Membrane Structure and Function

Tuesday, February 21st 2012

Outline

- Membrane Models
  - Fluid-Mosaic
- Plasma Membrane Structure and Function
  - Phospholipids
  - Proteins
- Plasma Membrane Permeability
  - Diffusion
  - Osmosis
  - Transport Via Carrier Proteins
- Cell Surface Modifications

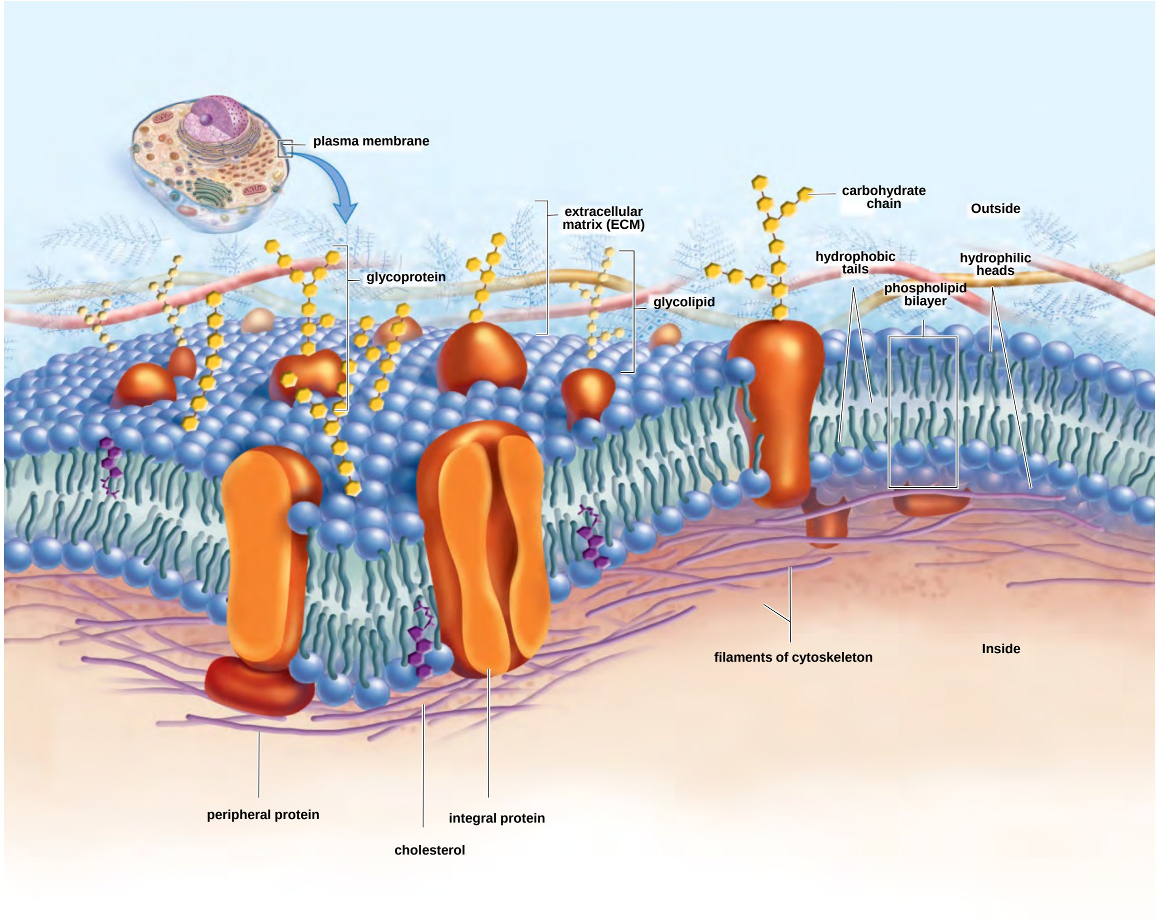
Structure and Function: The Phospholipid Bilayer

- The plasma membrane is common to all cells
- Separates:
  - Internal living cytoplasmic from
  - External environment of cell
- Phospholipid bilayer:
  - External surface lined with hydrophilic polar heads
  - Cytoplasmic surface lined with hydrophilic polar heads
  - Nonpolar, hydrophobic, fatty-acid tails sandwiched in between

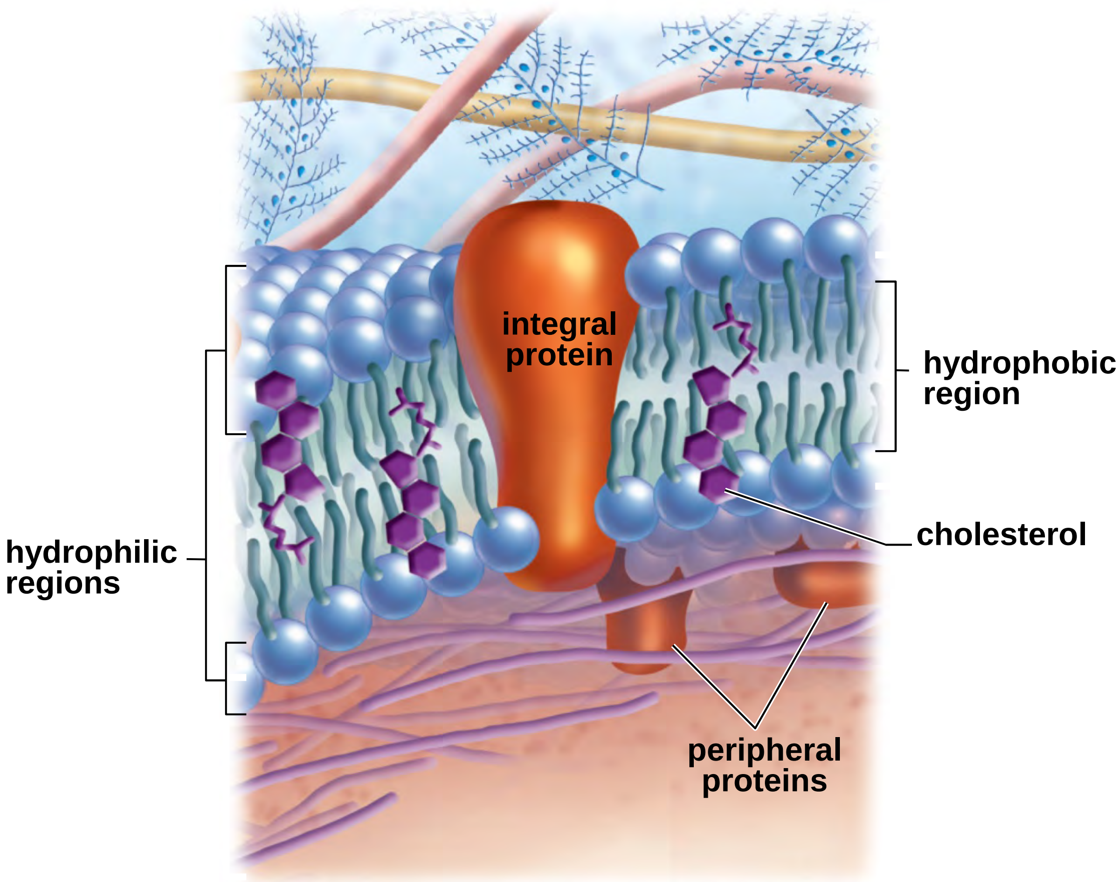
Membrane Models

- Fluid-Mosaic Model
- Three components:
  - Basic membrane 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
    - Some have carbohydrate chains attached
  - Cholesterol

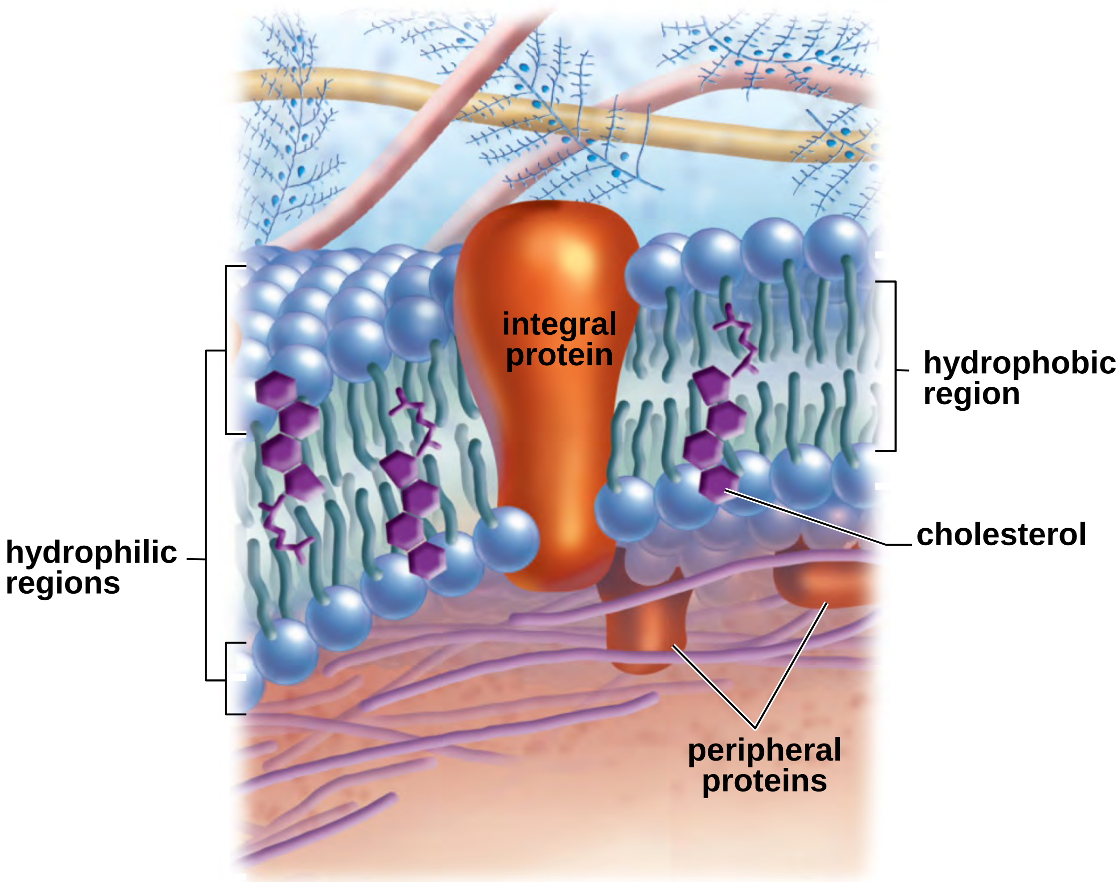
The Fluid Mosaic Model



Transmembrane Proteins



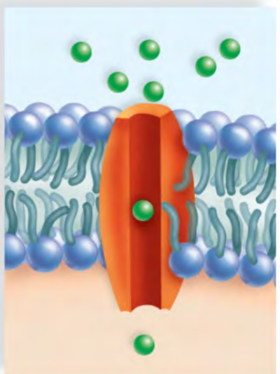
Lateral Migration of Membrane Proteins



Functions of Membrane Proteins

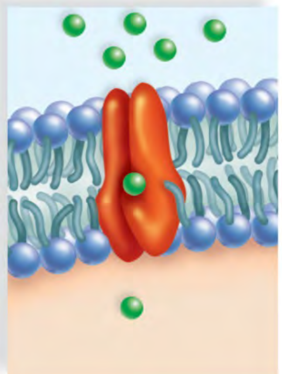
- Channel Proteins:
  - Tubular
  - Allow passage of molecules through membrane
- Carrier Proteins:
  - Combine with substance to be transported
  - Assist passage of molecules through membrane
- Cell Recognition Proteins:
  - Provides unique chemical ID for cells
  - Help body recognize foreign substances
- Receptor Proteins:
  - Binds with messenger molecule
  - Causes cell to respond to message
- Enzymatic Proteins:
  - Carry out metabolic reactions directly

Membrane Protein Diversity



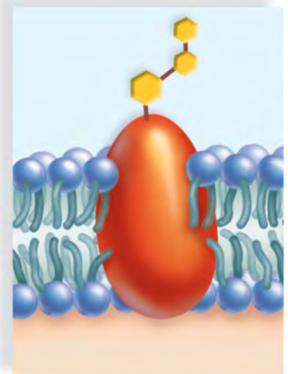
a.

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.



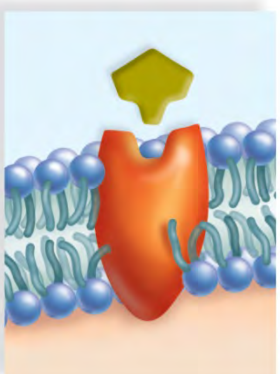
b.

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.



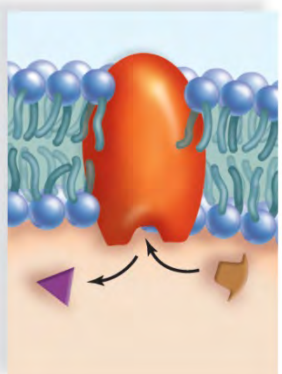
c.

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.



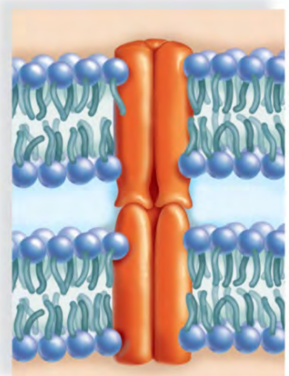
d.

Receptor Protein: Is shaped in such a way that a specific molecule can bind to it. Pygmies are short, not because they do not produce enough growth hormone, but because their plasma membrane growth hormone receptors are faulty and cannot interact with growth hormone.



e.

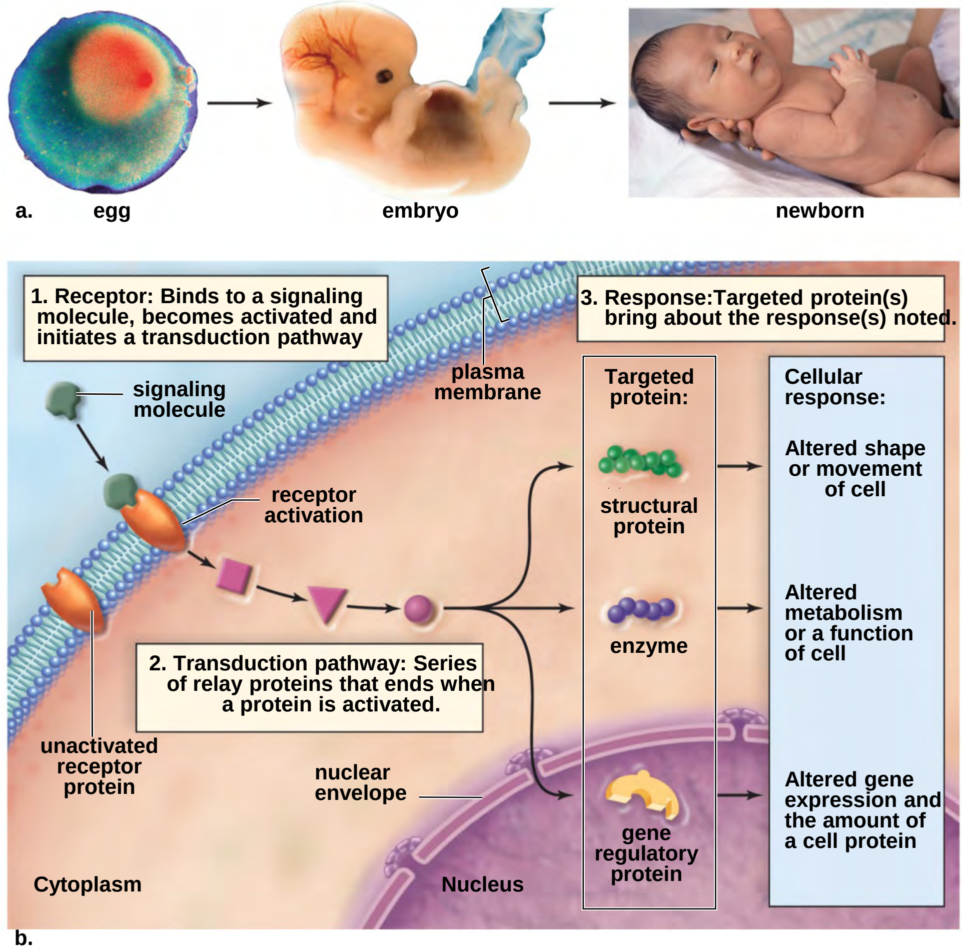
Enzymatic Protein: Catalyzes a specific reaction. The membrane protein, adenylate cyclase, is involved in ATP metabolism. Cholera bacteria release a toxin that interferes with the proper functioning of adenylate cyclase; sodium (Na+) and water leave intestinal cells, and the individual may die from severe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



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.

Science Focus: Cell Signaling



Types of Transport: Active vs. Passive

- Plasma membrane is differentially (selectively) permeable
  - Allows some material to pass
  - Inhibits passage of other materials
- Passive Transport:
  - No ATP requirement
  - Molecules follow concentration gradient
- Active Transport
  - Requires carrier protein
  - Requires energy in form of ATP

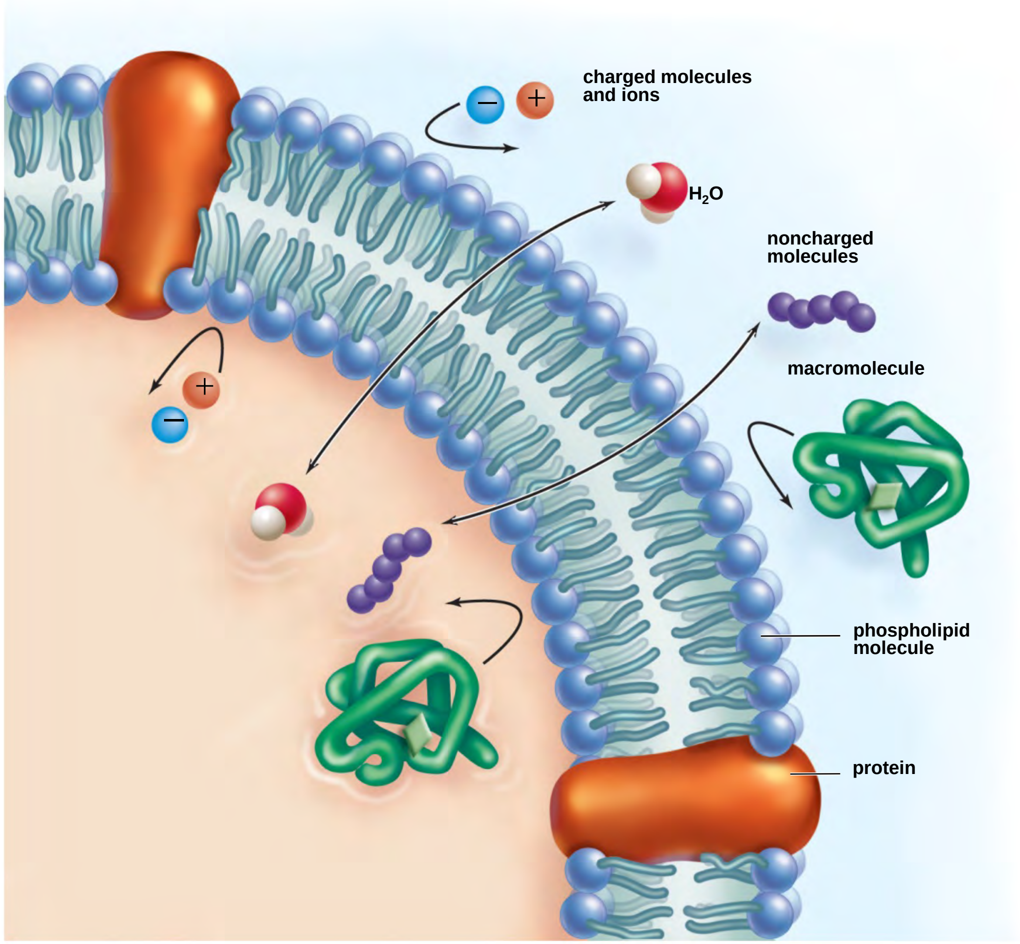
Passage of Molecules Across the Membrane

TABLE 5.1

Passage of Molecules into and out of the Cell

	Name	*Direction*	*Requirement*	*Examples*
Energy Not Required	Diffusion	Toward lower concentration	Concentration gradient	Lipid-soluble molecules, and gases
	Facilitated transport	Toward lower concentration	Channels or carrier and concentration gradient	Some sugars, and amino acids
Energy Required	Active transport	Toward higher concentration	Carrier plus energy	Sugars, amino acids, and ions
	Bulk transport	Toward outside or inside	Vesicle utilization	Macromolecules

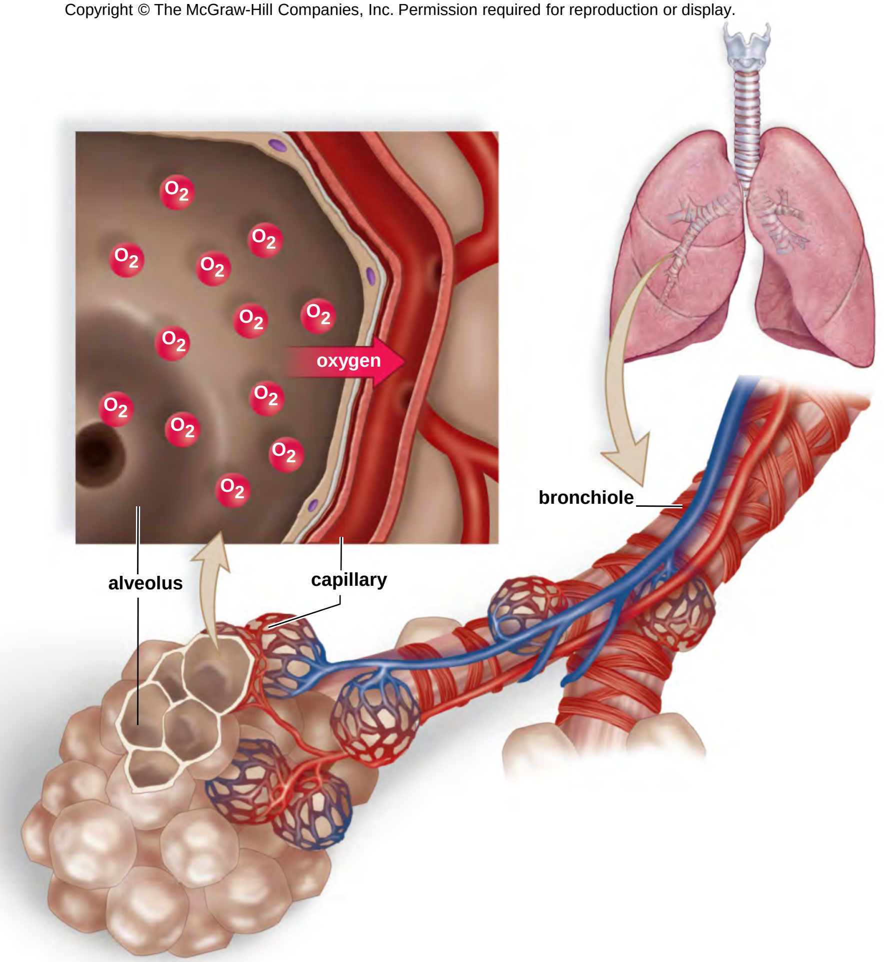
Types of Membrane Transport: Overview



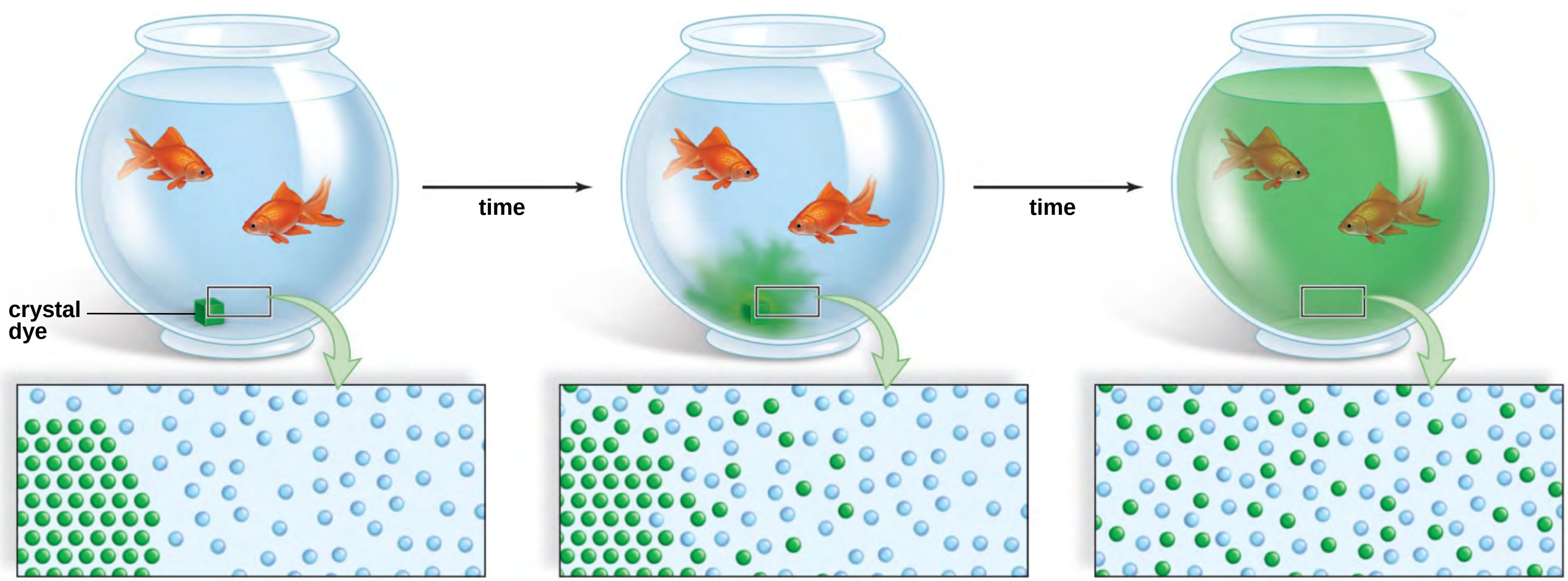
Types of Transport: Diffusion

- A solution consists of:
  - A solvent (liquid), and
  - A solute (dissolved solid)
- Diffusion
  - Net movement of solute molecules down a concentration gradient
  - Molecules both ways along gradient
  - More move from high to low concentration than vice versa
  - Equilibrium:
    - When NET change stops
    - Solute concentration uniform – no gradient

Gas Exchange in Lungs: Diffusion Across Lung



Types of Membrane Transport: Diffusion

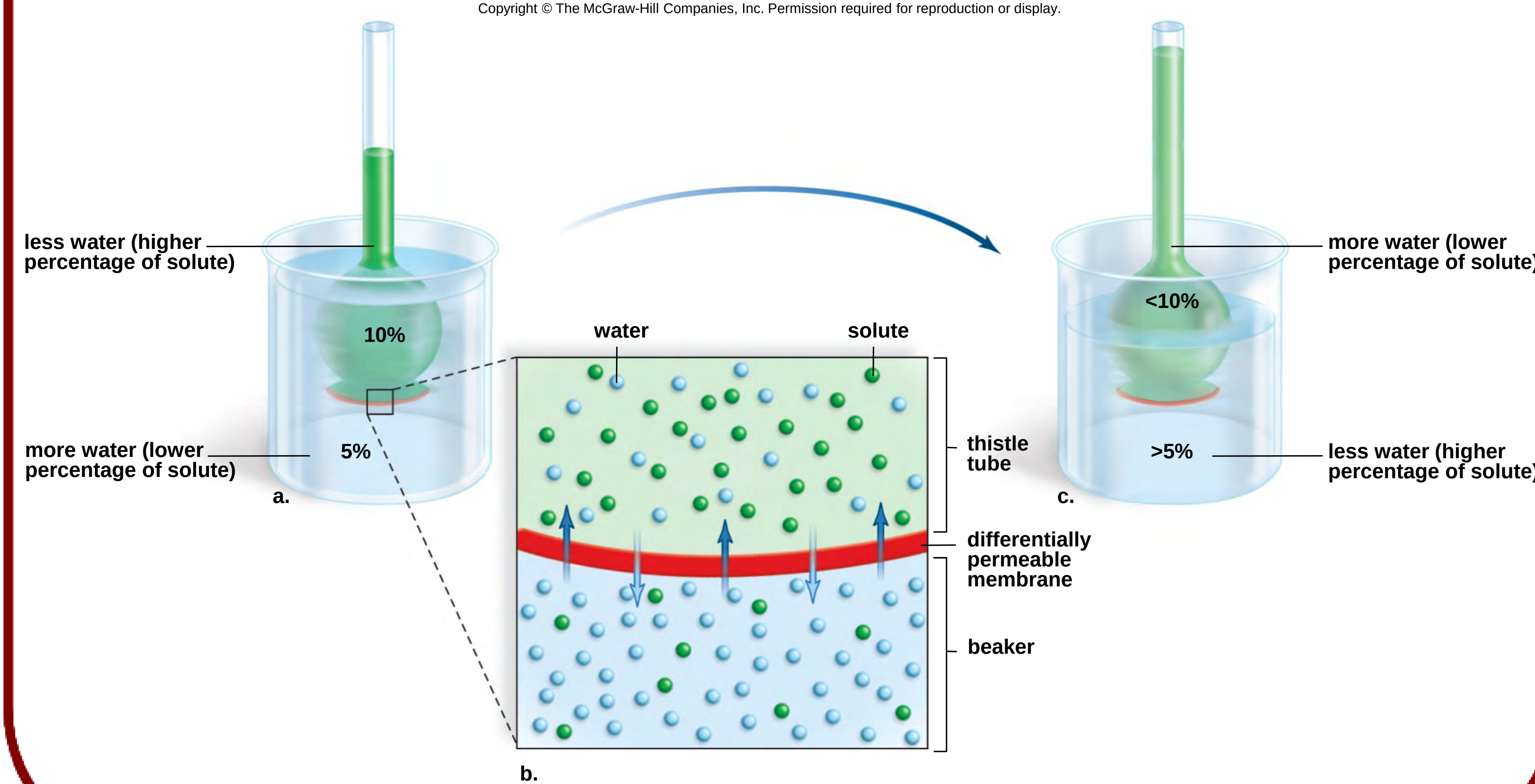


a. Crystal of dye is placed in water
b. Diffusion of water and dye molecules
c. Equal distribution of molecules results

Types of Transport: Osmosis

- Osmosis:
  - Special case of diffusion
  - Focuses on solvent (water) movement rather than solute
  - Diffusion of water across a differentially (selectively) permeable membrane
    - Solute concentration on one side high, but water concentration low
    - Solute concentration on other side low, but water concentration high
  - Water diffuses both ways across membrane but solute can't
  - Net movement of water is toward low water (high solute) concentration
- Osmotic pressure is the pressure that develops due to osmosis

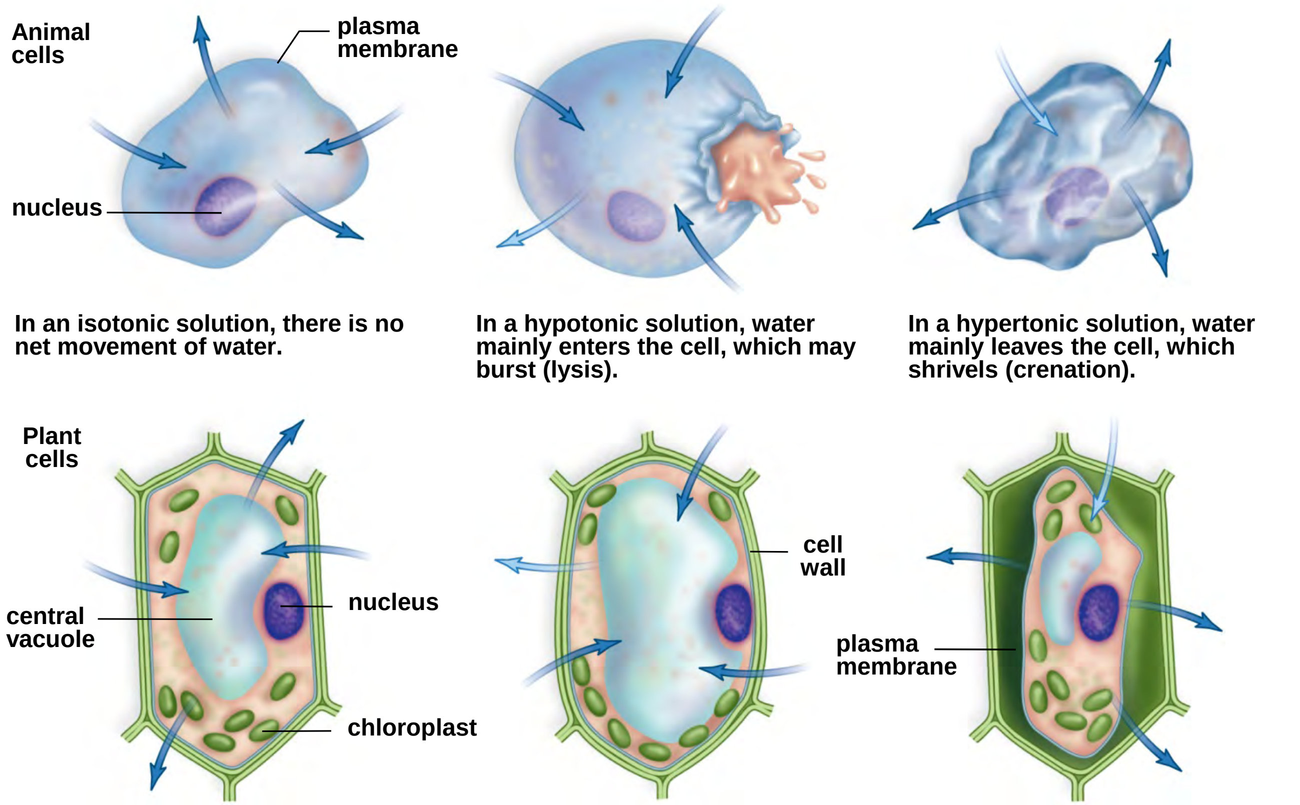
Types of Transport: Osmosis



Types of Transport: Osmosis

- Isotonic Solution
  - Solute and water concentrations equal on both sides of membrane
- Hypotonic Solution
  - Concentration of solute *lower* than on other side
  - Cells placed in a hypotonic solution will swell
  - May cause cells to break – Lysis
- Hypertonic Solution
  - Concentration of solute *higher* than on other side
  - Cells placed in a hypertonic solution will shrink – Plasmolysis

Osmotic Effects on 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.

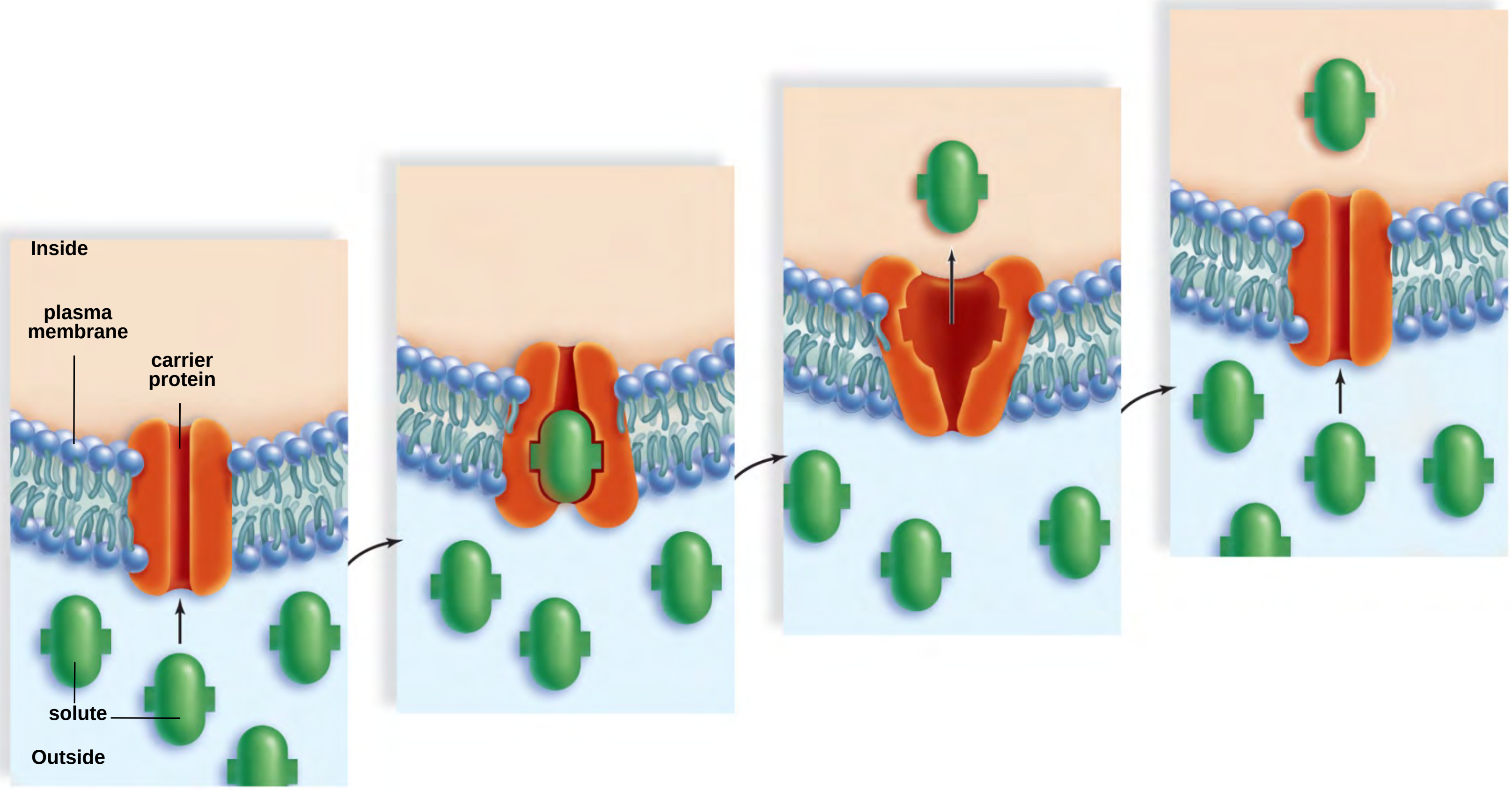
In a hypertonic solution, vacuoles lose water, the cytoplasm shrinks (plasmolysis), and chloroplasts are seen in the center of the cell.

Summary Video

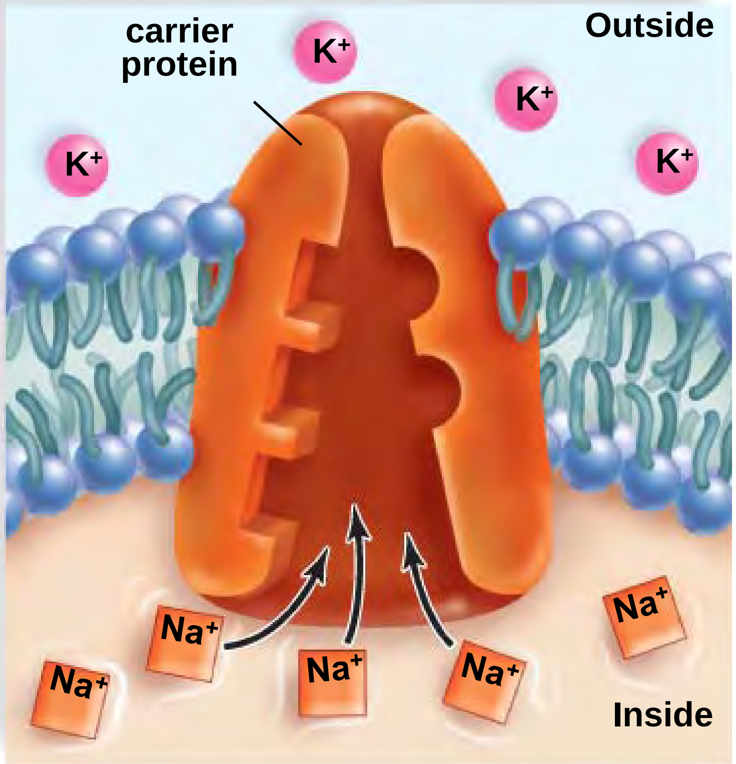
Types of Transport: Carrier Proteins

- Facilitated Transport
  - Small molecules
  - Can’t get through membrane lipids
  - Combine with carrier proteins
  - *Follow* concentration gradient
- Active Transport
  - Small molecules
  - Move *against* concentration gradient
  - Combining with carrier proteins
  - Requires energy

Types of Membrane Transport: Facilitated Transport

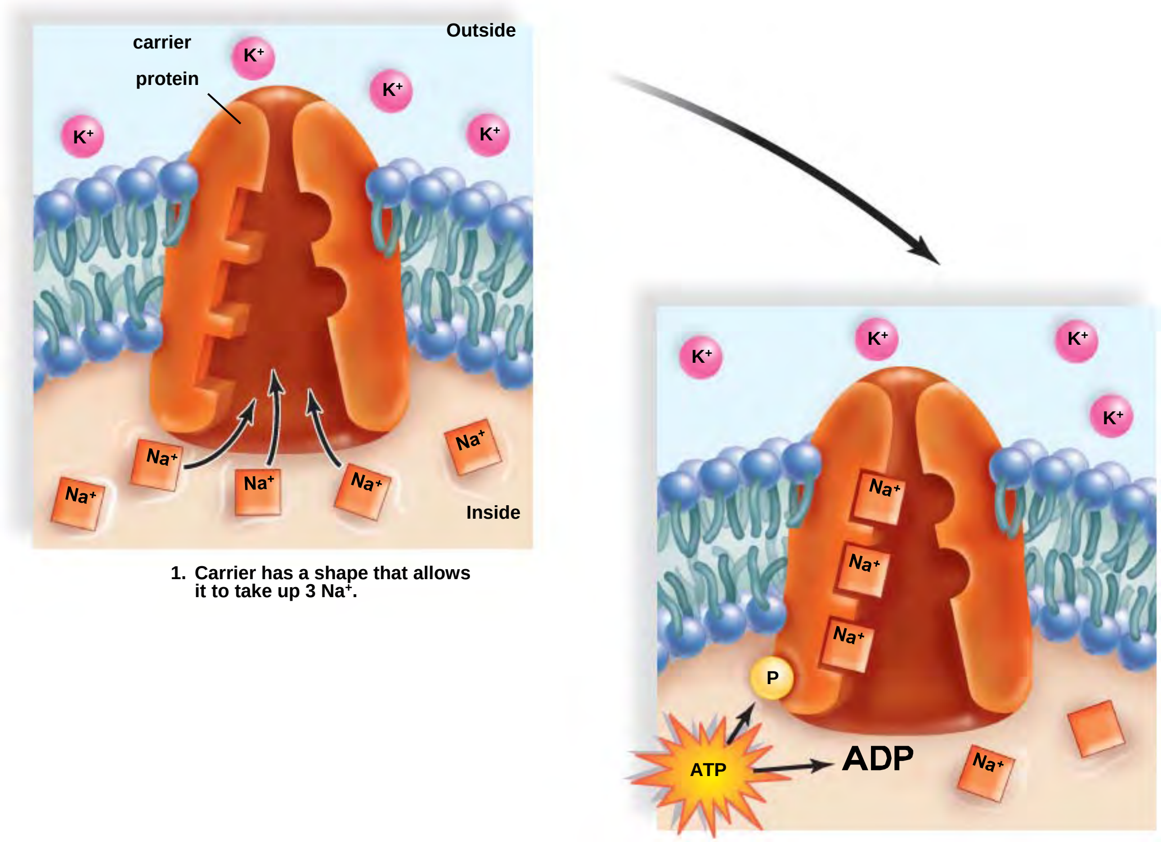


Facilitated Transport:
The Sodium-Potassium Pump



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

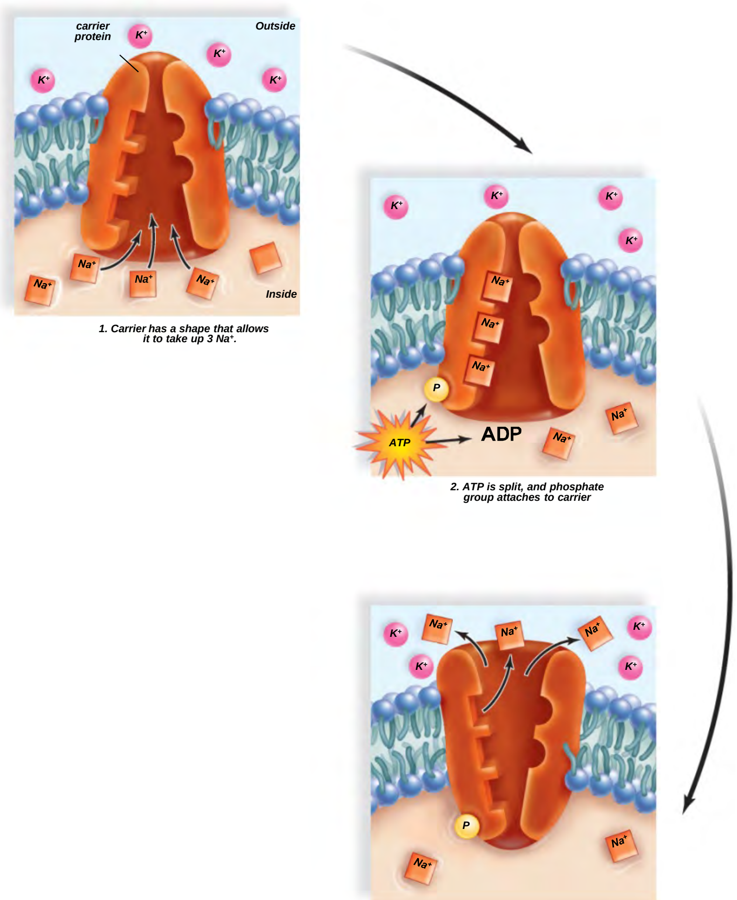
Facilitated Transport: The Sodium-Potassium Pump



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

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

Facilitated Transport: The Sodium-Potassium Pump

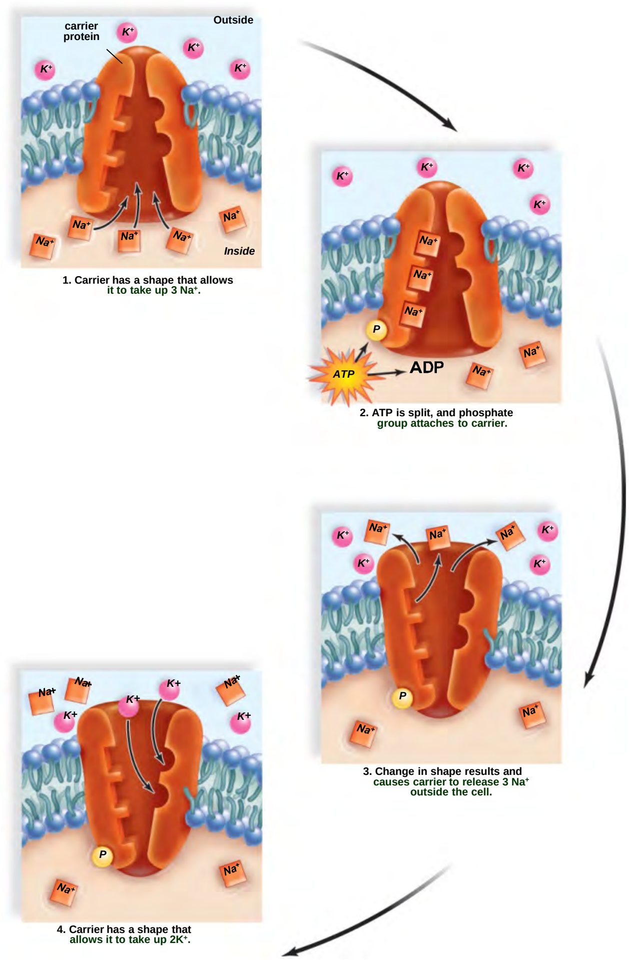


1. Carrier has a shape that allows it to take up 3 Na^+.

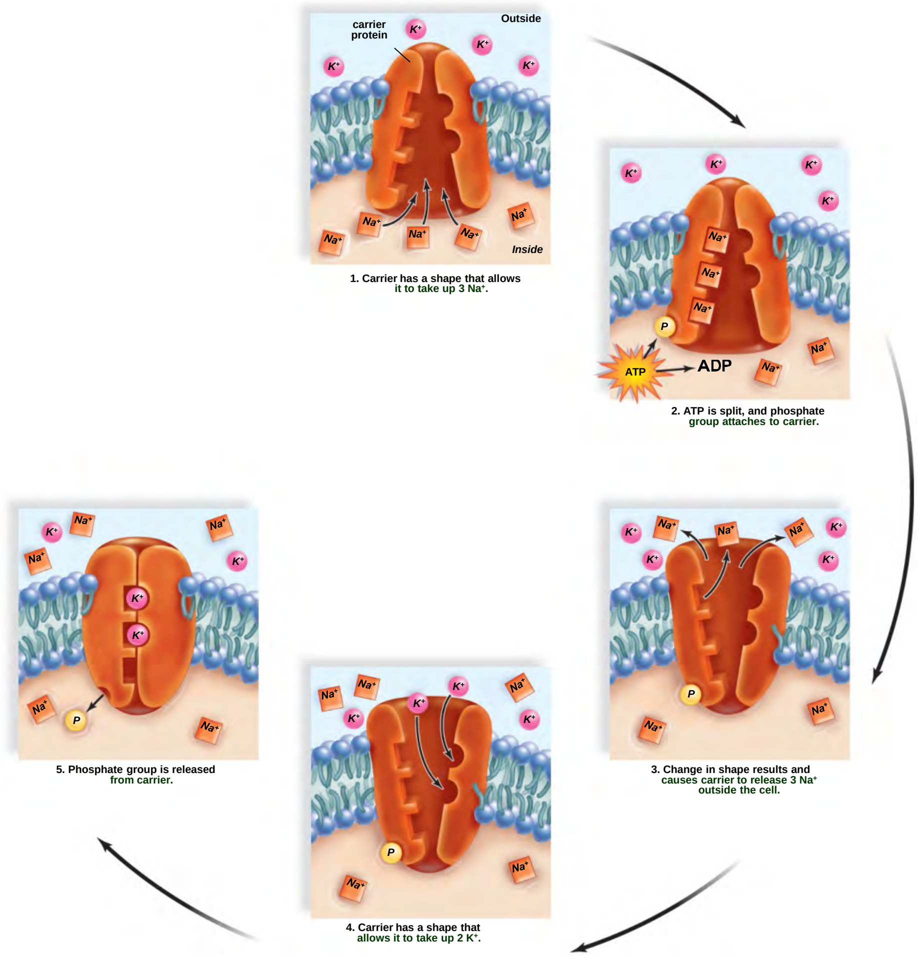
2. ATP is split, and phosphate group attaches to carrier

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

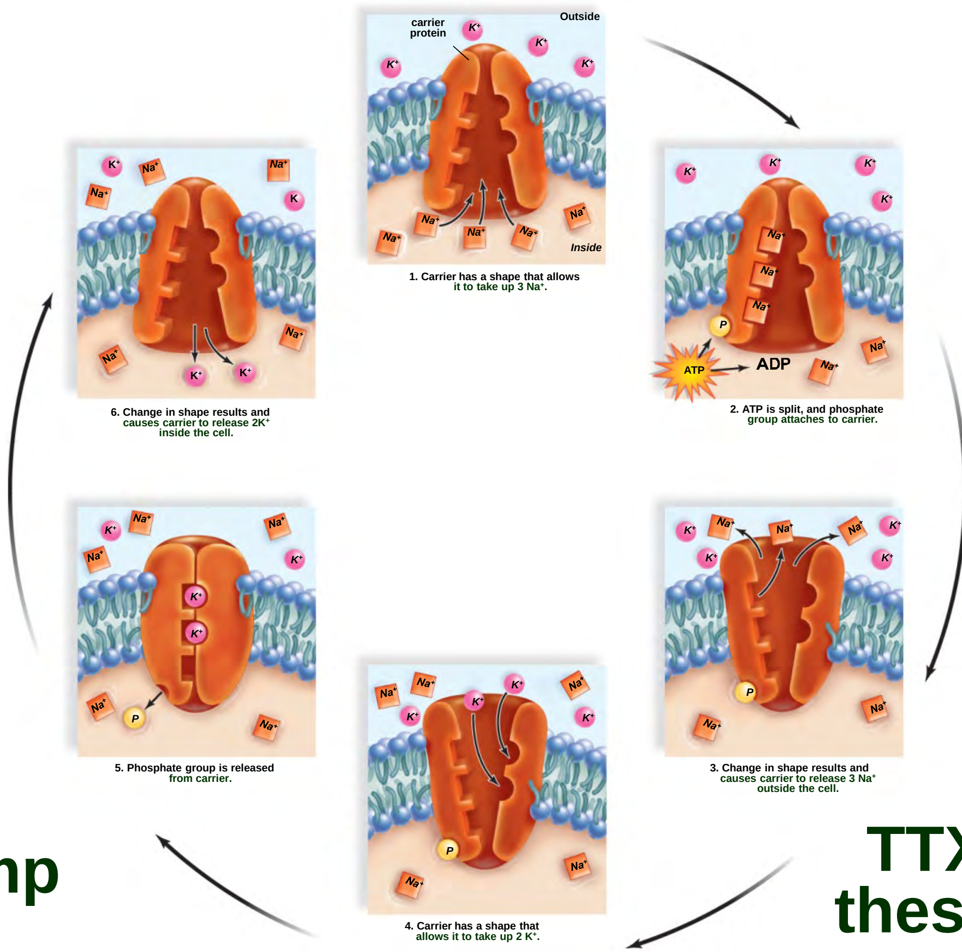
Facilitated Transport: The Sodium-Potassium Pump



Facilitated Transport: The Sodium-Potassium Pump



Facilitated Transport:
The Sodium-Potassium Pump



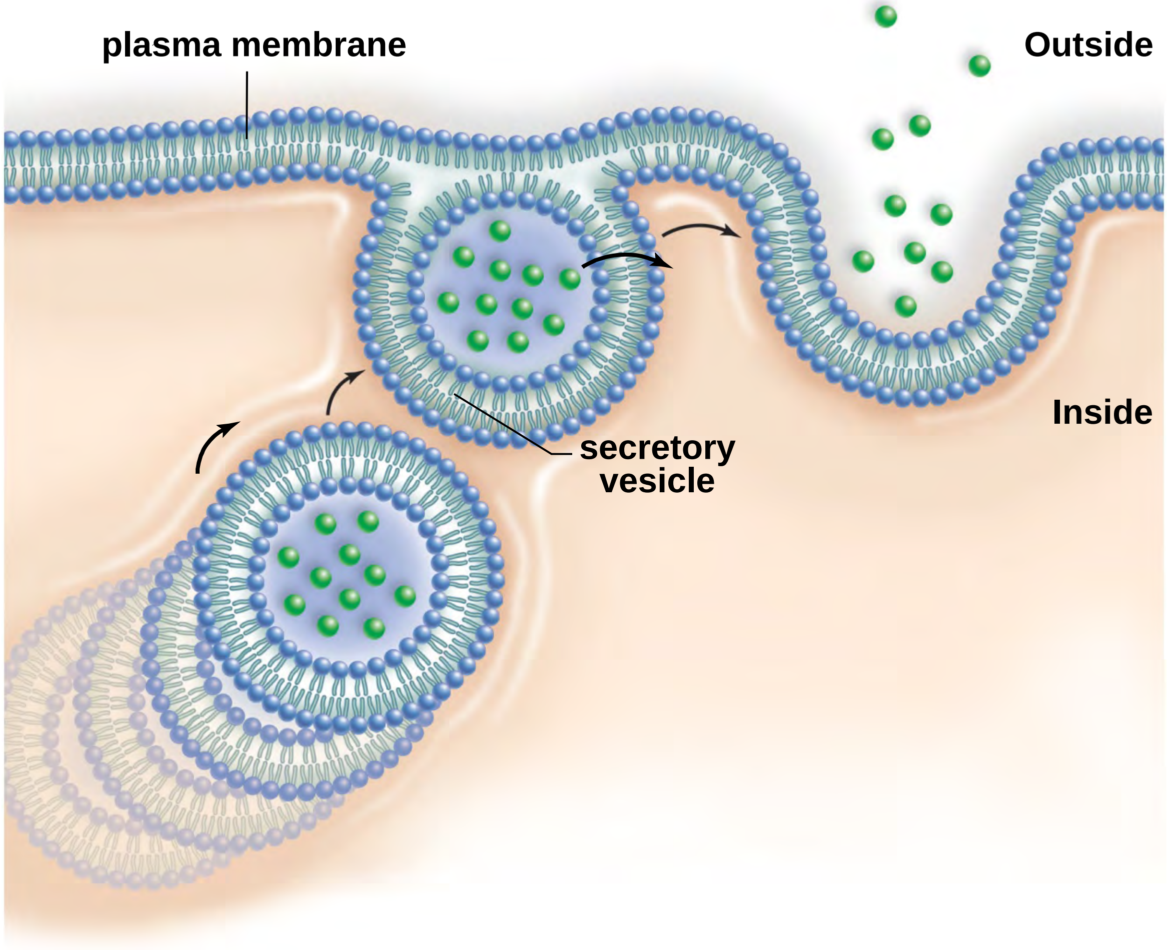
Na-K Pump Video

TTX Disrupts these channels

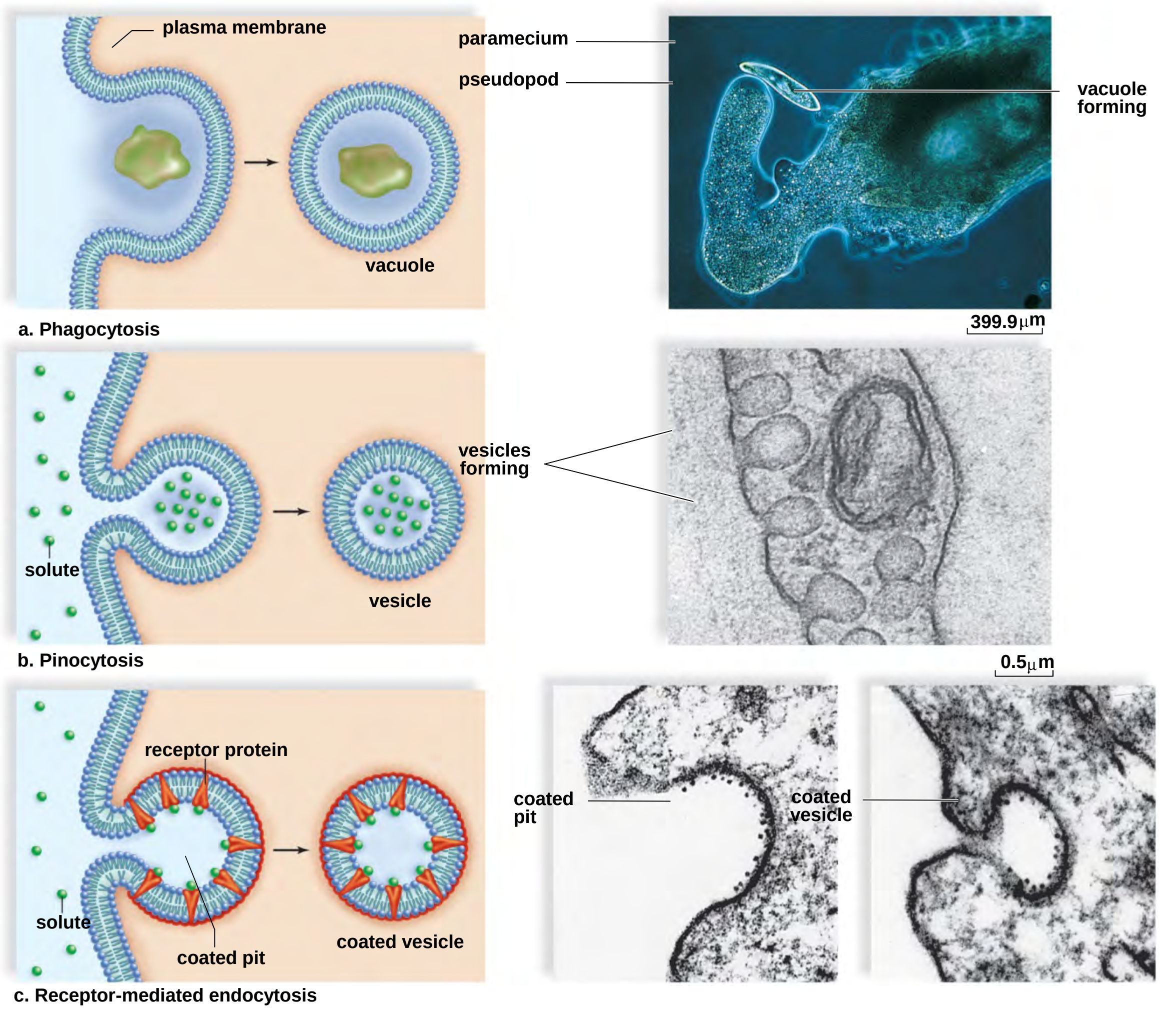
Types of Transport: Membrane-Assisted Transport

- Macromolecules transported into or out of the cell inside vesicles
  - Exocytosis – Vesicles fuse with plasma membrane and secrete contents
  - Endocytosis – Cells engulf substances into pouch which becomes a vesicle
    - Phagocytosis – Large, solid material into vesicle
    - Pinocytosis – Liquid or small, solid particles go into vesicle
    - Receptor-Mediated – Specific form of pinocytosis using a coated pit

Membrane-Assisted Transport: Exocytosis



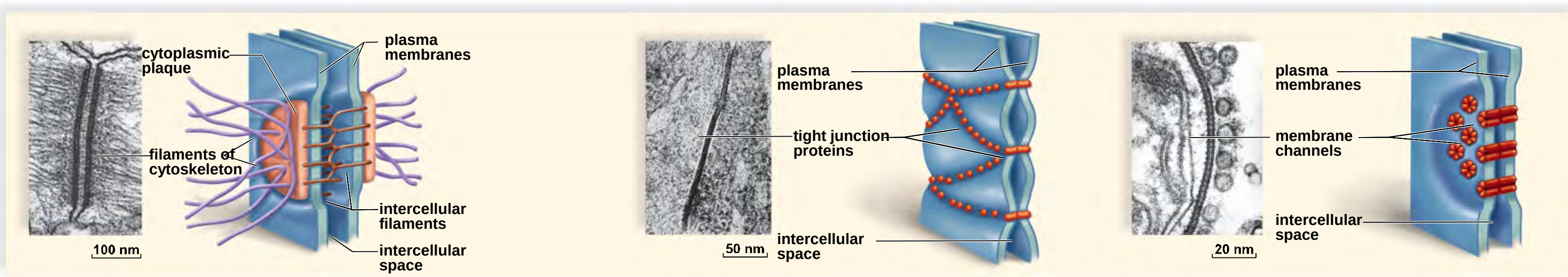
Membrane-Assisted Transport: Three Types of Endocytosis



Cell Surface Modifications: Junctions

- Cell Surfaces in Animals
  - Junctions Between Cells
    - Adhesion Junctions
      - Intercellular filaments between cells
    - Tight Junctions
      - Form impermeable barriers
    - Gap Junctions
      - Plasma membrane channels are joined (allows communication)

Cell-Surface Modifications: Junctions

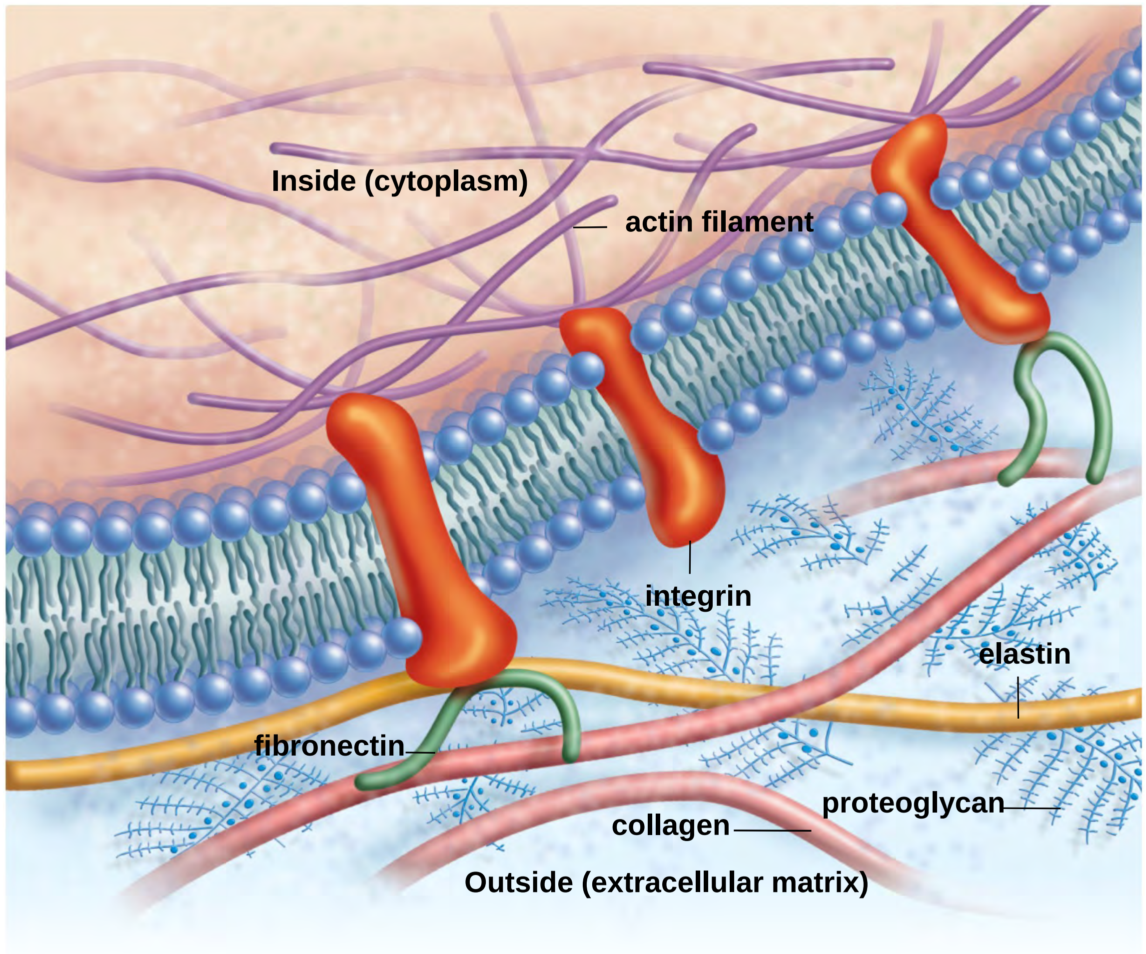


a. Adhesion junction b. Tight junction c. Gap junction

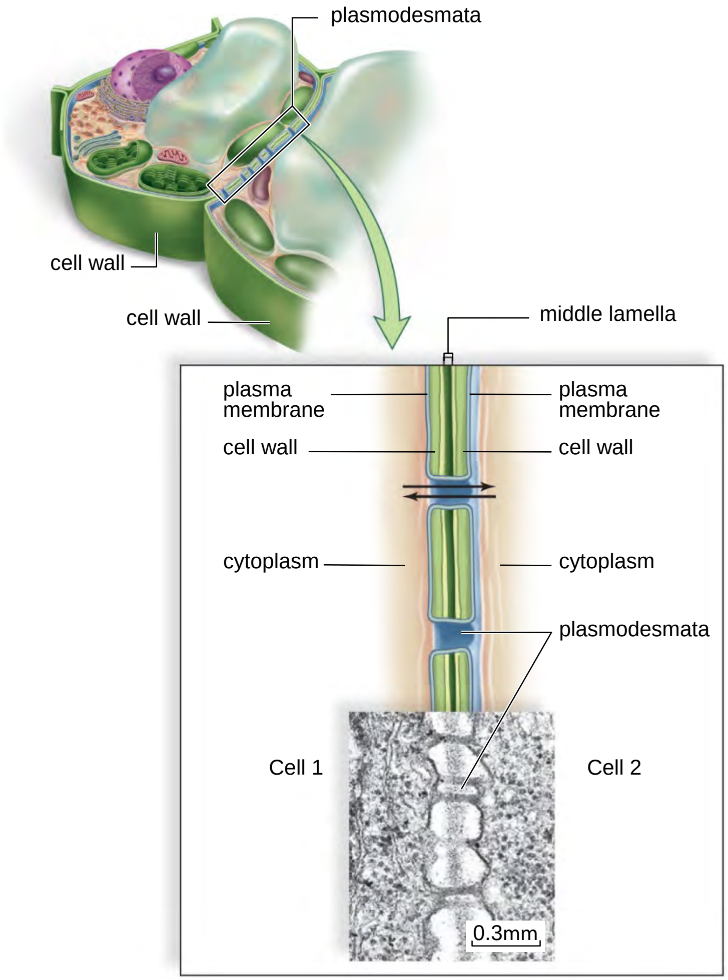
Cell Surface Modifications

- Extracellular Matrix
  - External meshwork of polysaccharides and proteins
  - Found in close association with the cell that produced them
- Plant Cell Walls
  - Plants have freely permeable cell wall, with cellulose as the main component
    - Plasmodesmata penetrate cell wall
    - Each contains a strand of cytoplasm
    - Allow passage of material between cells

Cell-Surface Modifications: Extracellular Matrix



Cell-Surface Modifications: Plasmodesmata



Review

- Membrane Models
  - Fluid-Mosaic
- Plasma Membrane Structure and Function
  - Protein Functions
  - Plasma Membrane Permeability
    - Diffusion
    - Osmosis
    - Transport Via Carrier Proteins
- Cell Surface Modifications