



# HL IB Biology



Your notes

## Membranes & Membrane Transport

### Contents

- \* Lipid Bilayers
- \* Membrane Proteins
- \* Membrane Transport
- \* Glycolipids & Glycoproteins
- \* The Fluid Mosaic Model: Skills
- \* Membrane Fluidity (HL)
- \* Active Transport & Bulk Transport (HL)
- \* Cell Adhesion (HL)



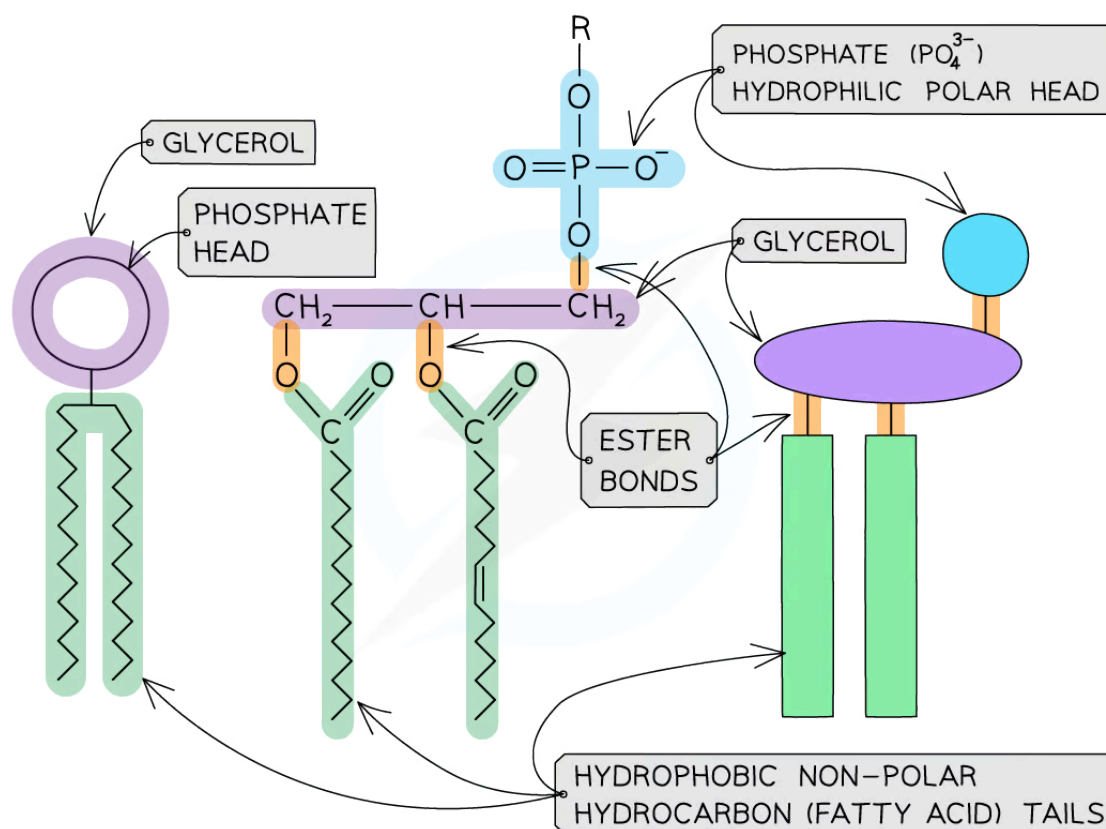
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## Lipid Bilayers

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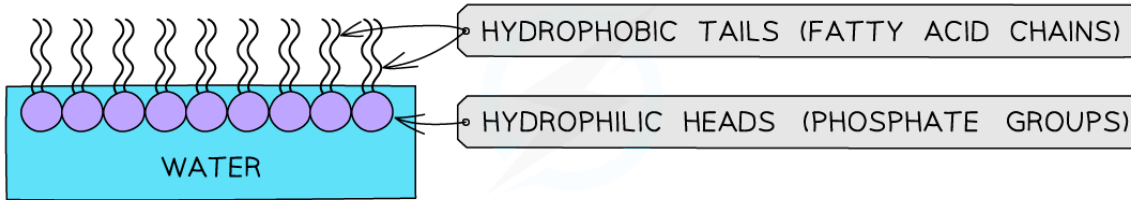
**Phospholipids consist of a molecule of glycerol, two fatty acid tails, and a phosphate group**

- 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**



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### Phospholipid monolayer diagram

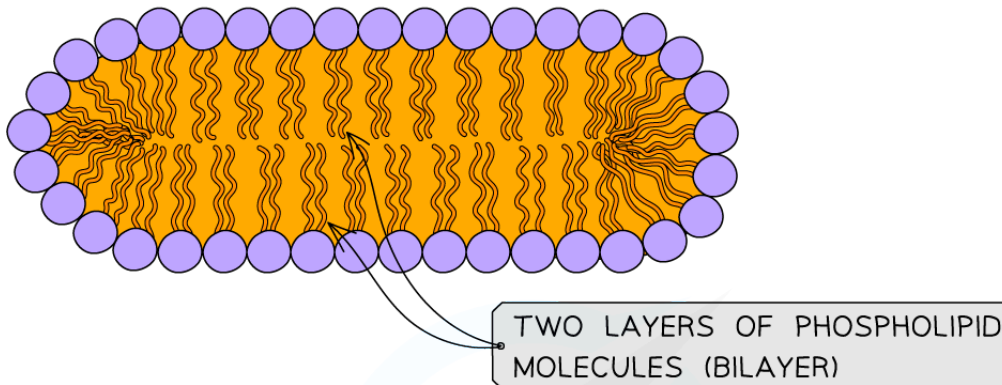


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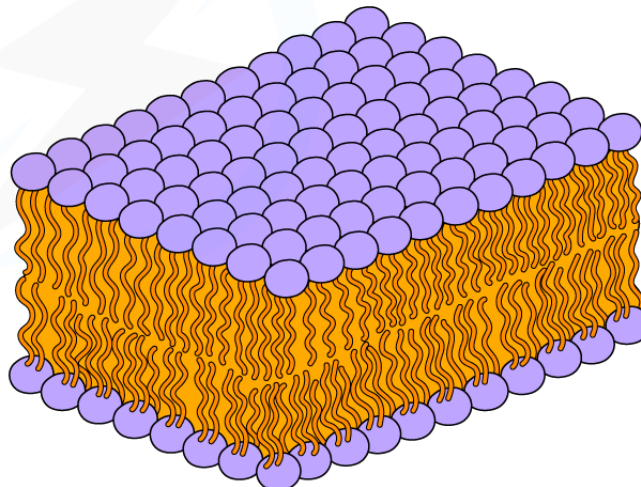
### Phospholipids can form a monolayer in water

- 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*



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## 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



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## 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



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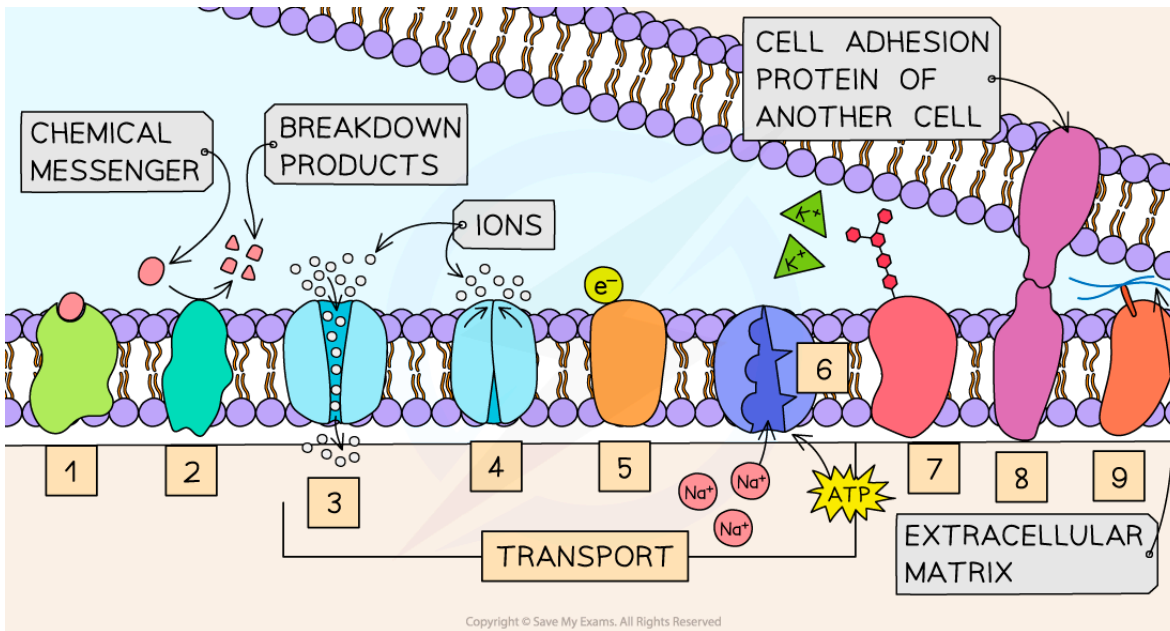
**Cell adhesion**

- 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



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## 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**

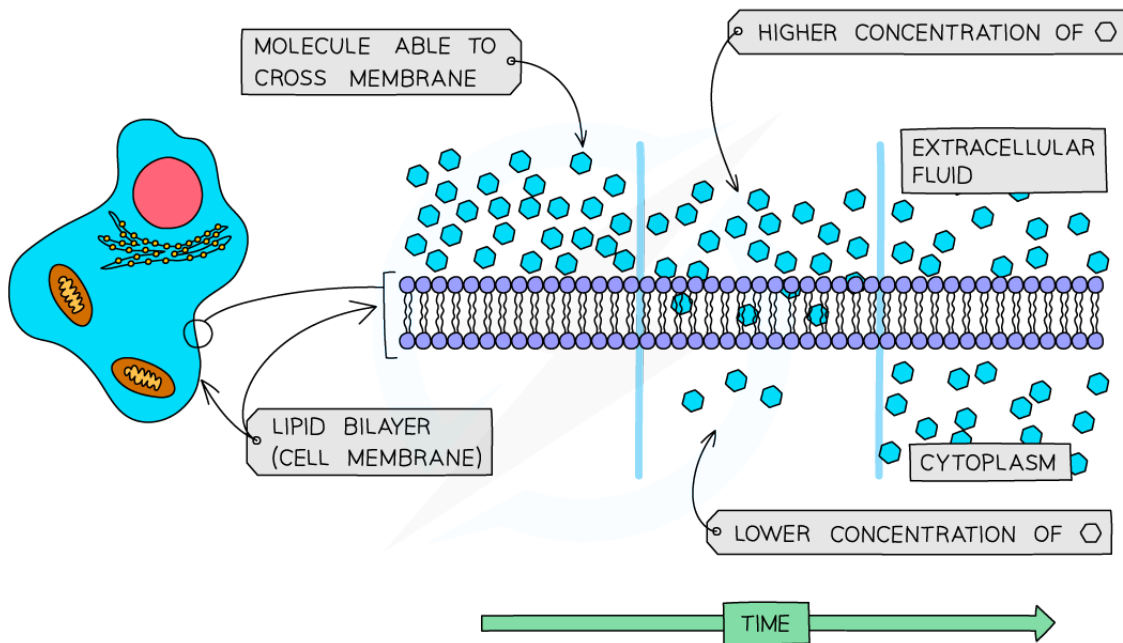
- The random movement is caused by the **kinetic energy** of the molecules or ions
- The molecules or ions are said to move **down a concentration gradient**
- If diffusion takes place for a long enough time period, molecules eventually reach **equilibrium**, where they are **evenly distributed** on 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





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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



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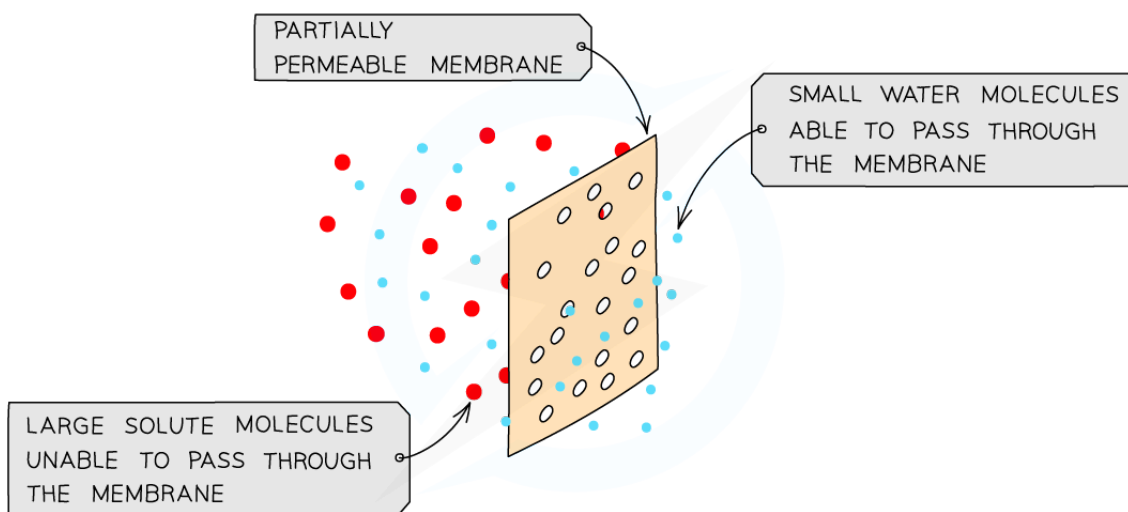
## Osmosis

- 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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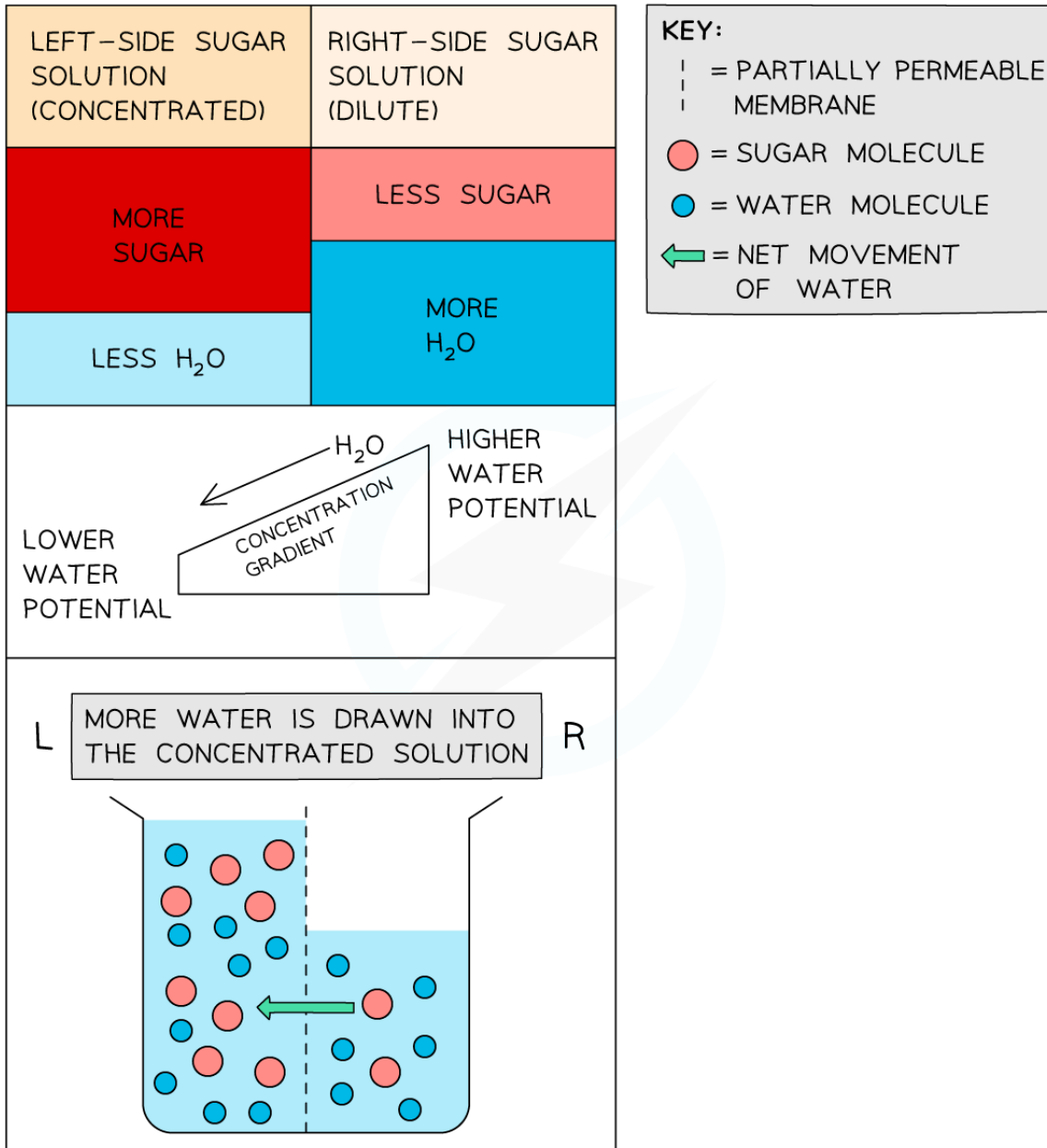
### *Water molecules can cross partially permeable membranes*

- 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



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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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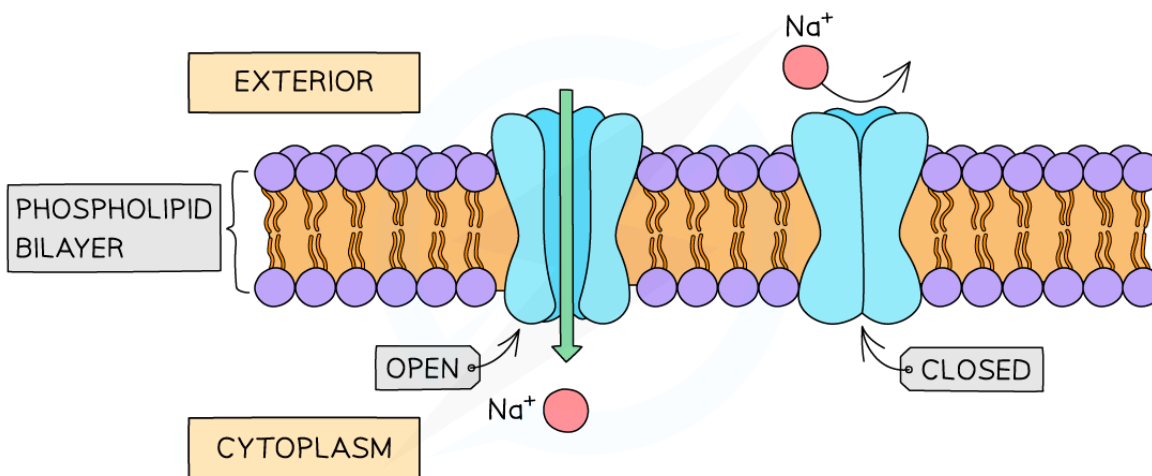
## Facilitated Diffusion

- 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*

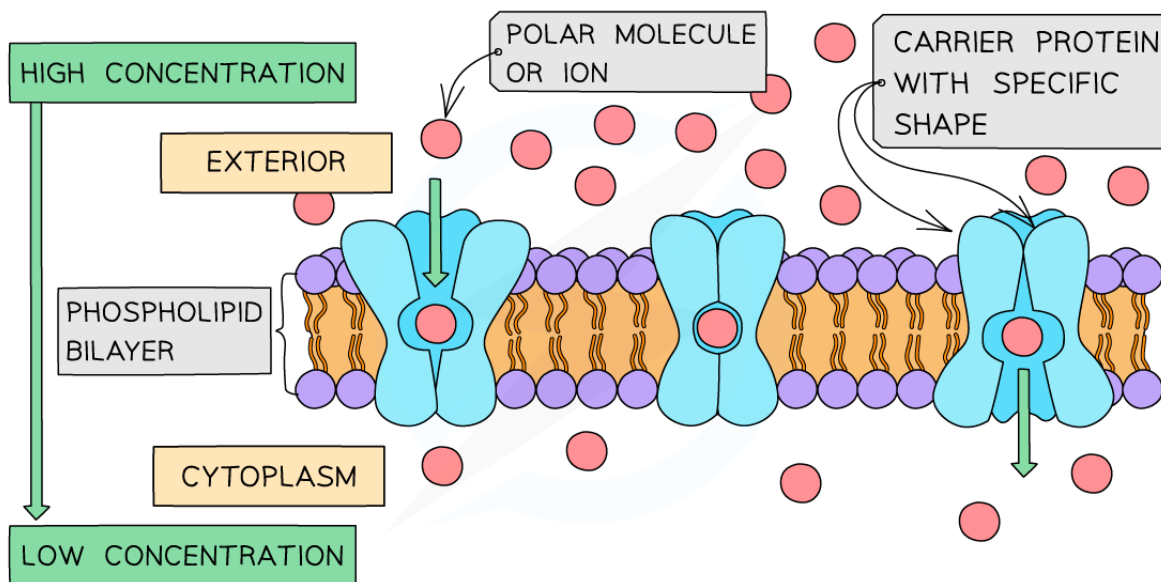


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## Carrier proteins

- 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.



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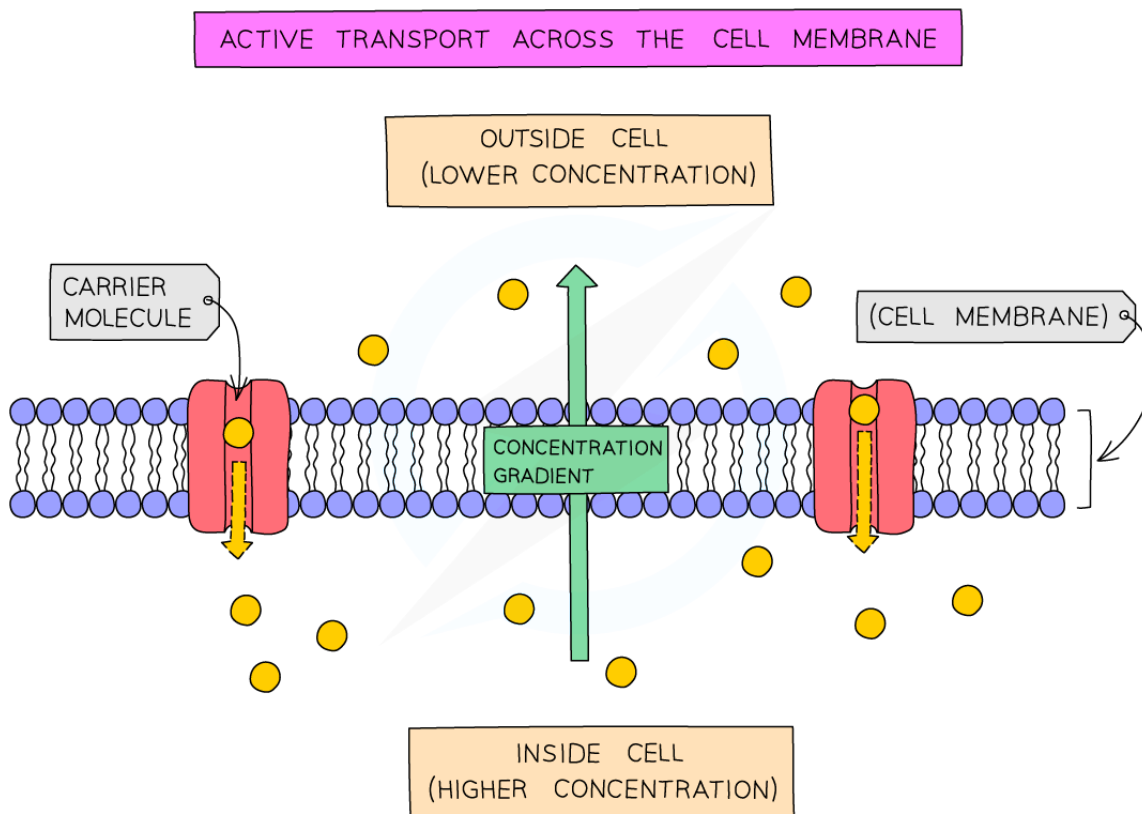
## Active Transport

- 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*



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## 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



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## 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

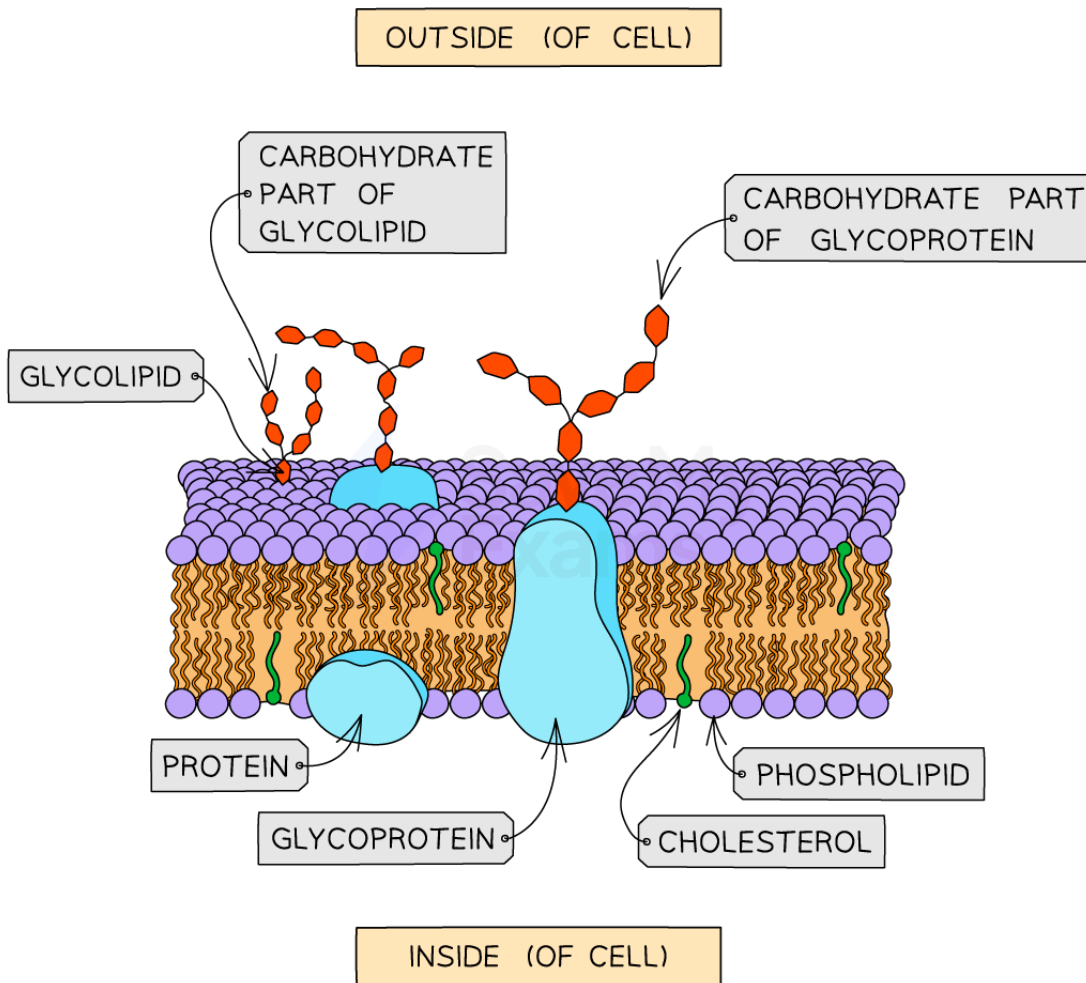
- The carbohydrate chain enables them to act as **receptor molecules**
  - This allows them to **bind** with substances at the cell surface
  - Receptor types include:
    - **Signalling receptors which bind to hormones and neurotransmitters**
    - Receptors involved in endocytosis
    - Receptors involved 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





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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



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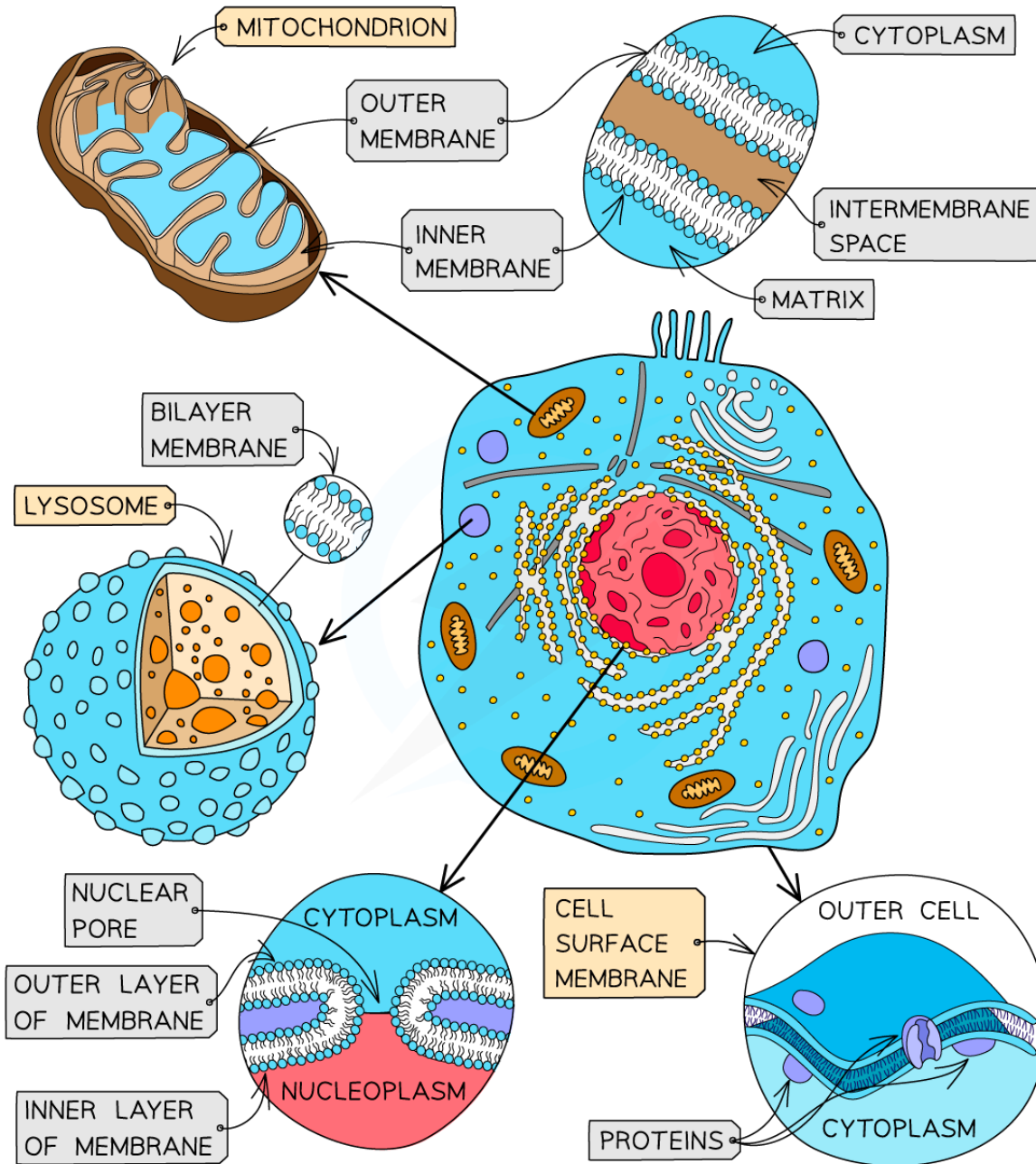
### The Fluid Mosaic Model

#### 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**



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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

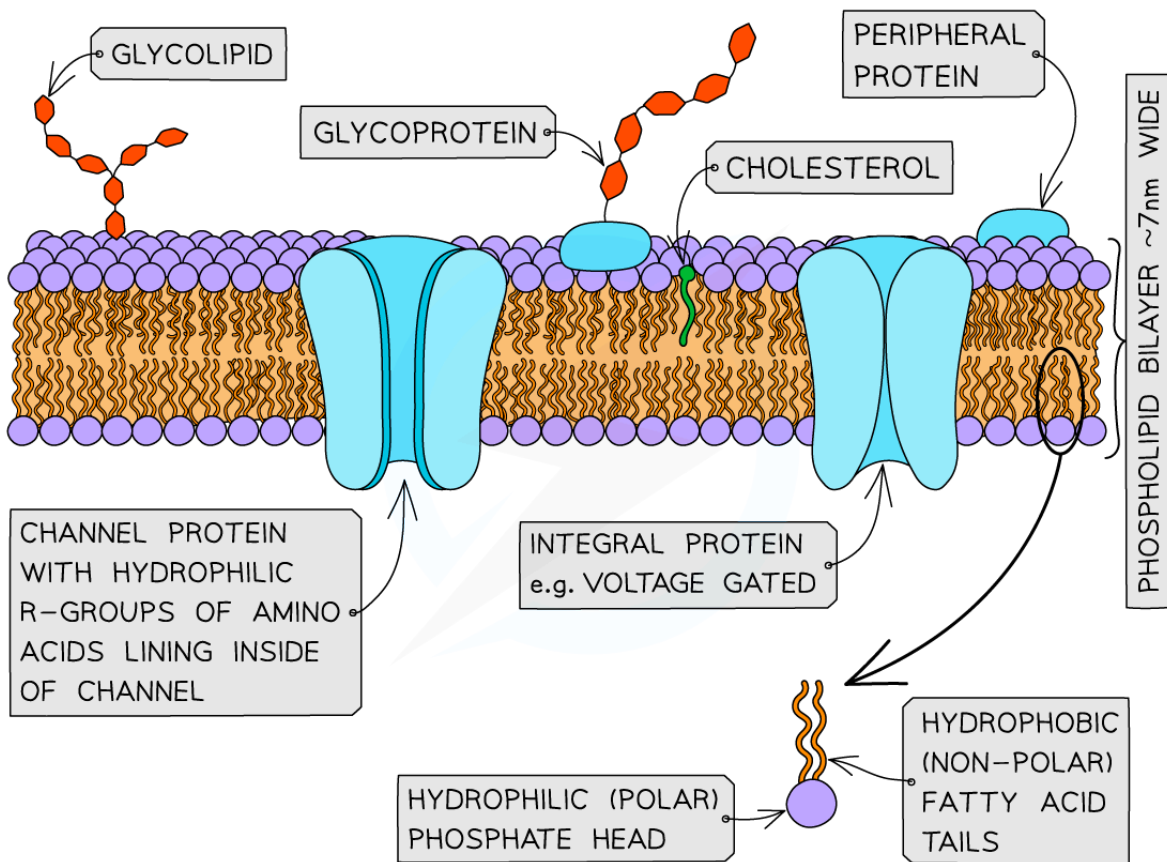
- The **fluid mosaic model** of membranes was first outlined in 1972 by **Singer and Nicolson** and it explains how biological molecules are arranged to form cell membranes



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- 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



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**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



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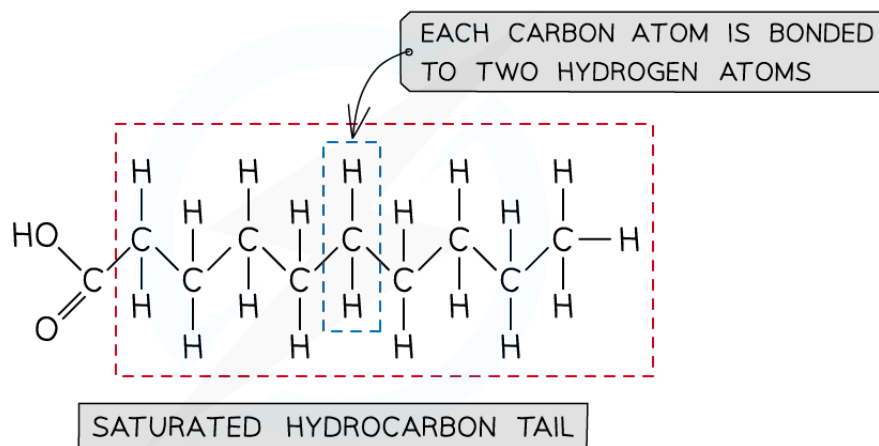


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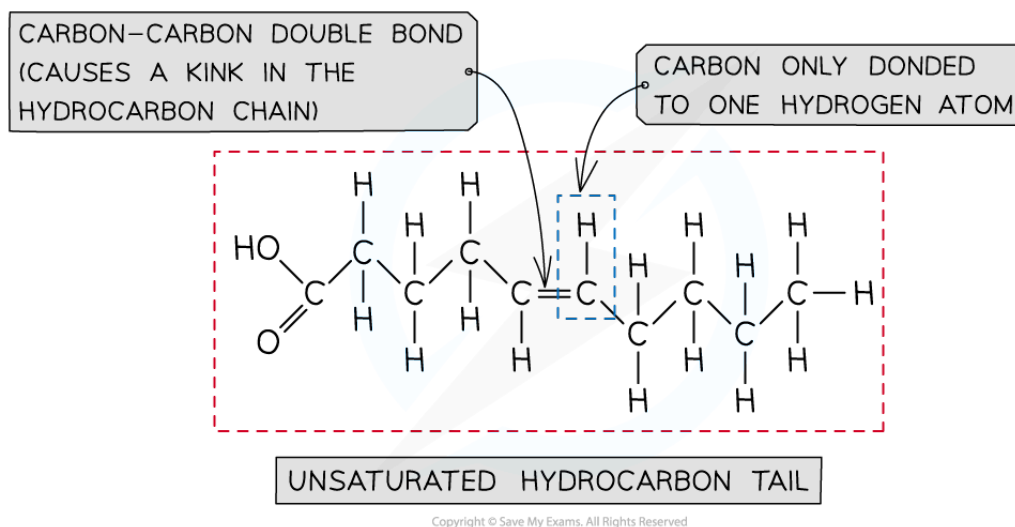
## Membrane Fluidity (HL)

### Fatty Acid Composition

- Phospholipids contain glycerol, a phosphate group, and two **fatty acid chains**
- Fatty acids can vary in two ways:
  - **Length** of the hydrocarbon chain
  - The fatty acid chain may be **saturated** or **unsaturated**
- **Saturated fatty acids**
  - Every carbon atom is bonded to 4 other atoms, meaning that each carbon in the chain is linked to 2 hydrogen atoms
    - The chain can be said to be 'saturated' with hydrogens; it contains as many hydrogen atoms as it possibly can
  - Saturated fatty acids are **straight**, allowing the molecules to **pack together tightly**
  - They therefore have **higher melting points**, so their presence in cell membranes allow membranes to **maintain stability** at higher temperatures
- **Unsaturated fatty acids**
  - Contain one or more double bonds between carbon atoms
    - One double bond - mono-unsaturated
    - More than one double bond = polyunsaturated
  - Unsaturated fatty acids have **bends**, or kinks, in the chain, meaning that they **cannot pack together so tightly**
  - Unsaturated fatty acids have **lower melting points** so they allow membranes to be **fluid and flexible**



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**Fatty acids can be saturated (top) or unsaturated (bottom); this affects the shape, and therefore the properties of the fatty acid**

## Fatty acids & regulating membrane fluidity

- **Bacteria** do not regulate their internal temperature, so their cell membranes are subject to temperature change
  - This means that they require mechanisms to overcome temperature fluctuations
  - Some bacteria species produce enzymes called **fatty acid desaturases** which **increase the number of double bonds** within a fatty acid as part of the membrane; this helps to **maintain membrane fluidity**, particularly during exposure to colder temperatures
- **Deep-sea marine organisms** have to contend with extreme temperatures
  - Correlations have been found between sea temperature and membrane-fluidising lipid components, such as polyunsaturated fatty acids
- **Plants**, such as *Arabidopsis thaliana*, have shown fatty acid unsaturation pathways that appear to have key roles in the acclimatisation of membranes to high temperature

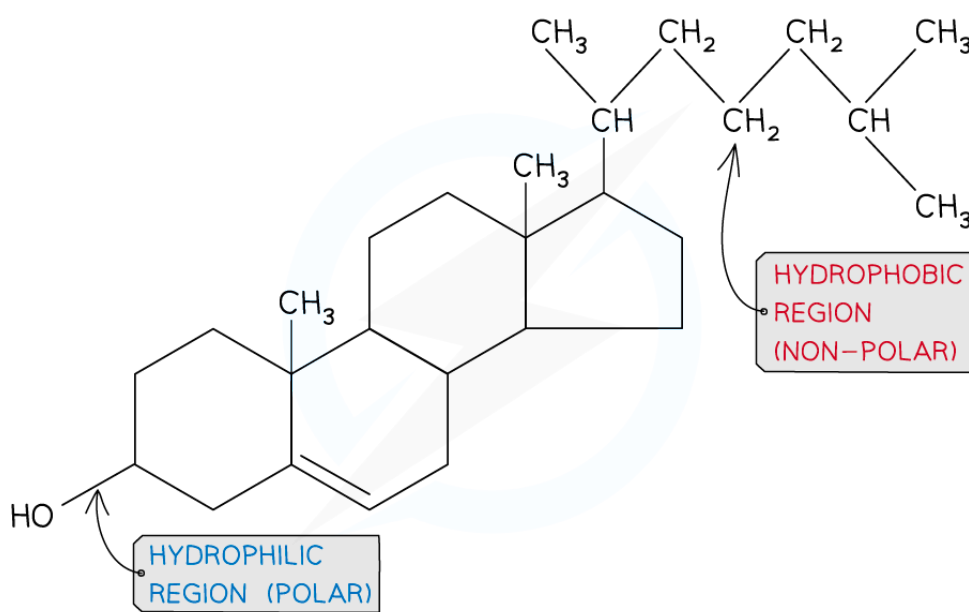


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## Cholesterol

- Cholesterol is an important membrane **lipid**
- Just like phospholipid molecules, cholesterol molecules have **hydrophobic** and **hydrophilic regions**
  - Their chemical structure allows them to exist within the bilayer of the membrane
- Cholesterol **affects the fluidity and permeability** of cell membranes
  - It **maintains membrane fluidity** at low and high temperatures
    - It disrupts the close-packing of phospholipids, **increasing the flexibility** of the membrane at **low temperatures**
    - It holds the fatty acid tails together, providing **increased membrane stability** at **high temperatures**
  - It acts as a **barrier**, fitting in the spaces between phospholipids
    - This prevents water-soluble substances from diffusing across the membrane

Cholesterol structure diagram



*The structure of a cholesterol molecule gives it a hydrophobic region and a hydrophilic region*





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## Active Transport & Bulk Transport (HL)

### Bulk Transport

- The processes of diffusion, osmosis and active transport are responsible for the transport of **individual molecules or ions** across cell membranes
- However, the **bulk transport of larger quantities of materials** into or out of cells is also possible
- Examples of these larger quantities of materials that might need to cross the membrane include:
  - Bulk transport **into** cells = **endocytosis**
  - Bulk transport **out** of cells = **exocytosis**
- Bulk transport processes **require energy** and are therefore forms of **active transport**
- They also require the formation of **vesicles**, which is dependent on the fluidity of membranes
  - **Vesicles** are **small spherical sacs** of plasma membrane that containing substances for transport, e.g. enzymes
  - The formation of vesicles is an **active** process and involves a small region of the plasma membrane being **pinched off**
  - Vesicles can also **fuse with** cell membranes, at which point they are re-incorporated into a larger membrane
  - In order to form from or fuse with membranes, vesicles need membranes to flex and bend, so **fluidity is essential**

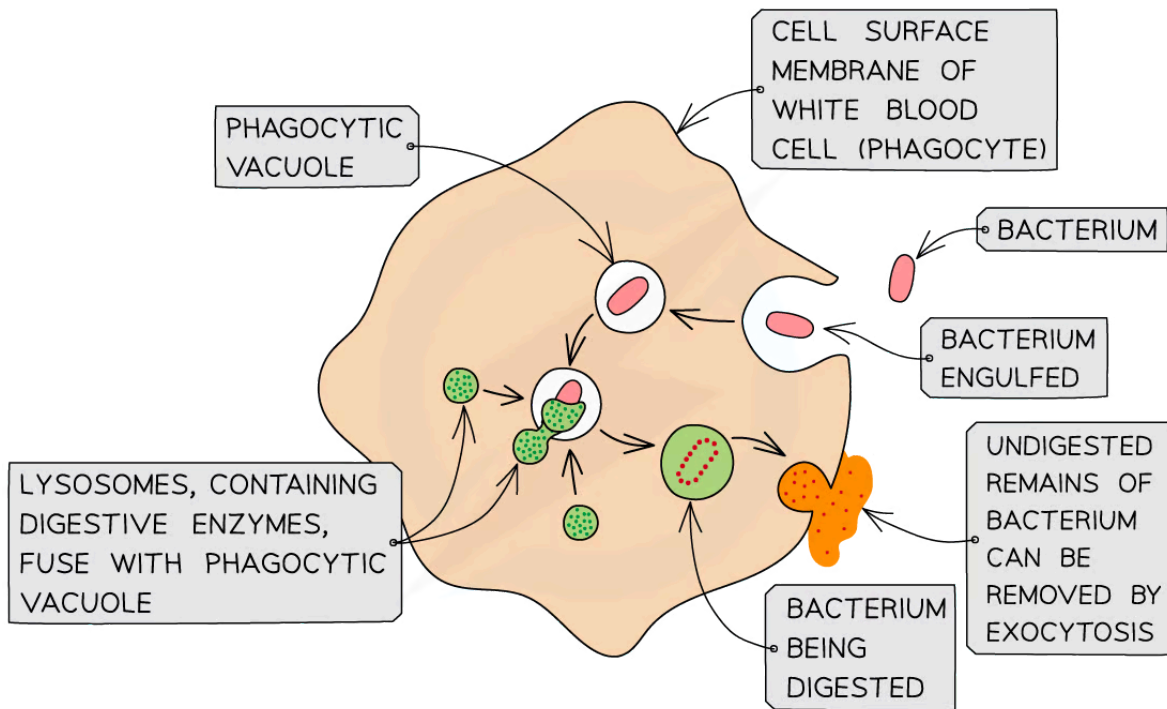
### Endocytosis

- Endocytosis transports material **into** cells
- During endocytosis the plasma membrane **engulfs material**, forming a small sac around it
- There are two forms of endocytosis:
  - **Phagocytosis:**
    - This is the bulk intake of solid material by a cell
    - Cells that specialise in this process are called **phagocytes**
    - The vacuoles formed are called phagocytic **vacuoles**
    - An example is the engulfing of bacteria by phagocytic white blood cells
  - **Pinocytosis:**
    - This is the bulk intake of liquids

#### Endocytosis diagram



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*Phagocytosis is an example of endocytosis*

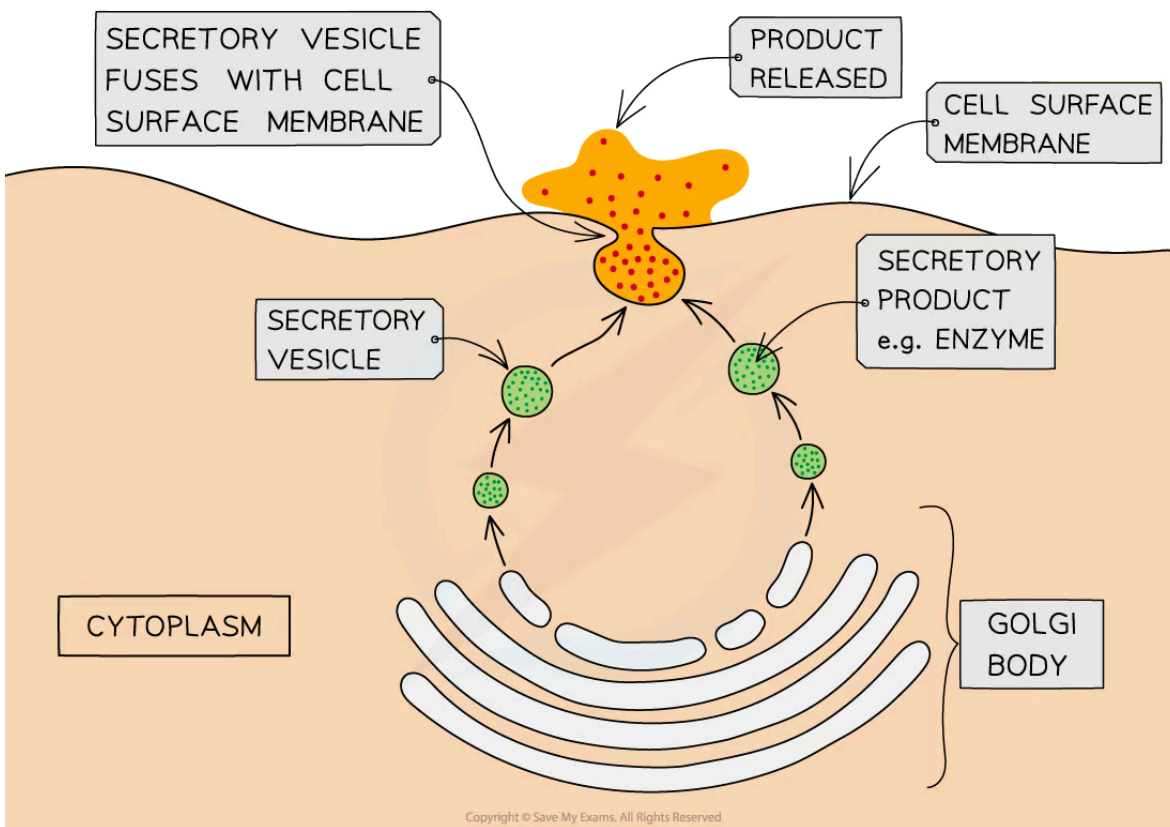
## Exocytosis

- Exocytosis is the process by which materials are removed from, or transported **out of**, cells
  - It is the **reverse of endocytosis**
- The substances to be released are packaged into **secretory vesicles**
- These vesicles then travel to the cell surface membrane
- Here they **fuse** with the cell membrane and **release their contents** outside the cell
- An example is the secretion of digestive enzymes from pancreatic cells

### Exocytosis diagram



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***Exocytosis involves the fusion of a vesicle with the cell surface membrane***



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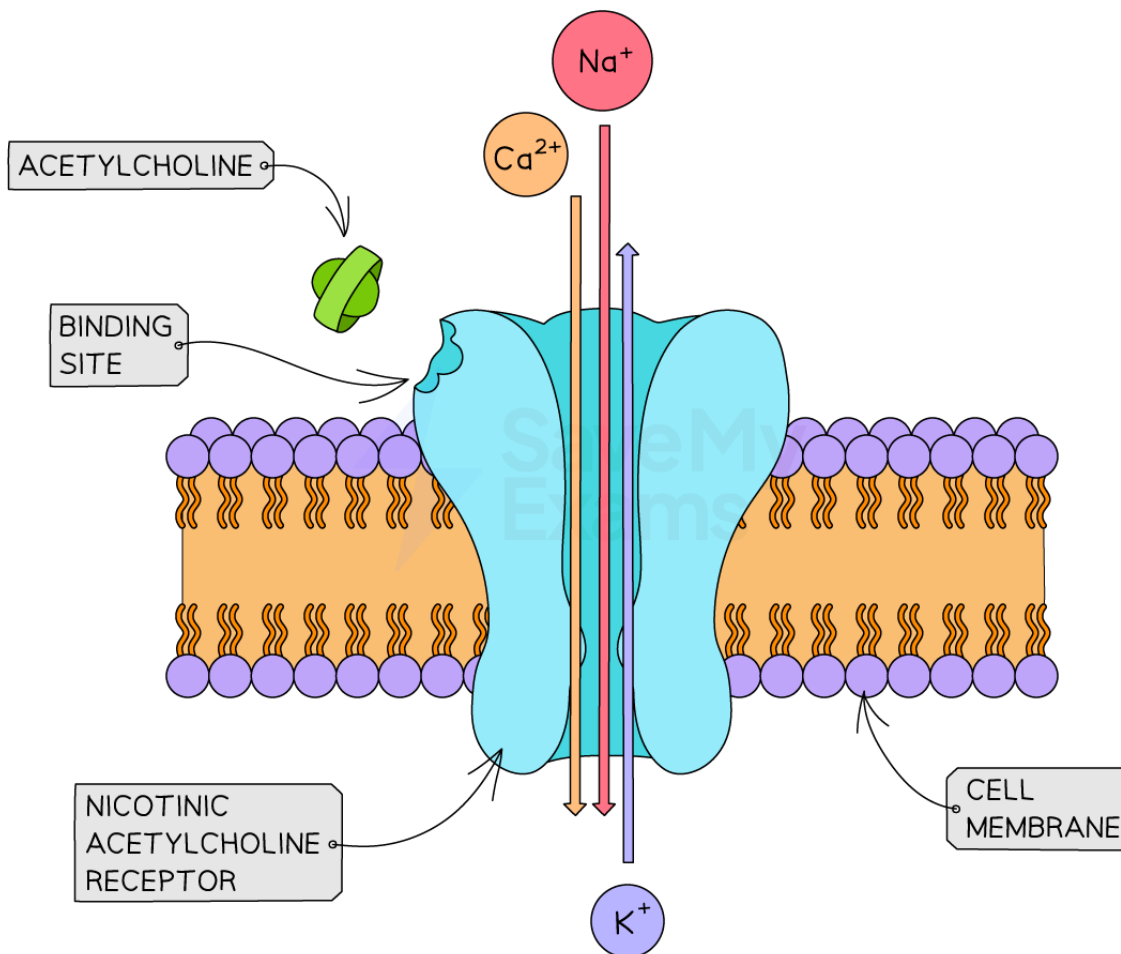
## Gated Ion Channels

- Specialised ion channels, called **gated ion channels**, are present in some cell membranes
  - These channels operate in response to **chemical** or **electrical stimuli**

### Nicotinic acetylcholine receptors

- Nicotinic acetylcholine receptors are an example of a gated ion channel, more specifically a **neurotransmitter-gated** ion channel
- The neurotransmitter acetylcholine can bind to nicotinic acetylcholine receptors which triggers the **ion channel to open** allowing certain ions, such as calcium ( $\text{Ca}^{2+}$ ) or sodium ( $\text{Na}^+$ ), to pass through
- The influx of ions causes the membrane potential to change; this can generate an action potential in neurones
- Nicotinic acetylcholine receptors are found specifically at the **neuromuscular junction**; the point at which nerve cells connect to muscles

Nicotinic acetylcholine receptor diagram



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*Nicotinic acetylcholine receptors are an example of a gated ion channel*



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## Sodium-Potassium Pumps

- **Sodium-potassium pump** proteins are **integral proteins** that generate an electrochemical gradient between the inside and outside of a nerve cell
- Sodium-potassium pumps are an example of an **exchange transporter**
  - The **sodium-potassium pumps** move **three sodium ions out** of the cell and **two potassium ions into** the cell using **one ATP molecule**
  - The pumps are always moving the ions **against their concentration gradient** via **active transport**
- The steps that occur during the pumping process are:
  1. **Three sodium ions** from the **inside** of the axon **bind** to the **pump**
  2. **ATP attaches** to the **pump** and **transfers a phosphate** to the pump (phosphorylation), causing it to change shape and resulting in the pump opening to the outside of the axon
  3. The three **sodium ions** are **released** out of the axon
  4. **Two potassium ions** from **outside** the **axon** enter and **bind** to their sites
  5. The **attached phosphate** is **released** altering the shape of the pump again
  6. The change in shape causes the **potassium ions** to be **released inside** the axon
- This process is essential to the function of nerve cells
  - The sodium-potassium pumps transport more positively charged sodium ions to the outside of the cell than positively charged potassium ions to the inside; the inside of the cell is **therefore negatively charged** in comparison to the outside
  - When nerve cells are stimulated, sodium ion channels open and sodium ions rush in down the electrochemical gradient, **reversing the charge** across the membrane
  - This can lead to the generation of a **nerve impulse**

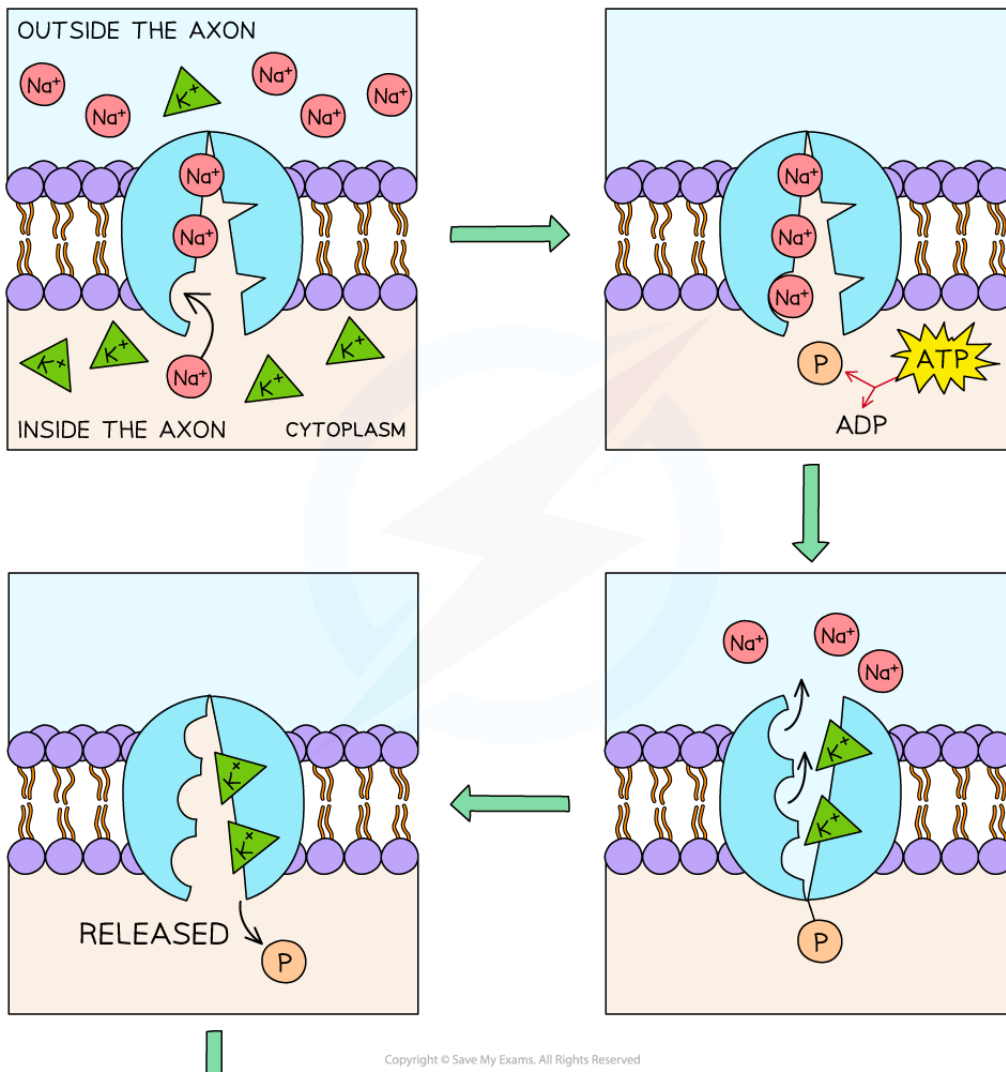
### Sodium-potassium pump diagram



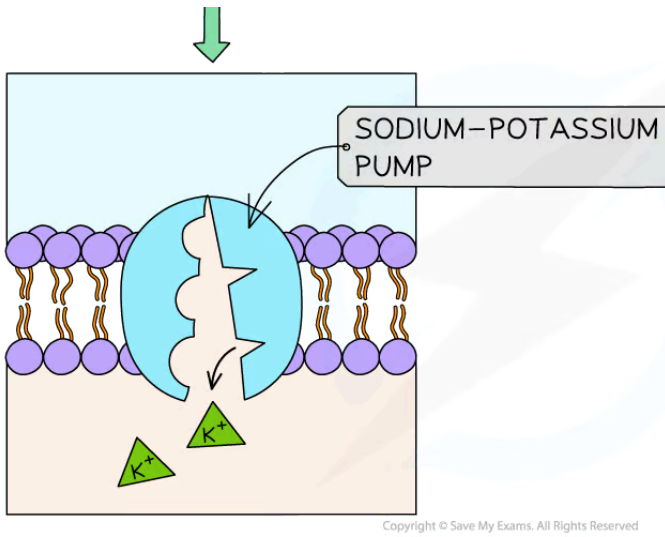
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**Sodium-potassium pumps use ATP to transport sodium and potassium ions across cell membranes**





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## Glucose Cotransporters

### Cotransport & indirect active transport

- Co-transport is the **coupled movement** of substances across a cell membrane via a carrier protein
  - Coupled processes occur at **the same time** and do not occur independently of each other
- Cotransport involves a combination of **facilitated diffusion** and **indirect active transport**
  - Indirect active transport uses the energy released by the movement of one molecule **down** its concentration gradient to move another **against** its concentration gradient
  - ATP is used to set up the initial gradient

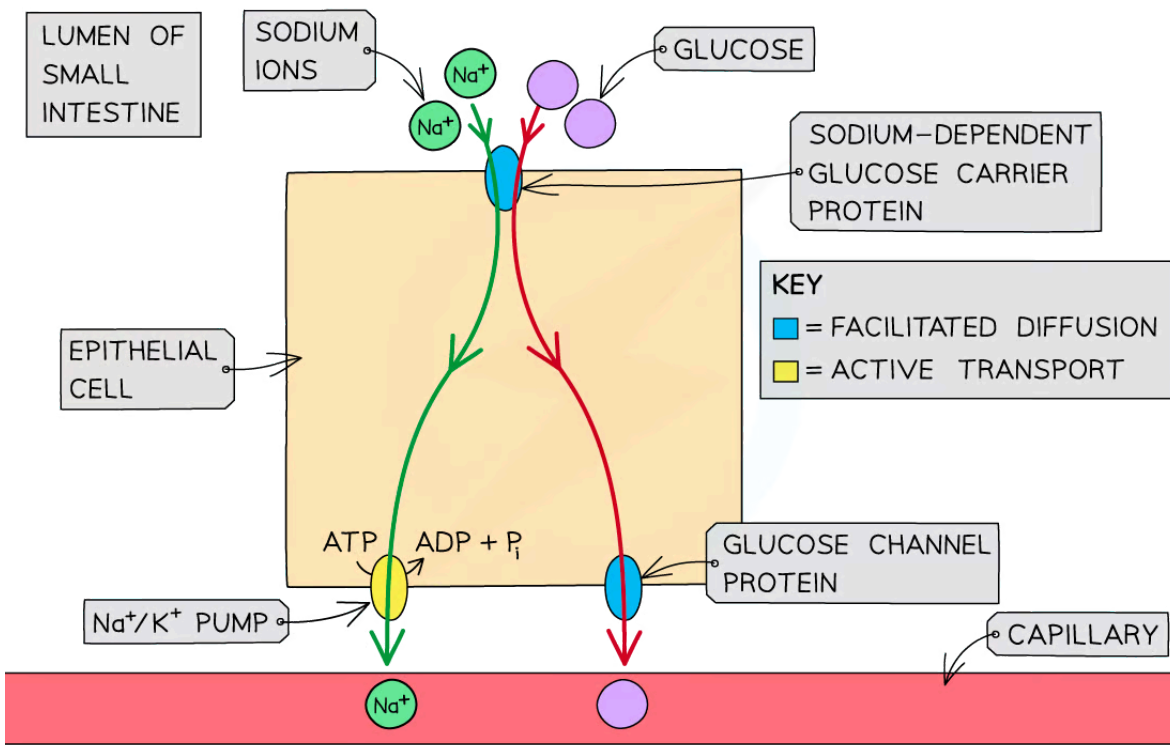
### Sodium-dependent glucose co-transport

- A well-known example of a co-transporter protein can be found on the cell surface membrane of the epithelial cells lining the mammalian ileum
- This specific **sodium-dependent glucose co-transporter protein** is involved in the absorption of **glucose** into the blood
  1. Sodium-potassium pumps actively transport sodium ions into the blood, **reducing the concentration of sodium ions** in the cell
  2. Sodium ions move **down their concentration gradient** into the cell via a **cotransporter protein**
  3. Glucose is **drawn into the cell along with sodium ions** via the same cotransporter protein
    - Glucose moves against its concentration gradient
  4. Glucose then moves down its concentration gradient into the blood
- The active part of the process is the generation of the initial sodium ion gradient; the transport of glucose itself does not require energy; this is why the process is described as indirect active transport

### Co-transport in the small intestine diagram



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**Both facilitated diffusion and active transport occur during co-transport. Glucose molecules can only enter the epithelial cell when sodium ions are present.**

- This process also takes place in the kidney
  - **Reabsorption of glucose** back into the blood is under the control of **sodium-dependent glucose cotransporter proteins**
  - Glucose is **co-transported** with sodium ions in the way described above

**💡 Examiner Tip**

It is worth being aware that the sequence of events in cotransport are sometimes given in a different order; the order above may seem a bit backwards, but it can be helpful to begin with the generation of the sodium gradient, as all the other steps then flow logically



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## Cell Adhesion (HL)

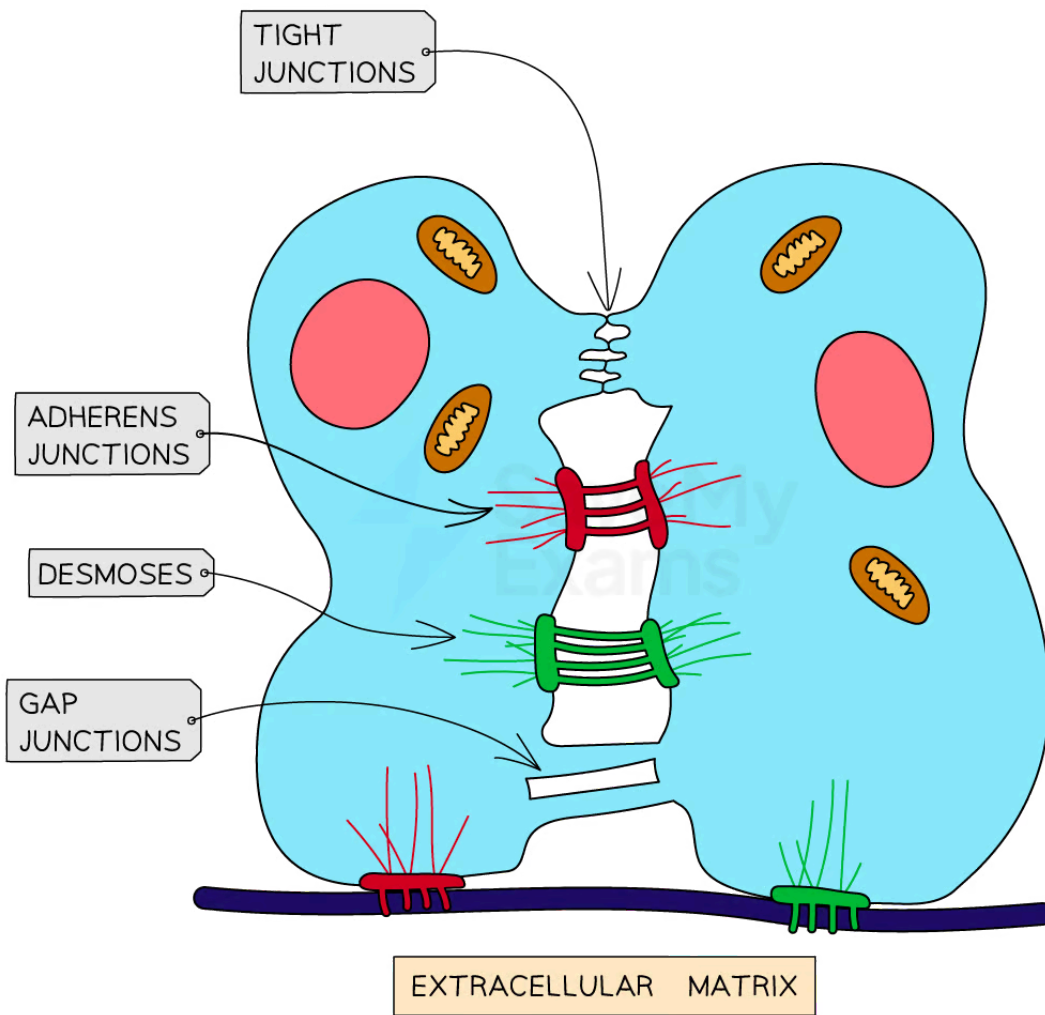
### Cell Adhesion

- In order for an organism to be multicellular, its cells need to **adhere**, or stick, to one another to form **tissues**
- The **plasma membrane** is responsible for cell adhesion and this can be permanent or temporary
- **Cell adhesion molecules (CAMs)** are required to carry out cell adhesion
  - CAMs are a type of **cell surface protein**
  - They work by **binding cells** with **other cells** or with the **extracellular matrix**
    - The extracellular matrix contains supporting structures, such as collagen proteins, and provides support for the cells
  - **Different CAMs** are present in different types of cell-cell junction
- Examples of different cell-cell junctions include:
  - Tight junctions
  - Adherens junctions
  - Desmosomes
  - Gap junctions

#### Cell adhesion diagram



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**Cell adhesion involves the binding of CAMs to other cells or to the extra-cellular matrix**

**Different types of cell-cell junction contain different CAMs**