TOPIC: MEMBRANES

Key Knowledge:

- The structure and function of the plasma membrane in the passage of water, hydrophilic and hydrophobic substances via osmosis, facilitated diffusion and active transport

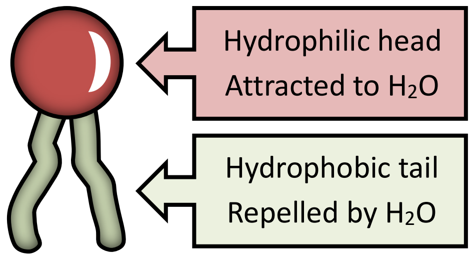
CELL MEMBRANES

Cell (plasma) membranes enclose the contents of the cell, separating intracellular components from the extracellular environment. This allows for the precise control of internal conditions (i.e. homeostasis). Cell membranes have two key properties that promote this homeostatic regulation:

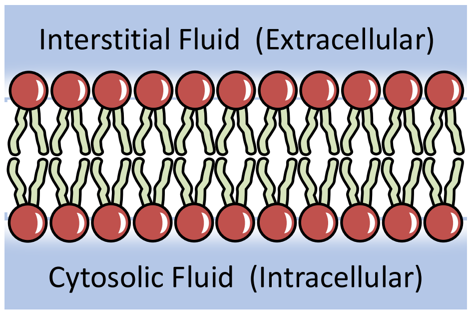
- They are **semi-permeable**, in that some material cannot cross the membrane without assistance
- They are **selective**, in that membrane scan regulate the passage of certain material according to need

PHOSPHOLIPID BILAYER

Membranes consist of a phospholipid bilayer. Each phospholipid consists of a polar phosphate head and two non-polar fatty acid tails. The phosphate head is **hydrophilic** (water-loving), while the fatty acid tails are **hydrophobic** (water-hating). This makes the phospholipid amphipathic (both hydrophilic and hydrophobic).



Phospholipids will spontaneously arrange into a **bilayer**, with the hydrophilic phosphate heads facing out towards the surrounding aqueous solutions (i.e. cytosolic and extracellular fluids), while the hydrophobic fatty acids face inwards to avoid exposure to the polar fluids. The bilayer is therefore held together by the **weak hydrophobic associations** between the fatty acid tails, allowing for membrane fluidity and flexibility (it can easily break and reform).



MEMBRANE PROTEINS

Phospholipid bilayers are embedded with proteins, which may be permanently or temporarily attached:

- **Integral proteins** are transmembrane (span the bilayer) and permanently attached to the membrane
- **Peripheral proteins** associate with one side of a membrane and are temporarily attached to the bilayer

Membrane proteins serve a variety of key functions:

- **Junctions:** They can connect cells together to form tissues (tight junctions)
- **Enzymes:** Immobilising enzymes on membranes localises specific reactions
- **Transport:** Allows passage of material across the bilayer (channel proteins)
- **Recognition:** May function as markers for cell identification (e.g. antigens)
- **Adhesion:** Act as attachment points for cytoskeleton or extracellular matrix
- **Transduction:** Functions as receptors for signalling pathways (glycoproteins)

Hint: JET RAT

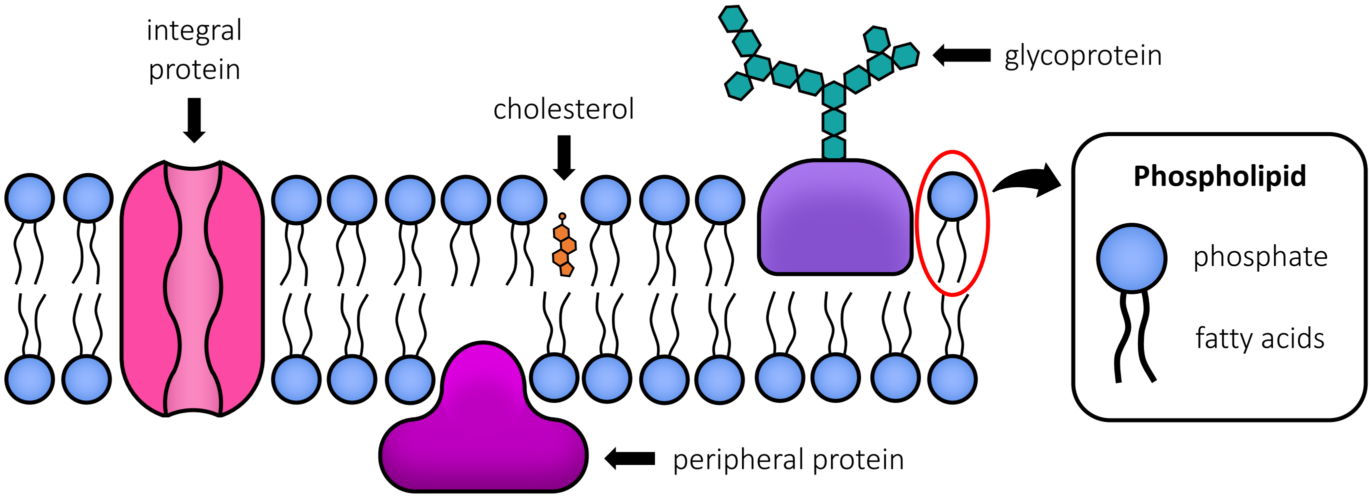
CHOLESTEROL

Cholesterol is a component of animal cell membranes, where it functions to maintain the integrity of the cell and the mechanical stability of the membrane. Cholesterol interacts with the fatty acid tails to **reduce fluidity** and make the membrane **less permeable** to small water-soluble substances. Cholesterol is **not** present in plant cell membranes, as these cells are alternatively supported by a cell wall made of cellulose.

FLUID MOSAIC MODEL

Cell membranes are represented by the fluid-mosaic model, which reflects the fact that they are:

- **Fluid:** The bilayer is held together by weak hydrophobic associations, making the membrane flexible
- **Mosaic:** The phospholipid bilayer is embedded with proteins (integral and peripheral) and cholesterol



MEMBRANE TRANSPORT

Movement of materials across a membrane will depend on both the size and solubility of the material. **Large** and **charged** molecules **cannot** freely cross the plasma membrane without additional assistance.

- Small, lipophilic molecules can freely pass across the bilayer (e.g. O_2, CO_2, water, steroids)
- Larger molecules or polar / charged molecules require membrane proteins to cross (e.g. glucose, ions)

TYPES OF TRANSPORT

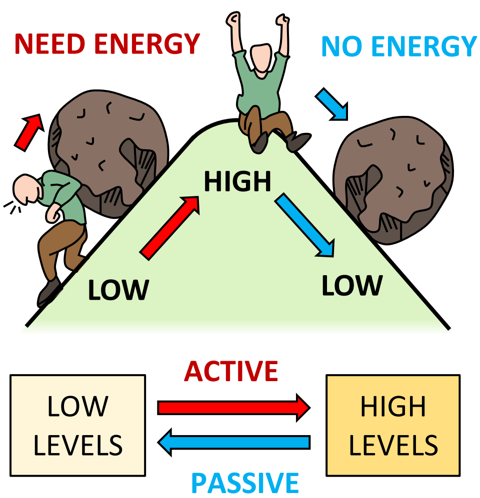
Movement of materials across a membrane may occur via:

Passive Transport:

- Movement from high concentration to low concentration (i.e. movement is **along** or **down** a concentration gradient)
- Does **not** involve the expenditure of energy (no ATP used)

Active Transport:

- Movement from low concentration to high concentration (i.e. movement occurs **against** a concentration gradient)
- **Does** involve the expenditure of energy (ATP is hydrolysed)



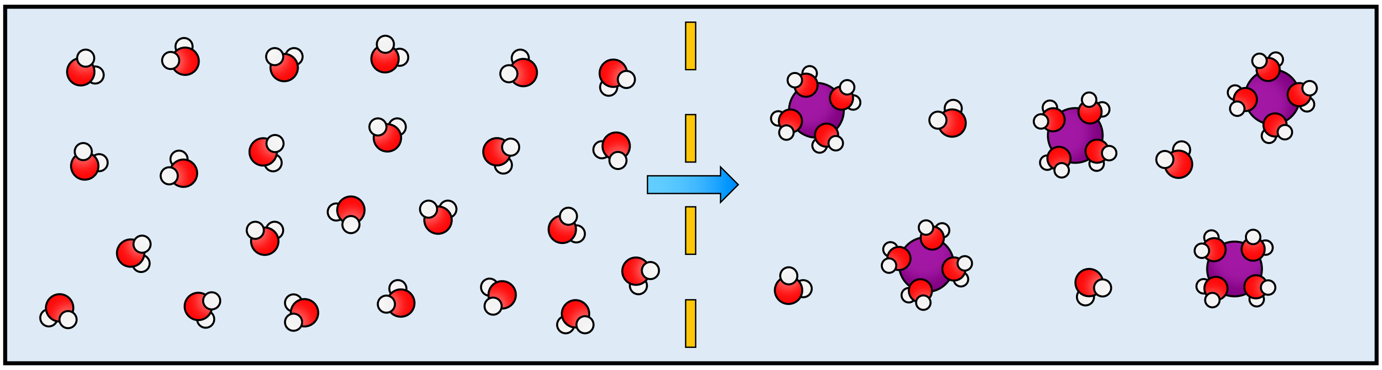
Passive transport mechanisms include either simple diffusion, facilitated diffusion or osmosis. Additionally, molecules may enter or exit the cell without crossing the membrane via cytosis (the membrane physically breaks and reforms around the material to facilitate its passage – this is an energy-dependent process).

SIMPLE DIFFUSION

Diffusion is the net movement of molecules from a region of higher concentration to lower concentration. This movement along the gradient will continue until the molecules are evenly dispersed (i.e. equilibrium). Simple diffusion occurs when **small** or **non-polar molecules** can freely cross the plasma membrane without impediment (e.g. O_2 , CO_2 , ethanol, glycerol, fatty acids). The rate of diffusion will be influenced by the size of the gradient and the kinetic energy of the particles.

OSMOSIS

Osmosis is the diffusion of **free water** molecules. While water is a polar molecule, it is still small enough to move across the phospholipid bilayer without assistance. The polarity of water will cause it to move towards charged or polar solutes that cannot freely cross the membrane (water is the **universal solvent**). Hence, osmosis involves the net movement of water molecules across a semipermeable membrane from a region of low solute concentration to a region of higher solute concentration (until equilibrium is reached). A high solute solution will draw water and is called **hypertonic**, while a low solute solution will lose water and is called **hypotonic** (if two solutions have equal solute concentrations, they are described as **isotonic**).

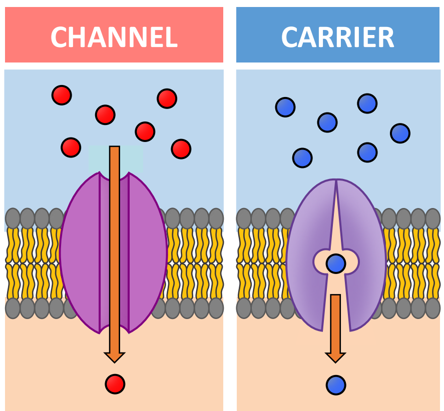


Hypotonic: *low solute levels = high free water* ➡ **Hypertonic:** *high solute level = low free water*

Water diffuses from a region of high **free** water to low **free** water *(i.e. from lower solute to higher solute)*

FACILITATED DIFFUSION

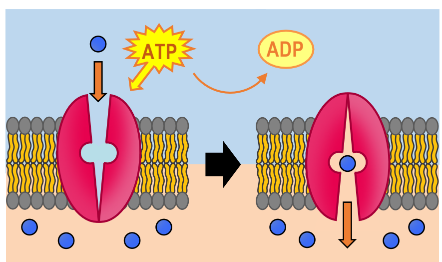
Facilitated diffusion is the passive movement of molecules across the cell membrane via the aid of a **membrane protein**. It is utilised by molecules that cannot cross a phospholipid bilayer unassisted (i.e. **large, polar molecules** or **ions**). The movement is facilitated by transport proteins (either carrier proteins or channel proteins).



- **Channel proteins** contain a hydrophilic pore to enable passage
- **Carrier proteins** undergo a conformational change in order to translocate molecules across a bilayer (slower than channels)

ACTIVE TRANSPORT

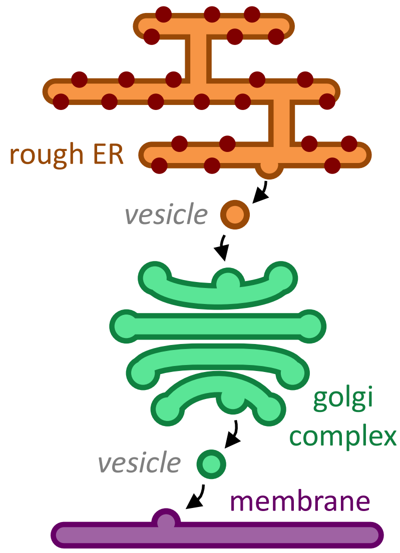
Active transport uses **energy** to move molecules against a gradient. This involves the use of protein pumps, which use **ATP hydrolysis** to trigger a conformational change that translocates molecules to the regions of higher concentration. Only molecules that cannot freely cross the membrane can be actively transported **against a gradient**.



VESICULAR TRANSPORT

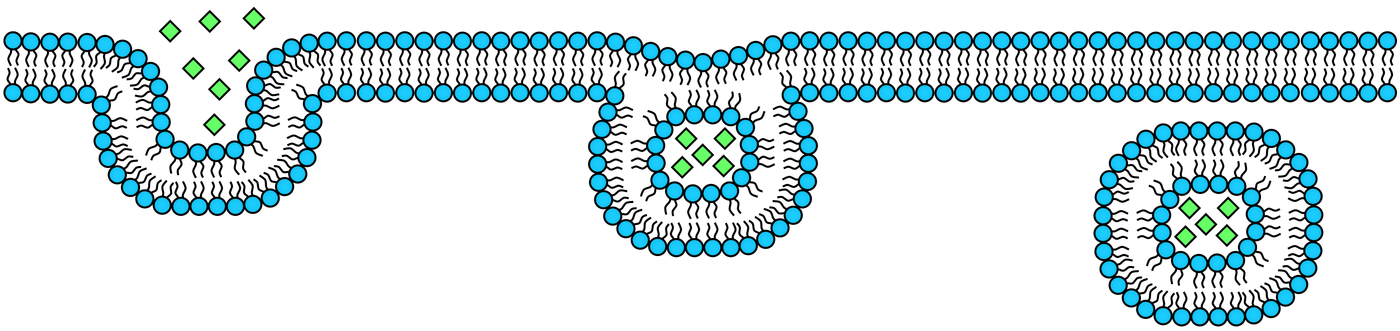
Cell materials are moved between organelles via a membrane network called the **endoplasmic reticulum (ER)**. Smooth endoplasmic reticulum is responsible for the synthesis and transport of lipids, while the rough endoplasmic reticulum is embedded with **ribosomes** and is responsible for the transport of proteins. The ER network shuttles the cell materials to organelles via **vesicles**. Materials destined for secretion from the cell are transported to the **Golgi apparatus**, where it may be sorted, stored or modified prior to export. Secretory products are transported to the **cell membrane** via a vesicle, which fuses with the bilayer to release the products externally. The Golgi complex regulates secretion in two ways:

- **Constitutive:** Products are released immediately as they are made
- **Regulatory:** Products are stored for release in response to a signal



BULK TRANSPORT (CYTOSIS)

The fluidity of membranes allows materials to be taken in or released by cells **without crossing the bilayer**. The membrane is principally held together by weak hydrophobic associations between the fatty acid tails of the phospholipids. These weak interactions can be spontaneously broken and reformed in a process that is energy dependent and requires ATP hydrolysis. Sections of a membrane can be excised to form internal vesicles, while membrane segments can be added as a result of fusion between the membrane and vesicle.

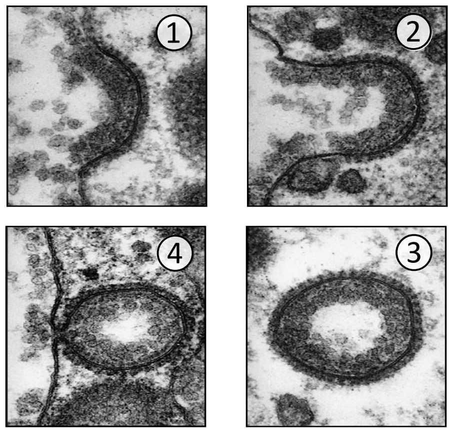


EXOCYTOSIS

Exocytosis is the process by which materials **exit the cell** without crossing the cell membrane. Vesicles derived from the Golgi apparatus will fuse with the plasma membrane, expelling their contents into the extracellular environment. The process of exocytosis adds vesicular phospholipids to the cell membrane, providing a mechanism for regulating the length and protein composition of the phospholipid bilayer.

ENDOCYTOSIS

Endocytosis is the process by which materials **enter the cell** without crossing the membrane. This process of cellular engulfment begins with an invagination of the cell membrane to form a depression that envelopes the extracellular material. The invagination is then sealed off to form an intracellular vesicle containing internalised material.



There are two main types of endocytosis that may occur in cells:

- **Phagocytosis:** The engulfment of large solid materials (e.g. cells)
- **Pinocytosis:** The engulfment of liquids or dissolved substances