The Cell / Plasma Membrane:

- Made up of phospholipids, proteins, carbohydrates, and other lipids.
- The main goal is to maintain homeostasis.
- Other functions:
  - 1. Regulates materials moving in and out of the cell
  - 2. Provides a large surface area on which specific chemical reactions can occur.
  - 3. Site for receptors containing specific cell identification markers that differentiate one cell from another. Cell communication.
  - 4. Separates cells from one another. Identification.
  - 5. Protects the inside of the cell (somewhat)
- The membrane doesn’t completely protect the cell because many substances that aren’t beneficial to the cell can still enter through diffusion.
- Membranes allow cells to create and maintain internal environments that differ from external environments.
- Semi-permeable or selectively permeable- Some materials can pass through and others cannot.
  - Permeability depends on:
    - 1. Lipid solubility
    - 2. Size
    - 3. Charge
    - 4. Presence of channels and transporters
- Also known as the Fluid Mosaic Model - a membrane that is a fluid (can move easily) structure with a “mosaic” of various proteins and carbohydrates embedded in it.
  - Phospholipids are made up of polar glycerol and phosphate hydrophilic heads and nonpolar fatty acid hydrophobic tails.
    - Lipid bilayer is stable because water’s affinity for hydrogen bonding never stops.
  - Some proteins that extend through the entire membrane are called amphipathic because they have both hydrophilic and hydrophobic regions.
  - Many proteins and lipids are attached to carbohydrates. Together they function in cell recognition and communication.
  - Cholesterol- Secure proteins in the membrane, prevent the cell from becoming too fluid, and give your cells the ability to communicate with each other. Holds phospholipids together.
Temperature can alter its fluid state- 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 because the “kinks” introduced by the double bonds prevent them from packing tightly together. The saturated fats are tightly packed together.
- 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.
- Bacteria- can maintain a constant fluidity no matter what the temperature is. Some have enzymes called fatty acid desaturases that can introduce double bonds into fatty acid membranes.

There are two main categories of membrane proteins:

- **1. Integral proteins**: embedded in the membrane, some move around, mostly hydrophobic regions but some extend throughout the entire transmembrane. They serve as transport channels for particles to enter and leave the cell.
- **2. Peripheral proteins**: loosely bound to the surface of the membrane sometimes to the integral proteins, may help regulating cell signaling.

Four Main Components of the Cell Membrane:

1. **Phospholipid Bilayer**- see above
2. **Transmembrane Proteins**: proteins that float in the membrane
   a. **Carrier Proteins**: Binding site on protein surface that “grabs” certain molecules and pulls them into the cell (gated channels, ex- sodium potassium pump)
   b. **Channel Proteins**: form small openings for molecules to diffuse through. Act as a tunnel or passage through the membrane (ex- sodium and potassium channels in nerve, heart, and muscle cells). Some are called **aquaporins**, which facilitate the passage of water.
   c. **Receptor Proteins**: Molecular triggers that set off cell responses (release hormones or opening of channel proteins).
d. **Roles of Membrane Proteins:**
   
i. **Transport** - allowing solutes to pass through, transport ATP (through channel and carrier proteins)
   
   ii. **Enzymatic Activity** - a protein built into the membrane may be an enzyme with an active site that binds to a specific substrate to create a desired or needed product for cellular function.
   
   iii. **Converting** one signal into another, example hormones
   
   iv. **Cell to cell recognition** via glycolipids and glycoproteins
   
   v. **Intercellular joining** - when membrane proteins from other cells join together to form junctions such as gap junction and tight junctions.
   
   vi. **Attachment to the cytoskeleton and extracellular matrix** - Microfilaments or other elements of the cytoskeleton may be bonded to membrane proteins, a function that helps maintain cell shape and stabilizes the location of certain membrane proteins. Proteins that adhere to the ECM can coordinate extracellular and intracellular changes.

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**Figure 7.7a**

(a) Transport  
(b) Enzymatic activity  
(c) Signal transduction
3. **Interior Protein Network** - maintains the membranes shape.
   a. **Spectrins** - determine cell shape; form a supporting scaffold beneath the membrane, anchored to both the cytoskeleton and the membrane. Ex- Red blood Cells- biconcave shape
   b. **Clathrins** - anchor certain proteins to a specific site, especially on the exterior of the membrane in receptor mediated endocytosis. This allows the membrane to control the lateral movements of some key membrane proteins, anchoring them to specific areas / sites.

4. **Cell Surface Markers**
   b. **Glycoproteins** - carbohydrates bonded to proteins on the membrane. Bring other cells together and act as receptors on cell surfaces. Offer strength and support as well. Ex- Major Histocompatibility complex protein recognized by the immune system= a set of protein cell surface markers anchored in the plasma membrane, which the immune system uses to identify “self.” If they aren’t identified as “self” the immune system sends attackers (WBC’s) to take care of the invaders.
   c. **Carbohydrate Chains** - serve as identification tags allowing cells to distinguish one cell from another.
Sides of the membrane:

- Aided by the ER and Golgi Apparatus
- They produce vesicles containing proteins that will fuse with the cell membrane and increase its size
- The inside of the vesicles corresponds to the outside of the plasma membrane; this is important because the interior and exterior of the membrane are different.

**Cellular Transport**

- Passive Transport- No energy needed
- Active Transport- Requires energy, ATP

<table>
<thead>
<tr>
<th>Diffusion</th>
<th>Osmosis</th>
<th>Facilitated Diffusion</th>
<th>Active Transport</th>
<th>Bulk Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passive= No energy</strong></td>
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</tr>
<tr>
<td>Particles move from areas of high to low concentration until equilibrium is met.</td>
<td>The diffusion of water molecules across a semi-permeable membrane.</td>
<td>Larger particles move from high to low concentration through a protein channel.</td>
<td>Larger particles need energy to move from low to high concentration through a protein channel. Requires ATP</td>
<td>The cell membrane making vesicles to bring materials in and out of the cell.</td>
</tr>
</tbody>
</table>
Diffusion:

- Particles move from areas of high to low concentration until equilibrium is met.
- No energy required, think of it as moving with the current
- Molecules move down the concentration gradient. Concentration gradient is the difference between the concentration on the inside of the membrane and that on the outside.
- Molecules and ions are in constant random motion
- Examples: Small lipids, CO$_2$, O$_2$
- Rate is dependent on:
  - Material= solid, liquid, gas
  - Size of molecules
  - Temperature

**Facilitated diffusion**

- Needs some extra help going across the membrane so a molecule will hitch a ride and bind temporarily to a carrier or channel protein in the cell membrane.
- Moves from high to low concentration until equilibrium is met.
- Examples- glucose, amino acids, nucleotides, and ions
  - Ions such as cations (carry a positive charge) and anions (carry a negative charge) interact well with polar molecules such as water, but are repelled by nonpolar molecules such as the fatty acid portion of the bilayer. Therefore they need assistance from **channel proteins** so that they can get into the cell.
  - **Ion channels**- have a hydrated interior that spans the membrane so that they can freely pass back and forth.
  - **Gated Channels**- open and close based on a certain stimulus (chemical or electrical)
  - **Movement of ions** is determined by:
    - 1. Concentration inside / outside the membrane
    - 2. Voltage differences- membrane potentials. These membrane potential changes form the basis for information to be exchanged in the nervous system and throughout tissues.
    - 3. State of the gate- opened or closed. Each channel is specific for a particular ion (ex- Ca, Na, K, Cl)
  - **Carrier Proteins**-
    - Help transport ions and other solutes (sugars and amino acids)
    - Carriers must bind to the molecule they transport; therefore the relationship between concentration and rate of transport differs due to simple diffusion.
    - **Ex-** Think of a cell as a stadium, where the crowd has to go through turnstiles to enter. If there are too many people going through the turnstiles you have to wait your turn. If they are empty them you can go right in.

Osmosis

- The diffusion of water across a semi-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
- Aqueous solution- ions, molecules, sugars, and amino acids dissolved in water.
- Aquaporins- specialized water channels.
- Tonicity- concentration of solutes in the water inside and outside the cell.
- Osmotic concentration- the concentration of all solutes in a solution.

Three types of tonicity:

<table>
<thead>
<tr>
<th>Hypertonic</th>
<th>Isotonic</th>
<th>Hypotonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration of water molecules</td>
<td>Concentration of water molecules</td>
<td>The concentration of water molecules are the same inside and outside the cell.</td>
</tr>
<tr>
<td>inside the cell is higher than</td>
<td>and solutes are the same inside</td>
<td>Animal cells need isotonic solutions to maintain homeostasis.</td>
</tr>
<tr>
<td>outside the cell. Solutmes are</td>
<td>and outside the cell.</td>
<td>Water does not stop moving</td>
</tr>
<tr>
<td>higher outside the cell. Therefore water moves outside the cell.</td>
<td>Animal cells need isotonic solutions to maintain homeostasis.</td>
<td>Cells reach dynamic equilibrium</td>
</tr>
<tr>
<td>Causes the cell to shrivel or</td>
<td>Concentration of water molecules</td>
<td>Solutes and solvents are equal on</td>
</tr>
<tr>
<td>“crenate” because the water is</td>
<td>and solutes are the same inside</td>
<td>the outside and inside of the cell.</td>
</tr>
<tr>
<td>leaving the cell.</td>
<td>and outside the cell.</td>
<td>Animal cells need isotonic solutions to maintain homeostasis.</td>
</tr>
<tr>
<td>When plants lose water they wilt</td>
<td>Animal cells need isotonic solutions to maintain homeostasis.</td>
<td>Water does not stop moving</td>
</tr>
<tr>
<td>Plasmolysis- process of water</td>
<td>Animal cells need isotonic solutions to maintain homeostasis.</td>
<td>Cells reach dynamic equilibrium</td>
</tr>
<tr>
<td>moving out of the cell.</td>
<td>Animal cells need isotonic solutions to maintain homeostasis.</td>
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Solution is Isotonic

Solution is Hypertonic

Solution is Hypotonic
- A good way to remember the direction is by remembering that “SALT SUCKS H₂O” Wherever there is more salt or solutes that is where the water is going to go.

- Hypertonic 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
  - Ex- The protist *Paramecium*, which is hypertonic to its pond water environment, has a contractile vacuole that acts as a pump to remove excess water through a pore.

**Active Transport - Requires energy**

- Moves substances against their concentration gradients- molecules move from high to low concentration. It’s like swimming against the current.
- Requires energy, usually in the form of ATP (directly and indirectly)
- Enables a cell to take up additional molecules of a substance that is already present in its cytoplasm in concentrations higher than in the extracellular matrix.
- Performed by specific proteins embedded in the membranes
- Carrier proteins pump molecules through the membrane
  - Uniporters- transport a single type of molecule
  - Symporters- transport two molecules at the same time in the same direction
  - Antiporters- transport two molecules at the same time in different directions
- **The Sodium Potassium Pump** runs directly on ATP
  - The cell removes 3 sodium ions for every two potassium ions that enter.

**Figure 7.15a**

1. Cytoplasmic Na⁺ binds to the sodium-potassium pump. The affinity for Na⁺ is high when the protein has this shape.

2. Na⁺ binding stimulates phosphorylation by ATP.

**Figure 7.15b**

3. Phosphorylation leads to a change in protein shape, reducing its affinity for Na⁺, which is released outside.

4. The new shape has a high affinity for K⁺, which binds on the extracellular side and triggers release of the phosphate group.
Phosphorylation - the addition of phosphates to a protein.

Why would you not want sodium to build up in the cytoplasm of your cells?

**Ion Pumps and Membrane Potentials**

- **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
**Bulk Transport**

- Requires energy
- Large molecules, such as polysaccharides and proteins, cross the membrane in bulk via vesicles
  - **EXOCYTOSIS**
    - Transport vesicles migrate to the membrane, fuse with it, and release their contents outside the cell
    - Many secretory cells use exocytosis to export their products
    - Ex- secretion of mucus or release of neurotransmitters
  - **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")
        - A cell engulfs a particle in a vacuole
        - The vacuole fuses with a lysosome to digest the particle
        - Ex- white blood cells engulf and digest harmful bacteria
      - Pinocytosis ("cellular drinking")
- Molecules dissolved in droplets are taken up when extracellular fluid is “gulped” into tiny vesicles
- Ex- kidney cells take in fluid
- Ex- mammalian egg cells, “nurse” from surrounding cells by obtaining the nutrients secreted from nearby cells to nourish the mature egg cell

- **Receptor-mediated endocytosis**
  - Binding of ligands to receptors triggers vesicle formation
  - Triggered by the receptor, forming a clathrin-coated vesicle
  - A **ligand** is any molecule that binds specifically to a receptor site of another molecule
  - Ex- cholesterol uptake

Label the Cell Membrane: