Lesson 2: Phospholipids

Instructions:

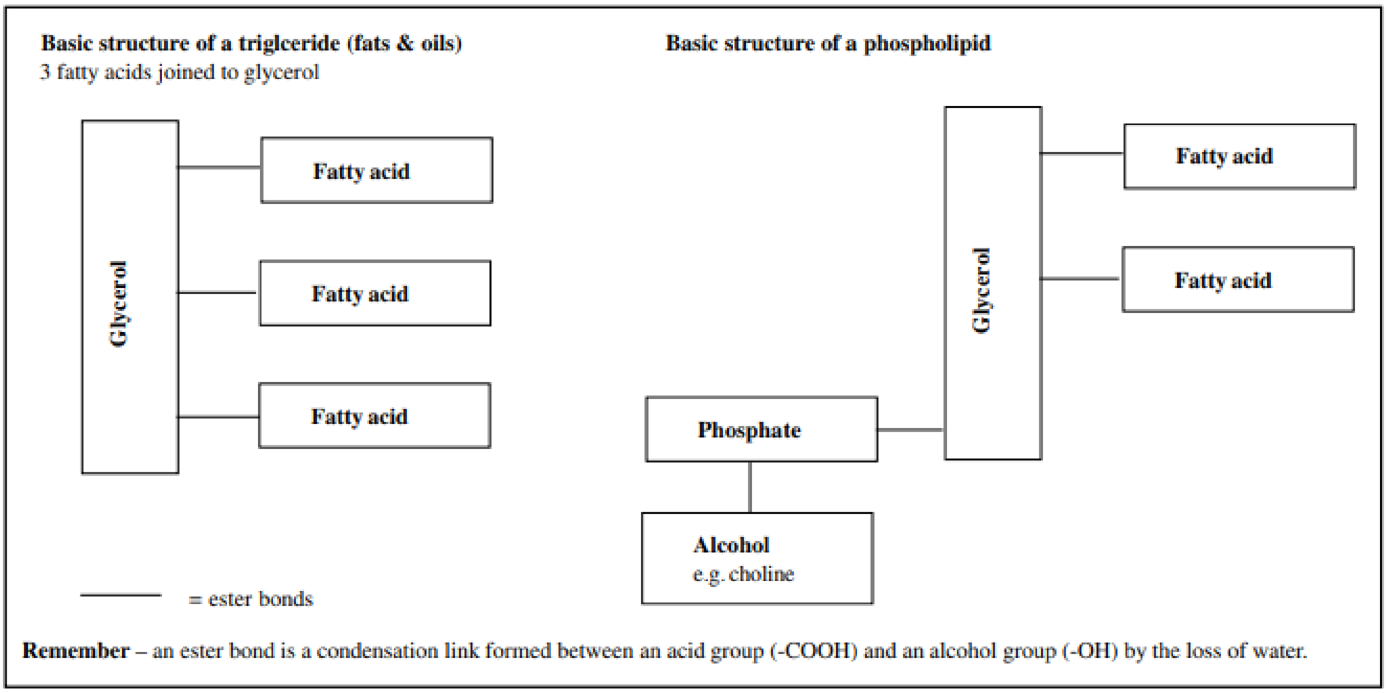
1. **Read through the fact file and summarise into one page, you only need to include the things you don't already know – which again I know for the content in this lesson may be quite a lot so feel free to take up more than one page.**
2. **Complete questions on fact file sheet, self-assess in green. Please don't just tick random things, tick/underline the exact thing you got right. Highlight what you got wrong.**
3. **Answer exam questions and again self-assess.**
4. **Attach a copy of your work.**

Fact file

Phospholipids are important biological compounds found in the membranes of organelles (e.g mitochondria) and plant and animal cells, including plasma, mitochondrial, chloroplast and bacterial membranes.

Basic structure of a phospholipid

Fig 1. Triglcerides & phospholipids



The fatty acids have long covalent side chains and these may be saturated (with all possible bonds filled with hydrogen) or unsaturated (with some bonds missing hydrogen – thus double bonds are present).

So in phospholipids one of the three fatty acids is replaced by a phosphate group and alcohol.

The main diffrences between a trglyceride and a phospholipid are:

• a phospholipid contains two fatty acid components but a triglyceride contains three.

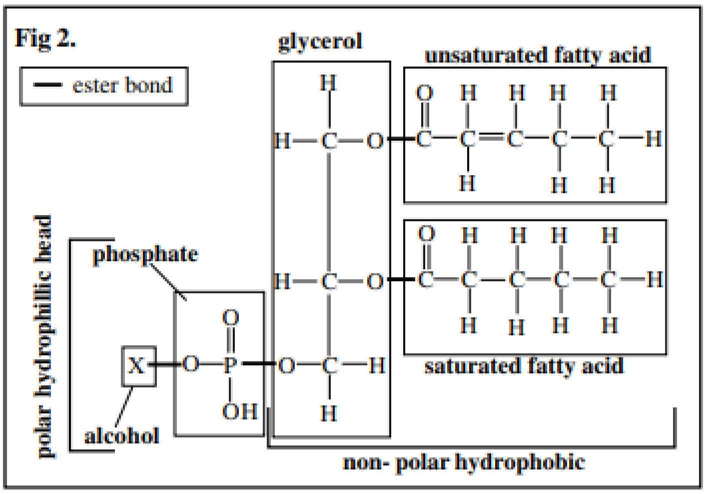
• a phospholipid contains a phosphate group but a triglyceride does not.

• a phospholipid contains an extra alcohol attached to the phosphate, the triglyceride does not.

• the third carbon in the glycerol of a phospholipid is rotated 180o , the glycerol in a triglyceride has all three carbons the same way round.

General structural chemical formula of a phospholipid (Fig 2)

> ***Exam Hint**: you will not be asked to write down the formula of a phospholipid but may be asked to recognise and identify the different components of the molecule.*



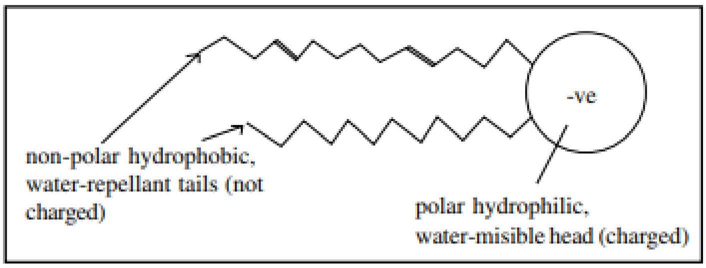
Properties of phospholipids

Glycerol and fatty acid components are non-polar (covalent) and so do not become ionised (charged). They are therefore repelled by water (which is ionic) and are said to be **hydrophobic** (water hating). The two fatty acid side chains form the two **non-polar tails** of the phospholipid molecule.

The phosphate component contains a free hydroxide/alcohol group (–OH group). This can lose its hydrogen atom and so becomes negatively charged (-O- group). The alcohol (X) may also contain a group or groups which can ionise to become negatively charged. This ionised end of the phospholipid molecule, including the phosphate and alcohol components, is the polar head. The **polar head**, being charged, can mix freely with water and is said to be **hydrophilic** (water loving).

So, Phospholipid molecules are **amphipathic** - meaning one end of the molecule will mix with water and the other end will not.

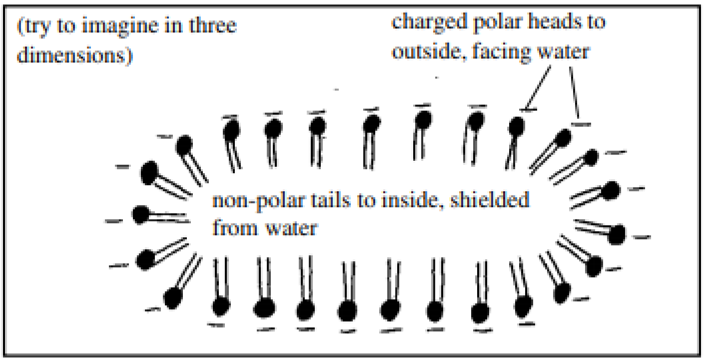
Because of these properties, on diagrams, phospholipids are usually shown by the following shape.



Phospholipids and membranes

Imagine thousands of phospholipid molecules dropped into water and prevented from reaching the water surface. Their tails will try to escape from water but their heads will mix with water. The only way they can achieve stability is by forming spheres or 'sausage' shapes with the heads to the outside facing the water, and the tails to the inside shielded from the water. The structures that the phospholipids form are called **micelles** and they are negatively charged on the outside (Fig 3).

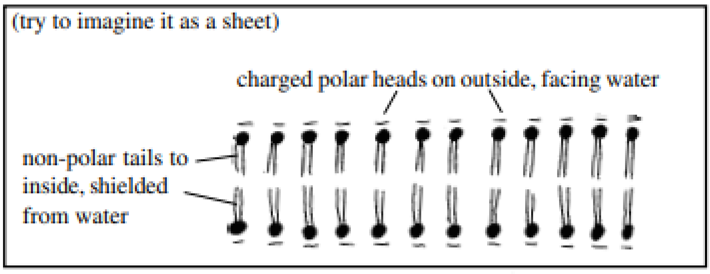
Structure of a micelle (Fig 3)



These minute structures, trapped inside the watery cytoplasmic contents of the cell, possibly form the basis of organelles. If the micelle or organelle contains water, the phospholipid layer will become double with polar heads facing the water both inside and outside, thus making a double membrane. Mitochondria and chloroplasts have double membranes, However, remember that membranes of such organelles also contain other molecules, for example, proteins (structural and enzymes), polysaccharides and sometimes, nucleic acids.

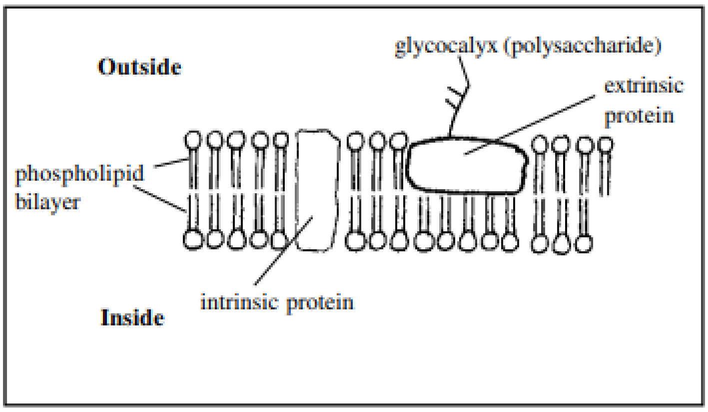
If the phospholipid molecules dropped into water could reach the surface, the only stable form that they could achieve, along the surface, would be a membrane consisting of two parallel rows of phospholipid with polar heads to the outside and non-polar tails to the inside. Such a structure could give rise to large components – for example, whole cells lined by a plasma membrane. The membrane would be negatively charged on both surfaces.

Phospholipid membrane



This type of phospholipid membrane, called a **bilayer**, is a main component of the cell plasma membrane. In the plasma membrane are other components, for example, proteins (structural, enzymes and carrier molecules) and polysaccharides.

General structure of the cell/plasma membrane (vertical section)



The cell membrane is about 45% lipid (mainly phospholipid) 45% protein and 10% polysaccharide. It is between 7 and 8 nm thick.

Phospholipids are important in plasma membranes because:-

• They give the membrane a '**fluid-mosaic** structure'. This refers to the fact that the phospholipid bilayer is fairly 'fluid', because the individual phospholipid molecules can move sideways and exchange places, within their own row. This allows the protein molecules in it to float about and move their positions. The fluidity increases the range of functions that the membranes can perform. For example, if punctured it allows the membrane to be self-sealing and it allows vacuole formation (important for phagocytic and pinocytic activities).

• The phospholipid layer enables lipid soluble substances to cross the plasma membrane into or out of the cell. • The phospholipid layer prevents passage of water soluble substances and so transport of these is restricted to some protein components (which act as carrier molecules, regulating what enters or leaves the cell).

• In some plasma membranes, phospholipids will weakly bond to cholesterol molecules. One cholesterol molecule binds to two adjacent phospholipid molecules. This acts to strengthen the membrane but may make it less flexible and less permeable.

Importance of phospholipids to human health

Although all lipids are essential components of a balanced diet, if too much lipid is eaten it can cause obesity and heart disease. Some lipoproteins, phospholipids and cholesterol may be deposited in the inner wall layers of blood vessels, forming plaques or atheromas. These impede blood flow and cause an extra workload on the heart. In the liver, triglycerides, phospholipids and cholesterol are made water soluble, by combination with proteins, forming lipoproteins. There are two major types of lipoprotein:

• **low density lipoproteins(LDLs).** These pick up blood cholesterol and deposit it inside cells, including in the smooth muscle cells of arteries. Because of this, high blood levels of LDLs may increase the risk of developing atheromas, particularly in the coronary arteries. To reduce LDL levels and activity, high cholesterol foods (for example, eggs and cheese) should only be eaten in moderation.

• **high density lipoproteins(HDLs).** These gather up extra cholesterol, triglycerides and phospholipids, from cells, and transport it to the liver for excretion. Thus high levels of HDLs in the blood reduce the risk of developing coronary artery disease. Red (oily) fish are good dietary sources of HDLs. Unsaturated fatty acids known as omega-3 fatty acids reduce the levels of cholesterol and LDLs in the blood, and so reduce the risk of heart disease. Omega-3 fatty acids are found in oily(red) fish and in shellfish and these should be eaten regularly.

Practice questions

1.

(a) State three ways in which a phospholipid molecule differs from a triglyceride molecule. (3)

(b) Name the type of chemical bond joins the components of a phospholipid together and say how is it formed? (3)

(c) List the products that would be formed if a phospholipid was hydrolysed. (4)

Total 10 marks

2. Suggest explanations for:-

(a) Phospholipids forming a bilayer in cell membranes. (4)

(b) Phospholipids endowing cell membranes with fluidity. (3)

(c) The presence of cholesterol in cell membranes. (3)

Total 10 marks

3.

(a) The myelin sheath in neurones is made from Schwann cells which wrap tightly around the axon in a spiral fashion. The main component of myelin is phospholipid. Why is this so? (2)

(b) Suggest why myelin is a good substance to surround axons with. (3)

(c) Why are high density lipoproteins (HDLs) better for you than low density lipoproteins (LDLs)? (3)

Total 8 marks

Answers

1.

(a) a phospholipid contains two fatty acid components but a triglyceride contains three;

a phospholipid contains a phosphate group but a triglyceride does not;

a phospholipid contains an extra alcohol attached to the phosphate, the triglyceride does not;

the third carbon in the glycerol of a phospholipid is rotated 180o ,

the glycerol in a triglyceride has all three carbons the same way round (max 3);

(b) an ester bond;

formed by condensation/removal of water;

between an acid and an alcohol/hydroxide group; (3)

(c) glycerol; (two) fatty acids; (ortho)phosphoric acid; an alcohol;

2.

(a) phospholipids have charged polar heads and uncharged non-polar tails;

thus the heads are hydrophilic/water miscible/can be in contact with water;

the tails are hydrophobic/water hating/cannot be in contact with water;

the heads must therefore shield the tails from water and so form a 4 bilayer with the heads outside and the tails inside; (4)

(b) unsaturated fatty acids have lower melting points than saturated fatty acids;

in combination with glycerol, unsaturated fatty acids tend to form oils or very soft fat;

in cell membranes the phospholipid molecules (probably) are mainly unsaturated which makes the bilayer fluid; (3)

(c) cholesterol binds weakly to phospholipid molecules;

holding them together in pairs;

this prevents to much fluidity/increases membrane strength/helps 3 to prevent membrane rupture; (3)

3. (a) Schwann cells contain very little cytoplasm and the main component is their cell membrane; thus the myelin sheath mainly consists of cell membranes which 2 have a high phospholipid content; (2)

(b) the non-polar tails will act as an insulator preventing electron flow across the depth of the myelin sheath; the polar heads on the outside of the myelin sheath will allow electron flow/the passage of nerve impulses; this makes nerve impulses flow along the neurone but not across it; (3)

(c) HDLs remove cholesterol from cells and carry it to the blood for excretion; LDLs collect cholesterol from blood and deposit it in cells; too much cholesterol can lead to atheroma and heart disease so 3 HDLs reduce the risk/LDLs increase the risk; (3)

Exam questions – multiple choice

1 Which one of the following is **not** a major component of the cell surface membrane?

A glycolipid

B glycoprotein

C cholesterol

D triglyceride

Your answer ☐

2 If two sucrose solutions of different concentrations are separated by a partially permeable membrane, which one of the following will occur?

A The solute will diffuse from the more concentrated to the less concentrated solution.

B Both solute and solvent will diffuse until equilibrium is reached.

C The volume of the less concentrated solution will increase.

D The volume of the less concentrated solution will decrease.

Your answer ☐

3 What is the approximate thickness of the plasma membrane?

A 0.75 nm

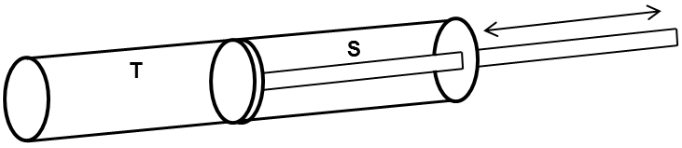
B 7.5 nm

C 75 nm

D 750 nm

Your answer ☐

4 The diagram shows a glass cylinder separated into two compartments, **T** and **S**, by a partially permeable membrane. The membrane is in the form of a sliding piston.



- the volume of **T** equals the volume of **S** ($V_T = V_S$).
- the concentration of sucrose solution in **T** is twice that in **S** ($C_T = 2C_S$).

Which one of the following will be true when osmotic equilibrium is reached?

A $C_T = 2C_S$ and $V_T = 2V_S$

B $C_T = C_S$ and $V_T = V_S$

C $C_T = 2C_S$ and $V_T = V_S$

D $C_T = C_S$ and $V_T = 2V_S$

Your answer

5 Potassium cyanide interferes with the formation of ATP. The use of potassium cyanide reduces the rate at which molecules of a certain chemical enter the cell.

Select the process by which the molecules would normally enter the cell.

A simple diffusion

B facilitated diffusion

C osmosis

D active transport

Your answer

If four solutions are made, each containing 10 g l^{-1} of one of the following molecules, which one would have the lowest water potential?

A sucrose

B glucose

C DNA

D haemoglobin

Your answer

7 The vacuolar sap of a freshwater alga *Nitella clavata* and the pond water in which it was growing were analysed. The table shows the results.

Ion	Sap concentration /mg ions dm^{-3}	Pond water concentration /mg ions dm^{-3}
Ca^{++}	26.0	2.6
Mg^{++}	21.6	6.0
Na^{+}	49.9	1.2
K^{+}	49.3	0.5

Which one of the following processes accounts for these results?

A active transport

B facilitated diffusion

C osmosis

D simple diffusion

Your answer

8. Which one of the following is **not** an acceptable description of the permeability of a cell surface membrane?

A differentially

B partially

C selectively

D semi

Your answer ☐

9 Which of these has the highest water potential?

A 5% sucrose solution

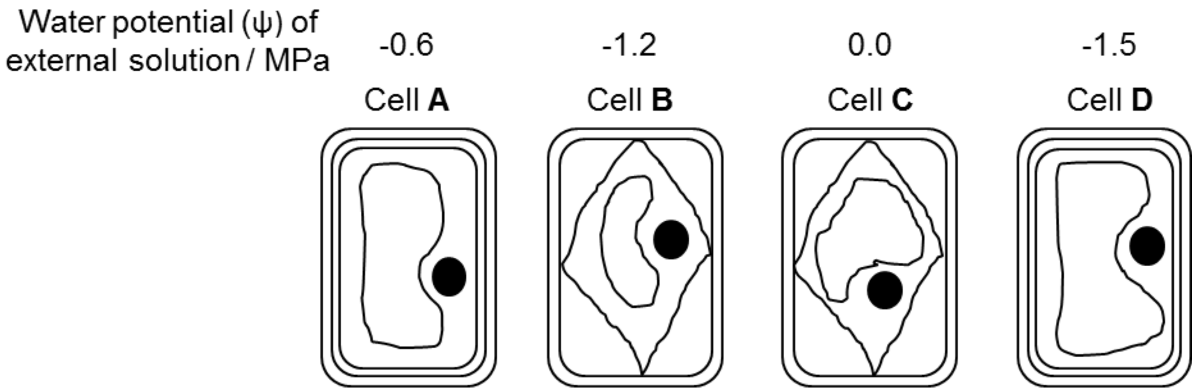
B 10% sucrose solution

C 20% sucrose solution

D pure water

Your answer ☐

10 Which diagram shows the appearance of a plant cell with an original ψ of -1.2 MPa after being placed in a solution as shown?



Your answer ☐

Answers

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