Organic Chemistry

Carbon Compounds

- Organic chemistry is the chemistry of carbon compounds
- Most chemicals of biological importance or used as fuels are composed primarily of carbon. Other organic compounds include plastics, drugs, pesticides, solvents, synthetic fibres, enzymes, and hormones.
- The major sources of organic compounds for manufacturing are coal, petroleum, crude oil and natural gas.
- Carbon compounds are a large and diverse group of chemicals because of the bonding characteristics of carbon:

  C $1s^2 2s^2 2p^2$ Carbon tends to form 4 bonds

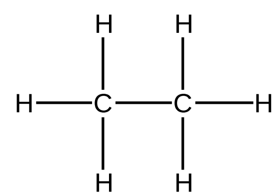
- The carbon atoms tend to form the "backbone" of the organic compounds

A. Hydrocarbons

- Compounds containing only carbon and hydrogen are called hydrocarbons.
- The longest carbon chain is referred to as the backbone and is used for naming the compounds

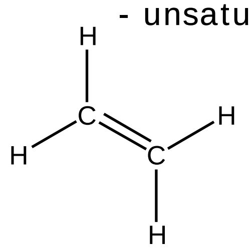
1. alkanes - single-bonded carbon atoms only
- referred to as saturated

Ex.



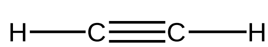
2. alkenes - one or more carbon-carbon double bonds
- unsaturated (if >1 double bond = polyunsaturated)

Ex.

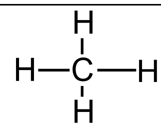
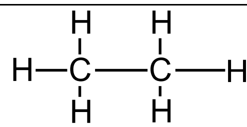
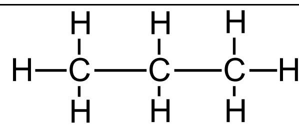
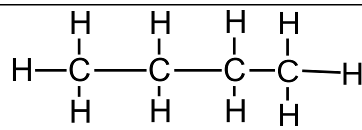
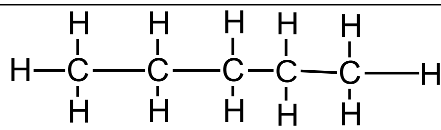
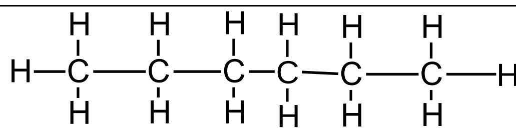
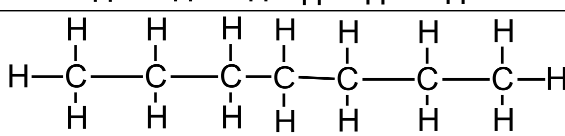
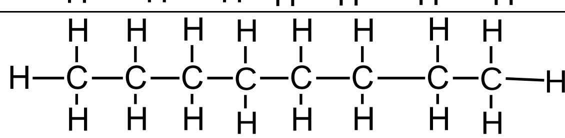
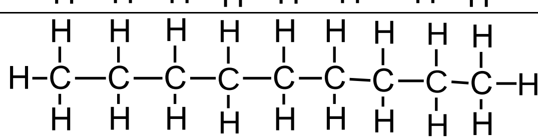
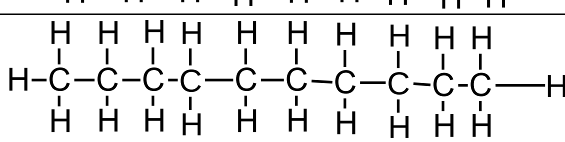


3. alkynes - one or more carbon-carbon triple bonds
- unsaturated (if >1 triple bond = polyunsaturated)

Ex.



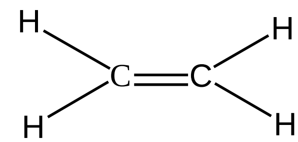
I. ALKANES NAMING AND FORMULAE

# of C's	Formula	Structure	Chemical formula	Name	BP
1	CH_4		CH_4	Methane	-162°C
2	C_2H_6		CH_3CH_3	Ethane	-89°C
3	C_3H_8		$CH_3CH_2CH_3$	Propane	-42°C
4	C_4H_{10}		$CH_3(CH_2)_2CH_3$	Butane	0°C
5	C_5H_{12}		$CH_3(CH_2)_3CH_3$	Pentane	36°C
6	C_6H_{14}		$CH_3(CH_2)_4CH_3$	Hexane	69°C
7	C_7H_{16}		$CH_3(CH_2)_5CH_3$	Heptane	98°C
8	C_8H_{18}		$CH_3(CH_2)_6CH_3$	Octane	126°C
9	C_9H_{20}		$CH_3(CH_2)_7CH_3$	Nonane	150^{o}C
10	$C_{10}H_{22}$		$CH_3(CH_2)_8CH_3$	Decane	174^{o}C

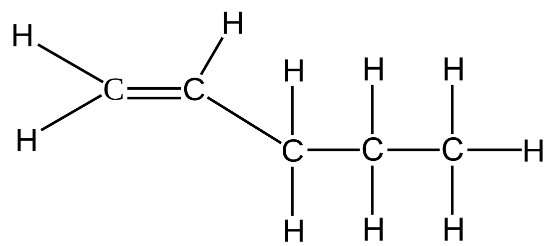
II. ALKENES NAMING AND FORMULAE

- Named as for the same number alkane but an '-ene' ending is substituted for the '-ane'.
- If more than one version is possible then numbers are used to differentiate. Always name so that you use the longest carbon chain and number from the end nearest to the double bond.
- ISOMERS – are compounds with the same formula but different structures

Ex. ethene

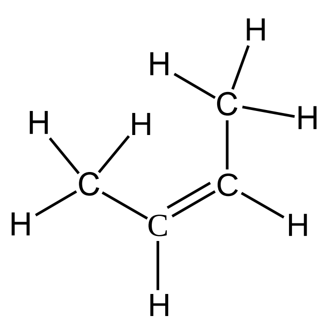


Ex. 1-pentene

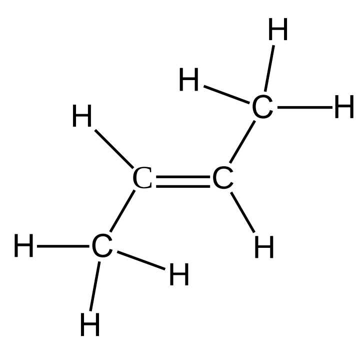


- CIS AND TRANS ISOMERS
    - the carbon double bond does not rotate, so the groups attached can either both be on the same side of the bond or the different side.
    - those on the same side are called CIS and the ones on the opposite side are called TRANS

Ex. cis-2-butene

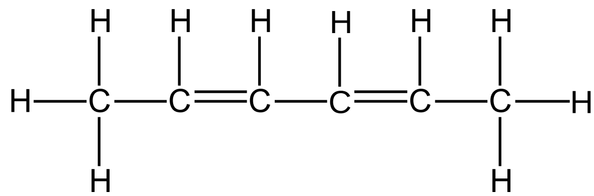


trans-2-butene



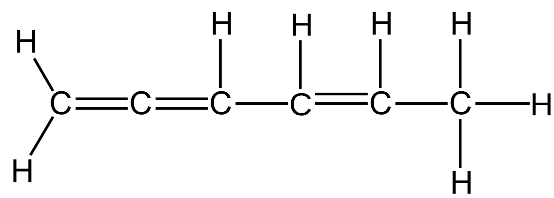
- DIENES - are compounds with two double bonds.

Ex. 2, 4-hexadiene



- TRIENES - are compounds with three double bonds

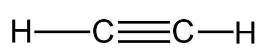
Ex. 1, 2, 4-hexatriene



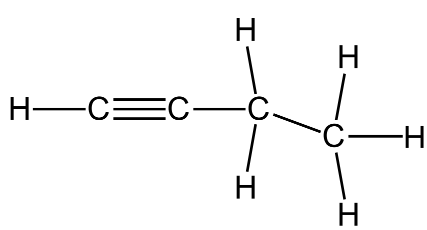
III. ALKYNES NAMING AND FORMULAE

- named as for the same number alkane but and 'yne' ending is substituted for the 'ane'
- if more than one version is possible then numbers are used to differentiate

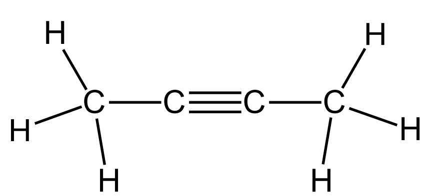
Ex. ethyne



Ex. 1-butyne



Ex. 2-butyne

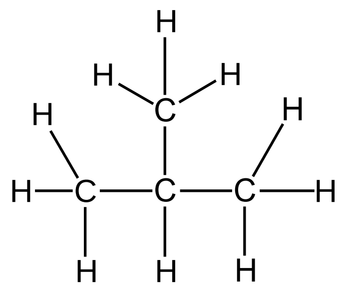


IV. SUBSTITUTING H WITH OTHER HYDROCARBONS

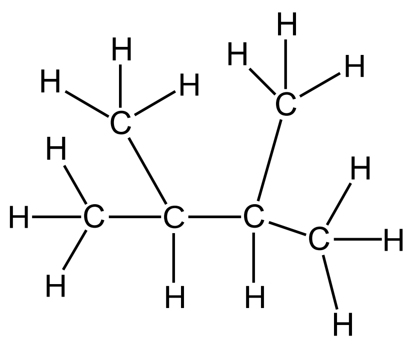
- short chain hydrocarbons can be added to the chain by attaching them instead of a hydrogen atom.
- substituted groups are named in alphabetical order before the name of the backbone chain and their positions are numbered if required.
- groups which are typically substituted are named:

$-CH_3$	methyl
$-CH_2CH_3$	ethyl
$-CH_2CH_2CH_3$	propyl

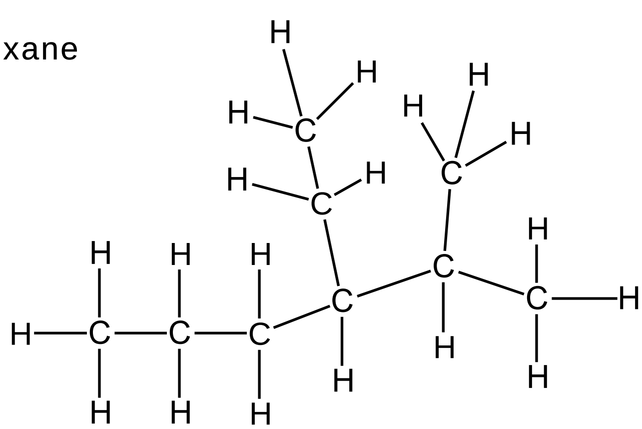
Ex. methyl propane



Ex. 2,3-dimethyl butane

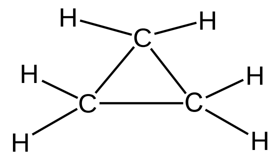


Ex. 3-ethyl, 2-methyl hexane



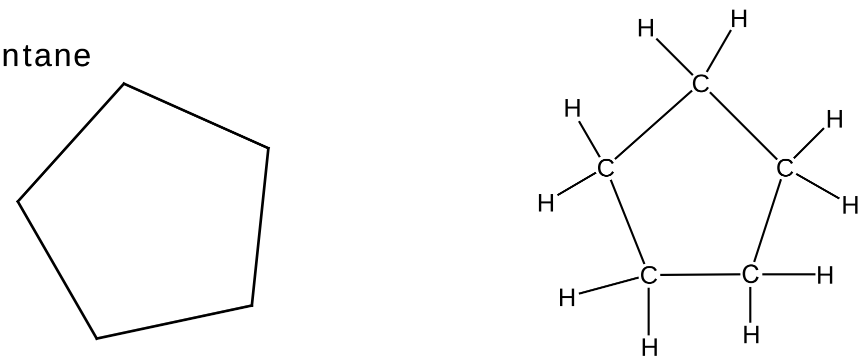
V. CYCLIC HYDROCARBONS

- some hydrocarbons form rings of carbon atoms or cyclic compounds
- C_3H_6 is the formula for propene but a structural isomer can be drawn which doesn't contain a double bond. This would be cyclopropane:



- cyclic compounds can have 3, 4, 5 or more carbon atoms in a ring.
- cyclic compounds are often represented by their geometric shapes.

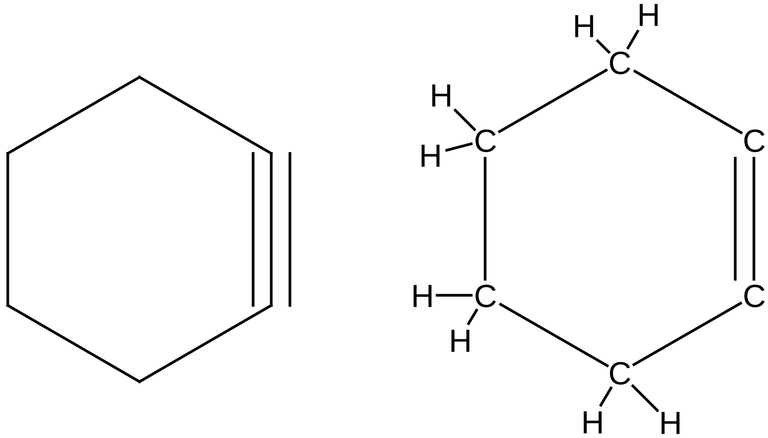
Ex. cyclopentane



- cyclic alkenes and alkynes also exist.

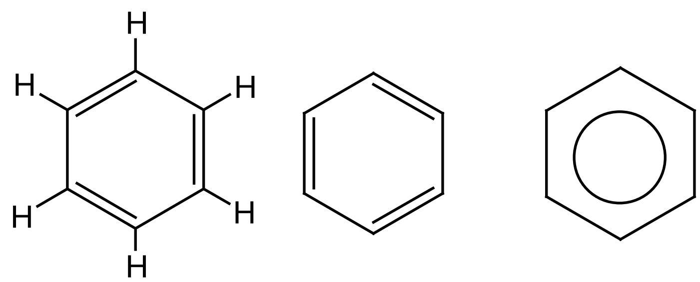
Ex. cyclobutene

Ex. cyclohexyne



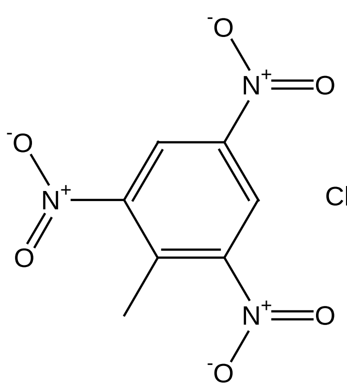
Aromatic hydrocarbons

Distinctive aromas or ordours
Made up of units of benzene (C_6H_6) – petroleum byproduct
All have basic structure of 1 or more rings of 6 carbon atoms.

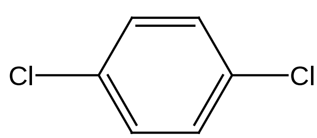


Bonding is unusual; all six c-c bonds are the same length and strength (recall resonance). Benzene bonds are between ethane and ethene in terms of strength, length and reactivity. Electrons of benzene are shared equally (delocalized) around the ring.

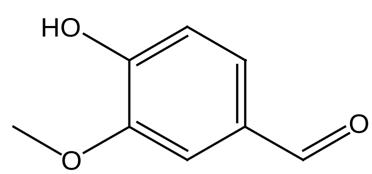
Ex.



tri nitro toluene



para dichloro benzene



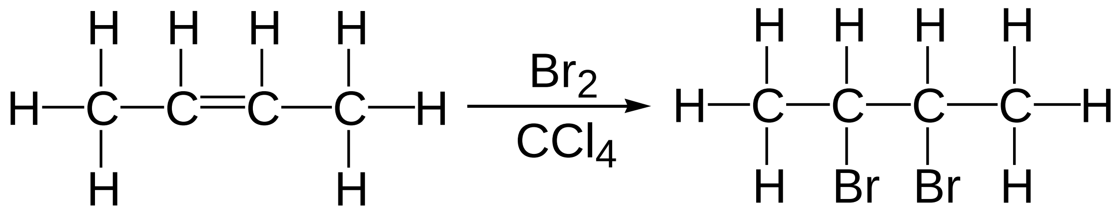
meta methoxy para hydroxy benzaldehyde

Any compound with a benzene functional group in the middle you can call an “aromatic compound” and they often have the associated aromatic odour

Halogenation Reactions

Double and triple bonds can undergo simple addition reactions with diatomic halogen species (Br_2, Cl_2 etc…). The halogens always add twice; both atoms (Ex. Cl-Cl) attach to one of the carbons in the double bond. Different reaction conditions can substitute the halogens in different orientations (More on that in university o-chem… much more!)

Ex.



Functional Groups

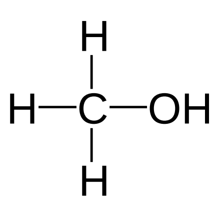
A functional group is: any atom, group of atoms, or organization of bonds that determines specific properties of a molecule.
Generally the most reactive portion of a molecule: presence signifies certain predictable behaviors or characteristics
Ex. alkene =; alkyne ≡ ; Cl ; OH… some atom or group of atoms attached to a C atom instead of H.
We use **R** to represent the rest of the molecule (usually a hydrocarbon chain) to which the functional group is attached
Organic compounds with the same functional group behave similarly in chemical reactions.

Oxygen Containing Functional Groups

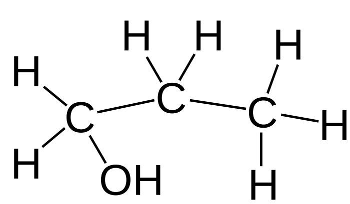
Alcohol

Substitute one of the hydrogens with a hydroxyl group (**R-OH**) = Alcohol
Replace the "e" ending in the name with "ol" ending

Ex. methanol



1-propanol

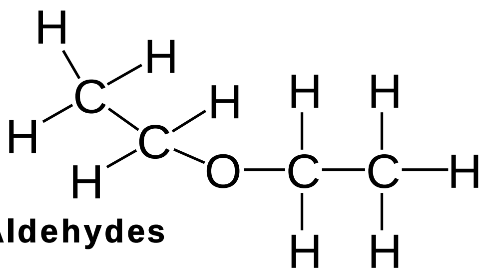


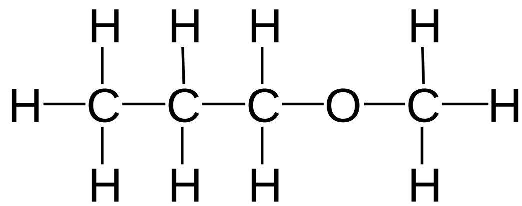
Primary (1^o) alcohols have hydroxyl (-**OH**) group at an end carbon
Secondary (2^o) alcohols have -**OH** on carbon in the middle of a chain
Tertiary (3^o) alcohols have **-OH** on a carbon that has only other carbons attached to it (no hydrogens)
Compounds with more than one **–OH** are called "glycols"

Ethers

Two hydrocarbon chains on either side of an oxygen (**O**), **R-O-R’**
Smaller chain named “oxy”, larger chain remains the same

Ex. ethoxy ethane methoxy propane

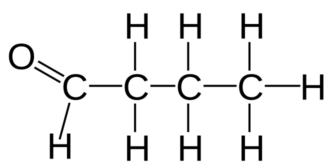




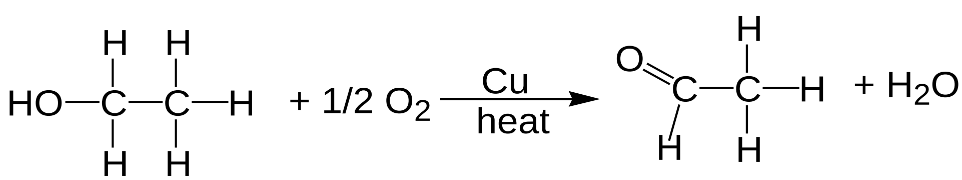
Aldehydes

Contain a ***carbonyl*** group (C=O) at the end of a chain, **R-CHO**
Ends with “al”
Formed from oxidation of primary alcohols

Ex. butanal



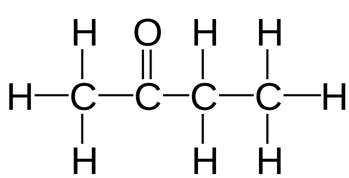
formation of an aldehyde



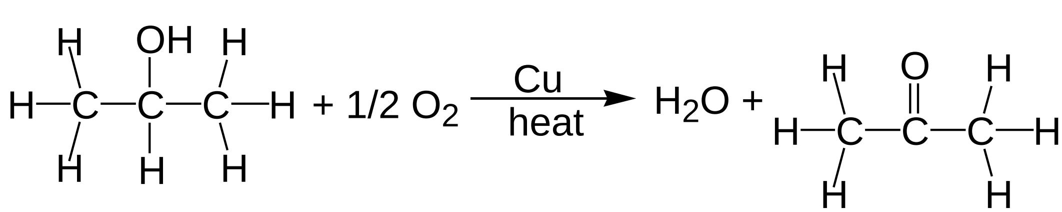
Ketones

Contain a ***carbonyl*** group (C=O) in the middle of a chain, **R-CO-R’**
Ends with “one”
Formed from oxidation of secondary alcohols

Ex. 2-butanone



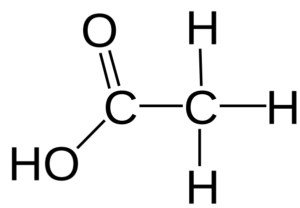
formation of a ketone



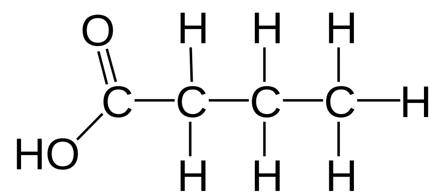
Organic (Carboxylic Acids)

Contain a ***carboxyl*** group (HO-C=O) at the end of a chain, **R-COOH**
Ends with “oic acid”

Ex. ethanoic acid (vinegar/acetic)



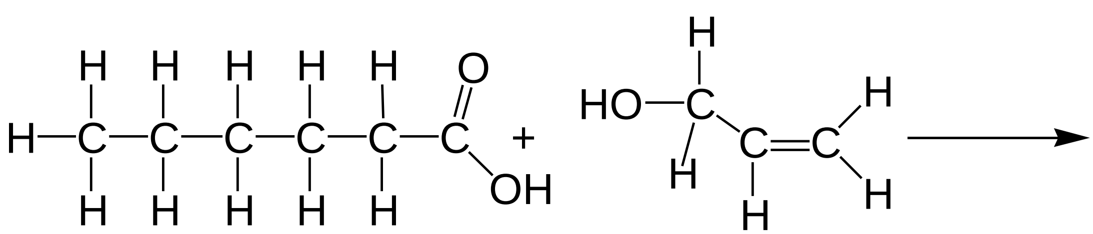
butanoic acid (butter)



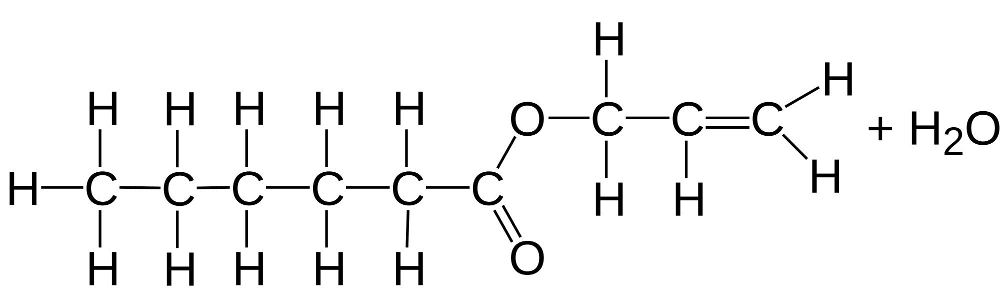
Esters

Formed from the dehydration (loss of water) reaction between alcohols and carboxylic acids, called “esterification
Alcohol loses “H” and the acid loses “OH”; generates H_2O
Named using the names of the alcohol and acid which formed them
Usually give a distinct and pleasant aroma and/or flavor (vanillin)

Ex. prop-2-enyl hexanoate (smells like pineapple)



hexanoic acid 3-propenol



Nitrogen Containing Functional Groups

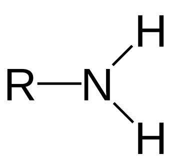
Just as oxygen has many functional groups and different configurations, so too does nitrogen; there are nitrogenous analogues of many of the above functional groups

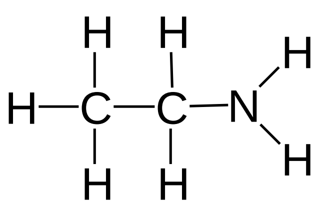
Amines

Closely related to ammonia (NH_3); **R** groups replace 1, 2 or 3 of the H's in NH_3
Amines are usually very basic compounds forming N^+ compounds
Amines are the nitrogen analogue of alcohols (and therefore have similar reactivity)

Primary (1^o) Amines

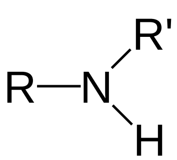
Example ethylamine

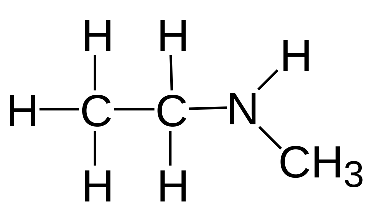




Secondary (2^o) Amines

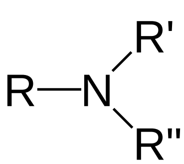
Example ethylmethylamine

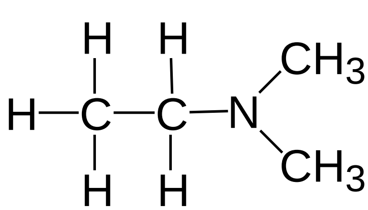




Tertiary (3^o) Amines

Example dimethylethylamine

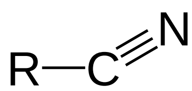




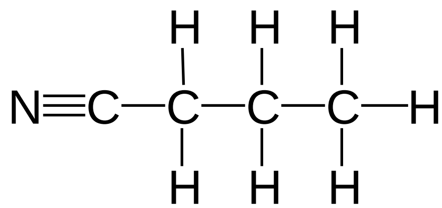
Nitriles

Contains the C≡N group (carbon/nitrogen triple bond)

Example



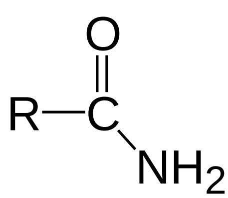
butanonitrile (butyronitrile)



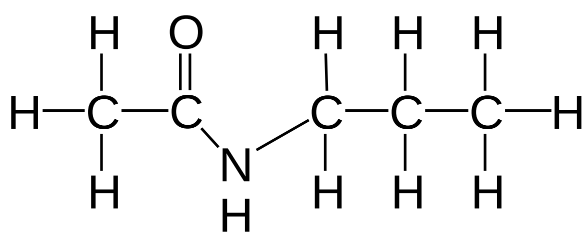
Amides

Primary and secondary amides are similar to carboxylic acids and esters (respectively). Because nitrogen has one more attachment (SN = 3, not 2 like with oxygen) you can also get tertiary amides. Has a similar naming convention as with esters. Uses “N” for carbon chains coming off nitrogen

Primary Amide



Secondary Amide (N-propyl-ethylamide)



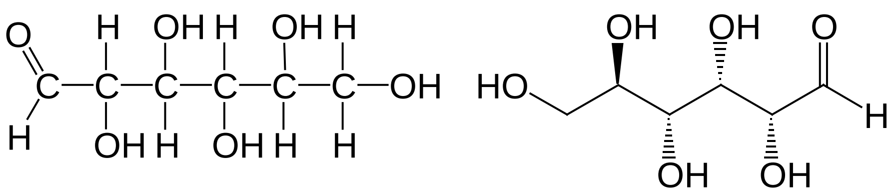
Biological Molecules

There are three major types of biological molecules; carbohydrates (sugars), Proteins (amino acids) and Fats (fatty acids)

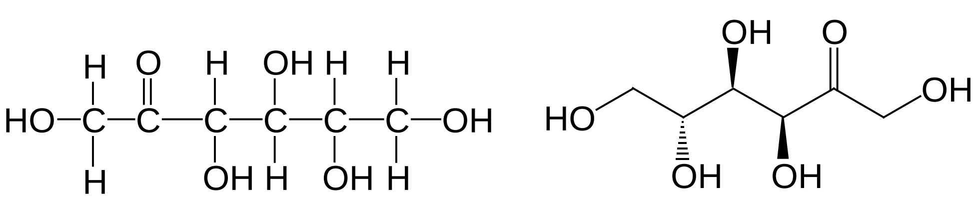
Carbohydrates (sugars)

Carbohydrates are used for energy storage and quick energy. Simple sugars are usually monosaccharides (contain 1 sugar unit) or disaccharides (contain 2 sugars). Complex carbohydrates contain many more sugar units and are more complex (as the name implies) in nature. We will not be addressing complex carbohydrates in chemistry 11. Monosaccharides are aldehydes or ketones with multiple hydroxyl groups. They generally exist in their cyclic form in solution called a ***pyranose*** *(6 member ring) or* ***furanose*** *(5 member ring)*.

Glucose (5 carbons, 1 oxygen in a ring, aldehyde)

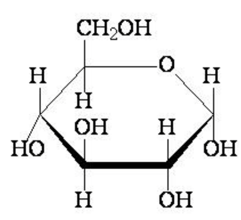


Fructose (4 carbons, 1 oxygen in a ring, ketone)

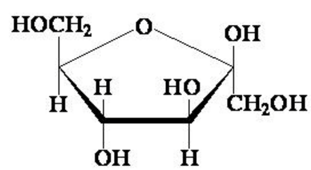


Sucrose (a disaccharide)

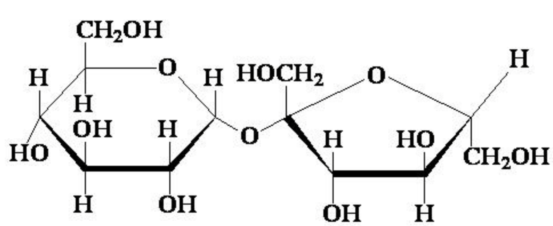
Forms an ester bond between glucose and fructose, losing water



glucose



fructose

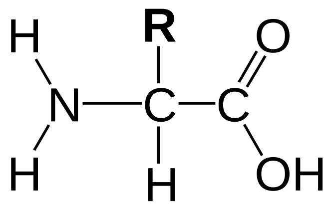


sucrose

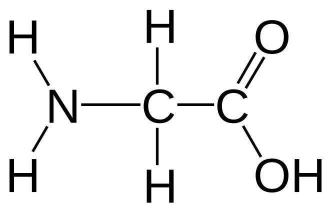
Proteins (amino acids)

Proteins are essential for building muscles, bones, and most other structural components of animals. Amino acids make up proteins through "peptide bonding" (dehydration, as in esterification) Proteins are made up of many amino acid residues. Amino acids, as the name implies, contain a *primary **amine*** and a *carboxylic **acid*** part.

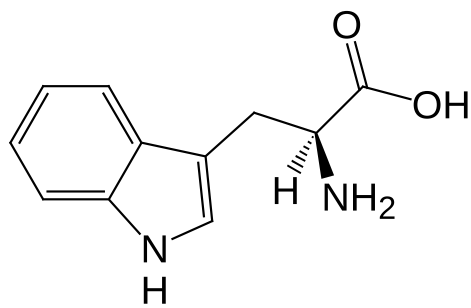
General Formula



Glycine (R = H)



Tryptophan (R = Indole group)

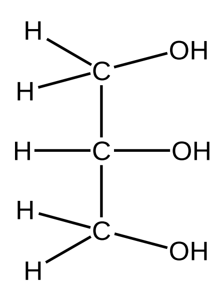


http://en.wikipedia.org/wiki/Amino_acid

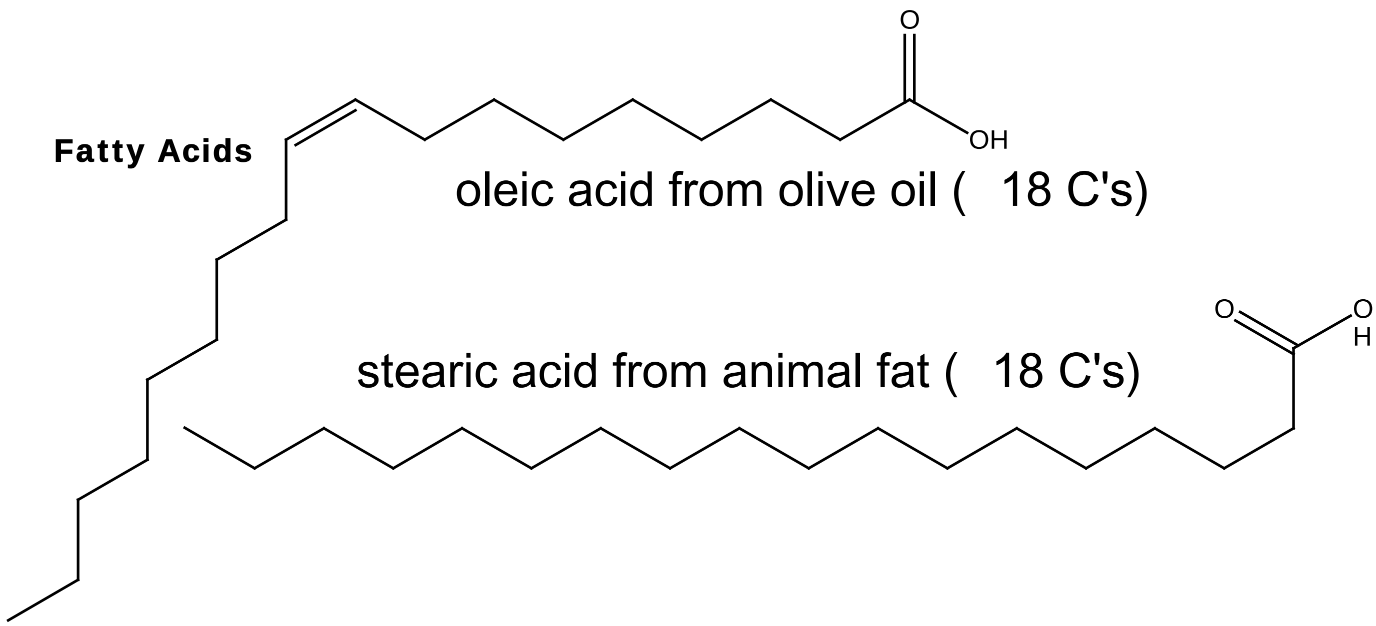
Lipids, Fats (Fatty Acids)

Fats are important to our body, they provide padding, energy storage, and are essential for our nervous system; there are also several essential vitamins that are fat soluble (vit. A, D, E, and K) Fats are known as ***triglycerides*** which are made up of 3 fatty acids and a glycerol molecule. They're called fatty acids because they contain a long hydrocarbon chain (non-polar, and hydrophobic, like oil/fat) and an organic acid. 3 of these fatty acids undergo esterification with the glycerol to make a triester. Another form of lipid is cholesterol, which is a steroid (made up of 4 cyclic rings and a long alkane chain)

Glycerol

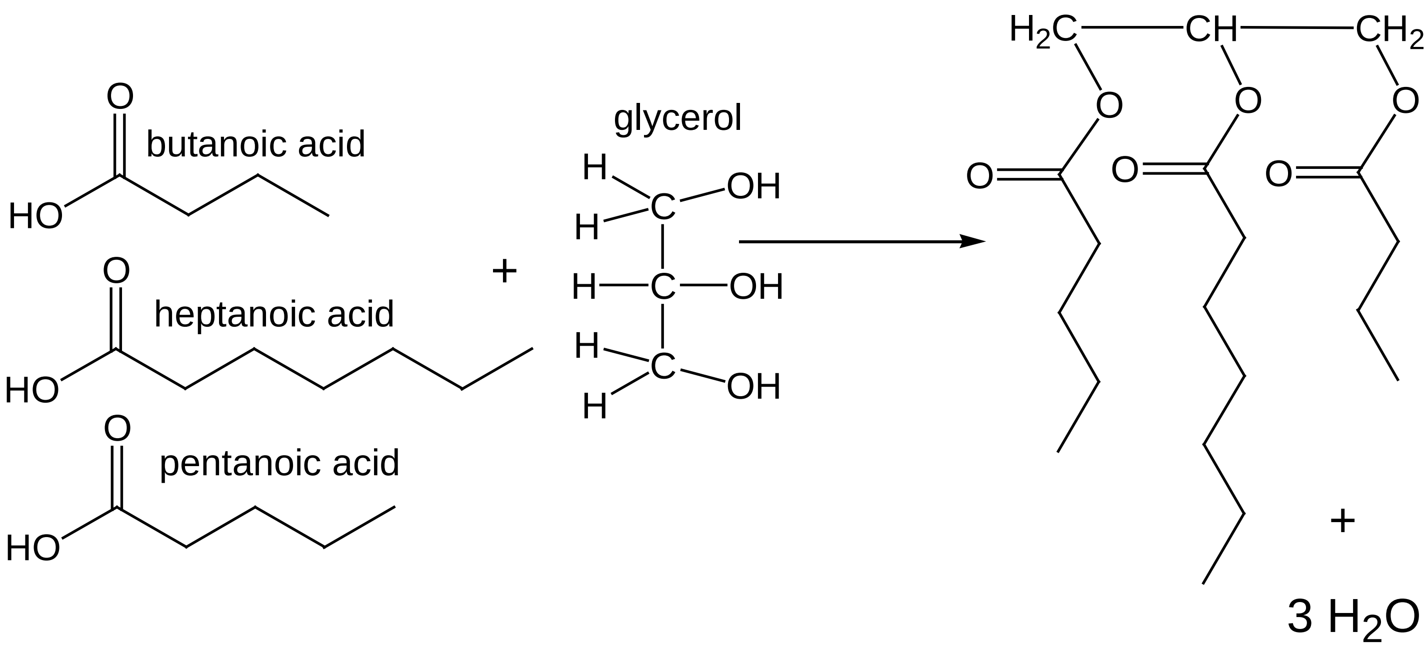


Fatty Acids



Fatty Acids (FA) can be one of two major types; saturated, and unsaturated. Saturated means it contains no double/triple bonds. Unsaturated means it contains at least one double bond. Saturated FA's tend to be solid at room temperature (think butter, lard etc…) whereas unsaturated FA's tend to be liquids (think olive oil, canola oil etc…) Saturated FA's are straight and tend to pack together really well (hence the solid form) Unsaturated (cis) are bent and are liquids. What kind of fats could be responsible for blocked arteries?

Triglyceride synthesis (ex. 3 saturated fatty acids give us a saturated fat)



- And that's all folks! -