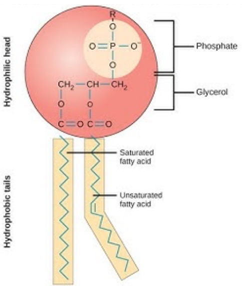
Membranes to interact with the environment

A cell is a highly dynamic system: it changes shape, it moves, it communicates, …
Its membrane has to be a complex structure to allow all this, while forming a clear limit between what's in and what's out.

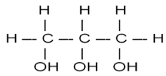
A phospholipid bilayer as a "barrier"



Structure of Phospholipid

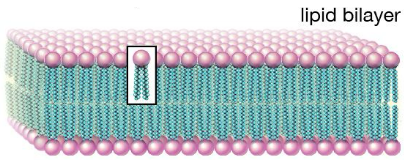
Phospholipids are a class of lipids crucial for the structure and function of cell membranes:

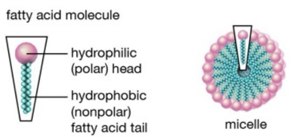
- Glycerol base
- 2 fatty acid chains => Hydrophobic tails
- Phosphate group => Hydrophilic head


Glycerol

Having 2 antagonistic features (hydrophobic AND hydrophilic), a phospholipid is said to have an amphipathic structure.

Cell membrane limits a region with the "same" medium inside and outside: water => Structured as a bilayer of phospholipids, "linked" through their hydrophobic tails and in contact with the water through their hydrophilic heads.



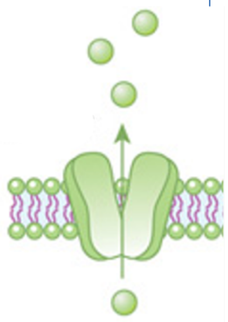


Note: A single layer of amphipathic molecules would tend to regroup by forming a micelle, to limit the interactions between the hydrophobic tails and the water.
This happens with individual fatty acids, for example when you wash your greasy hands with soap.

Polar molecules and ions are blocked by the "large" hydrophobic inner structure of the bilayer.

Small non-polar molecules, like O_2 and CO_2 (involved in cell respiration), for which the flux through the membrane **HAS TO BE** important, can pass through the membrane, by simple diffusion.
Note: The hydrophilic heads are too small to hinder the passage of these molecules.

Transporter proteins as doors for a "controlled" flux of chemicals



Transporter proteins (AKA transmembrane proteins) span the entirety of the membrane, forming a possible passage through the membrane.
They allow the flux of chemicals for several purposes: input of essential molecules (glucose, aminoacids, nucleotides, ...), disposal of waste (toxins, drugs, ...), maintenance of ion gradients (Na+, K+, H+, ...), osmoregulation (cell volume and pressure), and much more.

<u>2 types of transporter proteins:</u>

- **<u>Channel proteins</u>** are pores that open and close "on demand", responding to a change of concentration gradient between the inside and the outside. This allows an important flux of molecules and or ions to insure the maintenance of these gradients. This process is **passive**, as it doesn't require any energy.

*Ex: **Aquaporins** are the channel proteins specific to water. When there is a concentration gradient of a chemical between the inside and the outside of the cell, water can travel spontaneously through them from the region with lowest concentration to the region with highest concentration, until reaching an equilibrium, with the same concentration on both sides. This process is called **osmosis**.*

Note: When a cell finds itself in a hypotonic solution (lower concentration inside than outside), water enters the cell, making it swell. If the concentration gradient is very high, this can lead to the bursting of the cell.

Note to a specific student who will recognize themself: This could be a consequence of the ingestion of an important amount of distilled water.

- **<u>Carrier proteins</u>** transport molecules by binding with each of them individually, undergoing shape changes.
  Highly specific to the type of molecules they transport, they move only one or few molecules/ions at a time. However, they can move these entities both down AND against a gradient of concentration.

Ex: GLUT proteins are specific to the transport of glucose, needed by the mitochondria to release the energy needed for the metabolism of the cell, through cellular respiration.

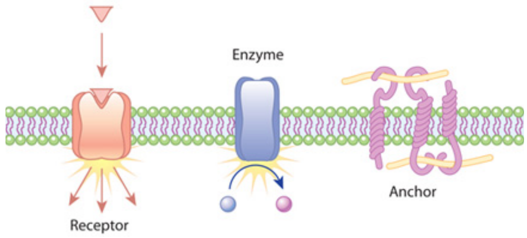
Carrier proteins who transport molecules/ions against their gradient of concentration require energy to function. The transport is said to be **active**, and these proteins are called **<u>pump proteins</u>**.

Ex: Na+/K+ ATPase are pump proteins for sodium and potassium ions. They pump Na+ ions out of the cell and K+ ions into the cell for several purposes:

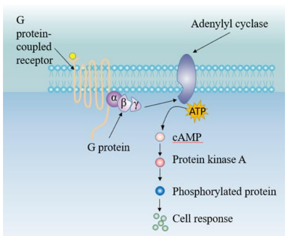
- *Maintaining the electrical potential of the cell, which can be fundamental in their response to outside solicitation (e.g. neurons and muscle cells)*
- *Control osmotic balance by regulating ion concentrations, thus regulating the cell volume*
- *Create an ion gradient beneficial to other transport proteins for other processes, like glucose or amino acid uptake.*

Peripherical proteins to communicate and interact

Peripherical proteins are proteins acting only on one side of the cell membrane, either inside or outside the cell. They can either be embedded in the membrane or loosely attached to its surface.



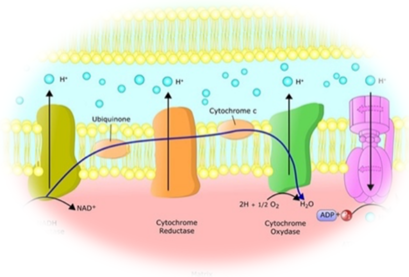
- **Receptors** allow the binding of hormons or neurotransmitters to the cell membrane, thus participating in the transmission of messages.



Ex: G-Protein Coupled Receptors (GPCRs) receive chemical signals (neurotransmitters, hormones) from outside the cell. When they bind to their specific ligand (dopamine, adrenalin, serotonine, …), their configuration changes, which activates the G-protein, an intermediary attached to the cytoplasmic side of the membrane. The activated G-protein transmits the signal to effector proteins inside the cell (enzymes) or embedded in the cell membrane.

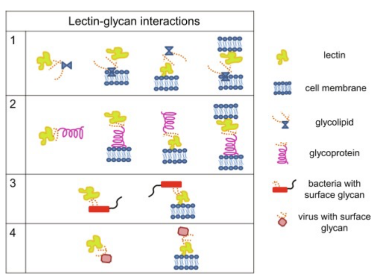
- **Enzymes** facilitate metabolic processes by speeding them up.

Ex: Mitochondria are an evidence for endosymbiosis, as they contain DNA and their membranes (they have 2) has the same structure than the cell membrane.
Cytochrome C is a peripheral protein located on the outer surface of the inner mitochondrial membrane. It acts as an enzyme vital for energy production (helps maintain the proton gradient needed for ATP synthesis) and for cellular regulation (it is released in the cytoplasm in response to cellular stress or damage, leading to apoptosis, aka programmed death of the cell)

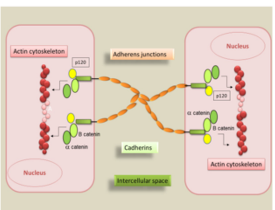


- **Adhesion junctions** play a crucial role in cell-to-cell adhesion and cell-to-cell communication.

Ex: Glycoproteins facilitate specific interactions of a cell with other cells or molecules, playing an essential role in cell recognition (leading to immune responses), adhesion and signaling (crucial in developmental processes of the cell).

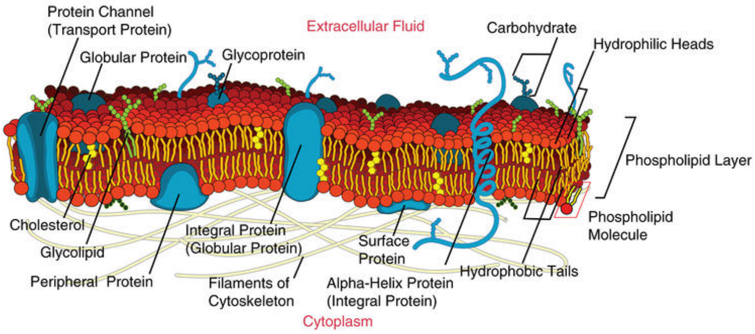


  - *The carbohydrate chain of glycoproteins can act as a specific molecular marker, allowing the identification of cells. Lectins (a type of glycoproteins found on the membrane of immune cells) will therefore recognize self vs. non-self (pathogens or foreign cells) and launch the appropriate response (e.g. MHC molecules present antigens for T-cells (type of white blood cells), which is a critical step in immune cell communication, while other white blood cells possess selectins, glycoproteins involved in immune surveillance and inflammation)*
  - *Cadherins are crucial for maintaining the structure of tissues. They can send signals that influence cellular behavior, such as growth, differentiation or migration.*
  - *Ephrin and Notch influence how cells communicate and coordinate their behaviors during embryonic development. They help establish cell polarity, thus guiding cell migration and ensuring the proper formation of tissues.*



Solid or liquid?

The best model to describe the cell's membrane has been proposed in 1972 by Singer and Nicholson. In their fluid mosaic model, the phospholipid bilayer forms a stable base for a mosaic of embedded and peripheral proteins. All of these molecules (both the phospholipids and the proteins) are in constant lateral motion, allowing the cell to support endocytosis, exocytosis or signal transduction, material to move into and out of the cell, cells to communicate with each other, and many other processes.



Note: The degree of fluidity of the membrane depends on external factors such as temperature. Cholesterol molecules are therefore interspersed in the membrane to prevent it from becoming too rigid at low temperatures or too fluid at high temperatures.

And what about the cell wall?

Plant and funghi cells (as well as some bacteria and algae) have an additional external layer separating them from the outside environment. The cell wall gives them structural support (allowing plants and funghi to stand upright), and protection from external damage and pathogens, while it prevents over-expansion (e.g. it limits the water uptake in plant cells) and contributes to growth.
Therefore, it cannot fit within the fluid mosaic model, and its structure has to be different from the cell membrane: it is made of materials (cellulose in plants or chitin in funghi) that are rigid and permeable to most molecules and ions (it limits the intake of large harmful molecules and pathogens).