S5 BIOLOGY (MR.SSEKIBUULE)

Chemicals of life cont…

Test for starch

Iodine test:

Starch forms a blue-black polyiodide complex with iodine solution.

Activity

TEST	OBSERVATION	DEDUCTION
IODINE TEST		

LIPIDS

Lipids are a large and variable group of organic compounds.

Like carbohydrates, they contain carbon, hydrogen and oxygen, although the proportion of oxygen is much smaller in lipids.

The chemistry of lipids is so variable to be defined precisely; however, true lipids are formed by condensation reactions between **fatty acids** and an **alcohol** (commonly glycerol**).**

They include the natural **fats** and **oils** which are compounds of fatty acids and glycerol.

Lipids are insoluble in water and soluble in organic solvents and are sometimes classified loosely as water-insoluble organic substances which can be extracted from cells by organic solvents such as ether, chloroform and benzene.

Constituents of lipids

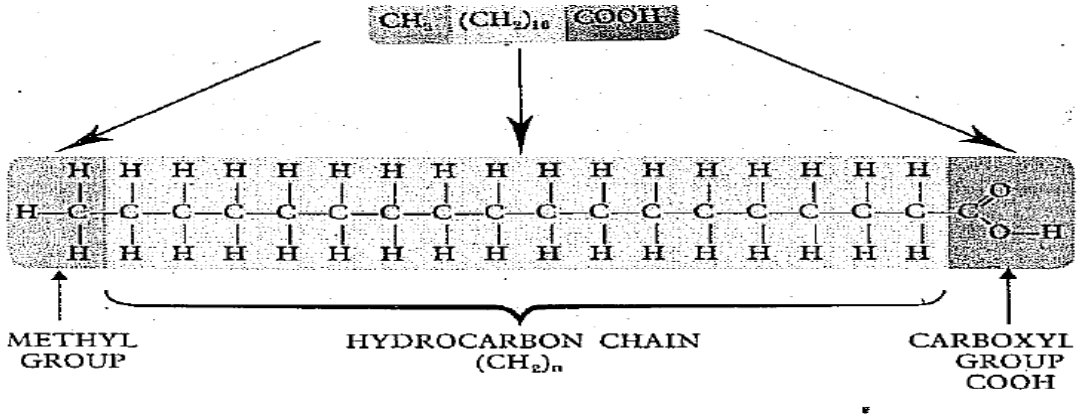
1. Fatty acids

The fatty acids show considerable variation and the nature of a particular lipid depends on the fatty acid it contains.

They have a general formula, $CH_3(CH_2)nCOOH$ where n varies but generally around 16. Most naturally occurring fatty acids have an even number of carbon atoms between 12 and 22, most commonly 16 and 18. Therefore the fatty acids have long hydrocarbon chain/tail terminating/ending in the carboxyl (COOH) group.

For example, stearic acid, the common constituent of adipose tissue has 16 CH_2 groups, and its formula is $CH_3(CH_2)_{16}COOH$.

Its structure formula is:



Most of the properties of the lipids are determined by the nature of hydrocarbon chain including solubility.

As there are no polar groups in the chain, fatty acids are insoluble in water (hydrophobic).

Fatty acids with one or more carbon-carbon double bonds in their chain are described as **unsaturated** fatty acids. These do not contain the maximum possible number of hydrogen atoms. Fatty acids with no carbon-carbon double bonds in the hydrocarbon chain are described as **saturated** fatty acids and they contain the maximum possible number of hydrogen atoms. Lipids containing unsaturated fatty acids are called unsaturated lipids and those containing only saturated fatty acids are called saturated lipids.

Unsaturated fatty acids melt at much lower temperatures than saturated fatty acids because the double bonds cause kinks/bends which disturb the close packing. Consequently, lipids made from these fatty acids are usually liquids at room temperature, for or example, oleic acid, the chief constituent of olive oil is an unsaturated lipid and is liquid at normal temperatures (melting point 13.4^{o}C) whereas palmic and stearic acids which are saturated lipids (melting points 63.1^{o}C and 69.6^{o}C) are solid at normal body temperatures.

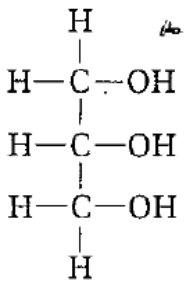
Assignment:

Account for the fact that cells of poikilothermic ('cold blooded') animals usually have a higher proportion of unsaturated fatty acids than homoeothermic ('warm blooded') animal.

2. Alcohols

The most common alcohol used in the formation of lipids is glycerol.

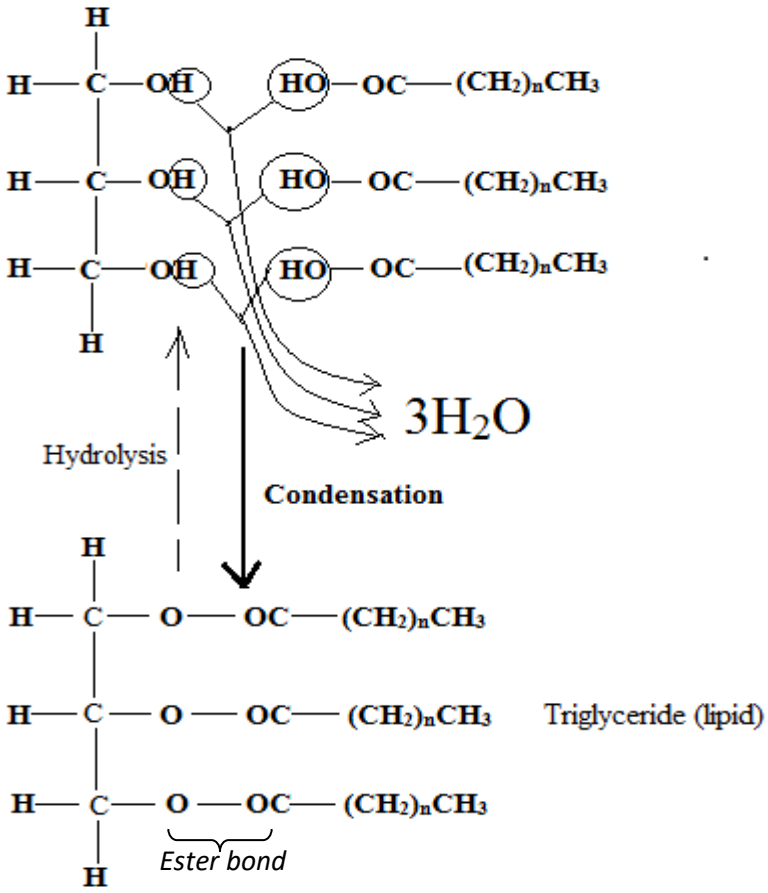
The glycerol has three carbon atoms each having an –OH group attached to it.



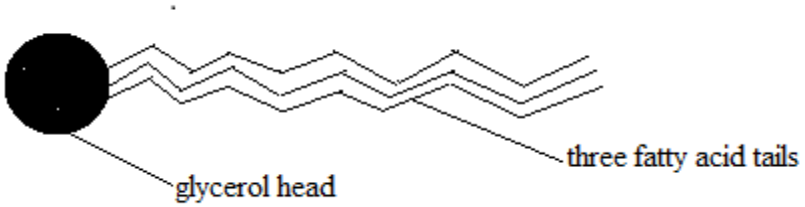
The lipids made from glycerol are called triglycerides. Therefore, most of the lipids are triglycerides.

Formation of a lipid

In the synthesis of lipids (fat or oil), three fatty acid molecules combine with one molecule of glycerol to form a triglyceride. Glycerol has three hydroxyl (-OH) groups and each of them undergoes a condensation reaction with –OH group of the COOH group of a fatty acid to form a lipid called **triglyceride**. This leads to the loss of three water molecules and an oxygen bond known as **ester bond** is established in between the glycerol and each of the fatty acids.



Simple representation of a lipid:



The particular fat or oil (lipid) resulting from this process depends on the fatty acids involved. All the three fatty acids may be the entirely the same or different, saturated or unsaturated complex or comparatively simple. It is this that determines the characteristics of individual fats and oils.

Properties of triglycerides

Triglycerides are the commonest lipids and they have the following properties

- ✓ They can either be solids or liquids at room temperature (20^{o}C). Triglycerides which are solids at room temperature are called **fats** and those which are liquids are called **oils.**
- ✓ The higher the proportion of unsaturated fatty acids, the more likely they are liquids at a given temperature.
- ✓ Triglycerides are non-polar, meaning that they do not form hydrogen bonds with water and therefore do not dissolve in water-they are hydrophobic
- ✓ Being non-polar, they dissolve in organic solvents such as ethers, chloroform and benzene.
- ✓ They are less dense than water and therefore float
- ✓ Their hydrocarbon tails may vary in length according to the particular fatty acids used.

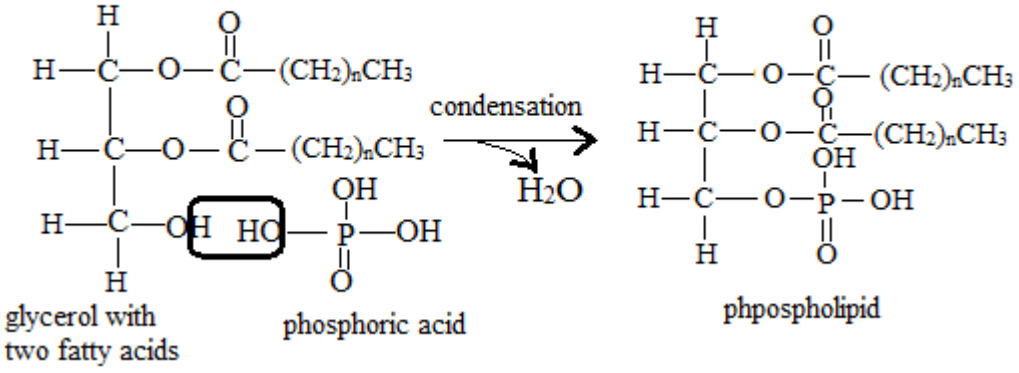
Phospholipids

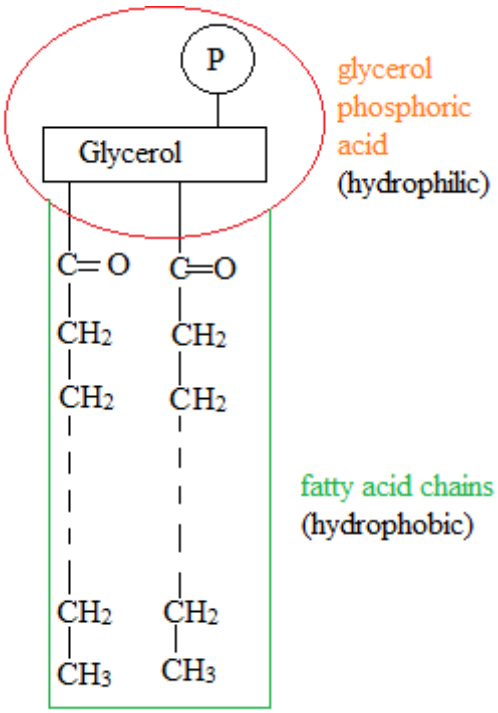
Phospholipids are lipids containing a phosphate group.

The most common type of phospholipid is formed when one of the three –OH groups combine with a phosphoric acid instead of a fatty acid. The other two –OH groups combine with fatty acids as in the formation of triglyceride.

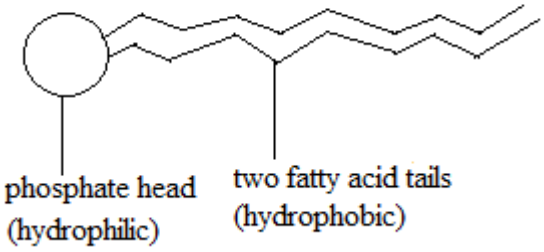
The molecule consists of a phosphate head, with two hydrocarbon tails from the two fatty acids.

Illustration:





Simple representation of a phospholipid:



The phosphate head is hydrophilic or water-loving (attracts water since it carries an electric charge) and the hydrocarbon tail is hydrophobic (repels water/insoluble in water). Having one end of the phospholipid attracting water (soluble in water) and the other end repelling it (insoluble in water) is important in the formation of cell membranes.

Glycolipids

Glycolipids are association of lipids with carbohydrates

The carbohydrate forms a polar head to the glycolipid molecule.

Glycolipids like phospholipids are found in cell membranes where they are involved in cell-cell recognition and may act as receptor sites for chemical signals.

Waxes

Waxes are formed by combination of fatty acids with an alcohol other than glycerol. This alcohol is much larger than glycerol, and therefore waxes have a more complex chemical structure.

The main role of waxes is waterproofing plants and animals, but they also form storage compounds in a few organisms e.g. castor oil and in fish.

Functions of lipids

1. **An energy source**-A major function of lipids is to act as energy stores. Upon oxidation, a given mass of lipids yields more energy than an equal mass of carbohydrate. This is because lipids have higher proportion of hydrogen and almost insignificant proportion of oxygen compared with carbohydrate. This means lipids are excellent energy stores since small mass stores a significant amount of energy. This makes them especially useful for animals where locomotion requires mass to be kept to a minimum. In plants they are useful in seeds where dispersal by wind or insects makes small mass a necessity. This explains the abundance of oils extracted from seeds and fruits, e.g. olive, linseed, caster, peanut, coconut and sunflower. Their insolubility is another advantage, as they are not easily dissolved out of cells.
2. **Insulation**-Fats are poor conductors of heat and therefore they are uses insulators in some animals. In endothermic animals, such as mammals, fats are stored beneath the skin (subcutaneous fat) where it helps to retain body heat. In aquatic mammals, such as whales, seals and manatees, hair is ineffective as an insulator because it cannot trap water in the same way as it can air. These animals therefore have extremely thick subcutaneous fat, called blubber, which forms an effective insulator.
3. **Protection**-Another secondary use to which stored fat is put is as packing material around delicate organs. Fat surrounding the kidneys, for instance helps to protect them from physical damage.
4. **Buoyancy**-Being less dense than water, lipids aid buoyancy of aquatic vertebrates such as sharks, seals and whales. Sharks have extremely fatty livers which make up to 25% of their body volume. Oils on bird feathers are especially important in keeping aquatic varieties afloat.
5. **Water proofing**-Terrestrial plants and animals have a need to conserve water. Animal skins produce oil secretions, e.g. from the sebaceous glands in mammals, which waterproof the body. Oils also coat the fur, helping to repel water which would otherwise wet it and reduce its effectiveness as an insulator. Birds spread oil over their feathers, from a special gland near the cloaca, for the same purpose. Insects have waxy cuticle to prevent evaporative loss in the same way the plant leaves have one to reduce transpiration.
6. **Cell membranes**-Phospholipids are major components of the cell membranes and contribute to many of its properties

   Other functions of lipids include

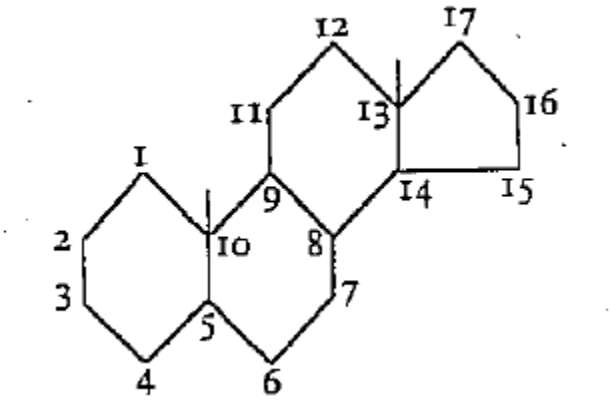
   - Plant scents are fatty acids (or their derivatives) and so aid the attraction of insects for pollination.
   - Bees use wax in constructing their honeycombs,
   - component of nerve fibres where it form the myelin sheaths,
   - Fats are oxidized to produce water is can be very useful to some desert animals, such as the kangaroo rat which stores fat for this purpose.

Assignment:

1. *Give the structural and physiological functions of lipids*
   - ***(i)*** *Structural functions*
   - ***(ii)*** *Physiological functions*
2. *Give reasons why lipids are better storage materials than carbohydrates.*
3. *Explain why glycogen is a preferred as storage material in high metabolic centres of mammals such as muscles and liver to fats (lipids)*

Steroids

Steroids are a biologically important group of compounds which have certain properties in common with lipids, for example their insolubility in water and solubility in organic solvent. But structurally, they are quite different from a typical lipid.
The general structure of steroid is



Four rings of carbon atoms are linked together to form the structure as shown above. It consists of 17 carbon atoms and the various steroids differ in the side group attached to the carbon atoms.
A typical steroid is **cholesterol** which occurs in the plasma membrane of animals and in the membranes of various organelles.
Other important steroids include *vitamin D, the bile acids, sexual hormones* e.g. oestrogen, progesterone and testosterone and a number of hormones secreted by adrenal cortex, *the adrenal corticotrophic hormones* e.g. aldosterone and cortisome.
Cholesterol is probably the source from which these hormones are synthesized in the body
Cholesterol is not found in plants but the latter contain other steroids collectively known as phytosterols.

Sources of cholesterol

Biosynthesis in the liver and intestines
By ingestion of meat, sea food, eggs and dairy products

Effects of excess cholesterol in the body

Cholesterol is insoluble in water but can be carried in blood plasma in the form of lipoproteins. The balance of these lipoproteins is usually maintained by special receptors in the liver cells but

saturated fats in the diet decrease their activity and hence a rise in plasma cholesterol. Deposits of crystalline cholesterol and droplets of cholesterol esters can cause thickening of the artery wall (atherosclerosis); this can lead to heart attacks (from blocking the coronary arteries), strokes (brain arteries blocked) or blockage of arteries of the legs.

Lipoproteins

Membranes are lipoproteins. It is a form in which lipids are transported in blood plasma and lymph. A decrease/damage of lipoproteins means that lipids can be transported in the blood plasma, leading to their accumulation in blood; this can lead to heart disease.

Lipids and the diet

The human body can synthesise most fatty acids from the products of carbohydrates and protein metabolism. However, there are certain unsaturated fatty acids which cannot be synthesized and must be supplied in the diet. These are known as **essential** fatty acids. Examples of essential fatty acids include linoleic and linolenic fatty acids. They are abundant in seed oils and vegetables, and only small quantities of them are required. They are found in cytoplasm, mitochondria and cell membranes where they are necessary for proper structure and functioning of cells.

Shortage of essential fatty acids cause symptoms like retarded growth, reproductive deficiency and kidney failure.

Saturated fats are more readily converted by the human body into steroid cholesterol which has been correlated with certain types of heart disease. Therefore, lower intake of animal fat (saturated fats) and replacement of butter (containing animal fat) by margarine with high concentration of unsaturated fats is recommended

Assignment:

Compare lipids and steroids

Test for Lipids

Emulsion test:

Basis for the test:

Lipids are immiscible (insoluble) in water but soluble in alcohol (an organic solvent). Adding water to a solution of the lipid in absolute ethanol results in an emulsion of tiny lipid droplets and gives a white emulsion/suspension.

Activity

TEST	**OBSERVATION**	**DEDUCTION**
EMULSION TEST		