Bio Factsheet

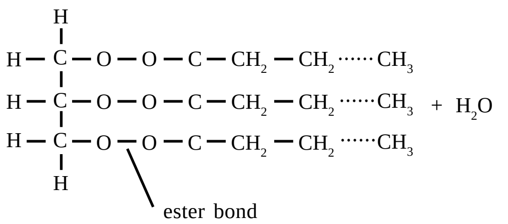
Number 42

The Structure and Function of Lipids

This Factsheet summarises the structure and function of lipids. Lipids are organic compounds found in every type of plant and animal cell. They always contain the elements carbon, hydrogen and oxygen, but the reletive amount of oxygen is less than in carbohydrates.

All lipids are **polymers** – long chains of repeating units joined together in a **condensation** reaction during which water is released. The commonest lipids are triglycerides – three fatty acids and glycerol linked by an **ester bond** (Fig 1).

Fig 1. Structure of a triglyceride



The three fatty acids may be identical but a mixture of fatty acids is also possible. Thus, many different triglyceride structures occur and this in turn means that they have a range of functions. Saturated fats are those which contain single bonds between the carbons in the hydrocarbon chain of fatty acids and these are usually solids at room temperature. Unsaturated fats, e.g. vegetable oils, are liquid at room temperature and have some/many double bonds between the carbons.

Functions

There are eight major functions of lipids.

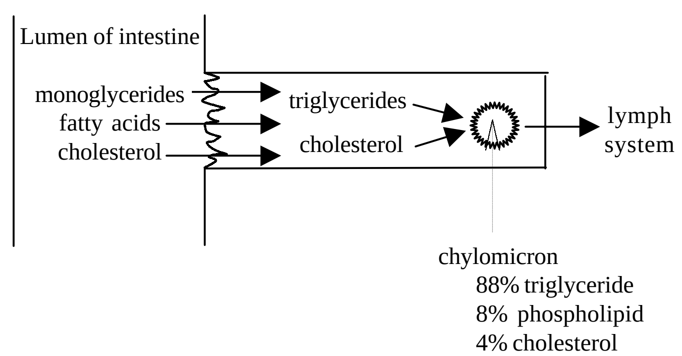
1. **Energy storage**
   Lipids form excellent energy storage molecules, e.g. as lipid deposits in the stroma of the chloroplast and as fats in seeds and adipose tissue of vertebrates. Oxidation of fats to release energy occurs in the mitochondria. As in the oxidation of glucose, acetylcoenzyme A is produced in the first stage, but so are many molecules of NAD and FAD. These are reoxidised in the electron transport chain and hence oxidation of fat yields more ATP than oxidation of carbohydrates. Weight for weight, they are therefore high-energy molecules, which is important in fruits or seeds that need to be dispersed.
2. **Structural components**
   Phospholipids usually make up 40% of cell membranes where their **amphipathic** nature (having a polar and a non-polar end) enable them to contribute to the spontaneous formation of the bilayer. Cholesterol is also a major component of animal cell membranes.
3. **Thermal insulation**
   Fat conducts heat slowly and therefore the triglycerides, which are stored as subcutaneous fat in vertebrates, are important for maintaining optimum temperature for metabolism.
4. **Mechanical protection**
   e.g. of delicate organs, such as kidneys.
5. **Electrical insulation**
   e.g. Sphingomyelin is a specialised phospholipid in the myelin sheet of nerve axons.
6. **Waterproofing**
   e.g. The waxy cuticle on the leaf epidermis or as oils on birds' feathers. The presence of waxy suberin in the Casparian strip of endodermal cells in plant roots forces water into the symplast pathway which is under the control of the nucleus. This strip therefore gives the plant control over substances entering the xylem.
7. **Buoyancy**
   Since fat is less dense than water, fat reserves provide buoyancy for aquatic animals.
8. **Precursors of many cell constituents**
   E.g. gibberellins – plant growth substances e.g. carotenes, photosynthetic pigments, coloration pigments, steroid hormones e.g. testosterone.

How do animals obtain lipids?

Since all cells contain lipids, any animal that eats a plant or animal cell will take in some lipid. Triglycerides and phospholipids are hydrolysed by lipase into glycerol and fatty acids. Since lipids do not dissolve in water, they are not easy to digest and their digestion is accelerated in vertebrates by the secretion of bile salts, which emulsify them into smaller particles, greatly increasing the surface area on which lipase can act.

Fats are hydrolysed by **pancreatic lipases** into fatty acids, monoglycerides and cholesterol. Single triglycerides, phospholipids and cholesterol then diffuse across the brush border of gut epithelial cells (Fig 2).

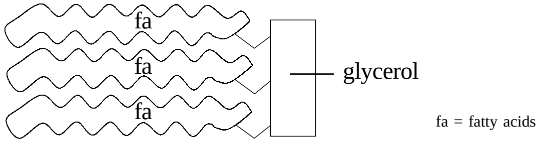
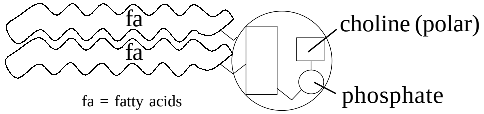
Fig 2. Uptake of lipids in ileum



Once inside the cell, triglycerides are reassembled to form **chylomicrons**. These, plus cholesterol and phospholipids move from the epithelial cells into the lymphatic system. The reassembly of triglycerides in the epithelial cells keeps the concentration of fatty acids low. This maintains the diffusion gradient between the ileum and the inside of the epithelial cells. Lipids are transported in the lymphatic system before entering the bloodstream near the heart.

Typical Exam Question
Describe the structure to function of epithelial cells of ileum.
Microvilli on luminal surface increase surface area for absorption.
Plasma membrane of epithelial cell has protein carriers for active transport.
Epithelial cells contain smooth endoplasmic reticulum for reassembly of triglycerides.

Table 1. Structure, properties and functions of Lipids

	Structure	**Properties**	**Function**
Fatty acids (Fig 1)	Composed of C, H and O and have a carboxyl – COOH group at one end. Saturated fatty acid e.g. Lauric acid $CH_3(CH_2)_{10}COOH$ Monounsaturated fatty acid e.g. Hexadecanoic acid $CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	May be saturated (no double bonds), monounsaturated (contain a single double bond), polyunsaturated (contain multiple double bonds). Animal fats are mainly saturated and solid at room temperature. Unsaturated fats tend to be liquid.	Energy source in most cells. Saturated fats contain more energy than unsaturated fats because more H, therefore more to reduce NAD/FAD during respiration. Precursors of all other lipids. Energy reserve, e.g. in seeds
Triglycerides (Fig 2)	Glycerol + three fatty acids joined by an ester bond. (May be three of the same fatty acids or may be different.) Contain many C-H bonds 	Determined by nature of fatty acids. Animal triglycerides tend to have (i) larger fatty acids (ii) more saturated fatty acids than plant lipids. Hydrolysis of triglycerides yields metabolic water.	Form in which fatty acids are transported around the body and stored (in adipose tissue) Vital in, for example, desert animals, e.g. camel
Phospholipids	Similar to triglycerides but one fatty acid is replaced with a molecule of phosphoric acid. 	Phosphate-choline 'head' of molecule is polar and hydrophilic. It therefore orientates itself towards any aqueous medium. The fatty acid 'tails' are non-polar and hydrophobic and therefore orientate themselves away from any aqueous layer.	Phospholipids form spontaneous bilayer and are therefore essential components of cell and organelle membranes. Phospholipids are also components of lung surfactants.
Steroids	Cholesterol forms the basis of all steroids e.g. oestrogen/testosterone.	Has a hydrophilic (polar) component and a hydrophobic (non-polar) part and therefore contributes to the membrane bilayer.	Cholesterol is only found in animals where it is a component of and provides fluidity to the cell membranes and is a precursor of bile salts and sex hormones (e.g. oestrogen).
Glycolipids	Combination of carbohydrate and lipid	Carbohydrate portion provides cell 'signature' allowing recognition.	Form hydrogen bonds with water molecules outside the cell membrane, thus stabilising the membrane. Carbohydrate portion may be 'recognised' by antibodies, hormones, etc.
Lipoproteins	Combination of lipid and protein. Large, water-soluble molecules	Polarity confers solubility.	Transport lipids in the blood. Low density lipoproteins (LDLs) transport cholesterol from cells into the blood. High-density lipoproteins (HDLs) remove cholesterol from the blood.
General	Non polar, compact	Insoluble in water Less dense than water Conduct heat poorly	No osmotic effect/cannot diffuse away therefore excellent storage molecule. Excellent waterproofing, e.g. waxy cuticle on plant leaf epidermis and in insect exoskeleton. Provide buoyancy. Subcutaneous fat provides insulation – important for endotherms.

Acknowledgements; *This Factsheet was researched and written by Kevin Byrne*

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