Cell (Plasma) Membrane

- At the surface of a cell, the plasma membrane separates the \textit{intracellular fluid} (ICF or cytosol) from the \textit{extracellular fluid} (ECF) of a cell.
- Provides a means to communicate with other cells.
- Provides a gateway for exchange between the ECF and ICF.
  - The arrangement of phospholipids in a bilayer makes most of the thickness of the membrane \textbf{NON-POLAR} and thus creates an \textbf{extremely effective barrier} against the movement of polar substances into or out of the cell.
  - Membrane \textit{proteins} determine what gets or stays in/out of a cell which allows the composition of the ICF to be optimal for cellular functions control the movement of substances into/out of the cell.
Cell Membrane Proteins

• Integral or transmembrane proteins
  – completely pass through the bilayer
    • extracellular portion is exposed to the ECF
      – composed of polar amino acids
    • intracellular portion is exposed to the ICF
      – composed of polar amino acids
    • “connect” the ICF and ECF
      – composed of nonpolar amino acids
  – different classes of integral proteins are based on function
Integral Membrane Protein Functions

(a) Receptor: A receptor that binds to chemical messengers such as hormones sent by other cells.
(b) Enzyme: An enzyme that breaks down a chemical messenger and terminates its effect on the target cell.
(c) Channel protein: A channel protein that is constantly open and allows solutes to pass into and out of the cell.
(d) Gated channel: A gated channel that opens and closes to allow solutes through only at certain times.
(e) Cell-identity marker: A glycoprotein acting as a cell-identity marker distinguishing the body’s own cells from foreign cells.
(f) Cell-adhesion molecule (CAM): A cell-adhesion molecule (CAM) that binds one cell to another.
Membrane Carbohydrates

• The **small** polysaccharides that are part of the plasma membrane are **always** immersed in the ECF
  – covalently bound to an **integral membrane protein** or a **phospholipid head**

• 2 varieties
  – Glycolipids
    • polysaccharides are covalently bound to the polar head of a **phospholipid**
  – Glycoproteins
    • polysaccharides are covalently bound the extracellular portion of an integral membrane protein
Modes of Membrane Transport

• **Transmembrane Transport**
  – movement of small substances *through* a cellular membrane (plasma, ER, mitochondrial..)
    • ions, fatty acids, H$_2$O, monosaccharides, steroids, amino acids…
  – polar substances use integral membrane proteins
  – nonpolar substances pass directly through the phospholipid bilayer

• **Vesicular Transport**
  – transport of substances that are **TOO LARGE** to move through a membrane
    • proteins, cellular debris, bacteria, viruses…
  – use *vesicles* to move substances into/out of the cell
Vesicles

- “Bubbles” of phospholipid bilayer membrane with substances inside
- Created by the “pinching” or “budding” of the phospholipid bilayer membrane
  - reduces the amount of membrane at that location
- Can “fuse” (merge) with another phospholipid bilayer membrane within the cell
  - adds to the amount of membrane at that location
1. Protein formed by ribosomes on rough ER.

2. Protein packaged into transport vesicle, which buds from ER.

3. Transport vesicles fuse into clusters that unload protein into Golgi complex.


5. Golgi vesicle containing finished protein formed.

Vesicular Transport

• **Exocytosis**
  – moves substance **out** of the cell
  – fusion of a vesicle with substances with the cell membrane

• **Endocytosis**
  – moves substances **into** the cell
  – cell membrane creates **pseudopods** (“false feet”) which traps substances in the ECF within a vesicle
Types of Endocytosis

- **Phagocytosis**
  - “cell eating”
  - endocytosis of few very large substances (bacteria, viruses, cell fragments)
  - vesicles containing cells fuse with lysosomes which digest the cells

- **Pinocytosis**
  - “cell sipping”
  - endocytosis of extracellular fluid
Endocytosis and **Lysosomes**

1. The phagocytic white blood cell encounters a bacterium that binds to the cell membrane.

2. The phagocyte uses its cytoskeleton to push its cell membrane around the bacterium, creating a large vesicle, the phagosome.

3. The phagosome containing the bacterium separates from the cell membrane and moves into the cytoplasm.

4. The phagosome fuses with lysosomes containing digestive enzymes.

5. The bacterium is killed and digested within the vesicle.
Solutions

- The ICF and the ECF are homogeneous mixtures of substances including water, ions, amino acids, disaccharides, triglycerides... called solutions

- Solutions are divided into 2 parts
  - **Solvent**
    - substance present in greatest amount
    - the solvent of the body is water
  - **Solute(s)**
    - substance(s) present in lesser amounts
    - every other substance in the body is a solute
      - ions, carbs, proteins, fats, nucleotides...

- Described in terms of their concentration of solutes
  - the amount of solutes in a given volume of solution
    - units include: molarity, %, weight per volume
ECF vs. ICF

- The **total** solute concentration of the ECF = ICF
- The concentration of every solute in the ECF is **different** from its concentration in the ICF – the cell membrane transports each solute between the ICF and ECF creating *gradients* for each solute to maintain optimal conditions within the ICF
Concentration Gradients

- The **difference** in the amount of a substance between 2 locations
  - area of greater amount vs. area of lesser amount
  - the difference may be **LARGE** or **small**
  - may exist across a physical barrier (membrane) or across a distance without a barrier
- Substances in an area of high concentration naturally move toward regions of lower concentrations
  - form of **mechanical energy** where location of greater amount provides more collisions
    - collisions cause substances to spread out
Concentration Gradients
Movement of Substances Relative to Gradients
Active Transport

• The movement of a substance from a region of lesser amount to a region of greater amount is called **active transport**
  – moves a substance **UP** or **AGAINST** a **concentration gradient** and **requires** an energy source
Movement of Substances Relative to Gradients

Passive Transport

• The movement of a substance from a region of greater amount to a region of lesser amount is called passive transport
  – moves a substance \textbf{DOWN} or \textbf{WITH} a \textbf{concentration gradient} and does \textbf{NOT} require an energy source
  – actually \textbf{releases} the (same amount of) energy required to create the gradient
Transmembrane Transport of Nonpolar vs. Polar Substances

- **Nonpolar** substances cross a membrane through the **phospholipid bilayer** – ineffective barrier against the movement of nonpolar molecules across a membrane
  - it is **impossible** to control the movement of nonpolar molecules through a membrane
- **Polar** substances cross a membrane by moving through **integral membrane transporting proteins**
  - Each transporting protein has a unique tertiary shape and therefore is designed to transport a unique polar substance across a membrane
  - the cell can control the movement of polar substances through a membrane by controlling the activity of the transporting proteins
Passive Transmembrane Transport

- Movement a substance to move **DOWN** its gradient
- Releases energy as a result of the movement
- **Nonpolar** substances diffuse through the nonpolar **phospholipid bilayer** in a process called **simple diffusion**
- **Polar** molecules require the help (facilitation) of integral membrane proteins (**channels** or **carriers**) to cross the bilayer in a process called **facilitated diffusion**

- Diffusion does not occur if there is no gradient
Facilitated Diffusion
Factors Affecting the Rate of Diffusion

- The **rate** at which a substance moves by way of diffusion is influenced by 3 main factors
  - **Concentration gradient**
    - a **large** concentration gradient, results in a **high** rate of diffusion
  - **Temperature**
    - a **high** temperature, results in a **high** rate of diffusion
      - heat causes motion
  - **Size of the substance**
    - a **large** substance, has a **low** rate of diffusion
      - larger objects move more slowly
Osmosis

- The diffusion of water (solvent) across a **selectively permeable membrane** is called **osmosis**.
- Solutes generate a force (osmotic pressure) that “pulls” water molecules toward the solutes – the greater the osmotic pressure, the greater the amount of water movement.

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**Diagram:**

1. Two compartments are separated by a membrane that is permeable to water but not glucose.
2. Water moves by osmosis into the more concentrated solution.
Tonicity

- The difference in the total solute concentration of the ECF vs. the ICF determines the direction and extent of osmosis across the plasma membrane.
- If the total solute concentration of the ECF = ICF, then the ECF is considered an isotonic (same) solution – water does not move into or out of cell causing no change in the cell volume.
- If the total solute concentration of the ECF > ICF, then the ECF is considered a hypertonic (more) solution – water diffuses out of the cell causing the cell to shrink (crenate).
- If the total solute concentration of the ECF < ICF, then the ECF is considered a hypotonic (less) solution – water diffuses into the cell causing the cell to swell.
Osmosis and cell volume changes

(a) Hypotonic
(b) Isotonic
(c) Hypertonic
Primary Active Transport

• Integral membrane transporters (pumps) use the energy stored in a molecule of **ATP** to transport substances across a membrane **UP** a concentration gradient
  – The pump:
    • **hydrolyzes** the high energy bond in a molecule of **ATP** (releasing energy)
    • uses the energy of ATP hydrolysis to move substances **UP** a concentration gradient
Na⁺,K⁺-ATPase (Na⁺,K⁺ pump)

- located in the plasma membrane
- actively co-transport:
  - 3 Na⁺ from the ICF (lesser amount) to the ECF (greater amount)
  - 2 K⁺ from the ECF (lesser amount) to the ICF (greater amount)
Secondary Active Transport

- Integral membrane transporters move at least 2 different substances across a membrane
  - One substance moves across a membrane DOWN a concentration gradient which releases energy to move a second substance UP a concentration gradient
  - “piggyback” transport
- This type of transport is called secondary because this process is driven by a gradient that is created by a previously occurring primary active transport process
Secondary Active Transport

**Na\(^+\), Glucose Cotransporter**

1. **Na\(^+\)-glucose symporter** brings glucose into the cell against its gradient using energy stored in the Na\(^+\) concentration gradient.

2. **GLUT transporter** transfers glucose to **ECF** by facilitated diffusion.

3. **Na\(^+\)-K\(^+\)-ATPase** pumps Na\(^+\) out of the cell, keeping **ICF Na\(^+\) concentration low.**
Transmembrane Concentration Gradients

Steady State

- **Steady State**
  - a condition that is met when substances move **passively** down a gradient, but then are moved **actively** back up the gradient
  - the gradient of a substance is **MAINTAINED** by the constant expenditure of energy by the cell fighting against equilibrium

- **no net** movement of substances from one location to another
  - one substance moving passively down the gradient, is **exactly balanced** by one substance moving actively up the gradient

- Life depends upon the ability of the organism to exist in a steady state
Transmembrane Concentration Gradients

Equilibrium

• Equilibrium
  – a condition that is met when substances move **passively** down a gradient until there is equal concentrations of a substance between 2 locations (NO gradient)
  • no net movement of substances from one location to another
    – substances continue to move due to heat energy, but movement occurs equally in both directions
  – Equilibrium of substances across the various membranes in the cells of the body = **DEATH**
  • your body is in a constant battle to ensure equilibrium of solutes across the membranes is never reached