Edexcel International AS Biology

Your notes

Gas Exchange, Cell Membranes & Transport

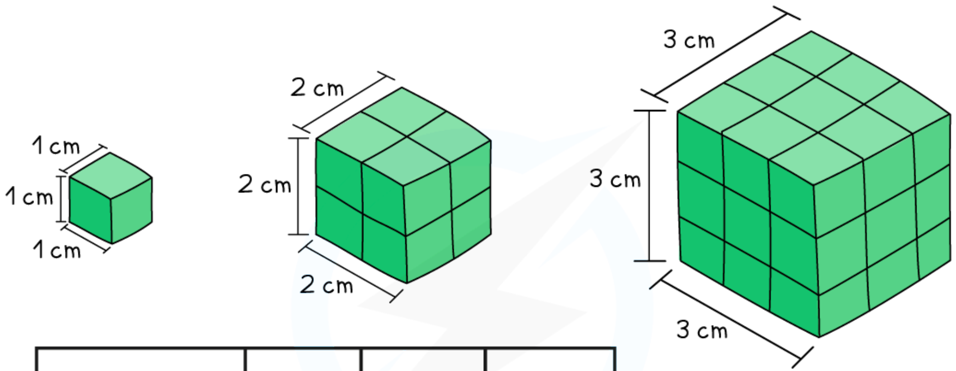
Contents

Properties of Gas Exchange Surfaces

- All organisms need to **exchange gases with their environment,** e.g.
  - Aerobic respiration requires oxygen and produces carbon dioxide as a waste product
  - Photosynthesis requires carbon dioxide and produces oxygen as a waste product
- The process of gas exchange occurs by diffusion
- The surface over which this gas exchange takes place is known as an **exchange surface**; exchange surfaces have specific properties that enable efficient exchange to take place

Surface area to volume ratio

- The surface area of an organism refers to the **total area of the organism that is exposed to the external environment**
- The volume refers to the **total internal volume of the organism,** or total amount of space inside the organism
- The surface area of an organism in relation to its volume is referred to as an organism's **surface area : volume ratio (SA:V ratio)**
- As the overall **size of the organism increases**, the surface area becomes smaller in comparison to the organism's volume, and the organism's **surface area : volume ratio decreases**
  - This is because **volume increases much more rapidly than surface area as size increases**



Surface area	$6\ cm^2$	$24\ cm^2$	$54\ cm^2$
Volume	$1\ cm^3$	$8\ cm^3$	$27\ cm^3$
Surface area: volume	6:1	3:1	2:1

- **Single-celled organisms** have a **high SA:V ratio** which allows the exchange of substances to occur by simple diffusion
  - The large surface area allows for maximum absorption of **nutrients** and **gases** and removal of **waste products**
  - The small volume within the cell means the diffusion distance to all organelles is short
- As organisms **increase in size** their **SA:V ratio decreases**
  - There is **less surface area** for the absorption of nutrients and gases and removal of waste products **in relation to the volume**, and therefore requirements, of the organism
  - The greater volume results in a longer diffusion distance to the cells and tissues of the organism
- **Large multicellular organisms** have evolved adaptations to facilitate the exchange of substances with their environment
  - The gas exchange systems of multicellular organisms are adapted to increase the surface area available for the exchange of gases e.g.
    - Alveoli increase the surface area of mammalian lungs
    - Fish gills have structures called **lamellae** which provide a very large surface area
    - Leaves have a **spongy mesophyll layer** within which a large area of leaf cell surface is exposed to the air
- Note that the problem of internal diffusion distance is a separate, though connected, issue solved by the presence of a mass transport system such as a circulatory system

Diffusion pathway

- The **diffusion pathway**, or **distance**, across an exchange surface is **very short**
- The surface often contains only **one layer** of epithelial cells
  - The cells can also be flattened in shape to further reduce the distance across them
- This means that substances have a very **short diffusion pathway**

Concentration gradient

- This is the **difference in concentration** of the exchange substances on either side of the exchange surface, e.g. between the air inside the alveoli and the blood
- A greater difference in concentration means a **greater rate of diffusion** as the gas molecules move across the exchange surface
- The continued movement of exchange substances away from the exchange surface mean that a **concentration gradient is maintained**
  - This is achieved by e.g.

Your notes

- The alveoli have a **good blood supply**; this constantly removes oxygen from the capillary side of the exchange surface and supplies carbon dioxide
- The ventilation system in mammals ensures constant **inhalation and exhalation**; this supplies oxygen and removes carbon dioxide from the alveoli side of the exchange surface

Your notes

Examiner Tips and Tricks

Be careful when discussing surface area; the phrases 'surface area' and 'surface area : volume ratio' cannot be used interchangeably. Larger organisms have a larger surface area than smaller ones (an elephant clearly has a larger surface area than a bacterial cell), but it is the surface area : volume ratio that gets smaller as body size increases.

Fick's Law of Diffusion

- Fick's Law relates the rate of diffusion to the concentration gradient, the diffusion distance and the surface area
- This relationship can be represented by the following equation, where $\propto$ means "proportional to"

rate of diffusion $\propto$ (surface area x concentration difference) $\div$ thickness of membrane

- **Proportionality** means the rate of diffusion will double if
  - The surface area or concentration difference **doubles**
  - The diffusion pathway **halves**
- Fick's Law can be written as an equation which can be used to calculate the rate of diffusion

$$\text{Rate} = P \times A \times ((C_1 - C_2) \div T)$$

- Where
  - P = A **p**ermeability constant that is a quantitative measure of the rate at which a particular molecule can cross a particular membrane
  - A = surface **a**rea
  - $C_1 - C_2$ = the difference in **c**oncentration between two areas
  - T = **t**hickness of the exchange surface

Worked Example

A sample of alveolar epithelium tissue from a mammal is 1.5 μm thick and has a surface area of 3 μm^2. The concentration of oxygen in the alveolus is 1.8×10^{-16} mol μm^{-3} and the concentration of oxygen in the blood is 7.5×10^{-17} mol μm^{-3}. The permeability constant for oxygen across alveolar epithelium is 0.012 molecule s^{-1}.

Calculate the rate of diffusion across the section of alveolar epithelium.

Answer:

Step 1: Substitute numbers into the equation

$$\text{Rate} = P \times A \times ((C_1 - C_2) \div T)$$

$$\text{Rate} = 0.012 \times 3 \times ((1.8 \times 10^{-16} - 7.5 \times 10^{-17}) \div 1.5)$$

Step 2: Complete the calculation

$$\text{Rate} = 0.012 \times 3 \times (1.05 \times 10^{-16} \div 1.5)$$

$$\text{Rate} = 0.012 \times 3 \times 7 \times 10^{-17}$$

$$\text{Rate} = 2.52 \times 10^{-18} \text{ molecules } \mu m^{-2}\, s^{-1}$$

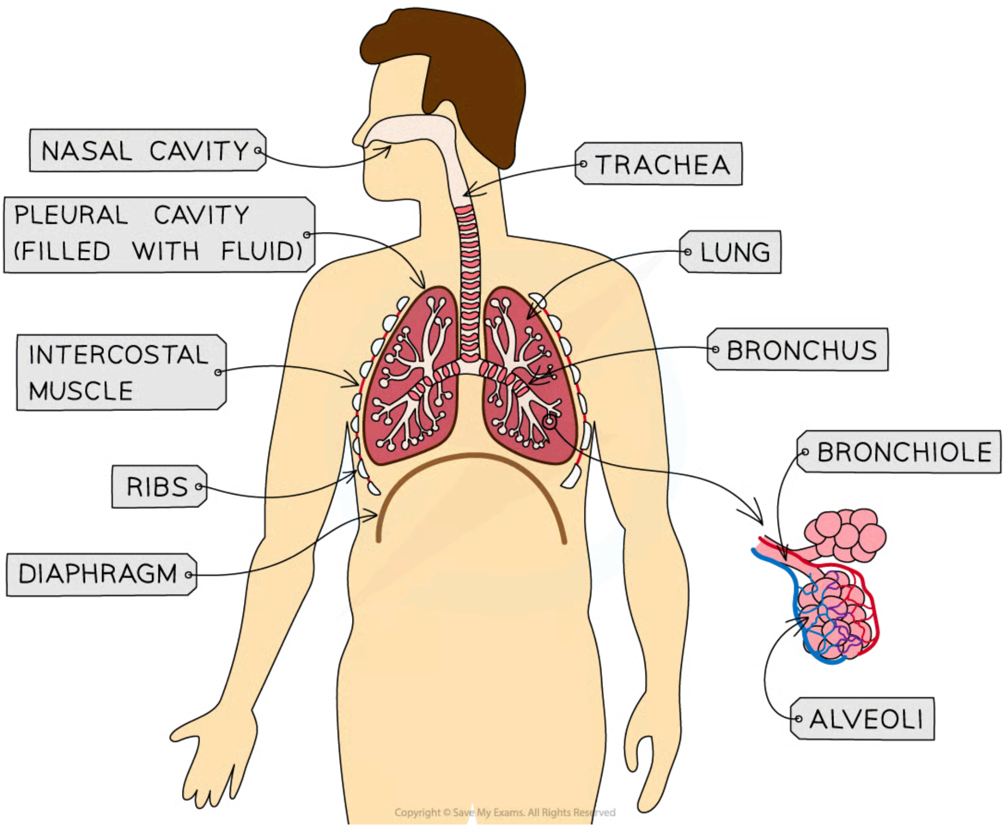
Examiner Tips and Tricks

You will be given the equation for Fick's Law in your exam, but it is important you understand what it means and how to interpret it.

The Lung & Gas Exchange

- The **lungs** of air-breathing animals provide an ideal exchange surface for the diffusion of gases
  - The lungs are located in the **thorax**, or chest cavity
  - Some animals rely entirely on their lungs for gas exchange, while amphibians use lungs alongside gas exchange across the skin
- The role of lungs is to **maximise gas exchange** while **minimising the loss of water** across the exchange surface
- Mammals have very **efficient** gas exchange structures in their lungs

Your notes

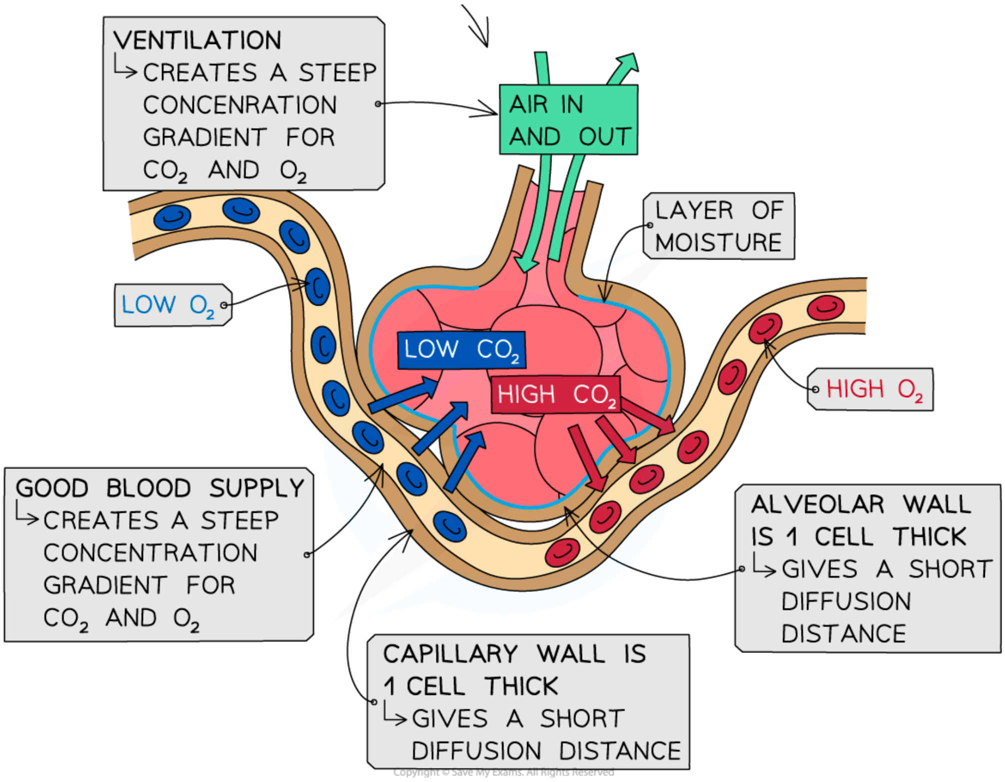


The lungs are located in the thorax, and enable efficient gas exchange

- **Trachea**
  - The trachea is the **tube** that allows air to travel to the lungs
  - It contains c-shaped rings of **cartilage** that ensure that the tube **remains open** at all times and does not collapse
    - The c-shape prevents any friction from rubbing with the oesophagus located close behind, as well as providing increased flexibility when food is being swallowed
  - There is a layer of **mucus** covering the lining of the trachea that helps to **trap dust and pathogens**, preventing them from entering the lungs where they could cause infection
    - Tiny hairs called **cilia** are also found on the lining of the airways, where they **waft mucus** towards the top of the trachea, removing any trapped particles and pathogens from the airways
- **Bronchi**
  - Bronchi (singular bronchus) have a similar structure to the trachea but they have **thinner walls** and a **smaller diameter**
  - Cartilage provides support for the bronchi in the form of rings and plates
- **Bronchioles**

Your notes

    - Bronchioles are narrow, self-supporting tubes with thin walls
    - There is a **large number of bronchioles** present in the gas exchange system
    - Each one varies in size, getting smaller as they get closer to the alveoli
    - The larger bronchioles possess **elastic fibres and smooth muscle** that enable adjustment of the size of the airway to increase or decrease airflow
        - The smallest bronchioles do not have any smooth muscle but they do have elastic fibres
- **Alveoli**
    - Groups of alveoli are located at the ends of the bronchioles
    - The **alveolar wall** consists of a **single layer of flattened**, or **squamous**, **epithelium**
        - The squamous epithelium forms the alveolar wall and is very **thin and permeable** for the **easy diffusion** of gases
        - The alveoli are surrounded by **elastic fibres**, allowing them to **stretch during inhalation**
    - Alveoli are surrounded by an extensive capillary network
        - **Carbon dioxide diffuses out of the capillaries and into the alveoli** to be exhaled, while **oxygen diffuses from the alveoli and into the capillaries** to be carried around the body
    - A layer of moisture lines the alveoli, facilitating the diffusion of gases
        - Oxygen and carbon dioxide are able to **dissolve** in the layer of moisture, so exchange occurs **in solution** rather than with the air inside the alveoli



Human alveoli are adapted for efficient gas exchange

Examiner Tips and Tricks

When describing the features of the alveoli, be careful to refer to the alveolar epithelium as the 'wall of the alveoli' or the 'alveolar wall', and not as a 'cell wall'; cell walls are only found in plants!

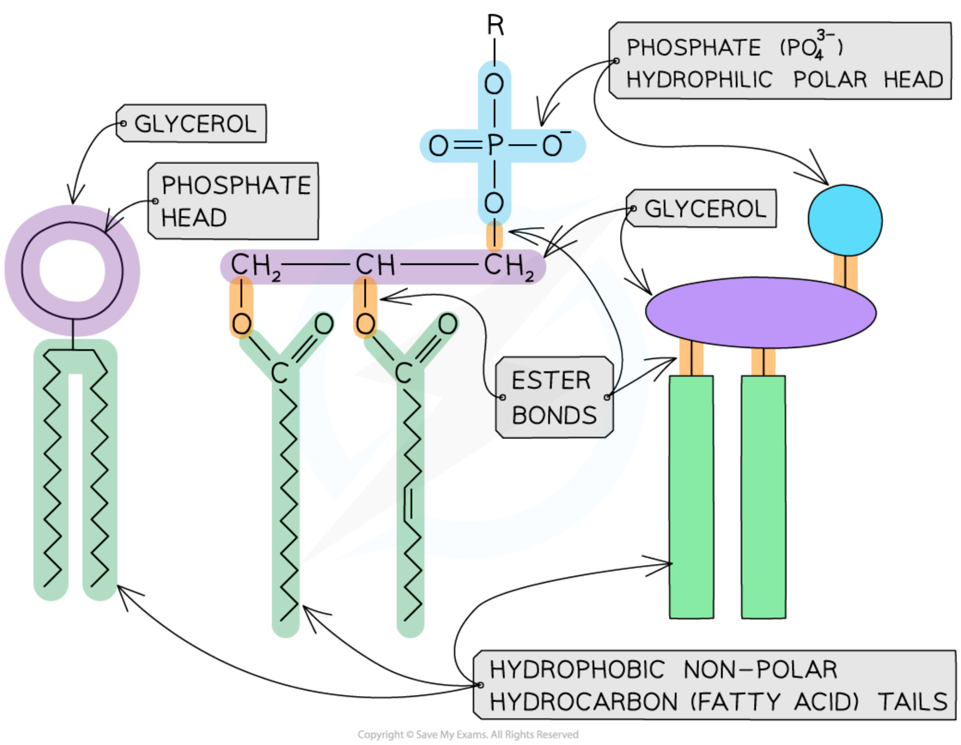
Your notes

Phospholipid Membrane Structure

- **Membranes** are vital structures found in all cells
- The **cell surface membrane** creates an enclosed space separating the internal cell environment from the external environment, and **intracellular membranes** form compartments within the cell such as the **nucleus**, **mitochondria,** and **endoplasmic reticulum**
- Membranes do not only separate different areas but also control the **exchange of substances** from one side of a membrane to the other, as well as acting as an **interface for communication**
  - Membranes are partially permeable
    - Substances can cross membranes by diffusion and active transport
  - Membranes contain receptor proteins, e.g. for binding to hormones, and antigens

Phospholipids

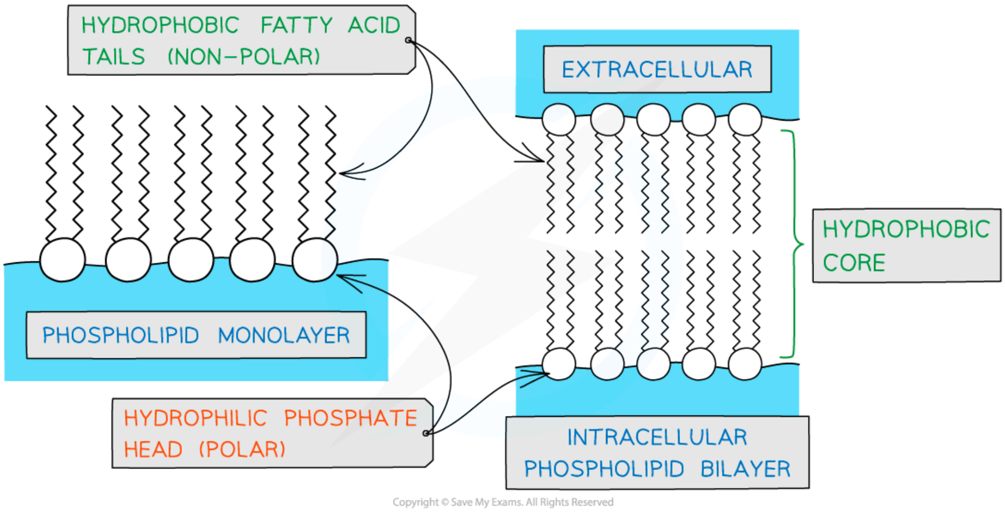
- Cellular membranes are formed from a double layer, or **bilayer**, of **phospholipids**
- Phospholipids consist of
  - A molecule of **glycerol**
  - A **phosphate group**, which forms the **phosphate head**
  - **Two fatty acid tails**, making up the **lipid tail**
- Phospholipids contain two distinct regions: a polar head and two non-polar tails
  - The **phosphate head** of a phospholipid is **polar,** meaning that it can interact with polar water molecules; the head is therefore described as being **hydrophilic**
    - Hydro = water
    - Philic = loving
  - The lipid tail is **non-polar,** meaning that it cannot interact with polar molecules; the tail is therefore described as hydrophobic
    - Hydro = water
    - Phobic = hating



Phospholipids can be visually represented in different ways. In the image above the left-hand diagram shows a simple representation of the phosphate head and lipid tails, while the central diagram shows the chemical structure of each region; the separate glycerol and phosphate group can be seen, as well as the ester bonds that join the components together. The right-hand diagram shows a diagrammatic representation of the chemical structure

- If phospholipids are spread over the surface of water, they form a single layer with the **hydrophilic phosphate heads in the water** and the **hydrophobic fatty acid tails sticking up** away from the water
  - This is called a **phospholipid monolayer**
- Alternatively, two-layered structures may form in sheets; these are called **phospholipid bilayers**
  - Phospholipid bilayers form the basic structure of the cell membrane

Your notes



Phospholipids can form monolayers and bilayers

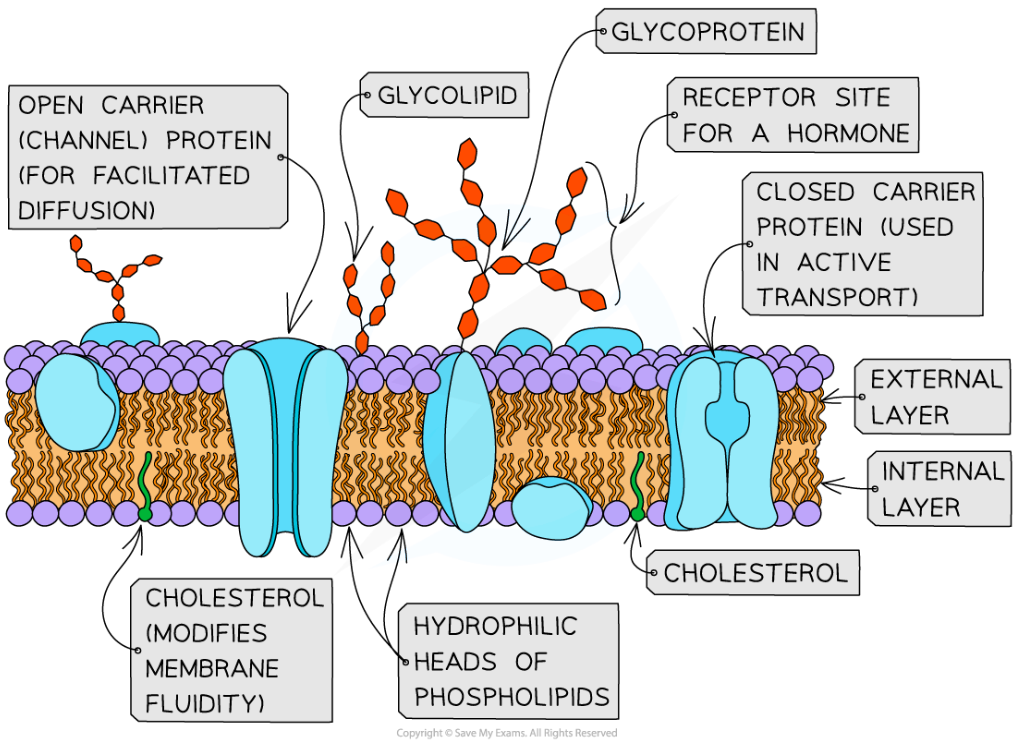
Structure of membranes

- The phospholipid bilayers that make up cell membranes also contain **non-lipid components**
  - **Proteins** are involved with **cell transport** and **communication**
    - The proteins can either be **intrinsic** or **extrinsic**
      - Intrinsic proteins can also be referred to as integral
      - Extrinsic proteins can also be referred to as peripheral
    - Intrinsic proteins are **embedded** in the membrane with their precise arrangement determined by their hydrophilic and hydrophobic regions
    - Extrinsic proteins are found on the **outer or inner surface** of the membrane
  - **Cholesterol** can be found between the phospholipids, where it **regulates membrane fluidity**
    - Cholesterol **increases the fluidity of the membrane at low temperatures,** stopping it from becoming too rigid
      - This occurs because cholesterol **stops the phospholipid tails packing too closely together**
    - Interaction between cholesterol and phospholipid tails also **stabilises the cell membrane at higher temperatures** by stopping the membrane from becoming too fluid
      - Cholesterol molecules bind to the hydrophobic tails of phospholipids, stabilising them and causing phospholipids to pack more closely together
    - Cholesterol **increases the mechanical strength and stability of membranes;** without it membranes would break down and cells would burst

- **Glycolipids** and **glycoproteins** are present on the surface of the cell, where they aid **cell-to-cell communication**
  - Glycoproteins are **proteins with carbohydrate** attached, while glycolipids are **lipids with carbohydrate** attached
  - The glycolipids and glycoproteins **bind with substances at the cell's surface**, e.g. hormones
  - Some glycolipids and 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

Your notes

- The phospholipid bilayer with its additional components is often described as a **'fluid mosaic'**
  - The scattered pattern produced by the components within the phospholipid bilayer looks somewhat like a **mosaic** when viewed from above
  - The mosaic of phospholipids and proteins can **move around within the bilayer by diffusion**, hence the mosaic is said to be 'fluid'
    - The phospholipids mainly move sideways, within their own layer
    - The many different types of proteins interspersed throughout the bilayer move about within it, although some may be fixed in position
  - Note that the **fluid mosaic model** is one **model** of membrane structure; other models have been considered and rejected as knowledge of membrane structure has advanced
- The membrane is **partially permeable**
  - **Small, non-polar molecules** can pass through the gaps between the phospholipids
  - **Large, polar molecules** must pass through specialised membrane proteins called **channel proteins** and **carrier proteins**



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

Examiner Tips and Tricks

In an exam it is good practice to always refer to the cell membrane that surrounds the cell as either the **cell surface membrane** or the **plasma membrane**; this distinguishes it from all of a cell's internal membranes

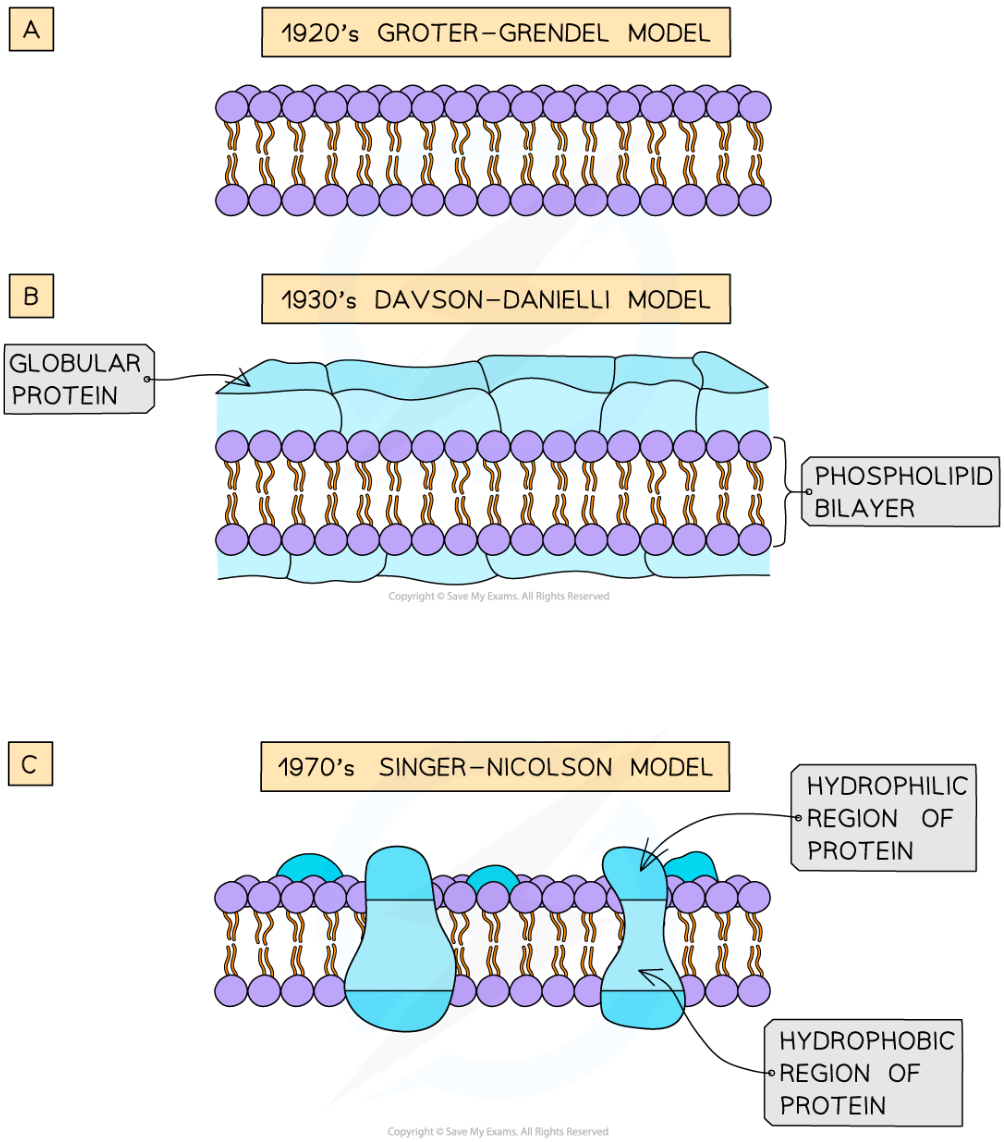
The Fluid Mosaic Model

- Scientists use **models** to represent real world ideas, organisms, processes, and systems that cannot be easily investigated
- Over time, as **technological developments** have been made, the models used to **represent the structure of cell membranes** have changed
- The **fluid mosaic model** of cell membrane structure was first proposed in 1972 by **Singer and Nicolson**
- The model has **evolved over time,** and is thought to best account for the structure and functions of cell membranes as scientists **currently** understand them
  - **Models can change** on the basis of new discoveries; if scientists found a new feature of cell membranes that didn't fit with the fluid mosaic model, the model would be **altered**, or a **new model** introduced

Your notes

Your notes

- Evolving cell membrane models have included the following
  - The **Gorter and Grendel** model of the 1920s showed that the **phospholipids** in the membrane of cells were arranged into a **bilayer**
    - **Evidence** for this model
      - The number of phospholipids extracted from red blood cell membranes was double the area of the plasma membrane if it was arranged as a monolayer
    - **Problems** with this model
      - Their model did not explain the location of proteins or how molecules that were insoluble in lipids moved into and out of the cell
  - **Davson and Danielli's** model of the membrane from the 1930s suggested that the **proteins** were arranged in **layers above** and **below** the **phospholipid bilayer**
    - **Evidence** for this model
      - Membranes were effective at controlling the movement of substances in and out of cells
      - Electron micrographs showed the membrane had two dark lines with a lighter band between
        - In electron micrographs, proteins appear darker than phospholipids
    - **Problems** with this model
      - Freeze etched electron micrographs of the centre of the membrane showed globular structures **scattered throughout**
      - Improvements in technology used to analyse the proteins in the membranes showed that **proteins** were **globular**, **varied in size** and had parts that were **hydrophobic**
  - **Singer and Nicolson** proposed the **fluid mosaic model** in the 1970s; the model stated that membranes were **fluid** and that the globular **proteins** were both peripheral and **integral**
    - **Evidence** for this model
      - Analysis of **freeze-etched electron micrographs** showed proteins **extending** into the **centre of membranes**
      - **Biochemical analysis** of the plasma membrane components showed that membrane proteins are **free to move** within the bilayer



Models of cell membrane structure have evolved over time

Examiner Tips and Tricks

You do not need to recall the names of the scientists or dates for different models of membrane structure, but it is important to understand that **models** of membrane structure are **interpretations of data** which can change when scientific advances enable **new discoveries**.

Remember that models **represent** real-life structures and processes.

Investigating Membrane Structure & Permeability

- The **permeability** of **cell membranes** is affected by several **factors** such as
  - **Temperature**
  - **pH**
- The effect of such factors on membrane structure and permeability can be investigated using **beetroot**
  - Beetroot cells contain a **dark purple-red pigment**
  - The **higher** the permeability of the beetroot cell membrane, the **more** of this pigment leaks **out of the cell**
- The amount of pigment in a sample can be measured using a piece of equipment known as a **colorimeter**
  - A colorimeter is a machine that passes light through a **coloured liquid sample** and measures how much of that light is absorbed by or transmitted through the sample
    - This gives an indication of how much of the colour is present in the solution, e.g. more absorbance or less transmission both indicate a darker coloured solution
  - A colour filter is used in the light path to ensure that the correct wavelength of light is used to measure the optical density of the specific pigment in the solution, e.g. the beetroot pigment called betalain
  - The colorimeter must be **zeroed** before each colorimeter is used; this can be done using **distilled water** in a small container called a cuvette
    - This process is known as **calibrating** the colorimeter

Investigating the effect of temperature on membrane permeability

Apparatus

- Scalpel
- Cork borer
- Cutting board
- Ruler
- Digital balance
- Test tubes

- Measuring cylinder
- Water baths
- Digital stopwatch
- Pipettes
- Colorimeter and cuvettes

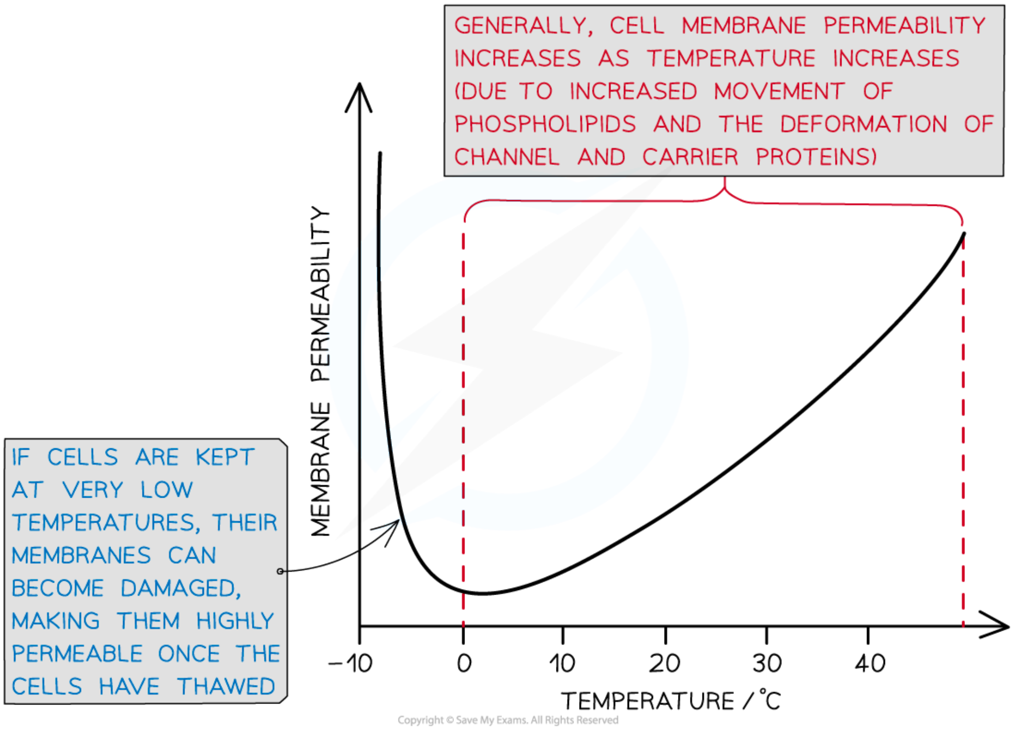
Method

1. Using a cork borer and scalpel, cut five equal-sized sections of beetroot
    - The pieces must have the same dimensions so that they all have **equal surface areas and volumes**, as these factors could affect the rate at which the pigment leaks out
    - A cork borer enables cores of equal diameter to be cut, which can then be cut to the **same length**
2. Rinse the beetroot pieces
    - To **remove** any pigment released during cutting
3. Add the beetroot pieces to five different test tubes, each containing the same volume of water, e.g. 5 cm^3
4. Put each test tube in a water bath at a different temperature, e.g. 10 ℃, 20 ℃, 30 ℃, 40 ℃, and 50 ℃, for the same length of time
    - The time should be **long enough to allow the pigment to diffuse into the water,** e.g. around 30 minutes
5. Remove the beetroot pieces, leaving just the coloured liquid in the five test tubes
6. Use pipettes to transfer samples of the coloured liquid to colorimeter cuvettes
    - Cuvettes are **small cuboid containers** that hold the liquid to be measured in a colorimeter
    - A different pipette should be used for each sample to **avoid the transfer of pigment** molecules between samples
7. Use a colorimeter to measure how much light is absorbed as it passes through each of the five samples of coloured liquid
    - The **higher** the **absorbance**, the **more pigment** must have been released due to a **greater** membrane **permeability**

Results

- The general pattern you would expect to see is that **as temperature increases, membrane permeability also increases**
    - As temperature increases, the phospholipids within the cell membrane **move** more because they have more **kinetic energy;** increased movement means the phospholipids are **not** as **tightly packed** together, increasing the permeability of the membrane

- Temperature affects the 3D shape of **proteins;** at high temperatures **membrane proteins** denature, **increasing the permeability of the membrane**
- The volume of water inside the cells **expands**, putting **pressure** on the membrane and damaging membrane components; this can increase membrane permeability
- If experimenting with temperatures below 0 °C, membrane permeability may be increased once the cells have thawed again
  - **Ice crystals** that form can **pierce** the cell membrane, making it highly permeable



Both high and very low temperatures can increase membrane permeability

Limitations

- Cuvettes may differ in **thickness;** a thicker cuvette will absorb slightly **more light** than a thinner cuvette
  - Solution: use the **same cuvette** for every reading, or **repeat** the investigation many times and find a **mean**
  - Note that **scratched** cuvettes can have the same impact on absorbance as thicker cuvettes
- The beetroot pieces may not be identical in size and shape, meaning some test tubes could contain slightly more beetroot tissue than others
  - Solution: cut the discs as **accurately** as possible using a **scalpel and ruler**, and **repeat** each investigation several times to find a mean
- Some **parts** of beetroot tissue have **more pigment** in their cells than others

Your notes

    - Solution: conduct several **repeats**, using **different parts** of the beetroot and find a **mean**

Your notes

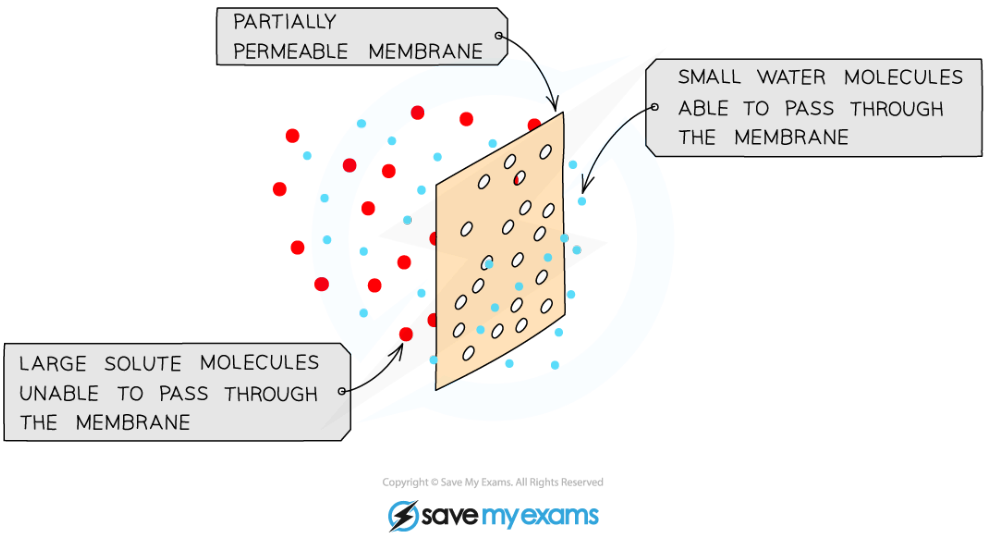
Variations

- The impact of **alcohol** on membrane permeability could also be investigated
- The expected trend is
    - As alcohol concentration i**ncreases** the permeability of the membrane **increases**
    - This is because **alcohol dissolves lipids** in the cell surface membrane so the membrane loses its structure and the beetroot pigment can leak out

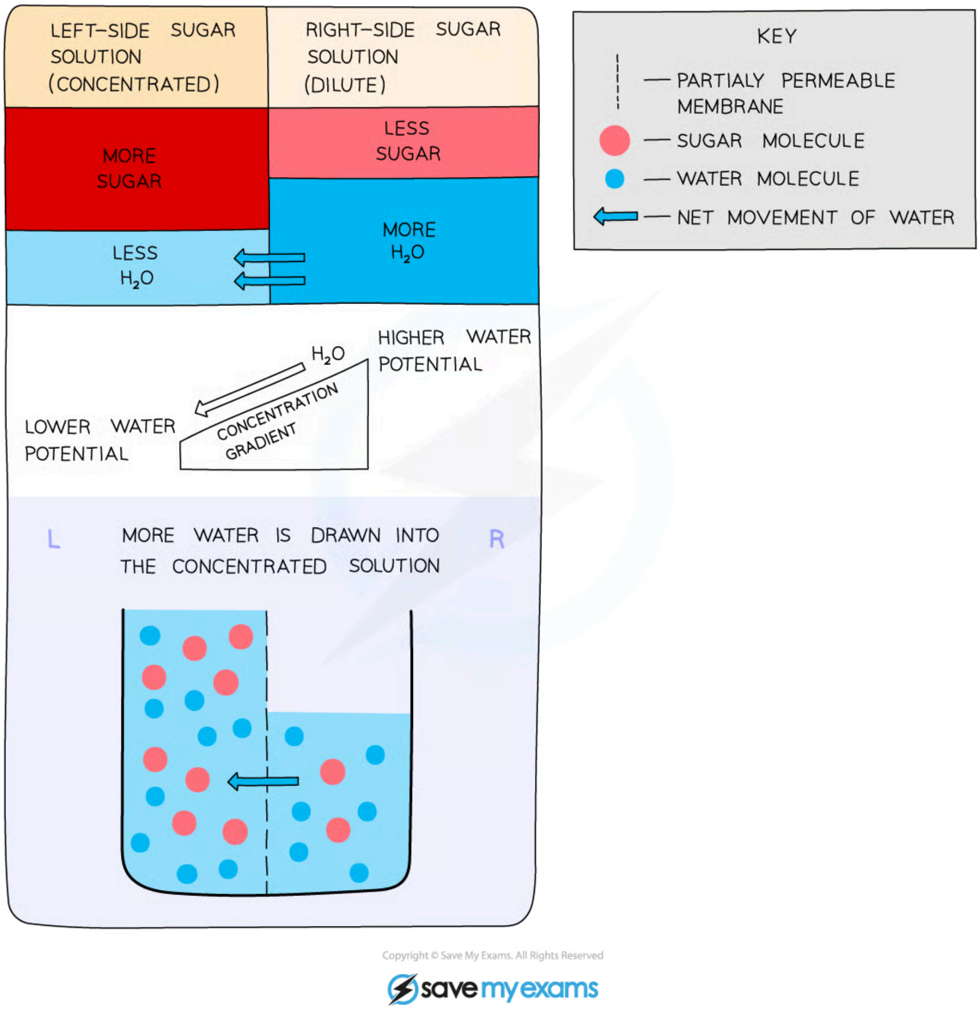
Your notes

Osmosis

- All cells are surrounded by a cell surface membrane which is **partially permeable**
- Water can move in and out of cells across the cell surface membrane by a process called **osmosis**
  - **Osmosis is 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** is a measure of **the number of free water molecules** present in a solution; higher water potential = more free water molecules
  - Water molecules will move from an area of **more free water molecules** to an area of **fewer free water molecules**
    - Water molecules are considered 'free' when they are **not surrounding substances in a solution**; when a substance dissolves it becomes surrounded by water molecules; such water molecules are **no longer free** and **cannot move through a membrane** readily
- During osmosis water is **moving down its concentration gradient**, so it is a specialised form of diffusion
- Cell membranes are partially permeable, allowing small molecules like water through but not larger molecules such as solutes
  - Although water molecules are polar, they can still pass through the bilayer because of their small size.



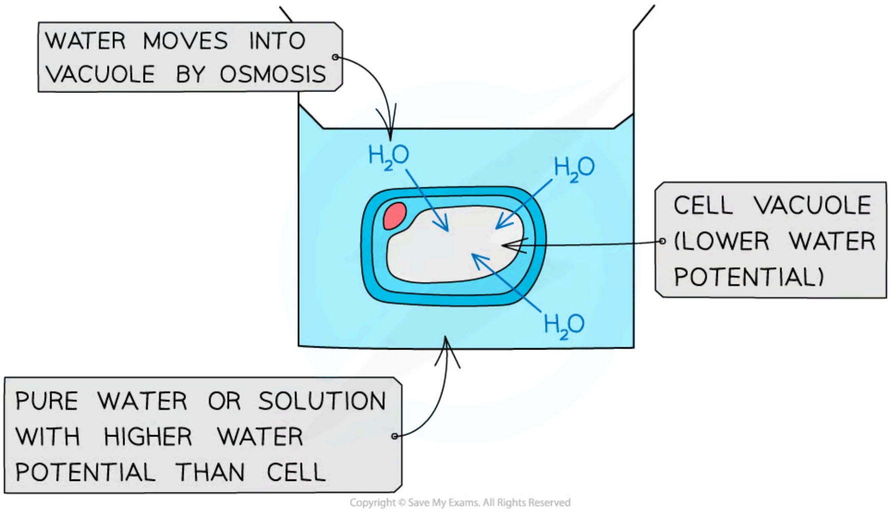
Osmosis is the movement of water molecules from an area of high water potential to an area of low water potential through a partially permeable membrane



Osmosis is the movement of water molecules down their concentration gradient. Note that 'water potential' is a term used to describe the number of free water molecules present

- Osmosis is important because it constantly affects the **cells** of living organisms
  - Cell cytoplasm consists of **water and dissolved substances**, meaning that it has a **water potential** of its own
  - Cells **lose or take on water** depending on the water potential of their surroundings in comparison to their cytoplasm
- When cells are placed in pure water, which has the highest possible water potential, water **moves into the cells by osmosis** and the cells **swell**
  - In animal cells this could lead to cell **bursting**
  - In plant cells the **cell wall prevents bursting**

- When cells are placed into a solution that has a lower water potential than their cytoplasm, e.g. a concentrated glucose solution, water moves **out of the cells by osmosis** and the cells **shrink**
    - In animal cells the entire cell **shrivels**
    - In plant cells the vacuole and cytoplasm shrink but the **cell wall maintains the overall shape of the cell**



When cells are placed into solution they are affected by osmosis. A cell placed in pure water will take on water as water moves into the cell by osmosis from an area of high water potential to an area of low water potential. In plant cells this causes the cell to swell, but the cell wall prevents the cell from bursting

Osmosis in Plant and Animal Cells Table

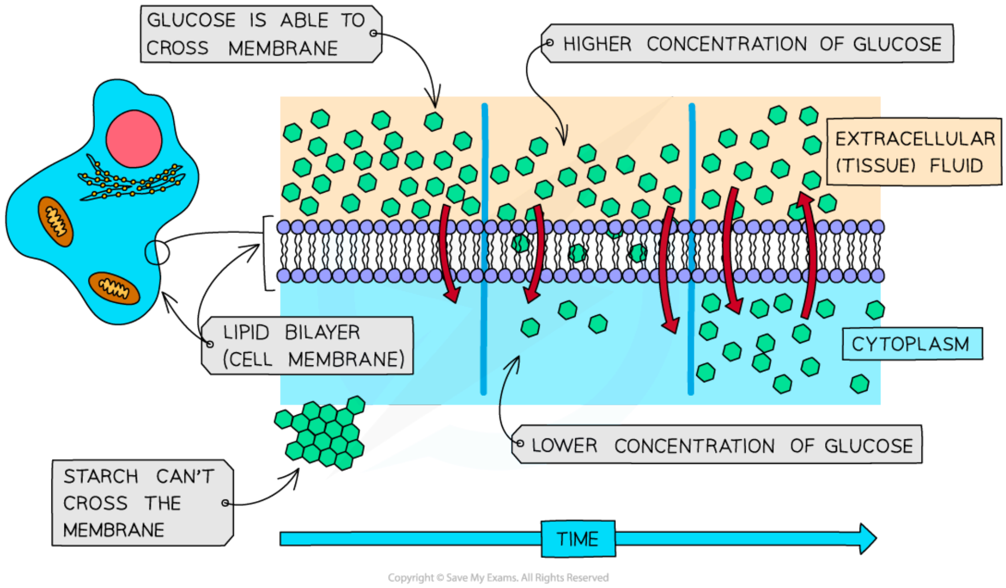
Your notes

Your notes

	Plant cells	Animal cells
Cell membrane	- Present Composed of a phospholipid bilayer - Partially permeable	
Cell wall	- Present Composed of cellulose - Fully permeable	Absent
Osmosis of water into and out of cell	Can occur	
Cell placed in solution with lower water potential	- Water leaves cell through partialy permeable cell surface membrane by osmosis - Volume of cell decreases - Protoplast shrinks / pulls away from cell wall - Cell is plasmolysed	- Water leaves cell through partialy permeable cell surface membrane by osmosis - Volume of cell decreases - Cell shrinks / shrivels up
Cell placed in solution with higher water potential	- Water enters cell through partialy permeable cell surface membrane by omosis - Volume of cell increases - Protoplast expands / pushes against cell wall - Cell wall withstands increased pressure created - Pressure increases until cell is rigid and firm (turgid) - Cell is fully inflated with water and no more can enter	- Water enters cell through partially permeable cell suface membrane by osmosis - Volume of cell increases - No cell wall to withstand increased pressure created - Cell membrane eventually stretched too far and cell bursts

Diffusion & Facilitated Diffusion

- Diffusion is a type of **transport** that can occur **across a cell membrane**
  - Note that diffusion can also happen within a cellular compartment; the presence of a membrane is not essential
- It can be defined as **the net movement of a substance from a region of its higher concentration to a region of its lower concentration**
  - **Net movement** refers to the **overall direction of movement**; in reality molecules in a liquid or gas move in all directions, but most molecules move from a high to a low concentration
    - The molecules of a liquid or a gas move randomly due to the kinetic energy of the molecules or ions
- The molecules or ions move **down a** concentration gradient
- Diffusion is a **passive process** meaning that it does **not require energy** in order to occur
  - Diffusion can be described as **passive transport**
- Diffusion will continue until the concentration of a substance on each side of a membrane has become equal; this is known as **equilibrium**
- Some molecules are able to diffuse directly between the phospholipids of a membrane; this can be described as **simple diffusion**
  - Molecules that can move by simple diffusion tend to be **small** and non-polar
    - Small molecules can fit between the phospholipids
    - Non-polar molecules are able to interact with the non-polar tails of the phospholipids



Diffusion can occur across a cell surface membrane. The image above shows the progression of glucose diffusion; on the left of the diagram there is a steep concentration gradient, and by the end of the process on the right of the diagram the glucose concentration has reached equilibrium

- The **rate** at which a substance diffuses across a membrane depends on **several factors**
  - Concentration gradient
  - Temperature
  - Surface area
  - Properties of substance involved

Factors Affecting Diffusion Table

Your notes

Factor	How the factor affects the rate of diffusion
'Steepness' of concentration gradient	∘ This is the difference in the concentration of the substance on the two sides of the surface ∘ If there are more molecules on one side of a membrane than on the other, at any one moment more molecules will randomly move across the membrane from that side than from the other ∘ A greater difference in concentration means a greater difference in the number of molecules passing in the two directions and therefore a faster rate of diffusion
Temperature	∘ Molecules and ions have more kinetic energy at higher temperatures ∘ They move faster, resulting in a higher rate of diffusion
Surface area	∘ The greater the surface area across which diffusion is taking place, the greater the number of molecules or ions that can cross it at any one moment and therefore the faster diffusion occurs ∘ The surface area of cell membranes can be increased by folding (eg. microvilli in the intestine or cristae in mitochondria) ∘ As a cell increases in size, the surface area to volume ratio decreases which slows the rate substances can diffuse through a cell as the distance required becomes too great
Properties of molecules or ions	∘ Large molecules diffuse more slowly than smaller ones as they require more energy to move ∘ Uncharged and non–polar molecules diffuse directly across the phospholipid bilayer ∘ Non–polar molecules diffuse more quickly than polar ones as they are soluble in the non–polar phospholipid bilayer

Facilitated diffusion

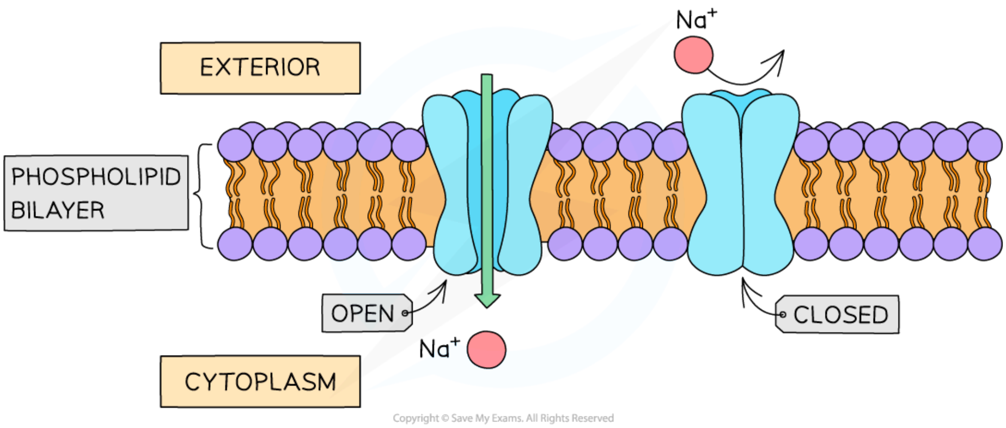
- Some substances cannot diffuse directly through the phospholipid bilayer of cell membranes, e.g.
  - **Large**, polar **molecules** such as glucose and amino acids
  - **Ions** such as sodium ions (Na^+) and chloride ions (Cl^-)
- These substances can only cross the phospholipid bilayer with the help of transport proteins; this form of diffusion is known as **facilitated diffusion**
- There are two types of transport protein that enable facilitated diffusion

Your notes

- **Channel proteins**
- **Carrier proteins**
- They are **highly specific,** meaning that they only allow one type of molecule or ion to pass through

Channel proteins

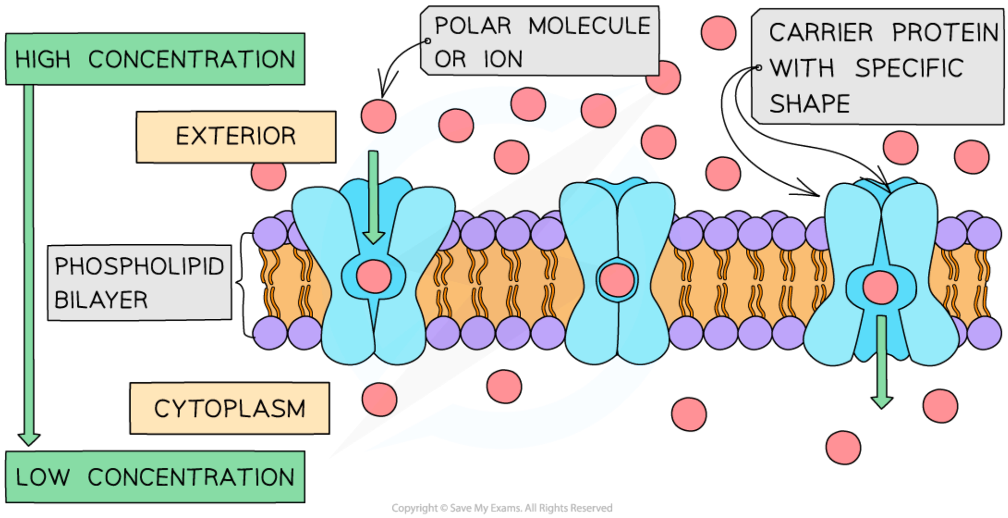
- Channel proteins are **pores** that extend through the membrane **from one side to the other**
- They allow **charged** substances, e.g. ions, to diffuse through the cell membrane
- The diffusion of these ions does not occur freely; most channel proteins are 'gated', meaning that part of the channel 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 proteins are pores in the cell membrane; they can open and close

Carrier proteins

- Unlike channel proteins which have a fixed shape, **carrier proteins can switch between two shapes**
- This causes the binding site of the carrier protein to be open to one side of the membrane first, and then open to the other side of the membrane when the carrier protein switches shape
- The direction of movement of molecules diffusing across the membrane **depends on their relative concentration** on each side of the membrane
    - Net diffusion of molecules or ions into or out of a cell via carrier proteins will occur **down a concentration gradient**



Carrier proteins change shape to transport molecules from one side of a membrane to the other

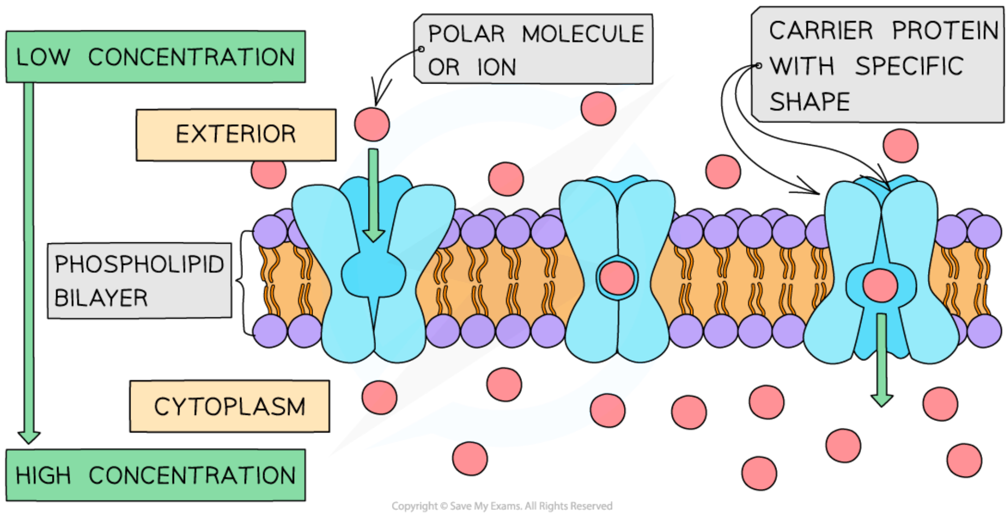
Examiner Tips and Tricks

Remember that the movement of molecules from high concentration to low concentration is **diffusion**. If this movement requires the aid of a protein, for example because the molecule is charged and cannot pass directly through the phospholipid bilayer, this is **facilitated diffusion**.

Active Transport

- Active transport is the **movement of molecules and ions through a cell membrane from a region of lower concentration to a region of higher concentration**
  - Active transport **requires energy** in the form of **ATP** from respiration to move substances **against their concentration gradient**; hence this is an **active** process
- Active transport requires **carrier proteins**
  - Each carrier protein is specific to a particular type of molecule or ion
- Energy is required to allow the carrier protein to **change shape**; this transfers 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

Your notes



Active transport moves substances across a membrane from low to high concentration. Note that ATP is required for carrier proteins to change shape

- Examples of active transport include
  - **Reabsorption** of useful molecules and ions **into the blood** after filtration into the kidney tubules
  - **Absorption** of some products of digestion from the digestive tract **into the blood**
  - **Loading sugar** from the photosynthesising cells of leaves **into the phloem** tissue for transport around the plant
  - **Loading inorganic ions** from the soil **into root hair cells**

Examiner Tips and Tricks

Be careful not to get carrier proteins and channel proteins confused when answering questions on active transport. Active transport requires **carrier proteins** (transmembrane transport proteins that undergo conformational change) **not** channel proteins.

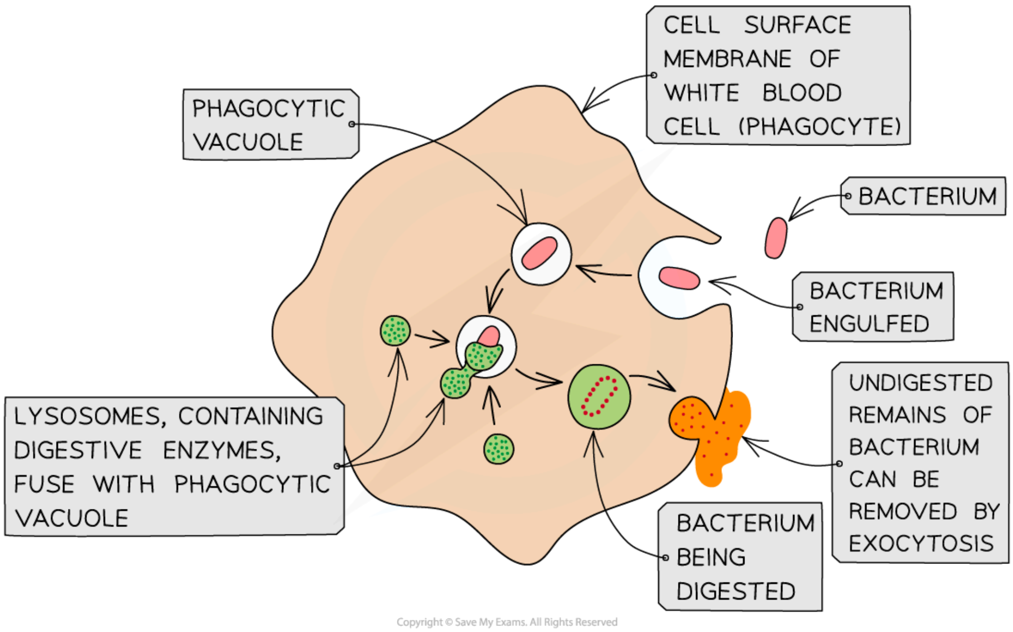
Endocytosis & Exocytosis

Endocytosis

- Some molecules are **too large** to travel via membrane proteins, e.g.
  - Proteins
  - Lipids
  - Some carbohydrates

Your notes

- In such cases a cell can **surround a substance with a section of the cell surface membrane**
  - The membrane **engulfs** the substance and pinches off inside the cell to form a **temporary vacuole** with the ingested substance contained inside
  - This is **endocytosis**
    - Phagocytosis is an example of endocytosis
- Endocytosis is an **active process** and requires a source of energy

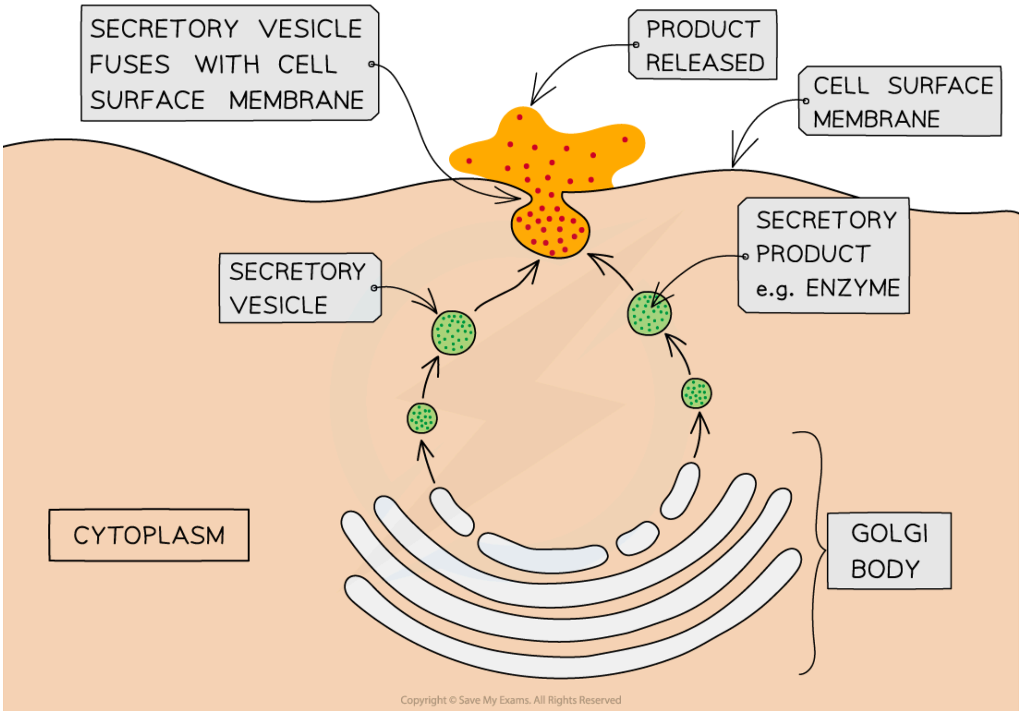


Phagocytosis is an example of endocytosis; the cell surface membrane extends around a pathogen, engulfing it and enclosing it within a temporary vacuole inside the cell

Exocytosis

- Some substances produced by the cell need to be **secreted**, such as hormones, some enzymes, and lipids
- **Vesicles** containing the substance **pinch off from sacs of the Golgi apparatus**
- These vesicles are moved toward the cell surface and fuse with the cell surface membrane to be released outside the cell
  - This is **exocytosis**
- Exocytosis is an **active process** and requires a source of energy

Your notes



Exocytosis allows the bulk secretion of substances from cells