Fats and Oils
Learning Outcomes

By the end of these lessons you will be able to:

- Explain the chemistry and structure of edible fats and oils.
- Explain the difference in melting points of fats and oils in terms of structural differences.

Fats in the Diet

Å Fats provide more energy per gram than carbohydrates.

Å Fat molecules are insoluble, and tend to group together and form a large droplet. This is how fat is stored in the adipose tissue.

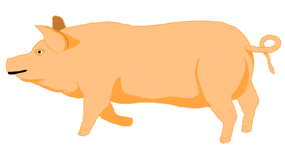
Å We store our extra energy as fat. The type of fat we eat is important. Animal fats contain important fat soluble vitamins. Oils, are thought to be healthier than solid fats, as they are less likely to be deposited inside our arteries. However, there is an ongoing debate about which fats are better for us.

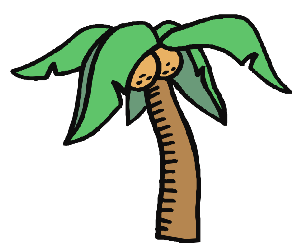
Å Polyunsaturated fats are considered to be less potentially harmful to the heart.

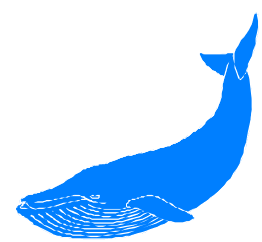
Fats and oils

Naturally occuring

- Animal fat
  - lard
  - suet
- Vegetable oil
  - sunflower oil
  - coconut oil
- Marine oil
  - cod liver oil
  - whale oil





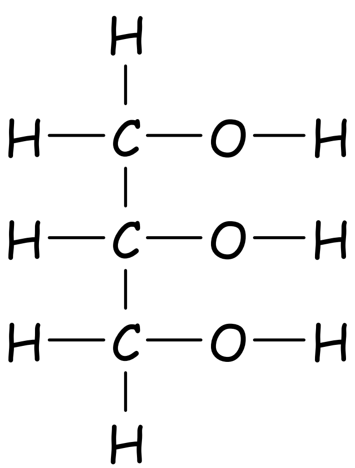


Fats and Oils

50% of your brain is fat!

Fats and oils are a range of substances all based on glycerol, propan-1,2,3-triol.

Natural fats and oils are a mixture of triglyceride compounds.



Glycerol
propan-1,2,3-triol

Each -OH group can combine chemically with one carboxylic acid molecule.

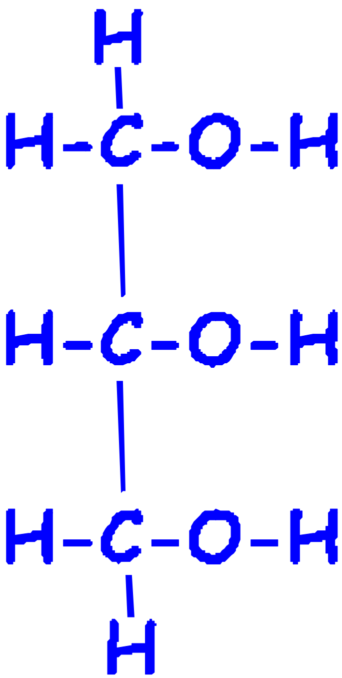
The resulting molecules are fats and oils. They are described as triglycerides.

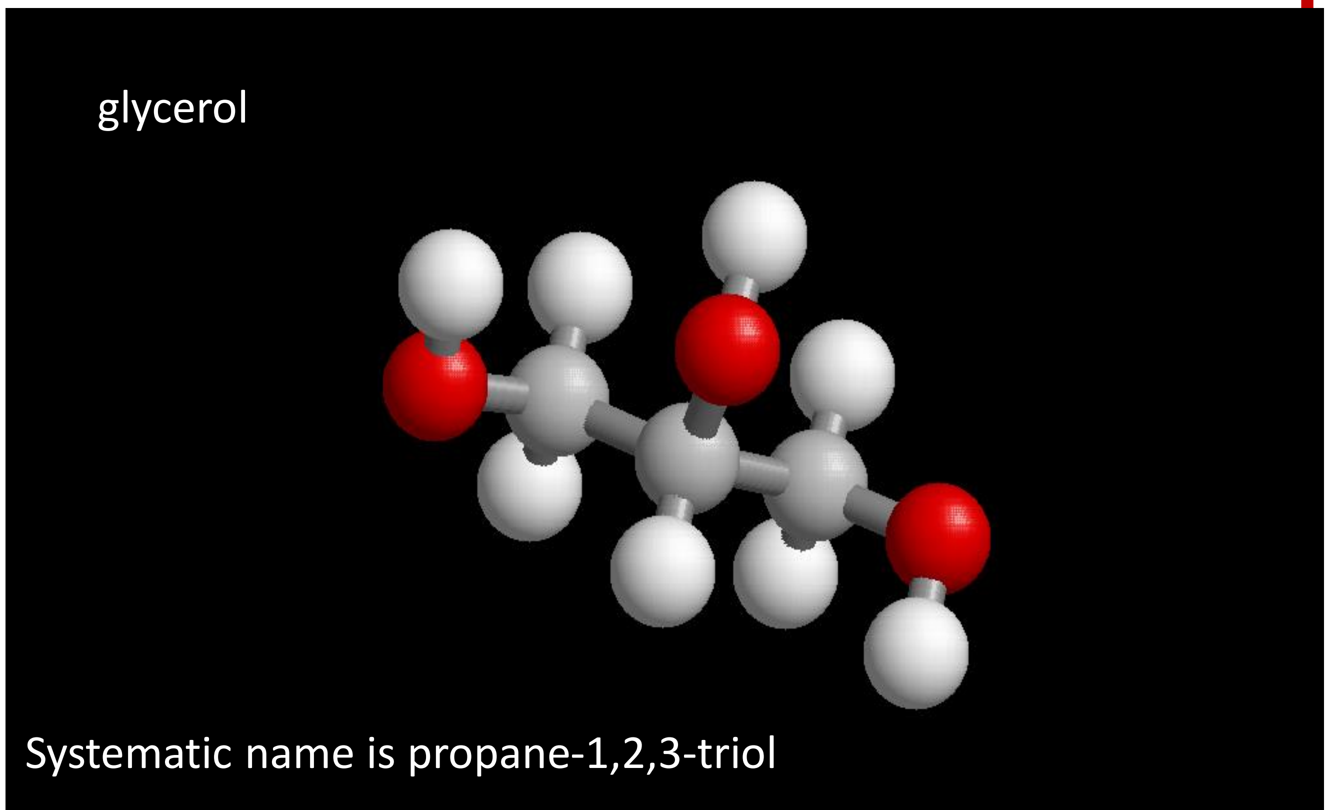
The hydrocarbon chain in each carboxylic acid can be from 4 to 24 C's long.

The C's can be single bonded (saturated) or double bonded (unsaturated).

Fats and oils

Both fats and oils are built from glycerol; an alcohol with three -OH groups.

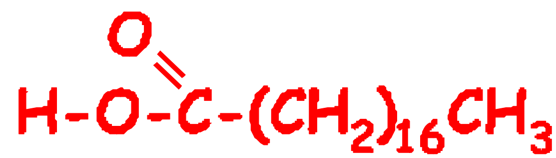


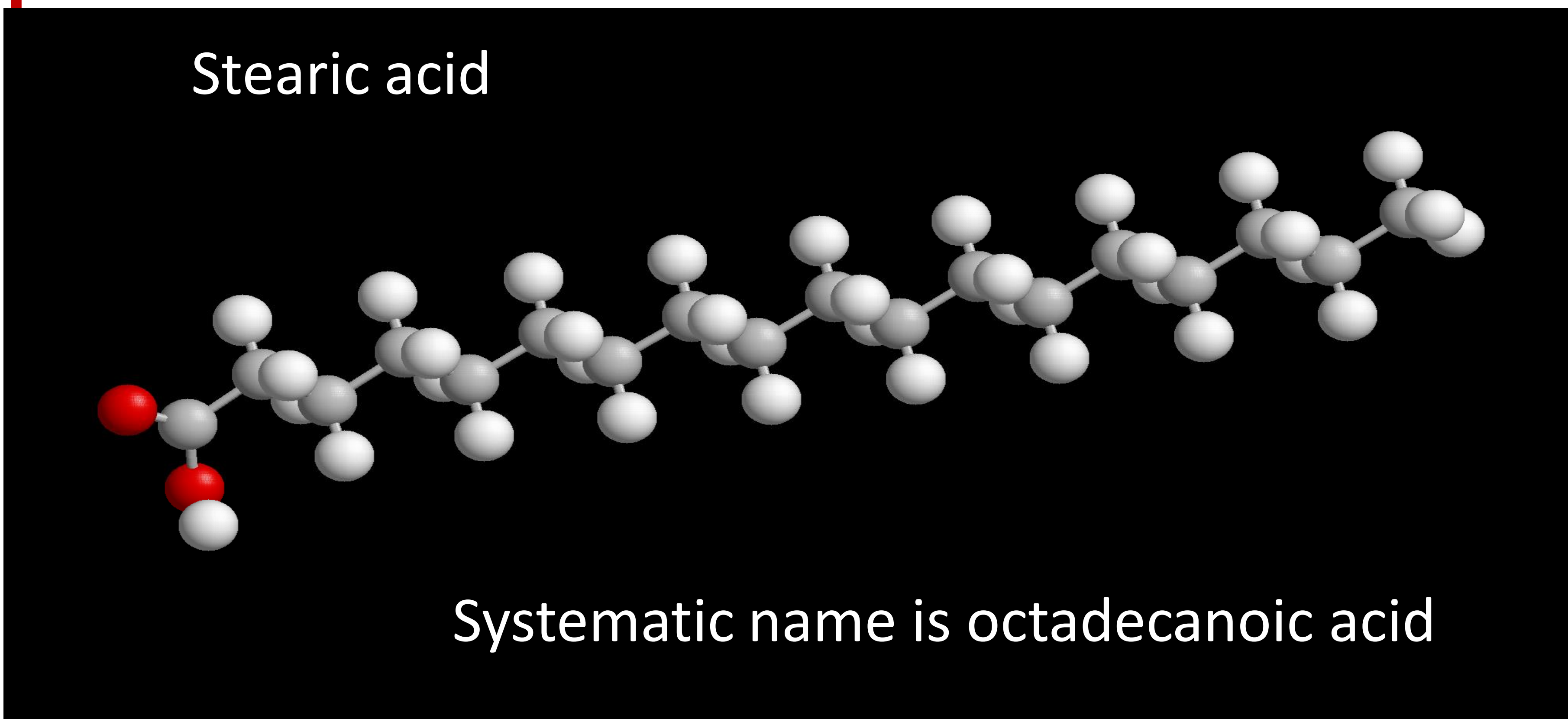


The other components of fat molecules are carboxylic acids.

Long chain carboxylic acids are known as Fatty Acids.

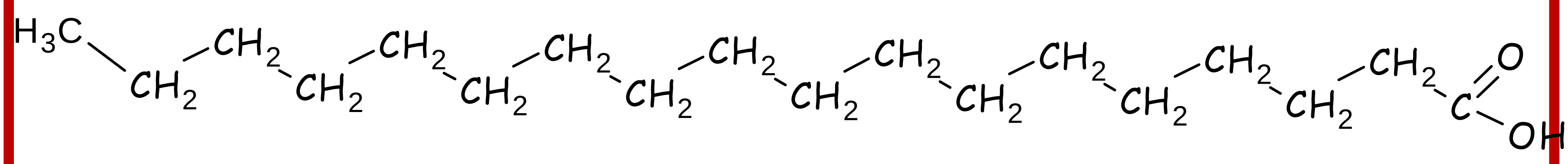
One such fatty acid is Stearic acid:



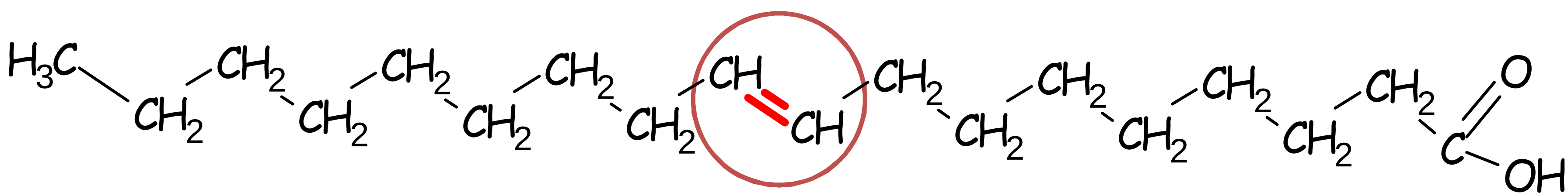


Examples of Fatty Acids

$C_{17}H_{35}COOH$ $CH_3(CH_2)_{16}COOH$ Stearic Acid (suet, animal fat) Saturated



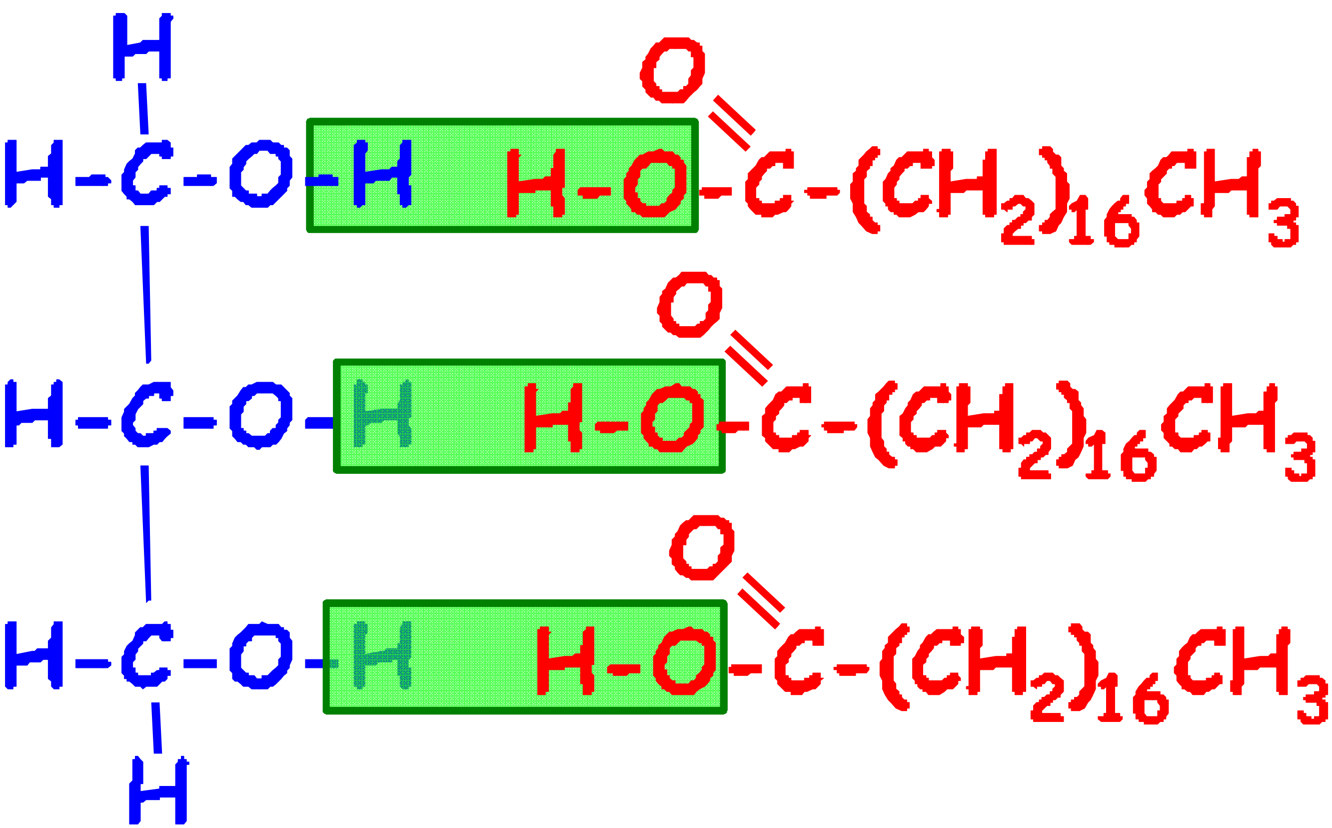
$C_{17}H_{33}COOH$ $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$ Oleic Acid (olive oil) Unsaturated



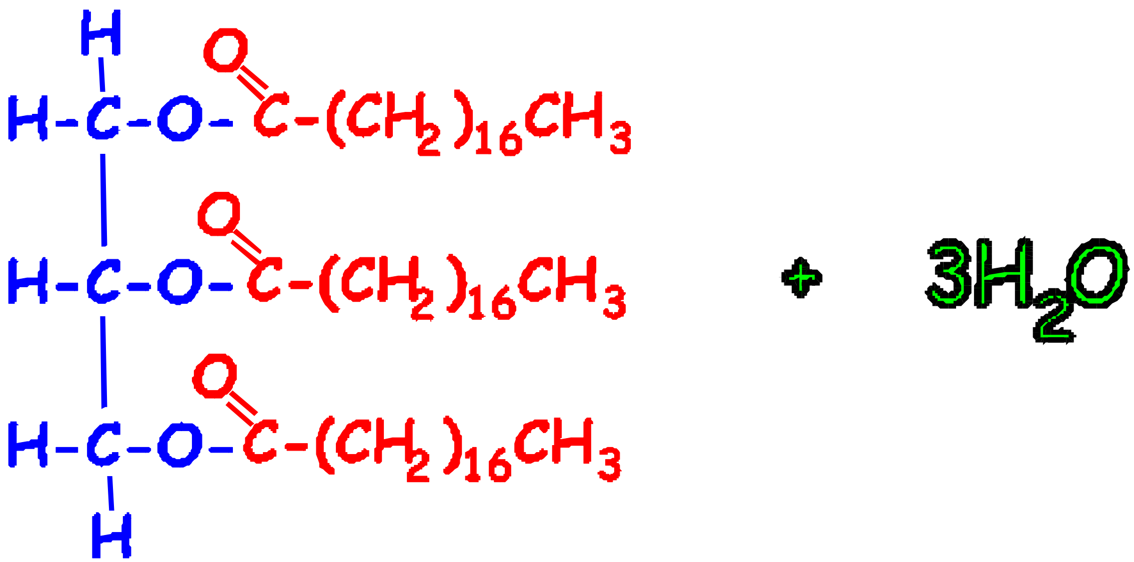
The glycerol molecule and fatty acids form ester links.

Fats and oils are ESTERS made from

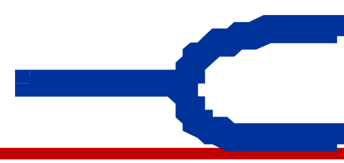
glycerol and long chain carboxylic acids



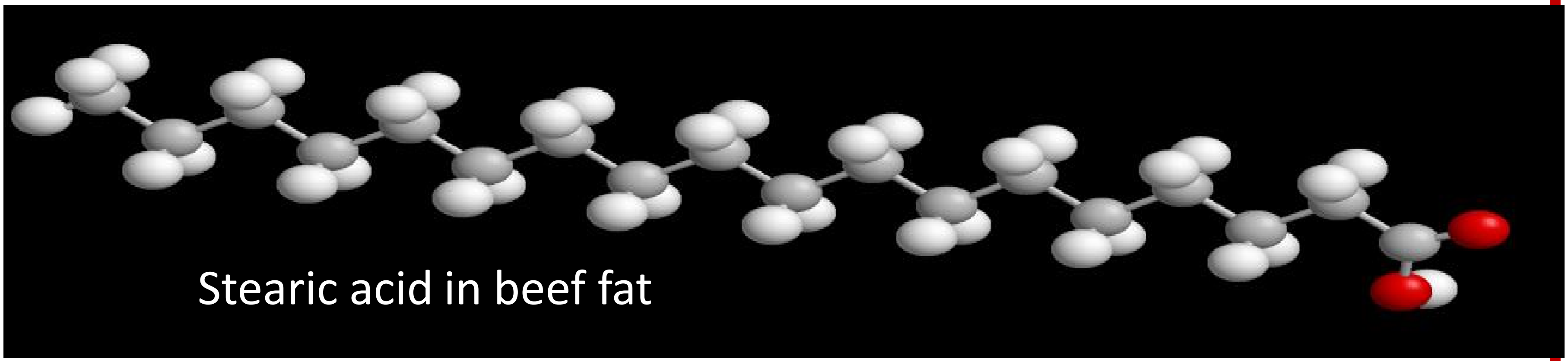
The formation of the ester links is an example of a condensation reaction. Formation / removal of water in the condensation reaction gives -



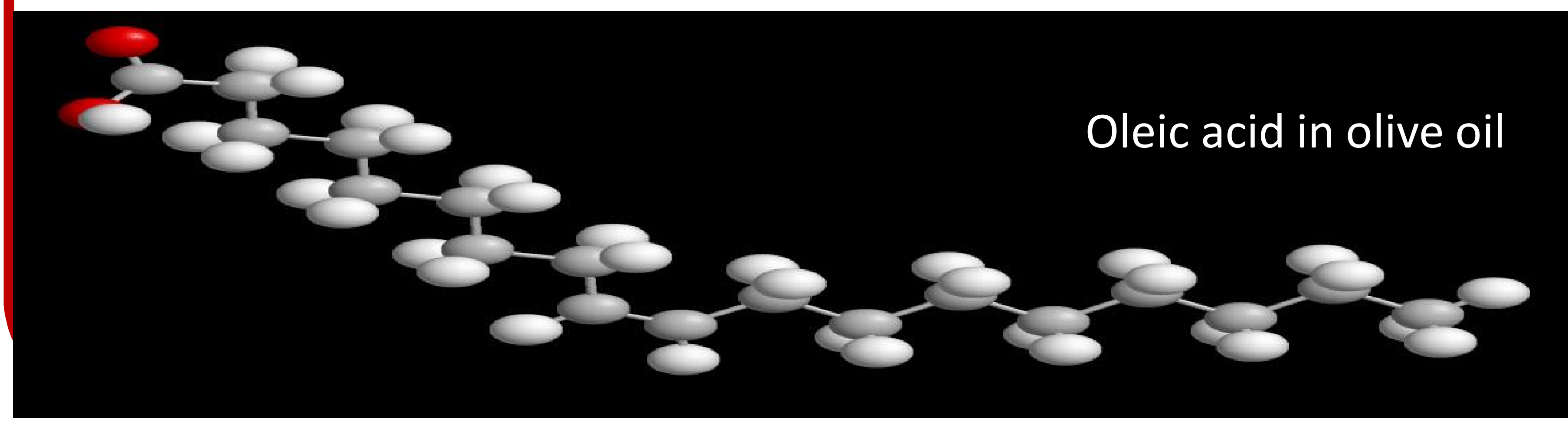
The molecular formula shown above suggests that the fat molecule is shaped like an E, but the molecule is actually shaped more like this:



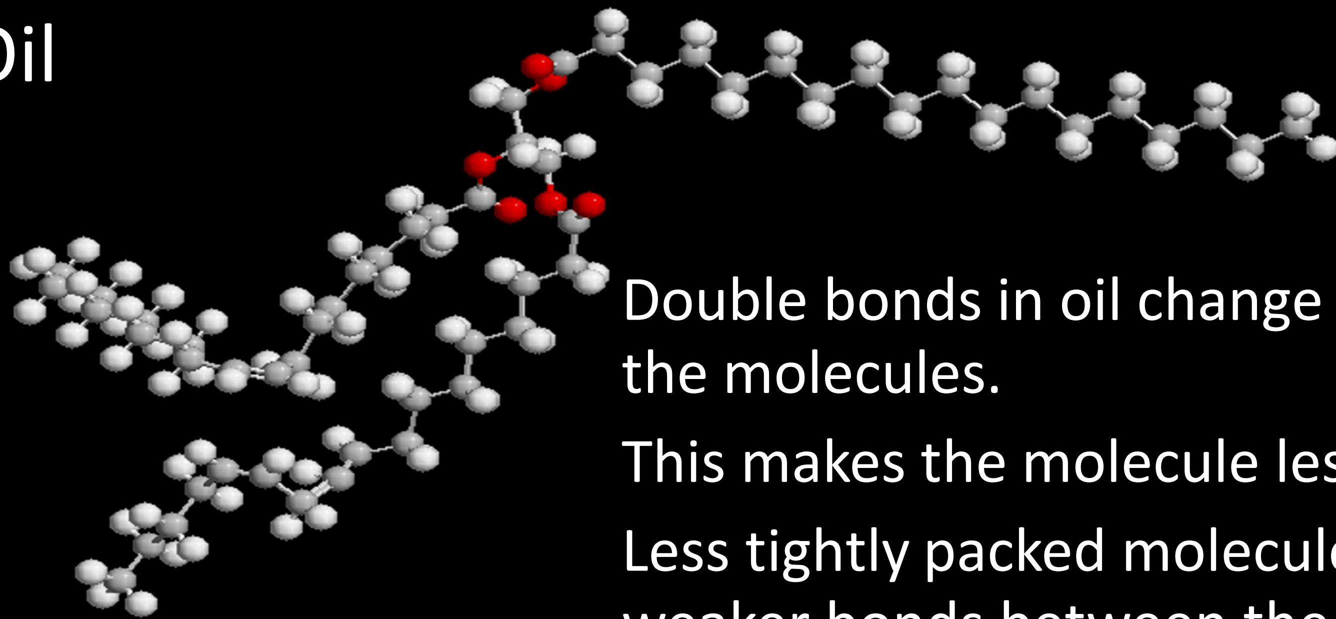
Fats are mainly built from carboxylic acids with C-C single bonds. (SATURATED)



Oils have at least one C=C bonds in the carboxylic acids from which they are made. (UNSATURATED)



Oil

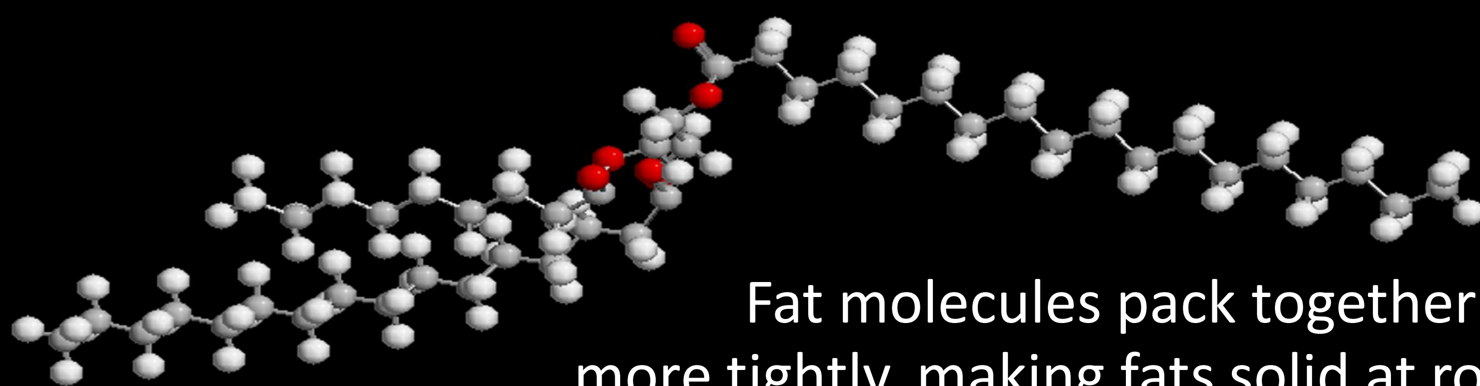


Double bonds in oil change the shape of the molecules.

This makes the molecule less compact.

Less tightly packed molecules result in weaker bonds between the molecules this makes oils liquid.

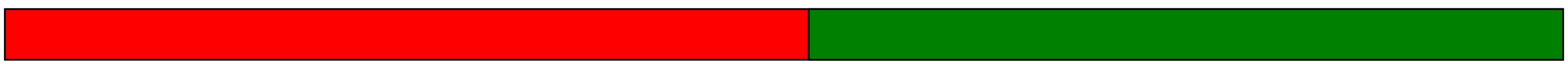
Fat



Fat molecules pack together more tightly, making fats solid at room temperature.

In practice both fats and oils are mixtures of esters containing both saturated and unsaturated compounds.

Beef Fat



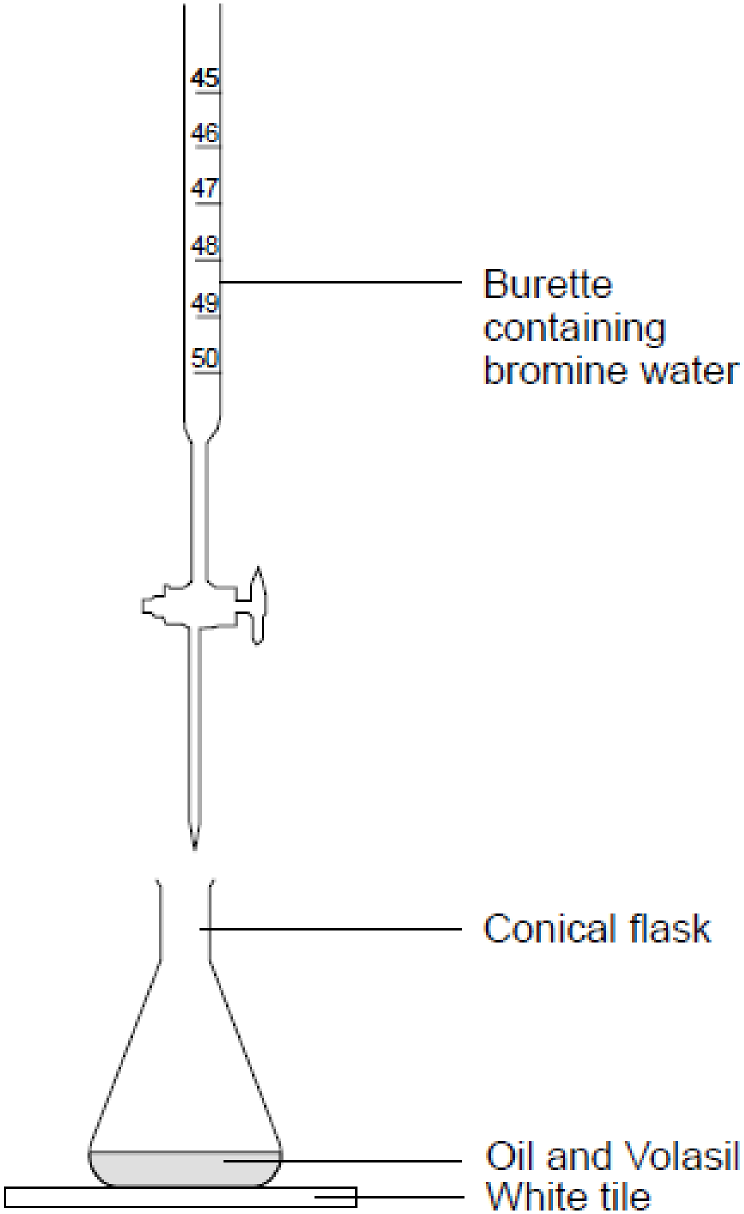
Olive oil

In general oils have a higher proportion of unsaturated molecules.

Notes:

- *How do the melting points of the fats compare with the melting points of the oils?*
- *What is meant by saturated and unsaturated?*
- *How does the proportion of unsaturated molecules in an oil compare with that in a fat?*
- *Explain why fats are likely to have relatively high melting points and oils are likely to have relatively low melting points.*

Unsaturation in fats and oils

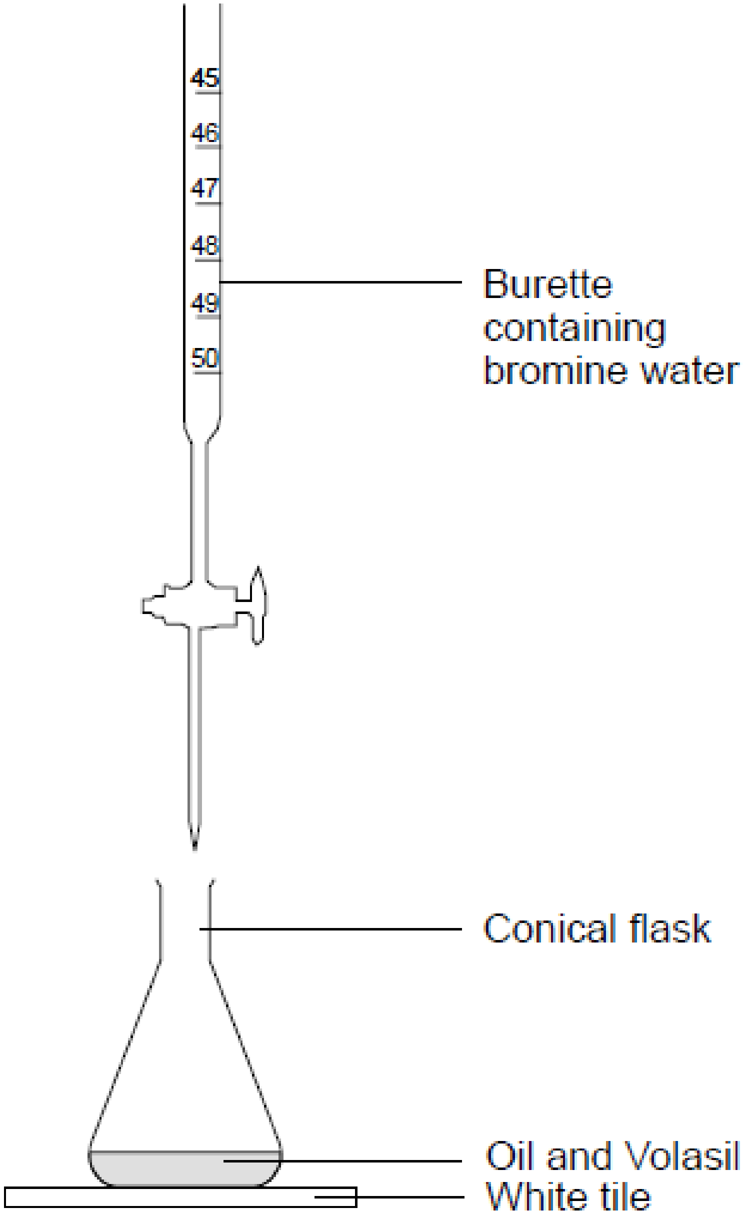


1.Using a plastic pipette, add five drops of olive oil to 5 cm^3 of hexane in a conical flask.

2. Use a burette filled with a dilute solution of bromine water (0.02 mol dm–3) **(Harmful and irritant).**

3. Read the burette.

Unsaturation in fats and oils



4. Run the bromine water slowly into the oil solution. Shake vigorously after each addition. The yellow colour of bromine disappears as bromine reacts with the oil. Continue adding bromine water to produce a permanent yellow colour.

5. Read the burette. Subtract to find the volume of bromine water needed in the titration.

6. Repeat the experiment with: five drops of cooking oil (vegetable) and five drops of cooking oil (animal).

Fats and Oils

The degree of saturation in a fat or oil can be determined by the Iodine Number. (bromine can also be used).
The iodine reacts with the C=C bonds, so the greater the iodine number, the greater the number of double bonds.

Fat	Av Iodine No
Butter	40
Beef Fat	45
Lard	50
Olive Oil	80
Peanut Oil	100
Soya Bean Oil	180

Solid fats – butter, beef fat & lard have low iodine numbers because they are more saturated than the unsaturated oils.

Margarine is made from vegetable oils, butter from animal fats. One reason why margarine spreads better!

Omega 3 fatty acids make up a large % of your brain's fat.

Hydrogenation

Å The addition of hydrogen to an unsaturated oil will ‘harden’ the oil.

Å This will Increase it’s melting point.

Å The hydrogen is added across the double bond.

Å Used with margarine, otherwise margarine would be a liquid when taken out of the fridge.

Lesson Starter: Hydrolysis of Esters

For the hydrolysis of each of the following esters, name the products and draw their full structural formulae.

(a) methyl propanoate

(b) ethyl ethanoate

(c) propyl methanoate

(d) $CH_3\text{-}CH_2\text{-}O\text{-}\overset{\overset{\displaystyle O}{\|}}{C}\text{-}H$

(e) $CH_3\text{-}CH_2\text{-}CH_2\text{-}\overset{\overset{\displaystyle O}{\|}}{C}\text{-}O\text{-}CH_3$

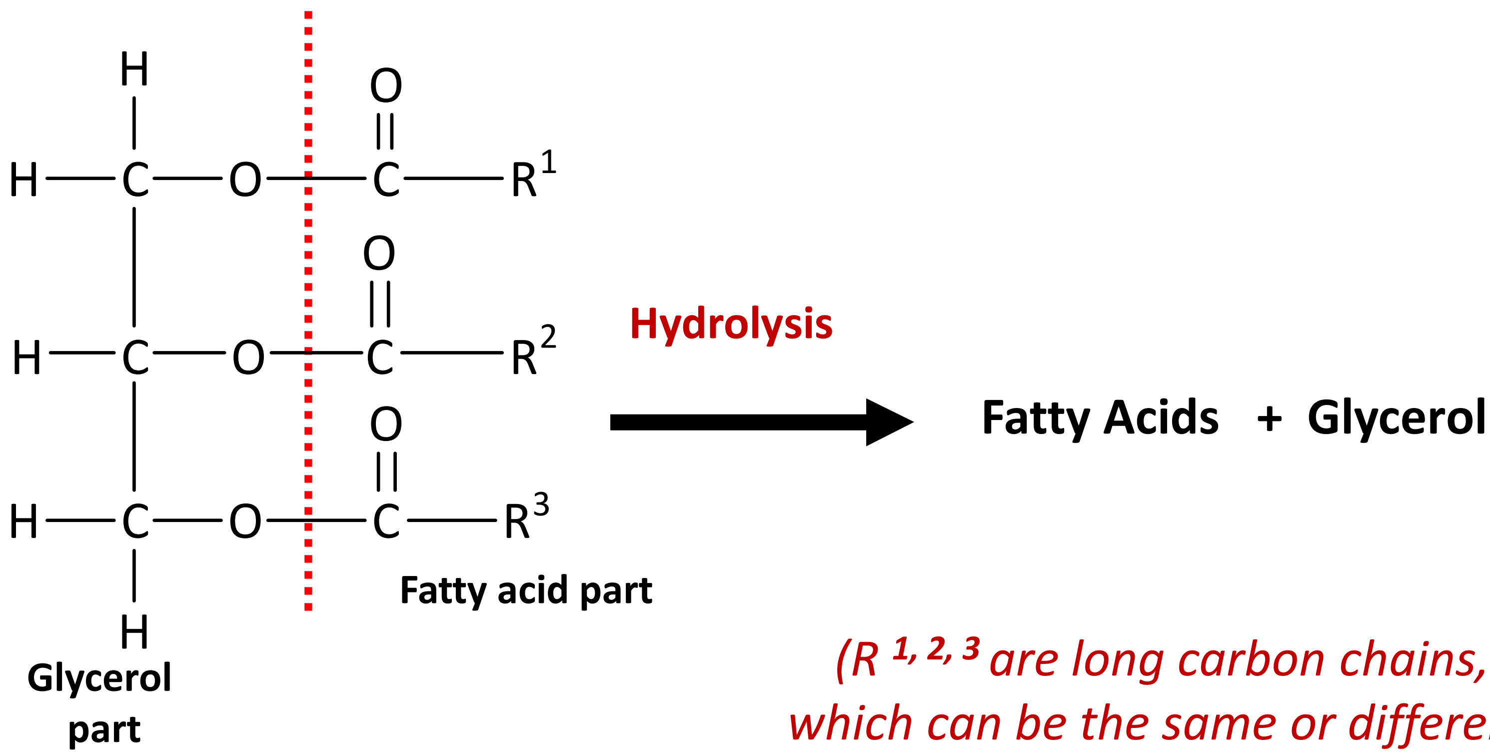
Soaps and Emulsions

Learning Outcomes :

- explain how soaps are produced
- relate the cleansing action of soaps to the structure of the soap molecules.

Structures of fats and oils - Revision

- Fats and Oils are esters of glycerol and long chain fatty acids.
- Hydrolysis of a fat or oil produces glycerol (alcohol) and 3 carboxylic acids / fatty acids.



(R 1, 2, 3 are long carbon chains, which can be the same or different)

Hydrolysis

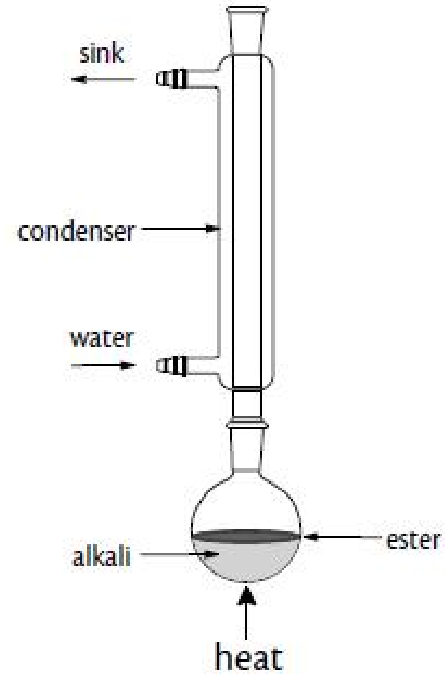
- To hydrolyse an ester we need to react it with water.
- However in practice the ester is heated under "reflux" with either dilute acid or dilute alkali.

- When sodium hydroxide solution is used the ester is 'split up' into the alkanol and the sodium salt of the acid.
- The alkanol can be removed by distillation and the alkanoic acid can be regenerated by reacting the sodium alkanoate with dilute hydrochloric acid.
- The equations for these reactions are:

Apparatus for Hydrolysis

The apparatus usually used is shown:

Heating under reflux



eg $CH_3COOC_2H_{5(l)} + Na^+OH^-_{(aq)} \longrightarrow CH_3COO^-Na^+_{(aq)} + C_2H_5OH_{(aq)}$

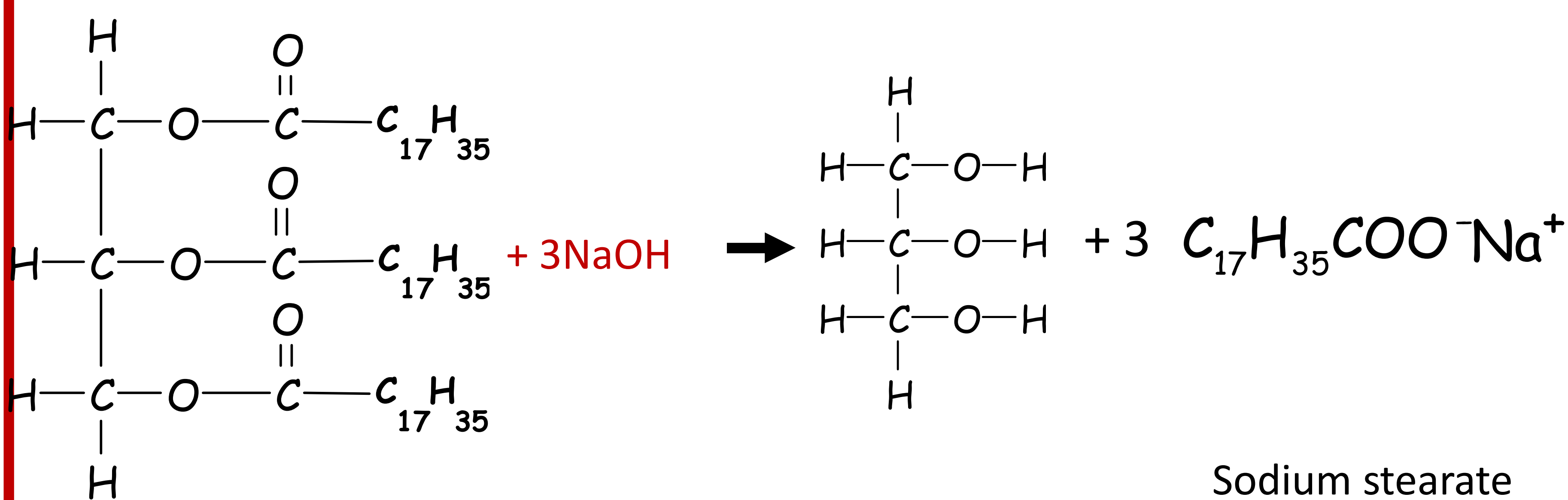
then,

$$CH_3COO^-Na^+_{(aq)} + H^+Cl^-_{(aq)} \longrightarrow CH_3COOH_{(aq)} + Na^+Cl^-_{(aq)}$$

Soaps

Soaps are salts of fatty acids.

Soaps are formed by the alkaline hydrolysis of fats and oils by sodium or potassium hydroxide by boiling under reflux conditions:



Glyceryl tristearate

Glycerol

Sodium stearate (soap)

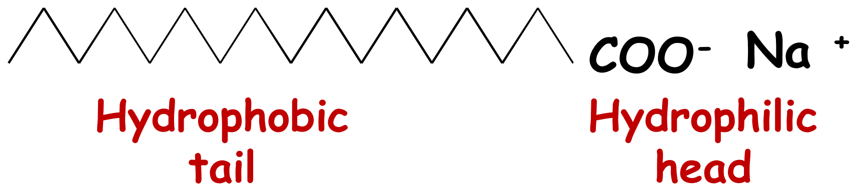
Structure of Soaps

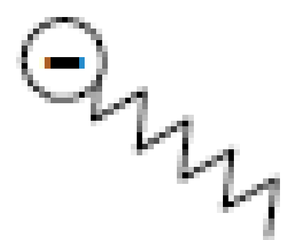
As most of the grime and dirt on skin, clothes and dishes tends to be trapped in oils and greases, water alone cannot rinse away the muck.

If the oils/greases can be made to mix with water then it becomes easy to wash off, along with the grime.

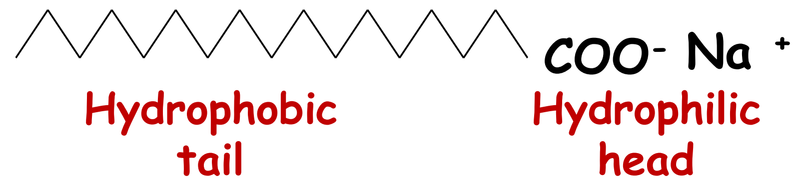
Soaps and detergents do this job in a clever way, due to the structure of the molecules:

Sodium or potassium salts of long chain fatty acids really have two quite separate parts in terms of their bonding types – a long hydrocarbon chain which is non polar and an ionic 'head'.



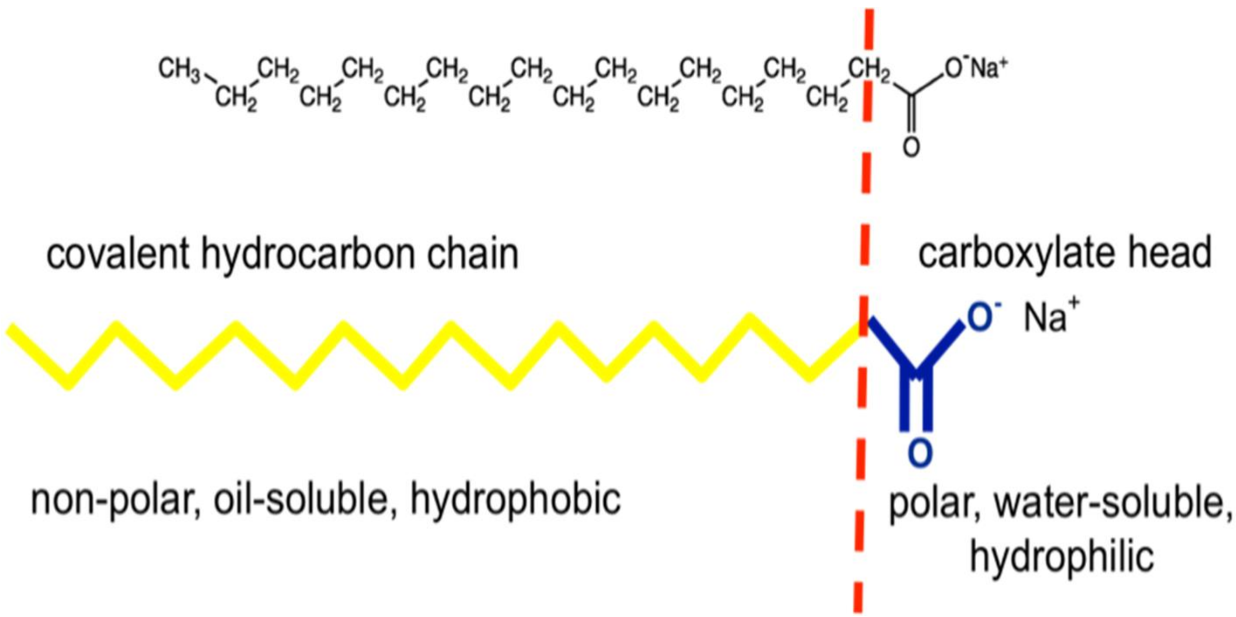


Structure of soap



The long covalent hydrocarbon chain "tail" gives rise to the hydrophobic (water hating) and oil-soluble (non-polar) properties of the soap molecule (represented in yellow).

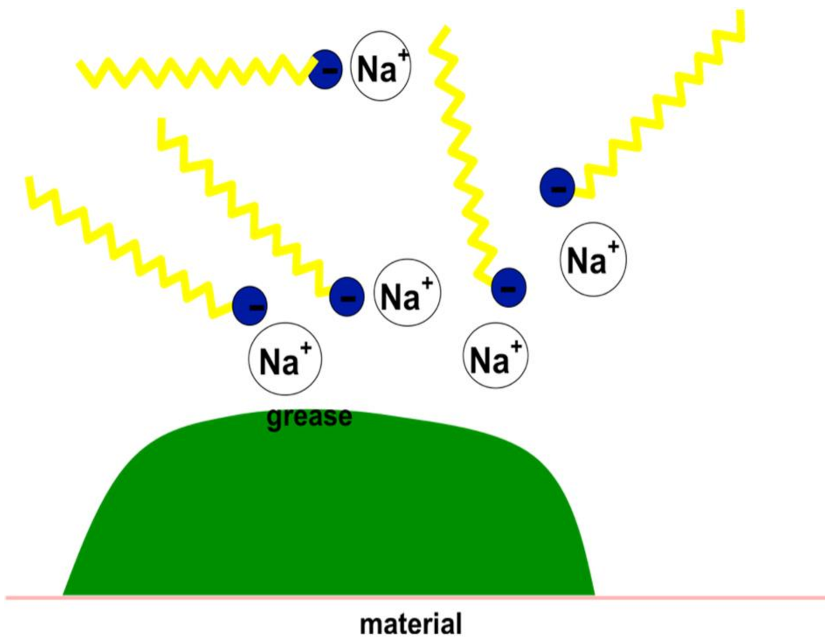
The charged carboxylate group "head" (represented in blue) is attracted to water molecules (hydrophilic). In this way, soaps are composed of a hydrophilic head and a hydrophobic tail:



Cleansing action of soaps

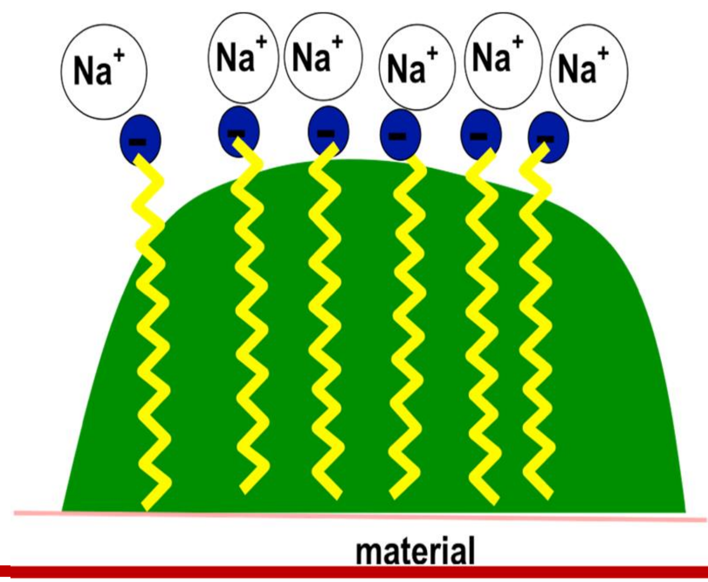
The following ball and stick diagram represents the initial interaction of soap on addition to water and material with a grease stain:

(blue for hydrophilic head group)

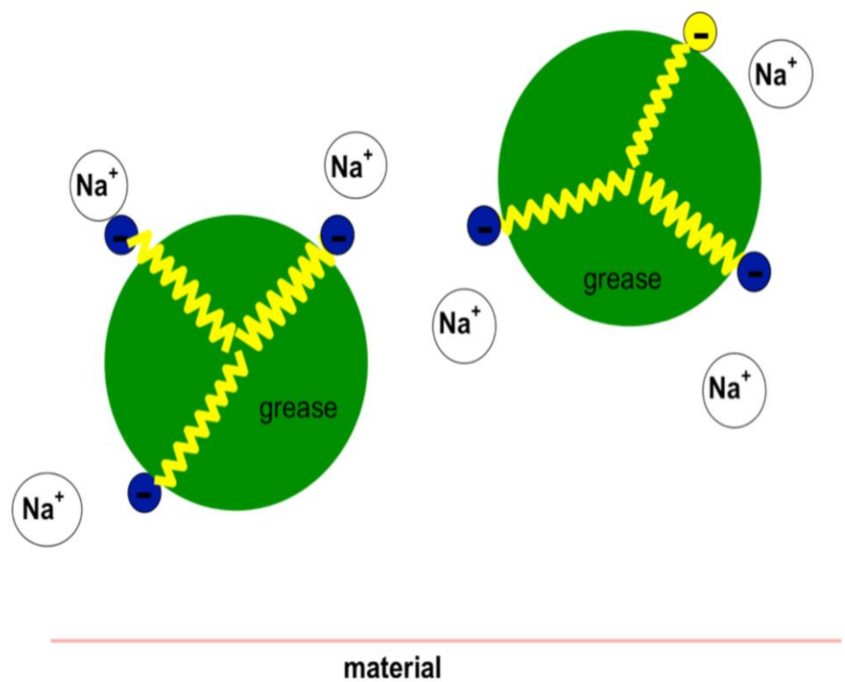


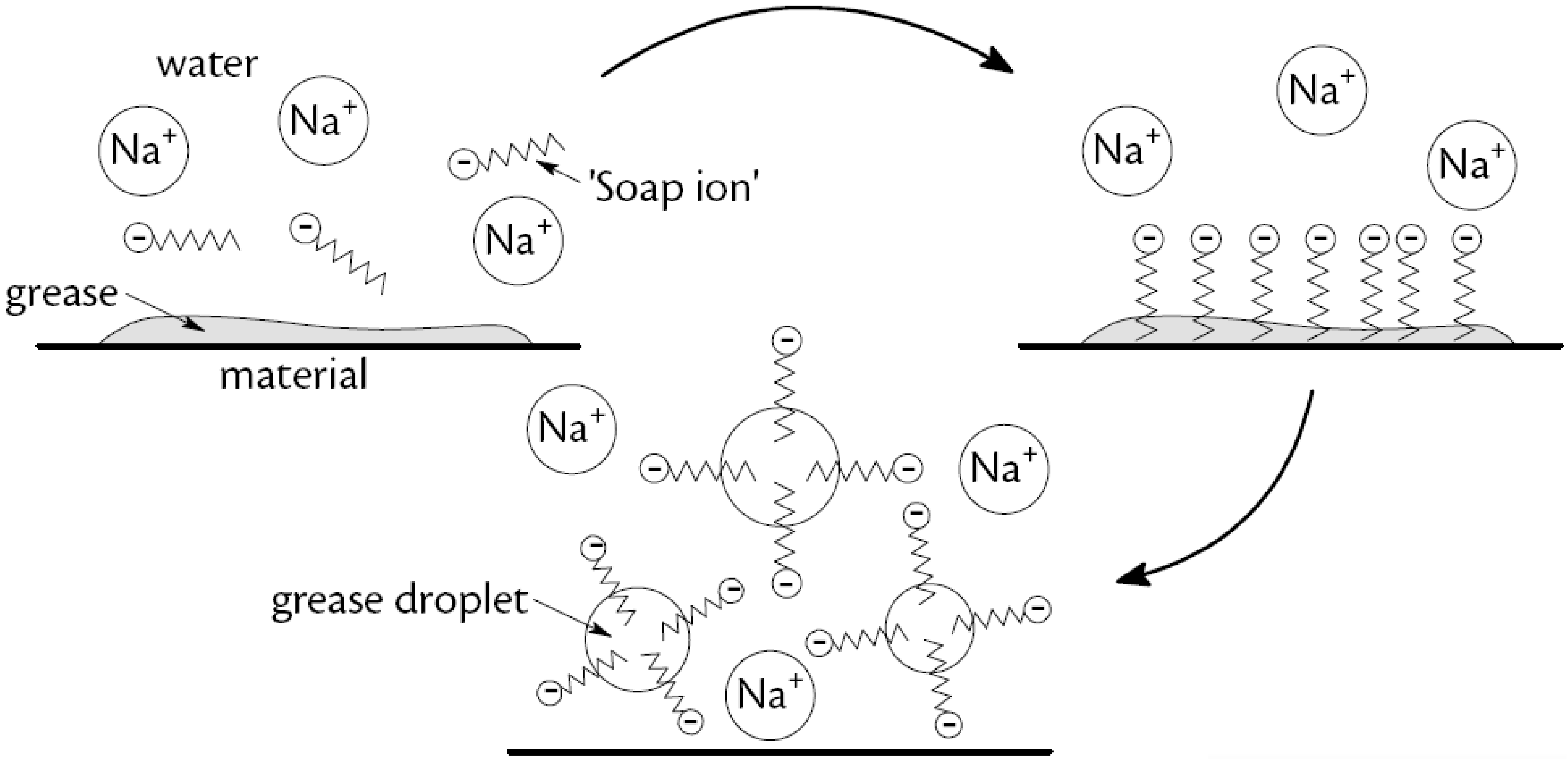
(yellow for hydrophobic tail group)

When the solution containing soap and water is agitated (stirred vigorously) the interactions of hydrophobicity and hydrophilicity become apparent. The hydrophobic, non-polar, tails burrow into the greasy, non-polar molecule – like attracting like. In the same way the polar hydrophilic head groups are attracted to polar water molecules. The head groups all point up into the water at the top of the grease stain.

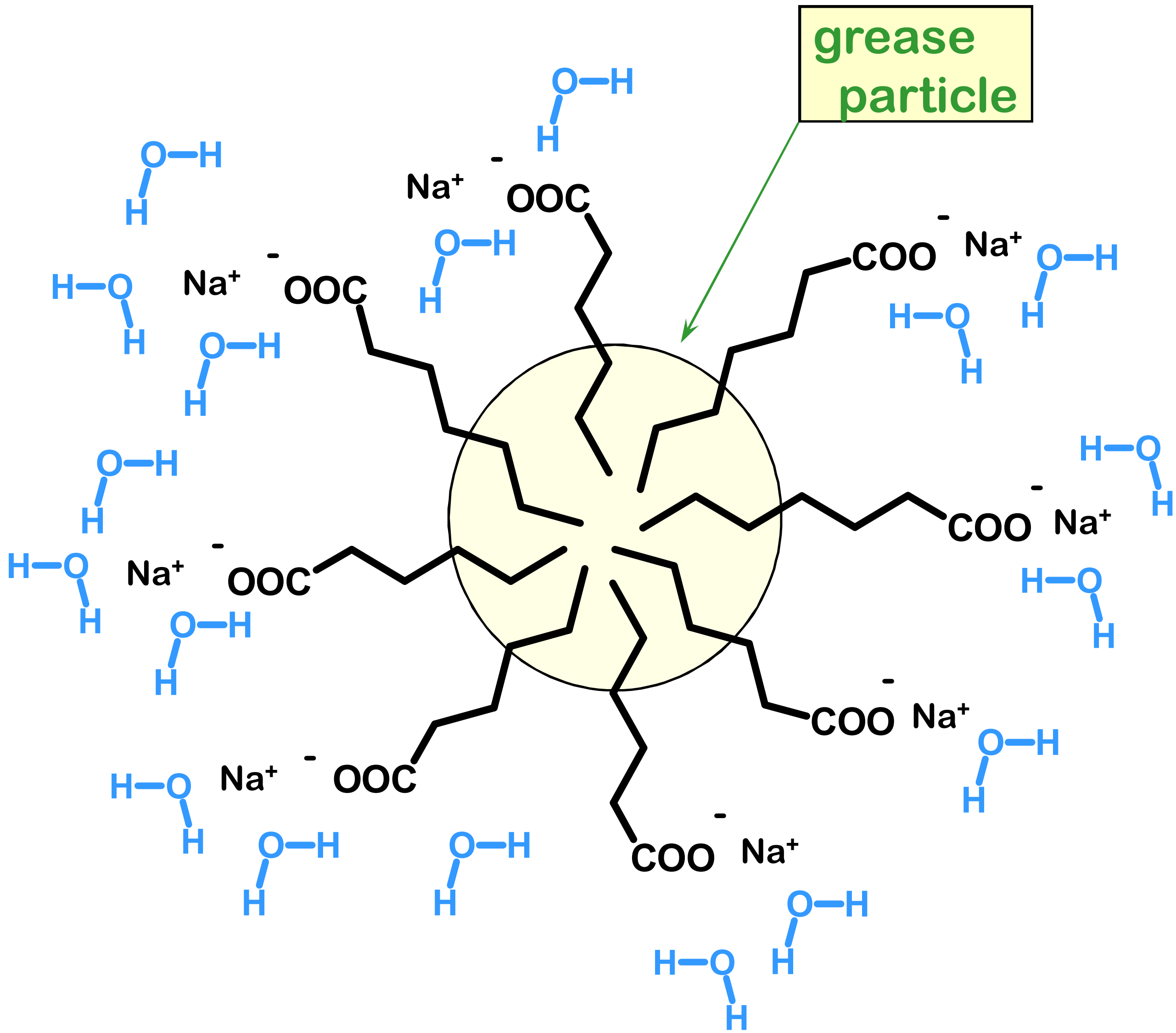


The attraction of the head group to the surrounding water, via polar-to-polar interactions, is so strong that it causes mechanical lift of the grease molecule away from the material on which it was deposited. The hydrophobic tails are anchored into the grease due to non-polar to non-polar attraction. In combination, these effects allow for the removal of the grease stain.




water
Na+
'Soap ion'
grease
material
grease droplet

MICELLE



Success Criteria: **Soaps**

- ✓ I can explain how soaps are produced by alkaline hydrolysis of fats and oils
- ✓ I can relate the cleansing action of soaps to the hydrophobic and hydrophilic nature of soap molecules.

Next Lesson:

Emulsions

Lesson Starter:

When vegetable oils are hydrolysed, mixtures of fatty acids are obtained. The fatty acids can be classified by their degree of unsaturation.

The table below shows the composition of each of the mixtures of fatty acids obtained when palm oil and olive oil were hydrolysed.

	Palm oil	**Olive oil**
Saturated fatty acids	51%	16%
Monounsaturated fatty acids	39%	75%
Polyunsaturated fatty acids	10%	9%

(*a*) Why does palm oil have a higher melting point than olive oil?

(*b*) One of the fatty acids produced by the hydrolysis of palm oil is linoleic acid, $C_{17}H_{31}COOH$.

To which class (saturated, monounsaturated or polyunsaturated) does this fatty acid belong?

Emulsions

Learning Outcomes :

- Describe the characteristics of an emulsion, and study the chemistry of typical emulsifier molecules.

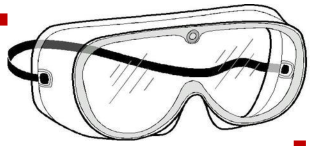
Emulsifiers

Å An emulsion contains small droplets of one liquid dispersed in an another liquid.

Å Emulsions in food are mixtures of oil and water.

Å To prevent oil and water components separating into layers, a soap-like molecule known as an emulsifier is added.

Experiment: Emulsifiers



Expt 2.8 (b)

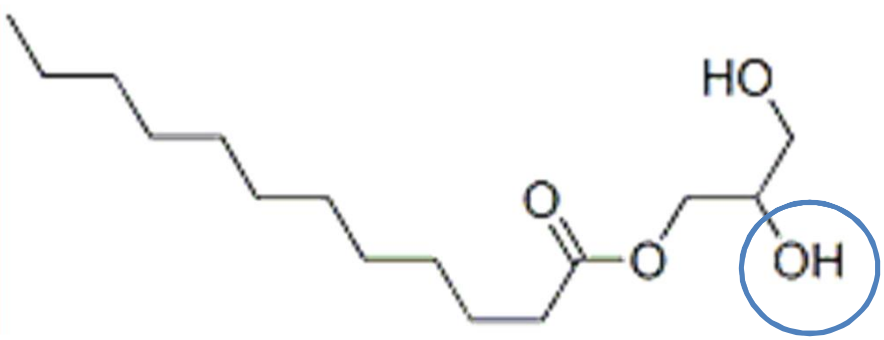
What to do

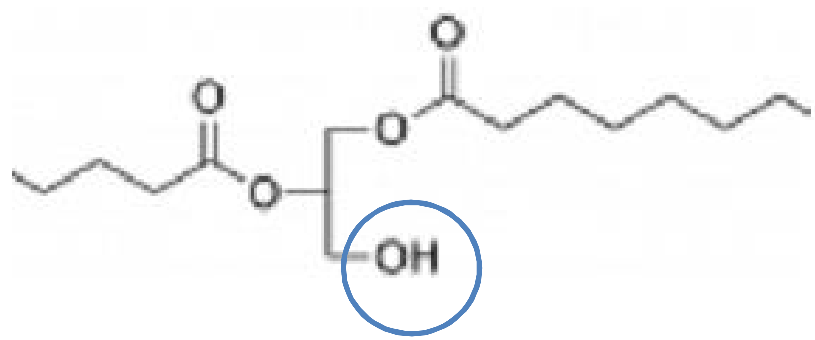
- Put about 2 cm^3 oil into the boiling tube. Add about the same amount of water.
- Put a bung into the top of the tube and shake it. Remove the bung, leave the mixture to stand and observe what happens.
- Repeat the experiment but add a small quantity of one of the test substances before you shake the tube.
- Decide how to record your results so that they will be clear enough for someone else to read and understand easily.

Emulsifier molecules

Emulsifiers for use in food are commonly made by reacting edible oils with glycerol to form molecules in which either one or two fatty acid groups are linked to a glycerol backbone rather than the three normally found in edible oils.

The one or two hydroxyl groups present in these molecules are hydrophilic whilst the fatty acid chains are hydrophobic.





The presence of this emulsifier is shown on packaging by E-numbers, E471 and is one of the most common on food packaging.

Emulsifiers

Mayonnaise contains oil and water.
The emulsifier keeps these mixed and without it the oil and water separate.

Emulsifiers in food

Emulsifiers are among the most frequently used types of food additives. They are used for many reasons:

- Emulsifiers can help to make a food appealing.
- They are used to aid in the processing of foods and also to help maintain quality and freshness.
- In low fat spreads, emulsifiers can help to prevent the growth of moulds which would happen if the oil and fat separated.

Foods that Commonly Contain Emulsifiers		
Biscuits	Toffees	Bread
Extruded snacks	Chewing gum	Margarine / low fat spreads
Breakfast cereals	Frozen desserts	Coffee whiteners
Cakes	Ice-cream	Topping powders
Desserts / mousses	Dried potato	Peanut butter
Soft drinks	Chocolate coatings	Caramels

Emulsifiers in food

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Success Criteria:

Soaps and Emulsions

- I can explain how soaps are produced by alkaline hydrolysis of fats and oils
- I can relate the cleansing action of soaps to the hydrophobic and hydrophilic nature of soap molecules.
- I can define an emulsion.
- I can explain why emulsifiers are added to food.
- I can describe how emulsifiers are made and how they work

Next Lesson:

Proteins