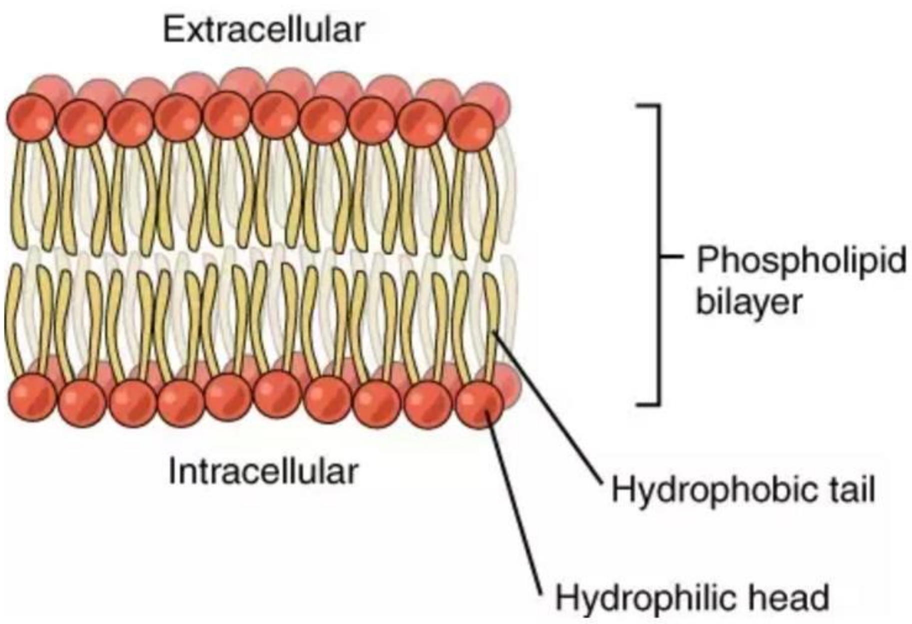
Cells Surface Membranes: An Introduction to the Phospholipid Bilayer and Transmembrane Transport

Part 1 – Cell Membranes: An Introduction to the Nature and Properties of the Phospholipid Bilayer

An Introduction to the Phospholipid Bilayer



- Cells are contained within a membrane which is specifically called a lipid bilayer
- As, more often than not, these lipids are phospholipids, this lipid bilayer is commonly known as a *phospholipid bilayer*
- These phospholipids exist as a bilayer due to the nature of these lipids: phospholipids possess hydrophilic ‘heads’ and hydrophobic ‘tails’, which thus align as per the diagram (with the hydrophilic heads in contact with the hydrated ‘outside’ and the hydrophobic tails positioned away from this hydration)
- The fluid nature of the surface membrane is important: it allows signalling lipids and proteins to easily and quickly diffuse across it
- The fluidity of the phospholipid bilayer also permits fusion with other membranes, thus enabling endocytosis and exocytosis
- Membrane fluidity also ensures that the surface membrane is equally shared between daughter cells during cytokinesis.

Cholesterol and the Phospholipid Bilayer

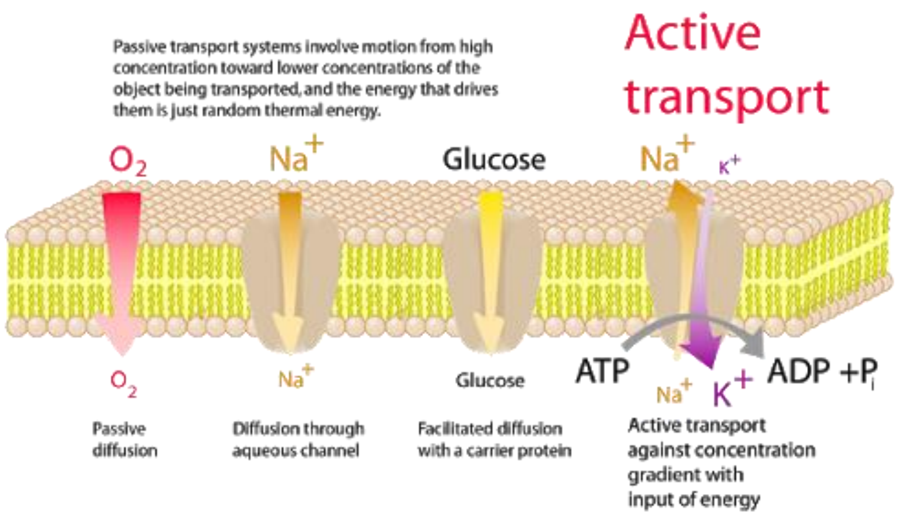
- Similarly, cholesterol is often inserted into the phospholipid bilayer which makes the cell surface membrane more rigid
- Cholesterol is intercalated between the phospholipids of the membrane, and due to its small and rigid nature (due to the planar steroid ring structure that makes up much of the molecule), cholesterol also reduces the fluidity and permeability of the membrane.

Proteins and the Phospholipid Bilayer

- Proteins such as receptors, ion channels and transporters are inserted into and through this bilayer
- The insertion of integral membrane proteins takes advantage of the structure of the surface membrane: the trans-membrane domains of these proteins are predominantly hydrophobic due to hydrogen bonding within α-helix structures
- Proteins that exist in the surface membrane include transporters (i.e. channels and pumps); integrin anchors, chemical receptors and signal transduction molecules.

Part 2 – Transport across Cell Surface Membranes

Transport across membranes: active versus passive transport

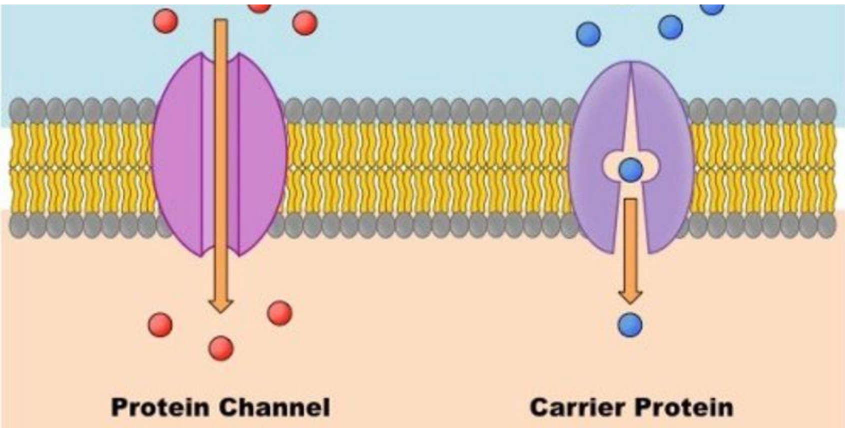


- Transport across cell membranes occurs in two ways - either **passively** or **actively**
- As their names suggest, the former requires no energy input, whilst the latter does require energy input
- Passive transport occurs by either simple or facilitated diffusion:
  - Simple diffusion occurs across the membrane itself – this is where particles move from a high to a low concentration (i.e. *with* the concentration gradient)
  - Meanwhile, facilitated diffusion occurs through membrane protein channels
  - Neither simple nor facilitated diffusion requires energy input as both are driven by the electrochemical gradient rather than energy/ATP
- Not all molecules can diffuse through the phospholipid bilayer itself, hence requiring the presence of membrane proteins that will allow them entry
- There are two classes of these proteins that are involved in facilitated diffusion: **protein channels** and **uniporter carrier proteins**
- Active transport moves solutes regardless of the electrochemical gradient
  - As active transport often moves molecules against the concentration gradient (i.e. from a low to a high concentration gradient), active transport thus requires energy input to drive this movement
  - This energy input comes from ATP (as shown in the diagram)

Transport through Protein Channels

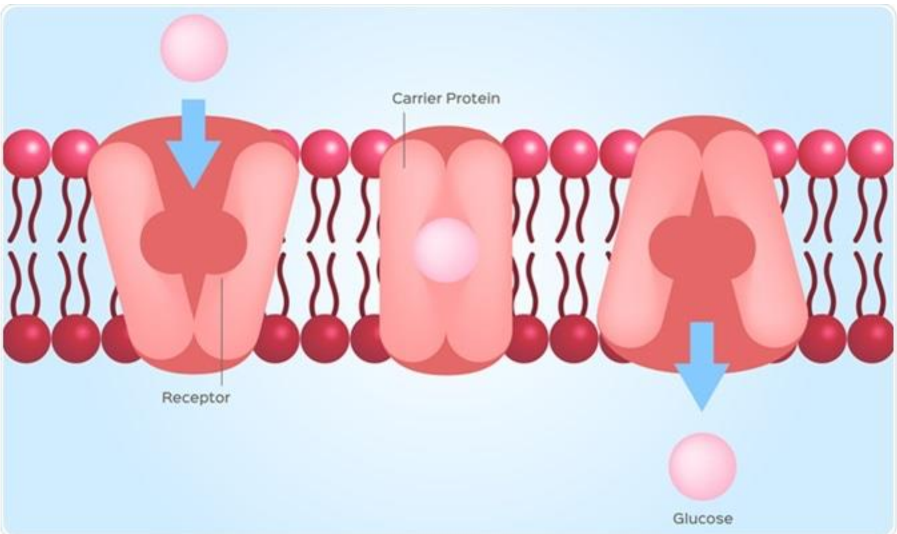
- Channels are proteins that form hydrophilic pores in the surface membrane of a cell
- Hydrophilic surfaces on the interior of the protein permit this aperture to allow non-directional flow of solutes across the membrane
- The most common channels are non-directional ion channels
- Channels do show some selectivity – however, this is almost always based upon the size and charge of the particle attempting to flow through them

- The potential rate of diffusion through these channels is also very large - up to 107 ions per second!
- Channels may be gated to allow them to be closed or opened - though the processes involved in doing so may require energy, diffusion when open is still a passive process which does NOT require energy/ATP input
- Gated protein channels allow for greater control over the flow of ions in and out of cells (an example being the voltage-gated Na+ and K+ channels that are so important in the propagation of action potentials in neurones)

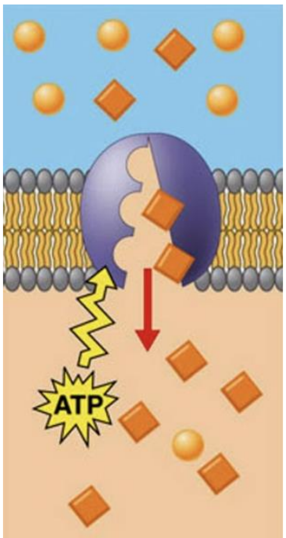


Transport through Uniporter Carrier Proteins

- Uniporter carrier proteins are highly selective proteins which substrates bind to
- The binding of the substrate then changes the uniporter's conformation resulting in the substrate being released on the other side of the membrane (as shown in the diagram below)
- Almost all small organic molecules (i.e. glucose) require these carrier proteins to diffuse across cell membranes
- It is important to note that uniporter carrier proteins are NOT a form of active transport as they are powered by the diffusion gradient of the substrate itself and thus only move a substrate along its concentration gradient (unlike active transport which can move a substrate *against* the concentration gradient)



Part 3 – Active Transport across Phospholipid Bilayers



The process of active transport

- Active transport moves solutes regardless of the electrochemical gradient
- As such, active transport often moves solutes against the concentration gradient and thus requires energy input to drive this movement
- This energy is derived from ATP
- Active transport is very important – it is key to maintaining electrochemical gradients to perpetuate passive transport
- Active transport is also essential in acquiring and removing molecules too large to diffuse through the membrane or channel proteins

Active transporters

- There are three main types of active transporters:
    - 1) ATPases
        - ATPases include the Na^+K^+ATPase – these transport solutes against their concentration gradient using energy derived from the hydrolysis of ATP
        - This is considered to be *primary active transport*
    - 2) Coupled transporters
        - Coupled transporters like symporters and antiporters do NOT require ATP to function
        - Coupled transporters transport a substrate against its concentration gradient by coupling its transport to another substrate which the transporter moves along its electrochemical gradient (or, in other words, from a high concentration to a low concentration)
        - This is considered a form of active transport as the substrate moving along its gradient is often maintained by primary active transport elsewhere
        - As such, this can be considered to be *secondary active transport*
    - 3) Light-driven pumps
        - As their name suggests, light-driven pumps transport a solute against its concentration gradient with energy provided by light
        - As one might suspect, this is not prevalent in humans – it is more prevalent in photosynthetic organisms