# Introduction to Organic Chemistry

# What is Organic Chemistry?

- Organic chemistry studies compounds containing carbon
  - Some carbon compounds are excluded because they act more like non-carbon containing compounds (carbon oxides, metal carbides, and carbonates)
- Organic compounds include drugs, fuels, toiletries, plastics, and fabrics.

Organic Chemistry – studies compounds containing carbon.

→ examples of organic compounds include drugs, fuels, toiletries, plastics, fabrics.

# Why is Carbon So Special?

- Carbon can form a vast array of long chain and ring containing compounds because carbon has the unique ability to bond to itself.
- There is no theoretical limit to the number of organic compounds that can exist
- Aliphatic vs aromatic
- Carbon forms strong covalent bonds to hydrogen, nitrogen, oxygen, sulfur, and phosphorus in addition to others

Why is carbon So Special?

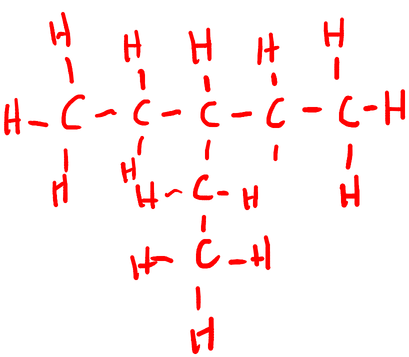
→ 4 valence electrons allow for a unique ability to bond to itself in chains and rings.

→ there is no theoretical limit to the number of organic compounds that exist.

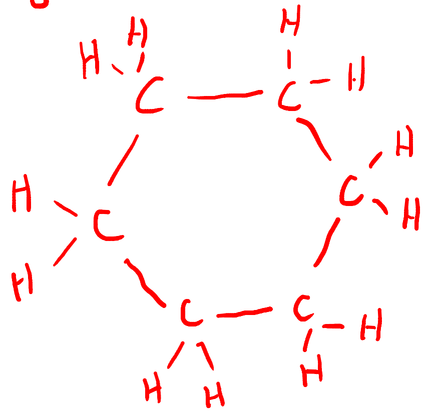
# Classification of Carbon Compounds

## aliphatic

### Straight Chains

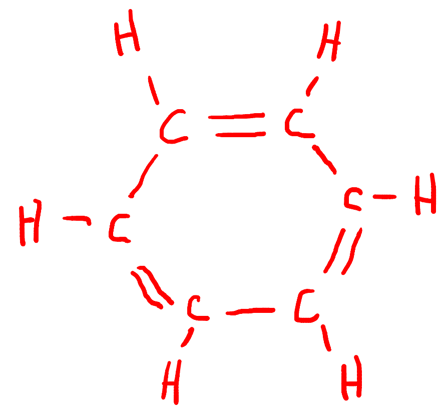


### Cyclostructures



## aromatic

### Benzene



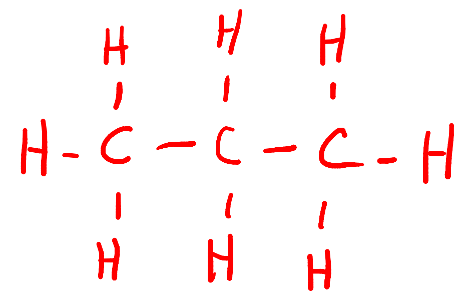
- six carbon ring with 3 double bonds

# Carbon Bonding

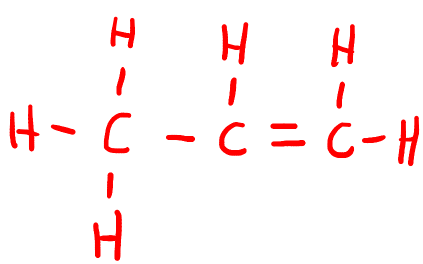
- Most organic molecules have a hydrocarbon chain foundation, sometimes with "things" attached to it called substituent groups
- Two Categories of Hydrocarbon chains
- 1. Saturated
- 2. Unsaturated
  - *Caution: Some saturated carbon-containing molecules may have carbon double bonded to an OXYGEN…being saturated or unsaturated has to do with the bonds between carbon atoms*

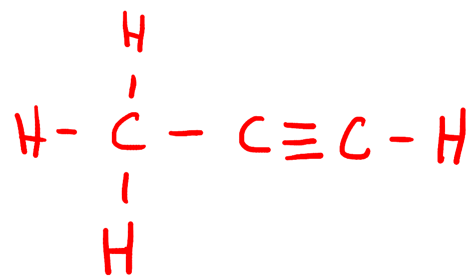
2 categories of hydrocarbons

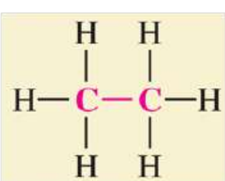
1) Saturated - carbon chains contain all single bonds.



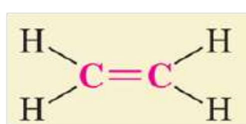
2) Unsaturated - Carbon chains contain at least one double or triple bond.





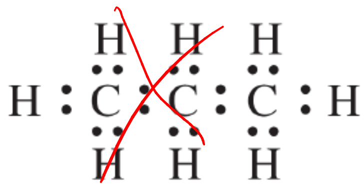


Ethane is a saturated hydrocarbon because it has all single bonds.

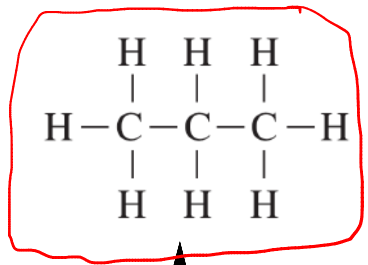


Ethene is an unsaturated hydrocarbon because it has a double bond.

# Organic Formulas and Molecular Models



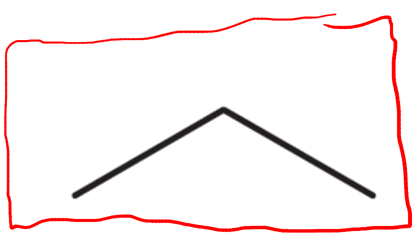
Lewis structure



Structural formula

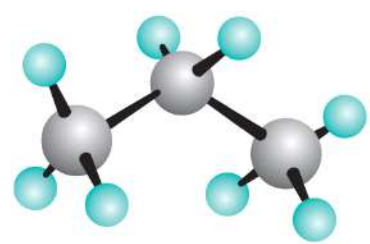
$CH_3CH_2CH_3$

Condensed structural formula



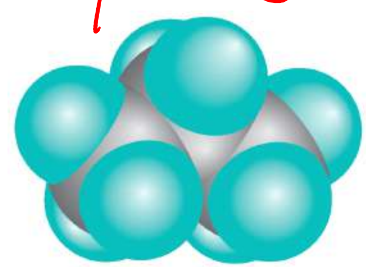
Line structure

Build

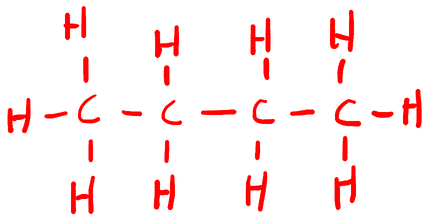
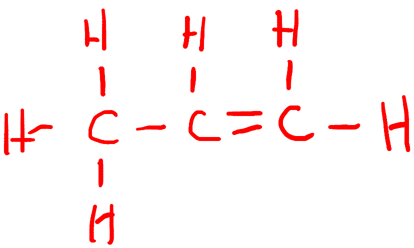
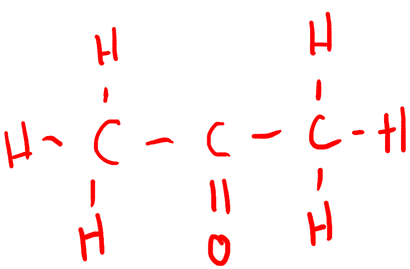
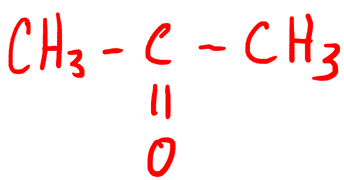
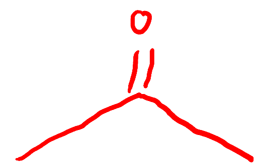
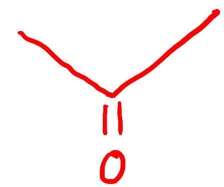
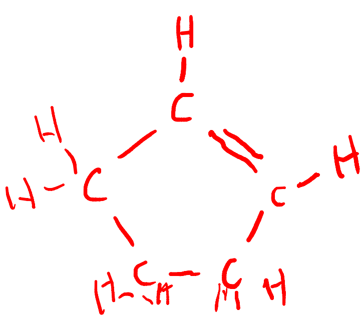
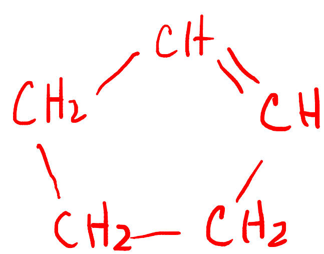
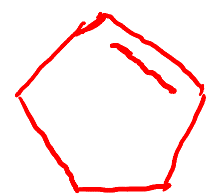


Ball-and-stick model

pictures

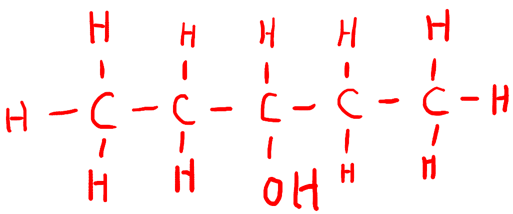


Space-fillng model

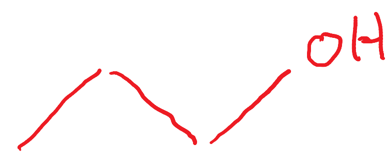
| Structural Formula | Condensed | Line |
| --- | --- | --- |
|  | $CH_3CH_2CH_2CH_3$ or $CH_3-CH_2-CH_2-CH_3$ |  |
|  | $CH_3-CH=CH_2$ |  |
|  |   |   |
|  |   |  |

# Practice with Drawing Organic Structures

| Structural Formula | Condensed | Line |
| --- | --- | --- |



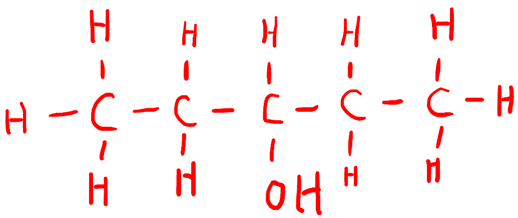
$$CH_3-\underset{\underset{O}{\|}}{C}-CH_2-CH_3$$

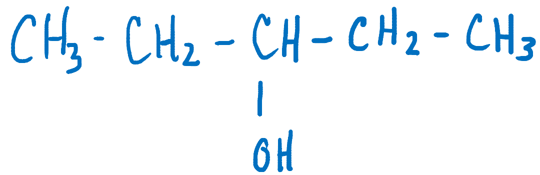


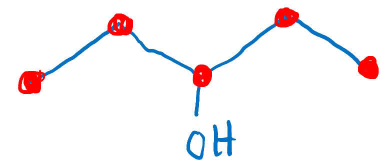
# Practice with Drawing Organic Structures

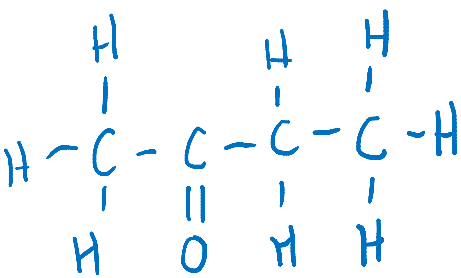
| Structural Formula | Condensed | Line |
|---|---|---|

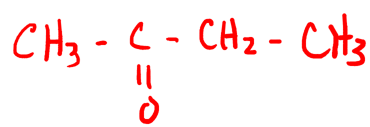
$CH_3CH_2CH(OH)CH_2CH_3$

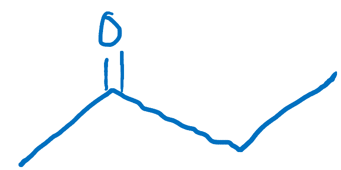


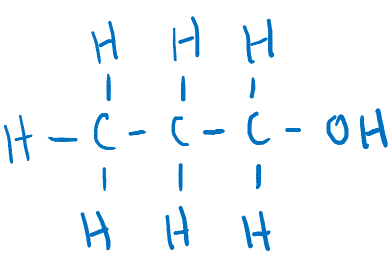




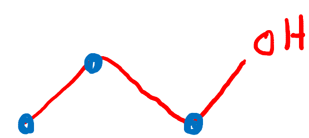







$CH_3-CH_2-CH_2-OH$

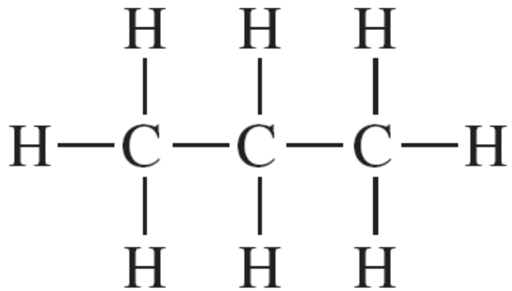


# Organic Formulas and Molecular Models

Structural formulas or models are often used in organic chemistry to illustrate molecules.

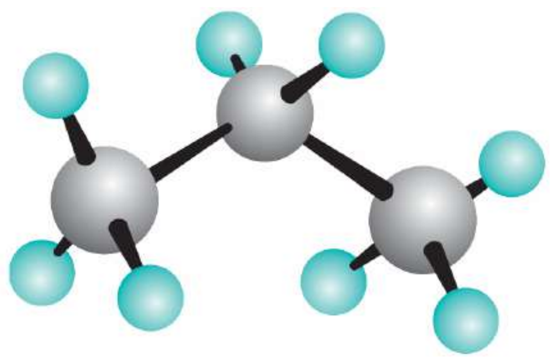
For example,

$C_3H_8$ is shown as




or in the case of a model.

$C_3H_8$ is shown as

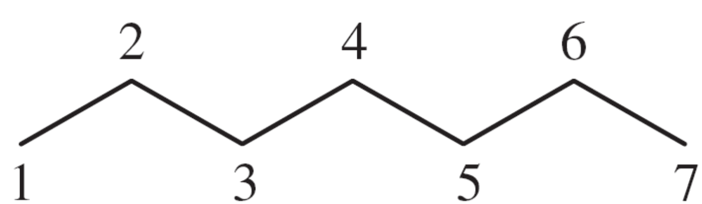


# Organic Formulas and Molecular Models

This is an example of how to change a condensed structural formula into a line structure.

1 2 3 4 5 6 7

$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$ *(condensed structural formula)*




*(line structure)*

The table on the next slide summarize formulas and models used in organic chemistry.

# Classifying Organic Compounds

Functional groups are group of atoms *(or one atom)* that have specific behavioral characteristics in organic compounds.

Organic compounds are classified based on the functional groups that they contain.

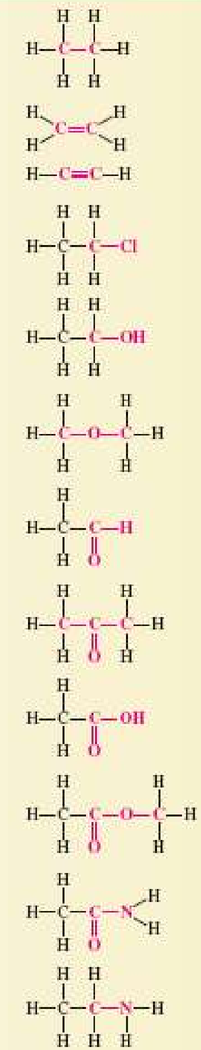
# Classifying Organic Compounds

The list of common functional groups found in organic compounds are shown here on Table 19.1.

**Table 19.1 Classes of Organic Compounds**

| Class of compound | General formula* | IUPAC name**, *** | Molecular formula | Condensed structural formula |
|---|---|---|---|---|
| Alkane | RH | Eth*ane* (Ethane) | $C_2H_6$ | $CH_3CH_3$ |
| Alkene | $R-CH=CH_2$ | Eth*ene* (Ethylene) | $C_2H_4$ | $H_2C=CH_2$ |
| Alkyne | $R-C\equiv C-H$ | Eth*yne* (Acetylene) | $C_2H_2$ | $HC\equiv CH$ |
| Alkyl halide | RX | Chloroethane (Ethyl chloride) | $C_2H_5Cl$ | $CH_3CH_2Cl$ |
| Alcohol | ROH | Ethan*ol* (Ethyl alcohol) | $C_2H_6O$ | $CH_3CH_2OH$ |
| Ether | $R-O-R$ | Methoxymethane (Dimethyl ether) | $C_2H_6O$ | $CH_3OCH_3$ |
| Aldehyde | $R-\underset{H}{C}=O$ | Ethan*al* (Acetaldehyde) | $C_2H_4O$ | $CH_3CHO$ |
| Ketone | $R-C(=O)-R$ | Propan*one* (Dimethyl ketone) | $C_3H_6O$ | $CH_3COCH_3$ |
| Carboxylic acid | $R-C(=O)-OH$ | Ethan*oic acid* (Acetic acid) | $C_2H_4O_2$ | $CH_3COOH$ |
| Ester | $R-C(=O)-OR$ | Methyl ethan*oate* (Methyl acetate) | $C_3H_6O_2$ | $CH_3COOCH_3$ |
| Amide | $R-C(=O)-NH_2$ | Ethan*amide* (Acetamide) | $C_2H_5ON$ | $CH_3CONH_2$ |
| Amine | $R-CH_2-NH_2$ | Aminoethane (Ethylamine) | $C_2H_7N$ | $CH_3CH_2NH_2$ |

Structural formula

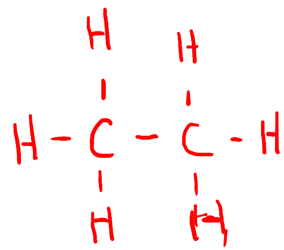


* The letter R is used to indicate any of the many possible alkyl groups. ** Class name ending in italic. *** Common name in parentheses

# Functional Groups

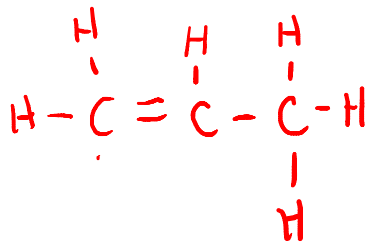
R - hydrocarbon chain

alkane



ethane $CH_3CH_3$

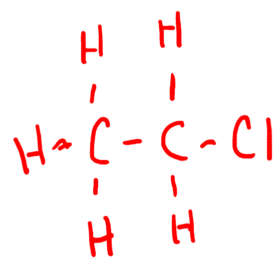
alkene



propene $CH_2=CHCH_3$

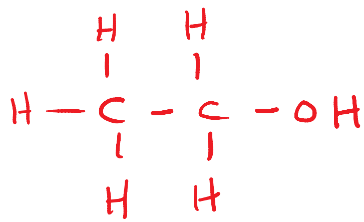
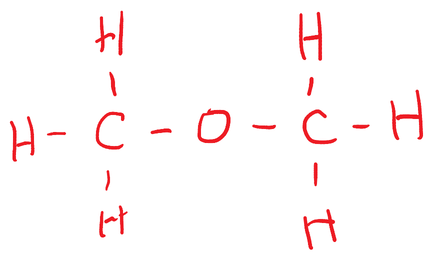
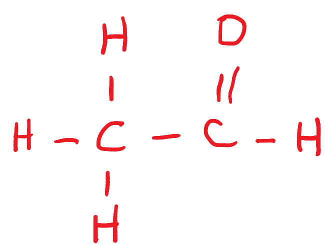
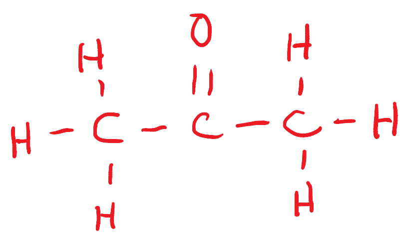
alkyne $H-C\equiv C-H$ ethyne $CH\equiv CH$

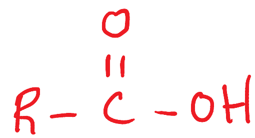
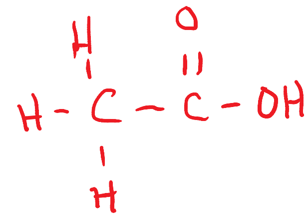
alkyl halide R - Cl

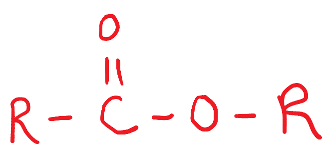
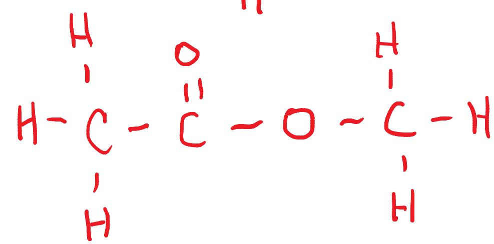


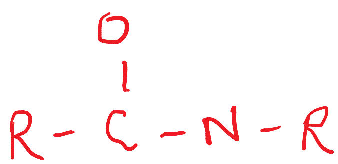
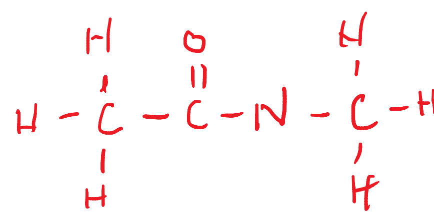
chloroethane $CH_3CH_2Cl$

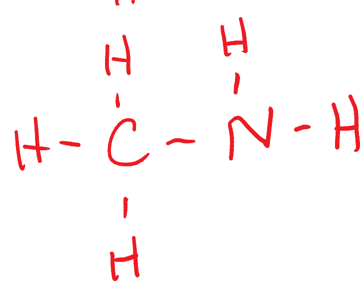
halogens:
- Cl
- F
- Br
- I

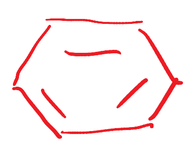
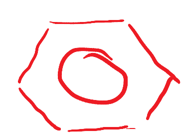
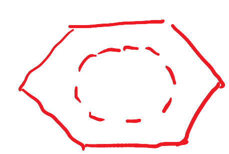
| | | | | |
|---|---|---|---|---|
| alcohol | R - OH |  | ethanol | $CH_3CH_2OH$ |
| ether | R - O - R |  | dimethyl ether | $CH_3-O-CH_3$ |
| aldehyde | $R-\overset{O}{\overset{\Vert}{C}}-H$ |  | ethanal | $CH_3CHO$ |
| Ketone | $R-\overset{O}{\overset{\Vert}{C}}-R$ |  | propanone | $CH_3-\overset{O}{\overset{\Vert}{C}}-CH_3$ |

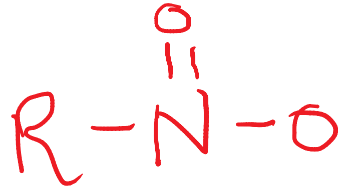
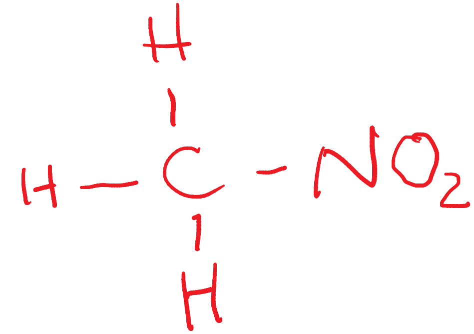
carboxylic acid   ethanoic acid $CH_3COOH$

ester   methyl-ethyl-ester $CH_3COOCH_3$

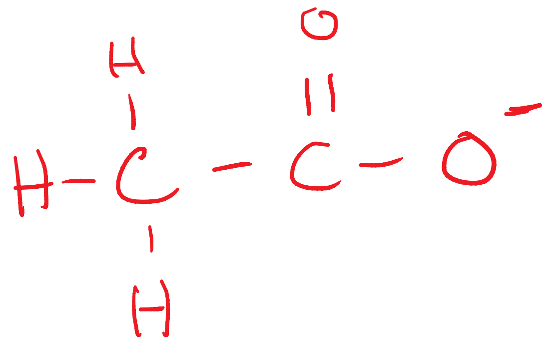
amide   methyl ethyl amide $CH_3CONCH_3$

amine $R-NH_2$  methyl amine $CH_3NH_2$

Benzene (aromatic)   

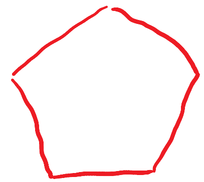
nitro $R-NO_2$ or  

Cyanide $R-CN$ or $R\equiv CN$

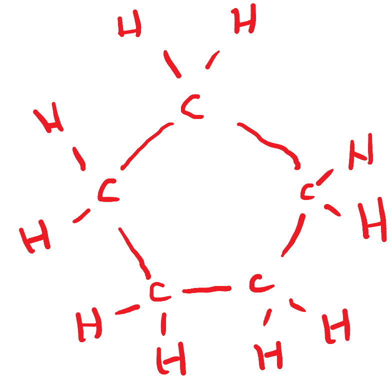
Carboxylate $R-COO^-$ 

→ Note: this is a carboxylic acid that has lost an electron. It is an ion and has a -1 charge.

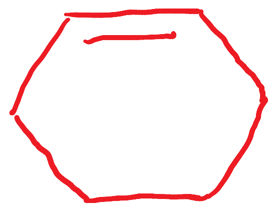
Cycloalkane



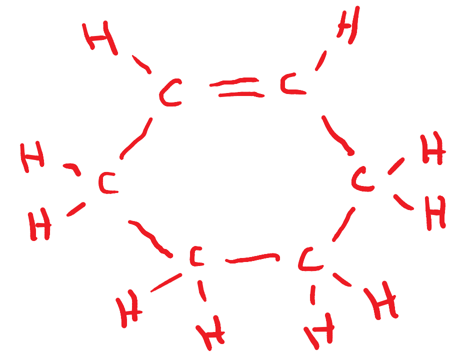
cyclopentane



Cycloalkene



cyclohexene



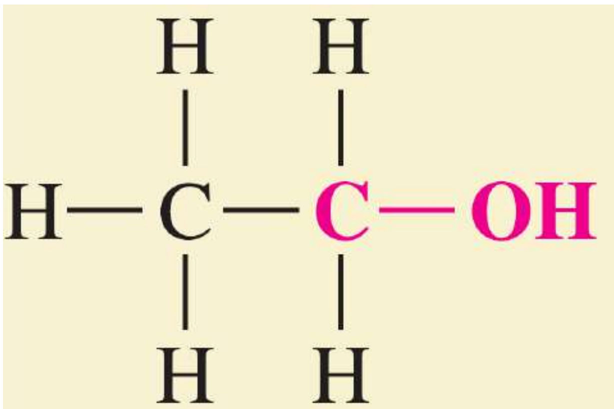
# Classifying Organic Compounds

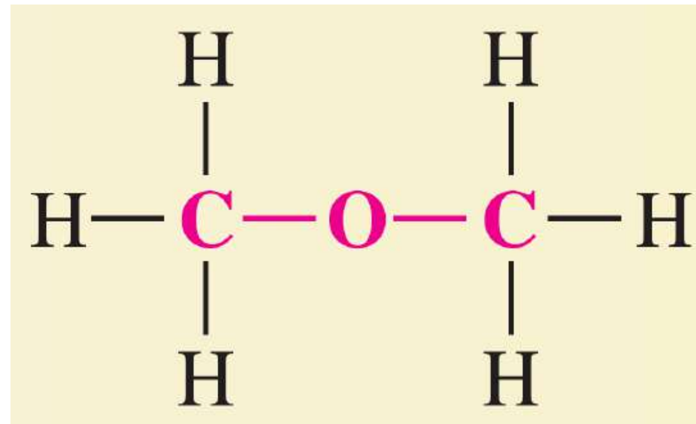
The list of important functional groups found in biological compounds is shown here on Table 19.2.

**TABLE 19.2 | Important Functional Groups in Biochemistry**

| Biochemical class | Functional groups important to the biochemical | | |
|---|---|---|---|
| Carbohydrates | $R-C(H)=O$<br>aldehyde | $R-C(=O)-R$<br>ketone | $ROH$<br>alcohol |
| Fatty acids | $R-C(=O)-OH$<br>carboxylic acid | | |
| Proteins | $R-C(=O)-OH$<br>carboxylic acid | | $RCH_2NH_2$<br>amine |
| Nucleic acids | $ROH$<br>alcohol | [ $H_3PO_4$<br>phosphoric acid ] | |

# Classifying Organic Compounds



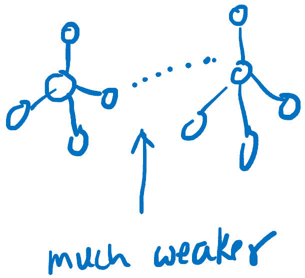

Ethanol contains the alcohol functional group and dimethyl ether contains the ether functional group. They have the same molecular formula but the boiling point (b.p.) of ethanol is 78°C while the b.p. of dimethyl ether is -23°C because of the structural differences between the molecules.

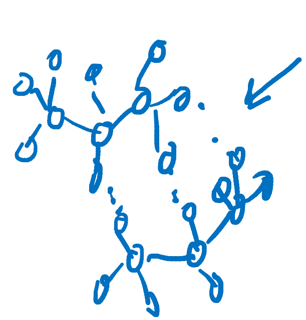
# Intermolecular Forces

* Weaker forces result in low boiling points and fast evaporation.

## 1) Van der Waals / Dispersion Forces

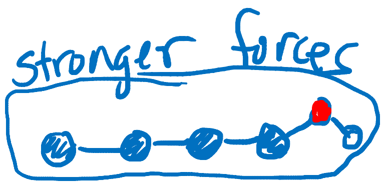
→ very weak attractive forces between all molecules
→ molecule size and shape affect this.



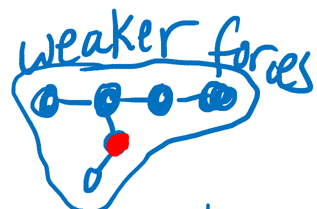





Interspaghetti forces




1-butanal

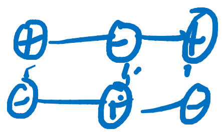



2-butonal

→ more compact molecules will have weaker forces compared to spread-out molecules with the same mass.

## 2) Dipole-Dipole Forces

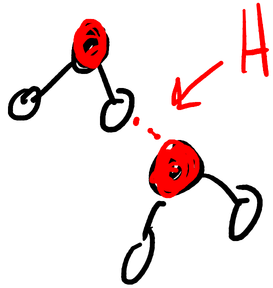
- occur between oppositely charged regions on molecules.
- Reminder: polar covalent bonds result in the charged regions.



← relatively strong forces

**Hydrogen Bond** - special type of dipole-dipole force between molecules that have hydrogen bonded specifically to Fluorine, oxygen, or nitrogen (F, O, N)

* High boiling points and low evaporation rates.



Hydrogen bond is the strongest type of dipole-dipole force.