Life as we know it is cellular. The human body is a community of trillions of cells. In order for those cells to live and function, there must be a structure that separates the interior of each cell from its exterior. This structure is the **plasma membrane**.

The PM separates the cell's interior from the surrounding **extracellular space**.
Extracellular space is primarily occupied by **extracellular fluid**.

There are 2 major components to extracellular fluid: **interstitial fluid** and **blood plasma**.
Interstitial fluid surrounds and bathes the cells, tissues, and organs of the human animal and is often referred to as **tissue fluid**.
Interstitial fluid must contain the right balance of water, **electrolytes** (chemical ions that make a fluid electrically conductive, e.g., $Na^+$, $K^+$, $Cl^-$, etc.), nutrients, wastes, and gases.
Interstitial fluid is constantly refreshed and replenished by the blood plasma which circulates through blood vessels supplying tissues with necessary substances and removing wastes.

A typical human has an ECF volume of about 15l. About 12l is ISF and 3l is plasma.

The main components of the cell interior are the **cytoplasm** and the **nucleus**.
Cytoplasm consists of **intracellular fluid** and the various internal organelles that perform specific functions. The nucleus contains the cell's **DNA** and controls the cell's activities.

The structure of the PM is described by the **fluid mosaic model**.
According to this model, the PM is a **bilayer** (double layer) of **lipids** with **proteins** dispersed within it.

The vast majority of membrane lipids are **phospholipids**.
A phospholipid consist of 2 parts – a "head" that is **hydrophilic** (Gr. *hydros* – "water" and *philia* – "love") and a pair of tails that are **hydrophobic** (Gr. *phobos* – "fear").
Phospholipids spontaneously arrange into a spherical bilayer. This allows the hydrophilic heads to be exposed to the aqueous (watery) intracellular and extracellular fluids. The hydrophobic tails are in the interior of the bilayer associating with one another.
The phospholipids freely move laterally within the bilayer, however, they cannot flip flop from the intracellular to extracellular surface or vice-versa.

**Cholesterol** is also a constituent of the lipid bilayer. It stiffens and strengthens the PM.

By weight, the PM is 50% protein. There are 2 major classes of membrane proteins: **integral proteins** and **peripheral proteins**.

Integral proteins are firmly wedged into position in the plasma membrane.
Some integral proteins are **transmembrane proteins**, which span the entire bilayer and are exposed to both the intracellular and extracellular fluids.
Integral proteins can function as:

- **Transport Proteins** that move chemicals into / out of the cell.
- **Receptor Proteins** that allow an extracellular signal to be turned into an intracellular response.
- **Adhesion Proteins** that attach cells to other cells or fibrous extracellular material.
- **Channel Proteins** that allow electrolytes to move into / out of the cell.
- **Enzymes** that catalyze (speed up) chemical reactions.
- **Structural Proteins** that stabilize the cell.

Peripheral proteins are not embedded in the PM but are loosely attached to integral proteins.
Their functions include acting as enzymes or structural proteins.

Many of the peripheral proteins exposed to the extracellular fluid are **glycoproteins** (Gr. *glykys* – "sweet") – proteins with a chain of **monosaccharides** (simple sugars like glucose or fructose) attached.

The combination of glycoproteins on the cell surface is referred to as the **glycocalyx** (Gr. *kalyx* – "husk"). The cell's unique glycocalyx serves as a means of cellular recognition. This is vital for proper functioning of the immune system – so that invading cells (e.g., bacteria) can be distinguished from our own. The glycocalyx also causes cells to adhere to one another.

Cells are also linked by special junctions made from proteins.
There are main 3 membrane junctions: **tight junctions**, **desmosomes**, and **gap junctions**.

Tight junctions fuse adjacent cells together creating an almost impermeable barrier that prevents molecules from passing between cells. These are common in the epithelial lining of the digestive tract.

Desmosomes (Gr. *desm* – "chain" and *soma* – "body") are spot-like junctions that bind cells together but do not prevent materials from passing between the cells. Desmosomes are common in cells subjected to mechanical stress – such as epithelial cells in the skin and muscle cells in the heart.

Gap junctions are protein channels that allow material to flow from the intracellular space of one cell to the intracellular space of another. This is essential in muscle cells that must contract in unison (e.g. cardiac muscle) b/c they allow electrolytes to spread from cell to cell.

The PM is a **selectively permeable** membrane. It allows some things to pass through but not others.
The selective permeability is a function of the lipid bilayer and the membrane's integral proteins.
Things like nutrients, oxygen, water, electrolytes, and signaling molecules must be allowed to enter the cell, while things like wastes and carbon dioxide must be able to exit the cell.

There are 2 basic ways substances pass through the plasma membrane.
**Passive processes** occur when substances pass through the PM w/o any energy input from the cell itself.
**Active processes** occur when cellular energy is used to move things through the PM.

The main type of passive process is **diffusion**.
Diffusion is the movement of molecules from areas where their concentration is high to areas where their concentration is low.
All molecules exhibit **kinetic energy** and are constantly in some sort of motion.
This motion causes molecules to spread out or **diffuse**.
KE, and thus the rate of diffusion, is directly proportional to T°.

The mass of a substance is inversely proportional to its diffusion rate. This is because KE is equal to $(\frac{1}{2})(\text{mass})(\text{velocity})^2$. A heavy molecule and a light molecule have the same KE if they are at the same T°. Thus the heavy molecule must have a slower velocity since it has the greater mass.

The limitation on diffusion is that it is only good at moving things a short distance.

B/c the interior of the PM is composed of hydrophobic phospholipid tails, hydrophilic molecules cannot diffuse through it.
Substances can only diffuse through the PM if they are lipid-soluble (hydrophobic) or if they are able to pass through a protein channel or transport protein.

**Simple diffusion** occurs when lipid soluble molecules diffuse directly through the PM.
$O_2$, $CO_2$, steroids, and fat-soluble vitamins (ADEK) all undergo simple diffusion.
Diffusion of hydrophilic molecules thru the PM via a protein channel or carrier is **facilitated diffusion**.

**Carriers** are integral proteins that bind to a molecule on one side of the PM and release it on the other.
The movement of glucose into cells occurs via a carrier protein.

Membrane transport via carriers differs from simple diffusion in that it is dependent on the number of carrier molecules and there is a limit to the rate at which facilitated diffusion can occur.
When all carrier proteins are engaged, they are said to be **saturated**.

**Channels** are integral proteins that have a water pore that penetrates the PM and allows small hydrophilic molecules to pass through. Ions often enter/exit cells via protein channels.

The ionic charge on a molecule can influence its diffusion thru a protein channel (charged molecules are hydrophilic and cannot undergo simple diffusion) because the protein channel may be charged as well.

The size of the concentration gradient is directly proportional to the rate of diffusion. However in facilitated diffusion this relationship only holds until the protein carriers/channels have reached the saturation point.

The diffusion of water through a selectively permeable membrane is referred to as **osmosis**.
Water will move from areas where its concentration is high to areas where its concentration is low.
Note that the concentrations of solutions are given in reference to the solutes, not the solvent (water).

Solutions with high solute concentrations will have low concentrations of water.
Solutions with low solute concentrations will have high concentrations of water.

The solute concentration of a solution is its **osmolarity**.
Water will diffuse into solutions with a high osmolarity and out of solutions with a low osmolarity.

A solution with a high osmolarity has a high **osmotic pressure** b/c of its ability to cause osmosis, i.e. to cause water to diffuse into it. Similarly a solution with a low osmolarity has a low osmotic pressure.

If the ECF surrounding a cell has a lower solute concentration than the cell, water will then enter the cell from the surrounding ECF. In such a scenario, the ECF is said to be **hypotonic** to the cell.

If the ECF surrounding a cell has a higher solute concentration than the cell, water will then exit the cell and enter the surrounding ECF. In such a scenario, the ECF is said to be **hypertonic** to the cell.

If the ECF surrounding a cell has the same solute concentration than the cell, water will neither exit nor enter the cell. In such a scenario, the ECF is said to be **isotonic** to the cell.

Active processes require an input of cellular energy. The 2 main active processes are **active transport** and **vesicular transport**.

In active transport, energy in the form of **ATP** (**adenosine triphosphate**) is expended in order to move a substance through the PM *against its concentration gradient*.

The proteins responsible for active transport are referred to as **solute pumps**.
There are 2 main types of active transport: **primary active transport** and **secondary active transport**.

In primary active transport, the transport protein directly breaks down ATP and uses the energy released to change its shape and move the solute(s) across the PM.
The best example of this is the **sodium-potassium pump** which continuously pumps 3 sodium ions out of the cell and 2 potassium ions into the cell.

In secondary active transport, the use of energy derived from ATP is indirect.
In this mechanism, the movement of an ion down its concentration gradient can provide the energy to move another solute against its gradient.
For example, in many cells the movement of glucose into the cell (against its gradient) is coupled to the movement of sodium into the cell (with its gradient). The "downhill" movement of sodium provides the energy for the uphill movement of glucose.
The energy originally came from the breakdown of ATP that was used to create the high concentration of sodium outside the cell.

In vesicular transport, fluids & large particles move across the PM in membranous bags called **vesicles**.
Movement out of the cell via vesicles is known as **exocytosis**. Within the cell, the particle to be expelled will be packaged into a vesicle made of a phospholipid bilayer. Intracellular proteins will shuttle the vesicle to the plasma membrane where it fuses with the membrane and ejects its contained particles.

Movement into the cell via vesicles is known as **endocytosis**. 2 important varieties of endocytosis are **receptor-mediated endocytosis** and **phagocytosis**.

In receptor-mediated endocytosis, specific particles outside the cell will bind to specific receptors (proteins) on the cell surface. The membrane will then invaginate and pinch off a vesicle containing the receptors and bound particles. The receptors will then be recycled and the particles will be used by the cell as needed.

Phagocytosis is performed by **white blood cells** and **macrophages**.
The **phagocyte** will extend a pair of membranous "arms" (**pseudopods**) that wrap around the foreign particle (e.g. a bacterium) and engulf it, forming a vesicle (a **phagosome**).
The phagosome will fuse with an organelle (a **lysosome**) that contains digestive enzymes which will destroy the engulfed particle.