A Closer Look at Cell Membranes

Chapter 5 Part 1
Impacts, Issues:
One Bad Transporter and Cystic Fibrosis

- Transporter proteins regulate the movement of substances in and out of cells; failure of one of these proteins causes cystic fibrosis
5.1 Organization of Cell Membranes

- The basic structure of all cell membranes is the lipid bilayer with many embedded proteins.

- A membrane is a continuous, selectively permeable barrier.
Revisiting the Lipid Bilayer

- Phospholipid molecules in the plasma membrane have two parts
  - Hydrophilic heads interact with water molecules
  - Hydrophobic tails interact with each other, forming a barrier to hydrophilic molecules
Cell Membrane Organization

[Diagram showing chemical structures of phosphatidylcholine and cholesterol, with hydrophilic and hydrophobic parts labeled]

- a phosphatidylcholine
- b cholesterol

hydrophilic (polar) parts
hydrophobic (nonpolar) parts
a phosphatidylcholine
b cholesterol
The Fluid Mosaic Model

- Fluid mosaic model
  - Describes the organization of cell membranes
  - Phospholipids drift and move like a fluid
  - The bilayer is a mosaic mixture of phospholipids, steroids, proteins, and other molecules
Fluid Mosaic Model

- one layer of lipids
- lipid bilayer

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Fig. 5-2c, p. 78

c lipid bilayer

one layer of lipids

fluid
Variations on the Model

- Differences in membrane composition
  - Different kinds and numbers of carbohydrates attached to membrane proteins
  - Different kinds of phospholipids

- Differences in fluidity
  - Some proteins are attached to the cytoskeleton; others drift around
  - Archaeans have more rigid membranes than bacteria or eukaryotes
Two Studies of Membrane Structure

A Researchers first froze a cell membrane, then they split apart the two layers of its lipid bilayer. Microscopic analysis revealed many proteins embedded within the lipid bilayer.

B Cells of two species were fused into a hybrid cell. In less than one hour, most of the plasma membrane proteins from both species had drifted through the hybrid cell’s lipid bilayer and intermingled.
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5.2 Membrane Proteins

- Cell membrane function begins with the many proteins associated with the lipid bilayer
Membrane Proteins

- Each type of protein in a membrane has a special function
  - Adhesion proteins
  - Recognition proteins
  - Receptor proteins
  - Enzymes
  - Transport proteins (active and passive)
## Table 5.1 Common Types of Membrane Proteins

<table>
<thead>
<tr>
<th>Category</th>
<th>Function</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive transporters</td>
<td>Allow ions or small molecules to cross a membrane to the side where they are less concentrated. Open or gated channels.</td>
<td>Porins; glucose transporter</td>
</tr>
<tr>
<td>Active transporters</td>
<td>Pump ions or molecules through membranes to the side where they are more concentrated. Require energy input, as from ATP.</td>
<td>Calcium pump; serotonin transporter</td>
</tr>
<tr>
<td>Receptors</td>
<td>Initiate change in a cell’s activity by responding to an outside signal (e.g., by binding to a signaling molecule).</td>
<td>Insulin receptor; B cell receptor</td>
</tr>
<tr>
<td>Cell adhesion molecules</td>
<td>Help cells stick to one another and to extracellular matrix.</td>
<td>Integrins; cadherins</td>
</tr>
<tr>
<td>Recognition proteins</td>
<td>Identify cells as self (belonging to one’s own body or tissue)</td>
<td>Histocompatibility molecules</td>
</tr>
<tr>
<td>Enzymes</td>
<td>Speed reactions without being altered by them.</td>
<td>Diverse hydrolases</td>
</tr>
</tbody>
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Types of Membrane Proteins

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Animation: Fusing membranes
Adhesion Protein  Enzyme  Receptor Protein  Recognition Protein  Passive Transporter  Active Transporter
Animation: Cell membranes
Cell membranes have a lipid bilayer that is a boundary between the outside environment and the cell interior.

Diverse proteins embedded in the bilayer or positioned at one of its surfaces carry out most membrane functions.
Ions and molecules tend to move from one region to another, in response to gradients.
Membrane Permeability

- **Selective permeability**
  - The ability of a cell membrane to control which substances and how much of them enter or leave the cell
  - Allows the cell to maintain a difference between its internal environment and extracellular fluid
  - Supplies the cell with nutrients, removes wastes, and maintains volume and pH
A  Gases (such as oxygen and carbon dioxide), small nonpolar molecules, and water cross a bilayer freely.

B  Other solutes (molecules and ions) cannot cross a lipid bilayer on their own.
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Animation: Selective permeability
Concentration Gradients

- **Concentration**
  - The number of molecules (or ions) of substance per unit volume of fluid

- **Concentration gradient**
  - The difference in concentration between two adjacent regions
  - Molecules move from a region of higher concentration to one of lower concentration
Diffusion

- The net movement of molecules down a concentration gradient
- Moves substances into, through, and out of cells
- A substance diffuses in a direction set by its own concentration gradient, not by the gradients of other solutes around it
Examples of Diffusion

**A**  Dye is dropped into a bowl of water. The dye molecules diffuse until they are evenly dispersed among the water molecules.

**B**  *Red* dye and *yellow* dye are added to a bowl of water. Each substance moves according to its own concentration gradient until all are evenly dispersed.
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The Rate of Diffusion

- Rate of diffusion depends on five factors
  - Size
  - Temperature
  - Steepness of the concentration gradient
  - Charge
  - Pressure
Gases and nonpolar molecules diffuse freely across a lipid bilayer.

Ions and large polar molecules require other mechanisms to cross the cell membrane:
- Passive transport
- Active transport
- Endocytosis and exocytosis
Membrane-Crossing Mechanisms

A  **Diffusion**  
A substance simply diffuses across lipid bilayer.

B  **Passive Transport**  
A solute moves across bilayer through interior of passive transporter; movement is driven by concentration gradient.

C  **Active Transport**  
Active transporter uses energy (often, ATP) to pump a solute through bilayer against its concentration gradient.

D  **Endocytosis**  
Vesicle movement brings substances in bulk into cell.

E  **Exocytosis**  
Vesicle movement ejection substances in bulk from cell.

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Many types of molecules and ions diffuse across a lipid bilayer only with the help of a specific transport protein.
Passive Transport

- **Passive transport** (facilitated diffusion)
  - Requires no energy input
  - A passive transport protein allows a specific solute (such as glucose) to follow its concentration gradient across a membrane
  - A gated passive transporter changes shape when a specific molecule binds to it
Passive Transport

A glucose molecule (here, in extracellular fluid) binds to a transport protein embedded in the lipid bilayer.

Binding causes the protein to change shape.

The glucose molecule detaches from the transport protein on the other side of the membrane (here, in the cytoplasm), and the protein resumes its original shape.
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Animation: Passive transport
Active Transport

- **Active transport**
  - Requires energy input (usually ATP)
  - Moves a solute against its concentration gradient, to the concentrated side of the membrane

- **Calcium pumps**
  - Active transporters move calcium ions across muscle cell membranes into the sarcoplasmic reticulum
Active Transport: Calcium Pump

A  Calcium ions bind to a calcium transporter (calcium pump).

B  A phosphate group is transferred from ATP to the pump. The pump changes shape so that it ejects the calcium ions to the opposite side of the membrane, and then resumes its original shape.
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Cotransporter

- An active transport protein that moves two substances across a membrane at the same time
- *Example:* The sodium-potassium pump moves \( \text{Na}^+ \) out of the cell and \( \text{K}^+ \) into the cell
Cotransport: Sodium-Potassium Pump

Figure 5.11  Cotransport. This model shows how a sodium–potassium pump transports sodium ions (Na+, red) from the cytoplasm to the extracellular fluid, and potassium ions (K+, purple) in the other direction across the plasma membrane. A phosphate group transfer from ATP provides energy for the transport.
Figure 5.11  Cotransport. This model shows how a sodium–potassium pump transports sodium ions (Na\(^+\), red) from the cytoplasm to the extracellular fluid, and potassium ions (K\(^+\), purple) in the other direction across the plasma membrane. A phosphate group transfer from ATP provides energy for the transport.
5.3-5.4 Key Concepts: Diffusion and Membrane Transport

- **Gradients drive the directional movements of substances across membranes**

- **Transport proteins work with or against gradients to maintain water and solute concentrations**
Animation: Lipid bilayer organization