

 **SL IB Biology**

Membranes & Membrane Transport

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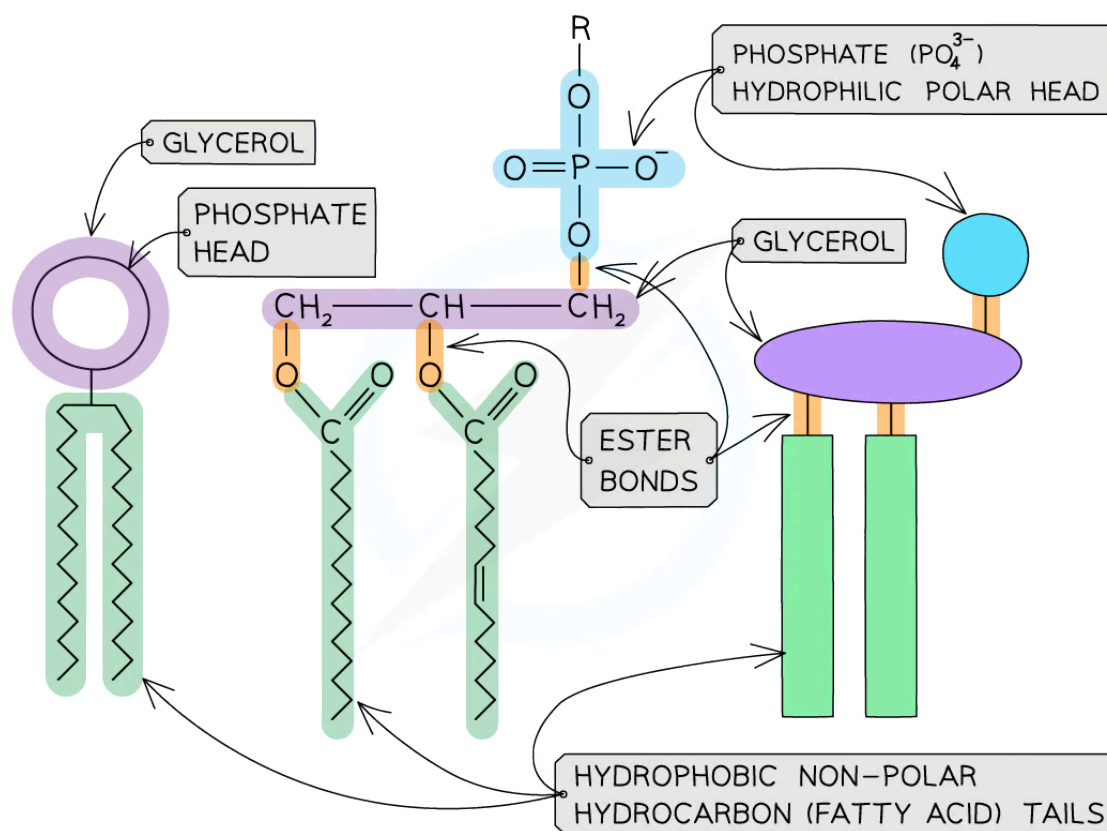
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Lipid Bilayers

Lipid Bilayers: Basis of Cell Membranes

- Phospholipids form the basic structure of cell membranes, which are formed from phospholipid bilayers
- They are formed by a hydrophilic **phosphate head** bonding with two hydrophobic **hydrocarbon (fatty acid) tails**
- As phospholipids have a **hydrophobic** and **hydrophilic** part they are known as **amphipathic**
 - The **phosphate head** of a phospholipid is **polar** and therefore **soluble** in water (hydrophilic)
 - The **fatty acid tail** of a phospholipid is **nonpolar** and therefore **insoluble** in water (hydrophobic)

Phospholipid structure diagram



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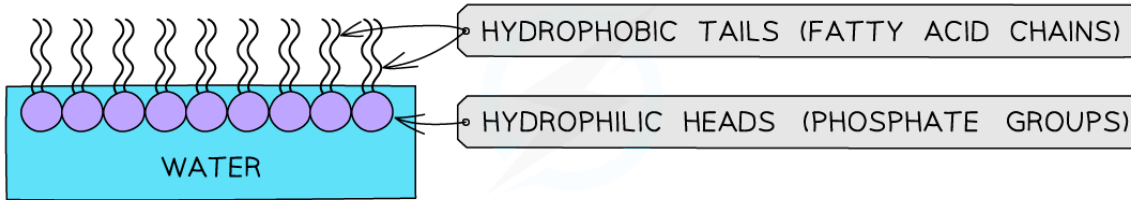
Phospholipids consist of a molecule of glycerol, two fatty acid tails, and a phosphate group

- When phospholipids are placed in water the hydrophilic phosphate heads orient **towards the water** and the hydrophobic hydrocarbon tails orient **away from the water**
 - This forms a **phospholipid monolayer**



Your notes

Phospholipid monolayer diagram

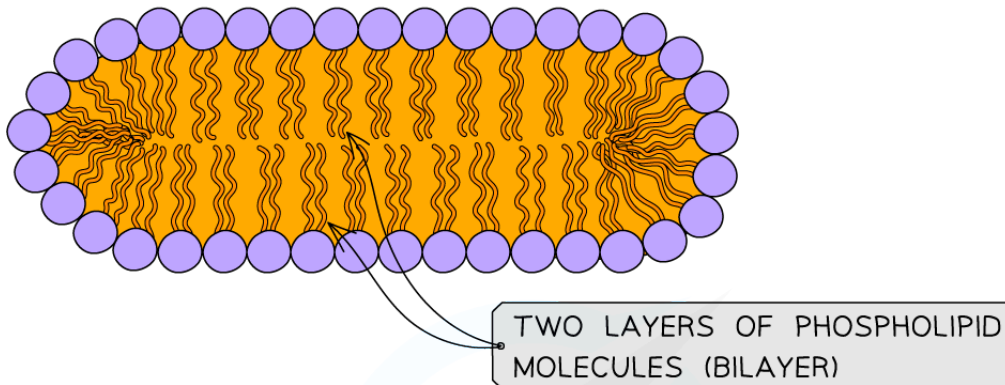


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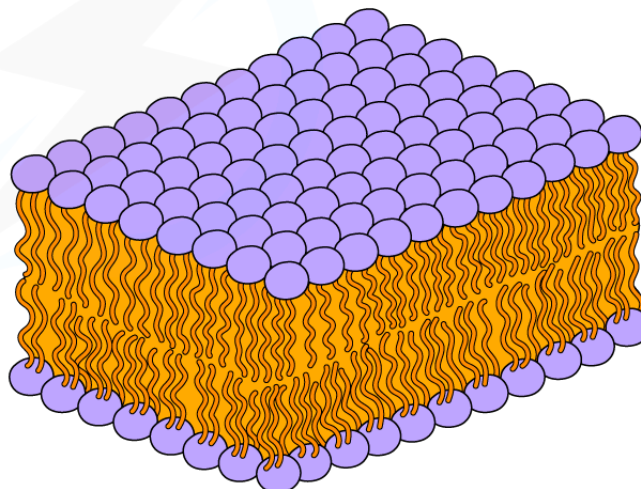
Phospholipids can form a monolayer in water

- When there is a sufficient concentration of phospholipids present then two-layered structures may form
- These sheets are called **phospholipid bilayers**

Phospholipid bilayer diagram



SHEET-LIKE STRUCTURE OF A BILAYER SEEN IN THREE DIMENSIONS



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A phospholipid bilayer is composed of two layers of phospholipids; their hydrophobic tails facing inwards and hydrophilic heads outwards



Your notes

Lipid Bilayers: Barriers

- The phospholipid bilayer has two regions - a **hydrophobic core** and a **hydrophilic outer layer**
- The hydrophobic regions are attracted to each other and the hydrophilic regions are attracted to water in the cytoplasm or the extracellular fluid
- These properties allow the bilayer to form a **barrier**
 - **Large molecules** cannot pass through the barrier as the hydrophobic region is tightly packed and has low permeability to larger molecules
 - **Polar molecules** and **ions** cannot pass through the hydrophobic tails of the phospholipid structure
 - The hydrophilic nature of these molecules and ions means that they will not interact with the hydrophobic fatty acid tails of the phospholipids
- The bilayer forms an effective barrier so that it is able to control which molecules pass through and out of the cell



Your notes

Membrane Proteins

Membrane Proteins

- The phospholipid bilayer carries out the main function of the plasma membrane, providing a barrier to the movement of some substances into and out of the cell
- Additional functions are carried out by **proteins** in the membrane
- These proteins are grouped into two categories:
 - **Integral**
 - These are partially **hydrophobic**, i.e. they are amphipathic
 - They are **embedded** in the phospholipid bilayer
 - They can be embedded across **both layers** or just **one layer**
 - **Peripheral**
 - These are **hydrophilic** proteins
 - They are **attached** to either the surface of integral proteins, or to the plasma membrane via a hydrocarbon chain
 - They can be **inside** or **outside** the cell
- The protein content of membranes can vary depending on the function of the cell
 - E.g. membranes of the mitochondria and chloroplasts have the highest protein content with their many electron carriers

Membrane protein functions

- Membrane proteins carry out many functions: transport, receptors, cell adhesion, cell-to-cell recognition and immobilized enzymes

Transport

- Transport proteins **allow ions and polar molecules to travel across the membrane**
- There are two types:
 - **Channel** proteins
 - These form holes, or pores, through which molecules can travel
 - **Carrier** proteins
 - Carrier proteins **change shape** to transport a substance across the membrane, e.g. protein pumps and electron carriers
- Each transport protein is **specific to a particular ion or molecule**
- Transport proteins allow the cell to **control** which substances enter or leave

Receptors

- Receptors are for the binding of peptide hormones, e.g. insulin, neurotransmitters or antibodies
- The binding generates a signal that triggers a series of reactions inside the cell

Immobilised enzymes

- Immobilized enzymes are integral proteins with the active site exposed on the surface of the membrane
- They can be inside or outside the cell



Your notes

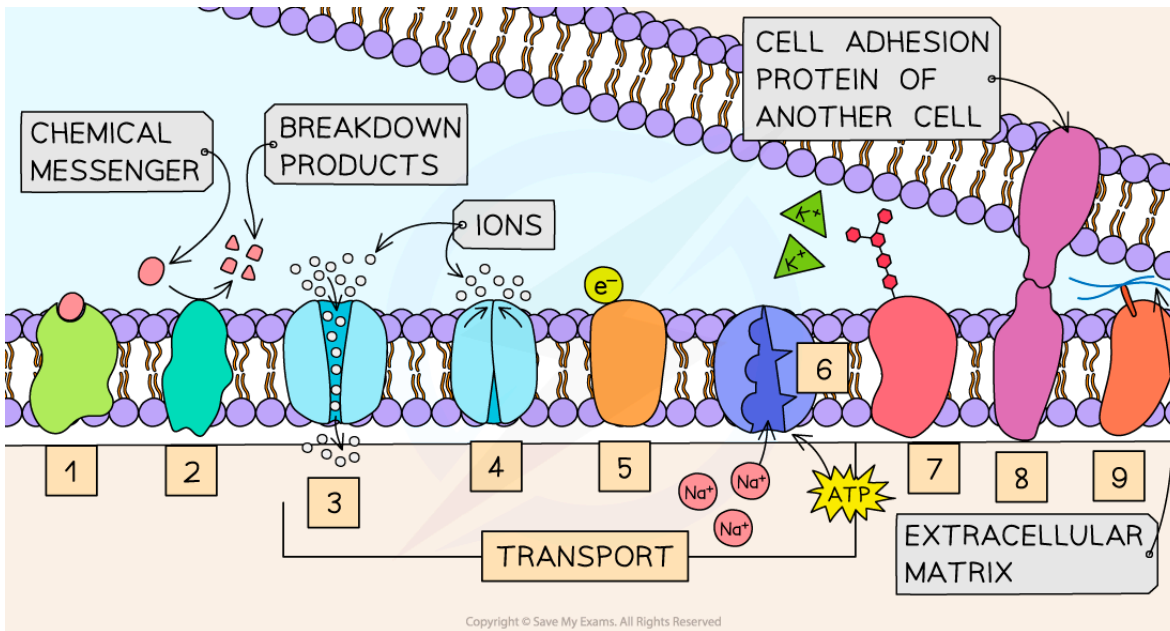
Cell adhesion

- Cell adhesion allows cells to attach to neighbouring cells within a tissue

Cell-to-cell recognition

- Glycoproteins act as cell markers, or antigens, for cell-to-cell recognition
- E.g. the ABO blood group antigens are glycolipids and glycoproteins that differ slightly in their carbohydrate chains

Plasma membrane proteins diagram



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1	RECEPTOR e.g. HORMONE RECEPTOR (INSULIN)	5	CARRIER ELECTRONS e.g. CYTOCHROME
2	IMMOBILIZED ENZYME e.g. MALTASE	6	CARRIER-PROTEIN PUMP e.g. SODIUM-POTASSIUM PUMP
3	CHANNEL e.g. SODIUM IONS	7	CELL-TO-CELL RECOGNITION e.g. GLYCOPROTEIN-ANTIGEN
4	CHANNEL - VOLTAGE-GATED e.g. POTASSIUM IONS	8	CELL ADHESION
		9	ANCHOR PROTEIN

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Membrane proteins have multiple functions

 **Examiner Tip**

As you go through the biology course you will learn specific examples of how membrane proteins are used; making links between the content here and other sections of the course will make it easier to learn examples of membrane proteins



Your notes



Your notes

Membrane Transport

Simple Diffusion

- Simple diffusion is a type of **membrane transport** that involves particles passing directly between the phospholipids in **the plasma membrane**
- It can be defined as:

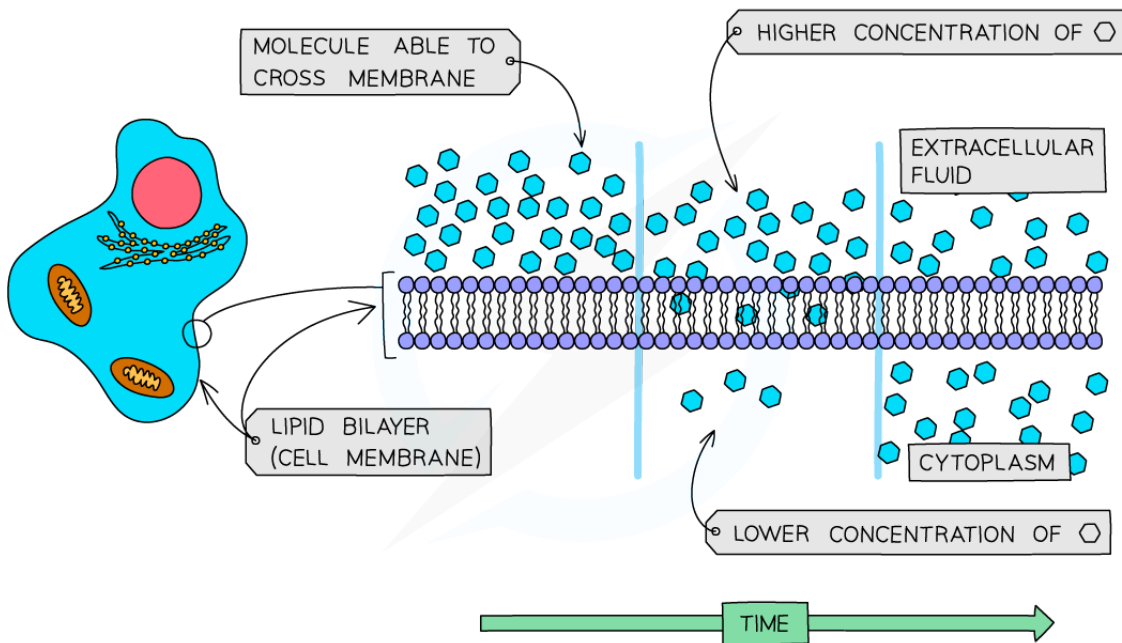
The net movement, as a result of the random motion of molecules or ions, of a substance from a region of higher concentration to a region of lower concentration

- The random movement is caused by the **kinetic energy** of the molecules or ions
- The molecules or ions are said to move **down a concentration gradient**
- If diffusion takes place for a long enough time period, molecules eventually reach **equilibrium**, where they are **evenly distributed** on either side of a membrane
- Examples of molecules that move by simple diffusion include
 - **Oxygen**
 - Oxygen diffuses into cells from the surrounding capillaries
 - Respiration uses up oxygen, resulting in a low concentration inside cells and so generating a concentration gradient
 - **Carbon dioxide**
 - Carbon dioxide diffuses out of cells and into the surrounding capillaries
 - Respiration produces carbon dioxide as a product, resulting in a high concentration inside cells and so generating a concentration gradient

Simple diffusion diagram



Your notes



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Simple diffusion involves the movement of molecules directly between the phospholipids of a cell membrane

- The **rate** at which a substance diffuses across a membrane depends on several factors:
 - **'Steepness' of the concentration gradient**
 - The greater the difference in concentration across a membrane, the higher the rate of diffusion
 - **Temperature**
 - The higher the temperature the higher the rate of diffusion
 - The molecules have more kinetic energy at high temperatures, so random movement of molecules is faster
 - **Surface area**
 - The greater the surface area the higher the rate of diffusion
 - **Properties of the molecules or ions**
 - **Large molecules** diffuse more slowly as they require more energy to move
 - **Uncharged** molecules, e.g. oxygen, diffuse faster as they move directly across the phospholipid bilayer
 - **Non-polar** molecules diffuse more quickly as they are soluble in the non-polar phospholipid bilayer
 - Although polar molecules cannot easily pass through the hydrophobic part of the membrane, **smaller polar** molecules (e.g. urea) can diffuse at low rates



Your notes

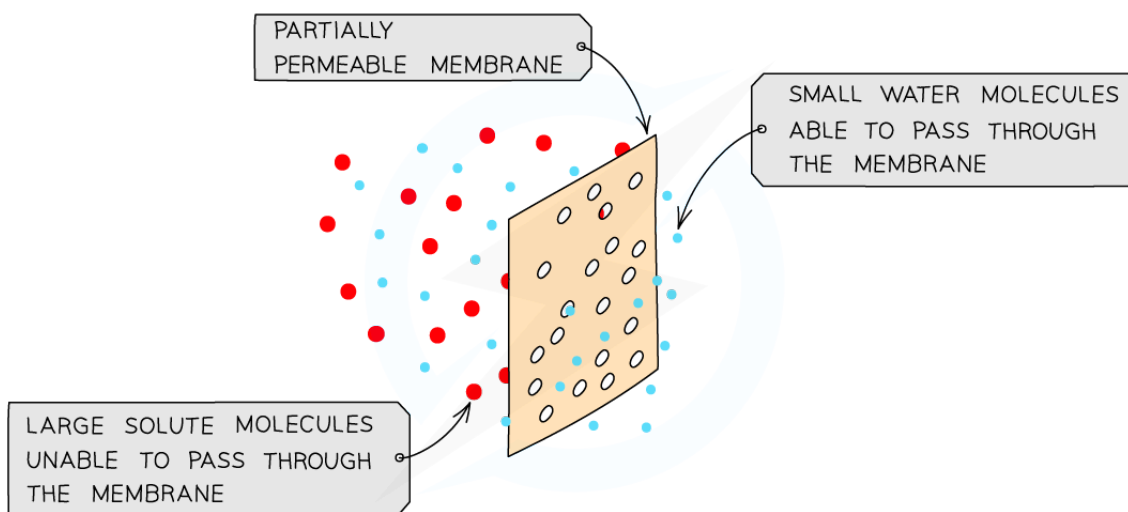
Osmosis

- Osmosis can be defined as:

The diffusion of water molecules, from a dilute solution to a solution with a higher solute concentration, across a partially permeable membrane

- In doing this, water is moving down its **concentration gradient**, and so osmosis can be said to be a **type of diffusion**
 - A dilute solution has a high concentration of water molecules and a concentrated solution has a low concentration of water molecules
- As with facilitated diffusion, osmosis occurs as the result of the **random movement** of molecules, so is technically the **net** movement of water
- While water can move directly in between the phospholipids, channel proteins called **aquaporins** allow water to pass through membranes more freely
 - Water is unusual for a polar molecule in its ability to pass directly across cell membranes

Movement of water molecules diagram



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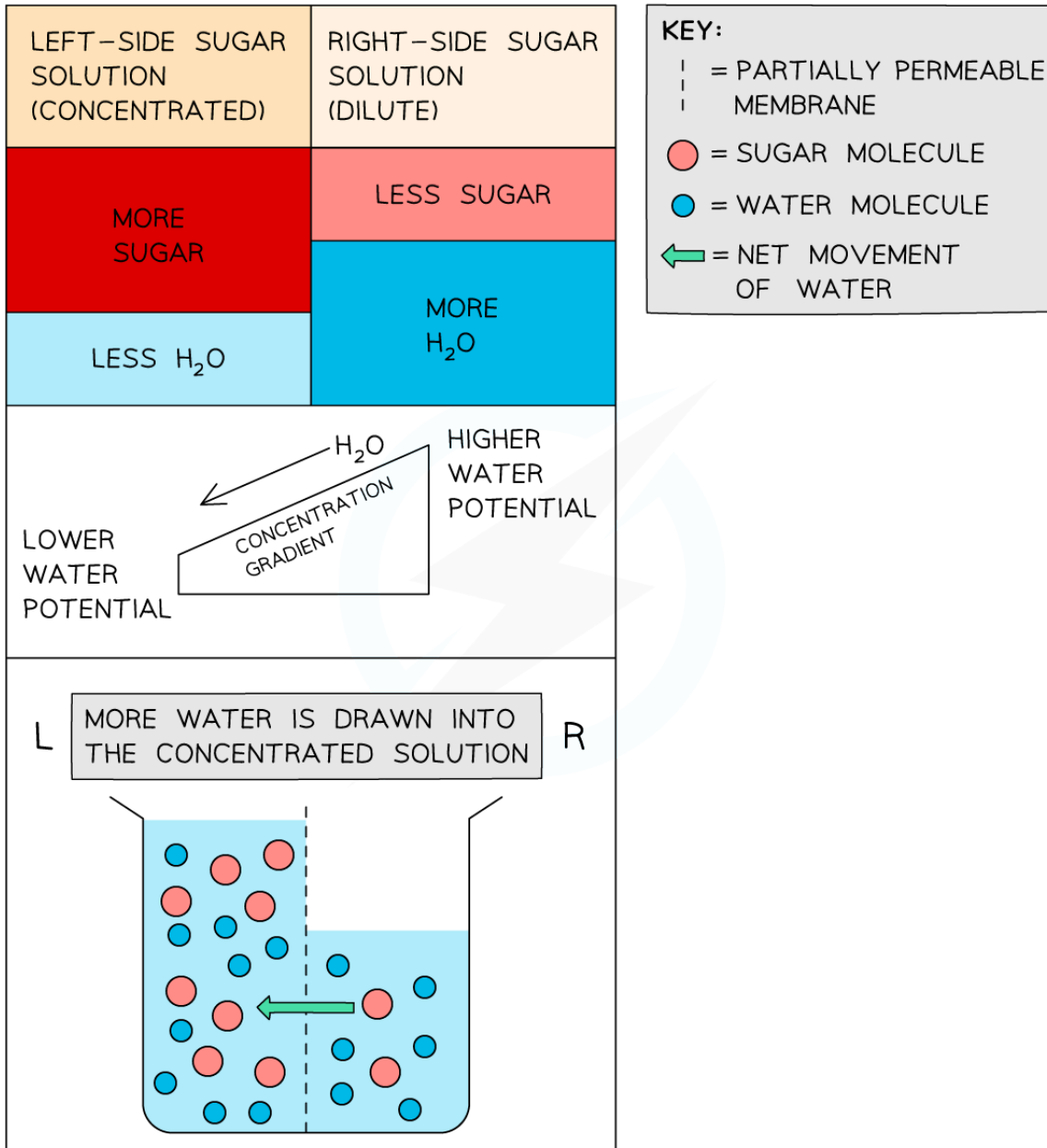
Water molecules can cross partially permeable membranes

- Osmosis can also be described as the net movement of water molecules from a region of **higher water potential** to a region of **lower water potential**, through a partially permeable membrane
 - Water potential describes the tendency of water to move; this term is used to avoid confusion between water concentration and solute concentration of a solution

Osmosis diagram



Your notes



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Osmosis is the movement of water molecules from a dilute to a concentrated solution across a partially permeable membrane



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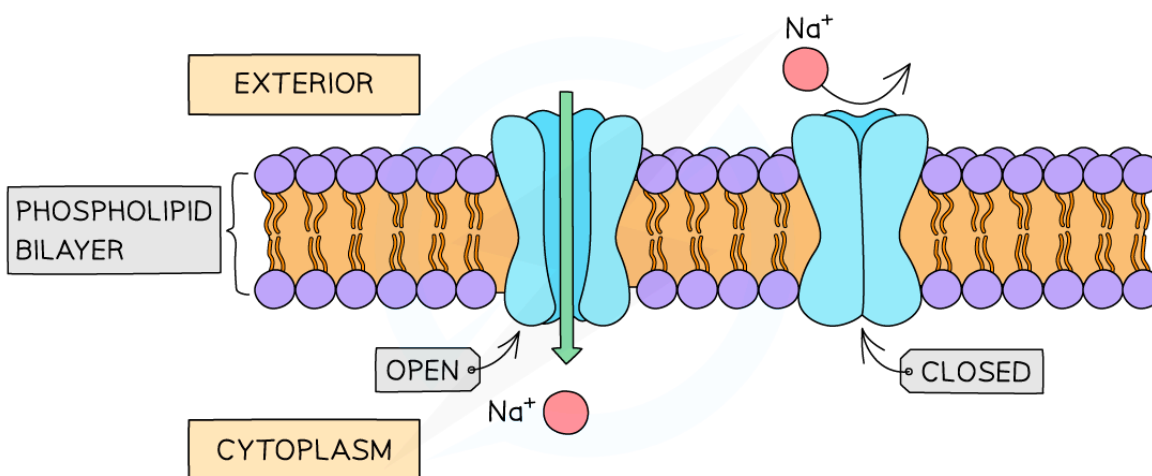
Facilitated Diffusion

- Some substances cannot diffuse through the phospholipid bilayer of cell membranes, e.g.:
 - Large** molecules
 - Polar** molecules
 - Ions**
- These substances can only cross the phospholipid bilayer with the help of transport proteins
- This form of diffusion is known as **facilitated diffusion**
- There are two types of proteins that enable facilitated diffusion:
 - Channel proteins**
 - Carrier proteins**
- Transport proteins are **highly specific**, meaning that they only allow one type of molecule or ion to pass through
- During facilitated diffusion the net diffusion of molecules or ions into or out of a cell will occur **down a concentration gradient**
 - Facilitated diffusion is a **passive** form of transport; it does not require energy
 - The direction of movement of molecules through a transport protein depends on their **relative concentration** on each side of the membrane

Channel proteins

- Channel proteins are **pores** that allow the passage of specific substances across a membrane
- They allow **charged substances** (eg. ions) to diffuse through the cell membrane
- Some channel proteins are **gated**, meaning that part of the channel protein on the inside surface of the membrane can move in order to close or open the pore
 - This allows the channel protein to **control** the exchange of ions

Channel protein diagram



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Channel proteins are membrane pores; some channel proteins can open and close

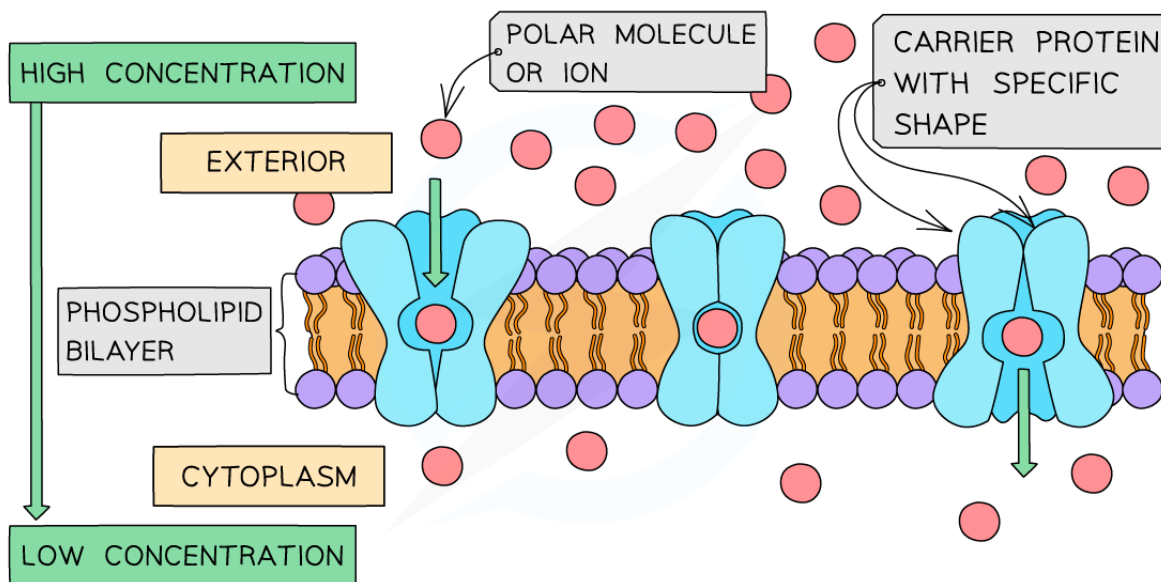


Your notes

Carrier proteins

- Unlike channel proteins, which have a fixed shape, **carrier proteins can switch between two shapes**
 - The substance to be transported attaches to a binding site, causing a shape change in the carrier protein
 - Initially the binding site of the carrier protein is open to one side of the membrane
 - When the carrier protein switches shape it opens to the other side of the membrane

Carrier protein diagram



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Carrier proteins change shape to carry substances across cell membranes

Examiner Tip

Remember that the movement of molecules from **high concentration to low concentration** is diffusion; this movement is **passive** and requires no energy

- If this movement requires the aid of a protein then it is facilitated diffusion
- If it involves the movement of water across a partially permeable membrane it is osmosis.



Your notes

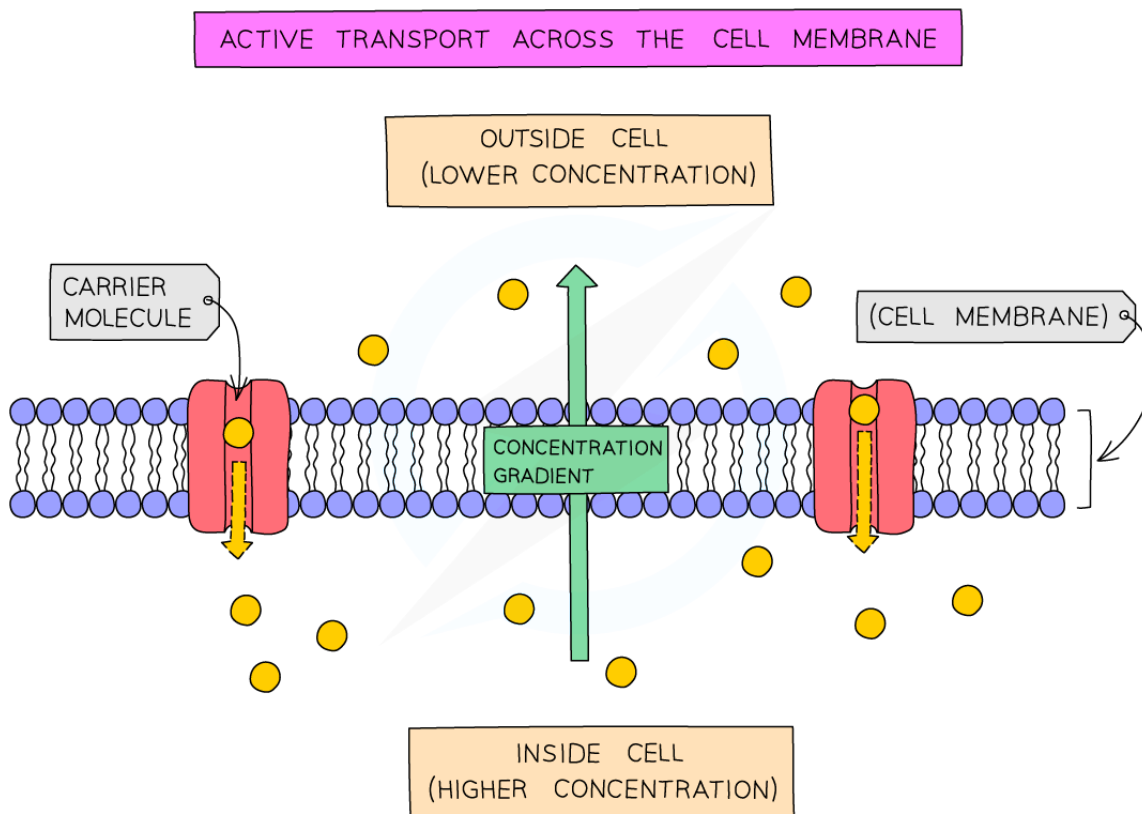
Active Transport

- Active transport can be defined as:

The movement of molecules and ions across a cell membrane, from a region of lower concentration to a region of higher concentration, using energy from respiration

- Active transport occurs **against**, or **up**, a **concentration gradient**
- Active transport requires **carrier proteins**
 - Carrier proteins in active transport are sometimes known as **pumps**
 - Although facilitated diffusion also uses carrier proteins, active transport is different as it requires **energy**
- Energy is required to allow the carrier protein to **change shape**, allowing it to transfer the molecules or ions across the cell membrane
 - The energy required is provided by **ATP** (adenosine triphosphate), produced during **respiration**.
 - The ATP is **hydrolysed** to release energy

Active transport diagram



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Active transport is the transport of substances across cell membranes from low to high concentration



Your notes

Selective Permeability

- **Facilitated diffusion** and **active transport** are mechanisms that allow cell membranes to be **selectively permeable**
 - Selective permeability is the ability of the membrane to **differentiate** between different types of molecules, only allowing some molecules through while blocking others
- **Simple diffusion** provides less control for cell membranes, as it is dependent only on the size and hydrophobic or hydrophilic nature of the molecules diffusing
 - Simple diffusion provides no ability for membranes to be selective with regard to **small, polar molecules**
 - Small, non-polar molecules can diffuse across the membrane with ease so this is not selective
 - Simple diffusion does allow for selective permeability with regard to **large or polar molecules**
 - Large or polar molecules cannot cross the phospholipid bilayer without transport proteins



Your notes

Glycolipids & Glycoproteins

Glycoproteins & Glycolipids

- **Glycoproteins** are cell membrane **proteins** that have a **carbohydrate** chain attached on the **extracellular** side
 - Extracellular = outside cells
- **Glycolipids** are **lipids** with **carbohydrate chains** attached, also located on the outer surface of cell membranes

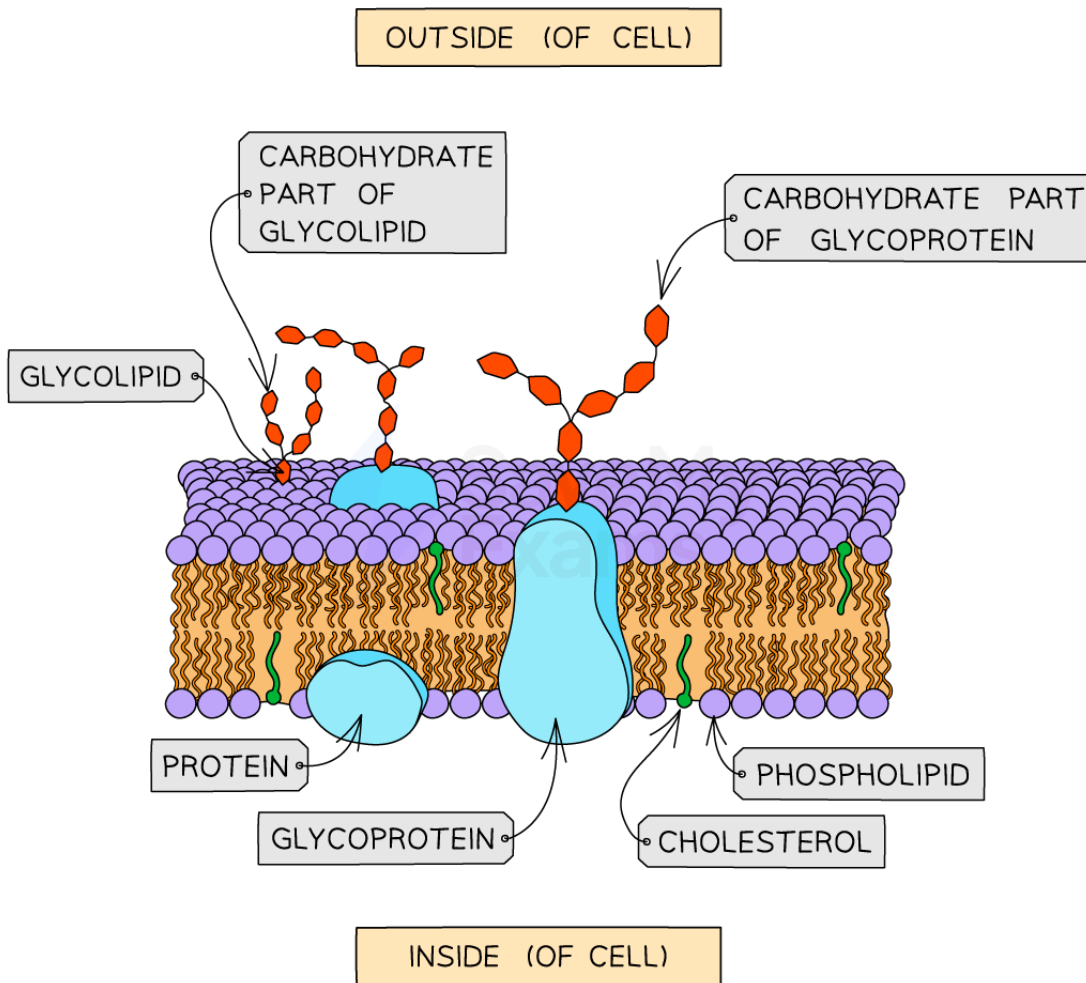
The function of glycoproteins and glycolipids

- The carbohydrate chain enables them to act as **receptor molecules**
 - This allows them to **bind** with substances at the cell surface
 - Receptor types include:
 - **Signalling receptors which bind to hormones and neurotransmitters**
 - Receptors involved in endocytosis
 - Receptors involved in **cell adhesion** and **stabilisation**
 - Cell adhesion allows cells to attach to each other to form tissues
- Some act as cell markers, or antigens, for **cell identification**
 - E.g. this allows the immune system to determine whether or not a cell belongs in the body, or whether it is a pathogen

Glycoproteins and glycolipids diagram



Your notes



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Glycoproteins are carbohydrate chains attached to membrane proteins and glycolipids are carbohydrate chains attached to the lipid element of the cell membrane

The Fluid Mosaic Model: Skills



Your notes

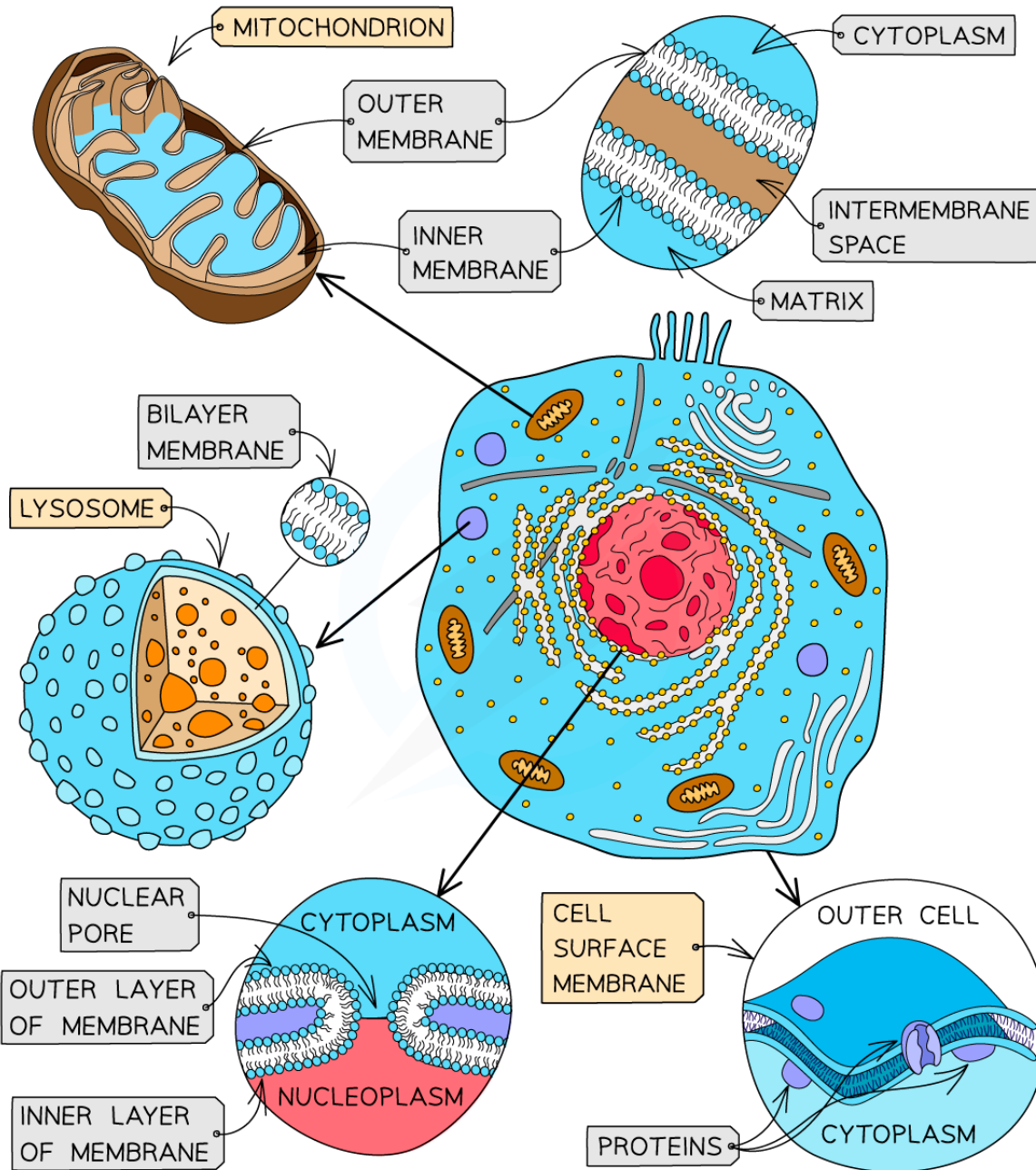
The Fluid Mosaic Model

Membranes

- Membranes form partially permeable **barriers** between the cell and its environment, between cytoplasm and organelles and also within organelles
- Substances can cross membranes by **diffusion**, **facilitated diffusion**, **osmosis** and **active transport**
- Membranes play a role in **cell signalling** by acting as an **interface** for **communication between cells**



Your notes



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Membranes formed from phospholipid bilayers help to compartmentalise different regions within the cell, as well as forming the cell surface membrane

Fluid mosaic model

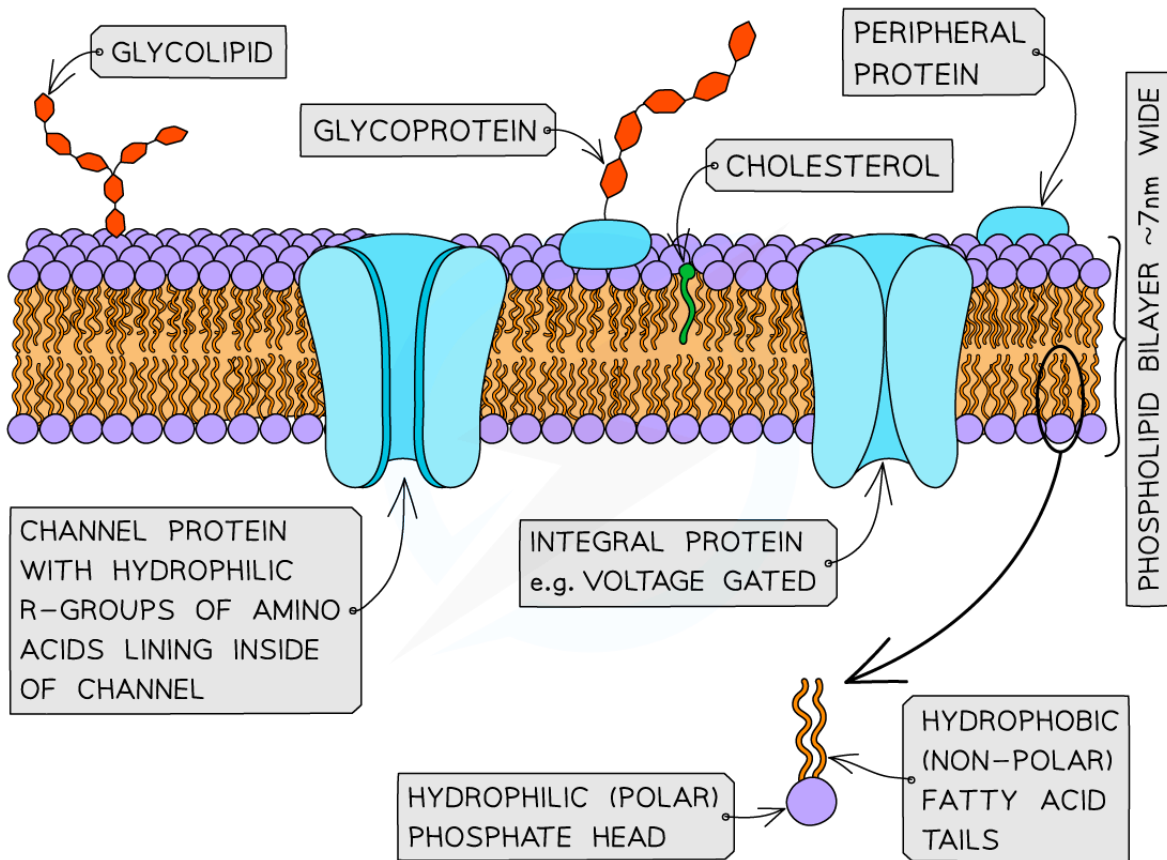
- The **fluid mosaic model** of membranes was first outlined in 1972 by **Singer and Nicolson** and it explains how biological molecules are arranged to form cell membranes



Your notes

- The fluid mosaic model also helps to explain:
 - **Passive and active movement between cells and their surroundings**
 - **Cell-to-cell interactions**
 - **Cell signalling**
- The fluid mosaic model describes cell membranes as ‘**fluid**’ because:
 - The **phospholipids** and **proteins** can **move around** within their own layers
- The fluid mosaic model describes cell membranes as ‘**mosaics**’ because:
 - The **scattered pattern** produced by the **proteins** within the phospholipid bilayer looks somewhat like a mosaic when viewed from above
- The **fluid mosaic model** of membranes includes four main components:
 - Phospholipids
 - Cholesterol
 - Glycoproteins and glycolipids
 - Integral and peripheral proteins

The fluid mosaic model diagram



The distribution of the proteins within the membrane gives a mosaic appearance and the structure of the proteins determines their position in the membrane

Examiner Tip

You should be able to draw a two-dimensional diagram of the fluid mosaic model of membrane structure.

You should show and **label** the following:

- The **phospholipid bilayer**, making it clear which part is the phosphate head and which parts are the hydrocarbon tails
- **Integral proteins**, e.g. channel/carrier
- **Peripheral proteins** that **do not** extend into the hydrophobic region
- **Glycoproteins** with a carbohydrate attached
- **Cholesterol**, with the OH group next to the phosphate heads and the rest positioned next to the tails



Your notes