Overview: Life at the Edge

- The plasma membrane is the boundary that separates the living cell from its surroundings
- The plasma membrane exhibits **selective permeability**, allowing some substances to cross it more easily than others

Concept 7.1: Cellular membranes are fluid mosaics of lipids and proteins

- Phospholipids are the most abundant lipid in the plasma membrane
- Phospholipids are **amphipathic molecules**, containing hydrophobic and hydrophilic regions
- The **fluid mosaic model** states that a membrane is a fluid structure with a “mosaic” of various proteins embedded in it

Membrane Models: **Scientific Inquiry**

- Membranes have been chemically analyzed and found to be made of proteins and lipids
- Scientists studying the plasma membrane reasoned that it must be a phospholipid bilayer

- In 1935, Hugh Davson and James Danielli proposed a sandwich model in which the phospholipid bilayer lies between two layers of globular proteins
- Later studies found problems with this model, particularly the placement of membrane proteins, which have hydrophilic and hydrophobic regions
- In 1972, S. J. Singer and G. Nicolson proposed that the membrane is a mosaic of proteins dispersed within the bilayer, with only the hydrophilic regions exposed to water
Phospholipid bilayer

Hydrophobic regions of protein

Hydrophilic regions of protein

Freeze-fracture studies of the plasma membrane supported the fluid mosaic model. Freeze-fracture is a specialized preparation technique that splits a membrane along the middle of the phospholipid bilayer.

The Fluidity of Membranes

- Phospholipids in the plasma membrane can move within the bilayer.
- Most of the lipids, and some proteins, drift laterally.
- Rarely does a molecule flip-flop transversely across the membrane.

Lateral movement occurs $\sim 10^7$ times per second.

Flip-flopping across the membrane is rare ($\sim$ once per month).
RESULTS

- As temperatures cool, membranes switch from a fluid state to a solid state
- The temperature at which a membrane solidifies depends on the types of lipids
- Membranes rich in unsaturated fatty acids are more fluid than those rich in saturated fatty acids
- Membranes must be fluid to work properly; they are usually about as fluid as salad oil

The steroid cholesterol has different effects on membrane fluidity at different temperatures
- At warm temperatures (such as 37°C), cholesterol restrains movement of phospholipids
- At cool temperatures, it maintains fluidity by preventing tight packing

Evolution of Differences in Membrane Lipid Composition

- Variations in lipid composition of cell membranes of many species appear to be adaptations to specific environmental conditions
- Ability to change the lipid compositions in response to temperature changes has evolved in organisms that live where temperatures vary

Membrane Proteins and Their Functions

- A membrane is a collage of different proteins, often grouped together, embedded in the fluid matrix of the lipid bilayer
- Proteins determine most of the membrane’s specific functions
- Peripheral proteins are bound to the surface of the membrane
- Integral proteins penetrate the hydrophobic core
• Integral proteins that span the membrane are called **transmembrane proteins**
  • The hydrophobic regions of an integral protein consist of one or more stretches of nonpolar amino acids, often coiled into alpha helices

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![Figure 7.10 Six major functions of membrane proteins](image)

- **Transport**
- **Enzymatic activity**
- **Signal transduction**

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**The Role of Membrane Carbohydrates in Cell-Cell Recognition**

- Cells recognize each other by binding to surface molecules, often containing carbohydrates, on the extracellular surface of the plasma membrane
- Membrane carbohydrates may be covalently bonded to lipids (forming **glycolipids** or more commonly to proteins (forming **glycoproteins**)
- Carbohydrates on the external side of the plasma membrane vary among species, individuals, and even cell types in an individual

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**Synthesis and Sidedness of Membranes**

- Membranes have distinct inside and outside faces
- The asymmetrical distribution of proteins, lipids, and associated carbohydrates in the plasma membrane is determined when the membrane is built by the ER and Golgi apparatus
Concept 7.2: Membrane structure results in selective permeability

- A cell must exchange materials with its surroundings, a process controlled by the plasma membrane
- Plasma membranes are selectively permeable, regulating the cell’s molecular traffic

The Permeability of the Lipid Bilayer

- Hydrophobic (nonpolar) molecules, such as hydrocarbons, can dissolve in the lipid bilayer and pass through the membrane rapidly
- Polar molecules, such as sugars, do not cross the membrane easily

Transport Proteins

- **Transport proteins** allow passage of hydrophilic substances across the membrane
- Some transport proteins, called channel proteins, have a hydrophilic channel that certain molecules or ions can use as a tunnel
  - **Aquaporins** facilitate the passage of water

- Other transport proteins, called carrier proteins, bind to molecules and change shape to shuttle them across the membrane
- A transport protein is specific for the substance it moves

Concept 7.3: Passive transport is diffusion of a substance across a membrane with no energy investment

- **Diffusion** is the tendency for molecules to spread out evenly into the available space
- Although each molecule moves randomly, diffusion of a population of molecules may be directional
- At dynamic equilibrium, as many molecules cross the membrane in one direction as in the other
Substances diffuse down their concentration gradient, the region along which the density of a chemical substance increases or decreases. No work must be done to move substances down the concentration gradient. The diffusion of a substance across a biological membrane is passive transport because no energy is expended by the cell to make it happen.

Effects of Osmosis on Water Balance

- Osmosis is the diffusion of water across a selectively permeable membrane.
- Water diffuses across a membrane from the region of lower solute concentration to the region of higher solute concentration until the solute concentration is equal on both sides.

Water Balance of Cells Without Walls

- Tonicity is the ability of a surrounding solution to cause a cell to gain or lose water.
- Isotonic solution: Solute concentration is the same as that inside the cell; no net water movement across the plasma membrane.
- Hypertonic solution: Solute concentration is greater than that inside the cell; cell loses water.
- Hypotonic solution: Solute concentration is less than that inside the cell; cell gains water.
Hypotonic or hypotonic environments create osmotic problems for organisms.

Osmoregulation, the control of solute concentrations and water balance, is a necessary adaptation for life in such environments.

The protist *Paramecium*, which is hypertonic to its pond water environment, has a contractile vacuole that acts as a pump.

**Water Balance of Cells with Walls**

- Cell walls help maintain water balance.
- A plant cell in a hypotonic solution swells until the wall opposes uptake; the cell is now **turgid** (firm).
- If a plant cell and its surroundings are isotonic, there is no net movement of water into the cell; the cell becomes **flaccid** (limp), and the plant may wilt.

- In a hypertonic environment, plant cells lose water; eventually, the membrane pulls away from the wall, a usually lethal effect called **plasmolysis**.

**Facilitated Diffusion: Passive Transport Aided by Proteins**

- In **facilitated diffusion**, transport proteins speed the passive movement of molecules across the plasma membrane.

- Channel proteins provide corridors that allow a specific molecule or ion to cross the membrane.
- Channel proteins include:
  - Aquaporins, for facilitated diffusion of water
  - Ion channels that open or close in response to a stimulus (gated channels)
- Carrier proteins undergo a subtle change in shape that translocates the solute-binding site across the membrane.
• Some diseases are caused by malfunctions in specific transport systems, for example the kidney disease cystinuria

Concept 7.4: Active transport uses energy to move solutes against their gradients
• Facilitated diffusion is still passive because the solute moves down its concentration gradient, and the transport requires no energy
• Some transport proteins, however, can move solutes against their concentration gradients

The Need for Energy in Active Transport
• Active transport moves substances against their concentration gradient
• Active transport requires energy, usually in the form of ATP
• Active transport is performed by specific proteins embedded in the membranes

• Active transport allows cells to maintain concentration gradients that differ from their surroundings
• The sodium-potassium pump is one type of active transport system
How Ion Pumps Maintain Membrane Potential

• **Membrane potential** is the voltage difference across a membrane
• Voltage is created by differences in the distribution of positive and negative ions across a membrane

**• Two combined forces, collectively called the **electrochemical gradient**, drive the diffusion of ions across a membrane**
  - A chemical force (the ion’s concentration gradient)
  - An electrical force (the effect of the membrane potential on the ion’s movement)
An **electrogenic pump** is a transport protein that generates voltage across a membrane.

- The sodium-potassium pump is the major electrogenic pump of animal cells.
- The main electrogenic pump of plants, fungi, and bacteria is a **proton pump**.
- Electrogenic pumps help store energy that can be used for cellular work.

**Figure 7.20**

**Cotransport: Coupled Transport by a Membrane Protein**

- **Cotransport** occurs when active transport of a solute indirectly drives transport of other solutes.
- Plants commonly use the gradient of hydrogen ions generated by proton pumps to drive active transport of nutrients into the cell.

**Figure 7.21**

**Concept 7.5: Bulk transport across the plasma membrane occurs by exocytosis and endocytosis**

- Large molecules, such as polysaccharides and proteins, cross the membrane in bulk via vesicles.
- Bulk transport requires energy.

**Exocytosis**

- In **exocytosis**, transport vesicles migrate to the membrane, fuse with it, and release their contents.
- Many secretory cells use exocytosis to export their products.

**Endocytosis**

- In **endocytosis**, the cell takes in macromolecules by forming vesicles from the plasma membrane.
- Endocytosis is a reversal of exocytosis, involving different proteins.
- There are three types of endocytosis:
  - Phagocytosis (“cellular eating”)
  - Pinocytosis (“cellular drinking”)
  - Receptor-mediated endocytosis.
• In **phagocytosis** a cell engulfs a particle in a vacuole
  - The vacuole fuses with a lysosome to digest the particle

• In **pinocytosis**, molecules are taken up when extracellular fluid is "gulped" into tiny vesicles

• In **receptor-mediated endocytosis**, binding of ligands to receptors triggers vesicle formation
  - **A ligand** is any molecule that binds specifically to a receptor site of another molecule

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**Receptor-Mediated Transport**

- **Specific transport**
- **Cholesterol**
  - Familial hypercholesterolemia, FH (type II) patients have defect membrane surface receptors that help to remove LDLs from circulation