Chapter 27: Organic Products

Organic compounds are derived from both natural and synthetic sources.

Sources

Natural:
Fossil fuels → oil, coal and natural gas,
Plants → scientists can extract essential oils (e.g. eucalyptus) and alkaloids (e.g. caffeine)
Animals → scientists extract fats and oils (e.g. lard, fish oil) and proteins (e.g. collagen).
Microorganisms → e.g. e.g. bacteria can be genetically modified to make a wide range of products (genetic engineering), such as human insulin, human growth hormones and antibiotics. Penicillin is produced from penicillium mould, and ethanol is produced by fermentation (involving yeast).

Synthetic:
Laboratories → Chemists synthesise organic compounds from simpler chemicals. Examples include pharmaceuticals (e.g. aspirin and paracetamol), plastics, synthetic fibres (e.g. nylon and polyester), dyes and flavourings.

Uses of organic products

Fuels: Petrol, diesel, kerosene (aircraft fuel) and fuel oil (used in ships) are all derived from crude oil (a mixture of hydrocarbons). Biofuels, e.g. ethanol, are renewable alternatives derived from sources like sugarcane or corn.

Pharmaceuticals: Many medicines and pharmaceuticals are based on naturally occurring organic compounds, e.g. aspirin (originally synthesised from salicylic acid in willow bark), antibiotics (e.g. penicillin – produced by penicillium mould), taxol (from yew trees). They can also be synthesised in labs, e.g. the aspirin made today, paracetamol, etc.

Plastics: Plastics, e.g. poly(ethene), poly(chloroethene) (PVC), and poly(phenylethene) (polystyrene), are used to make containers, bags, bottles, etc.

Pesticides: Pesticides include herbicides (used against weeds) and insecticides (used against insects). Organic compounds like glyphosate and pyrethroids are widely used as pesticides to protect crops and to control pests.

Synthetics: Nylon (used in clothing, ropes, parachutes, tents) and polyester (used in textiles for clothing & home furnishings).

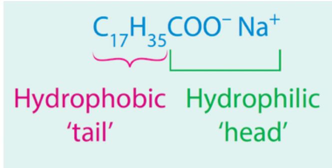
Surfactants: Widely used in soaps, detergents and other household products.

Surfactants

A surfactant is a substance that reduces the surface tension of a liquid to which it is added.

The term surfactant comes from ‘surface active agent’. Since surfactants have both polar and non-polar parts, they can interact with and dissolve both non-polar (e.g. oil and grease) and polar substances (e.g. water-based solutions).

Soap



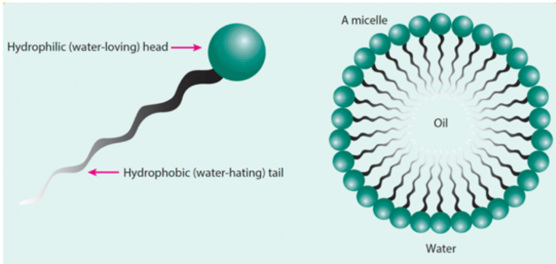
Soaps were among the first surfactants.

Soap consists of the salts of long chain carboxylic acids (carboxylate salts) produced by the base hydrolysis of esters, i.e. saponification.

The chemical formula for soaps is often written as RCOONa (or $RCOO^-Na^+$), where R represents a hydrocarbon chain, e.g. $C_{17}H_{35}COONa$.

Soap is a typical surfactant as it has both a non-polar hydrocarbon chain (its 'tail') and a negatively charged ionic 'head'. The hydrophilic polar head of the molecule is attracted to water, while the hydrophobic non-polar tail is attracted to grease and dirt.

The 'tail' of the soap will surround oil or grease particles, forming structures called micelles, trapping the oils and fats.



Since the polar head makes soap soluble in water, the micelles can then all be washed away.

Applications of surfactants

- Essential in cleaning, sanitising and preventing the spread of infections.
- Food hygiene and safety
- Used in;
- - personal hygiene items (e.g. shampoos, conditioners, toothpaste etc.)
- - mayonnaise, ice-cream and margarine
- - paints, polishes, pesticides, ointments
- - household cleaning products (e.g. detergents, fabric softeners, etc.)

Saponification

A simple soap can be made using an ester (found in oils, e.g. coconut oil, castor oil, olive oil etc.) and a base, e.g. sodium hydroxide (NaOH).

The by-product of this reaction is glycerol (also known as propane-1,2,3-triol).

Experiment 29: Conduct an activity to prepare soap, with NaOH either limiting or in excess

Soap can be prepared by mixing olive oil and coconut oil (which contain esters) and a solution of sodium hydroxide (NaOH) in water. The mixture is blended until thick. This mixture is then poured into moulds and allowed to set. Soap (carboxylate salts) and glycerol are produced.

Using limiting NaOH
Using limiting NaOH means that not all of the tri-esters in the oil will be converted to soap (carboxylate salts). Due to the unreacted oil, the soap produced is softer on the skin (less irritating and more moisturising) but will take longer to harden. The final soap may

feel greasy on the skin and may not lather very well.

Using excess NaOH
Using excess NaOH will result in some of the NaOH not reacting and can result in a very basic soap (i.e. pH of over 10). This may be too harsh to use, as NaOH is corrosive. The soap may cause skin irritation or burns. Due to excess NaOH and limiting oil, the soap produced is very hard and may crumble, crack or break easily.The soap may also develop a powdery white coating of sodium carbonate on the surface (due to excess NaOH reacting with carbon dioxide in the air: $2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$).

Pharmaceutical products

- A medicine is a drug that prevents or treats disease.
- A narcotic is a drug that has a sedative (narcosis is a state of stupor or sleep) or pain-relieving (analgesic) effect on the body.

Willow bark

- Willow bark has been used medicinally for centuries to treat fever and alleviate pain.
- The active ingredient is **salicin**, a precursor of salicylic acid, the active ingredient in **aspirin.**

Cinchona bark

- Cinchona (a tree native to Latin America) bark contains the alkaloid **quinine,** which has been used to treat malaria since the middle of the seventeenth century.
- It also contains quinidine, which can be used to treat heart palpitations (arrhythmias).

Opium poppy

- Opium is found in the unripe seed pods of the opium poppy.
- Opium contains a group of alkaloids, of which the most medically important are **morphine** and **codeine**, both widely used for pain management.
- Heroin is derived from morphine.

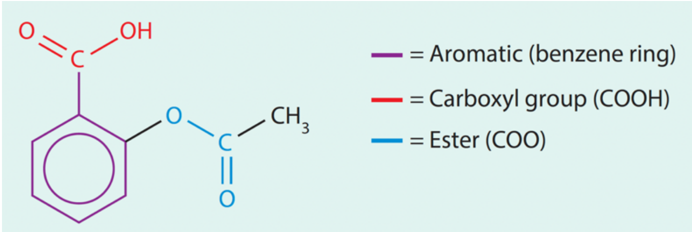
These plants have been used by people for centuries (some for thousands of years) – either medically or to alter their state of mind (i.e. as a drug).

In the nineteenth century chemists began **isolating and identifying the active ingredients in plants**. **Researchers started to isolate specific chemicals to develop targeted medicinal drugs with them. This was the beginning of the modern pharmaceutical industry.**

Nowadays, most products of the modern pharmaceutical industry are **large complex organic molecules with multiple functional groups (made from simpler organic starting products).**

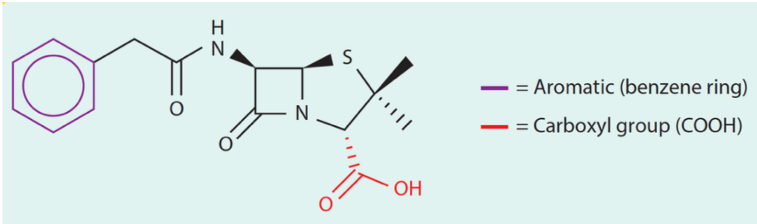
Aspirin

Aspirin is a common pain reliever, anti-inflammatory drug and anti-coagulant. Its chemical name is acetylsalicylic acid. In 1828, fairly pure salicin crystals were extracted from willow bark and in 1838, salicylic acid was extracted. In 1897, the German chemist Felix Hoffmann used salicylic acid refluxed with acetic anhydride to synthesise acetylsalicylic acid. In 1899, this drug was named aspirin and it is now one of the most commonly used drugs in the world.



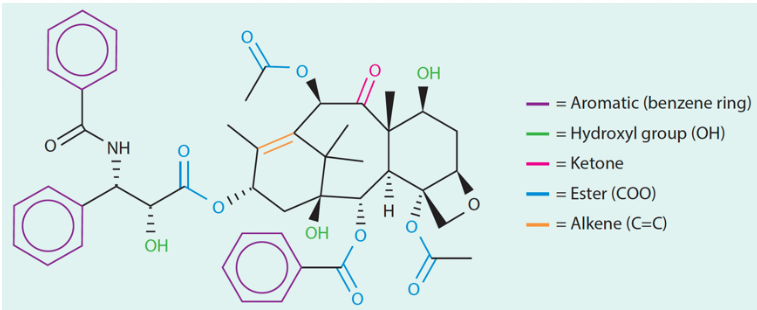
Penicillin

Penicillin is an antibiotic used to treat infections, especially bacterial infections. During the Second World War, there was an urgent need to produce very large quantities and, by 1944, penicillin was very widely available and saved countless lives.



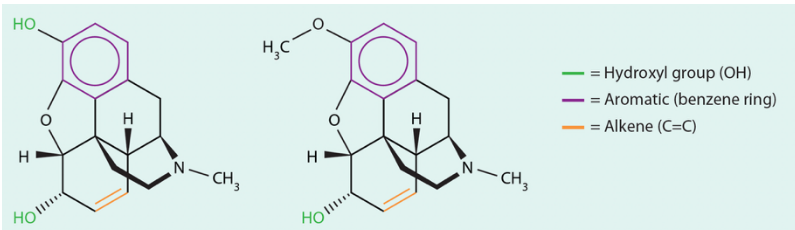
Taxol

Taxol (also known as paclitaxel – paclitaxel is the drug, taxol is the brand name) is an organic compound that can be extracted from the inner bark of the Pacific yew tree. It's used in cancer treatment as it can disrupt cell division.
Because only small amounts can be extracted from each tree, scientists have developed methods to synthesise it in the lab.



Opiates

Opiates are a class of drugs made from naturally occurring alkaloids derived from the opium poppy. These compounds are extracted directly from the plant and include morphine and codeine.



Polymers

A polymer is a long-chain molecule made up of many repeating units. Polymerisation is a process in which monomers bond to form a polymer.

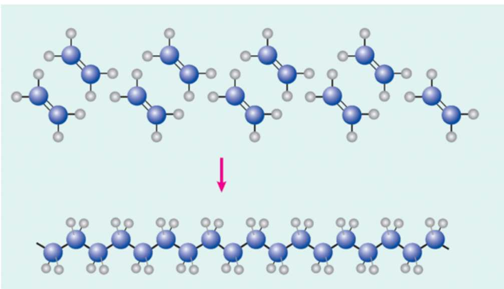
Polymers are large molecules made of many smaller molecules (monomers) covalently bonded to form a large repeating structure.

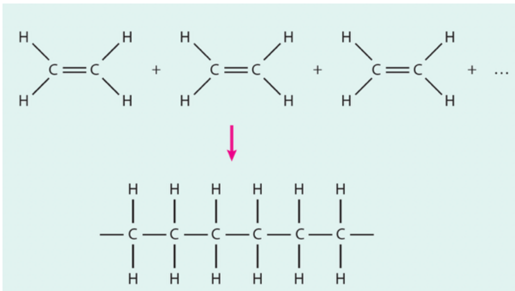
A monomer is a small molecule that can bond with other identical molecules to make a polymer.

Addition polymerisation occurs when unsaturated monomers react to form a long-chain polymer (retaining all original atoms and without forming any by-products).

Poly(ethene)

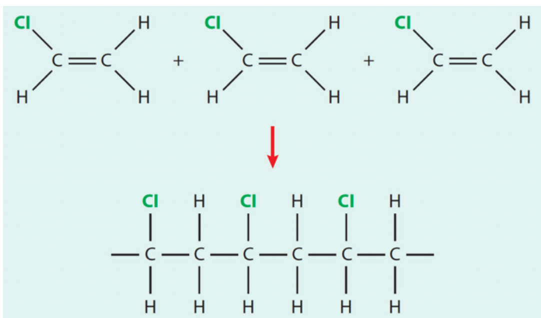
- Poly(ethene) is formed by the addition of many ethene molecules. The pi bond of the C=C breaks, and the newly available electrons form bonds between the monomers.
- These link together to form a long chain, creating the polymer called poly(ethene).
- Poly(ethene) has many uses – e.g. for plastic bags, cling film, squeezable bottles for shampoo and washing-up liquid, food containers, etc.
- Poly(ethene) is not used as a fuel directly, but can be pyrolised (broken down by heat in an oxygen free environment) in order to be processed into fuel.
- As well as producing fuel, this reduces plastic waste, though the process is expensive.





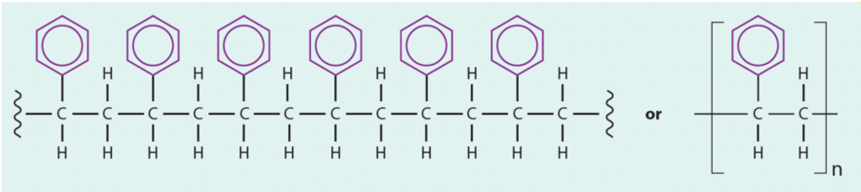
Poly(chloroethene)

- Poly(chloroethene) is also called PVC (because it used to be called polyvinyl chloride) and is one of the most widely used and cheapest plastics in the world.
- The monomer is chloroethene.
- Poly(chloroethene) is used to make PVC windows, pipes and construction materials, etc.
- PVC can be converted to fuel, but this is much more challenging than poly(ethene) because of the high chlorine content.



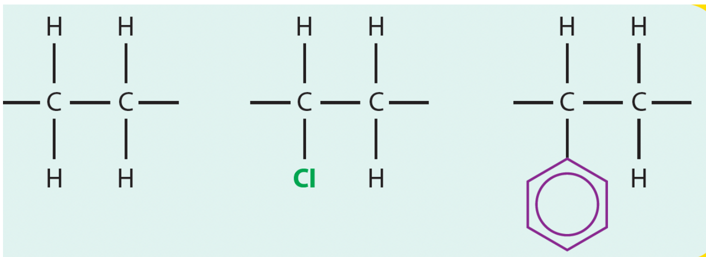
Poly(phenylethene)

- Poly(phenylethene) is a polymer made from the monomer phenylethene (also referred to as styrene).
- It's widely used because of its versatility, ease of manufacture and affordability.
- The polymerisation produces an addition polymer with phenyl groups (C_6H_5) attached to every second carbon atom in the carbon chain.
- Poly(phenylethene)/polystyrene is lightweight, and can be used to make egg boxes, disposable cutlery, plates, cups and food trays.
- Polystyrene (when expanded with trapped air) is also used as an insulator in buildings. Like poly(ethene), polystyrene can be converted into liquid fuel and gas through pyrolysis.



Repeating units

- Since polymers can have carbon chains thousands of atoms in length, the full polymer is not drawn.
- Instead, the repeating unit of a polymer is drawn, leaving open-ended bonds on either side to indicate a continuing chain of carbons on both sides.



Polymers & Biodegradability

- Biodegradability refers to the ability of a substance to be broken down into simpler compounds through natural processes, typically by microorganisms such as bacteria, fungi and other decomposers.
- sThe EU defines a material as biodegradable if at least 90% of it can degrade into water, minerals and carbon dioxide within six months.
- For a polymer to be biodegradable, microbes must be able to attack and break down the chemical bonds in its structure.
- **The three plastics – poly(ethene), poly(chloroethene) and poly(phenylethene) – that we've looked at are all very resistant to biodegradation. All contain a backbone of strong carbon-carbon bonds, which are highly resistant to chemical reactions such as hydrolysis or oxidation under normal environmental conditions.**
- This high level of stability means that all three plastics last in the environment for a very long time, and even when they do break down, it's often into smaller plastic fragments (microplastics) rather than biodegrading. This is why recycling plastics is essential.