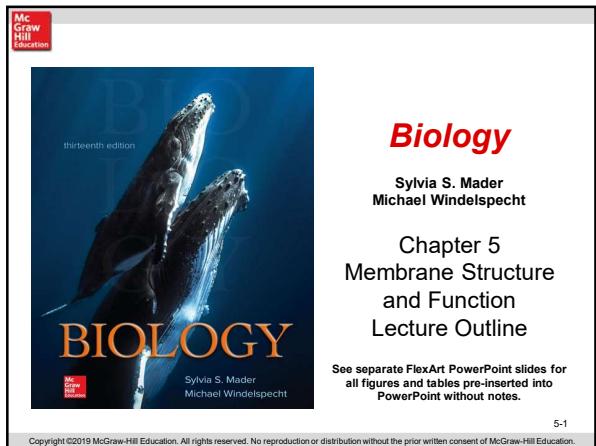


# Membranes



## 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.

5-1

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## 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

5-2

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## 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.

5-3

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# Membranes

## 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

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## 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.

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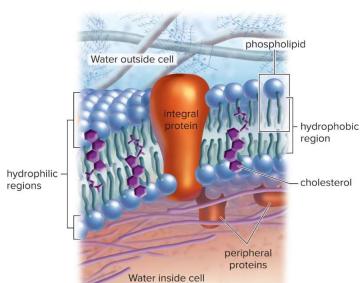
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## Membrane Proteins

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# Membranes

## 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

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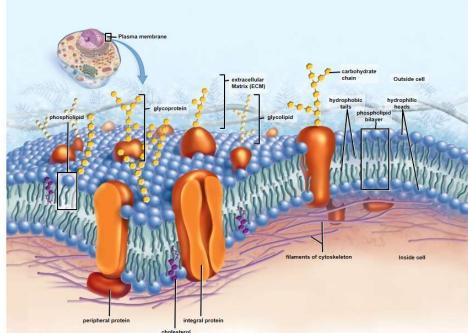
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## Fluid Mosaic Model of the Plasma Membrane



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## 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

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# Membranes

## 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

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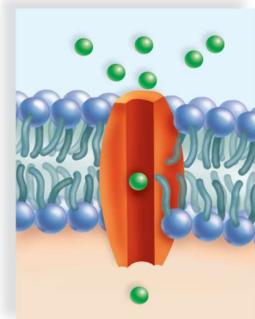
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## Membrane Protein Diversity (1)



**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 ( $\text{Cl}^-$ ) channel; a thick mucus collects in airways and in pancreatic and liver ducts.

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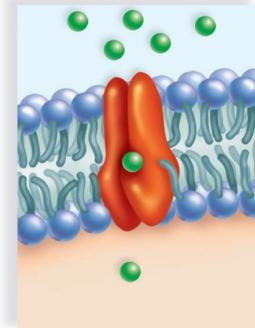
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## Membrane Protein Diversity (2)



**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 ( $\text{Na}^+ - \text{K}^+$ ) transport has been suggested as the cause of their obesity.

b.

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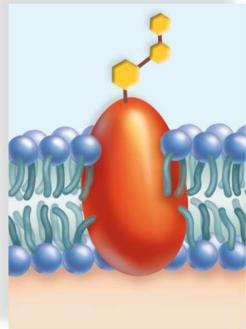
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# Membranes

## Membrane Protein Diversity (3)



**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.

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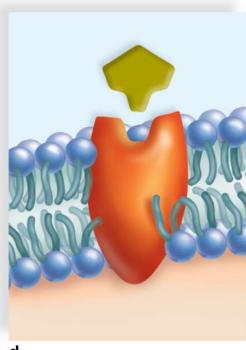
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## Membrane Protein Diversity (4)



**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.

d.

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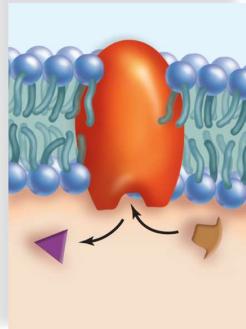
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## Membrane Protein Diversity (5)



**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 ( $\text{Na}^+$ ) and water leave intestinal cells, and the individual may die from severe diarrhea.

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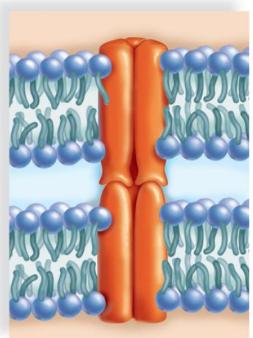
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# Membranes

## Membrane Protein Diversity (6)



**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.

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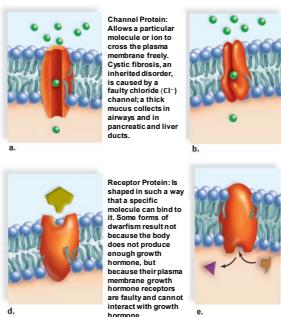
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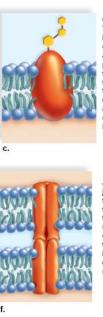
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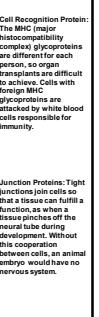
## Membrane Protein Diversity (7)



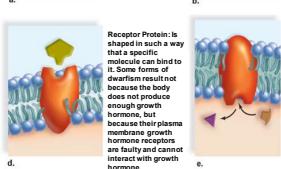
**Channel Protein:** Allows a particular molecule or ion to cross the plasma membrane. Cystic fibrosis, an inherited disorder, is caused by a faulty chloride ( $Cl^-$ ) channel protein. Mucus collects in airways and in pancreatic and liver ducts.



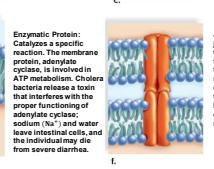
**Carrier Protein:** Selectively interacts with a specific molecule or ion and it carries the molecule across the plasma membrane. The inability to move glucose across the membrane is thought to be the cause of diabetes. Some forms of diabetes are caused by a mutation in the insulin receptor protein, which prevents insulin from interacting with its receptor.



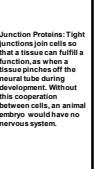
**Cell Recognition Protein:** The MHC (major histocompatibility complex) glycoproteins are unique to each person, so organ transplants are difficult to achieve. Cells with foreign MHC proteins on their surfaces are attacked by white blood cells responsible for immunity.



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



**Enzymatic Protein:** Catalyzes a specific reaction in the membrane protein, adenylate cyclase, is involved in the production of cyclic AMP. Some bacteria release a toxin that interferes with the production of cyclic AMP by adenylate cyclase; sodium ( $Na^+$ ) and water leave the cell, and the individual may die from severe diarrhea.



Jump to Membrane Protein Diversity (7) Long Description 5-17

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## 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.

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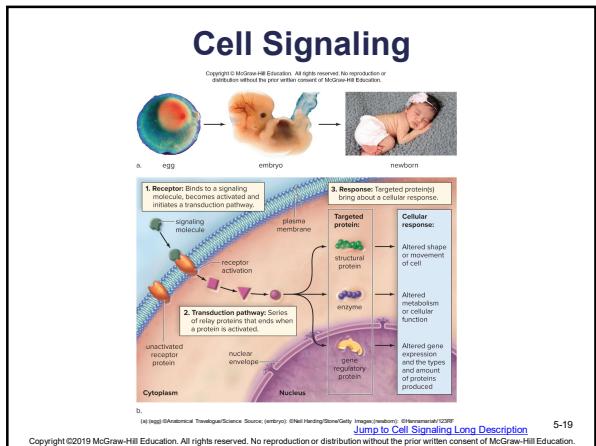
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# Membranes



## 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 ( $\text{CO}_2$ ,  $\text{O}_2$ , 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

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## Plasma Membrane Structure and Function (6)

### Permeability of the Plasma Membrane

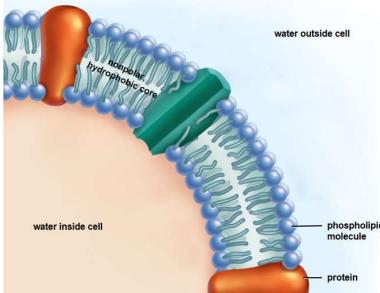
- Water moves across the plasma membrane.
  - Specialized proteins termed **aquaporins** speed up water transport across the membrane.
- The movement of ions and polar molecules across the membrane is often assisted by carrier proteins.
- Some molecules must move against their concentration gradient 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

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# Membranes

## How Molecules Cross the Plasma Membrane (1)



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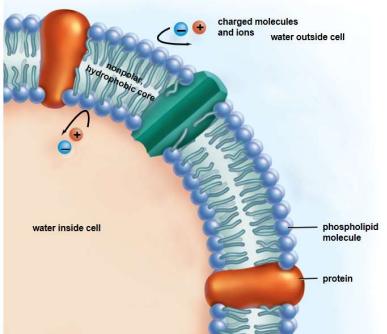
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## How Molecules Cross the Plasma Membrane (2)



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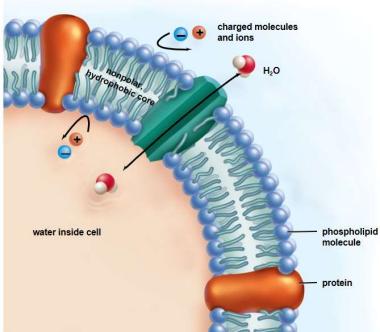
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## How Molecules Cross the Plasma Membrane (3)



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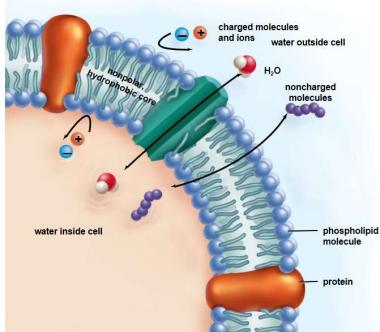
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# Membranes

## How Molecules Cross the Plasma Membrane (4)



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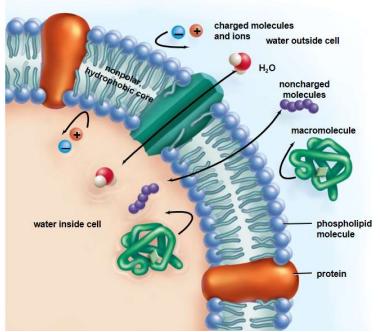
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## How Molecules Cross the Plasma Membrane (5)



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[Jump to How Molecules Cross the Plasma Membrane \(5\) Long Description](#)

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## 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

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# Membranes

## 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.

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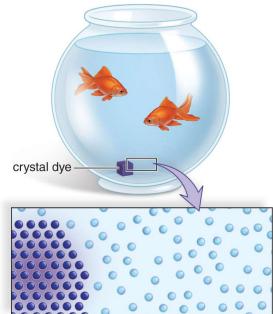
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### Process of Diffusion (1)

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a. Crystal of dye is placed in the water.  
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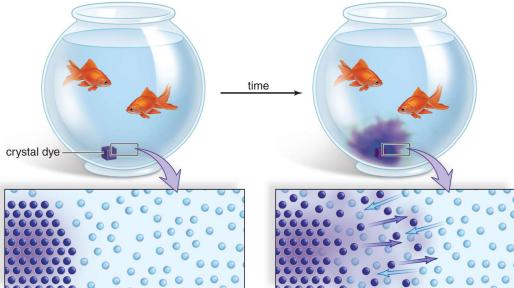
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### Process of Diffusion (2)

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a. Crystal of dye is placed in the water.  
b. Diffusion of water and dye molecules  
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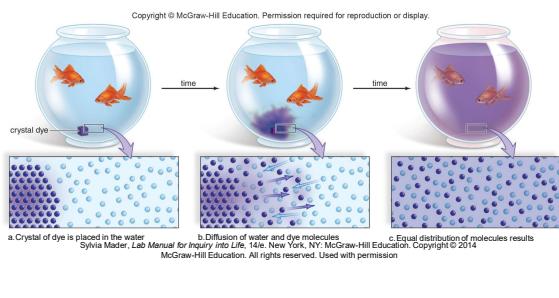
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# Membranes

## Process of Diffusion (3)

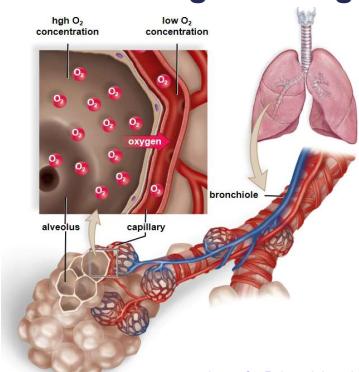


[Jump to Process of Diffusion \(3\) Long Description](#)

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## Gas Exchange in Lungs



[Jump to Gas Exchange in Lungs Long Description](#) 5-32

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## 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.

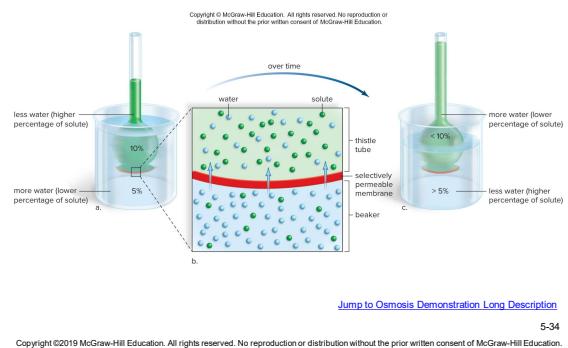
**Osmotic pressure** is the pressure that develops due to osmosis.

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# Membranes

## Osmosis Demonstration



[Jump to Osmosis Demonstration Long Description](#)

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## 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.

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### 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.

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## Passive Transport Across a Membrane (3)

### Hypertonic Solutions

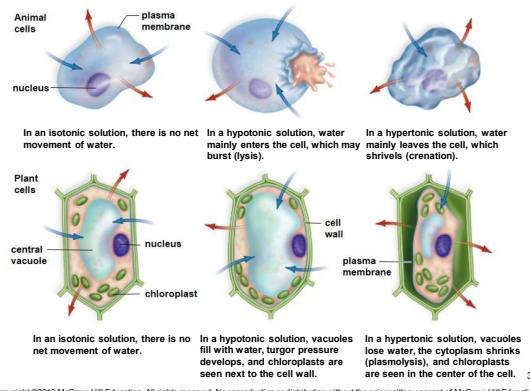
- Concentration of solute is *higher* in the solution than inside the cell.
- Cells placed in a hypertonic solution will shrink.
  - Crenation** in animal cells
    - Example of red blood cells placed in a hypertonic solution (higher than 0.9% sodium chloride)
  - Plasmolysis** in plant cells
    - Examples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

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# Membranes

## Osmosis in Animal and Plant Cells



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## 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.

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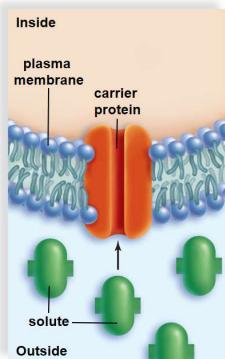
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## Facilitated Transport (1)



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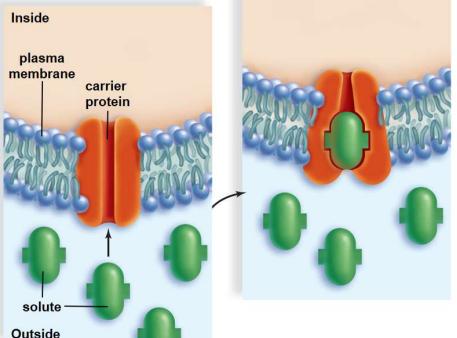
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# Membranes

## Facilitated Transport (2)



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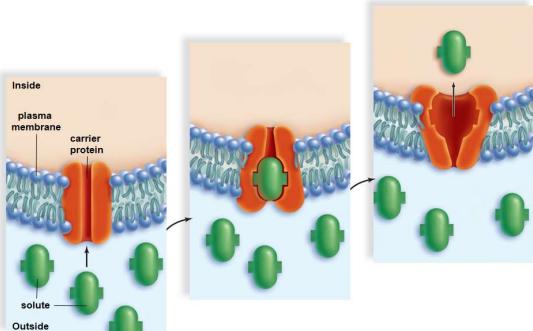
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## Facilitated Transport (3)



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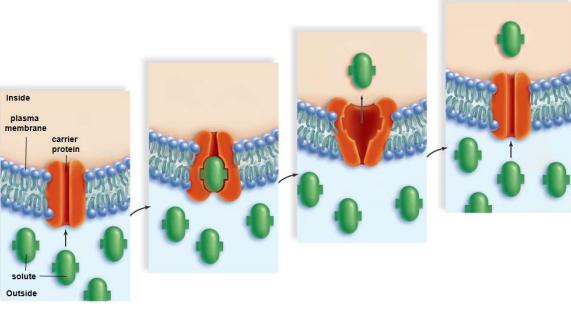
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## Facilitated Transport (4)



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# Membranes

## 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.

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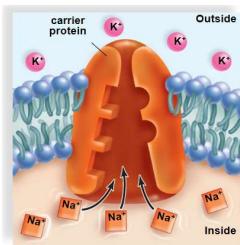
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## The Sodium-Potassium Pump (1)



- Carrier has a shape that allows it to take up 3 Na<sup>+</sup>.

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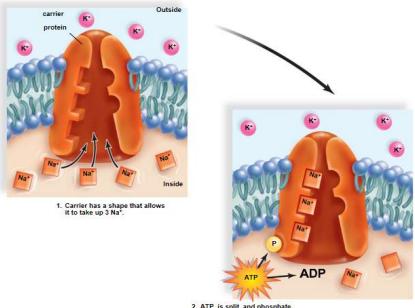
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## The Sodium-Potassium Pump (2)



- Carrier has a shape that allows it to take up 3 Na<sup>+</sup>.
- ATP is split, and phosphate group attaches to carrier

5-45

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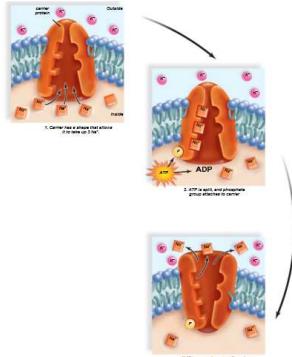
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# Membranes

## The Sodium-Potassium Pump (3)



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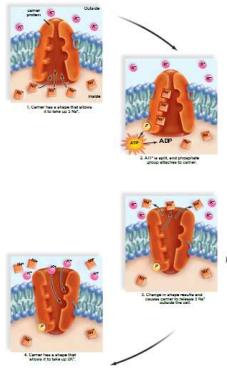
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## The Sodium-Potassium Pump (4)



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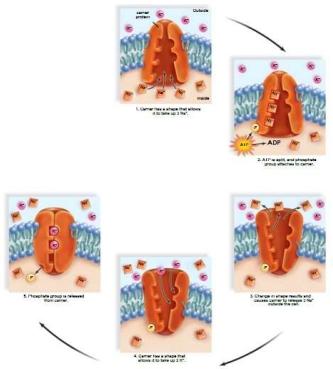
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## The Sodium-Potassium Pump (5)



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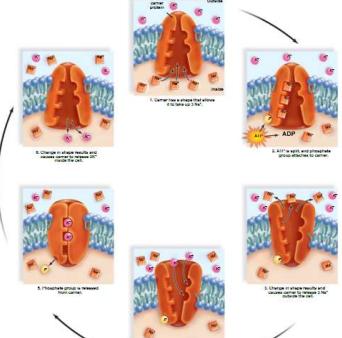
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# Membranes

## The Sodium-Potassium Pump (6)



[Jump to The Sodium-Potassium Pump \(6\) Long Description](#) 5-49

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## 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.

5-50

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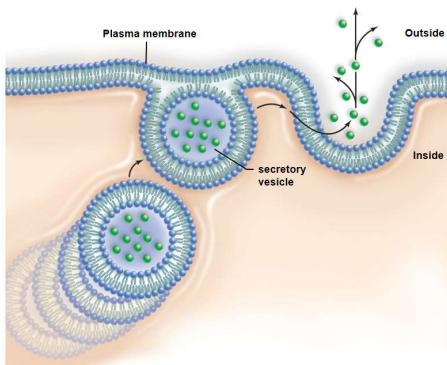
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## Exocytosis



[Jump to Exocytosis Long Description](#) 5-51

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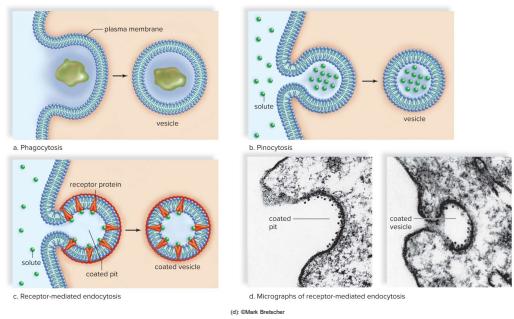
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# Membranes

## Three Methods of Endocytosis



[Jump to Three Methods of Endocytosis Long Description](#) 5-52

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## 5.4 Modifications of Cell Surfaces

### Cell Surfaces in Animals

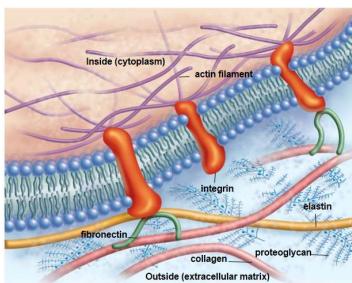
#### • Extracellular Matrix (ECM)

- 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

5-53

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## Animal Cell Extracellular Matrix



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# Membranes

## 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

5-55

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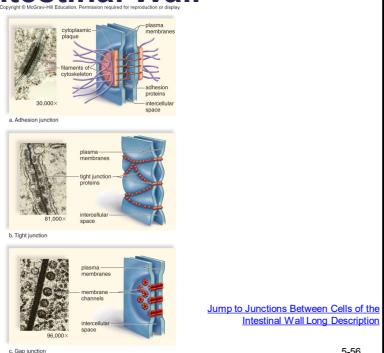
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## Junctions Between Cells of the Intestinal Wall



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## 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.

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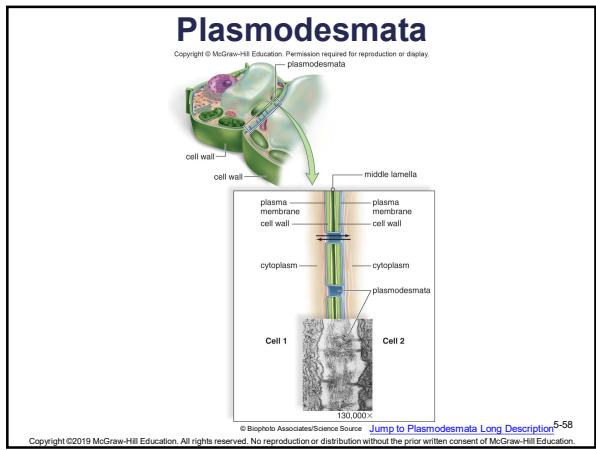
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# Membranes



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