Chapter 3

Cell Membrane Structure and Function
3.1 What Does The Plasma Membrane Do?

- The cell plasma membrane separates the cell contents from the external environment.
- The membrane acts as a gatekeeper, regulating the passage of molecules into and out of the cell.
Plasma Membrane

- Functions of the plasma membrane
  - Isolates the cell’s contents from environment
  - Regulates exchange of essential substances
  - Communicates with other cells
  - Creates attachments within and between other cells
  - Regulates biochemical reactions
Membranes Are “Fluid Mosaics”

- Membranes are dynamic, ever-changing structures
Membranes Are “Fluid Mosaics”

- “Fluid mosaic” model of a membrane proposed in 1972
  - A lumpy, constantly shifting mosaic of “tiles” or proteins
  - Proteins float around in a sea of phospholipids
3.2 What Is The Structure Of The Plasma Membrane?

- The phospholipid bilayer is the fluid portion of the membrane.

Fig. 3-2
The Phospholipid Bilayer

- Phospholipids are the basis of membrane structure
  - Polar, hydrophilic head
  - Two non-polar, hydrophobic tails
head (hydrophilic)

tails (hydrophobic)
The Phospholipid Bilayer

- The cell exterior and interior face watery environments
The Phospholipid Bilayer

- Hydrophobic and hydrophilic interactions drive phospholipids into bilayers
  - Double row of phospholipids
  - Polar heads face outward and inward
  - Non-polar tails mingle within the membrane
  - Cholesterol in animal membranes keeps them flexible
extracellular fluid
(watery environment)

phospholipid

hydrophilic heads

hydrophobic tails

hydrophilic heads

bilayer

cytosol
(watery environment)
The Phospholipid Bilayer

- Phospholipid bilayer is a flexible, fluid membrane to allow for cellular shape changes
The Phospholipid Bilayer

- Individual phospholipid molecules are not bonded to one another
- Some of the phospholipids have unsaturated fatty acids, whose double bonds introduce “kinks” into their “tails”
- The above features make the membrane fluid
more fluid

less fluid
3.3 How Does The Plasma Membrane Play Its Gatekeeper Role?

- The phospholipid bilayer blocks the passage of most molecules.
- The embedded proteins selectively transport, respond to, and recognize molecules.
- There are three types of membrane proteins—transport proteins, receptor proteins, and recognition proteins.
Membrane Proteins Form a Mosaic

- Proteins are embedded in the phospholipid bilayer
  - Some proteins can float and drift
  - Other proteins are anchored by protein filaments in the cytoplasm
  - Many proteins have attached carbohydrates (glycoproteins)
Membrane Proteins Form a Mosaic

- Categories of membrane proteins
  - Receptor Proteins
  - Recognition Proteins
  - Enzymatic Proteins
  - Attachment Proteins
  - Transport Proteins
Membrane Proteins Form a Mosaic

- **Receptor Proteins**
  - Trigger cellular responses upon binding specific molecules, e.g. hormones

- **Recognition Proteins**
  - Serve as identification tags on the surface of a cell
Membrane Proteins Form a Mosaic

- **Enzymes**
  - Promote chemical reactions that synthesize or break apart biological molecules

- **Attachment Proteins**
  - Anchor the cell membrane to inner cytoskeleton, to proteins outside the cell, and to other cells
Membrane Proteins Form a Mosaic

- **Transport Proteins**
  - Include *channel* and *carrier proteins*
  - Regulate import/export of hydrophilic molecules
Movement of Molecules in Fluids

- Definitions relevant to substance movement
  - A **fluid** is a substance that can move or change shape in response to external forces
  - A **solute** is a substance that can be dissolved (dispersed as ions or molecules) in a solvent
  - A **solvent** is a fluid capable of dissolving a solute
Movement of Molecules in Fluids

- Definitions relevant to substance movement (continued)
  - The **concentration** of molecules is the number of them in a given volume unit
  - A **gradient** is a physical difference in temperature, pressure, charge, or concentration in two adjacent regions
Movement of Molecules in Fluids

- Why molecules move from one place to another
  - Substances move in response to a concentration gradient
    - Molecules move from high to low concentration (diffusion) until dynamic equilibrium is reached
1. A drop of dye is placed in water.

2. Dye molecules diffuse into the water; water molecules diffuse into the dye.

3. Both dye molecules and water molecules are evenly dispersed.

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Movement of Molecules in Fluids

- The greater the concentration gradient, the faster the rate of diffusion
- Diffusion cannot move molecules rapidly over long distances
3.6 How Do Diffusion And Osmosis Affect Transport Across The Plasma Membrane?

- Concentration gradients of ions and molecules exist across the plasma membranes of all cells
- There are two types of movement across the plasma membrane
  - Passive transport
  - Energy-requiring transport
<table>
<thead>
<tr>
<th><strong>Passive transport</strong></th>
<th>Movement of substances across a membrane down a concentration, pressure, or electrical charge gradient. Does not require the cell to expend energy.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simple diffusion</strong></td>
<td>Diffusion of water, dissolved gases, or lipid-soluble molecules through the phospholipid bilayer.</td>
</tr>
<tr>
<td><strong>Facilitated diffusion</strong></td>
<td>Diffusion of molecules through a channel or carrier protein.</td>
</tr>
<tr>
<td><strong>Osmosis</strong></td>
<td>Diffusion of water across a selectively permeable membrane.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Energy-requiring transport</strong></th>
<th>Movement across a membrane of substances that travel against a concentration gradient. Requires the cell to expend energy.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active transport</strong></td>
<td>Movement of individual small molecules or ions through membrane-spanning proteins, using cellular energy, usually ATP.</td>
</tr>
<tr>
<td><strong>Endocytosis</strong></td>
<td>Movement into a cell of large particles, which are engulfed as the plasma membrane forms vesicles that enter the cytoplasm.</td>
</tr>
<tr>
<td><strong>Exocytosis</strong></td>
<td>Movement out of a cell of materials that are enclosed in a membranous vesicle. The vesicle moves to the cell surface, fuses with the plasma membrane, and opens to the outside, allowing its contents to diffuse out.</td>
</tr>
</tbody>
</table>
Movement Across Membranes

- **Passive transport**
  - Substances move down their concentration gradients across a membrane
  - No energy is expended
  - Membrane proteins and phospholipids may limit which molecules can cross, but not the direction of movement
Movement Across Membranes

- Energy-requiring transport
  - Substances are driven against their concentration gradients
  - Energy is expended
Passive Transport

- Plasma membranes are **selectively permeable**
  - Different molecules move across at different locations and rates
  - A concentration gradient drives all three types of passive transport: simple diffusion, facilitated diffusion, and osmosis
Passive Transport

- **Simple diffusion**
  - Lipid soluble molecules (e.g. vitamins A and E, gases) and very small molecules diffuse directly across the phospholipid bilayer
Simple diffusion through the phospholipid bilayer

lipid-soluble molecules (extracellular fluid) and $O_2$, $CO_2$, $H_2O$

$O_2$

(cytosol)
Passive Transport

- **Facilitated diffusion**
  - Water soluble molecules like ions, amino acids, and sugars diffuse with the aid of channel and carrier transport proteins
Facilitated diffusion through a channel protein

Proteins form a hydrophilic channel.

channel protein
(cytosol)
Facilitated diffusion through a carrier protein

1. Carrier protein has binding site for molecule.
2. Molecule enters binding site.
3. Carrier protein changes shape, transporting molecule across membrane.
4. Carrier protein resumes original shape.

(amino acids, sugars, small proteins)

(extracellular fluid)

(cytosol)

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Passive Transport

- **Osmosis** – the special case of water diffusion
  - Water diffuses from high concentration (high purity) to low concentration (low purity) across a membrane
  - Dissolved substances reduce the concentration of free water molecules (and hence the purity of water) in a solution
Passive Transport

- The flow of water across a membrane depends on the concentration of water in the internal or external solutions.
isotonic: no net flow of water
Passive Transport

- Comparison terms for solutions on either side of a membrane
  - **Isotonic** solutions have equal concentrations of water and equal concentrations of dissolved substances
    - No *net* water movement occurs across the membrane
isotonic: no net flow of water
Passive Transport

- Comparison terms for solutions on either side of a membrane (continued)
  - A **hypertonic** solution is one with lower water concentration or higher dissolved particle concentration
    - Water moves across a membrane *towards* the hypertonic solution
Passive Transport

- Comparison terms for solutions on either side of a membrane (continued)
  - A **hypotonic** solution is one with higher water concentration or lower dissolved particle concentration
  - Water moves across a membrane *away* from the hypotonic solution
Passive Transport

- The effects of osmosis are illustrated when red blood cells are placed in various solutions
(a) Isotonic solution

(b) Hypertonic solution

(c) Hypotonic solution

Equal movement of water into and out of cells.

Net water movement out of cells.

Net water movement into cells.

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Passive Transport

- Osmosis explains why fresh water protists have contractile vacuoles
- Water leaks in continuously because the cytosol is hypertonic to fresh water
- Salts are pumped into the vacuoles, making them hypertonic to the cytosol
- Water follows by osmosis and is then expelled by contraction
3.7 How Do Molecules Move Against A Concentration Gradient?

- Energy-requiring transport processes
  - During active transport, the cell uses energy to move substances against a concentration gradient.
  - Membrane proteins regulate active transport.
Active Transport

- Active-transport membrane proteins move molecules across using ATP
  - Proteins span the entire membrane
  - Often have a molecule binding site and an ATP binding site
  - Often referred to as pumps
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Endocytosis

- Cells import large particles or substances via endocytosis
Endocytosis

- Plasma membrane pinches off to form a vesicle in endocytosis
  - Types of endocytosis
    - Pinocytosis
    - Receptor-mediated endocytosis
    - Phagocytosis
Endocytosis

- Types of endocytosis
  - **Pinocytosis** ("cell drinking") brings in droplet of extracellular fluid
Pinocytosis

1. A dimple forms in the plasma membrane, which
2. deepens and surrounds the extracellular fluid. 3. The
membrane encloses the extracellular fluid, forming
a vesicle.
Pinocytosis in a smooth muscle cell.

1. A dimple forms in the plasma membrane, which deepens and surrounds the extracellular fluid.
2. The extracellular fluid.
3. The membrane encloses the extracellular fluid, forming a vesicle.

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Endocytosis

- Types of endocytosis
  - **Receptor-mediated endocytosis** moves specific molecules into the cell
Receptor-mediated endocytosis

1. Receptor proteins for specific molecules or complexes of molecules are localized at coated pit sites.
2. The receptors bind the molecules and the membrane dimples inward.
3. The coated pit region of the membrane encloses the receptor-bound molecules.
4. A vesicle ("coated vesicle") containing the bound molecules is released into the cytosol.

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Endocytosis

- Types of endocytosis
  - **Phagocytosis** ("cell eating") moves large particles or whole organisms into the cell.
1. The plasma membrane extends pseudopods toward an extracellular particle (for example, food). 2. The ends of the pseudopods fuse, encircling the particle. 3. A vesicle called a food vacuole is formed containing the engulfed particle.
An *Amoeba* (a freshwater protist), engulfs a *Paramecium* using phagocytosis.
White blood cell

A white blood cell ingests bacteria using phagocytosis.
Exocytosis

- Exocytosis
  - Vesicles join the membrane, dumping out contents in exocytosis
Material is enclosed in a vesicle that fuses with the plasma membrane, allowing its contents to diffuse out.
Cell Size and Shape

- Exchange affects cell size and shape
  - As a spherical cell enlarges, its innermost parts get farther away from the plasma membrane
  - Also, its volume increases more rapidly than its surface area
  - A larger cell has a relatively smaller area of membrane for nutrition exchange than a small cell
distance to center \((r)\) \hspace{1cm} 1.0 \hspace{1cm} 3.0

surface area \((4\pi r^2)\) \hspace{1cm} 12.6 \hspace{1cm} 113.1

volume \((4/3\pi r^3)\) \hspace{1cm} 4.2 \hspace{1cm} 113.1

surface area/volume \hspace{1cm} 3.0 \hspace{1cm} 1.0
Some plasma membranes are surrounded by cell walls.

- Cell walls occur around the plasma membranes of plants, fungi, and some bacteria.
- Cell walls provide support for the cells, making them capable of resisting gravity and blowing winds.
Some plasma membranes are surrounded by cell walls (continued).

- Cell walls are porous to small molecules, which can pass across these barriers to the plasma membrane.
- Plasma membranes of these cells regulate the transport of molecules by the same processes as those that occur in other cells without cell walls.