LIPIDS (FATS)

COMMON SOURCES

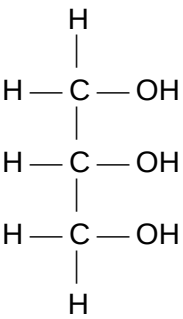
- Meat, dairy products and fish.

CHEMICAL COMPOSITION

- All fats contain the elements carbon, hydrogen and oxygen and sometimes other elements such as phosphorous.
- Lipids can be divided into fats, oils and waxes. They are non-polar molecules and so do not dissolve in water.
- Lipids are required by the human body for the following reasons:
- They form part of the structure of cell membranes
- A layer of fat underneath the skin insulates the body against extreme temperatures
- They can be used as an alternative energy supply to glucose

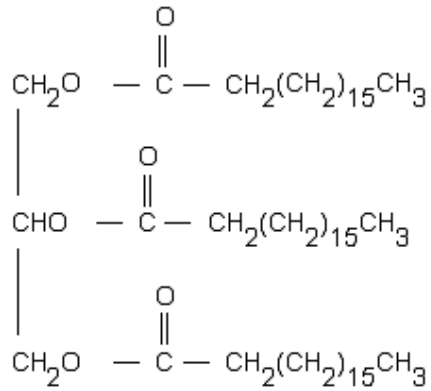
Fats are composed of 2 main chemical units – Glycerol and fatty acids.

Glycerol is a molecule with 3 hydroxy groups. Its structural and molecular formulae are given below.



Molecular formula = $\mathbf{C_3H_8O_3}$

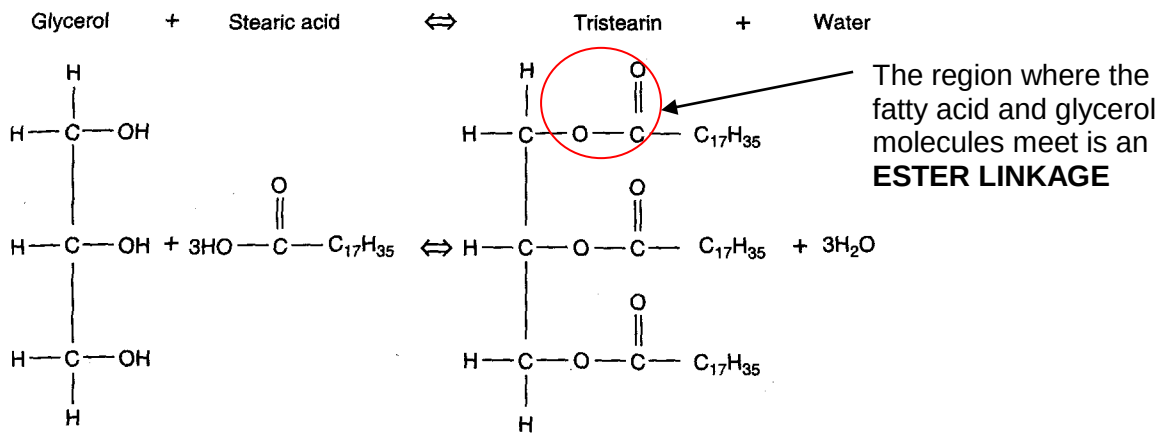
Fatty acids are carboxylic acids with a very long hydrocarbon chain. Recall that carboxylic acids contain the carboxyl functional group (COOH). An example is tristearin whose structural and molecular formulae are shown below:



Molecular formula = $\mathbf{C_{17}H_{35}COOH}$

A fat molecule is produced when 3 fatty acid molecules react with 1 glycerol molecule. For this reason fats are also referred to as **triglycerides**.

The equation below shows the reaction between glycerol and the fatty acid stearic acid to produce the triglyceride Tristearin. Water is a by-product of this equation so it is called a **condensation reaction.**



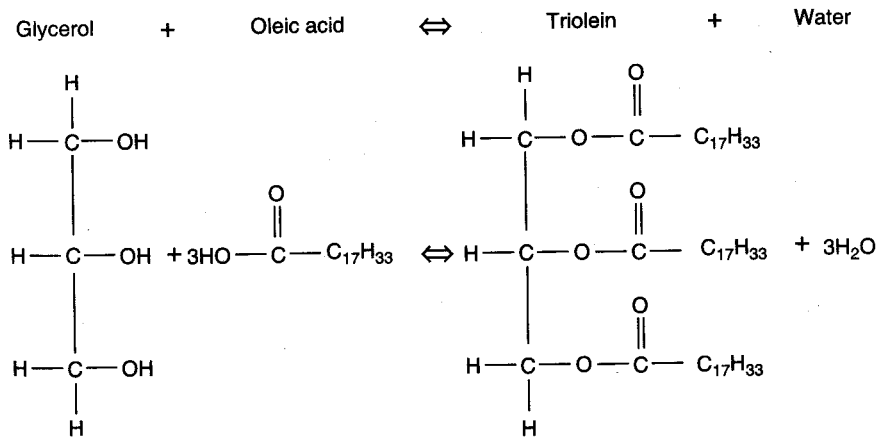
Each OH group on the glycerol molecule reacts a fatty acid molecule.

The tristearin molecule is an example of a **saturated fat**. This is because the hydrocarbon chains ($C_{17}H_{35}$) contain only single bonds between carbon atoms.

The hydrocarbon chains of saturated fats have the general formula $C_n H_{2n+1}$

Saturated fats are very difficult to digest due to the lack of reactivity of single C — C bonds. As a result the long molecules of saturated fats enter the blood stream unchanged. They tend to accumulate in the inner walls of the arteries and cause a condition known as **atherosclerosis** or "hardening of the arteries". This build up of fat deposits restricts blood flow through the body.

An **unsaturated fat** is one where the hydrocarbon chains contain at least one **double bond**. If the hydrocarbon chains contain one double bond it is known as **a mono-unsaturated fat**. When glycerol reacts with the mono-unsaturated fatty acid oleic acid, the triglyceride, triolein is formed.



The hydrocarbon chains of mono-unsaturated fats have the general formula $C_n H_{2n-1}$

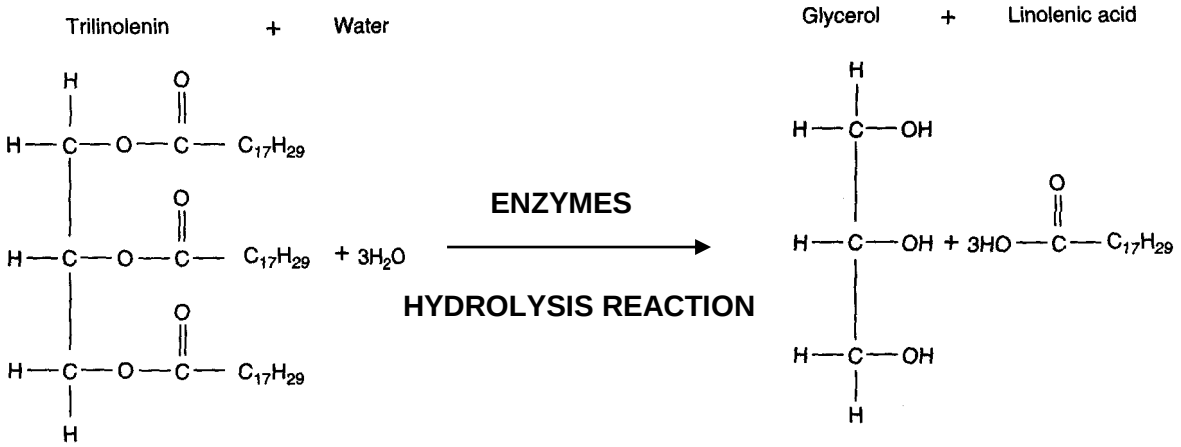
If the triglyceride formed contains hydrocarbon chains with more than one double bond it is known as a **polyunsaturated** fat. An example of this is Trininolenin which is formed from glycerol and Linoleic acid. Trininolenin has $C_{17}H_{29}$ hydrocarbon chains. There is no set general formula for polyunsaturated fats because there could be any number of double carbon to carbon bonds in the molecule. If mono-unsaturated fats have the general formula C_nH_{2n-1}, then polyunsaturated fats have the formula C_nH_{2n-3}, C_nH_{2n-5} etc.

- Fats and fatty acids are insoluble in water. Fatty acids have the carboxyl group which is capable of forming bonds with water but the much longer insoluble hydrocarbon chain has the greater influence on the molecule's properties.

DIGESTION OF FATS

Fats are digested in the small intestine. Bile is released from the gall bladder into the small intestine. The bile breaks down the fat into small droplets and an emulsion is formed. The smaller fat droplets expose a greater surface area to digestive enzymes that are released from the wall of the small intestine and the pancreas. The greater surface area of the fats and the digestive enzymes help increase the rate of fat digestion.

The chemical digestion of fat is a **hydrolysis reaction** and is the reverse reaction to that which occurs when fats are formed from the condensation reaction of fatty acids and glycerol. The reaction below shows the hydrolysis of Trilinolenin.



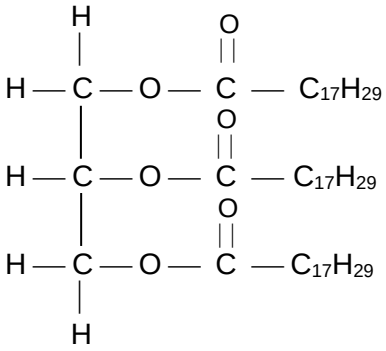
The products of fat digestion, which are fatty acids and glycerol, are absorbed through the walls of the small intestine via lymph vessels. Here they are reassembled into triglycerides, stored as adipose tissue (fat storage) or used as an energy source. The fatty acids can be used as a fuel for cellular respiration:

$$CH_3(CH_2)_{14}COOH(aq) + 23O_2(g) \rightarrow 16CO_2(g) + 16H_2O(l) \quad \Delta \mathbf{H = -}$$

QUESTION 1
Which of the following fatty acids can form a triglyceride that causes the disease atherosclerosis?

A $C_{17}H_{35}$
B $C_{17}H_{33}$
C $C_3H_8O_3$
D $C_{17}H_{29}$

QUESTION 2
The following triglyceride is known as an unsaturated fat.



(a) What is an unsaturated fat?

(b) Circle the ester linkage(SD).

(c) Name the 2 chemicals that are required for the hydrolysis of this compound.

(d) Give the structural and molecular formulae of the 3 carbon molecule that is a product of this hydrolysis.

(e) Give the molecular formula of the fatty acid from which this fat was derived. Write a balanced chemical equation showing this molecule undergoing cellular respiration.

(f) Name the 2 products of fat digestion. List 2 uses that the products of fat digestion have in the human body.

SOLUTIONS

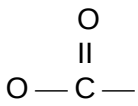
QUESTION 1

A (saturated fats have the general formula C_nH_{2n+1})

QUESTION 2

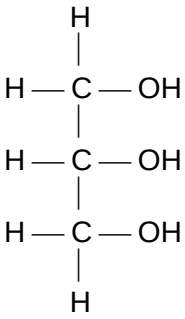
(a) A fat that has a hydrocarbon chain with only single carbon to carbon bonds. General formula = $C_nH_{2n-1 \text{ or } 3, 5, 7 \text{ etc.}}$

(b)



(c) Water and enzymes

(d)



(e) **2** $C_{17}H_{29}COOH$ (s) + **47** O_2 (g) → **34** CO_2 (g) + **30** H_2O (l)

(f) Fatty acids and glycerol. These 2 chemicals can be reassembled into fat and stored in the body as adipose tissue. The fatty acids can be used as an energy source.