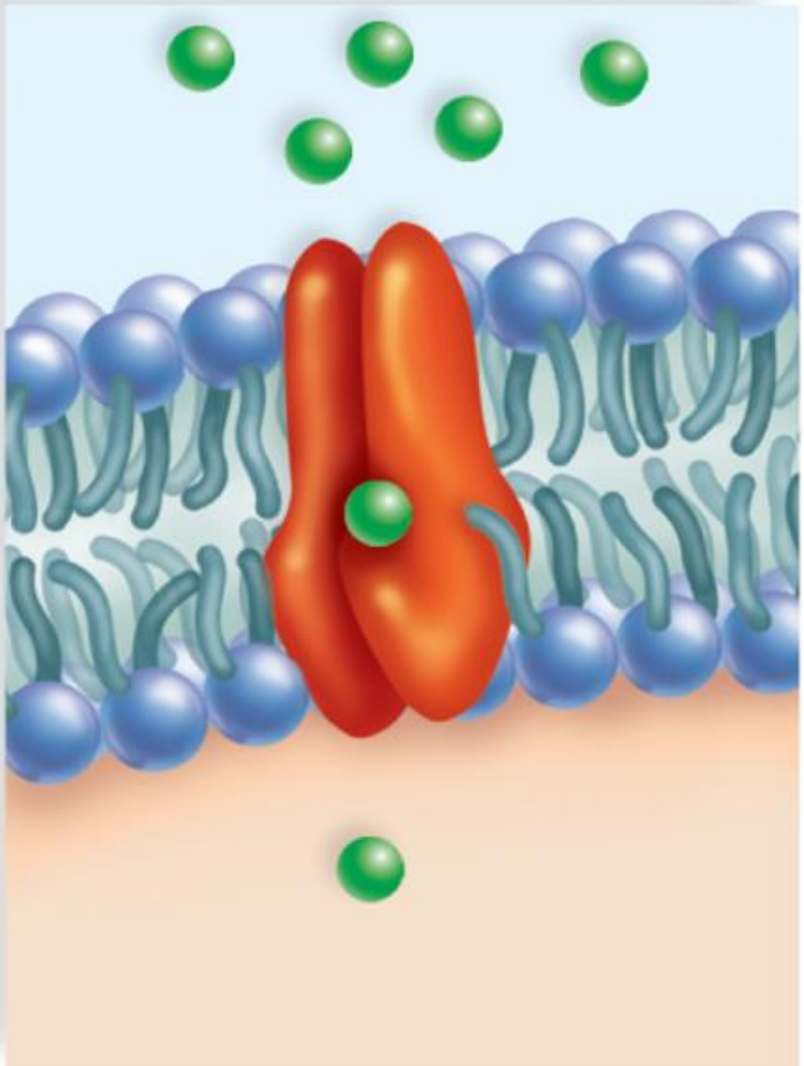
Membrane Protein Diversity (1)



a.

Channel Protein: Allows a particular molecule or ion to cross the plasma membrane freely. Cystic fibrosis, an inherited disorder, is caused by a faulty chloride (Cl^-) channel; a thick mucus collects in airways and in pancreatic and liver ducts.

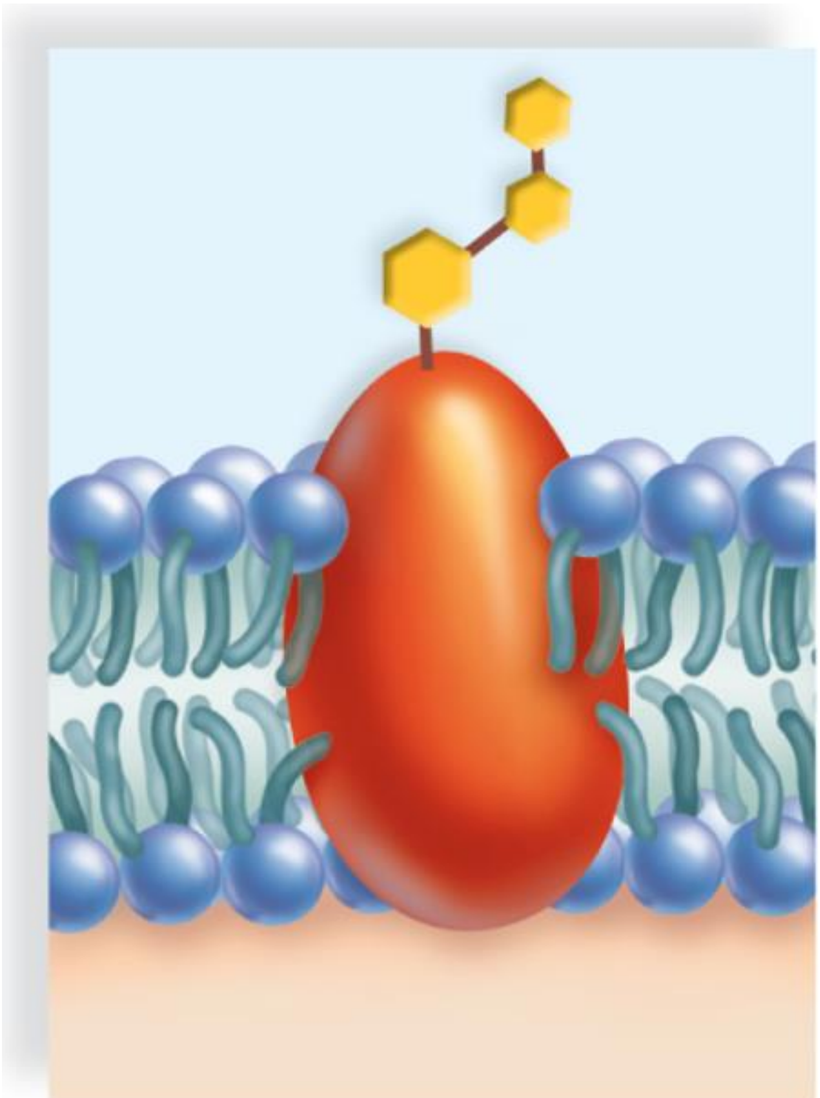
Membrane Protein Diversity (2)



b.

Carrier Protein: Selectively interacts with a specific molecule or ion so that it can cross the plasma membrane. The inability of some persons to use energy for sodium-potassium ($Na^+ - K^+$) transport has been suggested as the cause of their obesity.

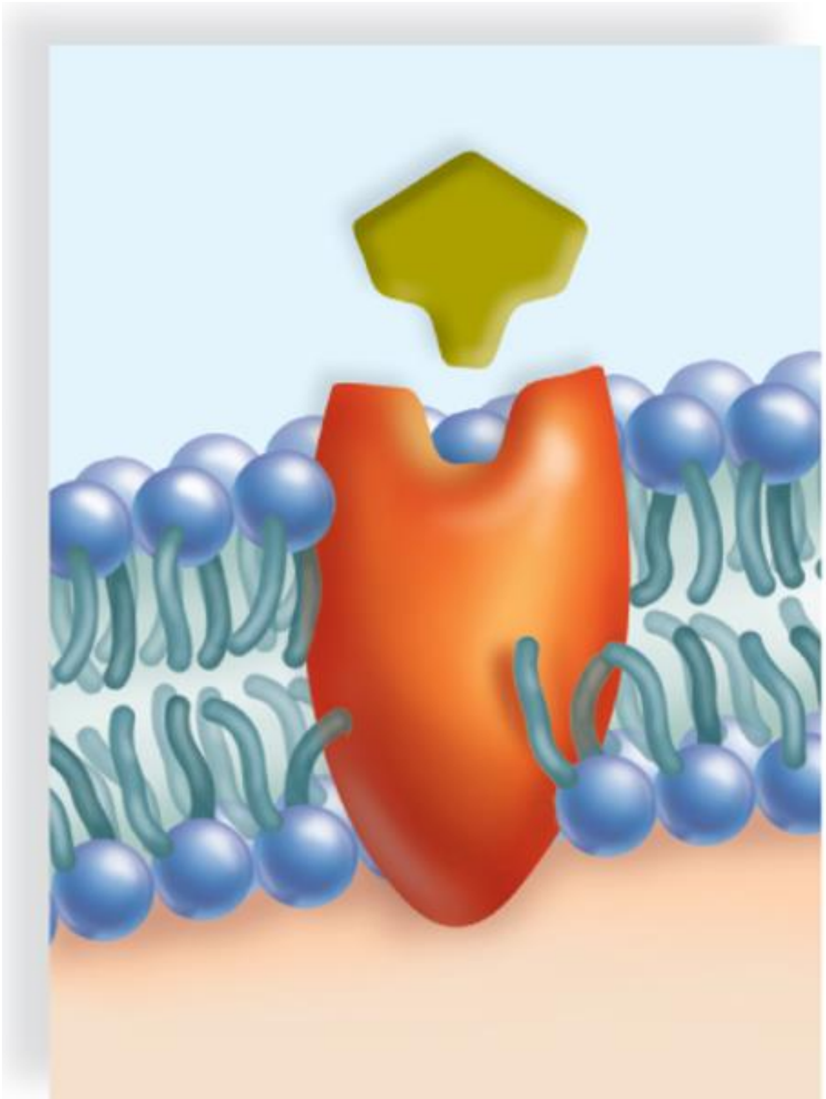
Membrane Protein Diversity (3)



c.

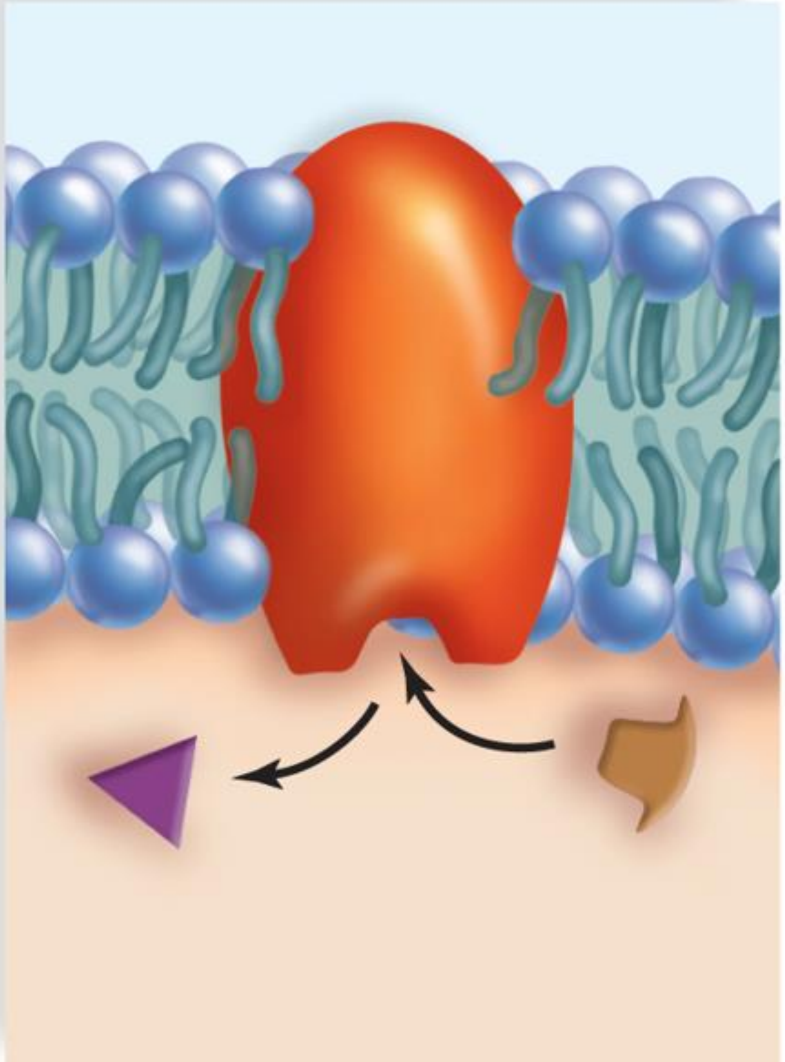
Cell Recognition Protein: The MHC (major histocompatibility complex) glycoproteins are different for each person, so organ transplants are difficult to achieve. Cells with foreign MHC glycoproteins are attacked by white blood cells responsible for immunity.

Membrane Protein Diversity (4)


d.

Receptor Protein: Is shaped in such a way that a specific molecule can bind to it. Some forms of dwarfism result not because the body does not produce enough growth hormone, but because their plasma membrane growth hormone receptors are faulty and cannot interact with growth hormone.

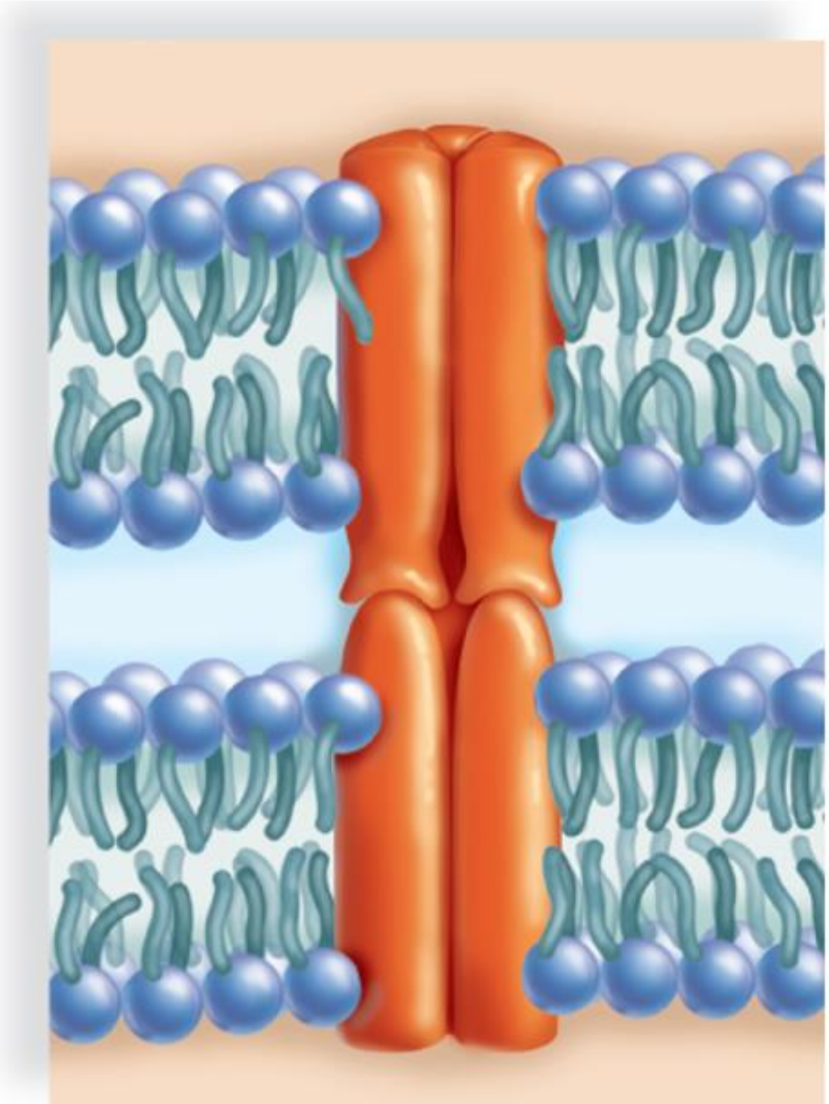
Membrane Protein Diversity (5)



e.

Enzymatic Protein: Catalyzes a specific reaction. The membrane protein, adenylate cyclase, is involved in ATP metabolism. Cholera bacteria release a toxin that interferes with the proper functioning of adenylate cyclase; sodium (Na^+) and water leave intestinal cells, and the individual may die from severe diarrhea.

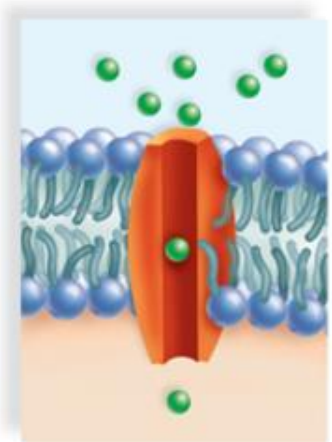
Membrane Protein Diversity (6)



f.

Junction Proteins: Tight junctions join cells so that a tissue can fulfill a function, as when a tissue pinches off the neural tube during development. Without this cooperation between cells, an animal embryo would have no nervous system.

Membrane Protein Diversity (7)



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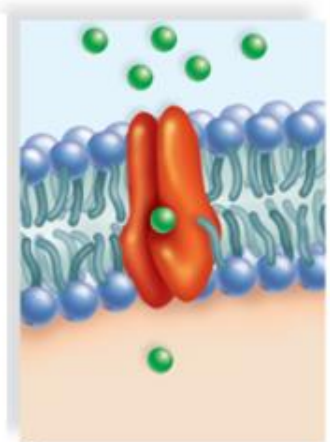

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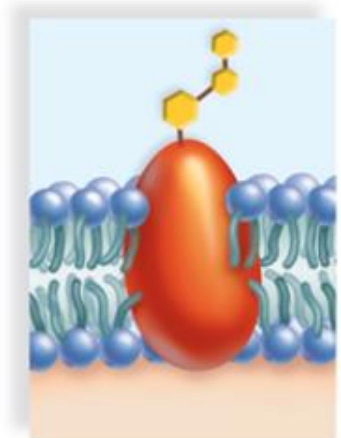

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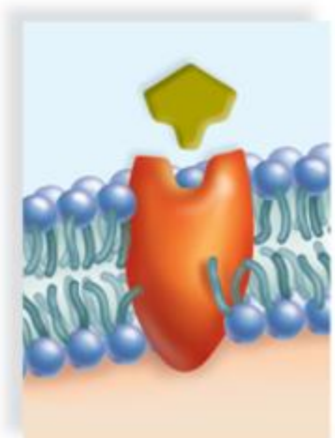

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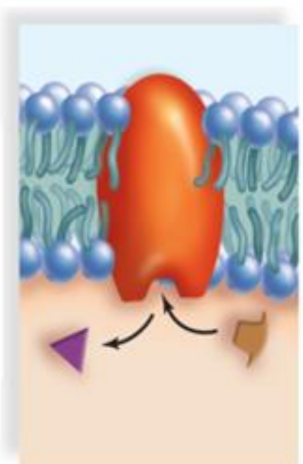

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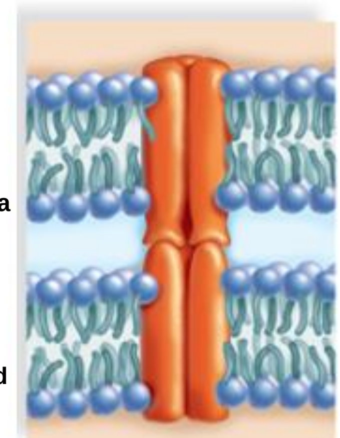


f.

Junction Proteins: Tight junctions join cells so that a tissue can fulfill a function, as when a tissue pinches off the neural tube during development. Without this cooperation between cells, an animal embryo would have no nervous system.

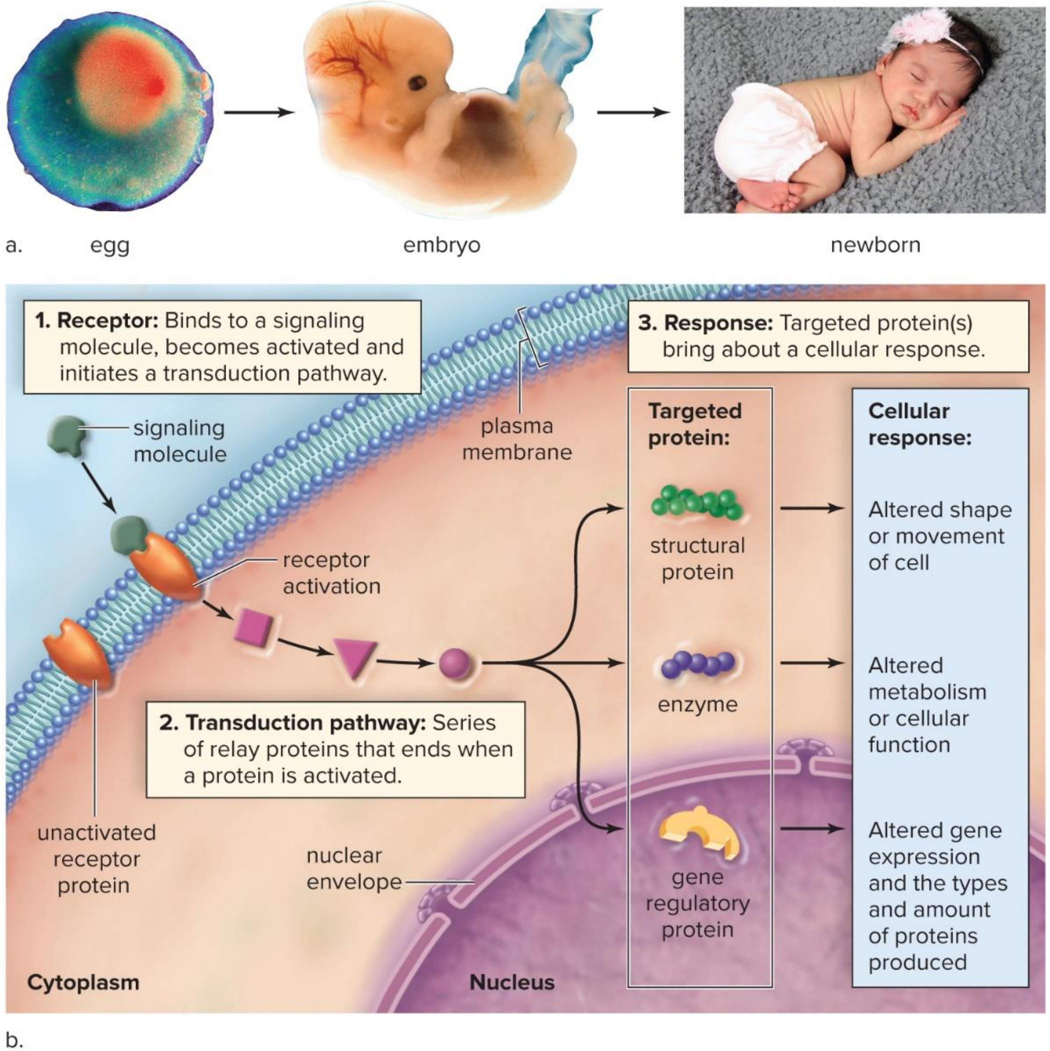
[Jump to Membrane Protein Diversity (7) Long Description]

How Cells Talk to One Another

Signaling molecules serve as chemical messengers, allowing cells to communicate with one another.

- Cell receptors bind to specific signaling molecules.
- Once the signaling molecule and the cell receptor bind, a cascade of events occurs that elicits a cellular response.
  - Signal transduction pathway
    - Example: The pancreas releases the hormone insulin, which is transported to blood vessels in the liver; this causes the liver to store glucose (blood sugar) as glycogen.
    - Failure to store glucose as glycogen causes a medical condition called diabetes.

Cell Signaling



(a):(egg):©Anatomical Travelogue/Science Source; (embryo): ©Neil Harding/Stone/Getty Images;(newborn): ©Hannamariah/123RF

[Jump to Cell Signaling Long Description]

Plasma Membrane Structure and Function (5)

Permeability of the Plasma Membrane

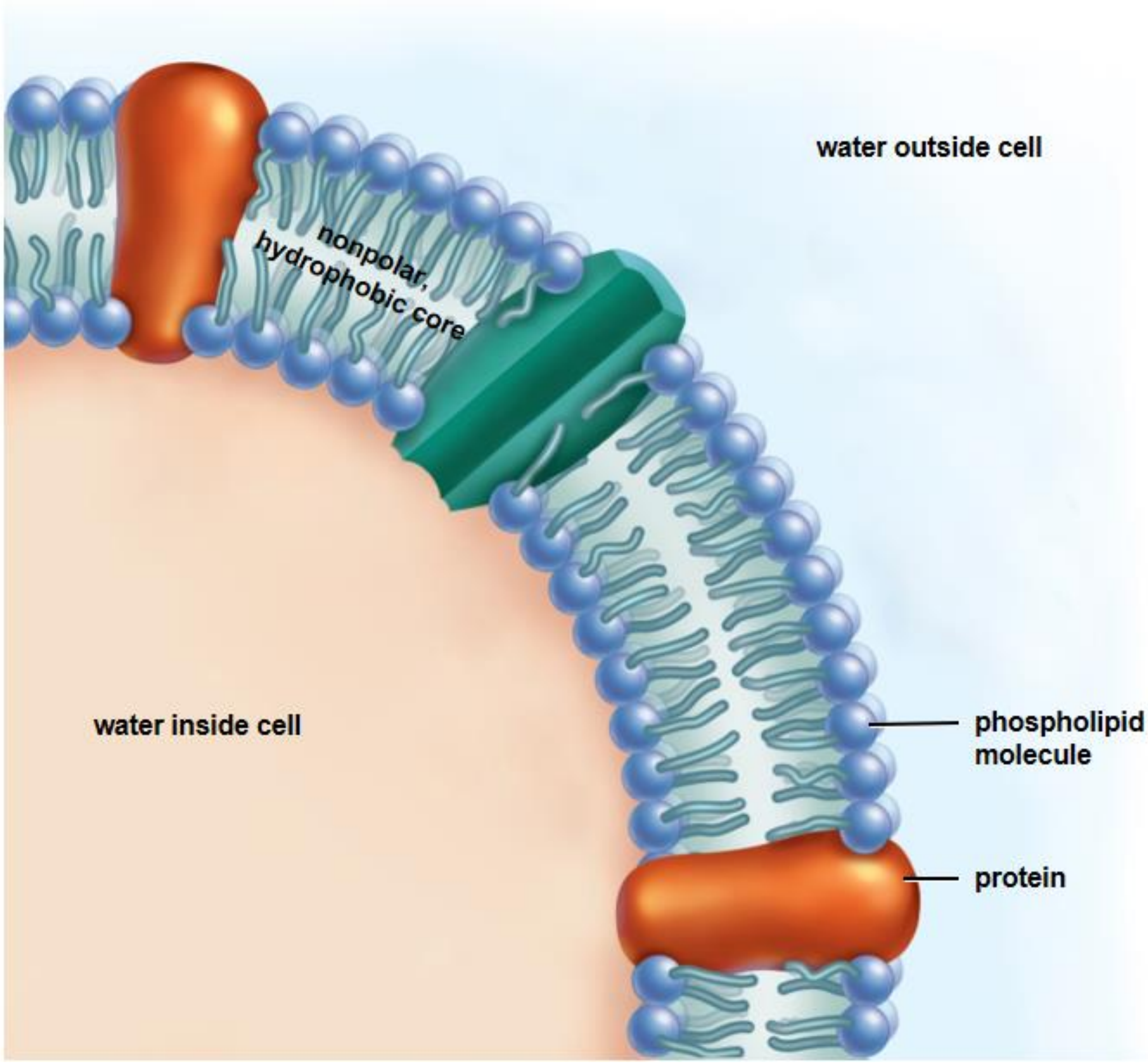
- The plasma membrane is **selectively permeable**.
  - Allows some substances to move across the membrane
  - Inhibits passage of other molecules such as polar molecules
- Small, non-charged molecules (CO_2, O_2, glycerol, alcohol) freely cross the membrane by passing through the phospholipid bilayer.
  - These molecules follow their **concentration gradient**.
    - Move from an area where they are in high concentration to an area of low concentration

Plasma Membrane Structure and Function (6)

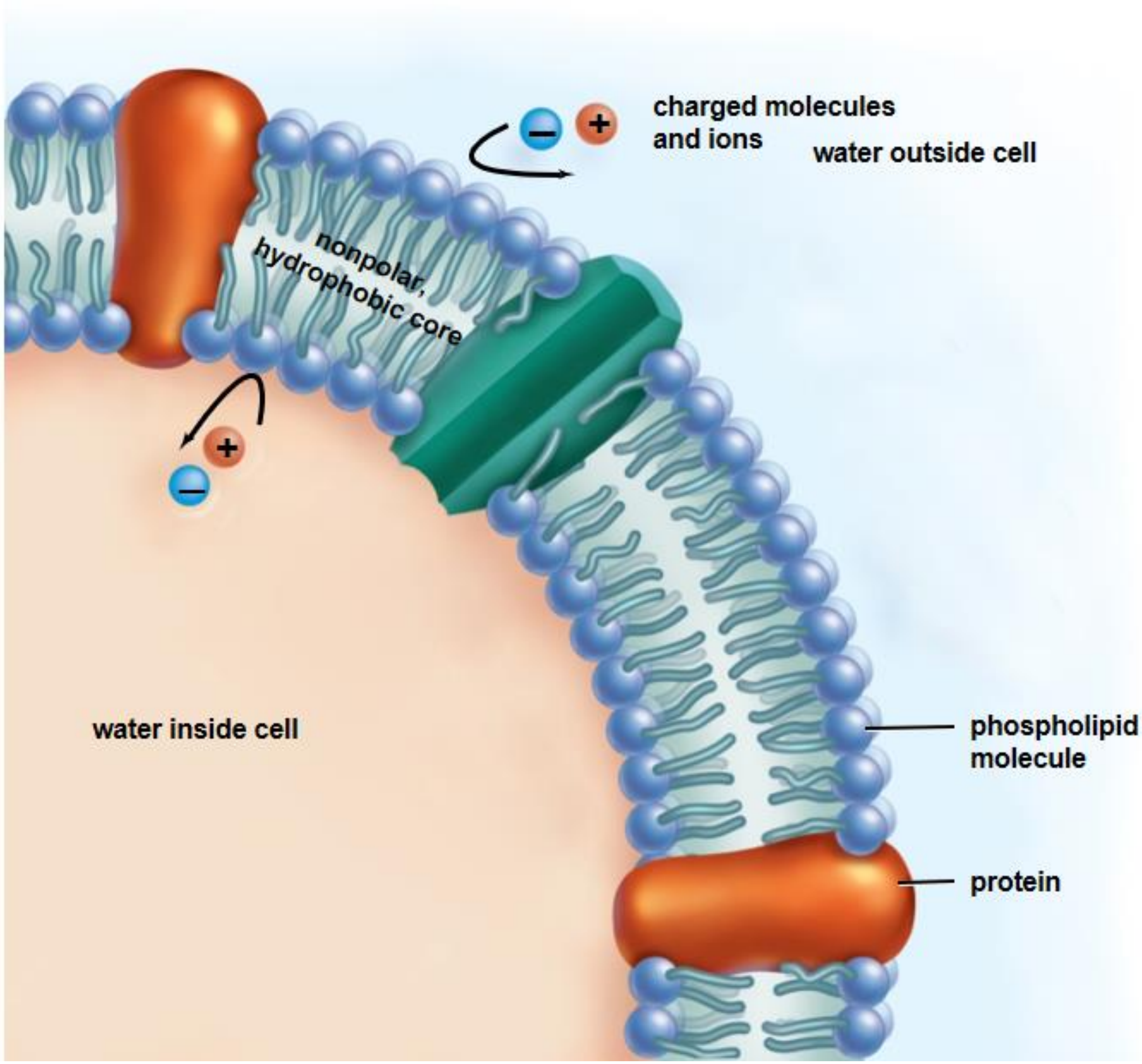
Permeability of the Plasma Membrane

- Water moves across the plasma membrane.
  - Specialized proteins termed **aquaporins** speed up water transport across the membrane.
- The movement of ions and polar molecules across the membrane is often assisted by carrier proteins.
- Some molecules must move against their concentration gradient with the expenditure of energy.
  - Active transport
- Bulk transport is the way large particles enter or exit the cell.
  - Exocytosis – fusion of a vesicle with the plasma membrane moves a particle to outside the membrane
  - Endocytosis – vesicle formation moves a particle to inside the plasma membrane

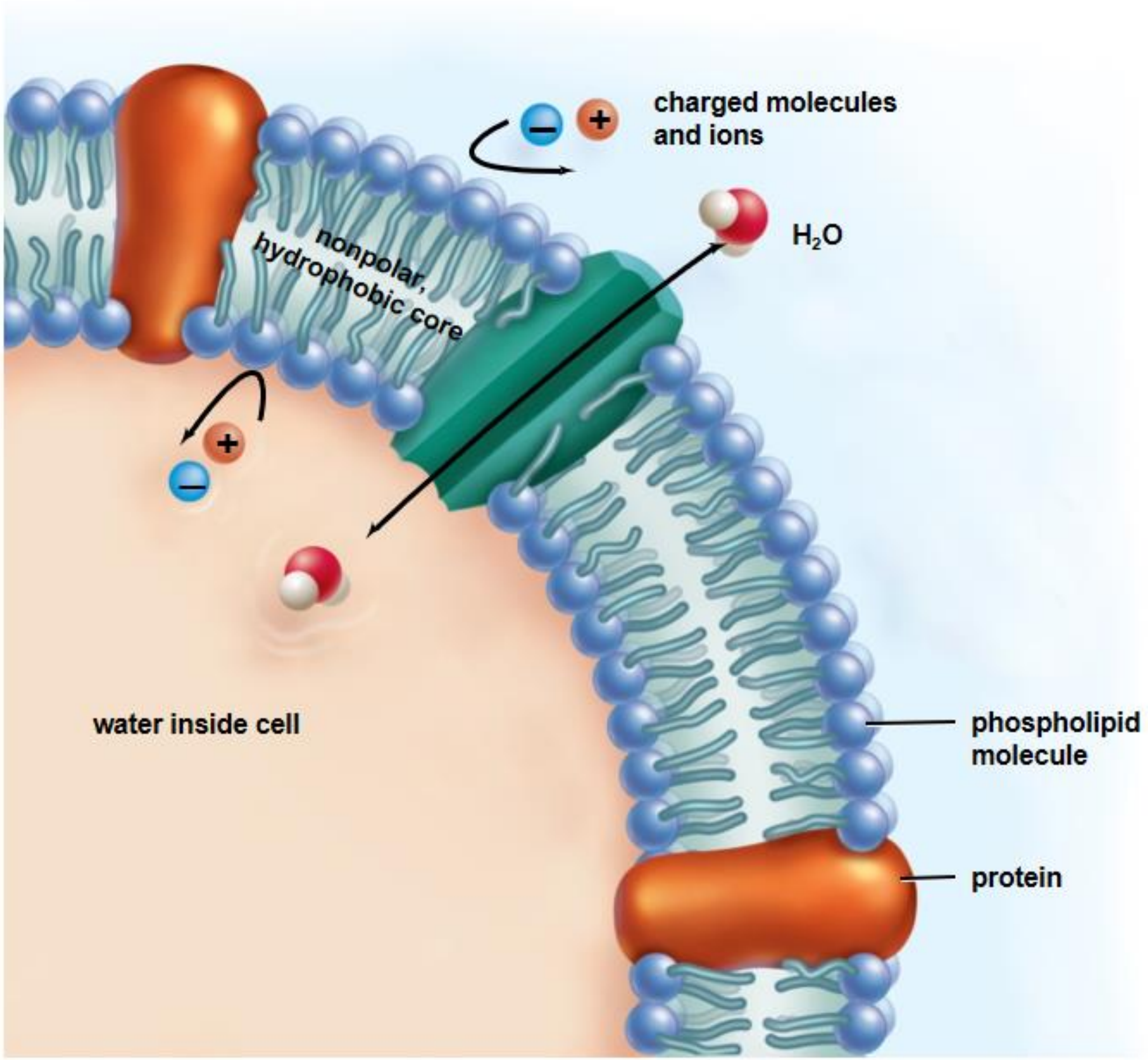
How Molecules Cross the Plasma Membrane (1)



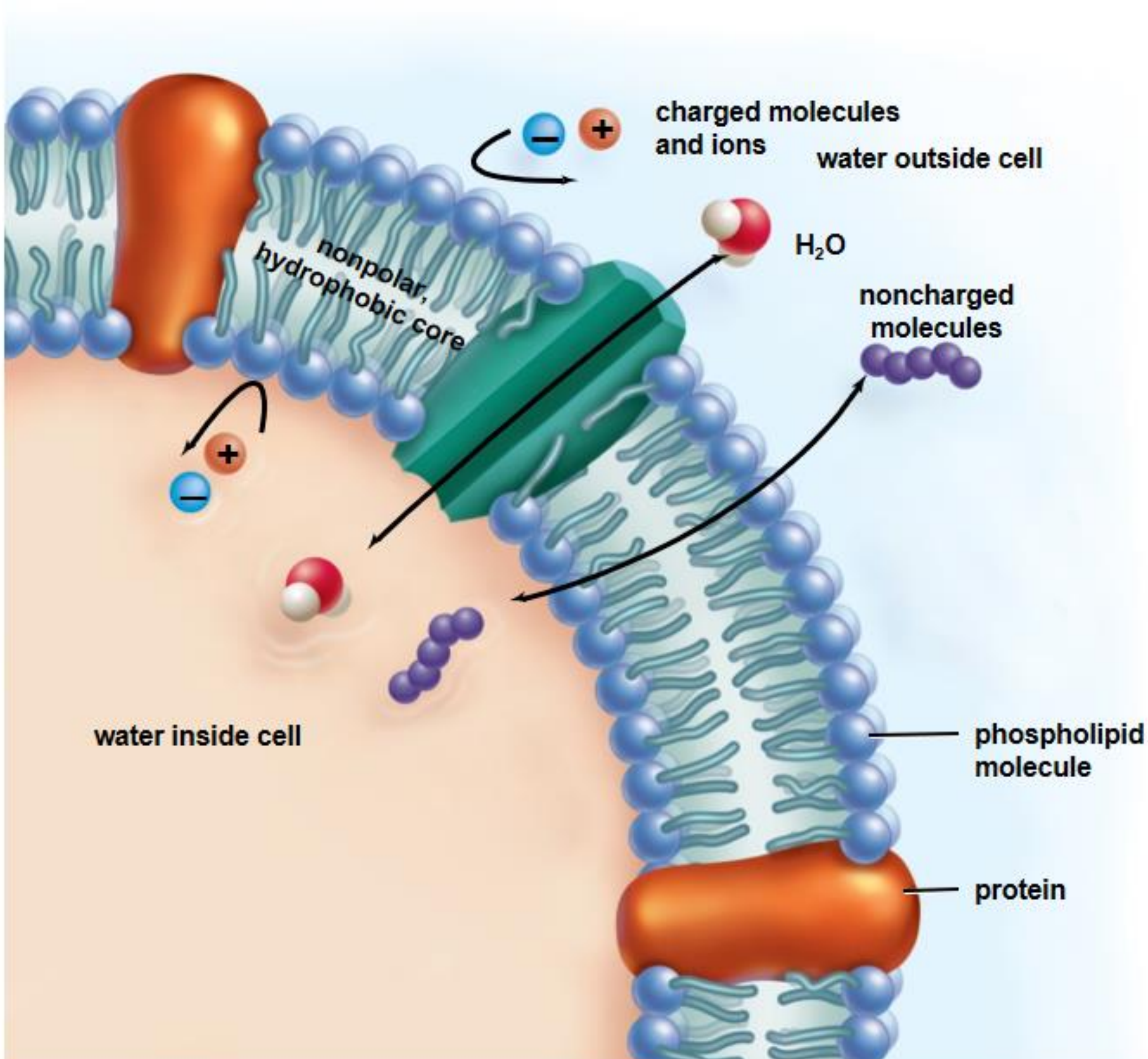
How Molecules Cross the Plasma Membrane (2)



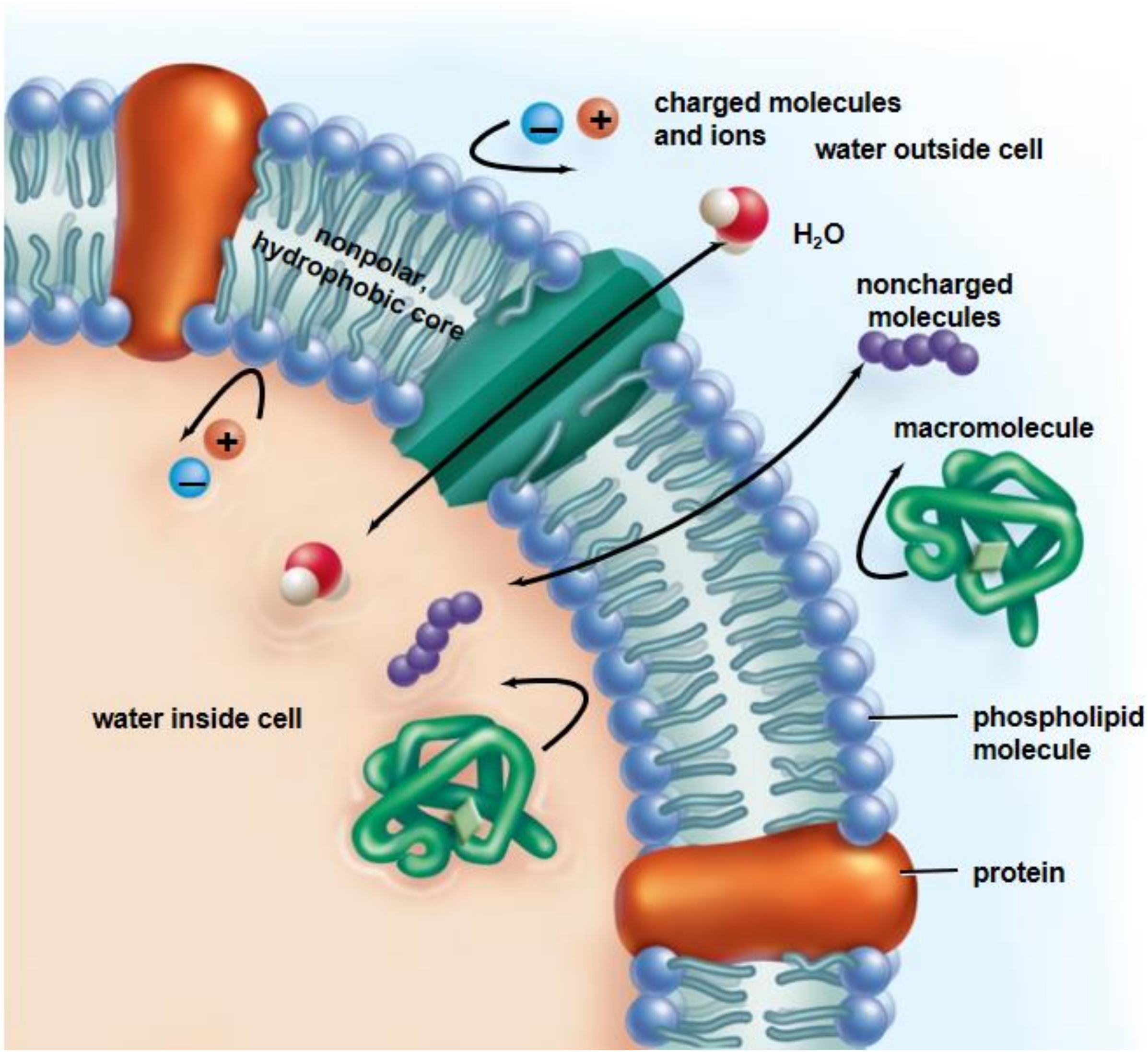
How Molecules Cross the Plasma Membrane (3)



How Molecules Cross the Plasma Membrane (4)



How Molecules Cross the Plasma Membrane (5)



Jump to How Molecules Cross the Plasma Membrane (5) Long Description

Passage of Molecules into and out of the Cell

Table 5.1 Passage of Molecules into and out of the Cell

Name	Direction	Requirement	Examples
Diffusion	Toward lower concentration	Concentration gradient	Lipid-soluble molecules, gases
Facilitated transport	Toward lower concentration	Channels or carrier and concentration gradient	Some sugars, amino acids
Active transport	Toward higher concentration	Carrier plus energy	Sugars, amino acids, ions
Bulk transport	Toward outside or inside	Vesicle utilization	Macromolecules

5.2 Passive Transport Across a Membrane

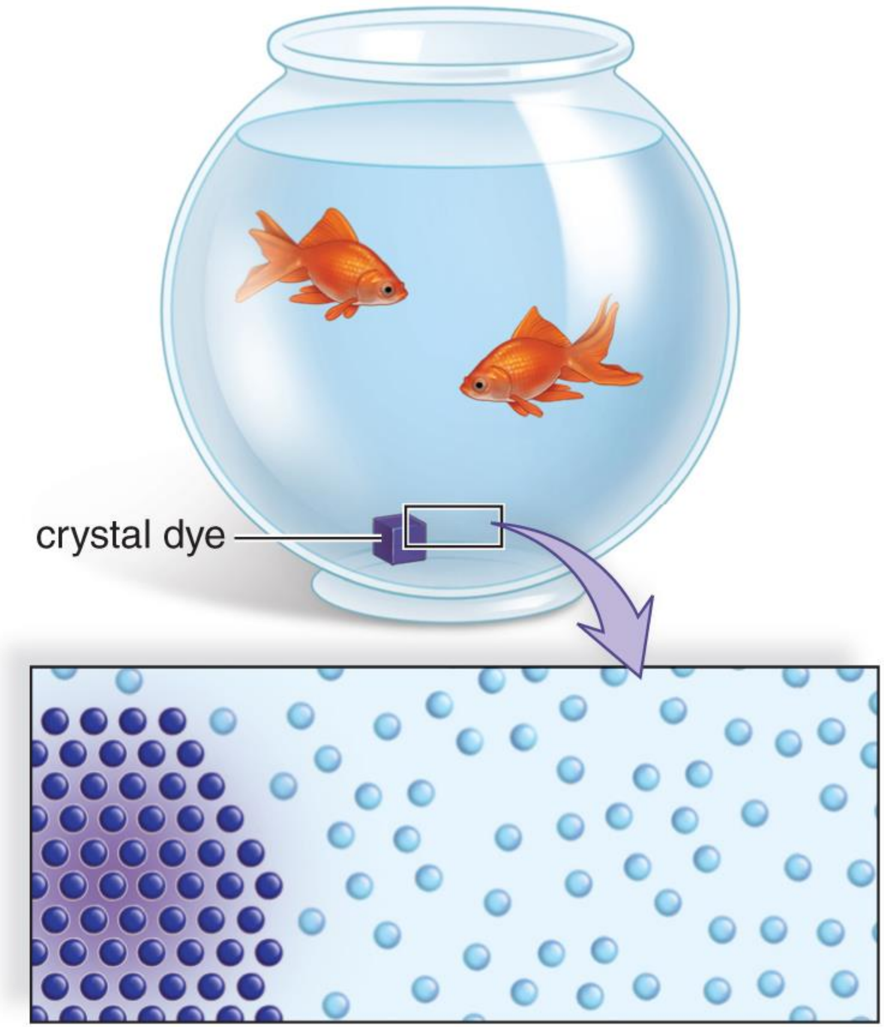
A **solution** consists of:

- A **solvent** (liquid), and
- A **solute** (dissolved solid)

Diffusion

- Diffusion is the net movement of molecules down a concentration gradient.
- Molecules move both ways along the gradient, but net movement is from high to low concentration.
- Equilibrium:
  - When NET movement stops
  - Solute concentration is uniform — no gradient.
- Temperature, pressure, electrical currents, and molecular size affect the rate of diffusion.

Process of Diffusion (1)



a.Crystal of dye is placed in the water

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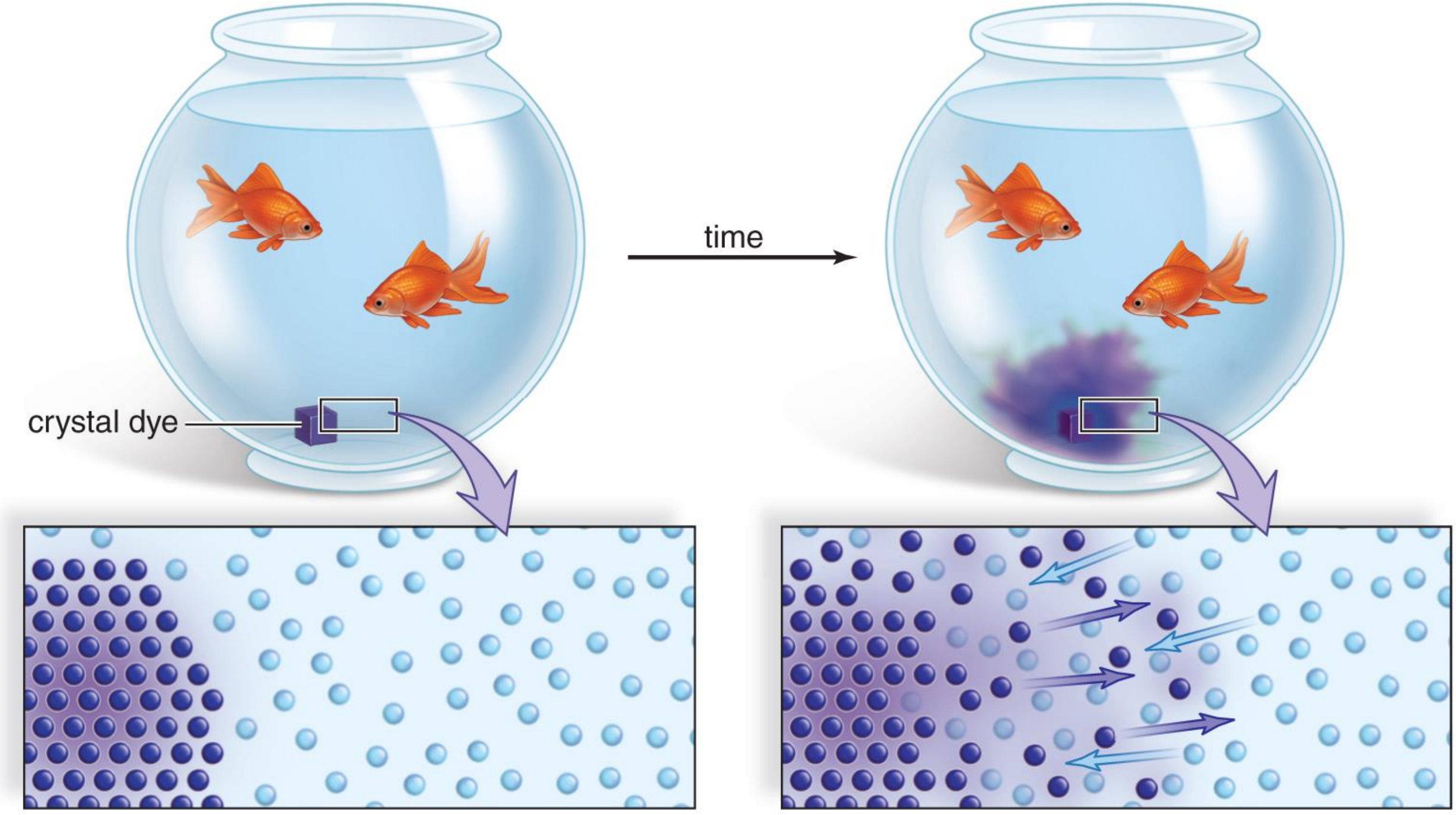
Process of Diffusion (2)



a. Crystal of dye is placed in the water.

b. Diffusion of water and dye molecules

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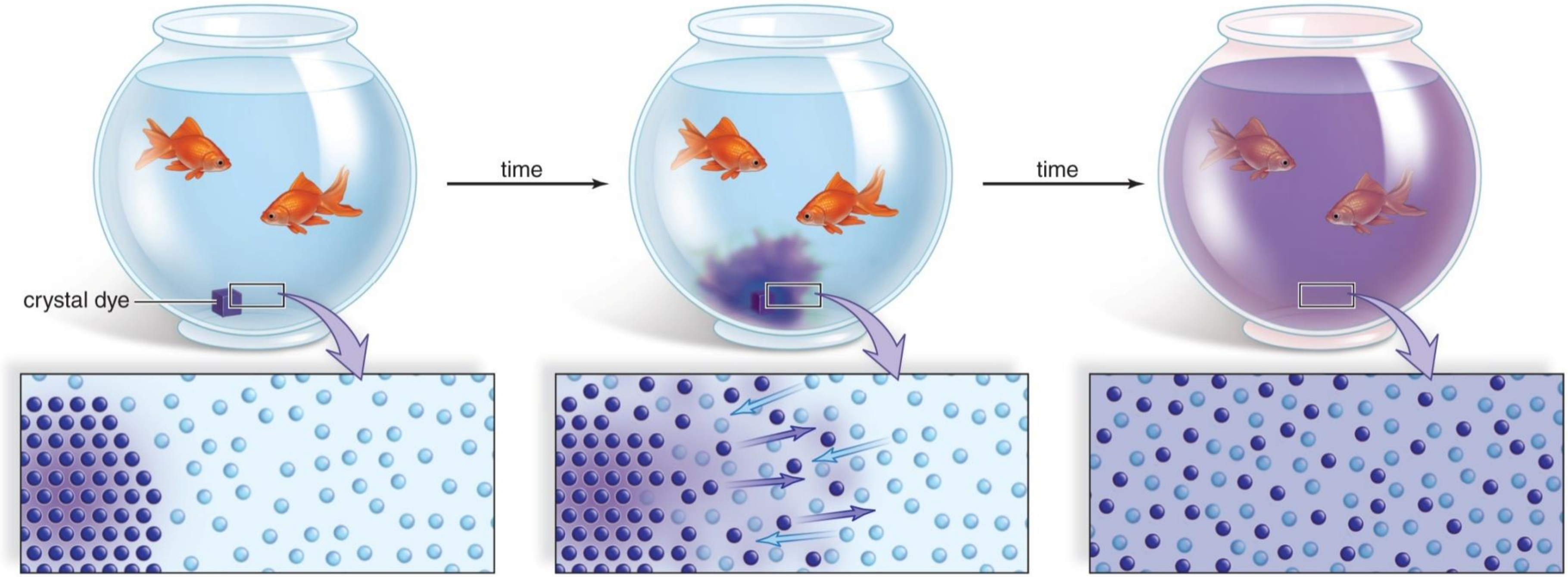
Process of Diffusion (3)



a. Crystal of dye is placed in the water
b. Diffusion of water and dye molecules
c. Equal distribution of molecules results

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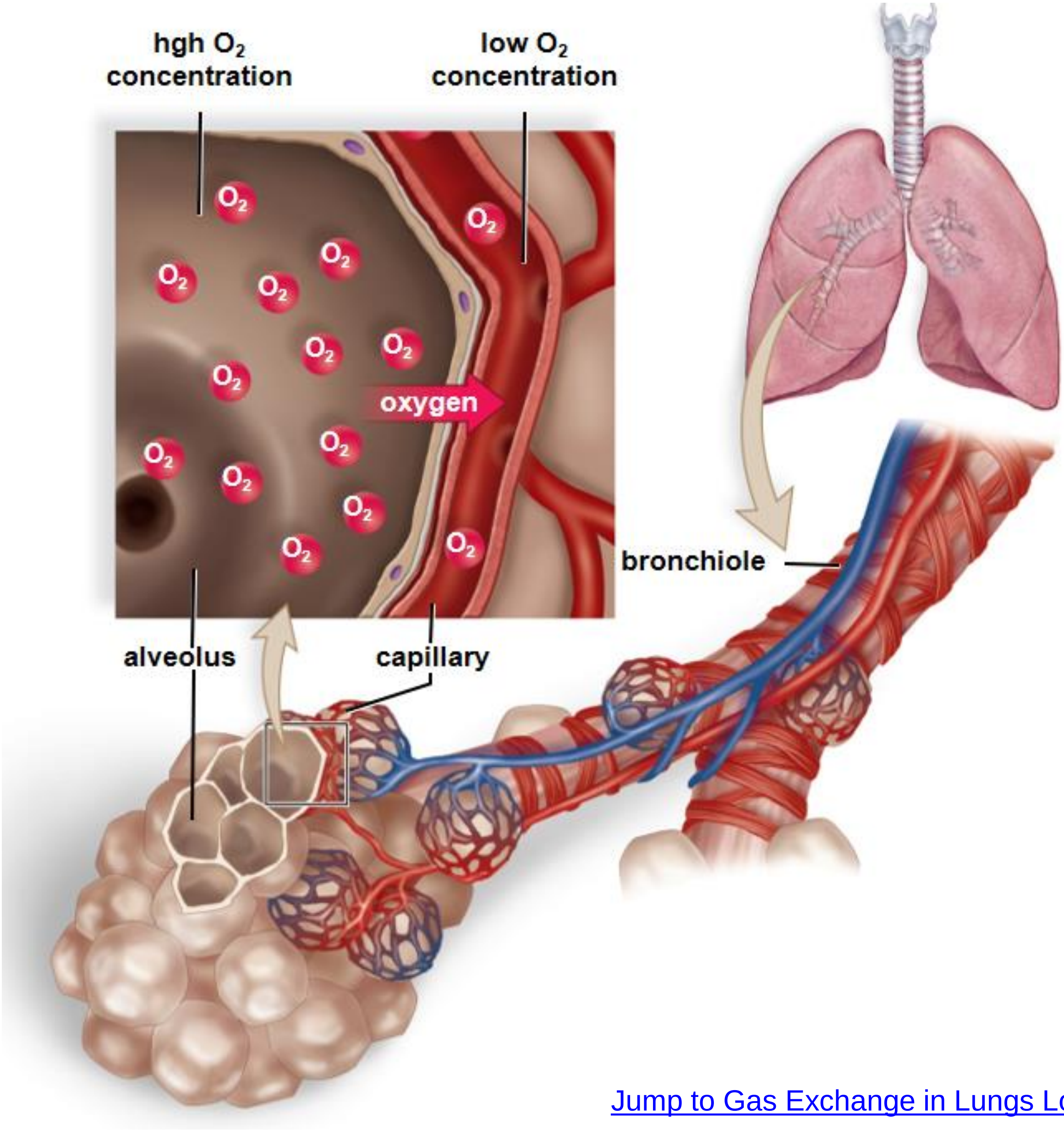
Jump to Process of Diffusion (3) Long Description

Gas Exchange in Lungs



Jump to Gas Exchange in Lungs Long Description

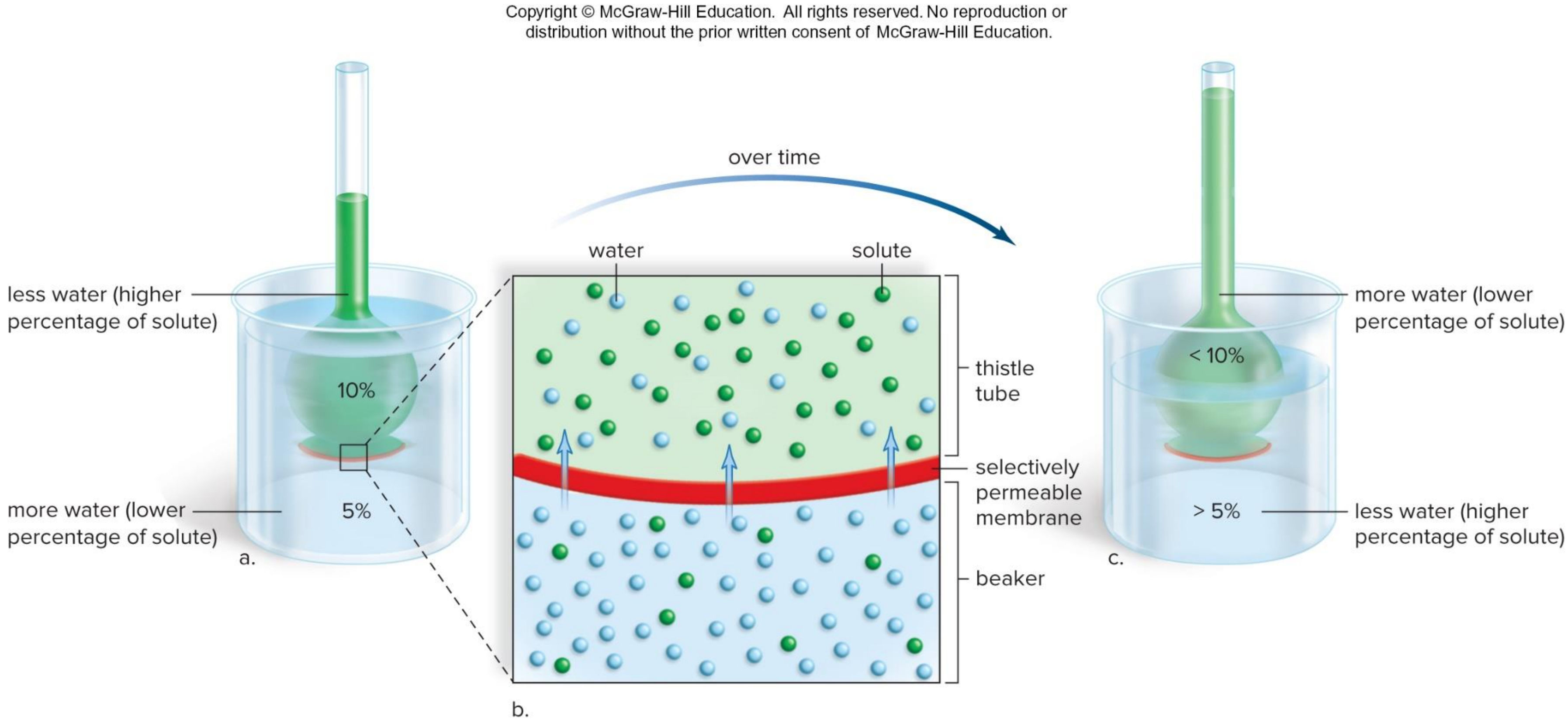
Passive Transport Across a Membrane (1)

Osmosis:

- Special case of diffusion
- Focuses on solvent (water) movement rather than solute
- Diffusion of water across a selectively permeable membrane
  - The solute concentration on one side is high, but the water concentration is low.
  - The solute concentration on other side is low, but the water concentration is high.
- Water can diffuse both ways across the membrane, but the solute cannot.
- Net movement of water is toward low water (high solute) concentration.

Osmotic pressure is the pressure that develops due to osmosis.

Osmosis Demonstration



Jump to Osmosis Demonstration Long Description

Passive Transport Across a Membrane (2)

Isotonic Solutions

- Solute and water concentrations are equal on both sides of cellular membrane.
- There is no net gain or loss of water by the cell.

Hypotonic Solutions

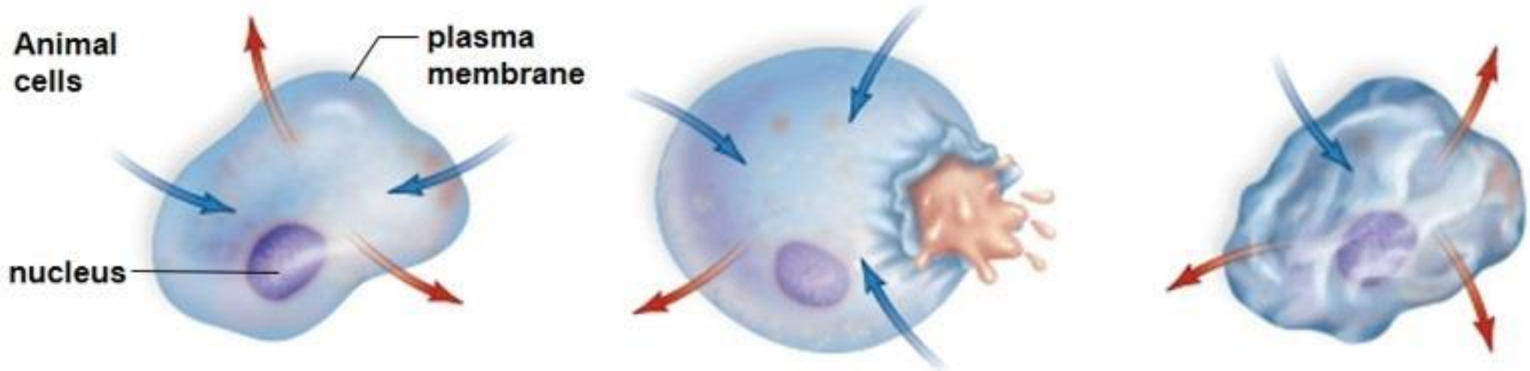
- Concentration of solute in the solution is *lower* than inside the cell.
- Cells placed in a hypotonic solution will swell.
  - Causes **turgor pressure** in plants
  - May cause animal cells to lyse (rupture)
- Protozoans living in fresh water environments have contractile vacuoles to rid themselves of excess water.

Passive Transport Across a Membrane (3)

Hypertonic Solutions

- Concentration of solute is *higher* in the solution than inside the cell.
- Cells placed in a hypertonic solution will shrink.
  - **Crenation** in animal cells
    - Example of red blood cells placed in a hypertonic solution (higher than 0.9% sodium chloride)
  - **Plasmolysis** in plant cells
    - Examples are dead plants along a salted roadway and marine animals that are able to make their blood isotonic with the environment.

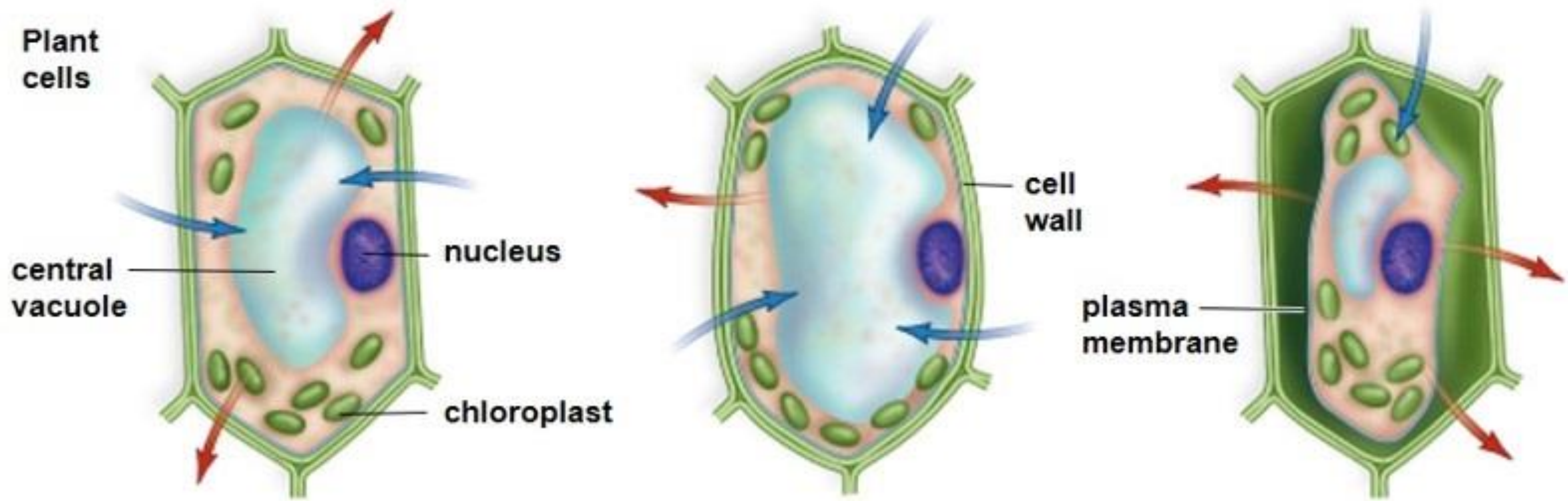
Osmosis in Animal and Plant Cells



In an isotonic solution, there is no net movement of water.

In a hypotonic solution, water mainly enters the cell, which may burst (lysis).

In a hypertonic solution, water mainly leaves the cell, which shrivels (crenation).



In an isotonic solution, there is no net movement of water.

In a hypotonic solution, vacuoles fill with water, turgor pressure develops, and chloroplasts are seen next to the cell wall.

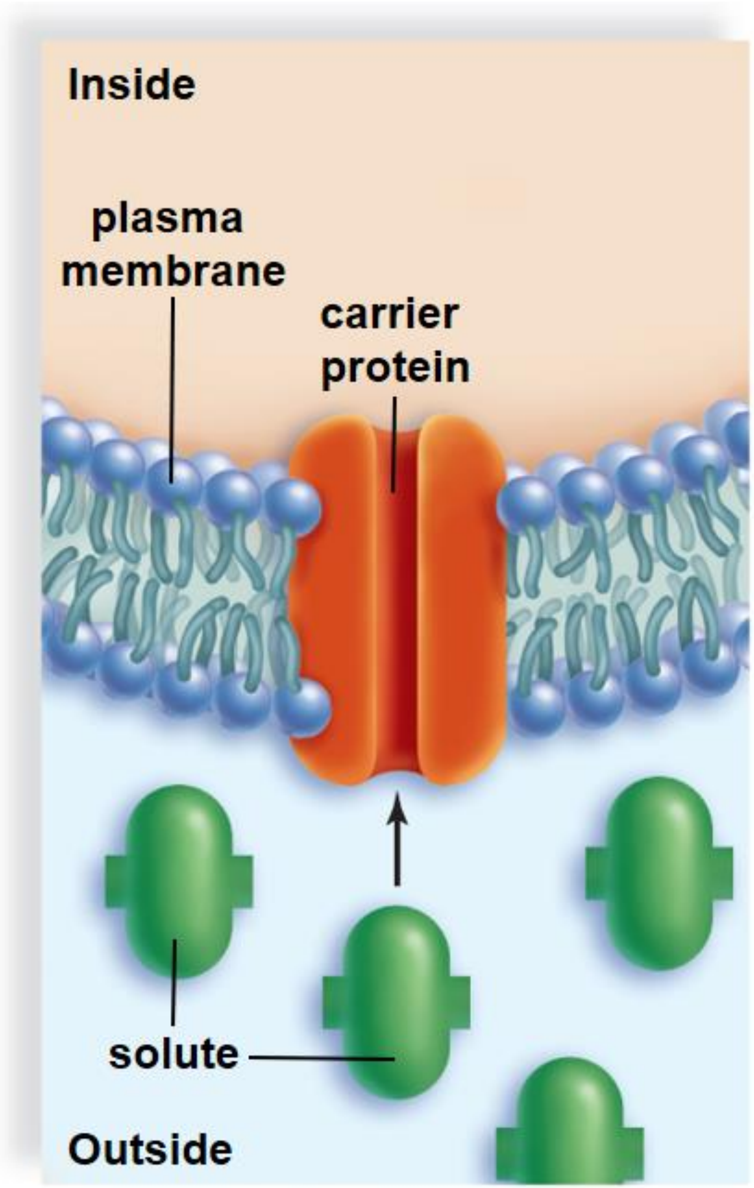
In a hypertonic solution, vacuoles lose water, the cytoplasm shrinks (plasmolysis), and chloroplasts are seen in the center of the cell.

Passive Transport Across a Membrane (4)

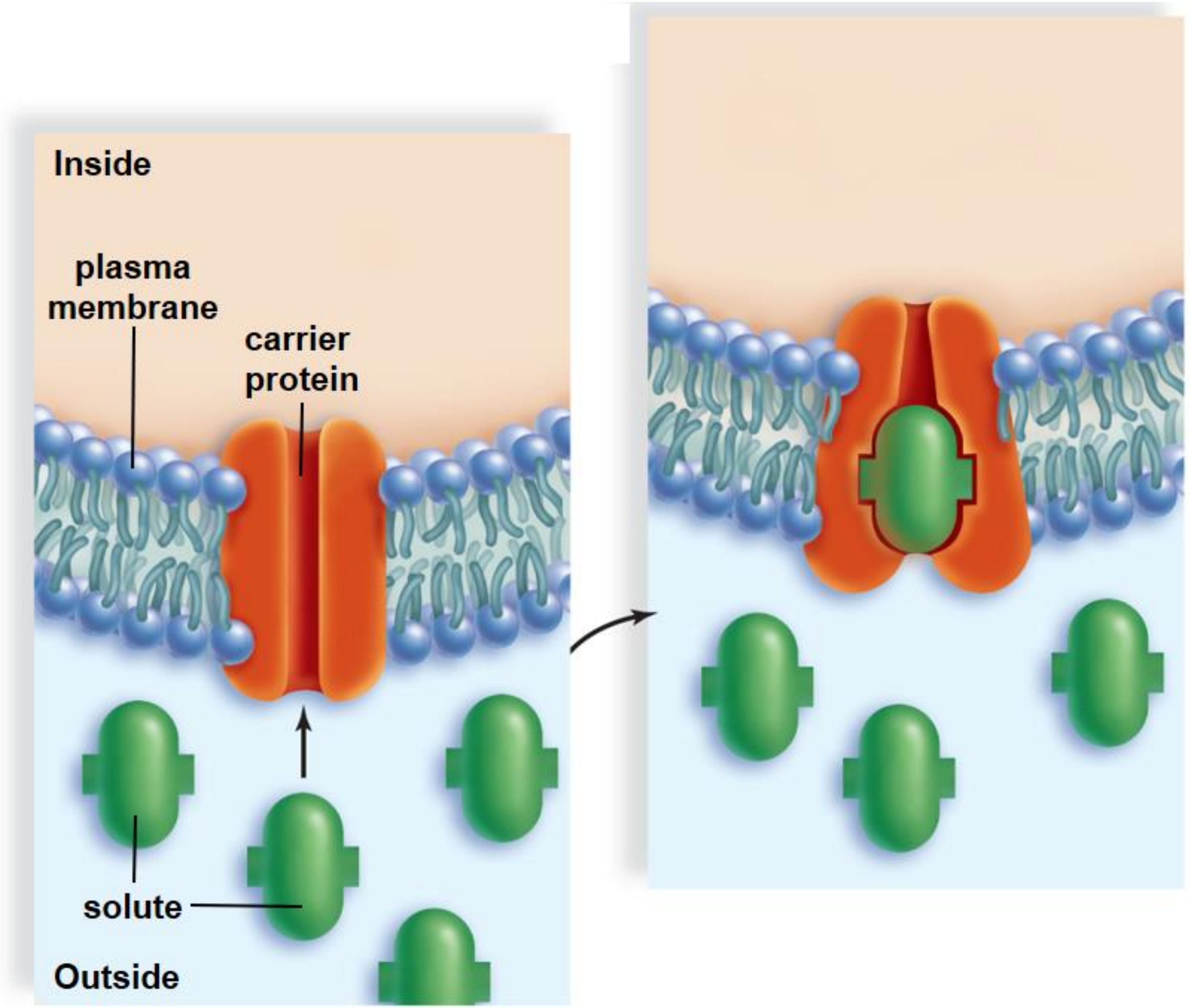
Facilitated Transport

- Movement of molecules cannot pass directly through the membrane lipids.
  - Examples: glucose and amino acids
- These molecules must combine with specific carrier proteins to move across the membrane.
- Follow concentration gradient, moving from high concentration to low concentration
- No energy is required.

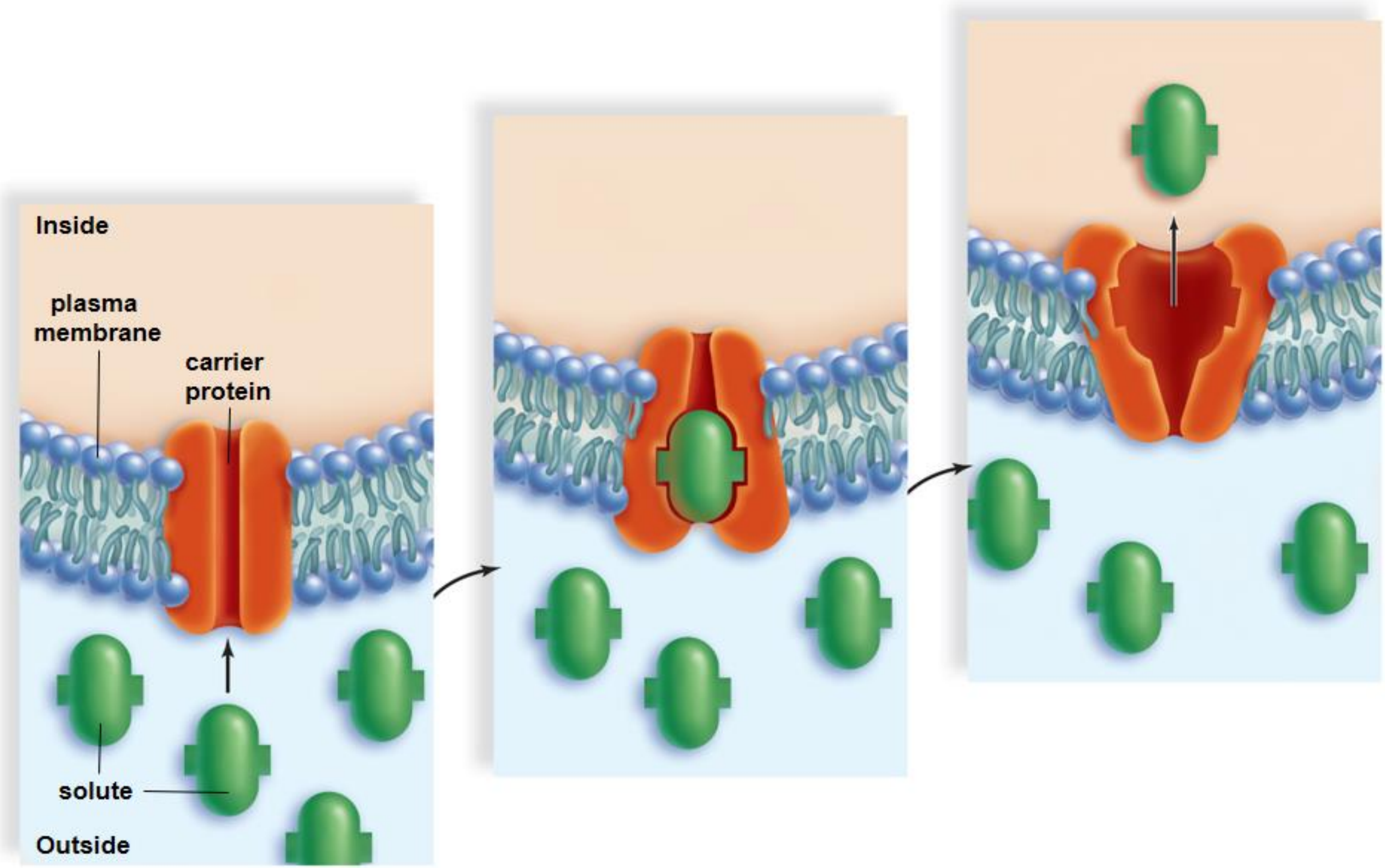
Facilitated Transport (1)



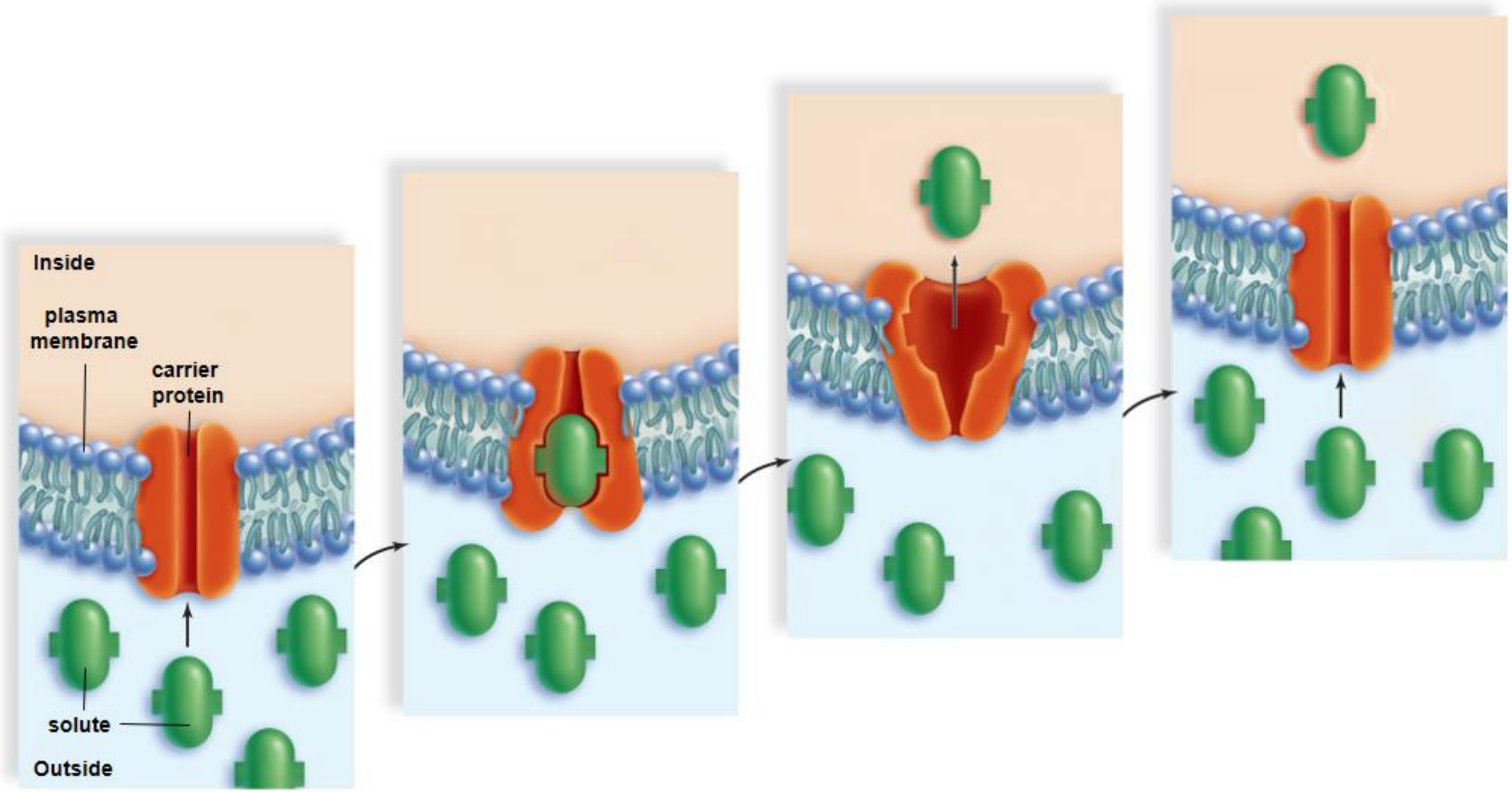
Facilitated Transport (2)



Facilitated Transport (3)



Facilitated Transport (4)



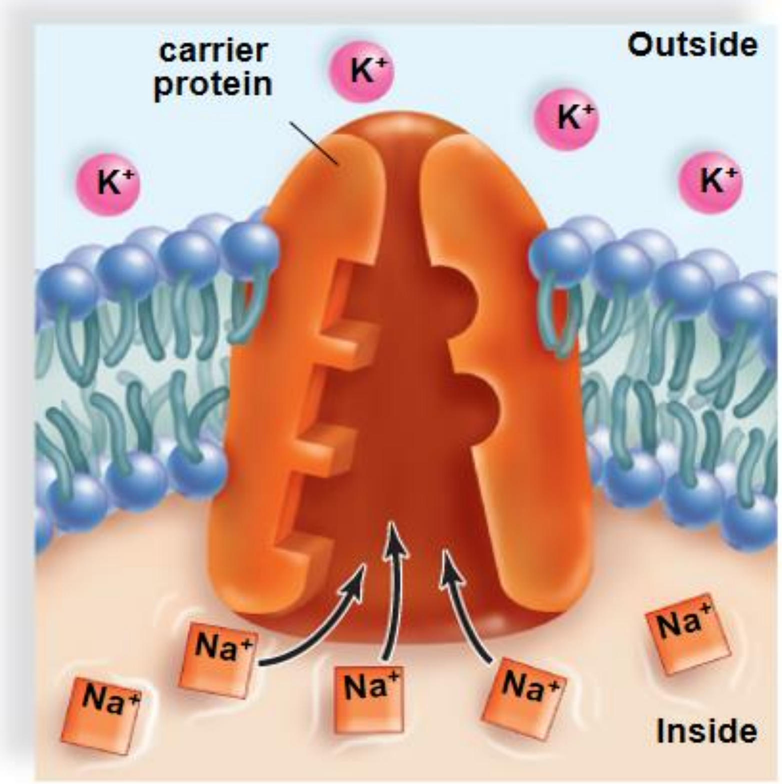
Jump to Facilitated Transport (4) Long Description

5.3 Active Transport Across a Membrane

Active Transport

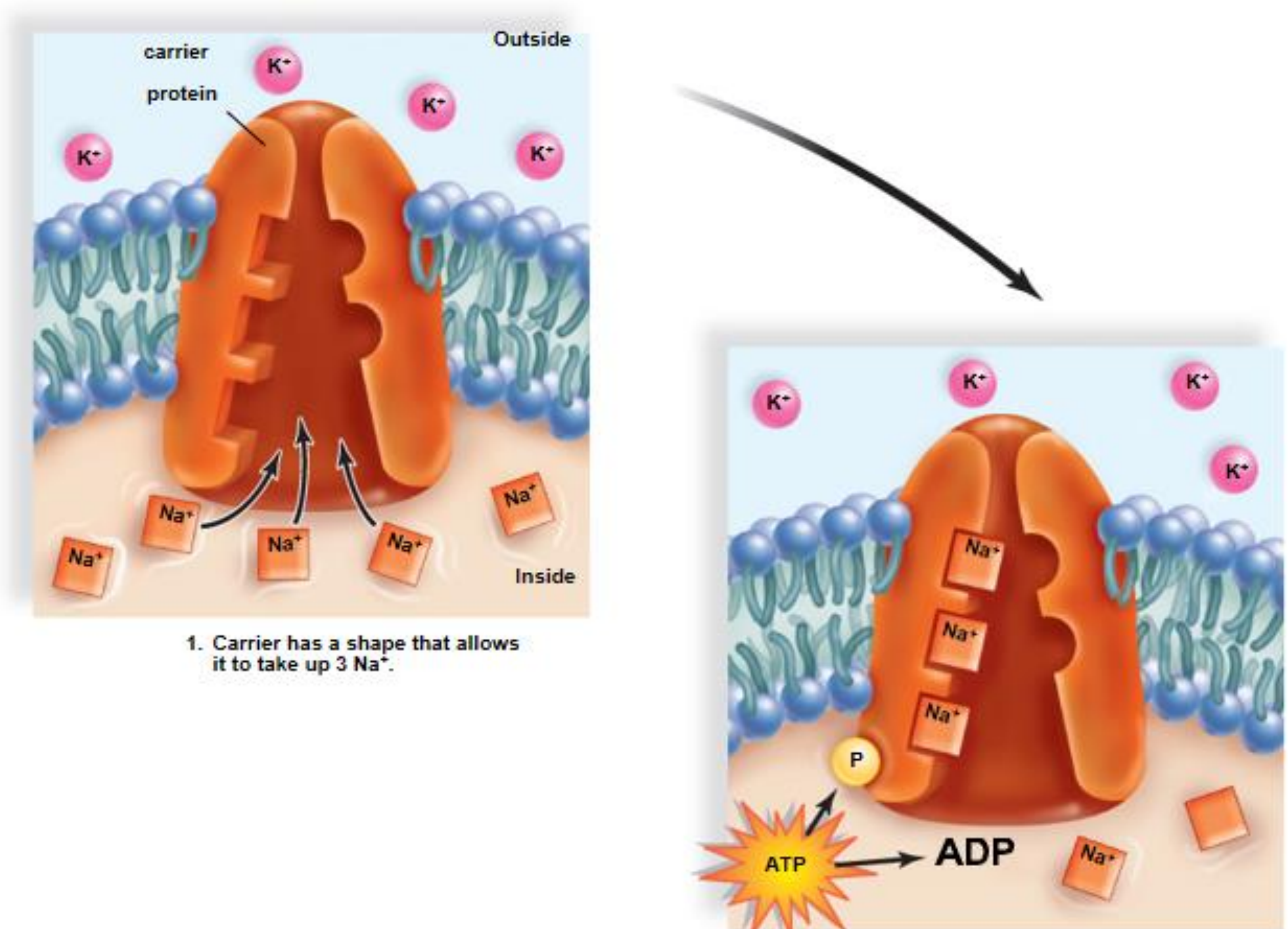
- The movement of molecules against their concentration gradient
  - Movement from low to high concentration
- Movement facilitated by specific carrier proteins
- Requires expenditure of energy in the form of ATP
- Example: **sodium-potassium pump**
  - Uses ATP to move sodium ions out of the cells and potassium ions into the cell against their concentration gradients
  - Shape change of the active transport carrier protein facilitates its binding to two different ions.

The Sodium-Potassium Pump (1)



1. **Carrier has a shape that allows it to take up 3 Na^+**

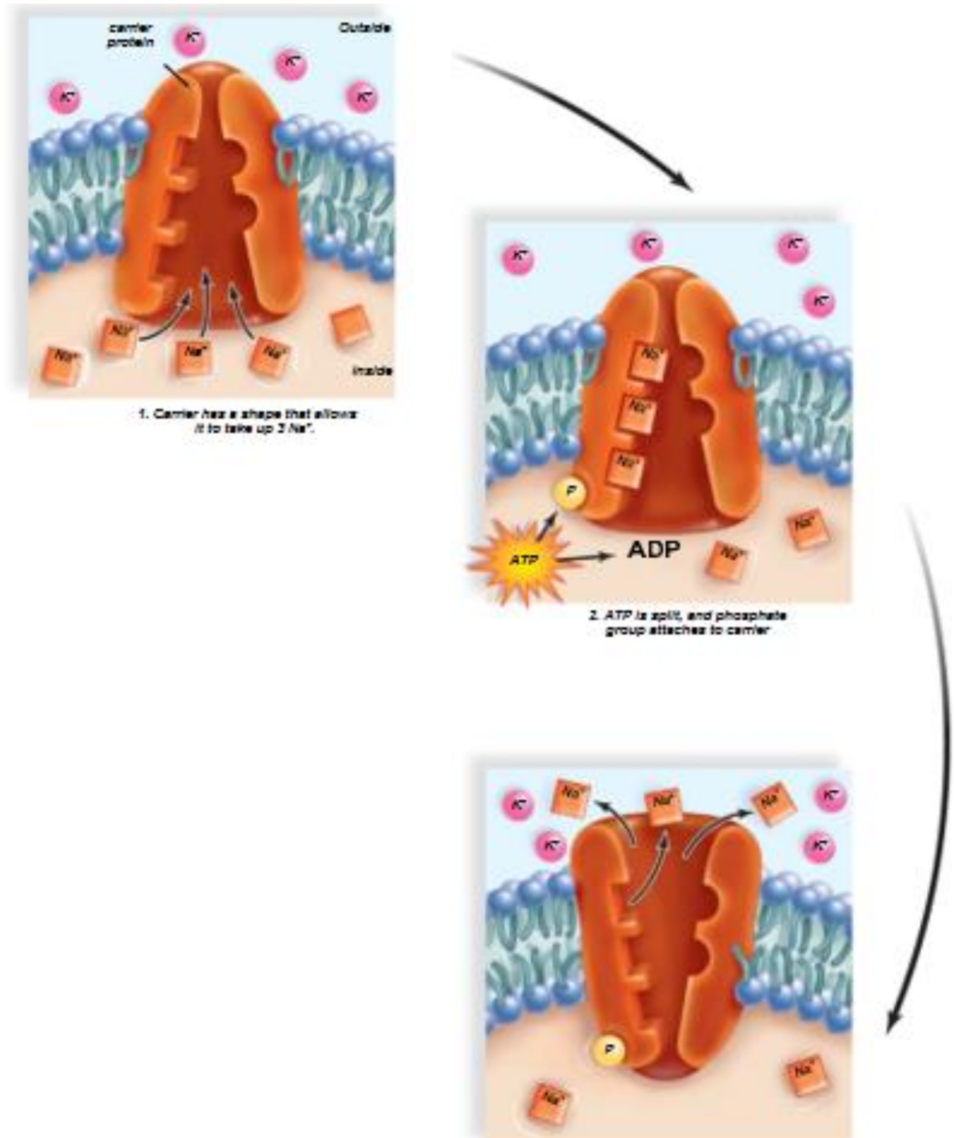
The Sodium-Potassium Pump (2)



1. Carrier has a shape that allows it to take up 3 Na^+.

2. ATP is split, and phosphate group attaches to carrier

The Sodium-Potassium Pump (3)

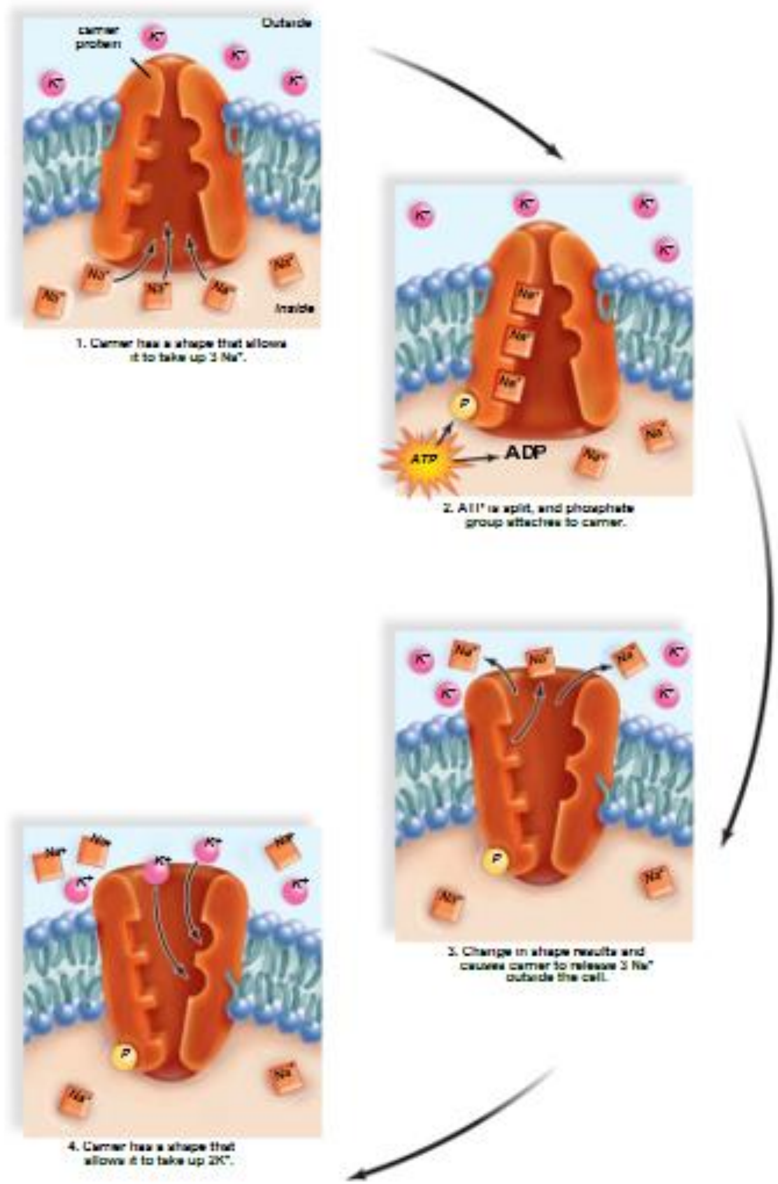


1. Carrier has a shape that allows it to take up 3 Na^+.

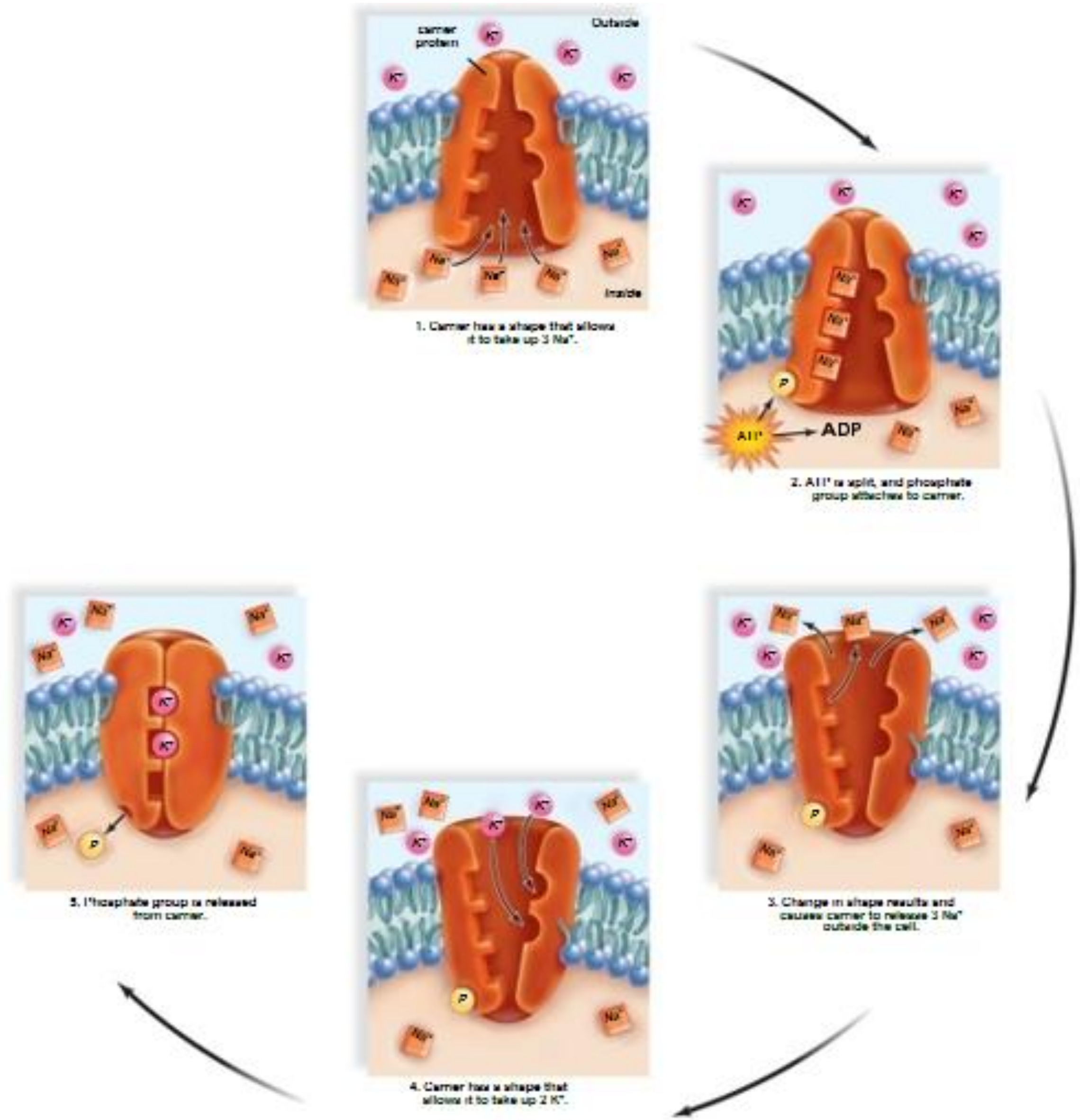
2. ATP is split, and phosphate group attaches to carrier

3. Change in shape results and causes carrier to release 3 Na^+ outside the cell.

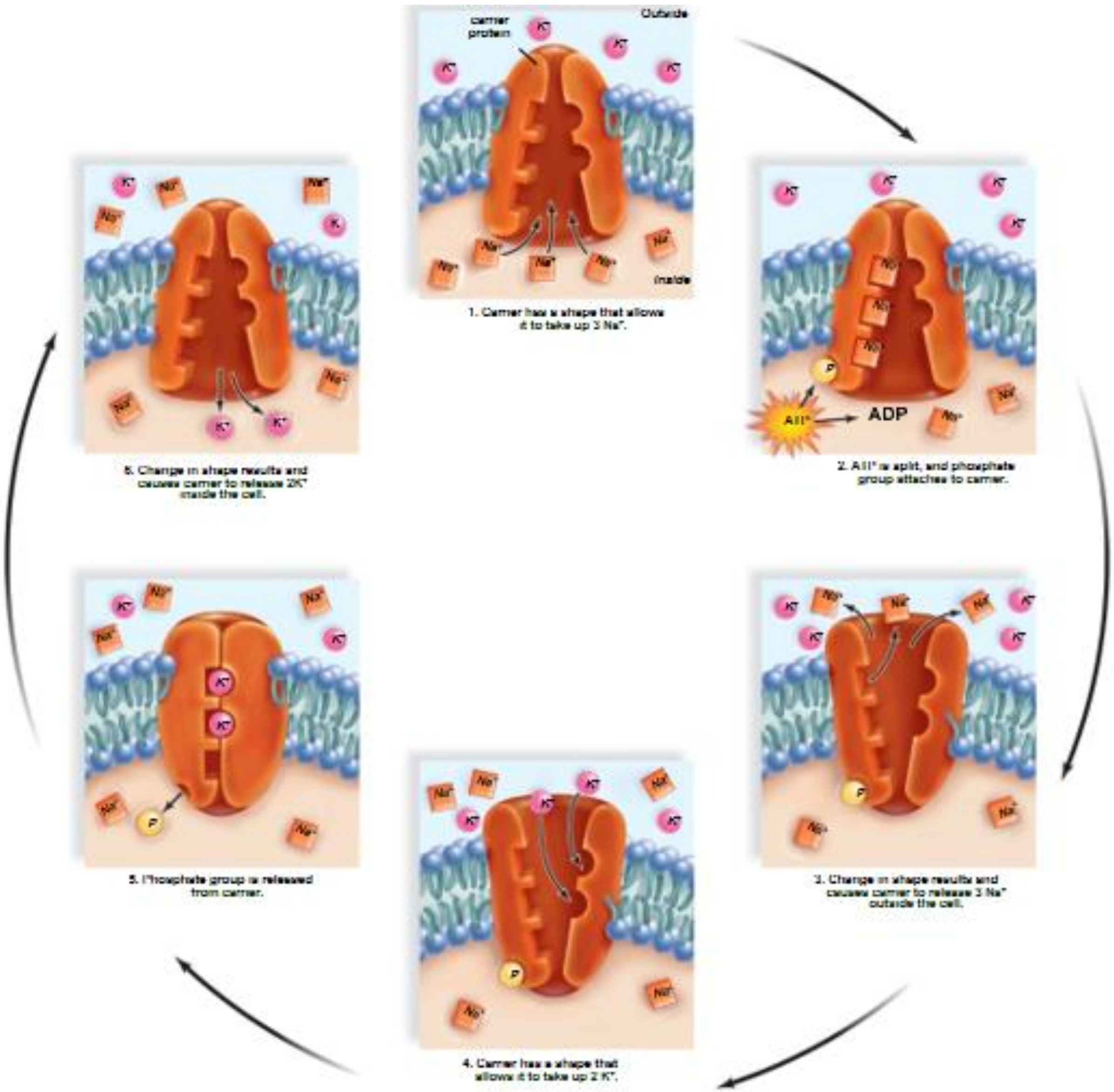
The Sodium-Potassium Pump (4)



The Sodium-Potassium Pump (5)



The Sodium-Potassium Pump (6)



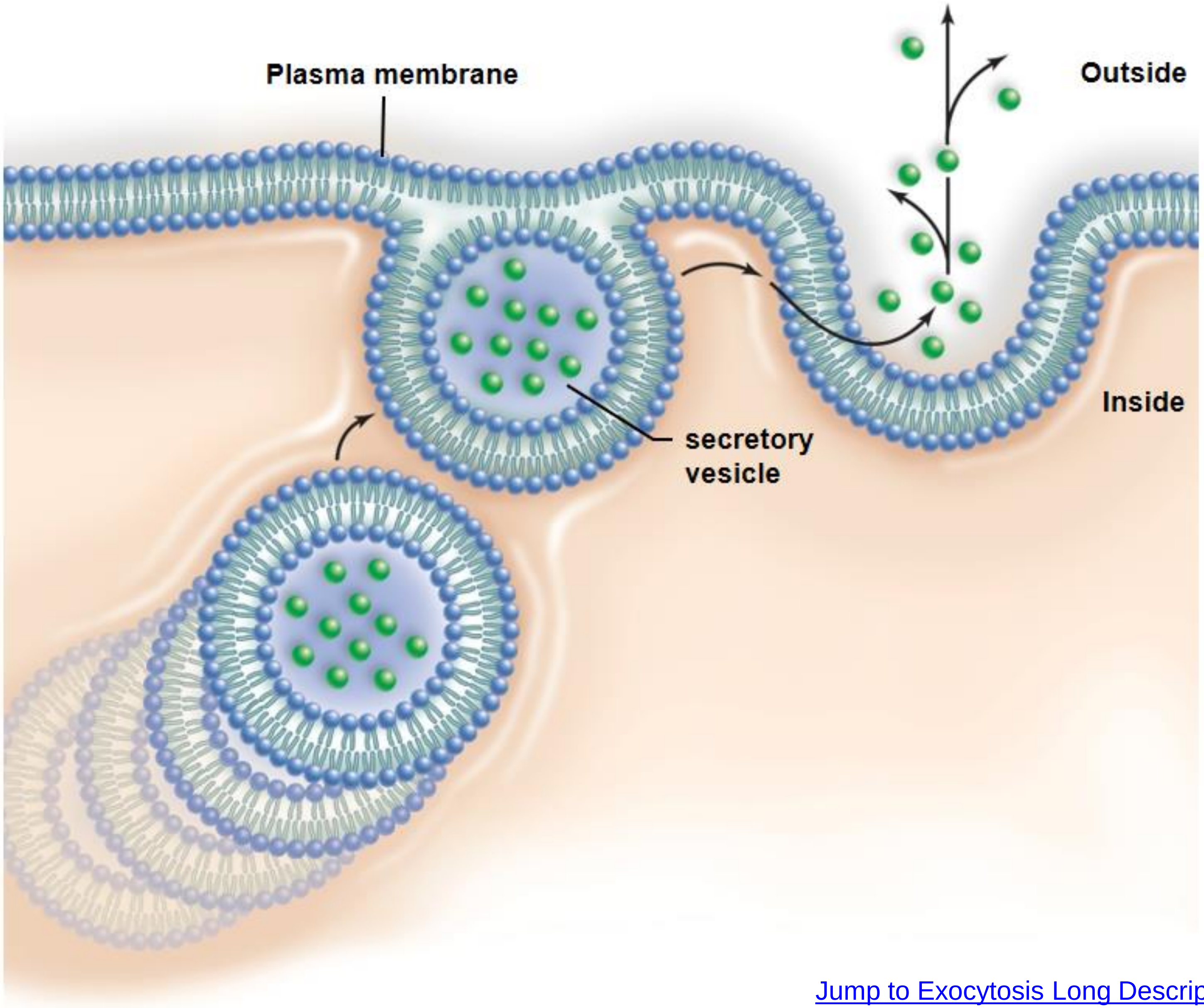
Jump to The Sodium-Potassium Pump (6) Long Description

Active Transport Across a Membrane

Macromolecules are transported into or out of the cell inside vesicles via bulk transport.

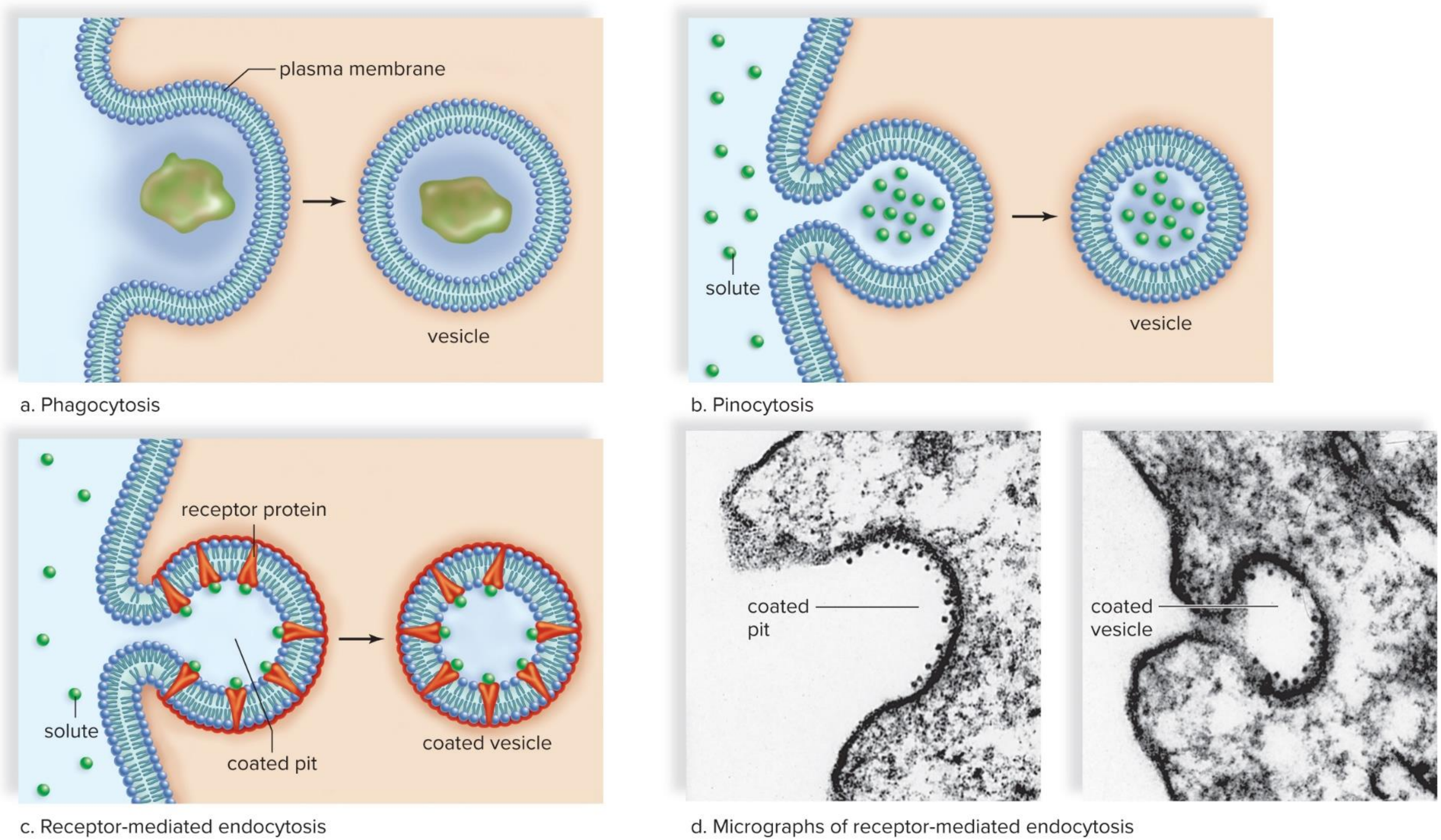
- **Exocytosis** – Vesicles fuse with plasma membrane and secrete contents.
- **Endocytosis** – Cells engulf substances into a pouch, which becomes a vesicle.
  - **Phagocytosis** – Large, solid material is taken in by endocytosis.
    - Example: human white blood cells can engulf debris or viruses
  - **Pinocytosis** – Vesicles form around a liquid or very small particles (cell drinking).
  - **Receptor-Mediated Endocytosis** – Specific form of pinocytosis using receptor proteins and a coated pit
    - In the genetic disease hypercholesterolemia, cholesterol transport is defective.

Exocytosis



Jump to Exocytosis Long Description

Three Methods of Endocytosis



(d): ©Mark Bretscher

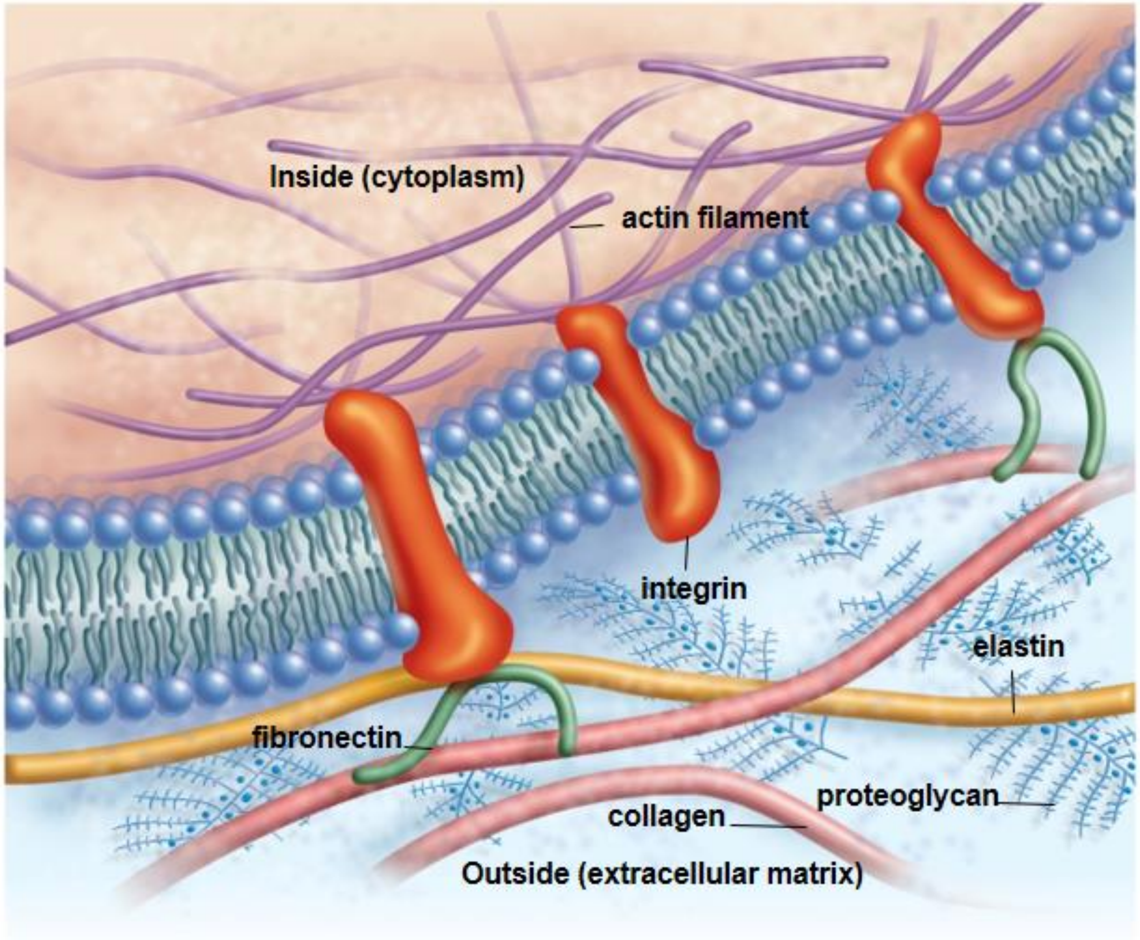
[Jump to Three Methods of Endocytosis Long Description](#)

5.4 Modifications of Cell Surfaces

Cell Surfaces in Animals

- Extracellular Matrix (ECM)
  - Meshwork of proteins and polysaccharides in close connection with the cell that produced them
    - Collagen – resists stretching
    - Elastin – provides resilience to the ECM
    - Fibronectin – adhesive protein which binds to
    - Integrin – plays role in cell signaling
    - Proteoglycans – attach to a long, centrally placed polysaccharide which resists compression of extracellular matrix
      - Assist cell signaling by regulating passage of material through the ECM to the plasma membrane

Animal Cell Extracellular Matrix



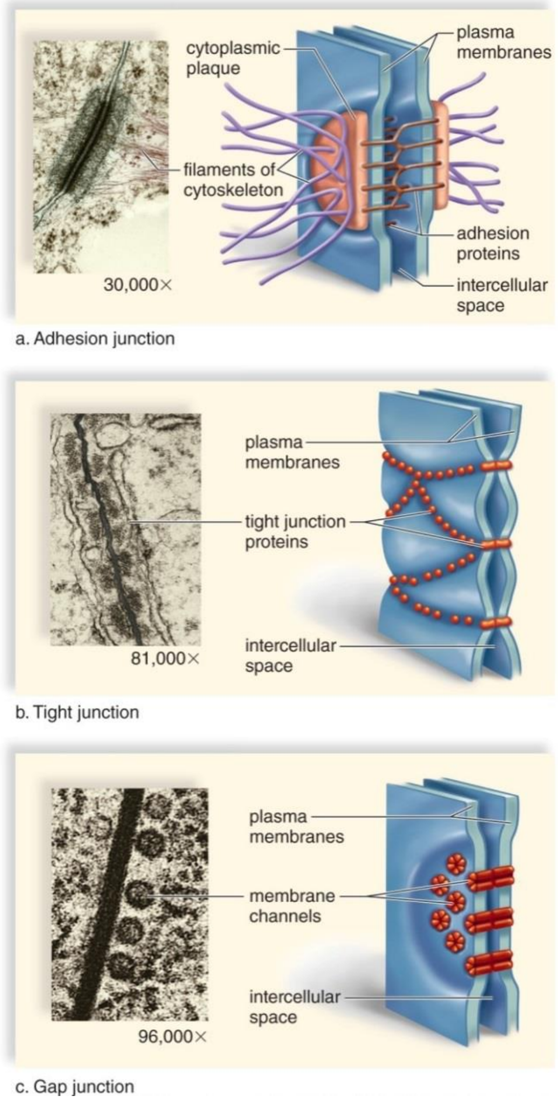
[Jump to Animal Cell Extracellular Matrix Long Description]

Modifications of Cell Surfaces (1)

Cell Surfaces in Animals

- Junctions Between Cells
  - **Adhesion Junctions** – Intercellular filaments between cells
    - **Desmosomes** – internal cytoplasmic plaques
    - **Tight junctions** – form impermeable barriers
  - **Gap Junctions**
    - Plasma membrane channels are joined (allows communication)
      - Important in heart muscle and smooth muscle

Junctions Between Cells of the Intestinal Wall



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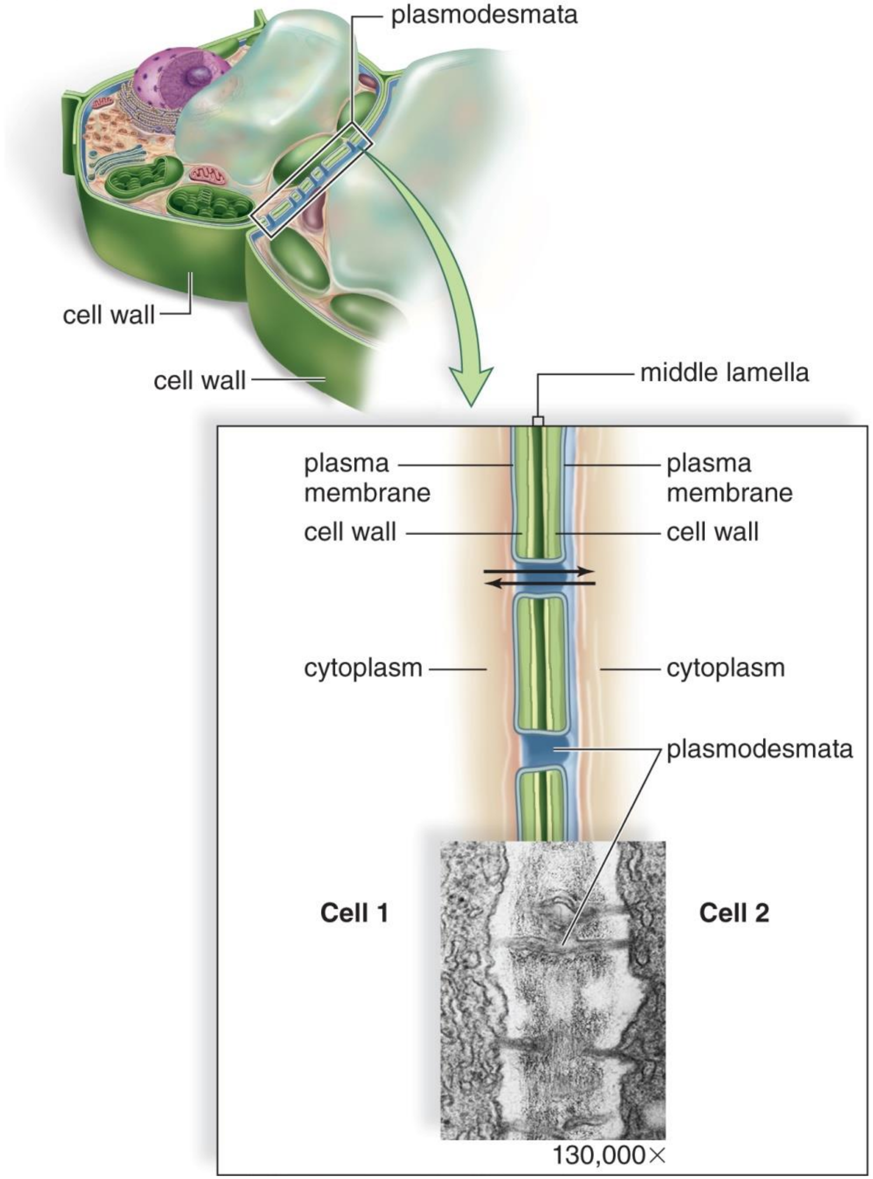
[Jump to Junctions Between Cells of the Intestinal Wall Long Description]

Modifications of Cell Surfaces (2)

Plant Cell Walls

- Plants have a freely permeable **cell wall**, with cellulose as the main component.
  - **Plasmodesmata** penetrate the cell wall
  - Each contains a strand of cytoplasm
  - Allow passage of material between cells
- Cells in woody plants have a secondary cell wall containing lignin and more cellulose fibers than the primary cell wall.

Plasmodesmata



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[Jump to Plasmodesmata Long Description]