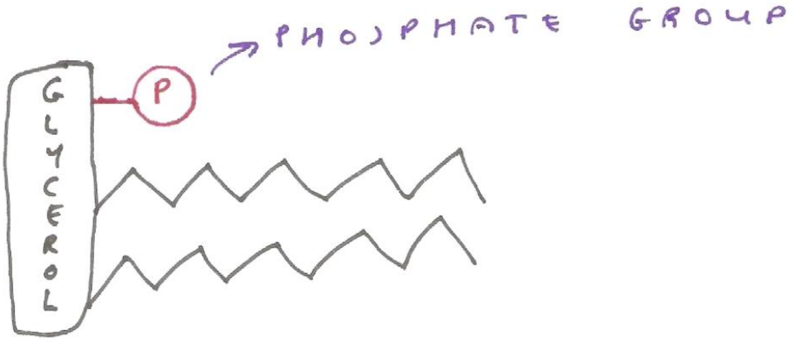
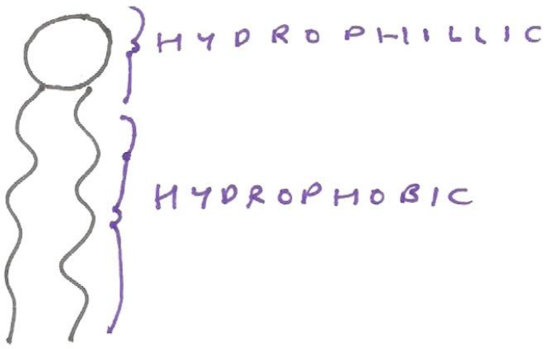
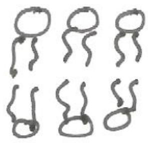
Lesson 7 – Phospholipids and cholesterol



Phospholipids are examples of macromolecules. They have the same structure as a triglyceride molecule but a **phosphate group** replaces one of the fatty acid chains.





The phosphate group is **hydrophilic** (attracts water molecules) whilst the tails are **hydrophobic**. This makes a phospholipid molecule **amphipathic**.

Phospholipids form membranes around cells and organelles; they form a **bilayer**. Within the bilayer, individual phospholipids can move around but the tails will always face inwards providing stability. In addition, only small non-polar molecules can freely pass through the cell membrane making it **partially permeable**.

Cholesterol is an example of a **sterol** (steroid alcohol); it does not consist of fatty acids and glycerol. It is a small hydrophobic molecule mainly made in the liver.

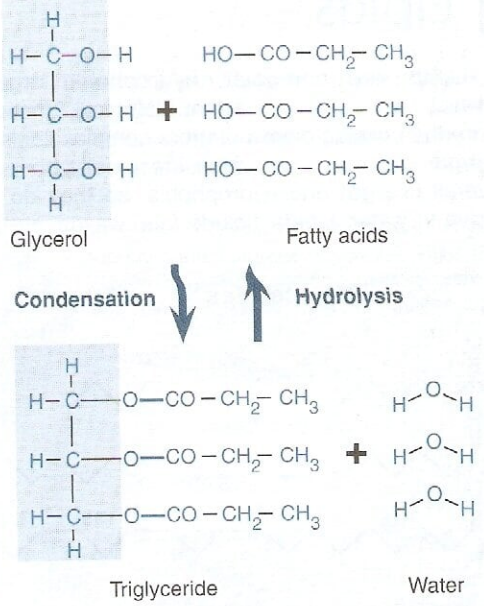
Cholesterol can sit within the phospholipid bilayer to regulate the fluidity and stability of the cell membrane.

Steroid hormones e.g. testosterone, oestrogen and progesterone are made from cholesterol. They can also pass across the cell membranes into cells to mediate their effects. Plants also contain steroids which, when absorbed, can be converted into animal hormones.

Triglycerides are formed by condensation reactions

Triglycerides form when glycerol bonds with three fatty acids. Glycerol is an alcohol containing three carbons. Each of these carbons is bonded to a hydroxyl (-OH) group.

When glycerol bonds with the fatty acid, an **ester bond** is formed and water is released. Three separate condensation reactions are involved in producing a triglyceride.

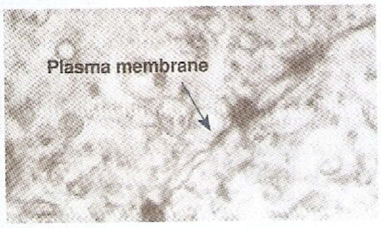


Esterification: A condensation reaction of an alcohol (e.g. glycerol) with an acid (e.g. fatty acid) to produce an ester and water. In the diagram right, the ester bonds are indicated by blue lines.

Lipolysis: The breakdown of lipids. It involves hydrolysis of triglycerides into glycerol molecules and free fatty acids.

Biological functions of lipids

Lipids are concentrated sources of energy and provide fuel for aerobic respiration.



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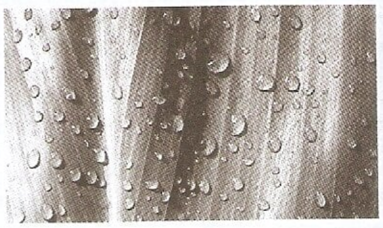
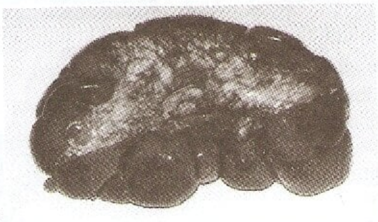
Phospholipids form the structure of cellular membranes in eukaryotes and prokaryotes.



Waxes and oils secreted onto surfaces provide waterproofing in plants and animals.



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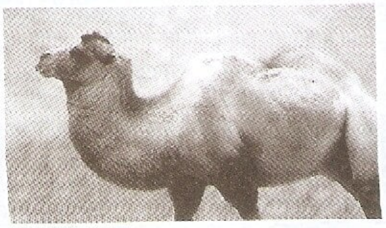
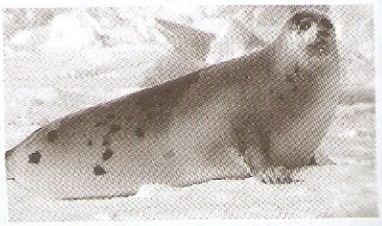
Fat absorbs shocks. Organs that are prone to bumps and shocks (e.g. kidneys) are cushioned with a relatively thick layer of fat.



Lipids are a source of metabolic water. During respiration stored lipids are metabolised for energy, producing water and carbon dioxide.



Stored lipids provide insulation. Increased body fat levels in winter reduce heat losses to the environment.

4. (a) Describe what happens during the esterification (condensation) process to produce a triglyceride:

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(b) Describe what happens when a triglyceride is hydrolysed: ___

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5. Discuss the biological role of lipids: ___

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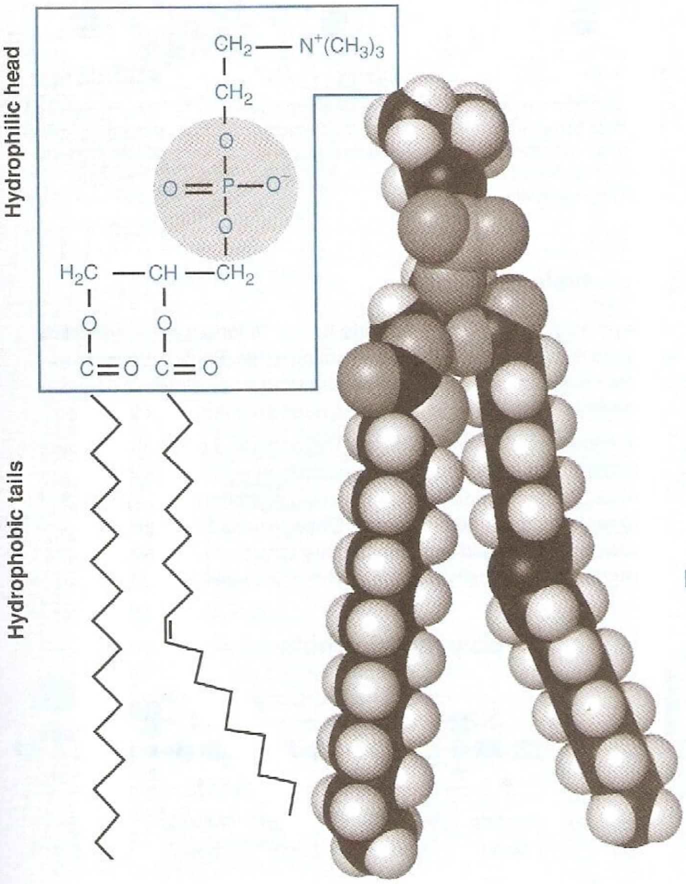
58 Phospholipids and Cholesterol

Key idea: Phospholipids and cholesterol are examples of lipids. Both are important components of cellular membranes. **Phospholipids** are similar in structure to a triglyceride except that a phosphate group replaces one of the fatty acids attached to the glycerol. Phospholipids naturally form bilayers and are the main component of all cellular membranes. Steroids are complex lipids and include the sterol lipid **cholesterol**. Cholesterol has important roles in membrane fluidity and also acts as a precursor for the production of many other steroids.

Phospholipids

Phospholipids consist of a glycerol attached to two fatty acid chains and a phosphate (PO_4^{3-}) group. The phosphate end of the molecule is attracted to water (it is hydrophilic) while the fatty acid end is repelled (hydrophobic). The hydrophobic ends turn inwards in the membrane to form a **phospholipid bilayer.**

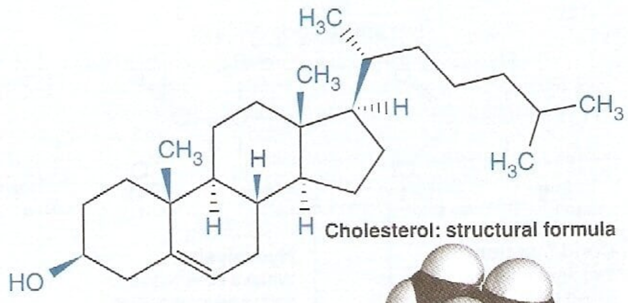


Steroids and cholesterol

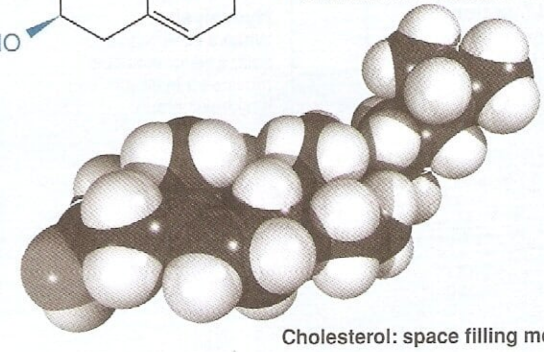
Although steroids are classified as lipids, their structure is quite different to that of other lipids. Steroids have a basic structure of three rings made of 6 carbon atoms each and a fourth ring containing 5 carbon atoms. Examples of steroids include the male and female sex hormones (testosterone and oestrogen), and the hormones cortisol and aldosterone.

Cholesterol, while not a steroid itself, is a sterol lipid and is a precursor to several steroid hormones. It is present in the plasma membrane, where it regulates membrane fluidity by preventing the phospholipids packing too closely together.

Like phospholipids, cholesterol is **amphipathic**. The hydroxyl (-OH) group on cholesterol interacts with the polar head groups of the membrane phospholipids, while the steroid ring and hydrocarbon chain tuck into the hydrophobic portion of the membrane. This helps to stabilise the outer surface of the membrane and reduce its permeability to small water-soluble molecules.



Cholesterol: structural formula



Cholesterol: space filling molecule

1. (a) Relate the structure of phospholipids to their chemical properties and their functional role in cellular membranes:

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(b) Suggest how the cell membrane structure of an Arctic fish might differ from that of tropical fish species: ___

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2. How does the structure of cholesterol enable it to perform structural and functional roles within membranes? ___

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room temperature.

4. (a) During esterification, a glycerol molecule is joined with a fatty acid. This occurs three times to form a triglyceride.
   (b) Hydrolysis of a triglyceride produces glycerol and three fatty acids

5. Key points for required answer underlined: Lipids are a more concentrated source of energy than carbohydrates or proteins, providing fuel for aerobic respiration through fatty acid oxidation. They are important as energy storage molecules, and carbohydrates and protein can both be converted into fats by enzymes and stored within adipose (fat) cells. Fat absorbs shocks and cushions internal organs such as the kidneys and heart. Stored lipids provide insulation and reduce heat loss to the environment. Lipids are a source of metabolic water, e.g. the camel's hump is a store of fat that can be metabolised to provide water as well as energy. As steroids, they are important as hormones (e.g. aldosterone, testosterone) and transport fat soluble vitamins (e.g. vitamin E). Waxes and oils provide waterproofing to the surfaces of organisms and phospholipids form cellular membranes.

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58. Phospholipids and Cholesterol (page 79)

1. (a) The amphipathic nature of phospholipids (with a polar, hydrophilic end and a hydrophobic, fatty acid end) causes them to orientate in aqueous solutions so that the hydrophobic 'tails' point in together. Hence the bilayer nature of membranes.
   (b) The cellular membranes of an Arctic fish could be expected to contain a higher proportion of unsaturated fatty acids than those of a tropical fish species. This would help them to remain functional at low temperatures.

2. Cholesterol is amphipathic. It contains a hydroxyl (-OH) group as well as a steroid ring structure and a hydrocarbon chain. The -OH group can interact with the polar head groups of the membrane phospholipids, stabilising the outer surface of the membrane and making it less permeable to some ions (less leaky). The steroid ring and hydrocarbon chain tuck into the hydrophobic part of the membrane, where the kinked structure increases membrane fluidity by preventing the phospholipids from packing too closely together.