Go to the "Slide Show" shade above

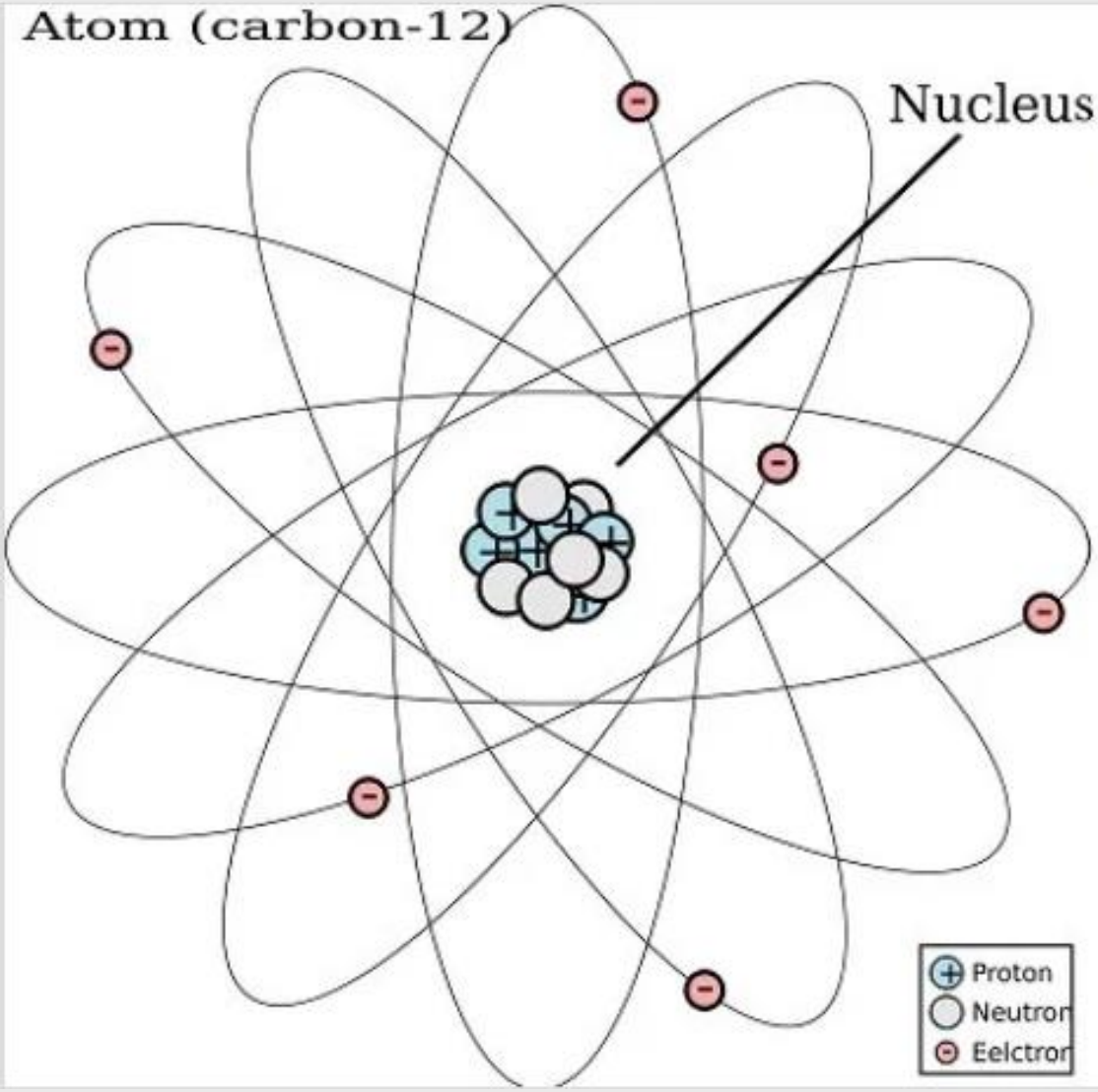
Click on "Play from Beginning"

Organic Chemistry

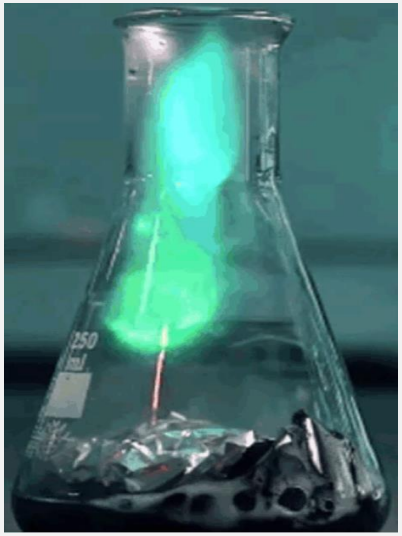
Carbon Chemistry

WARM-UP

What do all living things have in common?



Carbon Based Life Forms



Carbon Chemistry
Focus Points

- Identify three forms of carbon.
- Explain "organic" chemistry based on carbon, giving examples of carbon-based compounds.
- Define factors that determine the properties of a hydrocarbon and distinguish types of unsaturated hydrocarbons (alkenes, alkynes, and aromatic).
- Describe fossil fuels and their importance in the world, including combustion.

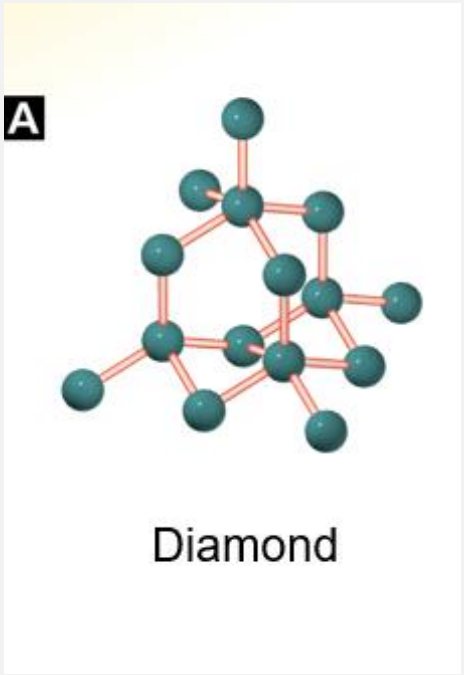
Carbon Based Life Forms

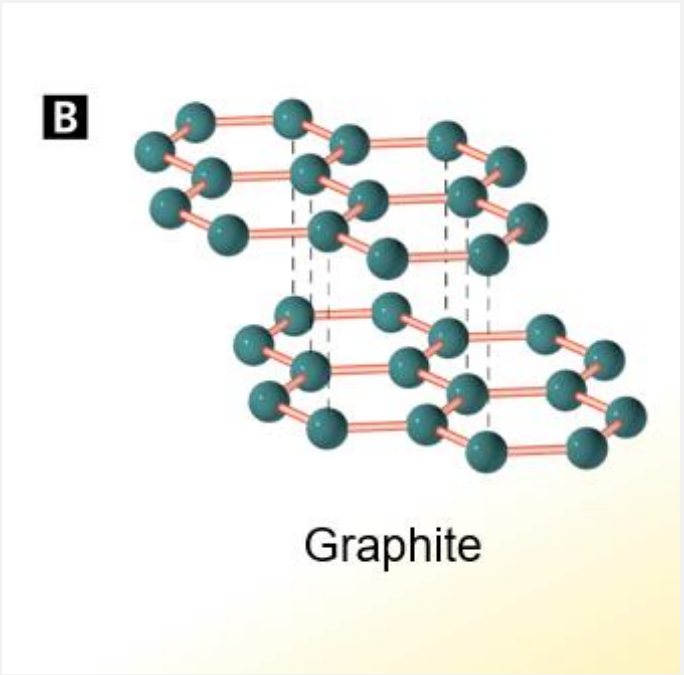
Carbon has three forms:

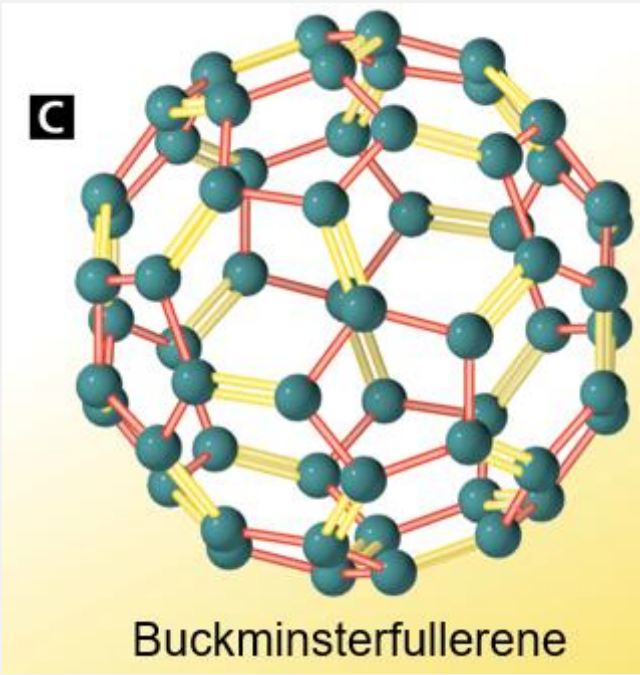
Diamond

Graphite

Fullerenes



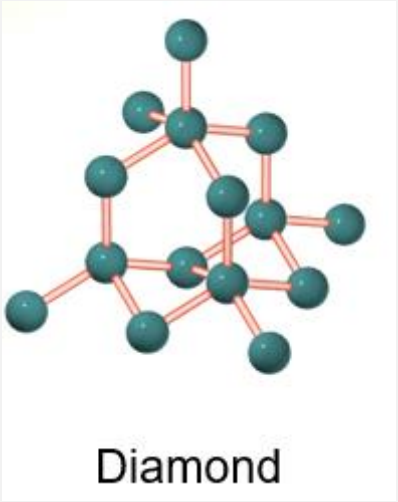




Diamond

Diamond is an example of a **network solid**, in which all the atoms are linked by covalent bonds.

- Covalent bonds connect each carbon atom to four other carbon atoms.
- The three-dimensional structure is rigid, compact, and strong.
- Diamond is harder than other substances because cutting a diamond requires breaking many covalent bonds.

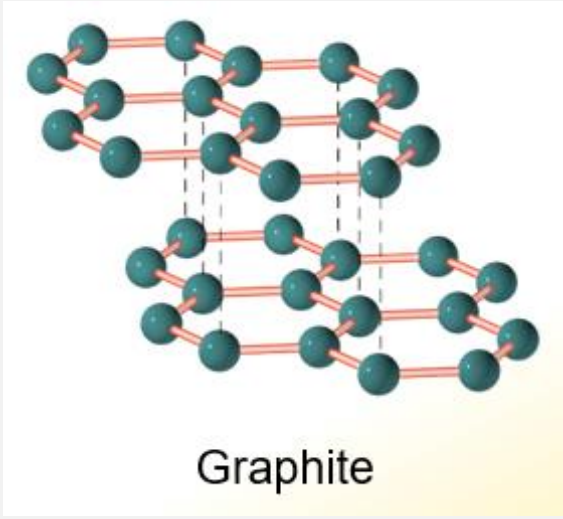


Diamond

Graphite

Graphite is extremely soft and slippery.

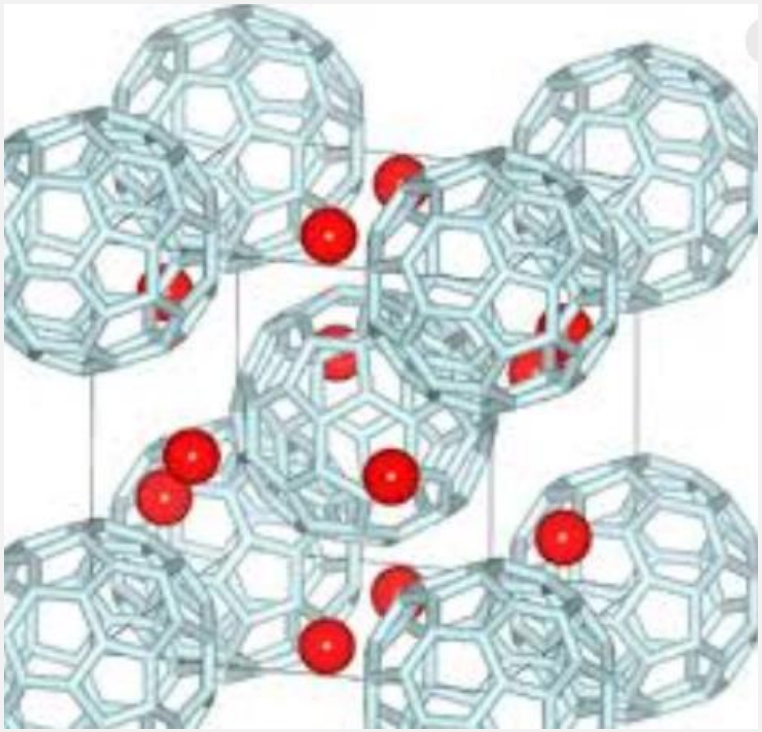
- Carbon atoms are arranged in widely spaced layers.
- Within each layer, carbon atoms form strong covalent bonds with three other carbon atoms.
- Between layers the bonds are weak, so layers slide easily past one another.



Graphite

Fullerenes

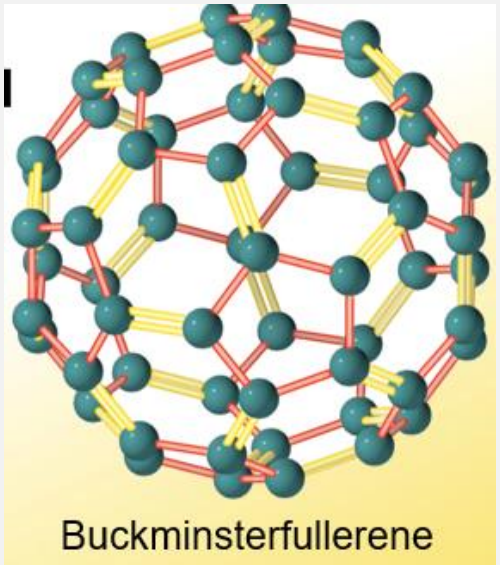
Carbon Based Life Forms



Fullerenes are large hollow spheres or cages of carbon.

Fullerenes are used **in the medical field as light-activated antimicrobial agents**.

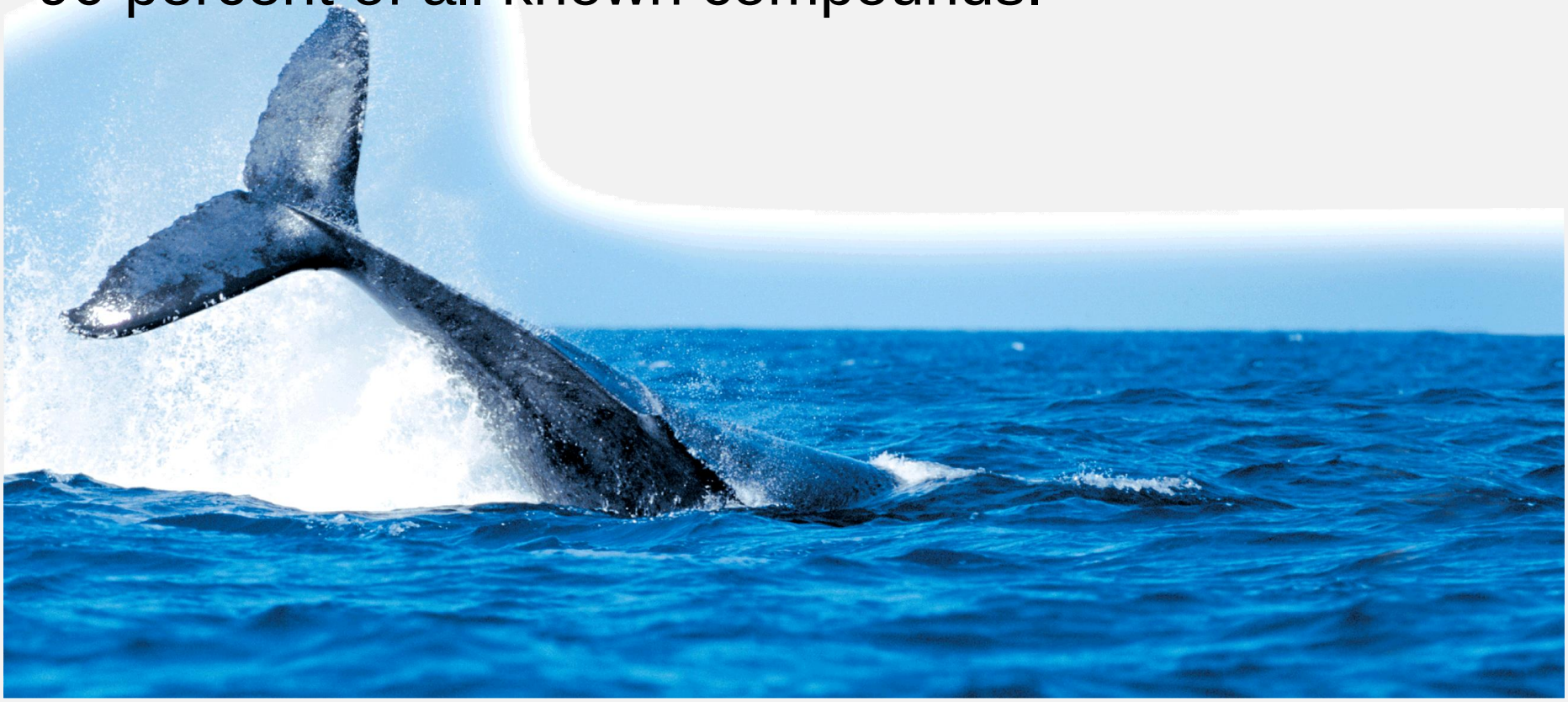
It is also used in several biomedical applications including the design of high-performance MRI contrast agents, X-ray imaging contrast agents, photodynamic therapy and drug and gene delivery.



Carbon Based Life Forms

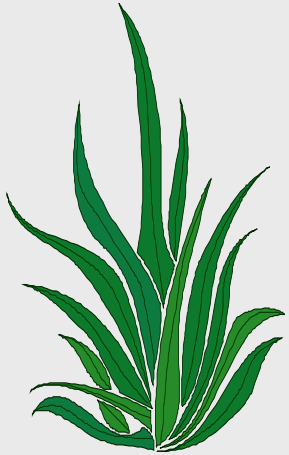
An **organic compound** contains carbon and hydrogen, often combined with a few other elements such as oxygen and nitrogen.

There are millions of organic compounds—more than 90 percent of all known compounds.



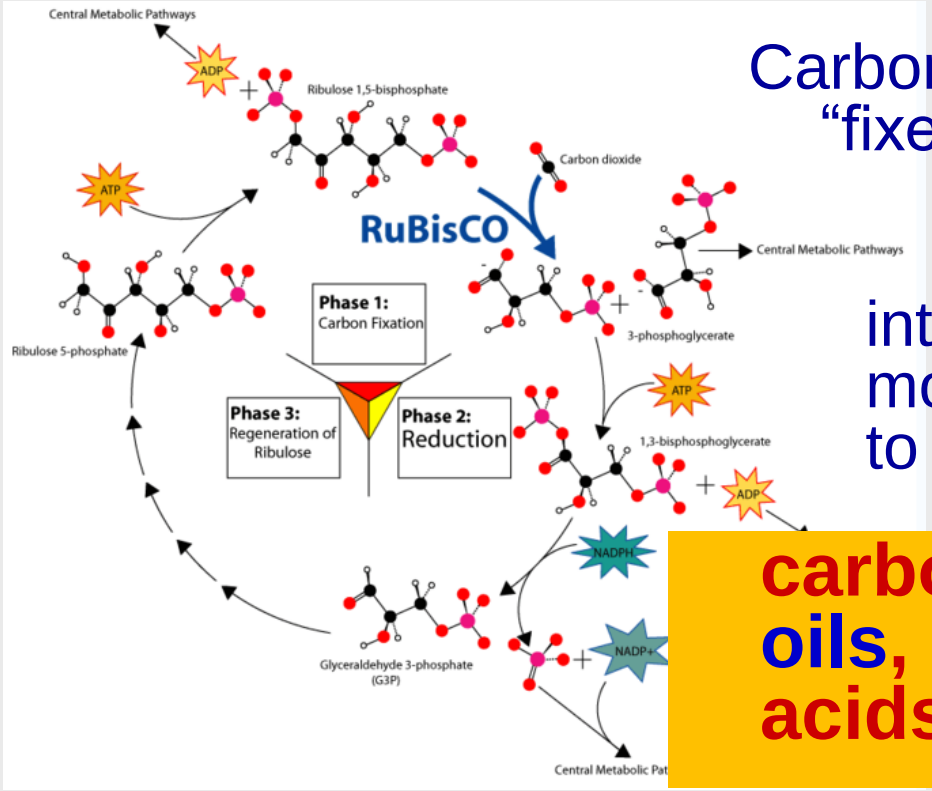
Origin of Organic Molecules

- Naturally occurring organic molecules are found in **PLANTS**, animals, and fossil fuels

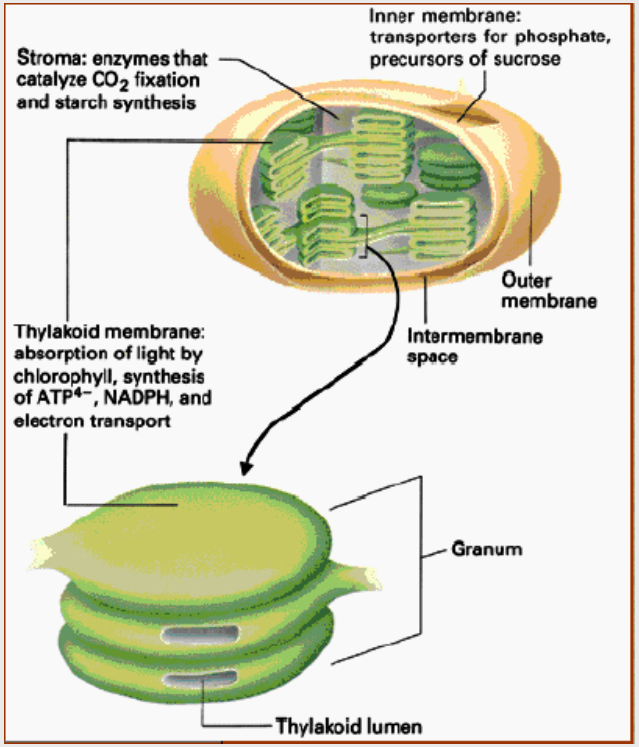


Origin of Organic Molecules

- **PLANTS** take carbon dioxide from the atmosphere to produce most of the chemicals and molecules that comprise life:



Carbon gets "fixed"



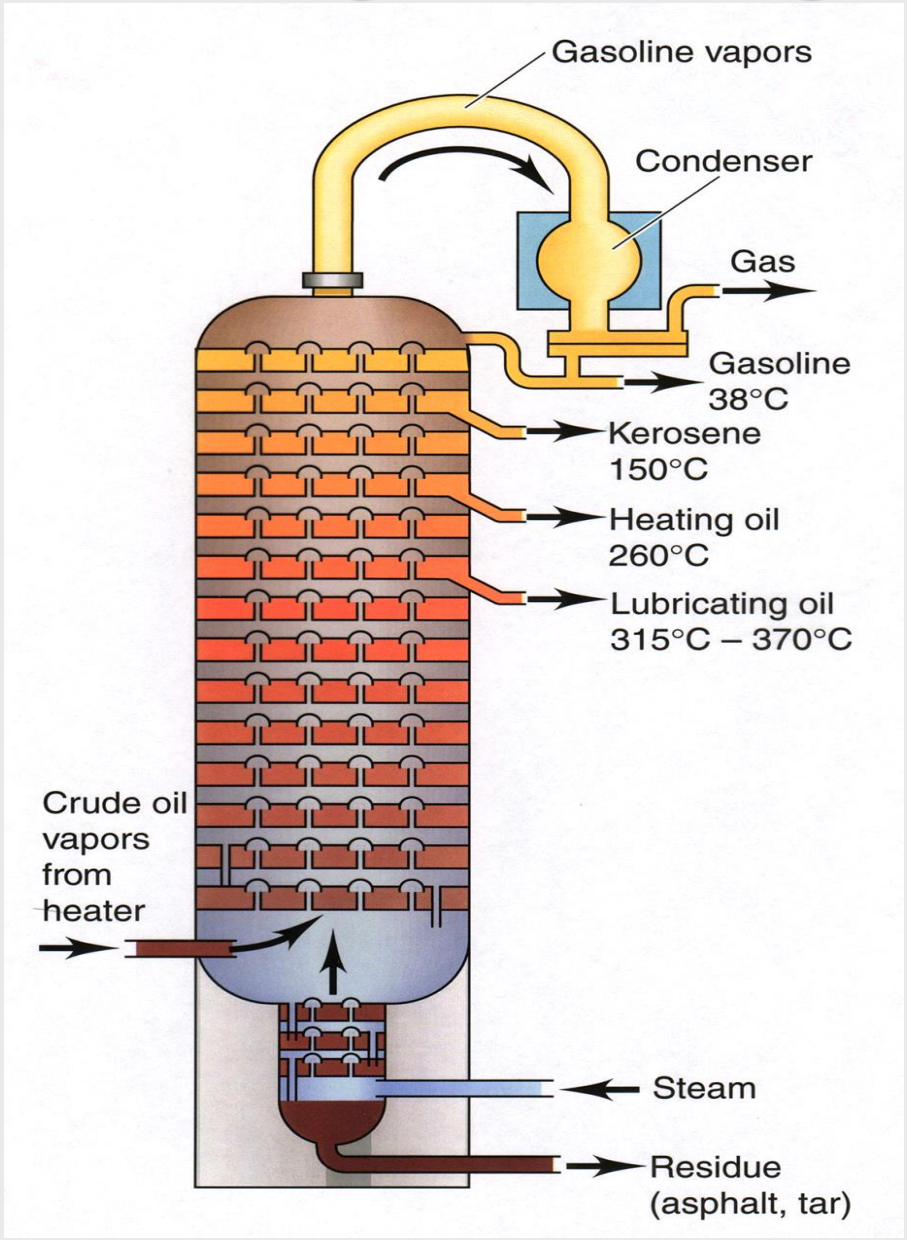
into molecules to produce:

carbohydrates, proteins, fats, oils, nucleic acids, fatty acids, vitamins

Origin of Organic Molecules

- **Animals are composed of organic molecules (carbon based life forms) … mainly proteins.**

Origin of Organic Molecules



- **Fossil Fuels include coal, natural gas, petroleum (oil, diesel, etc.)**
- **Synthetic organic molecules are derived from fossil fuels or plant material**

So what's a "**Fossil Fuel**?"

- Plants and animals die and are buried for many years under high temperature and pressure, produces fossil fuels.

- The type of fossil fuel depends on the origin of the organic (formerly alive) material and the conditions of temperature and pressure under which they decay.

So what's a "**Fossil Fuel**?"

Coal

- Giant tree ferns and other plants were buried in swamps.
- After many of years of pressure, the plant remains produced a mixture of hydrocarbons.

Natural Gas

- Natural gas formed from the remains of marine organisms.
- The main component of natural gas is methane. Natural gas also contains ethane, propane, and isomers of butane.
- Natural gas is used for heating and cooking.

Petroleum

- Petroleum also formed from marine organisms.
- Petroleum is pumped from deep beneath Earth's surface.

How do we use "**Fossil Fuels**?"

- Fossil fuels are burned in combustion reactions.

$$CH + O_2 \rightarrow CO_2 + H_20$$

Hydrocarbon + Oxygen → Carbon Dioxide + Water

- Burning fossil fuels gives off pollutants (**SO_2** and **NO_x**) and damages the environment.

Incomplete Combustion

If there is not enough oxygen available for complete combustion of all the fuel, carbon monoxide is produced.

Carbon monoxide is a colorless, odorless gas that is poisonous. It keeps hemoglobin from carrying oxygen to cells.

$$2C_3H_8 + O_2 \rightarrow 6CO + 8H_20$$

Hydrocarbon + Oxygen → **Carbon monoxide** + Water

Distinguishing Properties of Compounds.

Graphite is soft and slippery because its carbon atoms

a. are arranged in layers with weak attractions between layers.
b. have a large, interlocking network.
c. contain individual atoms with very weak bonds to other carbon atoms.
d. share a weak bond with hydrogen atoms.

Name three major fossil fuels:

Name three forms of Carbon:

Distinguishing Properties of Compounds.

QUICK CHECK

Graphite is soft and slippery because its carbon atoms

a. **are arranged in layers with weak attractions between layers.**
b. have a large, interlocking network.
c. contain individual atoms with very weak bonds to other carbon atoms.
d. share a weak bond with hydrogen atoms.

Name three major fossil fuels:

Coal

Natural gas

Oil (petroleum)

Name three forms of Carbon:

Diamond

Graphite

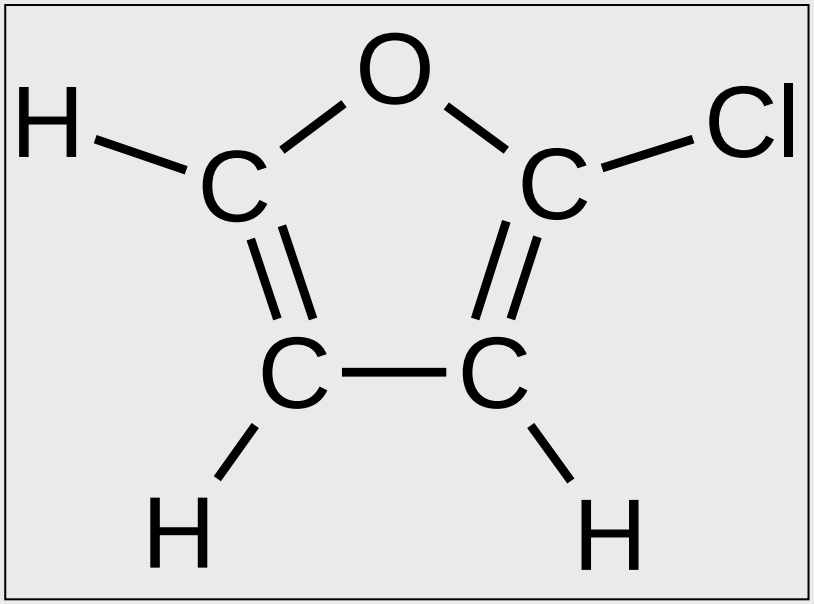
Fullerenes

Carbon is the BACKBONE

the
center
of
all
organic
molecules

Carbon forms four bonds

- Carbon usually forms **FOUR** strong covalent bonds, with other elements.

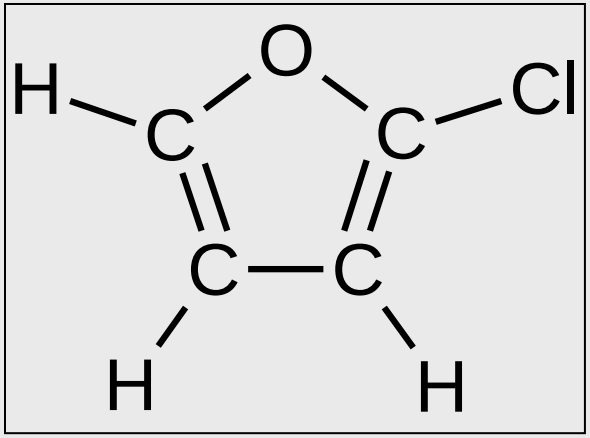


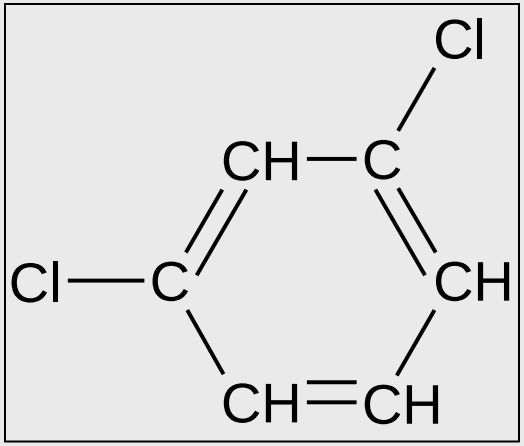
- Notice that around each “carbon” atom are **FOUR** dashes.

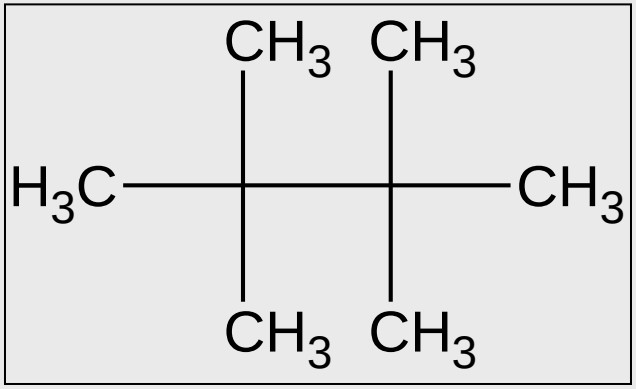
(**each representing 1 bond of 2 electrons**)

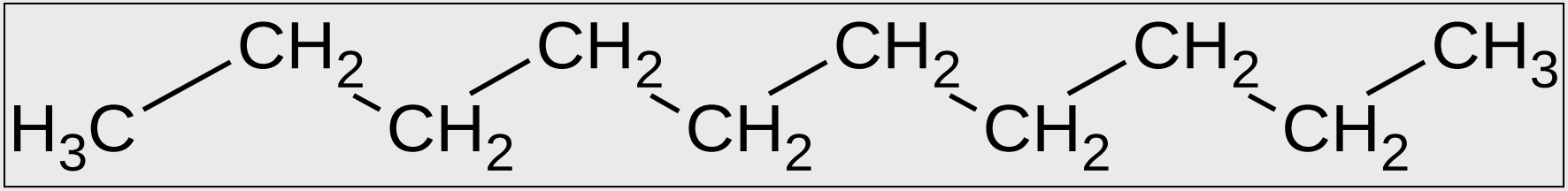
Carbon forms four bonds

- **The FOUR bonds to the carbon atom can be represented in many ways …**









Organic Molecules Can be Divided into GROUPS

- The **largest** group of Organic Molecules are the "**HYDROCARBONS**"
- The second largest group of Organic Molecules contain **OXYGEN**
- Other groups contain **NITROGEN** and / or **PHOSPHORUS** and / or **SULFUR**

Organic Molecules Can be Divided into GROUPS

- We will focus on the "**HYDROCARBONS**"
- And the Organic Molecules containing **OXYGEN**

Hydrocarbons

- are the simplest and most abundant class of organic compounds.

- consist entirely and ONLY of **carbon** and **hydrogen.**

There are **FOUR** types of Hydrocarbons:

1. **Alk<u>an</u>es** — contain only carbon-hydrogen and carbon-carbon **SINGLE COVALENT** bonds.

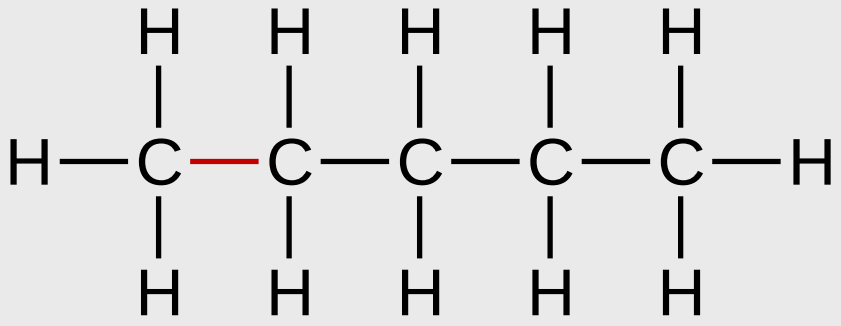
2. **Alk<u>en</u>es** — contain at least one carbon-carbon **DOUBLE COVALENT** bond.

3. **Alk<u>yn</u>es** — contain a least one carbon-carbon **TRIPLE COVALENT** bond.

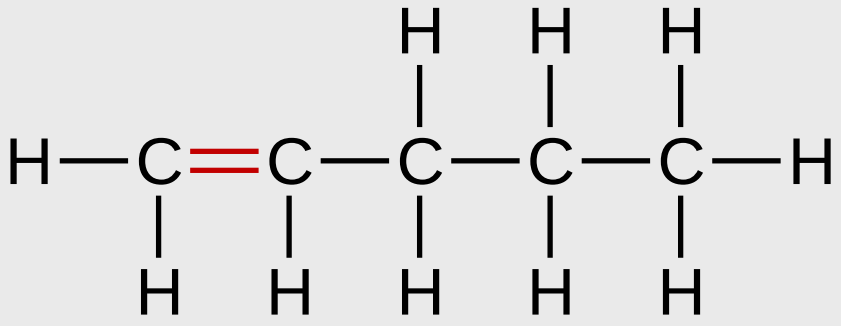
4. **Aromatics** — contain **RING** of **SIX** carbon atoms that can be drawn with alternating single and double bonds.

Hydrocarbons

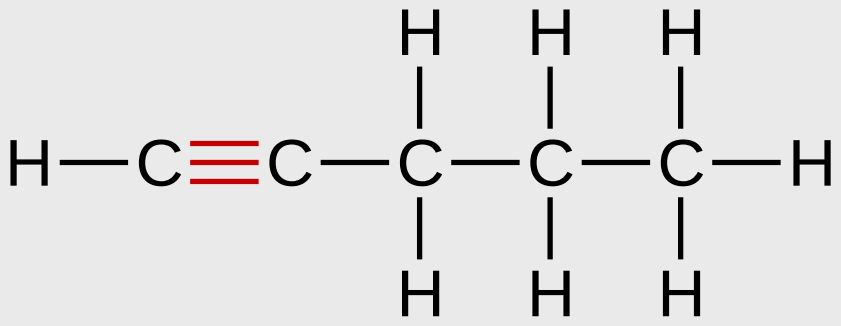
Alkanes C — C



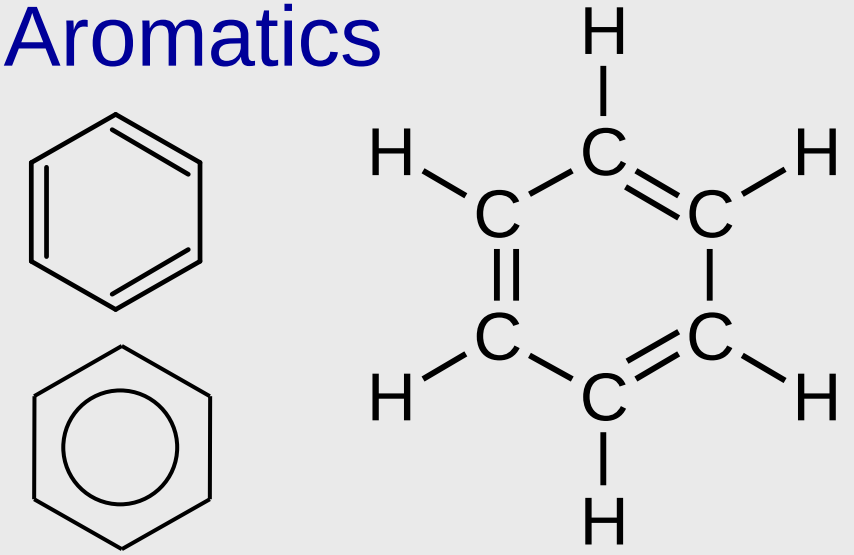
Alkenes C = C

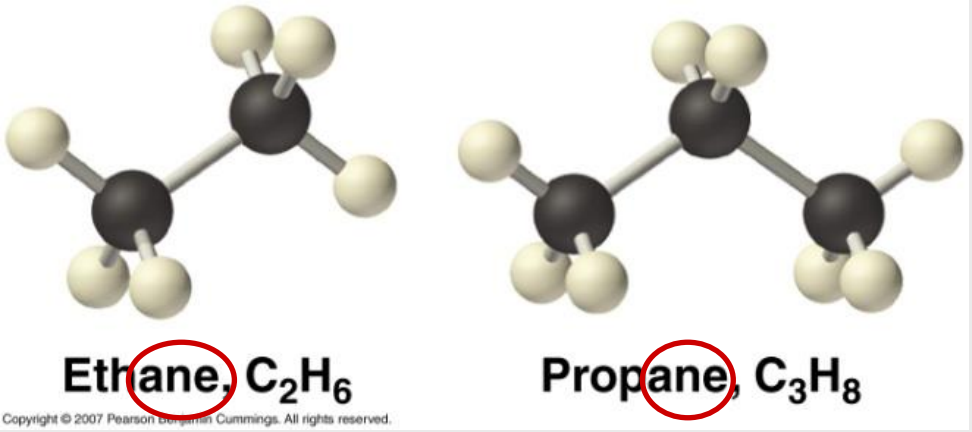


Alkynes C ≡ C



Aromatics

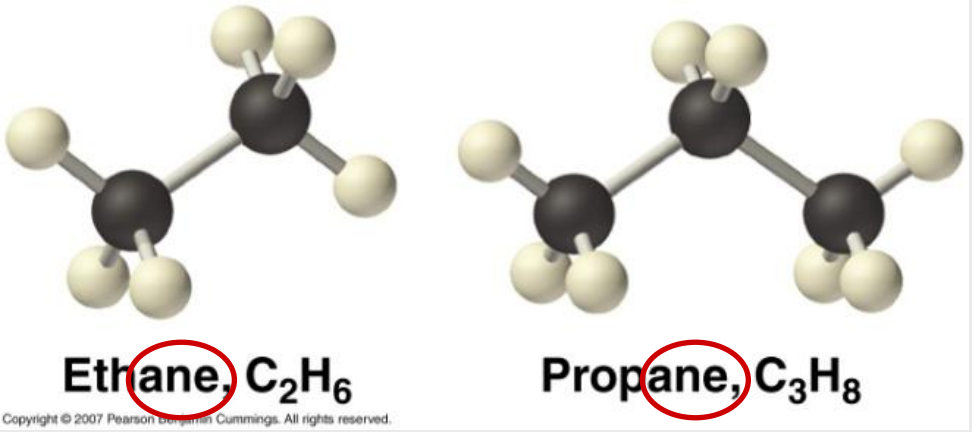




Saturated Hydrocarbons

In a **saturated hydrocarbon,** all of the bonds are single bonds.

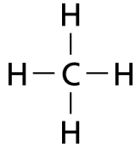
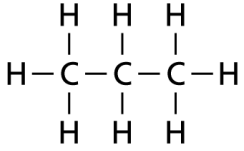
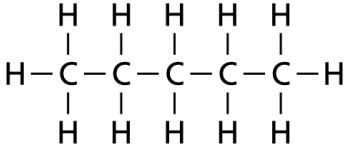
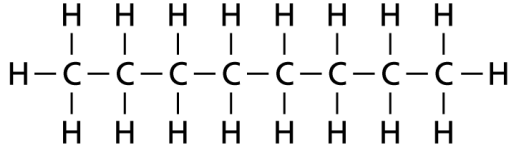
- A saturated hydrocarbon contains the maximum possible number of hydrogen atoms for each carbon atom.
- Saturated hydrocarbons are also called **alkanes**. Their names end in *–ane*.
- Saturated hydrocarbons can be straight-chains or branched.



Saturated Hydrocarbons

Straight-chain **saturated hydrocarbons** all have **SINGLE** bonds. Notice that their properties vary based on size (e.g. boiling point).

Some Straight-Chain Alkanes

Name	Methane	Propane	Pentane	Octane
Molecular Formula	CH_4	C_3H_8	C_5H_{12}	C_8H_{18}
Structural Formula				
Boiling Point	–161.5°C	–42.1°C	36.0°C	125.6°C

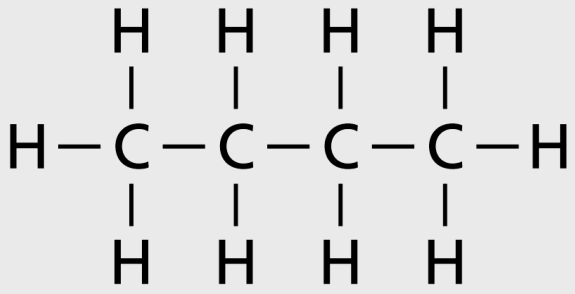
Saturated Hydrocarbons

Branched Chains

Butane and isobutane both have a molecular formula of C_4H_{10}, but their structural formulas are different.

Butane

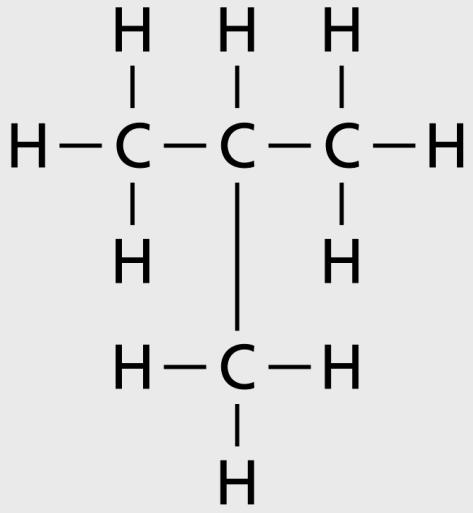
C_4H_{10}



Unbranched

Isobutane

C_4H_{10} **Branched**



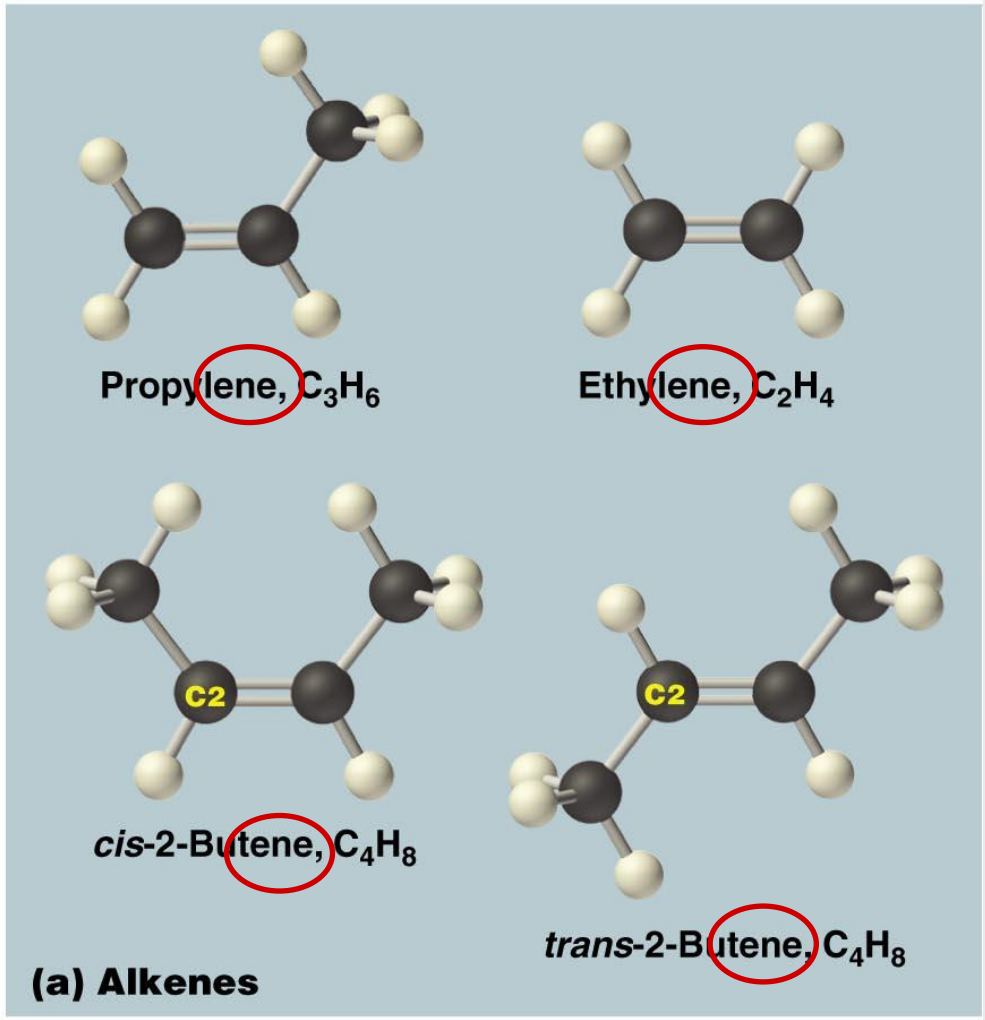
Unsaturated Hydrocarbons

A hydrocarbon that contains one or more double or triple bonds is an **unsaturated hydrocarbon.**

There are three types of unsaturated hydrocarbons—

alkenes,

alkynes, and aromatic hydrocarbons.

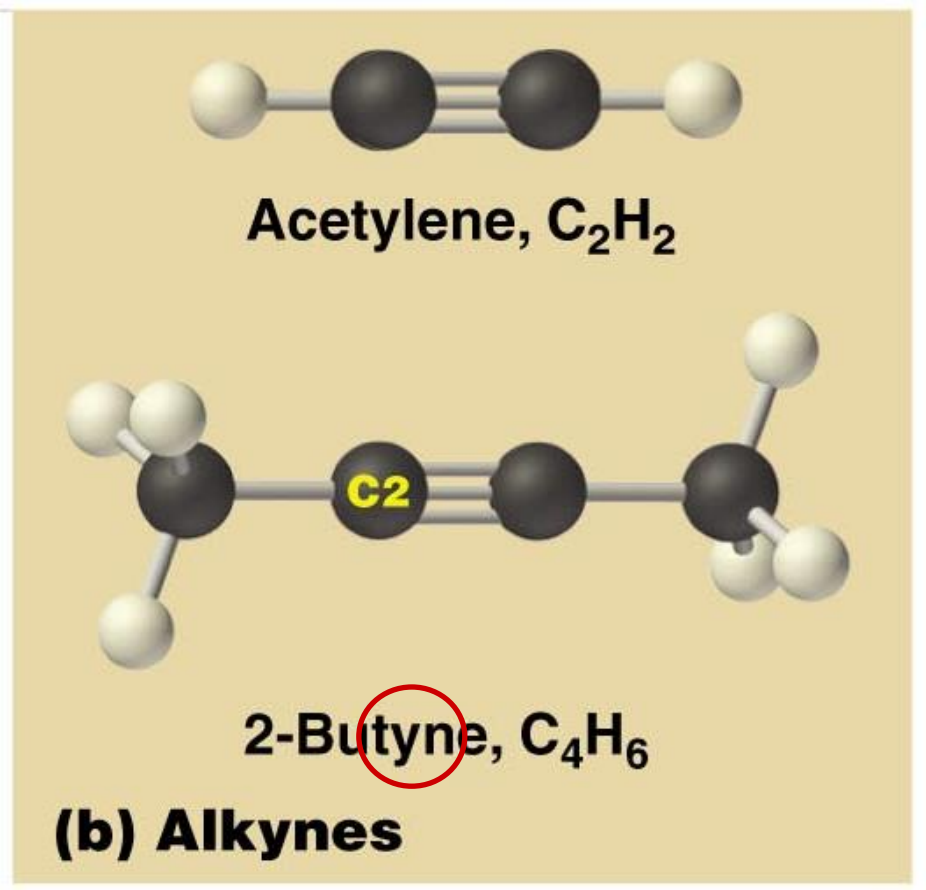


Unsaturated Hydrocarbons

Ethyne (C_2H_2) is an alkyne. **Alkynes** are straight- or branched-chain hydrocarbons that have one or more triple bonds. Alkyne names end in –yne.

Ethyne

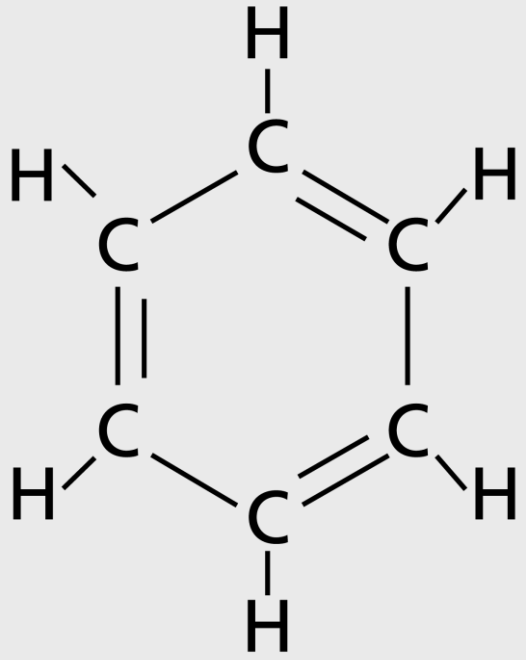
$$H-C\equiv C-H$$

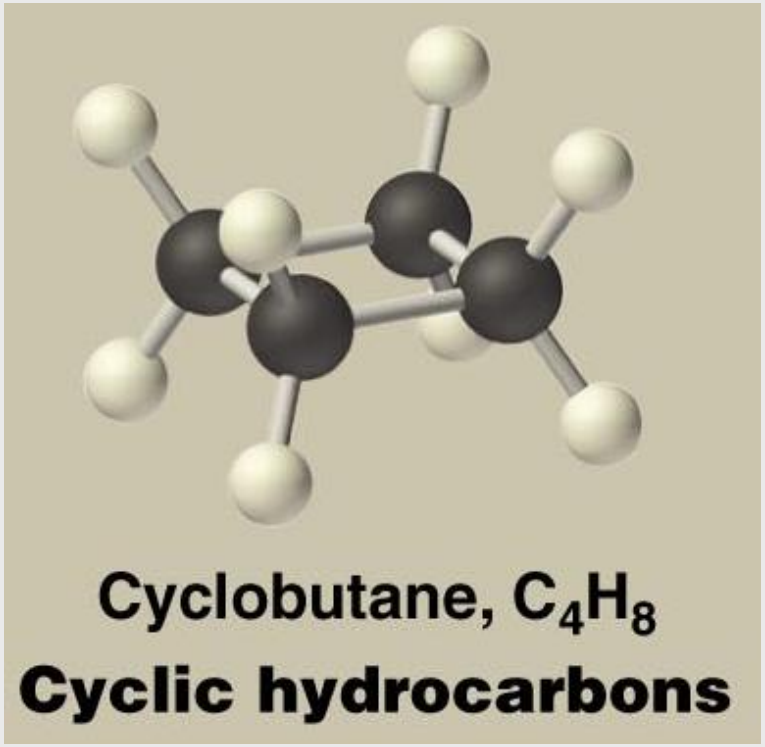


Unsaturated Hydrocarbons

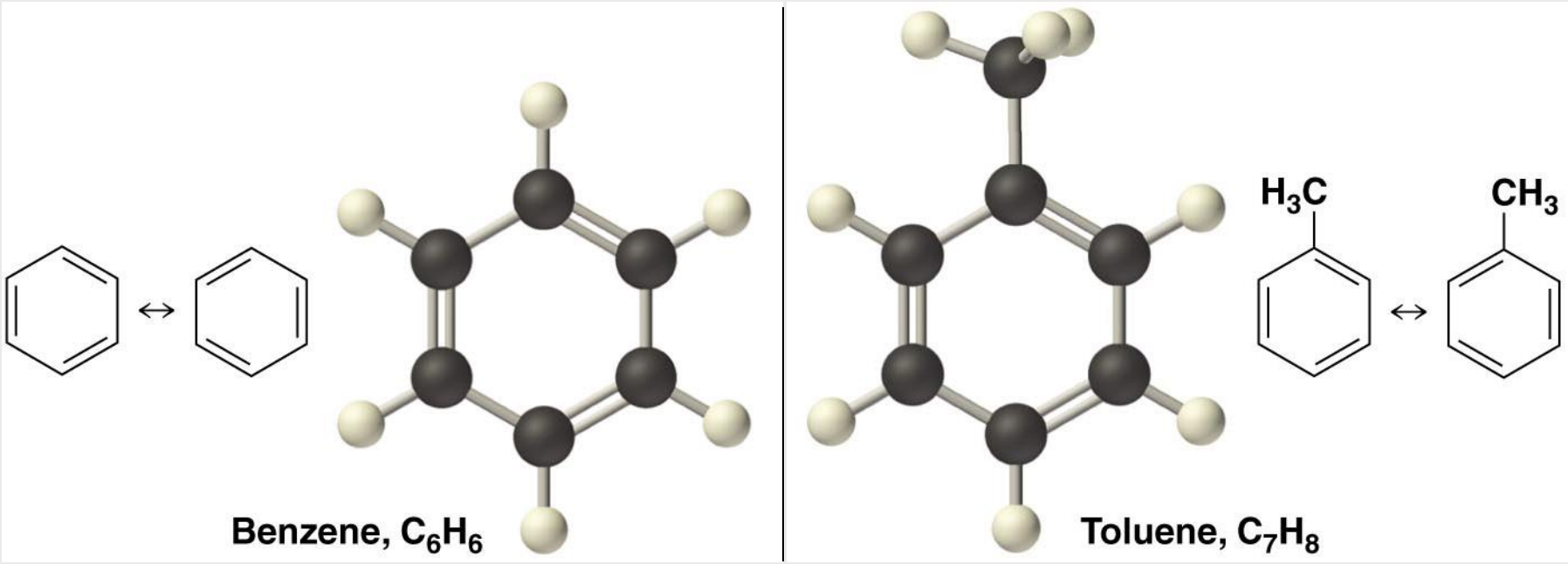
Hydrocarbons that contain similar ring structures are known as **aromatic hydrocarbons**. The name was chosen because many of these compounds have strong **aromas**, or **odors**.

Benzene





Aromatic Hydrocarbons



Although the formulas show alternating single and double bonds, the six BONDS IN THE RING ARE IDENTICAL. All six carbon atoms share six of the valence electrons.

This is known as RESONANCE.

Naming Hydrocarbons

(nomenclature)

We use Latin Prefixes to describe them

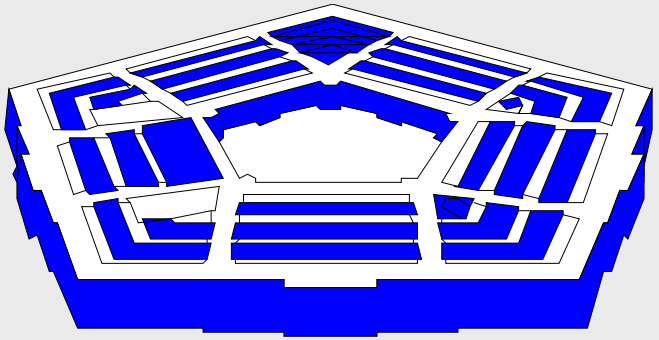
Mnemonic for first four prefixes

First four prefixes

- Meth- Monkeys
- Eth- Eat
- Prop- Peeled
- But- Bananas

Other prefixes

Pent-
5



Hex- … Hept- … Non-
6 7 9

Decade

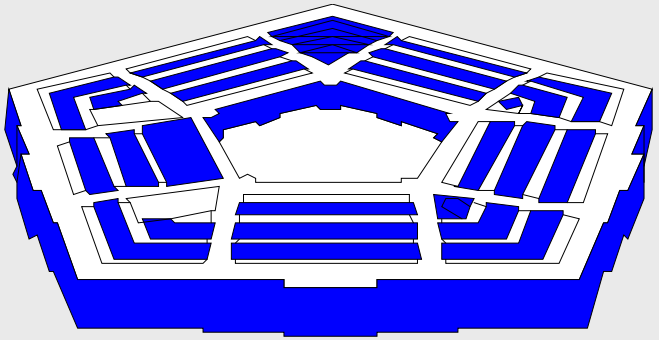
Dec-
10

Decimal

Decathalon

Other prefixes

Pent-
5



Hex- … Hept- … Non-
6 7 9

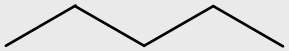
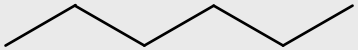
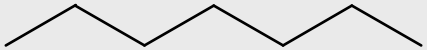
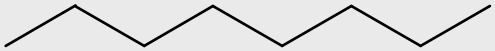
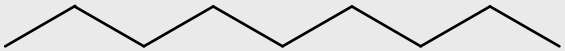
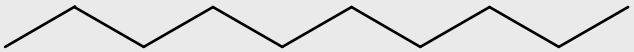
Decade

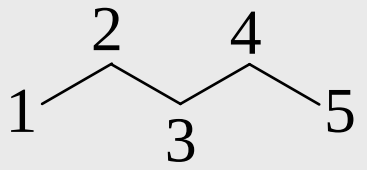
Dec-
10

Decimal

Decathalon

Names of Linear Alkanes

# of C atoms		Alkane
1	CH_4	methane
2	CH_3CH_3	ethane
3	$CH_3CH_2CH_3$	propane
4	$CH_3CH_2CH_2CH_3$	butane
5		pentane
6		hexane
7		heptane
8		octane
9		nonane
10		decane



Carbons are numbered

Names of Alkyl Substituents

# of C atoms		Alkane	Alkyl substituents	
1	CH_4	methane	$-CH_3$	methyl
2	CH_3CH_3	ethane	$-CH_2CH_3$	ethyl
3	$CH_3CH_2CH_3$	propane	$-CH_2CH_2CH_3$	Propyl
4	$CH_3CH_2CH_2CH_3$	butane	-CH3CH2CH2CH3	Butyl

Alkyl Groups:

The alkane groups are used as **"BRANCHES"** in other hydrocarbons.

Names of Alkyl Substituents

# of C atoms	Alkane		Alkyl substituents	
1	CH_4	methane	$-CH_3$	methyl
2	CH_3CH_3	ethane	$-CH_2CH_3$	ethyl
3	$CH_3CH_2CH_3$	propane	$-CH_2CH_2CH_3$	Propyl
	$CH_3CH_2CH_2CH_3$	butane	-CH3CH2CH2CH3	Butyl

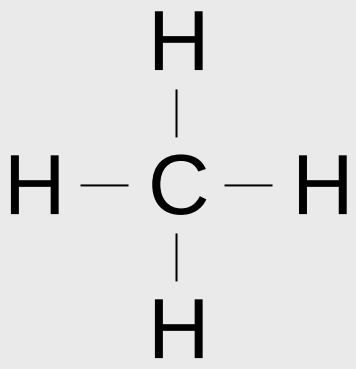
METHYL Alcohol → contains 1 carbon

ETHYL Alcohol → contains 2 carbons

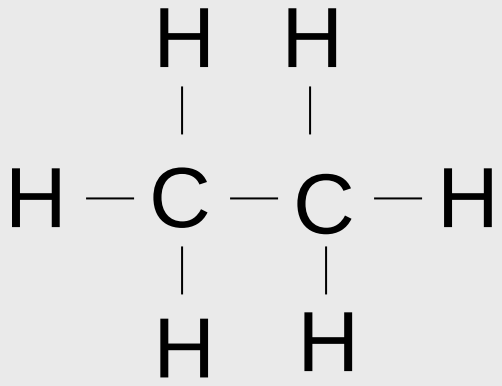
PROPYL Alcohol → contains 3 carbons

BUTYL Alcohol → contains 4 carbons

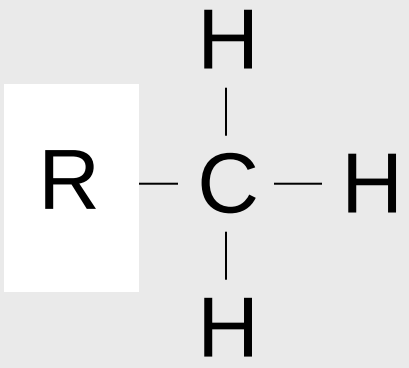
R is an **ALKYL** group of any other C atom or arrangement of C atoms in the organic molecule.



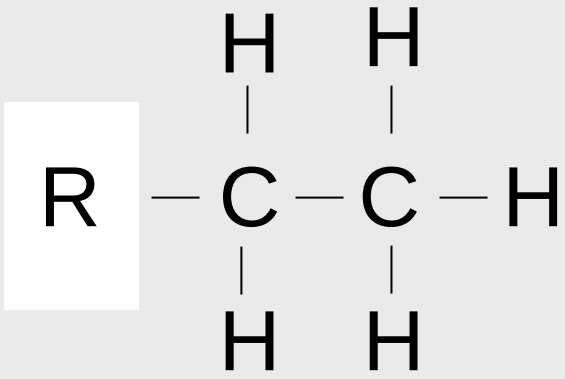
Methane
CH_4



Ethane
C_2H_6

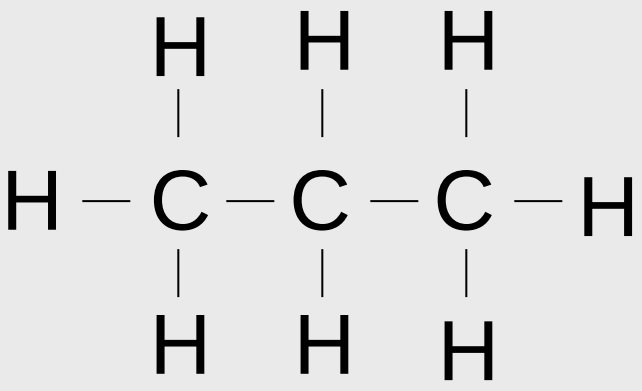


Methyl group
$-CH_3$

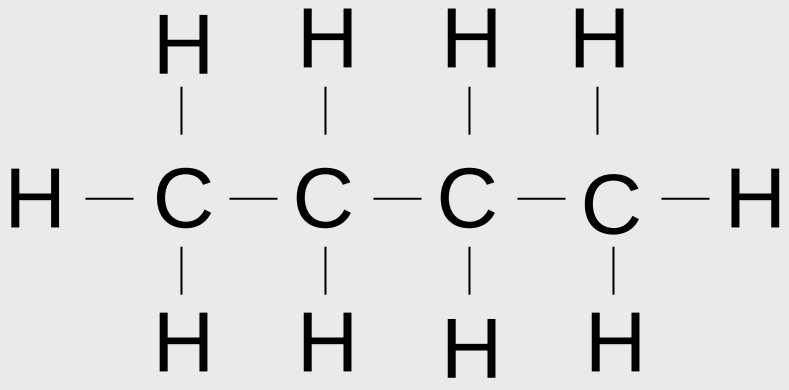


Ethyl group
$-C_2H_5$

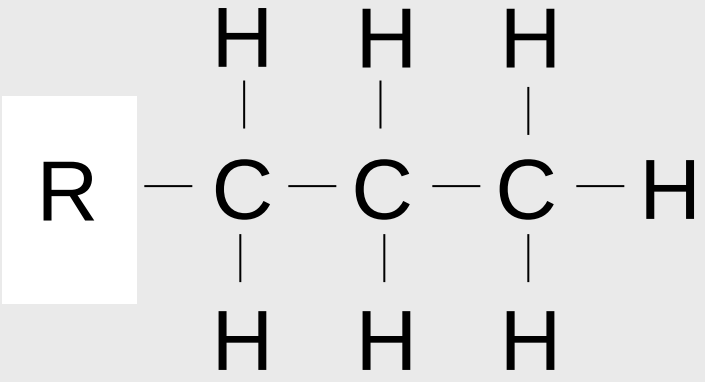
R is an alkyl group of any other C atom or arrangement of C atoms in the organic molecule.



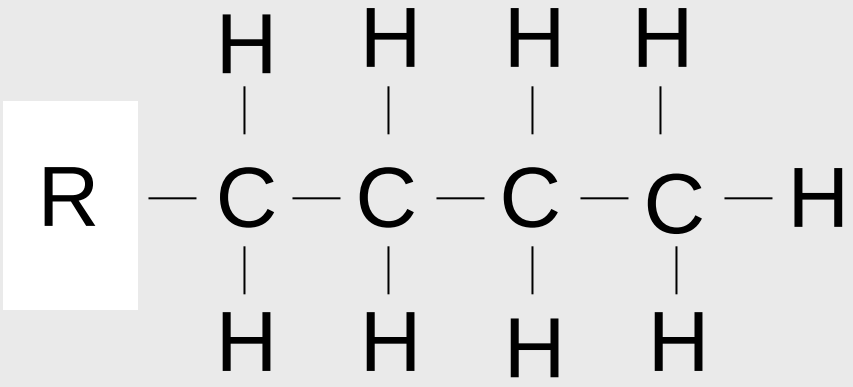
Propane
C_3H_8



Butane
C_4H_{10}



Propyl group
$-C_3H_7$



Butyl group
$-C_4H_9$

Distinguishing Properties of Compounds.

Define “Hydrocarbon”.

Distinguish each hydrocarbon:

- Alkane →
- Alkene →
- Alkyne →
- Aromatic →

Which of compounds formed during the combustion of fossil fuels and then react with water in the air to form acid rain?

The compound that is an indicator of incomplete combustion of hydrocarbons is ____ ____.

Distinguishing Properties of Compounds.

QUICK CHECK

Define “Hydrocarbon”.

Organic molecules containing only C and H atoms bonded together.

Distinguish each hydrocarbon:

- Alkane → **single C to C bonds**
- Alkene → **double C=C bonds**
- Alkyne → **triple C to C bonds**
- Aromatic → **Carbon ring**

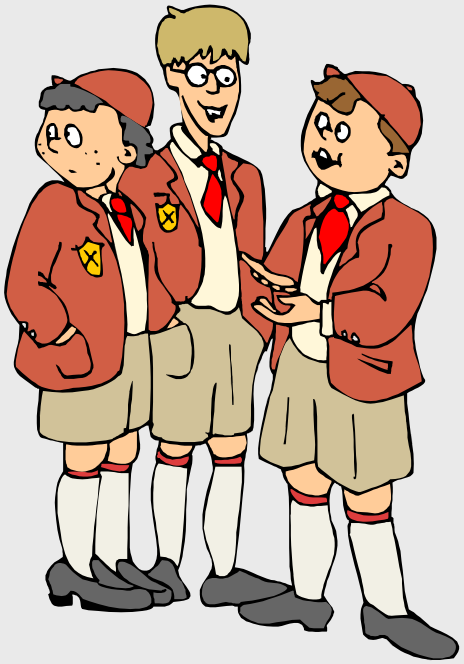
Which of compounds formed during the combustion of fossil fuels and then react with water in the air to form acid rain?

Sulfur dioxide, nitrogen oxides

The compound that is an indicator of incomplete combustion of hydrocarbons is **carbon monoxide**.

There are specialized groups that bonds with hydrocarbons

- We call these **FUNCTIONAL** groups.
- "**Alkyl**" groups are one kind of functional group.
- But there are many other specialized groups.



Organic Chemistry:

Functional Groups

Functional groups

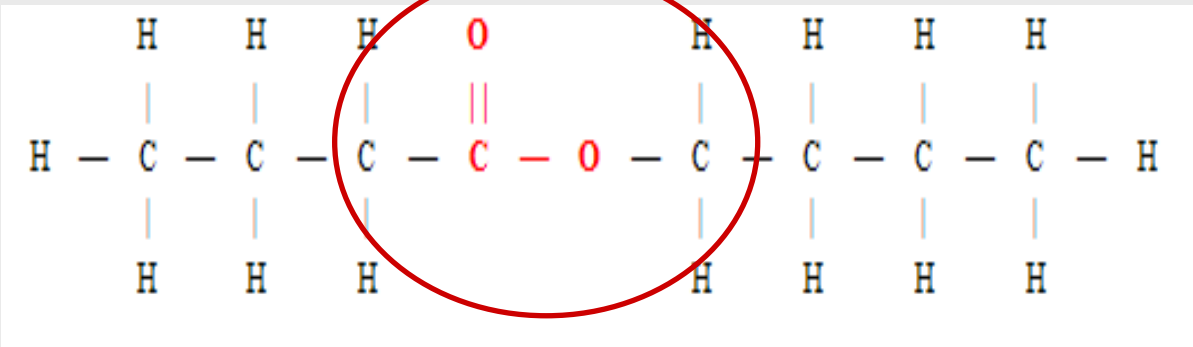
- Functional groups are parts of organic molecules that result in characteristic features:

  Properties such as **melting point**, **boiling point**, **solubility** change due to functional groups

- About 100 functional groups exist, we will focus on a few more (besides “alkyl” groups)

EXAMPLES of “functional Groups” are:

ester



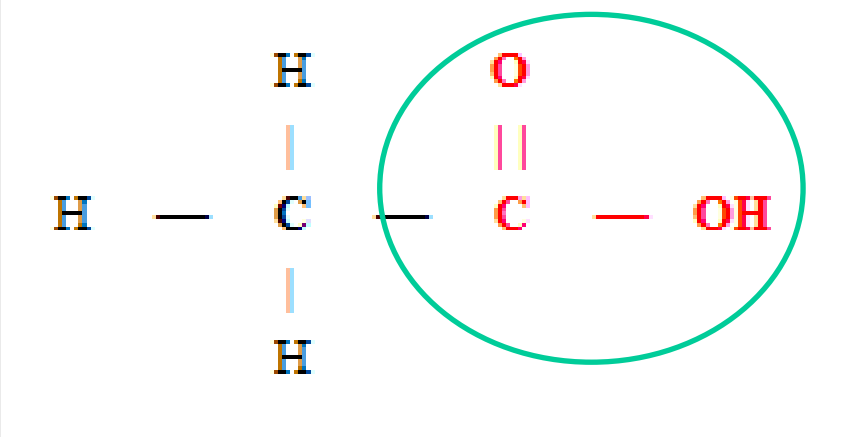
Esters that have fragrant odors are **used as a constituent of perfumes, essential oils, food flavorings, cosmetics**, etc.

They are used as an organic solvent. Natural esters are found in pheromones.

Naturally occurring fats and oils are esters.

EXAMPLES of “functional Groups” are:

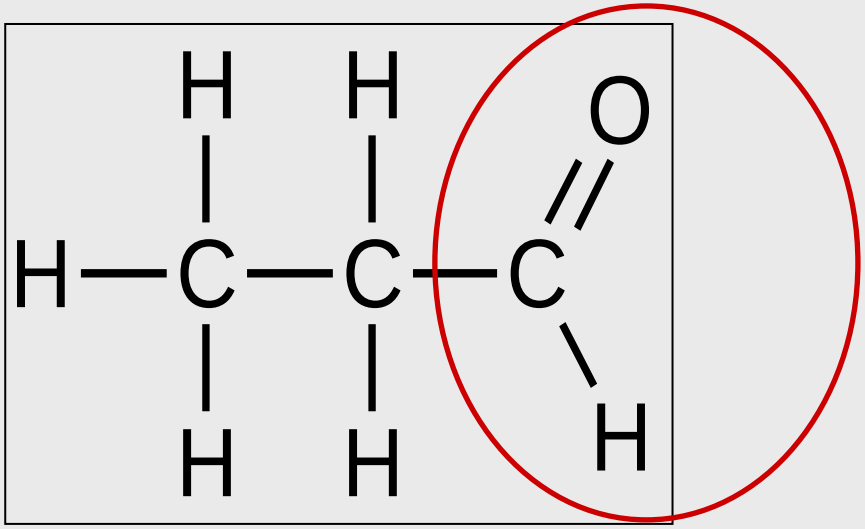
Carboxylic acid



Vinegar contains acetic acid, aspirin is acetylsalicylic acid, vitamin C is ascorbic acid, lemons contain citric acid, and spinach contains oxalic acid.

EXAMPLES of “functional Groups” are:

aldehyde

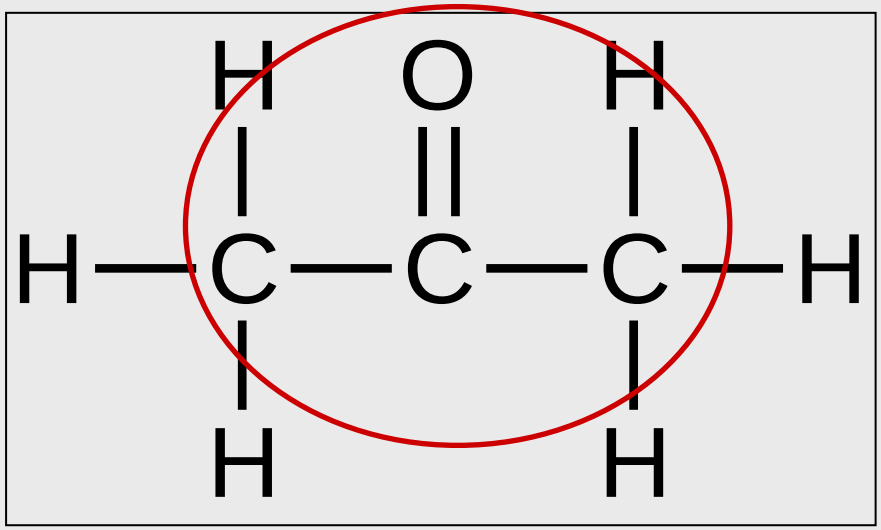


Aldehydes are present in many organic materials, everything from rose, citronella, vanilla, cinnamon, and orange rind.

Scientists also can create these compounds synthetically to use as ingredients for sweet-smelling perfumes and colognes.

EXAMPLES of “functional Groups” are:

ketone

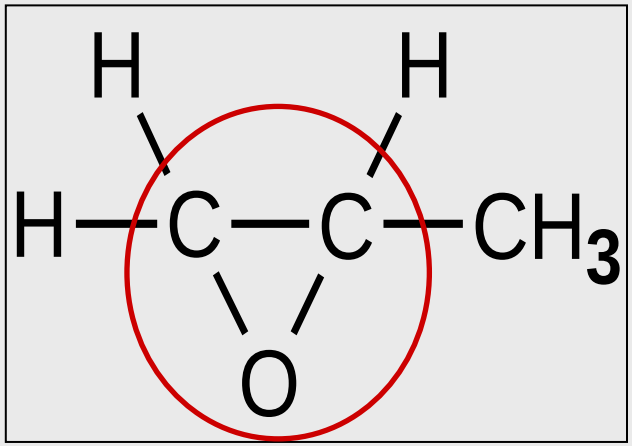


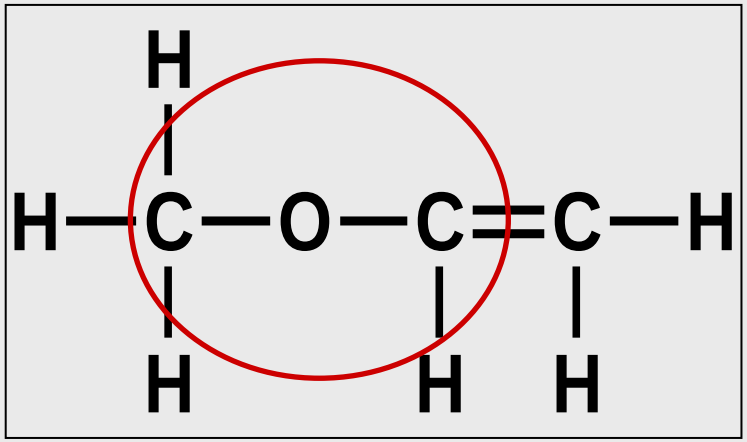
Ketones are used as excellent solvent in industry, acetone is used as a nail paint remover and paint thinner.

They are also used in medicine , textiles, varnishes, plastics, paint remover, paraffin wax etc.

EXAMPLES of “functional Groups” are:

ether





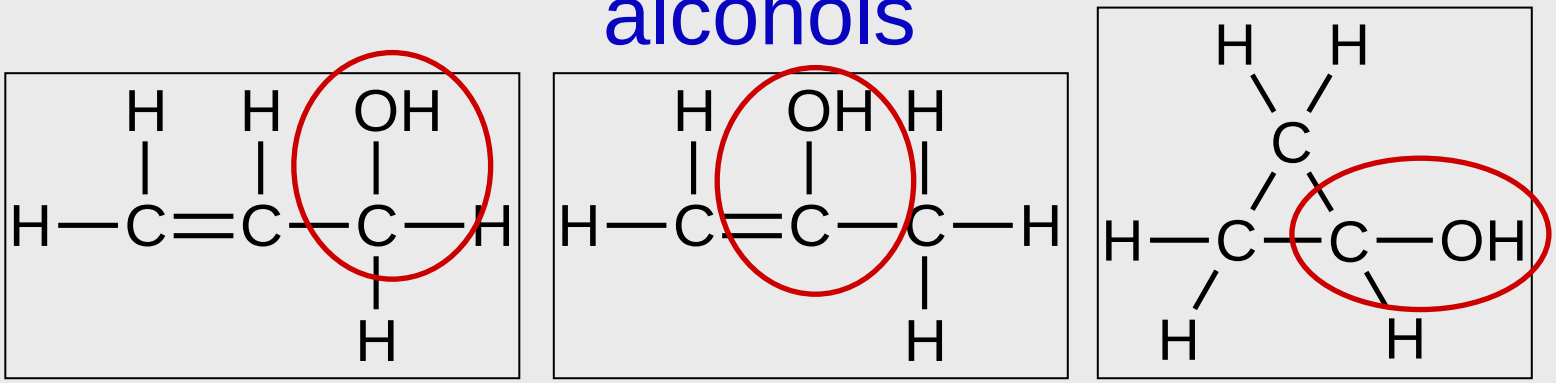
Ethers are used as cleansing agents in our daily life. For example, Glycol ether is used as cleaners for window glasses, carpets, floors, etc.

As ethers are highly volatile compounds, their vapors are used as insecticides, miticides, and fumigants for soil microorganisms.

Formerly used for anesthesia.

EXAMPLES of “functional Groups” are:

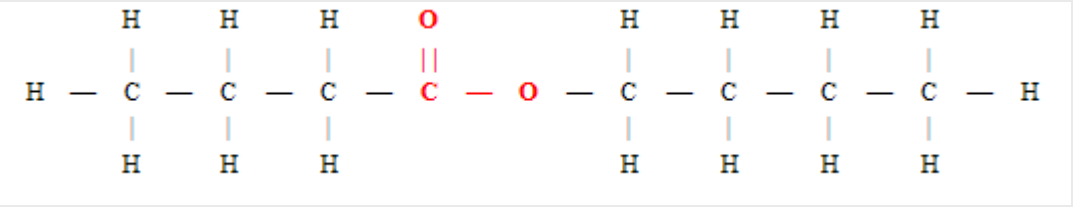
alcohols



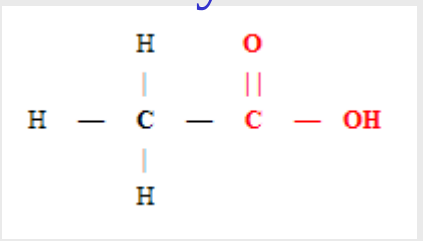
Alcohols are found in Liquid medications, like Dayquil. Breath strips, which have a small amount of alcohol like mouthwash. Aftershave, hairspray, mousse, and some body washes. Astringents for skin care. Bug sprays.

EXAMPLES of “functional Groups” are:

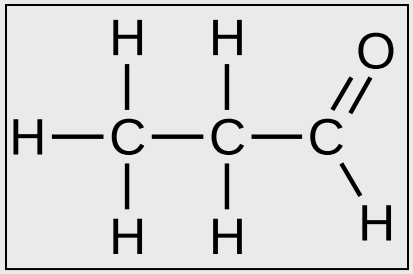
ester



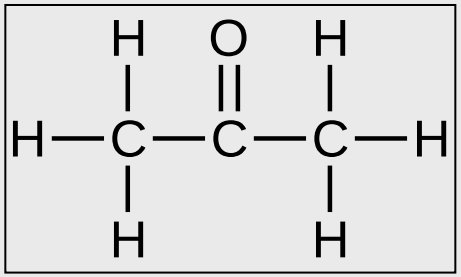
Carboxylic acid



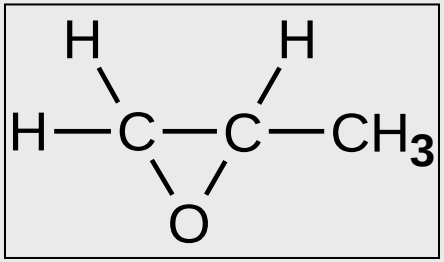
aldehyde

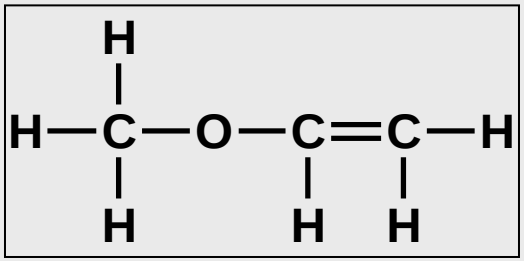


ketone

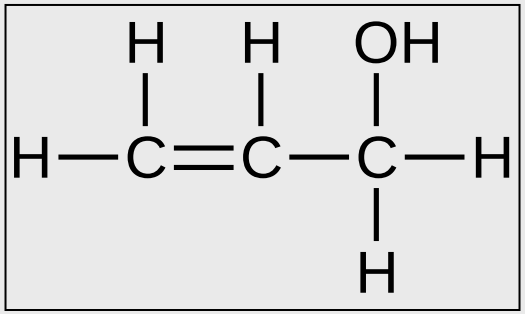


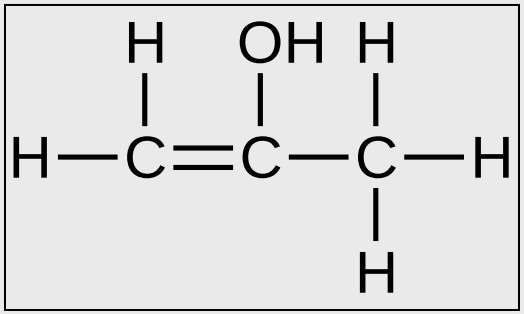
ether

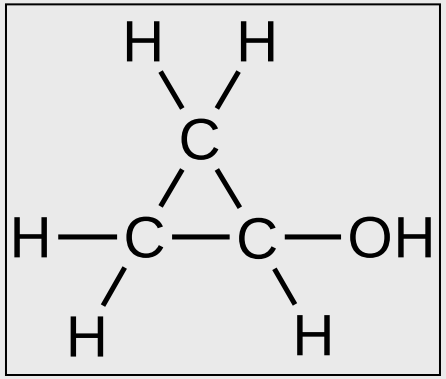




alcohols







Hydroxyl, Carbonyl, Carboxyl

Probably the most common functional groups:

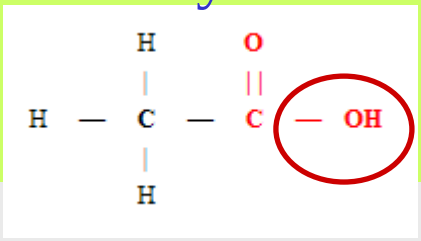
- "**Hydroxyl**" refers to –OH
- "**Carbonyl**" refers to C=O
- "**Carboxyl**" refers to COOH

Hydroxyl, carbonyl, carboxyl

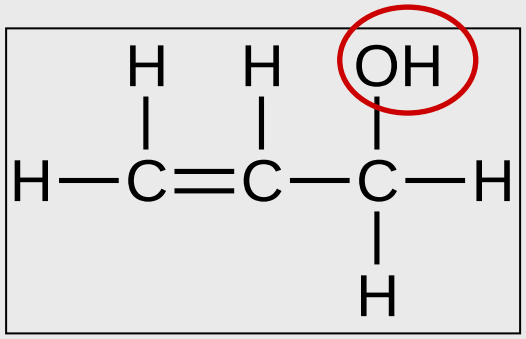
Which organic molecules contain a hydroxyl group?

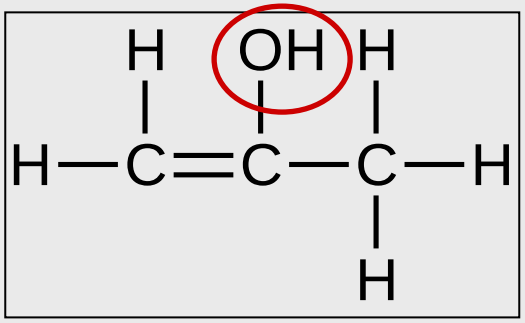
A: alcohols, carboxylic acids

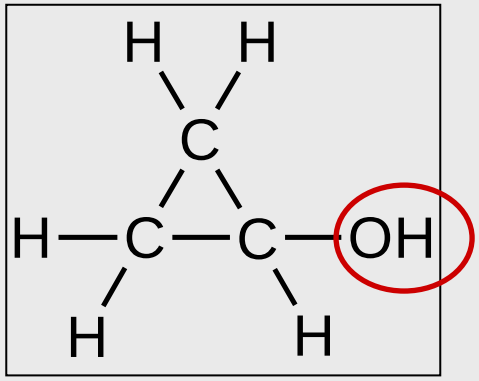
Carboxylic acid



alcohols



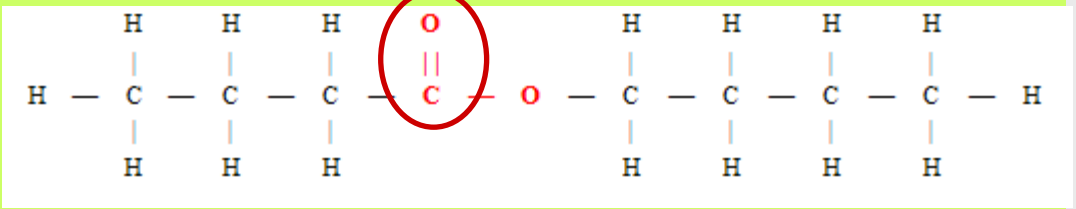




Hydroxyl, carbonyl, carboxyl

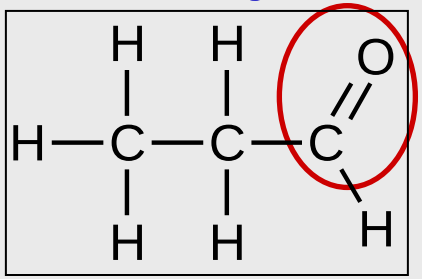
Which organic molecules contain a carbonyl group?

ester

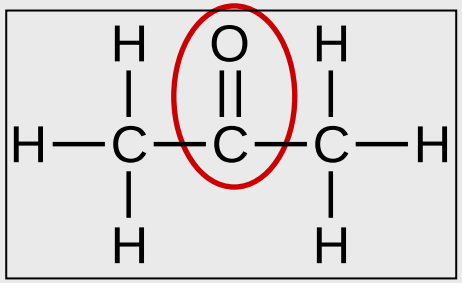


aldehydes, ketones, carboxylic acids, esters

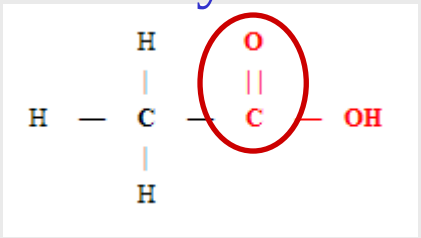
aldehyde



ketone



Carboxylic acid

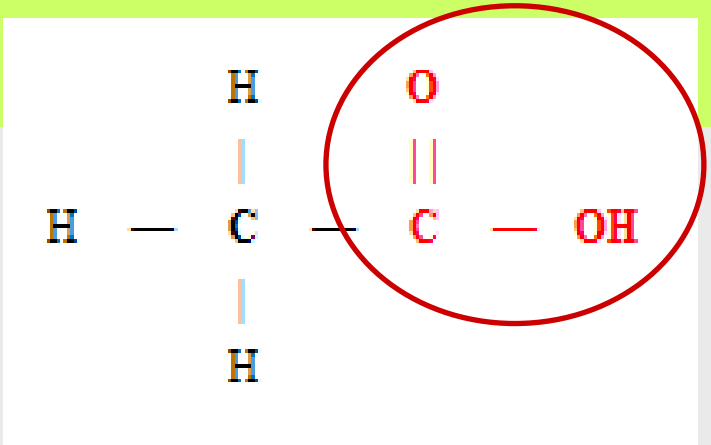


Hydroxyl, carbonyl, carboxyl

Which organic molecules contain a carboxyl group?

A: carboxylic acids

Carboxylic acid



Isomers

$C_6H_{12}O_6$

is a molecular formula for

THREE

different organic compounds

Isomers

$C_6H_{12}O_6$

Can be glucose (blood sugar)

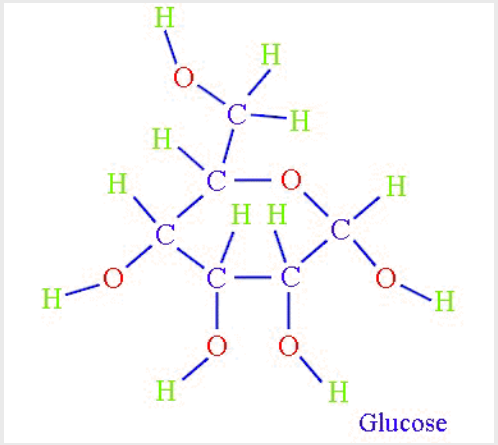
Can be fructose (fruit sugar)

Can be galactose (milk sugar)

So how can we tell which is which?

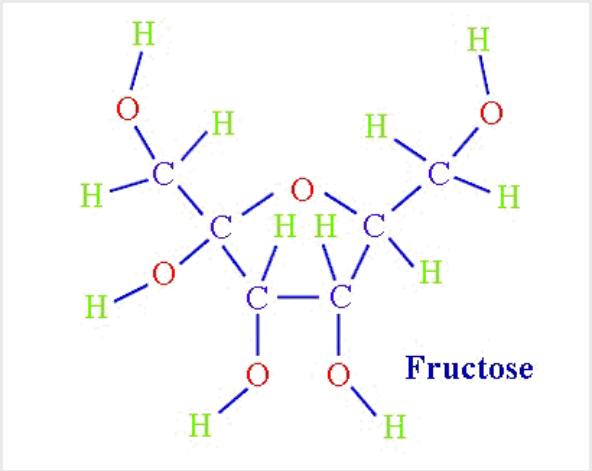
Isomers

$C_6H_{12}O_6$

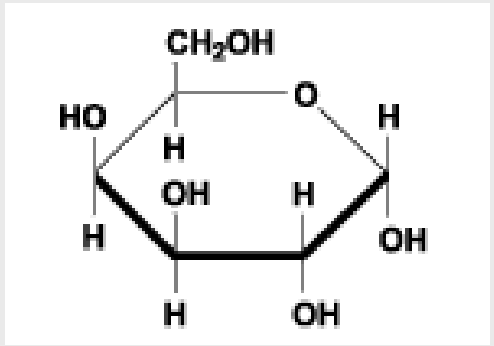


Notice the different STRUCTURAL formulas

$C_6H_{12}O_6$



$C_6H_{12}O_6$



galactose

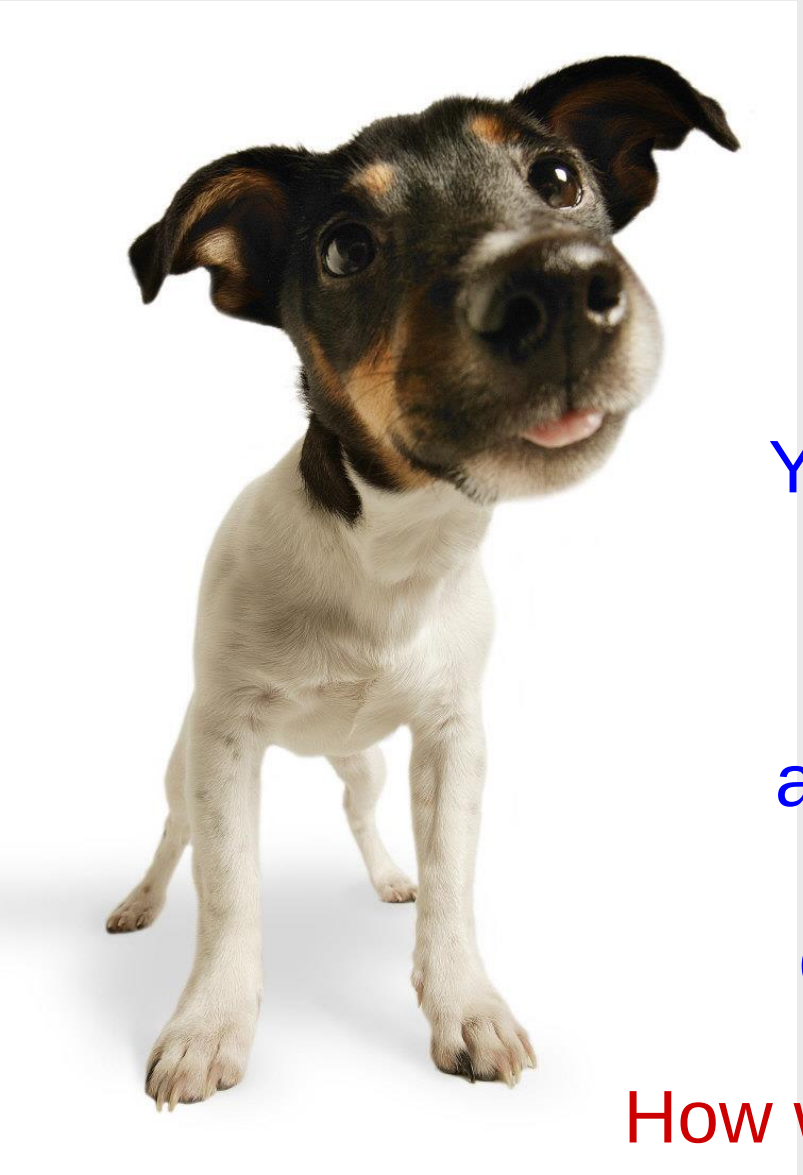
Isomers

"Iso" means similarity

"Mer" means unit

Notice that we could call each of the animals above a "dog"

Isomers



Yet, each is clearly unique

and can be classified differently

How would we tell them apart?

Isomers

Let’s assume we make a statement using common words.

LIKE

The fat dog shook himself,
and then rolled over on the wet rug.

Is it possible to reuse these exact same words, yet say something completely different?

Isomers

The fat dog shook himself,
and then rolled over on the wet rug.

Could be rearranged to say:

The dog shook the fat rug,
then rolled over and wet on himself.

Isomers

The fat dog shook himself,
and then rolled over on the wet rug.

OR

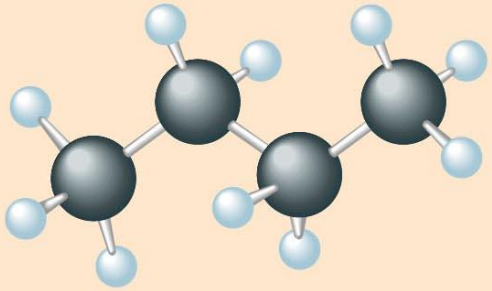
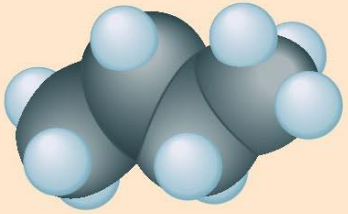
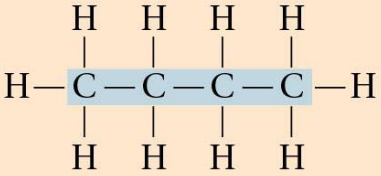
The dog shook the fat rug,
then rolled over and wet on himself.

These two statements use the same words…
but have very different meanings!

Likewise, ISOMERS may have the same formula,
but have very different STRUCTURES…

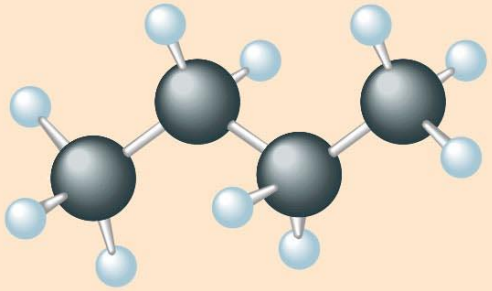
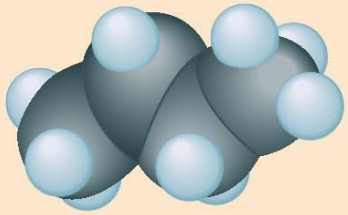
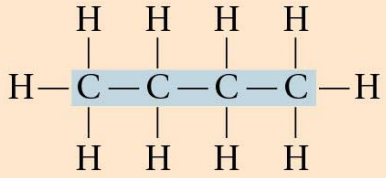
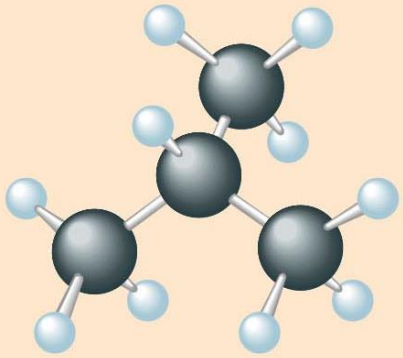
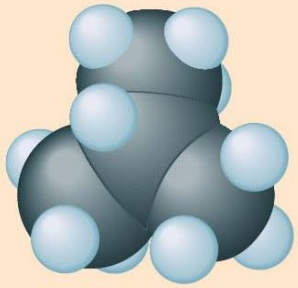
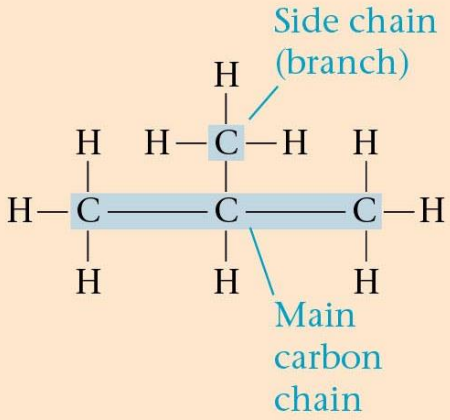
Structural Isomers of C_4H_{10}

Butane contains 4 Carbon Atoms

	Ball-and-stick structure	Space-filling structure	Lewis structure
n-butane			

Can the atoms of Butane be rearranged to form another molecule?

Structural Isomers of C_4H_{10}

	Ball-and-stick structure	Space-filling structure	Lewis structure
***n*-butane**			
2-methylpropane or isobutane			

Polymers

A **polymer** is a large molecule that forms when many smaller molecules are linked together by covalent bonds.

- The smaller molecules that join together to form a polymer are **monomers**.

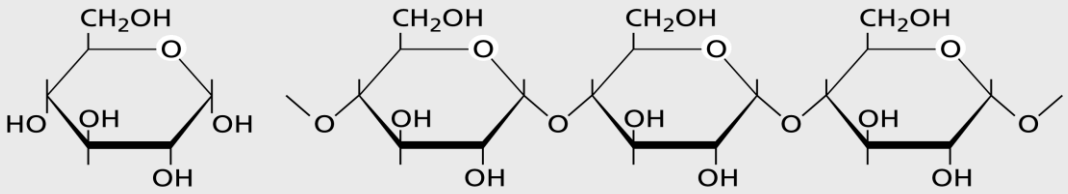
Many important types of biological molecules are natural polymers (e.g. silk and cotton fabrics). Organisms produce these polymers in their cells.

Synthetic polymers are developed by chemists in research laboratories and manufactured in factories (polar fleece).

Natural Polymers

Starches / Cellulose

Simple sugars (monomers) combine. Carbohydrates.

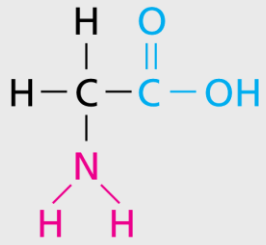


Glucose

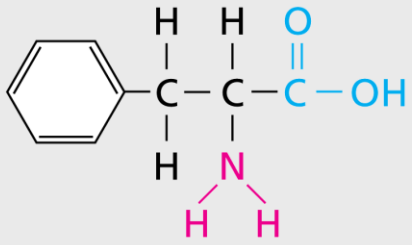
A type of starch found in plants

Proteins

- **Organic acids contain a –COOH group, and organic bases contains an –NH_2 group.**
- An **amino acid** is a compound that contains both carboxyl and amino functional groups in the same molecule.



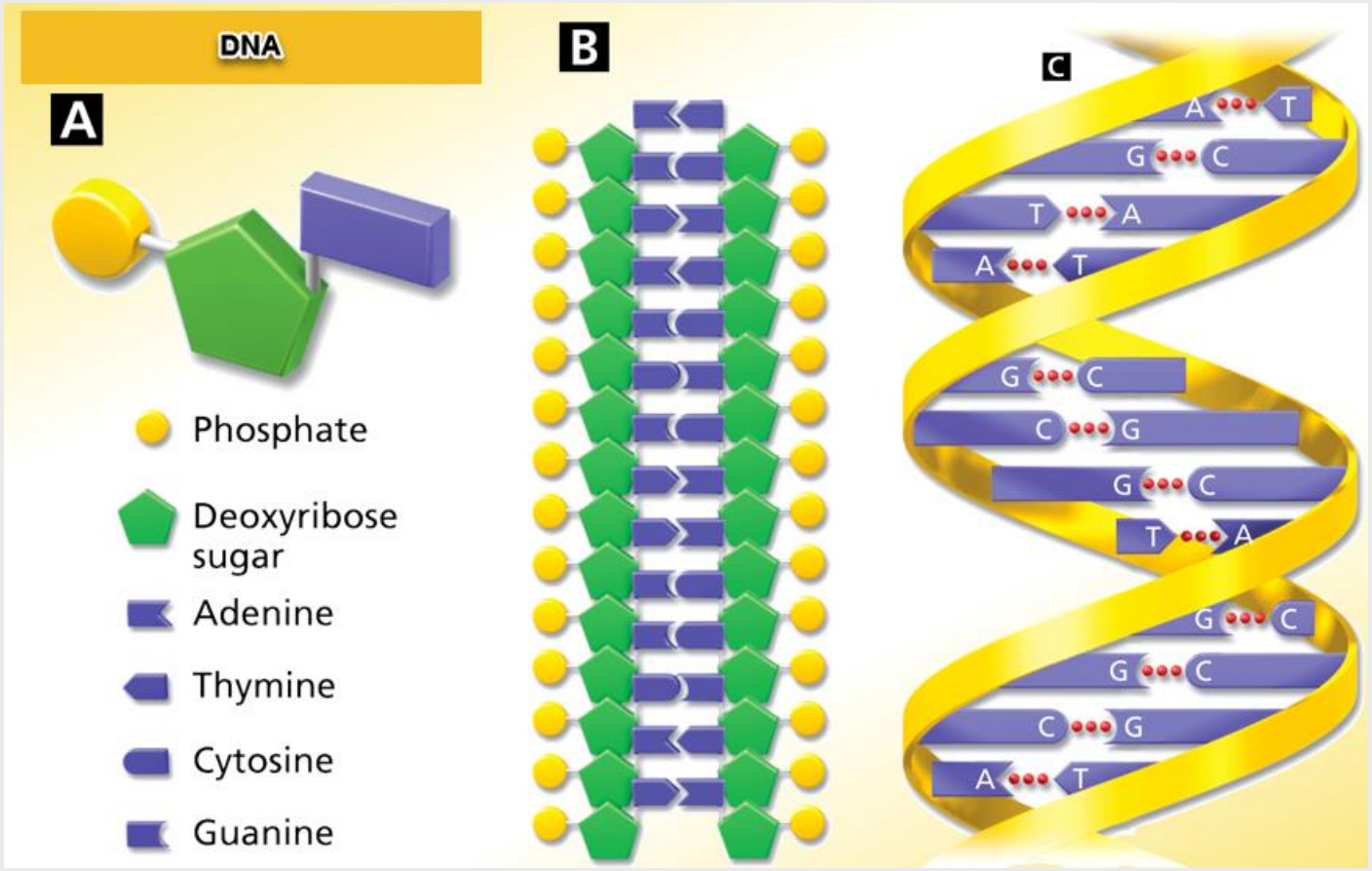
Glycine



Phenylalanine

Natural Polymers

Nucleic acids are large nitrogen-containing polymers found in the nuclei of cells. There are two types of nucleic acid, deoxyribonucleic acid (**DNA**) and ribonucleic acid (**RNA**).



Synthetic Polymers

Rubber, nylon, polyethylene.

A Rubber is used to manufacture tires.

B Nylon fibers are strong and do not wear out easily.

C Hard plastic shapes can be made from a polyethylene polymer.

Distinguishing Properties of Compounds.

The strong natural fiber, cellulose, is a polymer made of long chains of what type of molecule?

a. amino acid
b. organic bases
c. hydrocarbons
d. Sugar

An alcohol is formed by replacing at least one hydrogen in a hydrocarbon with a(n)

a. carboxyl group.
b. hydroxyl group.
c. amino group.
d. carbon group.

A synthetic polymer that can be formed into strong fibers suitable for making cloth and rope is

a. silk.
b. high-density polyethylene.
c. natural rubber.
d. nylon.

Small, repeating units of organic molecules are called ___. They make up larger molecules that linked together by covalent bonds called ___.

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Small, repeating units of organic molecules are called **monomers**. They make up larger molecules that linked together by covalent bonds called **polymers**.