Full Name:	Civics group: 21S	Index no.:	Date:

Core Idea 1: The Cell and Biomolecules of Life
Membranes & Protein Trafficking
Tutorial 3 (Annotated MS)

MCQ ANSWERS

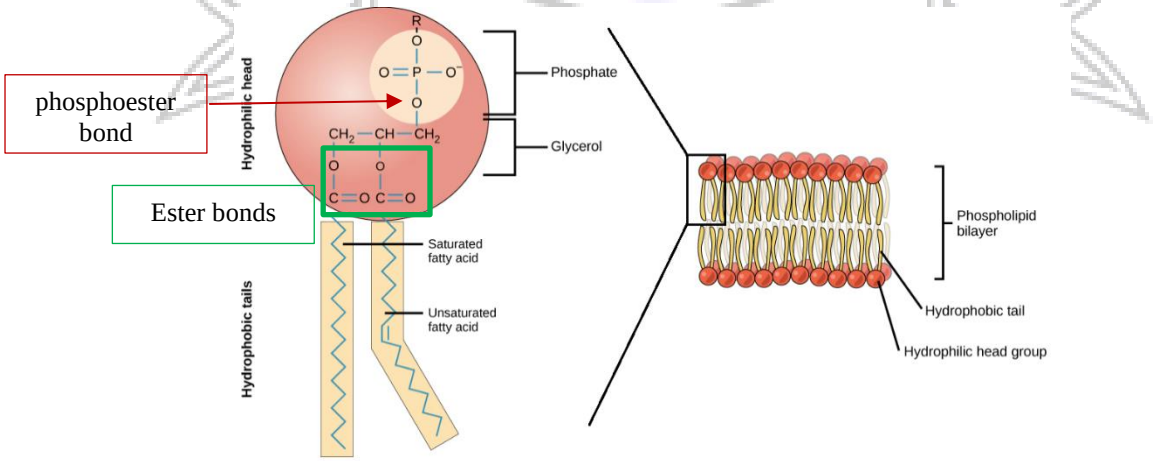
1	2	3	4	5	6	7	8	9	10
C	D	C	D	C	C	C	A	B	C

1 The structure of phospholipids includes the following:

1 glycerol linked to fatty acids (does not explain why phospholipid is amphipathic)
2 hydrophobic fatty acid chains (explains why phospholipids form a bilayer with hydrophobic tails facing inwards)
3 ester bonds (does not explain why phospholipid is amphipathic)
4 phosphate group attached to glycerol (explains why phospholipids form a bilayer with phosphate heads facing outwards)

Which structure(s) enable formation of a lipid bilayer in cell surface membranes?

A 1 and 3
B 2 and 3
C 2 and 4
D 1, 2 and 4



'fluid' refers to proteins & phospholipids being able to move within the membrane

2 The cell surface membrane structure is described as a 'fluid mosaic'.

Membrane model

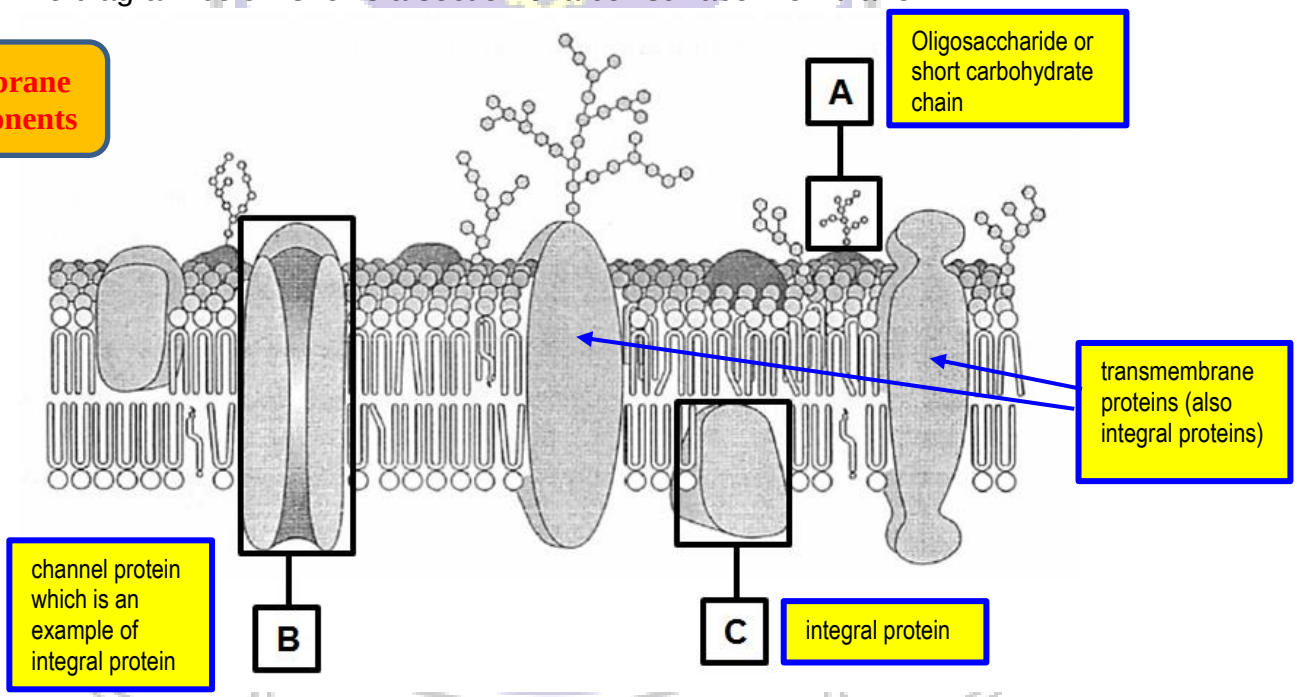
'mosaic' refers to the proteins embedded in a random manner

Which statement describes the 'mosaic' part of the cell surface membrane?

A the different patterns that are obtained by the moving phospholipid molecules
B the random distribution of cholesterol molecules within the phospholipid bilayer
C the regular pattern produced by the phospholipid heads and membrane proteins
D the scattering of the different proteins within the phospholipid bilayer

3 The diagram below shows a section of a cell surface membrane.

Membrane components



Which of the following statements are correct?

1 Structure **A** is found only on the extracellular surface of the membrane.
2 Structure **B** may contain a channel that is hydrophilic to allow ions to move across the membrane.
3 Structure **C** allows transport of substances across the membrane only in the presence of ATP. ➔ Carrier protein should be a **transmembrane** protein to allow transport of substances across membrane. Even if structure C is a carrier protein, it may **not be limited to active transport** as the statement implied. Carrier proteins can also refer to those which are in facilitated diffusion which can occur without hydrolysis of ATP as a source of energy.
4 Structure **C** is found only on one surface of the membrane. ➔ integral protein can be **found in either surface** of the membrane –facing the cytoplasm (inside cell) or facing the external environment (outside the cell).

A **1**, **2** and **4**
B **2**, **3** and **4**
C **1** and **2**
D **2** and **3**

Note: Structure B is an e.g of a **transmembrane** protein with water-filled channel to allow **glucose** which is **polar** and ions which are **charged** (e.g K^+ or Ca^{2+} **ions**) to pass through the phospholipid bilayer. The **hydrophobic core** which is made up of the non-polar hydrocarbon chain of fatty acids of phospholipids prevents such hydrophilic (glucose or ions) molecules from entering the cell.

Membrane fluidity regulation

4 The cell surface membranes of plants adapted to cold conditions change as the weather gets colder, allowing the plants to carry out exocytosis. (cell surface membrane needs to be fluid to allow fusion of membrane of vesicles in exocytosis to occur).

Which change occurs?

A a decrease in the ratio of proteins to saturated phospholipids × FALSE.
should be unsaturated phospholipids as saturated phospholipids will only allow tight packing of phospholipids to occur and hence membrane will be less fluid. Also proteins move relatively very slowly and **do not contribute much to membrane fluidity.**

B a decrease in the ratio of unsaturated phospholipids to saturated phospholipids ➔ FALSE;
This means **less unsaturated** phospholipids and these will make membrane less fluid at lower temperature.

C an increase in the ratio of proteins to unsaturated phospholipids ➔ FALSE
Proteins move relatively very slowly and **do not contribute much to membrane fluidity**. Cells rarely change their protein content of their cell membranes in response to temperature changes. At a **given protein concentration**, unsaturated phospholipids will be lower compared to proteins when there is an increase in the ratio of proteins to unsaturated phospholipids
Decreased unsaturated phospholipids decrease membrane fluidity at low temperature.

D an increase in the ratio of unsaturated phospholipids to saturated phospholipids ➔ TRUE
More unsaturated phospholipids (more kinks in tails) prevent close packing, thus hindering membrane solidification.

How did you deduce the answer?

- Exocytosis depends upon membrane / lipid fluidity and phospholipids become less fluid at lower temperatures.
- Membrane fluidity is influenced by the amount of unsaturated phospholipids (phospholipids with unsaturated hydrocarbon chain of fatty acids) in comparison to amount of saturated phospholipids, stated as a ratio here
- higher unsaturated phospholipids ➔ membrane more fluid because of C=C double bonds in the hydrocarbon tails, allowing kinks to form to prevent the close packing of phospholipid molecules together.

(Note: proteins are held in membrane by weak bonds and are "floating" in the "sea of phospholipids". Proteins move very slowly and contribution to the fluidity of membrane is less compared to phospholipid due to large numbers of phospholipids compared to proteins.)

5 The cell membrane of an African desert rat and that of the Arctic red fox are compared to investigate their composition. Which of the following is the most probable makeup of the respective membranes?

Membrane fluidity regulation

	Amount of saturated fatty acids		Amount of cholesterol	
	Arctic red fox	**Desert rat**	**Arctic red fox**	**Desert rat**
A	Low	High	Low	High
B	High	Low	Low	Low
C	Low	High	High	High
D	High	Low	High	Low

How did you deduce the answer?

- **African** desert rat lives in a **hot** climate (relatively high temperature) whereas **Arctic** red fox lives in a **cold** climate (relatively low temperature).
- As such, the African desert rat must reduce the membrane fluidity of their cells while the Arctic red fox must increase the membrane fluidity of their cells.
- High amount of saturated fatty acids –> membrane becomes less fluid at low temperature. Hence membrane of cells in organisms living at low temperature tend to have less saturated fatty acids to maintain fluidity of membrane. Reverse arguments for more saturated fatty acids in membranes of cells in organisms living at high temperature.

Explain the role of cholesterol

- High amount of cholesterol – can either reduce or increase membrane fluidity
- For the African desert rat, high cholesterol level would reduce membrane fluidity **by restricting the movement** of phospholipid molecules *(in hot climate)*.
- For the Arctic red fox, high cholesterol level would increase membrane fluidity by **preventing the close packing** of phospholipids *(in cold climate).*

6 What are the features of facilitated diffusion?

	uses proteins in membrane	uses ATP molecules	move down a concentration gradient
A	√	√	√
B	x	√	√
C	√	x	√
D	√	√	x

The following information serves as a revision:

Diffusion is defined as net movement of molecules from a region of higher concentration to a region of lower concentration, down a concentration gradient, across a selectively permeable membrane. **No ATP is used as energy and membrane proteins** are not required for this process.

Facilitated diffusion is defined as net movement of molecules from a region of higher concentration to a region of lower concentration, down a concentration gradient, across a membrane **via a specific protein**. Classified as a form of passive transport as no ATP hydrolysis to provide energy is required for the movement of molecules.

Active transport is the movement of molecules across a membrane from a region of lower concentration to a region of higher concentration via a specific protein using ATP (synthesised during cellular respiration) as energy source. The protein hydrolyses ATP to provide energy to pump substances across the cell membrane.

Osmosis is the net movement of water molecules from a region of higher water potential to a region of lower water potential across a selectively permeable membrane. Classified as a form of passive transport as no ATP hydrolysis to provide energy is required for the movement of molecules.

7 Which statements about the components of the cell surface membrane are correct?

1 Diffusion can take place through lipids and protein pores. ➔ TRUE
2 Endocytosis only involves lipids. ➔ FALSE
3 Facilitated diffusion only involves proteins. ➔ TRUE
4 Osmosis only involves proteins. ➔ FALSE

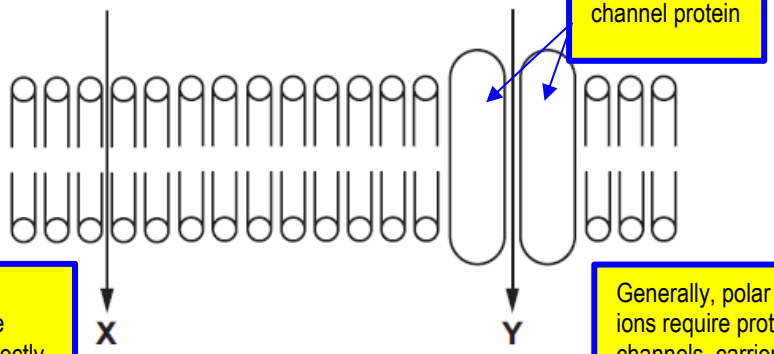
A 1, 2, 3 and 4
B 1, 3 and 4
C 1 and 3
D 2 and 4

Why did you not choose certain statement(s)?
Statement 2: False. Recall the fluid mosaic model that the cell membranes are made up of phospholipid molecules and proteins. Hence, when the invagination of the cell surface membrane to form endocytic vesicles occurs during endocytosis, the vesicle membrane would **contain both lipids and proteins**.
+ **Receptor-mediated endocytosis** involves protein receptors too.

Statement 4: Osmosis can also take place without involvement of proteins i.e. movement of water molecules through the phospholipid bilayer. Although water is polar, the water molecule is small enough to be able to pass through the phospholipid bilayer. But this process only allow a **small proportion** of water molecules to pass through the membrane directly and is insufficient for the cells. Majority of the water molecules enter the cells via facilitated diffusion using aquaporins.

Aquaporin is a protein channel that allows water to pass through via facilitated diffusion (involves protein channel)

8 The diagram shows two pathways, X and Y, through which molecules can diffuse across a cell surface membrane.



Generally, (small), non-polar, hydrophobic molecules can diffuse across the phospholipid bilayer directly.

Generally, polar molecules or charged ions require proteins as protein channels, carrier or pump to move across phospholipid bilayer directly.

Which row correctly shows possible pathways for lipids, water and glucose?

	lipids	water	glucose
A	X only	X and Y	Y only
B	X only	Y only	Y only
C	X and Y	X only	X and Y
D	X and Y	X and Y	X only

Lipids are non-polar, hydrophobic molecules

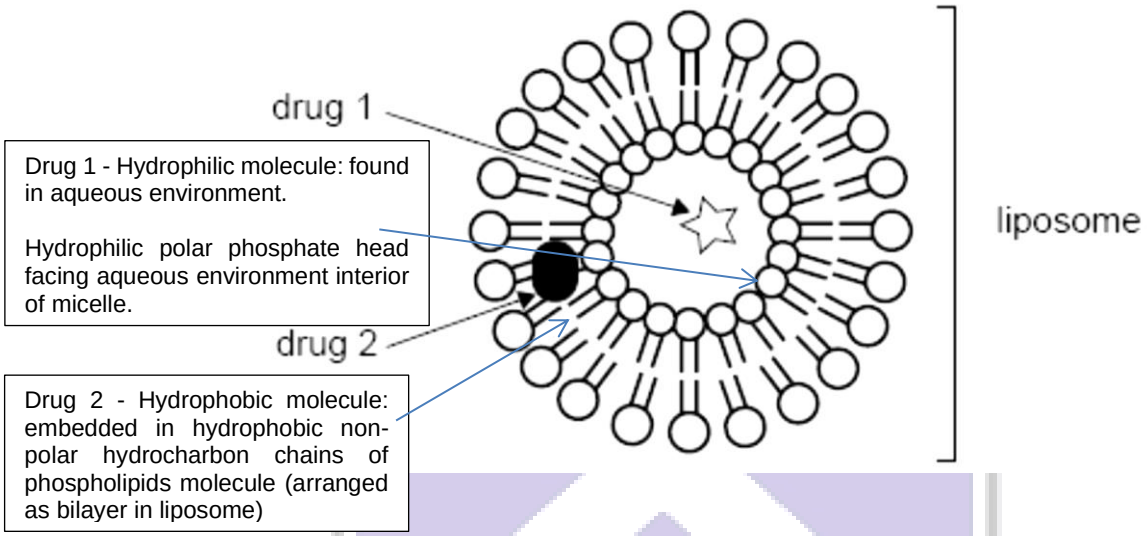
Water is a small, polar molecule.

Can go via both ways, see MCQ 9 explanation (Statement 4)

Glucose is a polar molecule.
Compared to water, glucose is not small.
Thus transport is via facilitated diffusion.

9 Liposomes are spherical vesicles consisting of a phospholipid bilayer. They can be designed to carry pharmaceutical drugs into cells. The figure below shows the structure of a liposome and two potential drugs, drug 1 and drug 2, that it can carry.

The diagram shows the structure of two lipid molecules.



Which of the following statements are true?

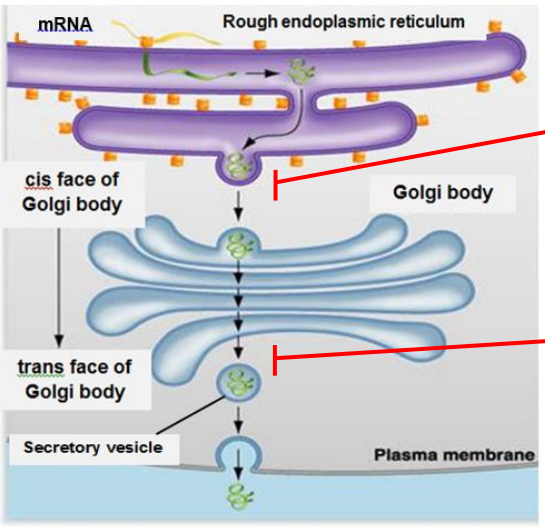
1 Liposomes can carry both hydrophobic and hydrophilic drugs. (Drug 1 is hydrophilic, drug 2 is hydrophobic)
2 The centre of the liposome is aqueous. (True as phosphate heads are facing the interior of liposome)
3 Liposomes are able to fuse with the cell surface membrane of a cell. (cell surface membrane is made up of the same material – phospholipid bilayer)
4 Liposome-based membranes have a rigid structure. (phospholipid bilayer is a fluid structure – link to topic: membranes)

A 1 and 2 only
B 1, 2, and 3 only
C 2 and 3 only
D 2, 3, and 4 only

10 Two chemicals, Brefeldin A and Monensin, are inhibitors of certain cellular processes:

- Brefeldin A inhibits the transport of substances from the rough endoplasmic reticulum to the Golgi apparatus.
- Monensin inhibits the formation of post-Golgi vesicles.

Secretory vesicles/lysosomes



Brefeldin A

Monensin

Researchers tested several samples of cells that produce a particular protein called APRIL with the above named inhibitors. The results are shown in the table below.

Brefeldin A interferes with the transport of polypeptides from rER to Golgi, hence the polypeptides cannot undergo further post-translational modifications there and will remain non-functional.

Monensin interferes with secretion of protein as it inhibits formation of secretory vesicles

Sample	Functional Protein formation	Secretion
1	Functional Protein APRIL formed	Protein APRIL not secreted from the cells
2	Functional Protein APRIL not formed	Protein APRIL not secreted from the cells
3	Functional Protein APRIL formed	Protein APRIL secreted from the cells

From this information, which treatment was each sample subjected to?

A Sample 1 was treated only with Brefeldin A. → Sample 1 was not treated with Brefeldin A as functional protein was formed. It was treated with only Monensin as protein was not secreted.

B Sample 3 was treated only with Monensin. → Sample 3 was not treated with either Brefeldin A or Monensin as functional protein was formed and secreted.

C Sample 2 was treated with Brefeldin A and Monensin. → Sample 2 was treated with both Brefeldin A and Monensin as functional protein was not formed and protein was not secreted.

D Sample 2 was treated only with Monensin. → Functional protein was not formed hence sample 2 was treated with Brefeldin A as well.

STQ
QUESTION 1

(a) The passage of most molecules through membranes is regulated by proteins. Fig. 1.1 is a diagram showing the four main steps in the release of insulin from beta cells, which involves three types of transmembrane proteins.

Such proteins span the entire phospholipid bilayer

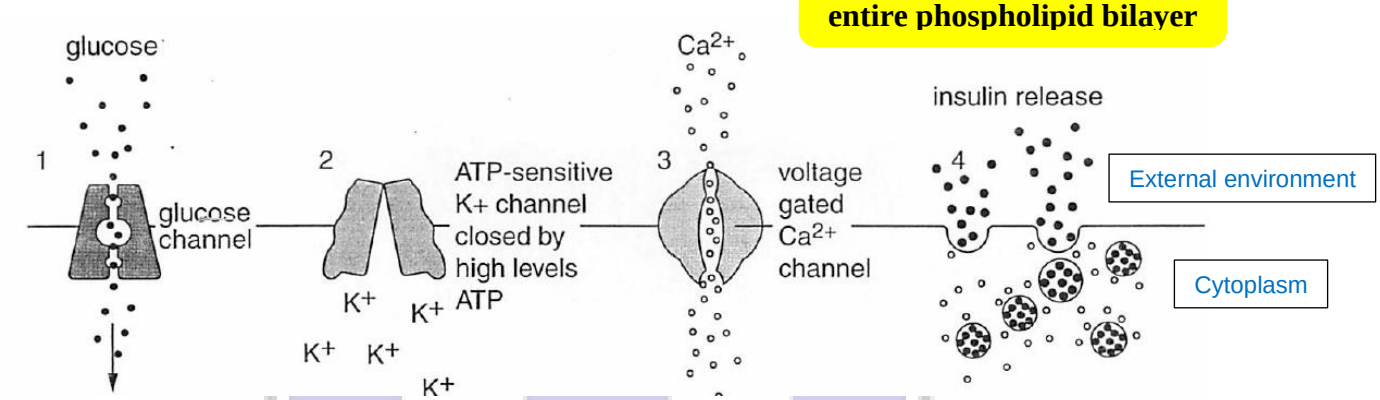


Fig. 1.1

(i) Explain why transmembrane proteins are necessary for glucose, potassium ions and calcium ions to pass through cell surface membrane.

……[3]

1 **Glucose** is a polar molecule / water soluble / hydrophilic and the **ions** are charged;
2 They are therefore unable to pass through the hydrophobic core of the plasma membrane;
3 The transport of glucose, potassium ions and calcium ions require **specific transport proteins** to provide a water-filled channel;

(ii) Describe (need details about structure 1st) the properties of the phospholipid bilayer and the aquaporin channels in relation to the movement of water across the cell surface membrane.

……[4]

1 [structure of phospholipid bilayer]
The phospholipid bilayer comprises two layers of amphipathic phospholipid molecules, with {**hydrophilic/charged/polar**} phosphate heads **facing** the aqueous extracellular environment and cytoplasm of the cell and the hydrophobic **hydrocarbon chains** of phospholipids **facing inwards,** forming the interior of the cell membrane ;

2 [property in relation to movement of water]
The hydrophobic core ; **restricts the free movement** of the polar water molecules across the cell membrane ;
However, the **fluidity** of the membrane; **allows some** of the small-sized, polar water molecules to pass through ;

3 [structure of aquaporin channel]
The aquaporin is a transmembrane protein channel (embedded in the phospholipid bilayer) consisting of a pore/channel lined with hydrophilic amino acids with polar or charged R groups ;

4 [property in relation to movement of water]
This **provide a water-filled channel / hydrophilic passage** for the easy passage of the polar water molecules down their water potential gradient ;

(iii) Suggest why (reason) there are no channels for insulin release across the membrane.

……[3]

Since there are 3 marks, some marks are allocated to: what are the consequences if there were to be channels large enough for insulin to pass through

1 Insulin is a protein which is **too large** to pass through membrane ;
2 A channel large enough to allow insulin through would also allow other molecules through (thus affecting the selective permeability of the membrane) ;
/ A channel large enough to allow insulin through would affect the integrity / stability of membrane ;
3 Therefore, it is released in vesicles across the membrane via exocytosis;

(iv) Describe how (method) transmembrane proteins are embedded in the membrane.

……[2]

1 Hydrophobic interactions between the non-polar hydrocarbon chains of fatty acids of the phospholipids and the hydrophobic R-groups of the non-polar amino acids on the surface of the protein in contact with the phospholipids ;
2 Ionic bonds and hydrogen bonds between the hydrophilic charged phosphate group / polar phosphate heads and the hydrophilic R-groups of the charged / polar amino acids at both ends of the protein (in contact with aqueous environment).

(b) Fig. 1.2 is an electronmicrograph showing release of insulin from a β (beta) cell in the pancreas.

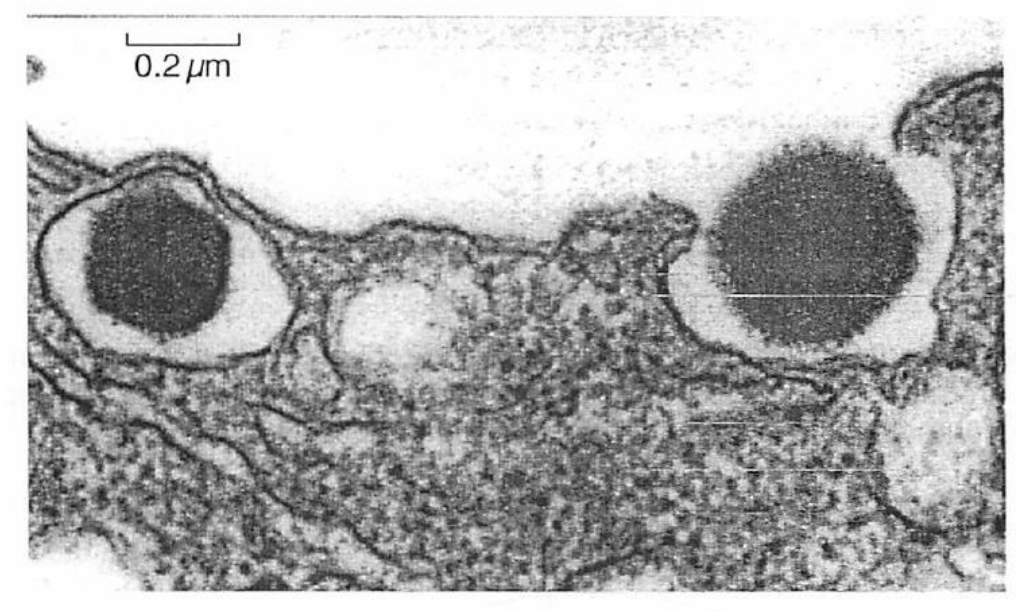


Fig. 1.2

Describe how (process) this release across the membrane occurs.

……[3]

1 vesicles containing insulin **move / migrate** to (cell surface) membrane ;
2 vesicles move along the filaments and microtubules in the cell cytoskeleton with the use of ATP as the energy source.
3 (membrane of) vesicle fuses with (cell surface) membrane and contents of vesicles emptied out of the cell, exocytosis occurs.

[Total: 11]

QUESTION 2

(a) Milk contains lipids, carbohydrates, proteins and glycoproteins. These components are synthesised in special milk-secreting cells in mammary glands and, together with water, are then secreted into cavities within the mammary glands to form milk.

(i) Milk lipids are synthesised in the cisternae of the smooth endoplasmic reticulum (smooth ER) within the milk-secreting cells.

These milk lipids collect in between the two layers of phospholipids that make up the phospholipid bilayer of the smooth ER membrane.

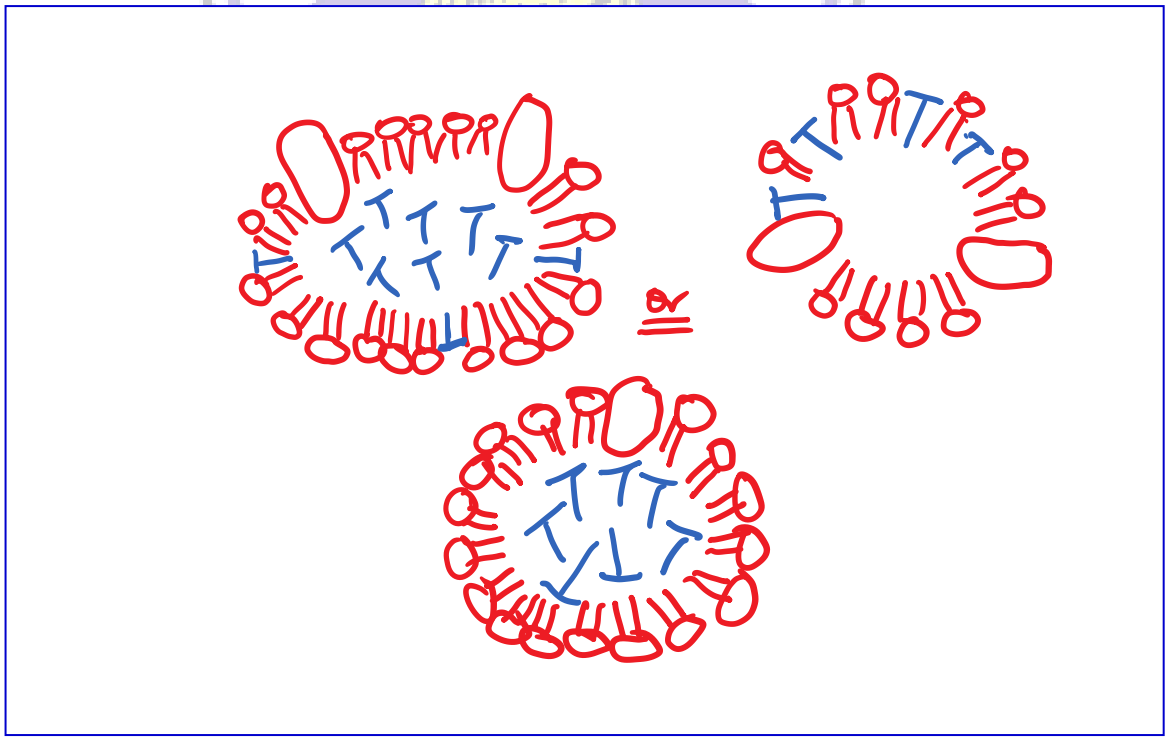
The outer phospholipid layer of the bilayer pinches off to from a droplet. The droplet consists of a single layer of phospholipids with some membrane proteins and contains milk lipids.

Sketch the arrangement of molecules in one complete droplet.

You should use the following symbols in your sketch. [3]

	phospholipid molecule
	protein molecule
T	lipid molecule

In-Class Discussion



The droplet moves through the cytoplasm to reach the surface of the cell, where it is secreted as a milk fat globule into a cavity within a mammary gland.

Fig. 2.1 shows the stages in this process.

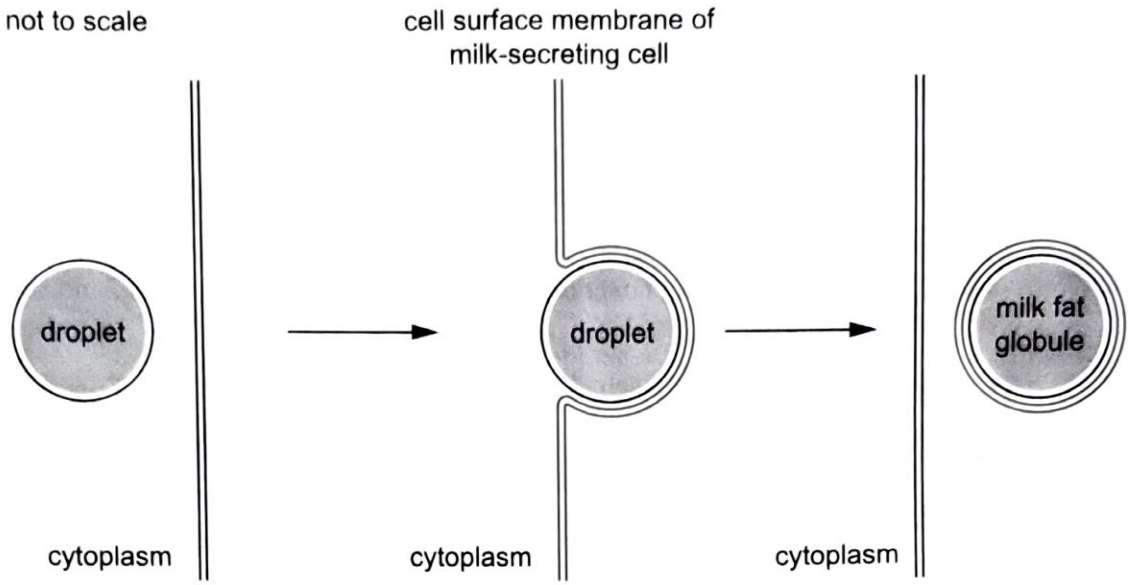


Fig. 2.1

The secreted milk fat globule has a unique membrane that has an outer phospholipid bilayer (approximately 7nm thick), then a layer of cytoplasm (approximately 15nm in thickness) and inside that a single phospholipid layer.

(ii) State the approximate thickness of the unique membrane of a milk fat globule. [1]

7 + 15 + 3.5 = 25.5nm

Glycoproteins in milk are also synthesised in milk-secreting cells and then secreted.
Note: Glycoproteins are secreted via exocytosis, and milk lipids are secreted in form of milk fat globule.

(iii) State the site of synthesis of glycoproteins in cells such as milk-secreting cells.
……..…[1]
1 Rough endoplasmic reticulum;

Note: newly synthesised proteins released into RER, undergo glycosylation in lumen of RER. Glycoproteins are then packaged into transport vesicles which bud off from RER, and fuse with Golgi body, releasing the glycoproteins into the lumen of the Golgi body. Further modification of glycoproteins take place within Golgi body.

(iv) Explain how newly synthesised glycoprotein molecules in the milk-secreting cells reach the cavities within the mammary gland.

……[4]

1 Glycoproteins are packaged into transport vesicles which bud off from RER, and fuse with (the cis face of) the Golgi body, releasing the glycoproteins into the Golgi body for further modification;
2 Mature glycoproteins in the lumen of Golgi body are packaged as secretory vesicles which bud off from the trans face of Golgi body;
3 Secretory/Golgi vesicles migrate towards the cell surface membrane of the milk-secreting cell, guided by the cytoskeleton with the use of ATP;
4 Vesicles fuse with the cell surface membrane, releasing the glycoproteins via exocytosis;

(v) Milk-secreting cells secrete lipids and glycoproteins at the same time. This helps the cells to maintain a constant cell surface membrane area.

Suggest why secreting lipids and glycoproteins at the same time helps to maintain a constant cell surface membrane area.

……[3]

1 Secretory vesicles containing glycoproteins, fuse with the cell surface membrane to secrete lipids via exocytosis;
2 ref. phospholipids from secretory vesicles being added to the cell surface membrane;
3 to replace the loss of phospholipids from the cell surface membrane from the budding of the fat droplet from the cell;

(b) Liposomes are small spheres, about 100nm in diameter, that are surrounded by a phospholipid bilayer.

Liposomes can be used to enclose a variety of drugs and transport these around the body in the blood.

It is possible to manufacture pH-sensitive liposomes that release their contents below specific pH values. Cancer cells in some tumours can be targeted using pH-sensitive liposomes containing anti-cancer drugs.

Tumours can form in many different tissues, including bone and muscle, and are often poorly supplied with blood.

Use this information to suggest why cancer cells in some tumours can be targeted using pH-sensitive liposomes containing anti-cancer drugs.

……[2]

1 ref. poor blood supply leading to inefficient removal of carbon dioxide and supply of oxygen;
2 high carbon dioxide concentration leads to decrease of pH in cancerous tissues/cells due to formation of carbonic acid; which can then be targeted by these pH-sensitive liposomes

QUESTION 3

An experiment was carried out to determine what happens to amino acids after they are absorbed by animal cells. The cells were incubated for 5 minutes in a medium containing radioactively labelled amino acids. The radioactive amino acids were then washed off the cells' surface and the cells were incubated in a medium containing only non-radioactive amino acids.

Samples of the cells were removed from the medium every five minutes for 40 minutes. For each sample, the levels of radioactivity in three different **membranous** organelles, **P**, **Q** and **R**, were determined. The results of the experiment are shown in Fig. 3.1 below.

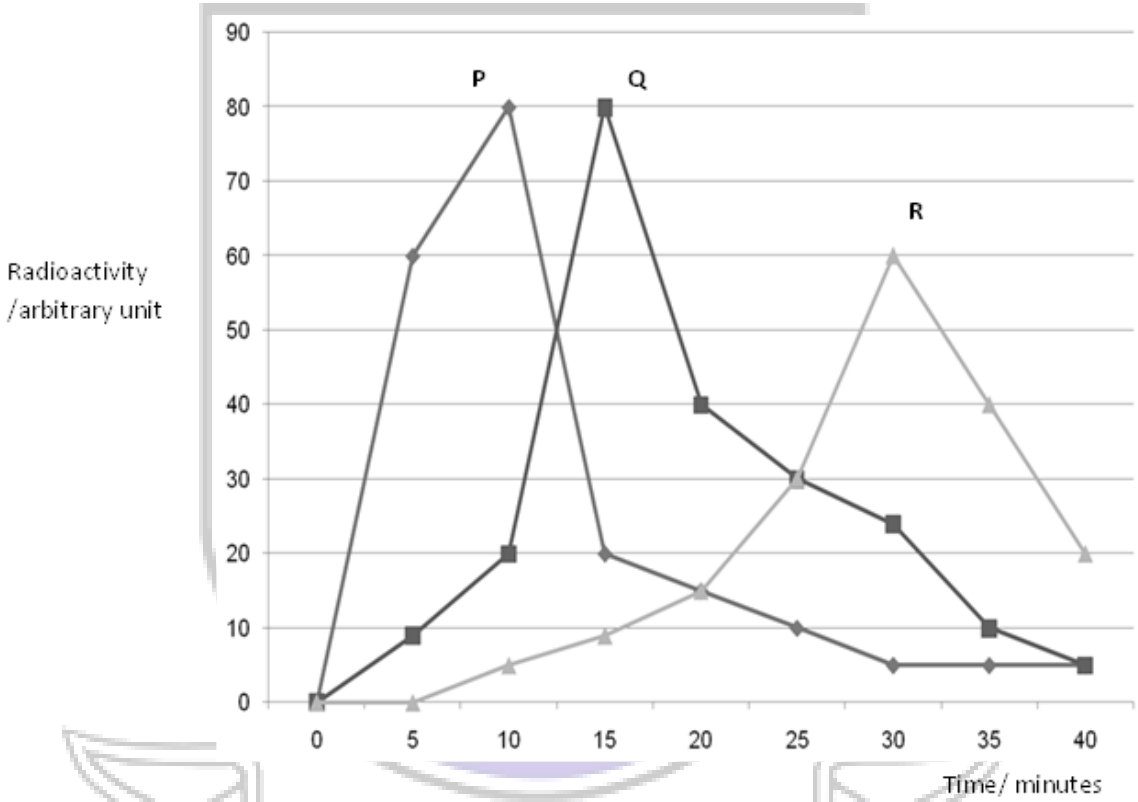


Fig. 3.1

Note: Radioactivity first appeared in Membranous organelle P, Q then R

(a) Identify the organelles **P**, **Q** and **R**

……..[3]

P: Rough Endoplasmic Reticulum; **Q**: Golgi Apparatus; **R**: Secretory vesicle
OR
P: Rough Endoplasmic Reticulum; **Q**: Transport Vesicle; **R**: Golgi Apparatus

(b) With reference to Fig. 3.1, explain the changes in the level of radioactivity of the three organelles with time.

……..[3]

1 *[data to answer 'with ref to Fig.1]* Radioactivity in **P** increased first, from 0 to 80 arbitrary units in the first 10 min, followed by **Q** and then **R**, which increased last, from 0 to 60 arbitrary units from 5 to 30 min); (award for at least two organelles' data described)
[reasons to explain changes]
2 Radioactivity is first detected in the ribosomes on the rough endoplasmic reticulum (**P**) because the ribosomes add the radioactive amino acids to the polypeptide chains during protein synthesis.

3 Transport Vesicles transport the radioactive proteins to the Golgi apparatus (**Q**) for further chemical modifications.
4 Resultant polypeptides are packaged into secretory vesicles (**R**) which bud off the Golgi apparatus and move toward the plasma membrane.

OR
3 Transport vesicles (**Q**) containing radioactive proteins then bud off the rER, move to and fuse with the Golgi apparatus (**R**)
4 where further chemical modifications/glycosylation of the proteins take place

(c) Suggest what will happen to the level of radioactivity in the cell after 40 minutes. Explain your answer.

……...[1]

1 *[what will happen to the level of radioactivity]* It will drop to a low level but not disappear / reach zero because
2 *[explanation]* some radioactive proteins may be retained within the cell OR some radioactive proteins are embedded in the cell's membranes (OWTTE).

[Total: 7]

Marked Assignment

Peptic cells from the lining of the mammalian stomach secrete the enzyme precursor pepsinogen. Some of these cells were isolated and maintained in a culture solution containing radioactively labelled amino acids. Samples of the cells were taken at regular intervals and prepared for electron microscopy.

Fig. 1 shows a drawing from an electron micrograph of a peptic cell. The right axis of the drawing indicates the **time taken**, in minutes, **for radioactivity to be detected** in the various cell organelles viewed under the electron micrograph.

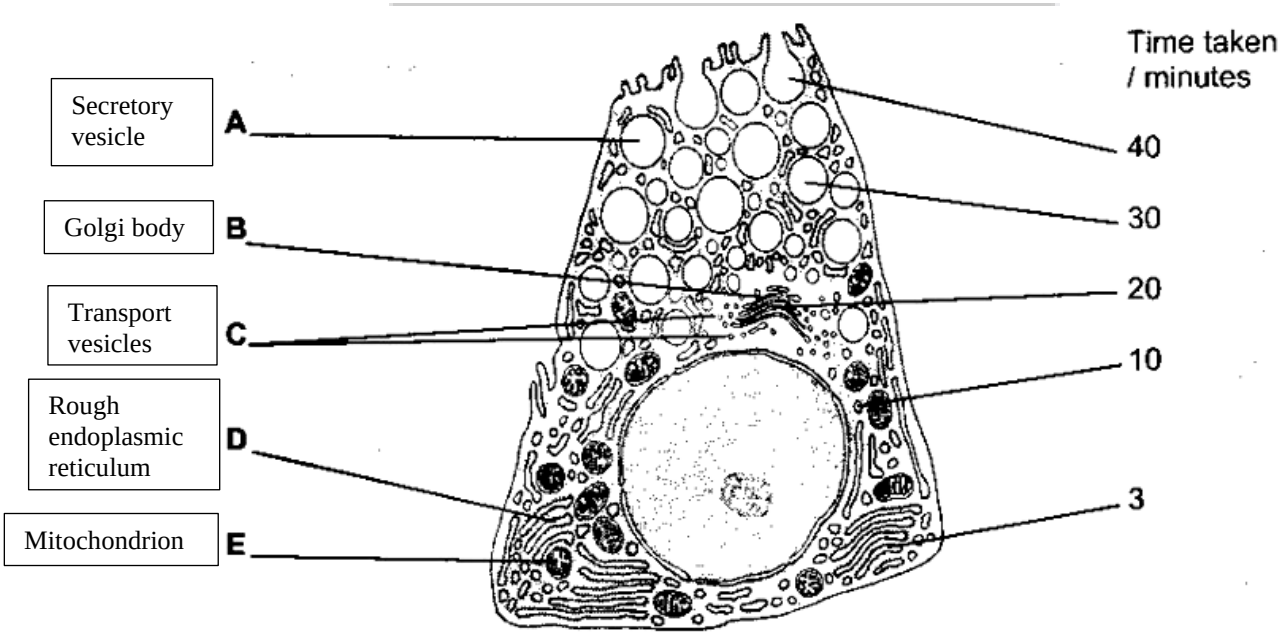


Fig. 1

(a) Identify the organelles labelled **A** to **D,** as shown in Fig. 1.

……[4]

A - secretory vesicle; REJECT: lysosome (Reasons: this is a secretory cell and similar vesicles can be seen fusing with cell surface membrane for exocytosis)
B - Golgi body / apparatus → due to presence of flattened membrane bound sacs known as cisternae, and the associated Golgi vesicles
C - Transport vesicles (plural) → these vesicles are about to fuse with cis face of Golgi body [the trans face of Golgi body faces the side of the cell that has a lot of secretory vesicles]
D - Rough endoplasmic reticulum → presence of ribosomes on the surface of the membrane

(b) With reference to Fig. 1, explain why radioactivity was detected in various organelles at different times.

……[5]

Protein trafficking involves the sequential transport of proteins through various organelles

1 Radioactivity is detected the earliest at time=3min at the ribosomes on the rER. This is because radioactive-labelled amino acids are first synthesized into polypeptides at the ribosomes on rER;

(Polypeptides then enter RER lumen to fold into their native 3D conformation and are transported within cisternae of rER)

2 Radioactivity is subsequently detected at the transport vesicles at time=10min as transport vesicles, containing radioactive proteins, **bud off from rER** to move to the cis face of the Golgi body;

3 At time = 20 min, radioactivity is observed when transport vesicles containing radioactive proteins **fuse with cis face of Golgi body**.

4 Radioactivity is then detected in the secretory vesicles at time = 30 min when they bud off the trans face of Golgi body.

5 Movement of vesicles along cytoskeleton takes time hence radioactivity is only detected at time = 40min when the secretory vesicles move towards the cell surface membrane, releasing the polypeptides via exocytosis.

Note: It is necessary to state the different times at which radioactivity are detected as the question's requirement is 'With reference to Fig. 1'.

(c) Describe how (process) the enzymes in organelle **A** is secreted out of the cell.

……[2]

1 Exocytosis
2 Secretory vesicle moves towards the cell surface membrane. Membrane of secretory vesicle membrane fuses with cell surface membrane, releasing the contents.
3 Movement of secretory vesicles within the cell is guided by filaments and microtubules with the use of ATP as energy source.

(d) Explain why (give reason) large numbers of organelle **E** (mitochondria) are required in cells synthesizing and secreting proteins.

……[2]

1 Organelle **E** (mitochondria) **produces ATP during aerobic respiration**; which release energy when hydrolysed.
2 This **provides** the **energy**; (any 1) required for movement of secretory vesicles / secretion via exocytosis / activation of amino acids / formation of peptide bonds / active uptake of amino acids (Topic: Protein Synthesis: Translation)

[Total: 13]