Bio Factsheet

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The Cell Surface Membrane

The cell surface membrane (formerly called the plasma membrane) surrounds the cytoplasm of eukaryotic cells. The membrane forms a selectively permeable barrier, controlling the substances that enter and leave the cell and therefore enables the cell to regulate its internal environment.

Structure

The cell surface membrane is approximately 7.5nm thick and consists of a bilayer of lipids along with a highly variable component of protein. Some of these proteins are embedded in the surface of the membrane whilst others (intrinsic proteins) span the entire width of the membrane. This is known as the **fluid mosaic model** (Fig 1).

Lipids

There are three types of lipid in the cell surface membrane.

1. Phospholipids - which make up 75% of the lipid. Phospholipids are amphipathic molecules - this means that they have a dual nature in that one end of the phospholipids (the phosphate group) is hydrophilic (water-loving and polar) whilst the other end of the phospholipid (the fatty acid chains) is hydrophobic and non-polar. The phospholipid bilayer forms spontaneously with the non-polar fatty acid chains facing inwards towards each other and the polar phosphate groups facing outwards into the extra-cellular fluid and the inside of the cell (both of which are water-based environments).

   The interaction between the hydrophobic and hydrophilic ends helps give the membrane stability and it is also these lipids which give the membrane selective permeability. Lipid soluble (hydrophobic) molecules easily pass through the membrane by diffusion whilst hydrophilic substances cannot diffuse through; instead they cross the membrane via water-filled pores or channels in intrinsic proteins.

2. Glycolipids - which make up 5% of membrane lipids. Glycolipids occur on the external surface of the cell surface membrane and the carbohydrate portion of the glycolipid extends into the intercellular space and is called a **glycocalyx**. These are important in cell-to-cell recognition.

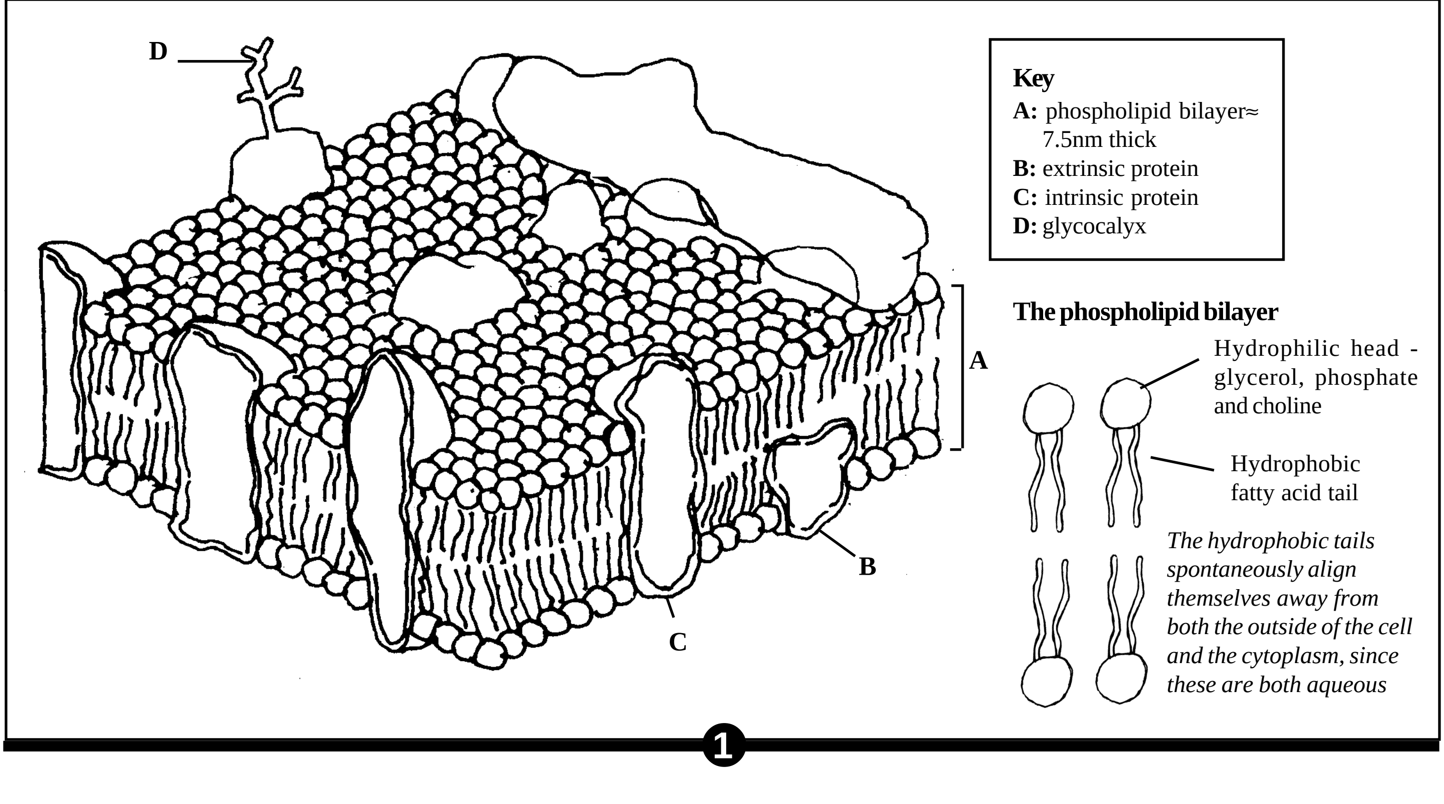
3. Cholesterol - a steroid which makes up 20% of lipids in animal membranes but is rarely found in plant cell membranes.

All lipids can move sideways (laterally) within the membrane and exchange position with each other. This gives the membrane **fluidity** which is essential in processes such as phagocytosis. The degree of fluidity of cell surface membranes is determined by:

1. The length of the fatty acid side chains (the longer the chains, the lower the fluidity).
2. The proportion of the fatty acids which are saturated (the higher the percentage of saturated fats, the lower the fluidity).
3. The steroid content (the higher the steroid content, the lower the fluidity).

> ***Exam Hint*** *- Although most candidates can recall the name of the model (fluid mosaic) a surprising number of candidates are unable to sketch the arrangement of phospholipids in the model. Similarly many candidates appear confused about which part of the phospholipid molecule is polar.*

Fig 1. The fluid mosaic model of the cell surface membrane



Proteins

Intrinsic proteins - those which span the entire membrane - are usually glycoproteins. They have four main functions:

1. To act as channels. By maintaining very different concentrations of ions on either side of the membrane, the cell surface membrane maintains an electrochemical gradient between the inside and outside of the cell which is essential for the efficient functioning of, for example, the sodium/potassium pump.
2. Transporters. For example, some proteins are able to identify and attach to specific substances such as nutrients, neurotransmitters or hormones.
3. Receptors. Some proteins recognise and bind to target molecules such as hormones. For example, the surface membrane of cells in the collecting duct of the kidney recognise and respond to ADH.
4. Enzymes. For example, ATPase.

As in lipids, intrinsic proteins have a hydrophobic and hydrophilic region and the interaction between these regions confers stability on the membrane. Extrinsic proteins are embedded in, but do not span, the membrane and many have a carbohydrate portion (glycocalyx) which extends into the intercellular space.

Transport across the cell surface membrane

Substances may move across the membrane by:

1. Diffusion
2. Osmosis
3. Facilitated diffusion
4. Active transport

1. Diffusion. This is the movement of molecules or ions from a region where they are at a high concentration to a region where they are at a lower concentration until the concentrations of the two regions are equal and a dynamic equilibrium is established.

The rate of diffusion is proportional to the concentration gradient but is also influenced by the size of the ions and the distance over which the diffusion must occur. Substances which can diffuse across the cell surface membrane include oxygen, carbon dioxide, steroids, the fat-soluble vitamins (A,D,E,K), glycerol, alcohols and ammonia.

2. Osmosis. This is a specialised form of diffusion and may be defined as the diffusion of water molecules from a region where they are at a high concentration to a region where they are at a low concentration through a partially permeable membrane. The cell effectively controls the amount of water which enters across the plasma membrane by regulating the concentration of ions in the cytoplasm via the sodium/potassium pump.

3. Facilitated diffusion. This is considerably faster than normal diffusion and is used to transport molecules such as glucose, fructose, non fat-soluble vitamins, urea and many ions across the membrane.

Typical exam question

Commonly, exam questions concentrate on two key principles of facilitated diffusion:
(a) That it occurs down the concentration gradient, not against it.
(b) That no ATP is required.

Occasionally, application questions are set which test, for example, a candidate's ability to infer that the mechanism by which insulin homeostatically regulates blood concentration of glucose is by altering the rate of facilitated diffusion into cells.

Using the transport of glucose as an example, there are four key steps in facilitated diffusion:

(i) The outside of the cell surface membrane contains transport protein molecules which bind with glucose. Different cells have different types of glucose transporter.

(ii) The protein changes shape.

(iii) The glucose is transported through the membrane to the other side.

(iv) The glucose detaches from the transporter protein and the protein reverts to its original shape. The glucose is then immediately phosphorylated. This keeps the concentration of free glucose inside the cell very low, so maintaining the diffusion gradient.

The rate of facilitated diffusion is proportional to the concentration gradient and to the number of channels or transporter proteins that are available. The key point to remember is that facilitated diffusion occurs along and not against the normal diffusion gradient.

4. Active Transport. Ions such as sodium (Na^+), potassium (K^+), chloride (Cl^-), hydrogen (H^+) and molecules such as amino acids and glucose may be transported across the cell surface membrane actively - i.e. ATP is required and the movement is against the concentration gradient. Note that all of these substances can cross the membrane by facilitated diffusion if the concentration gradient is the right way round and if transporter channels are available.

Active transport commonly involves a protein which acts as a Na^+/K^+ pump. Most cells have hundreds of these pumps per square micron.

The Na^+/K^+ pump

(i) On the inside of the cell sodium ions bind to the membrane

(ii) This triggers the breakdown of ATP into ADP and the energy which is released is used to phosphorylate the protein which forms the pump.

(iii) The protein changes shape and sodium is transported to the outside of the cell.

(iv) The changed shape of the cell now allows potassium ions on the outside of the cell to bind to the protein.

(v) This triggers dephosphorylation of the protein - that is, the phosphate group is removed.

(vi) This changes the shape of the protein and potassium is transported to the inside of the cell.

(vii) There is a tendency for sodium ions to diffuse back into the cell and potassium ions back out of the cell. Since the membrane is more permeable to potassium that sodium, more ions leave the cell than enter. This reduces the tendency of water to enter the cell by osmosis - thus the Na^+/K^+ pump is a method of controlling cell volume.

Exam Hint *- Most candidates are able to differentiate between simple diffusion and active transport but very few seem able to relate the properties of substances to the mechanism by which they are able to cross the cell surface membrane and enter cells. Also, candidates show great confusion between facilitated diffusion and active transport.*

It is transport proteins of this kind which are used to actively transport substances such as glucose against their concentration gradient in the epithelial cells of the ileum and the proximal convoluted tubule cells of the nephron.

Active transport of glucose:

(i) Sodium ions are pumped out of the cell against the electrochemical gradient.

(ii) Glucose molecules and sodium ions bind to transport proteins which span the membrane.

(iii) Sodium ions then diffuse back across the membrane i.e. into the cell carrying glucose with them.

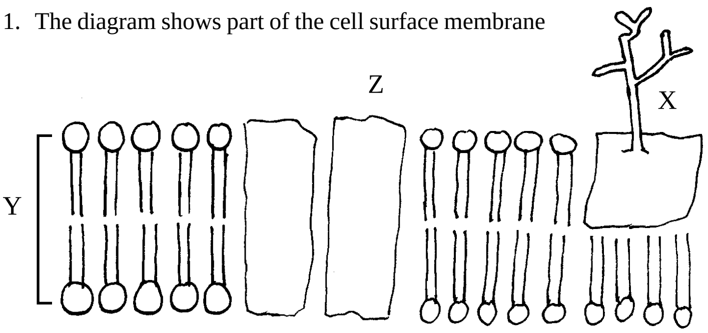
(iv) Glucose and sodium ions move apart once they are in the cell. Through this mechanism, glucose can be concentrated in particular cells, sometimes against huge concentration gradients.

Endocytosis

Phagocytosis and pinocytosis are different forms of endocytosis - when substances are taken into the cell across the plasma membrane through the formation of vesicles. In phagocytosis, solid particles or substances which are too large to cross the membrane are taken into the cell, whereas in pinocytosis, minute droplets of extra-cellular fluid are taken into the cell. In phagocytosis, the cell surface membrane produces two extensions called pseudopodia which surround the solid particle which is to be taken into the cell. The pseudopodia fuse and create a vacuole around the particle. In pinocytosis, the cell surface membrane invaginates, which allows the fluid to flow inwards. The liquid is then enclosed within a vesicle. Both phagocytosis and pinocytosis are only possible as a result of the **fluidity** of the membrane which is itself determined by the lipids of the membrane.

Practice Questions

1. The diagram shows part of the cell surface membrane



(a) Identify structure:

(i) X (1 mark)
(ii) Y (1 mark)
(iii) Z (1 mark)

(b) State one function of structure X. (1 mark)

(c) (i) Explain why the cell surface membrane can be said to be fluid. (1 mark)

(ii) Outline one way in which membrane fluidity is essential to cell function. (2 marks)

2. Complete the table below which compares the processes of diffusion, facilitated diffusion and active transport.

	Simple Diffusion	Facilitated Diffusion	Active Transport
Is ATP required?	N		Y
Rate of movement		Fast	
Direction of transport in relation to concentration gradient	With		Against

(4 marks)

Answers

Semicolons indicate marking points.

1. (a) (i) Glycocalyx;

(ii) Phospholipid bilayer;

(iii) Intrinsic protein;

(b) Cell recognition/receptor;

(c) (i) Lipids/proteins can move laterally/change places;

(ii) Allows endo/exocytosis;
eg. phagocytes attacking pathogens;
eg. pinocytosis; *(any two)*

2.

	Simple Diffusion	Facilitated Diffusion	Active Transport
Is ATP required?	N	N	Y
Rate of movement	Slow	Fast	Fast
Direction of transport in relation to concentration gradient	With	With	Against

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