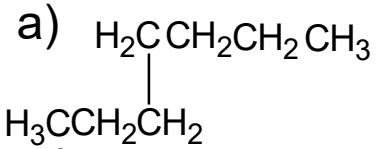
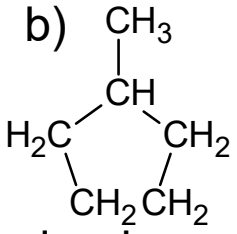
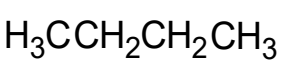
# Chapter 21: Phenomenon

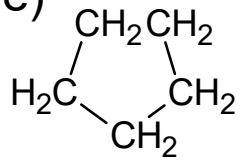
Phenomenon: Below are the names and pictures of several organic compounds. Can you determine the naming conventions of these compounds?

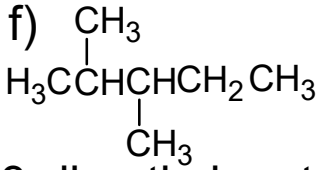
a) 
heptane

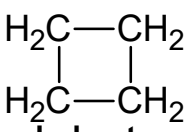
b) 
methylcyclopentane

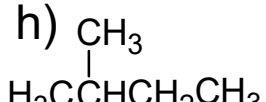
c) 
ethane

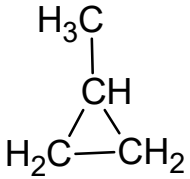
d) 
butane

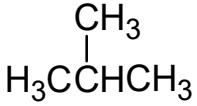
e) 
cyclopentane

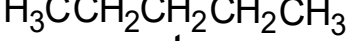
f) 
2,3-dimethylpentane

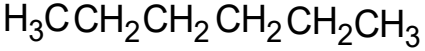
g) 
cyclobutane

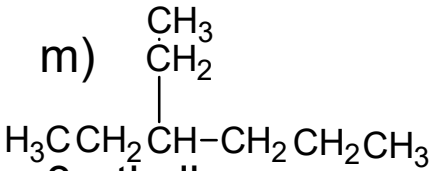
h) 
methylbutane

i) 
methylcyclopropane

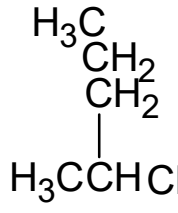
j) 
methylpropane

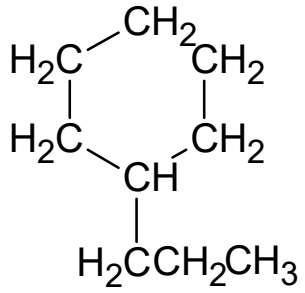
k) 
pentane

l) 
hexane

m) 
3-ethylhexane

What are the names of the following structures and why?





# Chapter 21: Organic and Biochemical Molecules

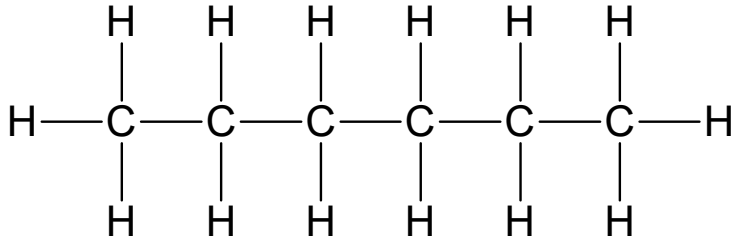
**Big Idea:** The large number of hydrocarbons arise from the ability of carbon atoms to form long chains and rings with one another. The properties of hydrocarbons are dominated by the functional groups present. Functional groups properties are independent of their bonding environment.

- Simple Organic Molecules
- Isomers
- Functional Groups
- Organic Reactions
- Polymers
- Biochemistry

# Simple Organic Molecules

## Structural Representations

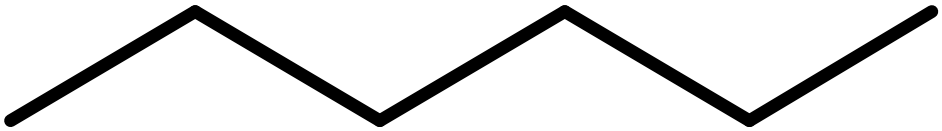
Lewis Structure



Chemical Formula

$CH_3CH_2CH_2CH_2CH_2CH_3$

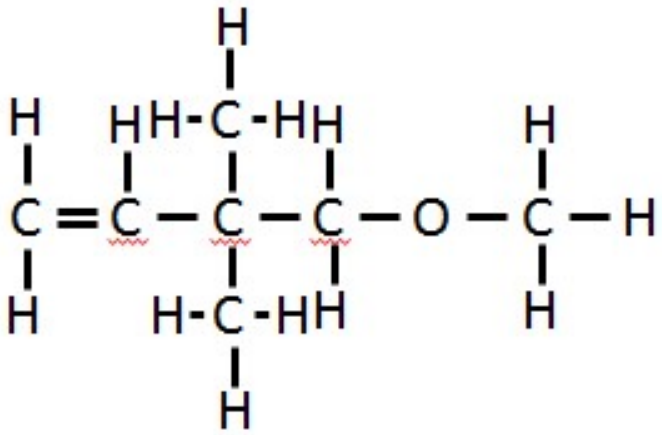
Line notation



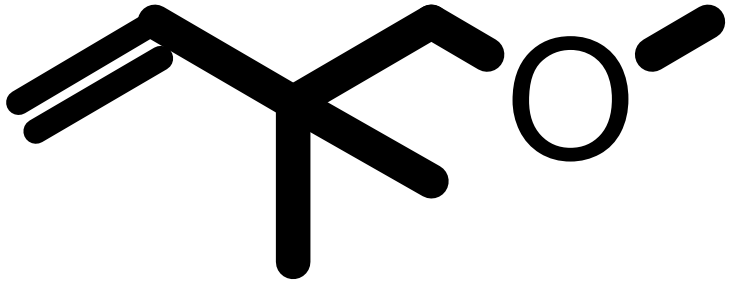
# Simple Organic Molecules

## Structural Representations

Lewis Structure



Line Notation

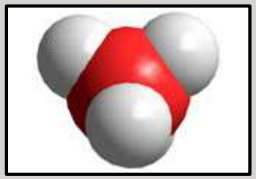
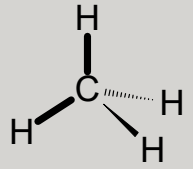
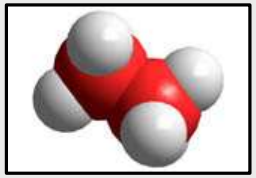
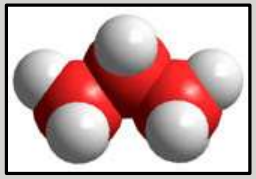
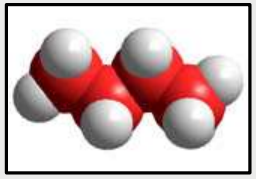
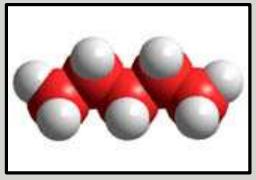


- Chemical Formula

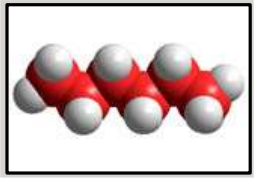
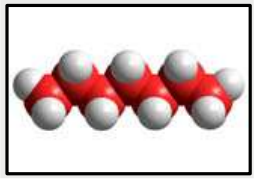
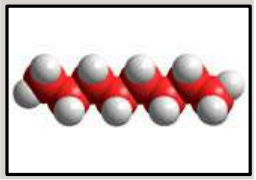
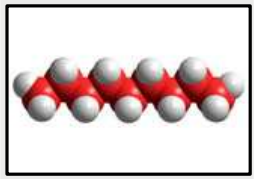
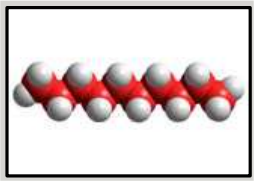
  $CH_2CHC(CH_3)_2CH_2OCH_3$

**Note:** When other groups of hydrocarbons are coming off of a longer chain of carbons they are put in parentheses in the chemical formula.

# Simple Organic Molecules

| Short Chemical Formula | Long Chemical Formula | Name | Space Filling Model | Short Hand |
|---|---|---|---|---|
| $CH_4$ | $CH_4$ | Methane |  |   |
| $C_2H_6$ | $CH_3CH_3$ | Ethane |  |  |
| $C_3H_8$ | $CH_3CH_2CH_3$ | Propane |  |  |
| $C_4H_{10}$ | $CH_3CH_2CH_2CH_3$ | Butane |  |  |
| $C_5H_{12}$ | $CH_3CH_2CH_2CH_2CH_3$ | Pentane |  |  |

# Simple Organic Molecules

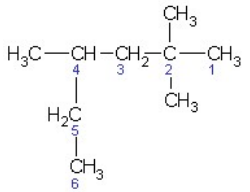
| Short Chemical Formula | Long Chemical Formula | Name | Space Filling Model | Short Hand |
|---|---|---|---|---|
| $C_6H_{14}$ | $CH_3CH_2CH_2CH_2CH_2CH_3$ | Hexane |  |  |
| $C_7H_{16}$ | $CH_3CH_2CH_2CH_2CH_2CH_2CH_3$ | Heptane |  |  |
| $C_8H_{18}$ | $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ | Octane |  |  |
| $C_9H_{20}$ | $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ | Nonane |  |  |
| $C_{10}H_{22}$ | $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ | Decane |  |  |

# Simple Organic Molecules

- Rules for Naming Branching Alkanes ($C_nH_{2n+2}$)

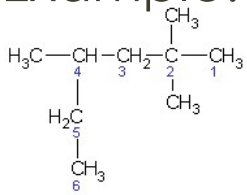
1. The longest continuous chain of carbon atoms determines the root name for the hydrocarbon. Note the longest chain might not be in a straight line.

- Example:



2. The longest chain will be named by taking the core name and adding -ane.

- Example:



root name: hexane

| # of Carbons | Core Name | # of Carbons | CoreName |
|---|---|---|---|
| 1 | meth- | 6 | hex- |
| 2 | eth- | 7 | hept- |
| 3 | prop- | 8 | oct- |
| 4 | but- | 9 | nan- |
| 5 | pent- | 10 | dec- |

# Simple Organic Molecules

- Rules for Naming Branching Alkanes ($C_nH_{2n+2}$)

3. When alkane groups appears as a substituent (bonded to a larger alkane), they are named by taking the core name and adding –yl.

   - Example: $CH_3CH_2$- ethyl

4. When halogens are present as substituents they are named using the following:

| Halogen | Name |
|---|---|
| F | fluoro |
| Cl | chloro |
| Br | bromo |
| I | iodo |

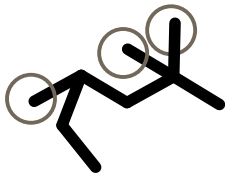
# Simple Organic Molecules

- Rules for Naming Branching Alkanes ($C_nH_{2n+2}$)

5. When multiple of the same substituents are present the appropriate prefix is added to the name of the substituent.

| # of the same substituents | Name |
|---|---|
| 2 | di- |
| 3 | tri- |
| 4 | tetra- |

- Example: trimethyl



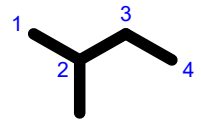
# Simple Organic Molecules

- Rules for Naming Branching Alkanes ($C_nH_{2n+2}$)

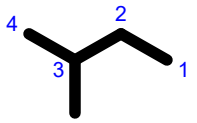
6. Number the carbons in the chain so that the lowest number is given to the substituent.

- Example:

Correct



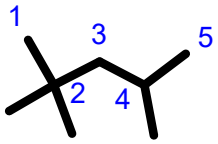

Incorrect




7. If both directions give the same lowest number for the 1st substituent then use the numbering which gives the lowest number for the 2nd substituent.

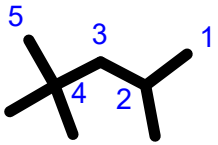
- Example:

Correct




2,2,4

Incorrect




2,4,4

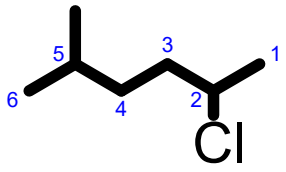
# Simple Organic Molecules

- Rules for Naming Branching Alkanes ($C_nH_{2n+2}$)

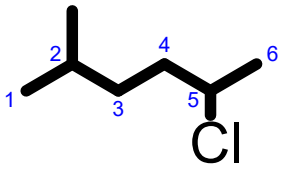
8. If two numbering schemes have the same lowest numbering scheme, give the lowest number to the substituent that appears first in the name.

- Example:

Correct

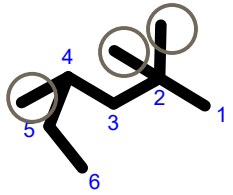



Incorrect




9. In front of each substituent, list the carbon number in which the substituent is bonds to in the alkane. If there are multiple of one type of substituent, multiple numbers will need to be used. Separate multiple numbers with comas. Separate the number from the name with a hyphen.

- Example: 2,2,4-trimethyl



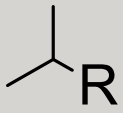
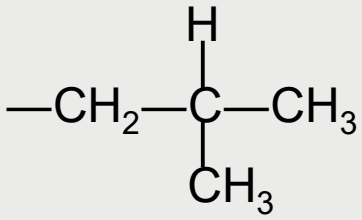
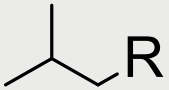
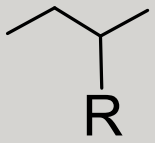
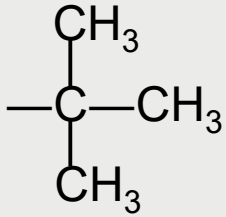
# Simple Organic Molecules

- Rules for Naming Branching Alkanes ($C_nH_{2n+2}$)

10. Substituents are listed in alphabetic order with respect to their root name (methyl, ethyl etc.). If multiple substituents are present, they are separated from each other with a hyphen. The substituent that is closest to the root name is combined with the root name.

    - Example:
      4-ethyl-2,3-dimethyloctane

# Simple Organic Molecules

| | | |
|---|---|---|
| $CH_3CHCH_3$ |  | isopropyl |
|  |  | *isobutyl* |
| $CH_3CHCH_2CH_3$ |  | sec-butyl |
|  |  | *tert*-butyl |

# Simple Organic Molecules

*Student Question*

Which of the following has the lowest boiling point?

a) Butane
b) Ethane
c) Propane
d) Methane

# Simple Organic Molecules

- Rules for Naming Alkene and Alkynes

1. If a double bond is present, the root hydrocarbon is the longest chain that contains the double bond. The root hydrocarbon will be named by adding –ene to the core.

   - Example: pentene

2. If a triple bond is present, the root hydrocarbon is the longest chain that contains the triple bond. The root hydrocarbon will be named by adding –yne to the core.

   - Example: butyne

# Simple Organic Molecules

- Rules for Naming Alkene and Alkynes

3. If multiple double and triple bonds are present the following notation is placed in front of the –ene or –yne suffix which identifies the number of bonds in addition an "a" is added to the root name.

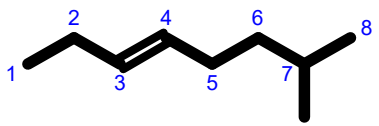
- Example: heptadiene

| # of bonds | Name |
|---|---|
| 2 | di- |
| 3 | tri- |
| 4 | tetra- |

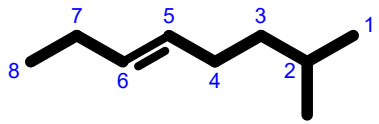
4. The root chain will be numbered so that multiple bonds get the lowest possible number. This takes precedence over giving branching hydrocarbons or halogens.

- Example:

Correct




Incorrect



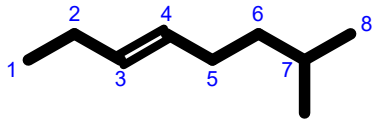
# Simple Organic Molecules

- Rules for Naming Alkene and Alkynes

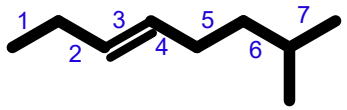
5. Bonds are numbered in the same order as the carbons.

- Example:

C Numbers

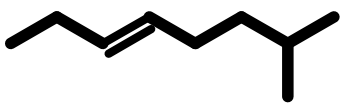



Bond Numbers



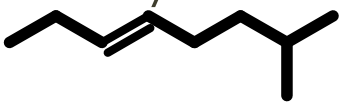

6. The bond number is placed in front of the root name. If there are multiple double or triple bonds, multiple numbers will need to be used. Separate multiple numbers with comas. Separate the number from the name with a hyphen.

- Example:
root name: 3-octene



7. Use the rules for naming alkanes to name the rest of the substituents.

- Example:
7-methyl-3-octene

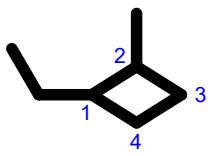


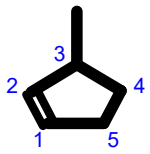
# Simple Organic Molecules

- Rules for Naming Cyclic Hydrocarbons

1. Use a ring for the root name if the ring has more carbons than any of the other chains.
2. The root name is formed by adding the prefix cyclo- to the core name (indicating the number of carbons).
3. If only single bonds exist in the ring, the suffix –ane is added to the core name.
4. If double bonds exist in the ring, the suffix –ene is added to the core name. If multiple double bonds exist, include di-, -tri-, etc.
5. Number the cyclic hydrocarbon so that double bonds get preference over halogen or hydrocarbon chains

- Examples:

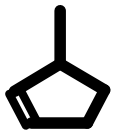


# Simple Organic Molecules

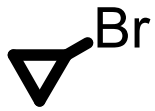
- Rules for Naming Cyclic Hydrocarbons

6. Include the number indicating the substituents placement in front of the name of the substituent. If there is only one double bond then the number 1 does not need to be included prior to the core name because the position of the double bond is implied. If there is only 1 substituent and no double bonds, the number does not need to be included because it is implied.
   - Examples:



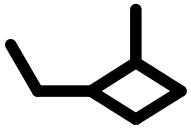
3-methylcylopentene

2-methyl-1,3-cylopentadiene




bromocylopropane

7. Use rules for naming alkanes to complete the name of the structure.
   - Example:



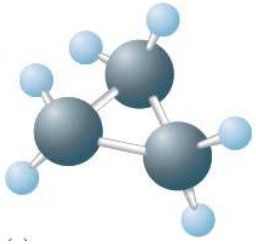
1-ethyl-2-methylcylobutane

# Simple Organic Molecules

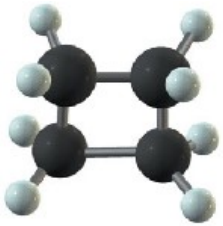
- Shapes of Cyclic Hydrocarbons

  Carbon atoms in cycloalkanes are $sp^3$ hybridized therefore the ideal C-C bond angle is 109.5˚.

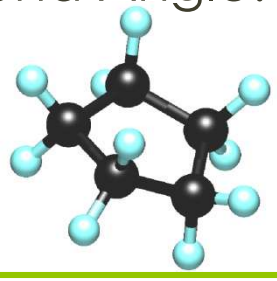
- Cyclopropane
  Bond Angle: ~60˚



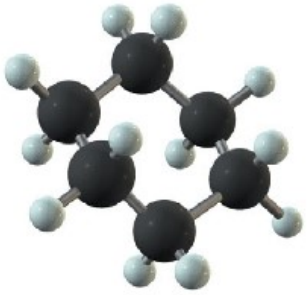
- Cyclobutane
  Bond Angle: ~90˚



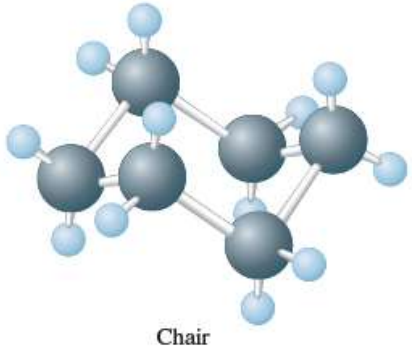
- Cyclopentane
  Bond Angle: 108˚



- Cyclohexane

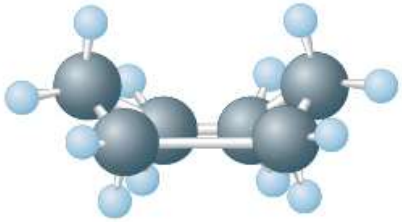


Flat Bond Angle: 120˚



Chair

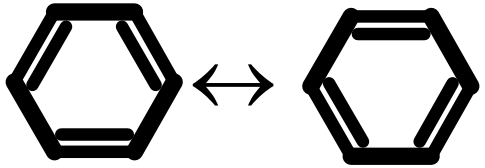
Bent Bond Angle: ~109.5˚



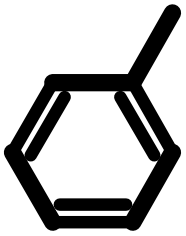
Boat

# Simple Organic Molecules

- **Aromatics:** A compound that includes a benzene ring as part of its structure



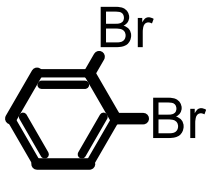
benzene



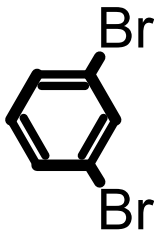
toluene

**Note:** Instead of showing the resonance structures for benzene, the symbol  is used to represent benzene.

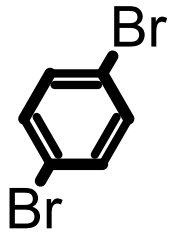
Otho/Meta/Para




Ortho




Meta




Para

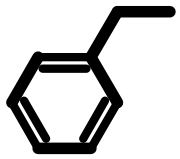
**Note:** The ortho/meta/para notation can be used for any ring structure but it is commonly used with aromatics.

# Simple Organic Molecules

- Rules for Naming Aromatics

1. The same rules are used for naming benzene complexes as other cyclohydrocarbons except instead of using 1,3,5-cyclohexatriene for the root name, benzene is used.

- Example: ethylbenzene



2. The same rules are used for naming toluene complexes as other cyclohydrocarbons except instead of using 1-methyl-1,3,5-cyclohexatriene for the root name, toluene is used. For toluene the methyl group is always counted as the number 1 carbon.

**Note: The numbering of the carbons can be different for the same compound depending if you are using toluene or benzene as the root name.**

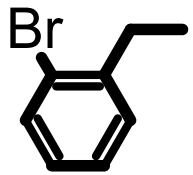
# Simple Organic Molecules

- Rules for Naming Aromatics

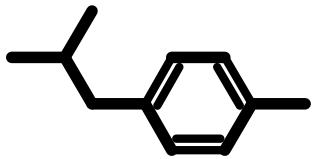
3. If two substituents are present on benzene or one on toluene the ortho/meta/para naming can be used. Place the following in front of the name when using ortho/meta/para naming.

| Configuration | Start of Name |
|---|---|
| ortho | o- |
| meta | m- |
| para | p- |

- Example:
  1-bromo-2-ethylbenzene
  o-bromoethylbenzene




- Example:
  4-isobutyltoluene
  p-isobutyltoluene
  1-isobutyl-4-methylbenzene
  p-isobutylmethylbenzene



# Isomers

*Student Question*

What is the maximum number of structural isomers of $C_5H_{12}$?

a) 2
b) 3
c) 4
d) 5
e) None of the Above

# Isomers

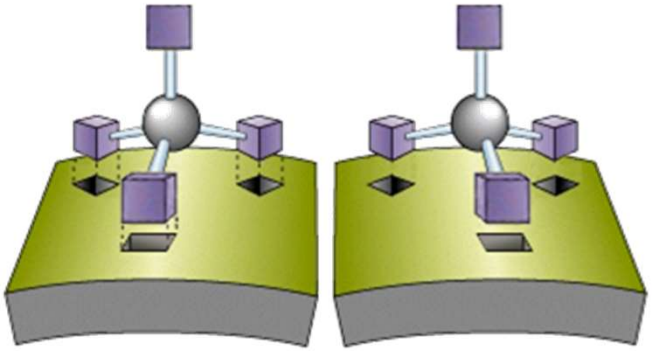
*Student Question*

What is the maximum number of structural and geometric isomers of $C_4H_8$?

a) 3
b) 4
c) 5
d) 6
e) None of the Above

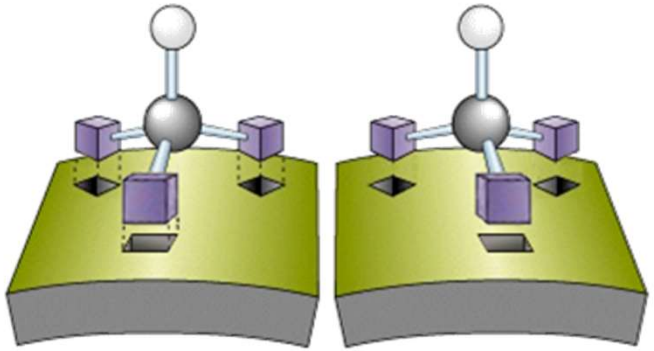
# Isomers

1type of atoms bond to C ($CR_4$)



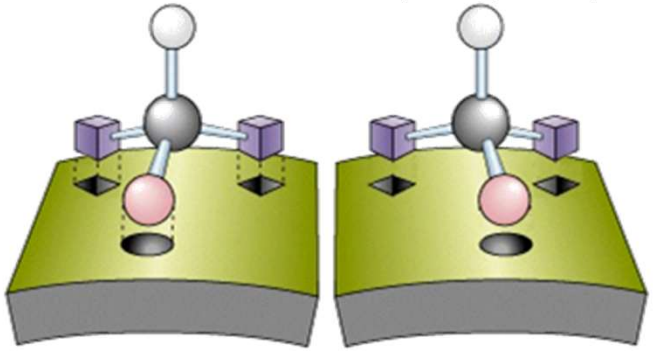
**No optical isomers**

2 different atoms ($CR_3R^1$)



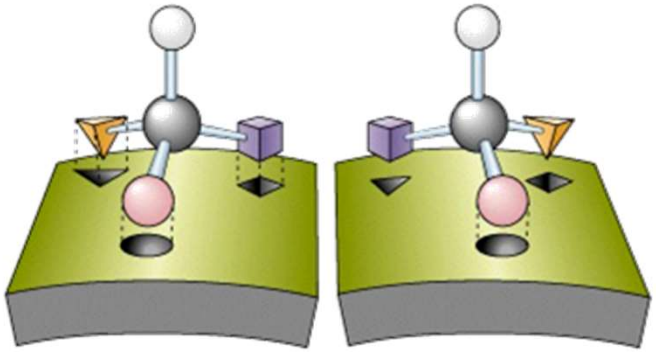
**No optical isomers**

3 different atoms ($CR_2R^1R^2$)



**No optical isomers**

4 different atoms ($CRR^1R^2R^3$)

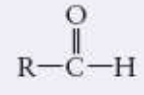
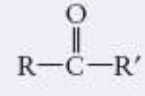
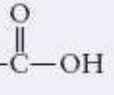
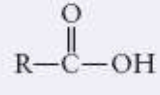
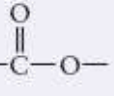
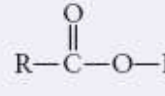


**optical isomers**

# Functional Groups

**TABLE 21.4**

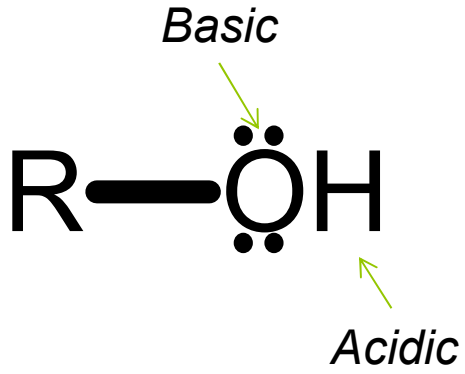
The Common Functional Groups

| Class | Functional Group | General Formula* | Example |
|---|---|---|---|
| Halohydrocarbons | —X (F, Cl, Br, I) | R—X | $CH_3I$ Iodomethane (methyl iodide) |
| Alcohols | —OH | R—OH | $CH_3OH$ Methanol (methyl alcohol) |
| Ethers | —O— | R—O—R′ | $CH_3OCH_3$ Dimethyl ether |
| Aldehydes |  |  | $CH_2O$ Methanal (formaldehyde) |
| Ketones |  |  | $CH_3COCH_3$ Propanone (dimethyl ketone or acetone) |
| Carboxylic acids |  |  | $CH_3COOH$ Ethanoic acid (acetic acid) |
| Esters |  |  | $CH_3COOCH_2CH_3$ Ethyl acetate |
| Amines | $-NH_2$ | $R-NH_2$ | $CH_3NH_2$ Aminomethane (methylamine) |

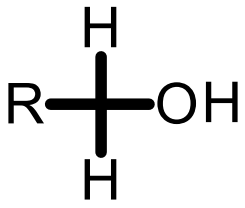
*R and R′ represent hydrocarbon fragments.

# Functional Groups

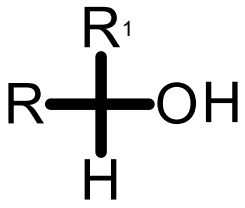
- Alcohols
  - H-Bonding occurs for alcohols
  - Increases boiling point and melting point from the alkanes
  - More soluble in water
  - Amphoteric, but better acid than a base



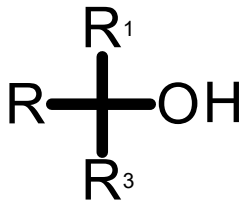

**Note: When the alcohol is functioning as an acid, the hydrogen bonded to the oxygen dissociates. When the alcohol is functioning as a base, a hydrogen bonds to the lone pair of electrons on the oxygen.**




Primary Alcohol




Secondary Alcohol



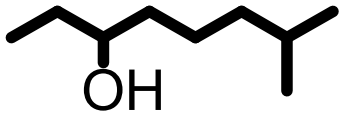

Tertiary Alcohol

# Functional Groups

- Rules for Naming Alcohols:-OH R–OH

1. The root name is formed by taking the alkane name corresponding to the number of carbons that the alcohol is bonded to, and replacing the e with -ol

- Example:

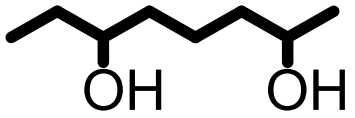



Root Name: octanol

2. If multiple alcohols are present the e is kept on the alkane name and the following is inserted between the alkane name and -ol:

| # of -OH | Name |
|---|---|
| 2 | di- |
| 3 | tri- |
| 4 | tetra- |

- Example:




octanediol

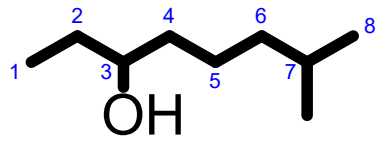
**Note: When prefix is put on the e in the alkane name goes back on.**

# Functional Groups

- Rules for Naming Alcohols:-OH R–OH

3. If the only functional group that is present is the alcohol, the root carbons are numbered such that the alcohol is bonded to the lowest numbered carbon. The number of the carbon that the alcohol is bonded to, is placed in front of the root name.

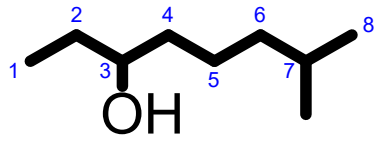
- Example:




Root Name:
3-octanol

4. Follow the remaining rules for naming alkanes and cycloalkanes.

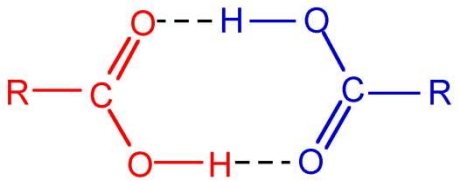
- Example:

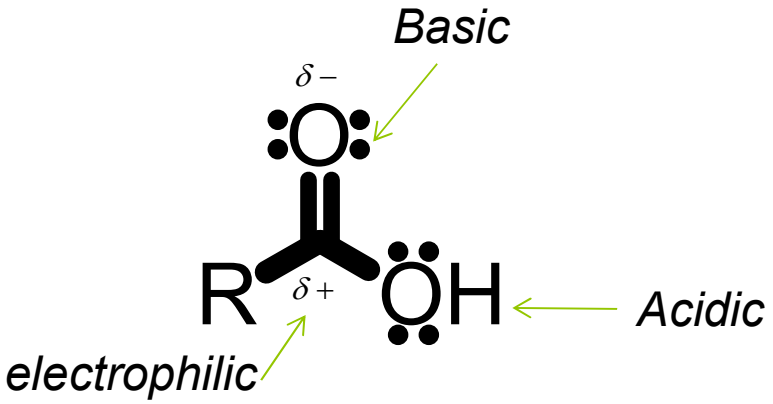



7-methyl-3-octanol

# Functional Groups

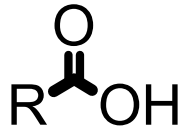
- Carboxylic Acids
  - H-Bonding occurs for carboxylic acids
  - Increases boiling point and melting point from the alcohols
  - Water soluble
  - Amphoteric



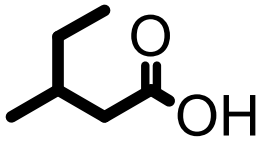
# Functional Groups

- Rules for Naming Carboxylic Acid: -COOH




1. The root name is formed by taking the alkane name corresponding to the number of carbons that the carboxylic acid is bonded to and replacing the e with –oic acid.

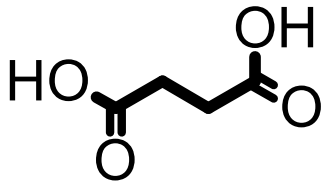
- Example:




Root Name:
pentanoic acid

2. If two carboxyl groups are present, add the suffix -dioic acid to the alkane name.

- Example:

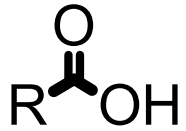



butanedioic acid

**Note: When prefix is put on the e in the alkane name goes back on.**

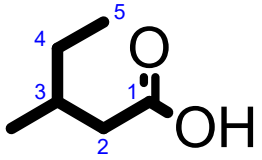
# Functional Groups

- Rules for Naming Carboxylic Acid: -COOH




3. If the only functional group that is present is the carboxylic acid, the root carbons are numbered such that the carboxylic acid is bonded to carbon number 1. Since the carboxylic acid always must be bonded to carbon number 1, no number needs to be included in front of the root name.

- Example:



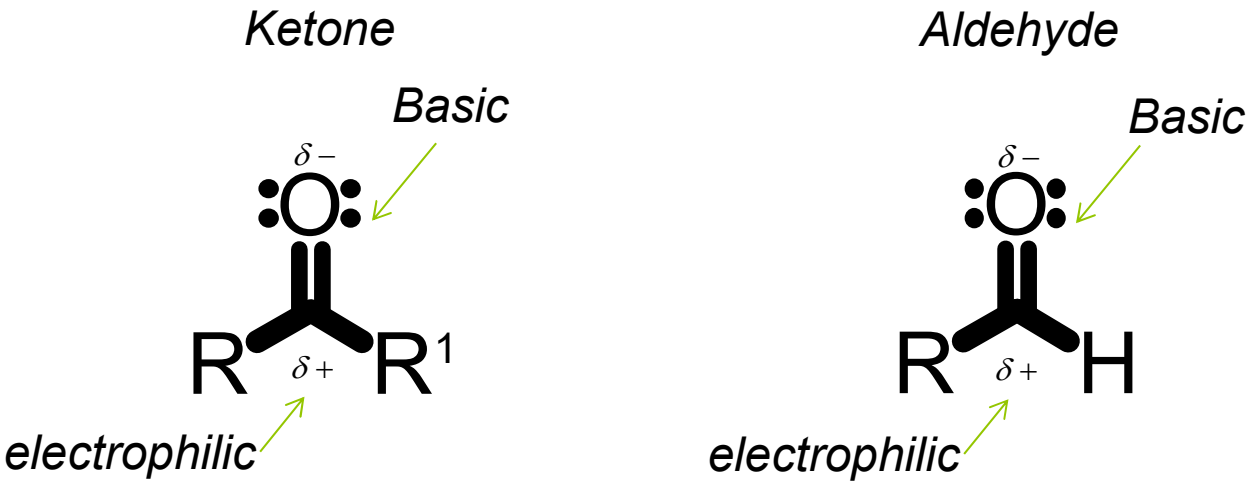

Root Name: pentanoic acid

4. Follow the remaining rules for naming alkanes and cycloalkanes

- Example: 3-methylpentanoic acid

# Functional Groups

- Aldehydes and Ketones
  - Cannot participate in hydrogen bonding by themselves.
  - Short ketones and aldehydes are water soluble.
  - Aldehydes are easier oxidized than ketones

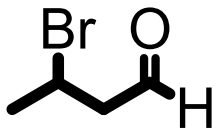


# Functional Groups

- Rules for Naming Aldehydes: -CHO


1. The root name is formed by taking the alkane name corresponding to the number of carbons that the aldehyde is bonded to, and replacing the e with –al.

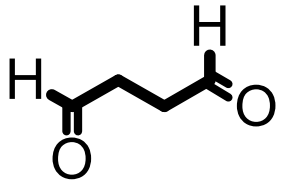
- Example:




Root Name: butanal

2. If two aldehydes are present add the suffix -dial to the alkane name.

- Example:




butanedial

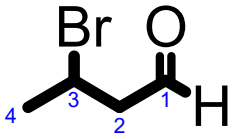
**Note: When prefix is put on the e in the alkane name goes back on.**

# Functional Groups

- Rules for Naming Aldehydes: -CHO


3. If the only functional group that is present is the aldehyde, the root carbons are numbered such that the aldehyde is bonded to carbon number 1. Since the aldehyde always must be bonded to carbon number 1, no number needs to be included in front of the root name.

- Example:



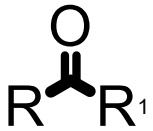

Root Name: butanal

4. Follow the remaining rules for naming alkanes and cycloalkanes.

- Example: 3-bromobutanal

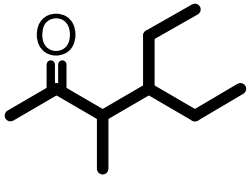
# Functional Groups

- Rules for Naming Ketone: -C=O-




1. The root name is formed by taking the alkane name corresponding to the number of carbons that the ketone is bonded to, and replacing the e with –one.

- Example:

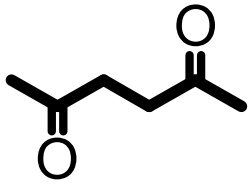



Root Name: hexanone

2. If multiple ketones are present the e is kept on the alkane name and the following is inserted between the alkane name and –one:

| # of =O | Name |
|---|---|
| 2 | di- |
| 3 | tri- |
| 4 | tetra- |

- Example:

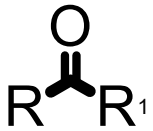



Root Name: hexanedione

**Note: When prefix is put on the e in the alkane name goes back on.**

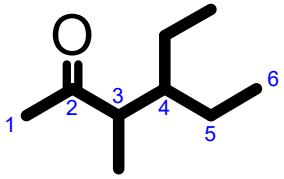
# Functional Groups

- Rules for Naming Ketone: -C=O-




3. If the only functional group that is present is the ketone the root carbons are numbered such that the ketone is bonded to the lowest number carbon. The number of the carbons that the ketone is bonded to is placed in front of the root name.

- Example:



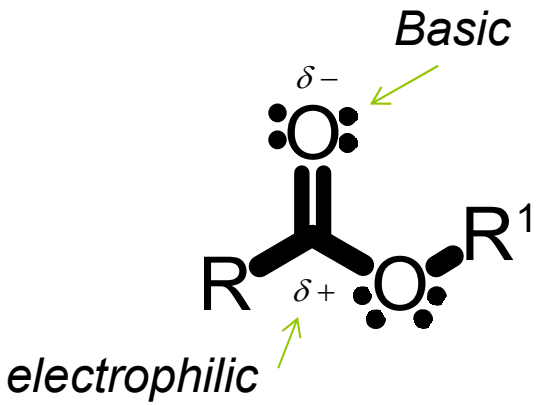

Root Name:
2-hexanone

4. Follow the remaining rules for naming alkanes and cycloalkanes.

- Example:
4-ethyl-3-methyl-2-hexanone

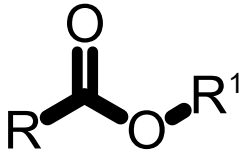
# Functional Groups

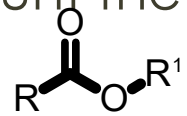
- Esters
  - Fairly high boiling points
  - Cannot participate in hydrogen bonding by themselves
  - Slightly water soluble (the larger the molecules, the less water soluble)



# Functional Groups

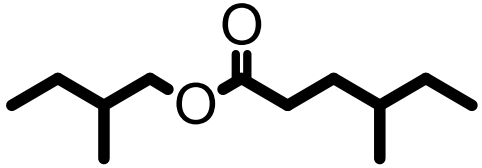
- Rules for Naming Esters: -COO-



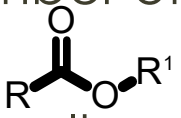

1. Count the number of carbons in $R^1$(  ). Take the corresponding core name and add –yl.



- Example:

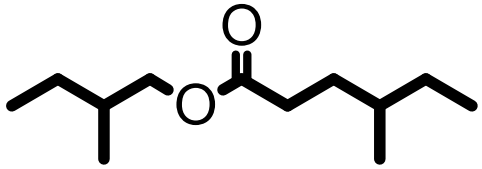



butyl

2. Count the number of carbons in R and add 1 (  ). Take the corresponding alkane name for R+1 and replace the e with -oate.



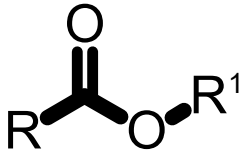
- Example:




hexanoate

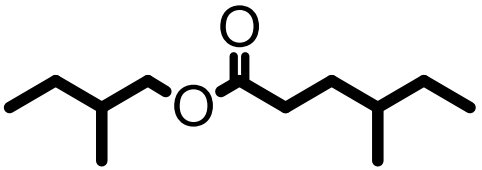
# Functional Groups

- Rules for Naming Esters: -COO-

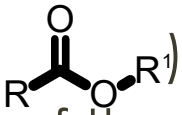



3. The root name of the ester is formed by placing the name in step 1 in front of the name in step 2.

- Example:

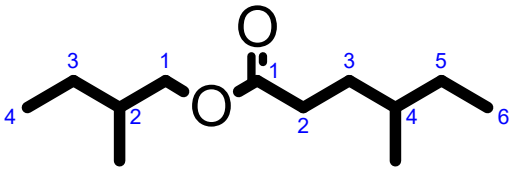



Root Name:
butyl hexanoate

4. The substituents that are bonded to $R^1$ (  ) are placed in front of the $R^1$ name and the substituents that are bonded to R are placed in front of the R name. This causes the root name to be broken up.



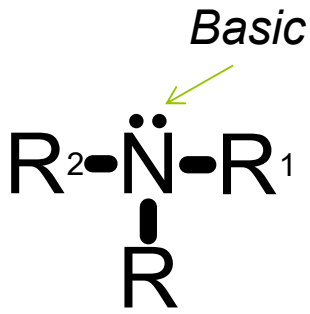
- Example:

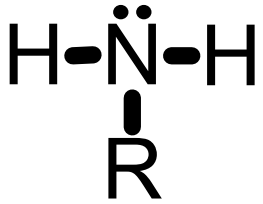



2-methylbutyl-4-methylhexanoate

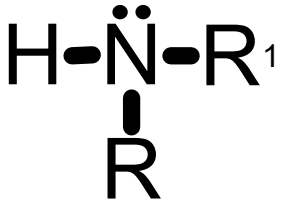
# Functional Groups

- Amines
  - Allows H-Bonding to occur (primary and secondary only).
  - Every amino acid contains at least 1 amine (and a carboxylic acid).

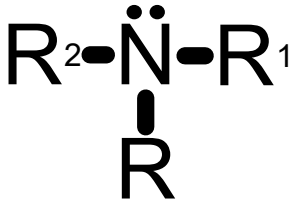



Primary Amine




Secondary Amine



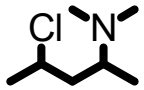

Teriary Amine

# Functional Groups

- Rules for Naming Amines:

1. Find the longest carbon chain. Take the corresponding alkane name and drop the e and add amine.

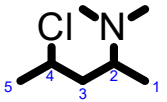
- Example:




Root Name: pentanamine

2. Number the carbons in the longest chain so that the nitrogen is attached to the lowest number carbon possible. Place the nitrogen attach number in front of the root name.

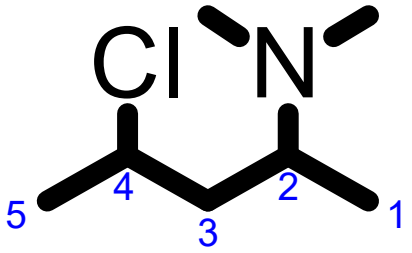
- Example:




Root Name: 2-pentanamine

# Functional Groups

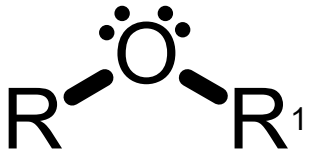
- Rules for Naming Amines:
  1. Follow the remaining rules for naming alkanes. If the substituent comes of the nitrogen put a *N* instead of a number in front of the substituents name.




- Example:
  4-chloro-*N*,*N*-dimethyl-2-pentanamine

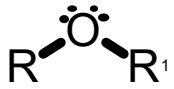
# Functional Groups

- Ethers
  - Slightly polar.
  - Not very soluble in water.
  - Relatively unreactive.
  - Most common ether reaction is cleavage of the carbon oxygen bond by a strong acid.



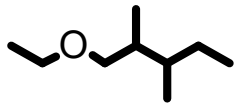
# Functional Groups

- Rules for Naming Ethers: $ROR_1$




1. Count the number of carbons in the shorter R chain. Take the corresponding core name and add –oxy.

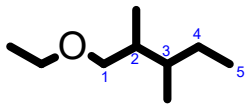
- Example:




Root Name: ethoxy

2. Number the carbons in the longer chain in order to give the shorter chain the lowest number attachment point. Place the attachment number in front of the root name.

- Example:




Root Name: 1-ethoxy

3. Name the longer chain using the rules for naming alkanes.

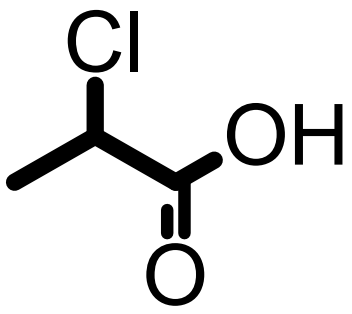
- Example:

1-ethoxy-2,3-dimethypentane

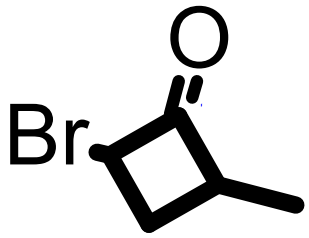
# Functional Groups (ADDITION)

a) Correct b) Incorrect

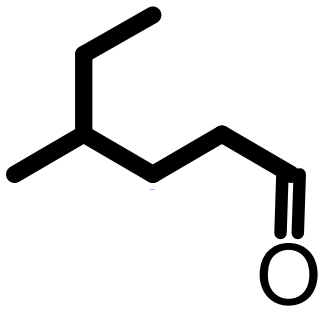
What is the name/structure of:

a) 


b) methyl ethanoate

c) 


d) 7-bromo-7-methyl-2,3-octanediol

e) 

# Functional Groups

*Student Question*

The boiling point of methanol is much higher than that of ethane. This is primarily due to:

a) the significant difference in the molar masses of methanol and ethane.

b) the hydrogen bonding in methanol and the lack of hydrogen bonding in ethane.

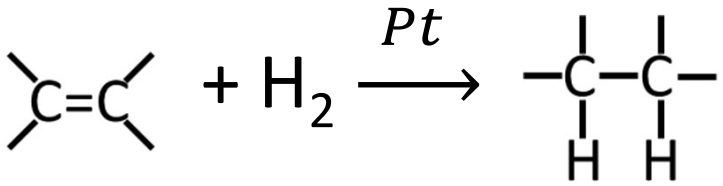
c) the significant difference in the molecular sizes of methanol and ethane.

d) the carbon–oxygen bond in the methanol.

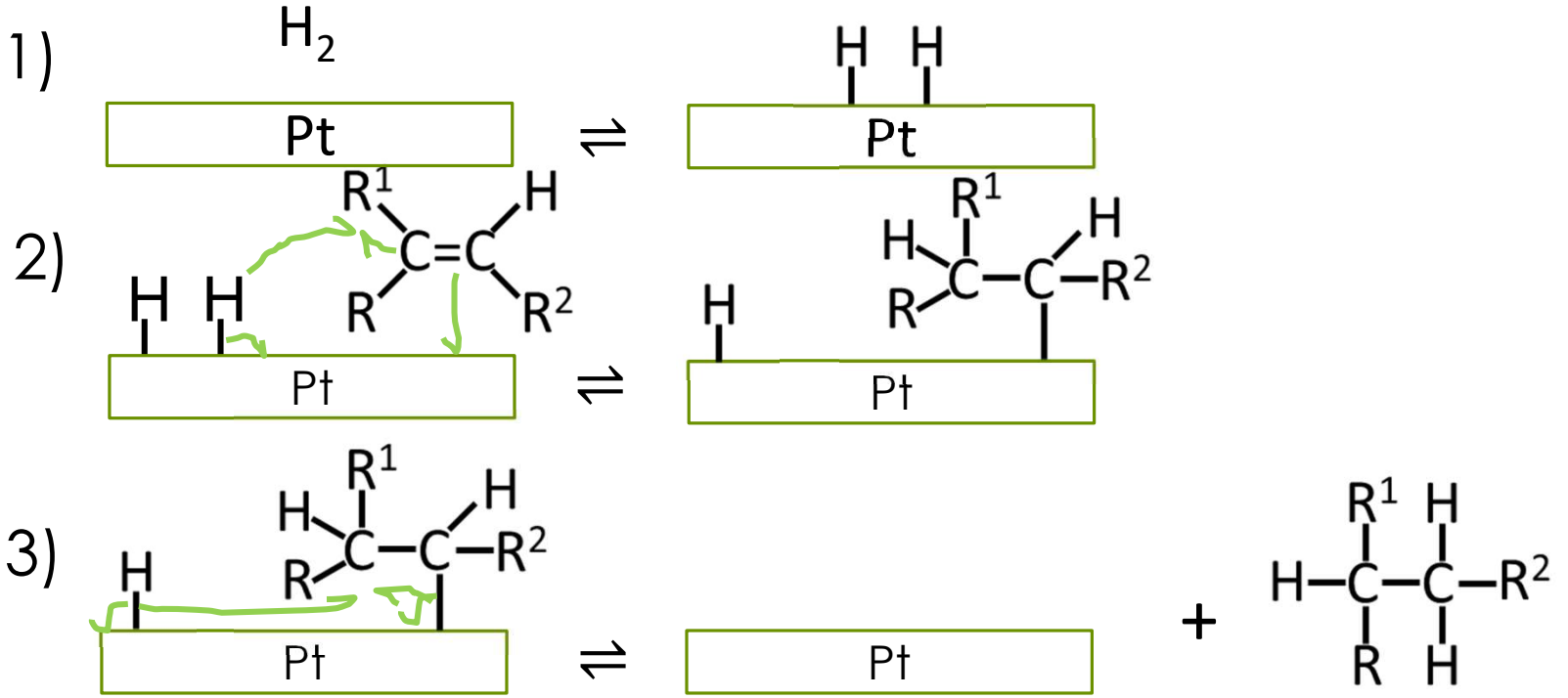
# Organic Reactions

## Hydrogenation Reactions

- Overall Reaction

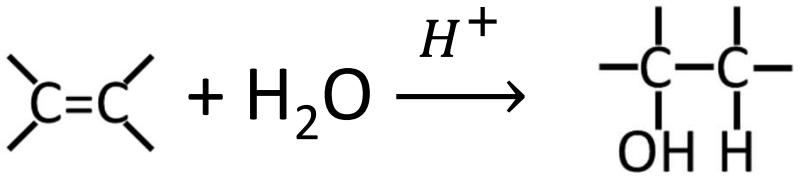



- Mechanism



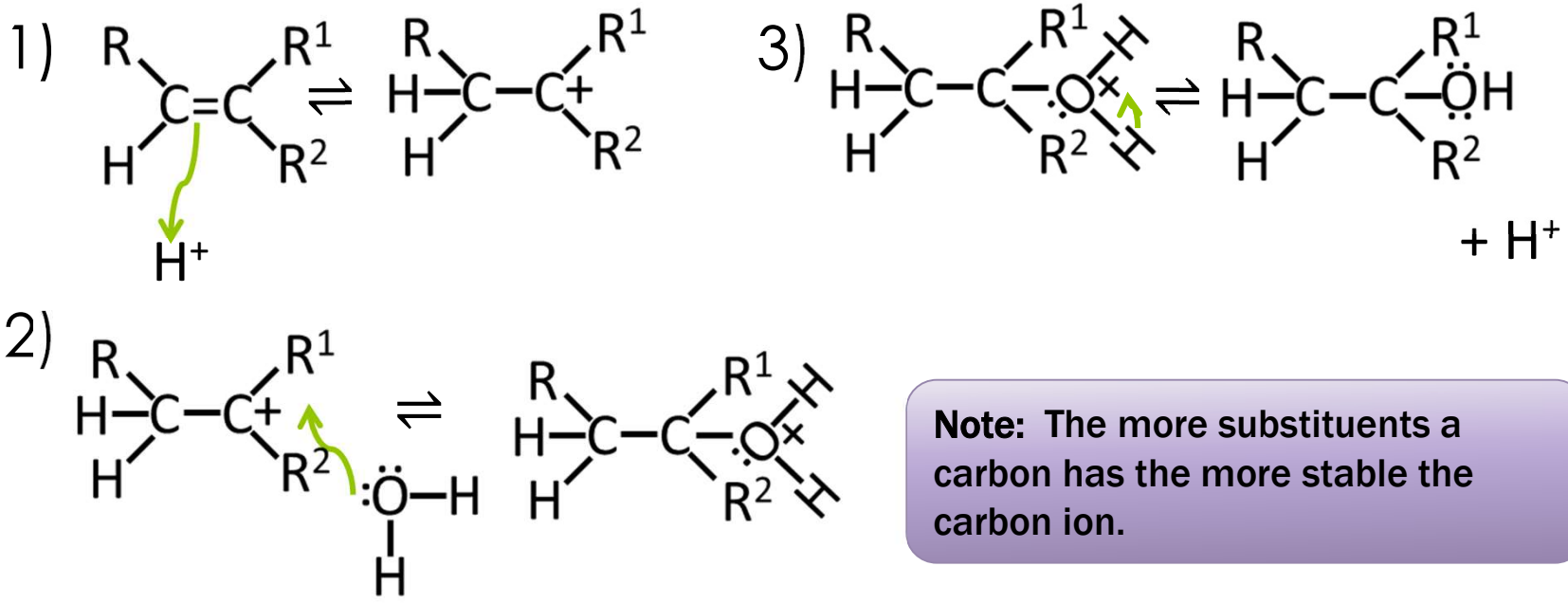
# Organic Reactions

- Overall Reaction




**Note:** The OH will add to more substituted side.

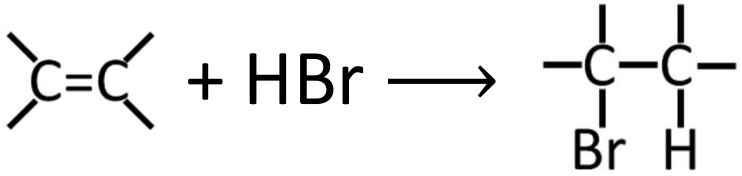
- Mechanism




**Note:** The more substituents a carbon has the more stable the carbon ion.

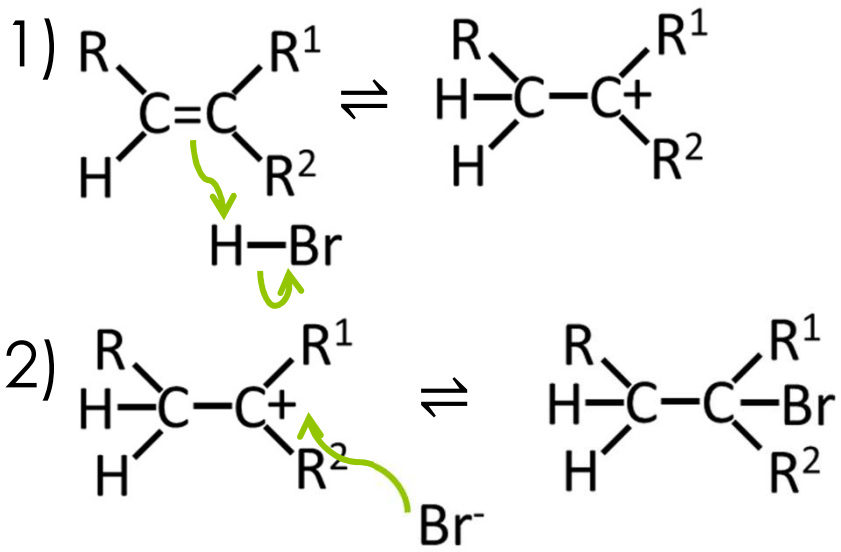
# Organic Reactions

- Overall Reaction




**Note: The Br will add to the more substituted side.**

- Mechanism

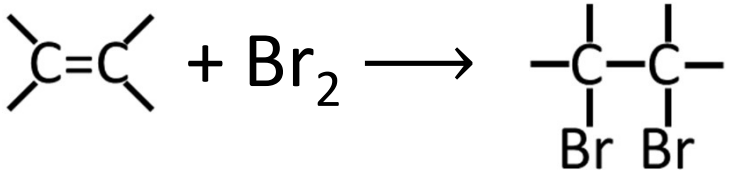



**Note: The more substituents a carbon has the more stable the carbon ion.**

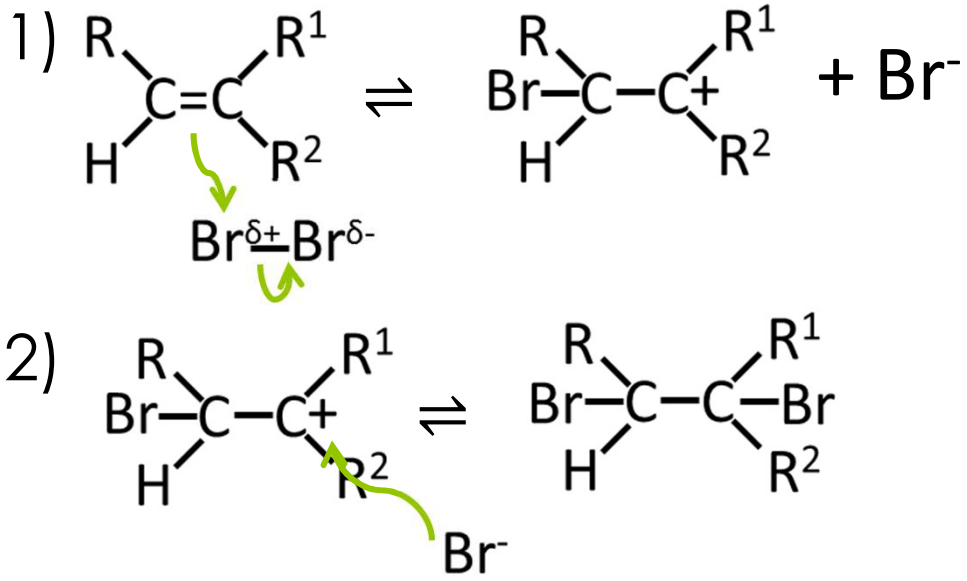
# Organic Reactions

## Halogenation

- Overall Reaction




- Mechanism



# Organic Reactions

## Substitution Reactions

- Overall Reaction

$$CH_4 + Cl_2 \xrightarrow{h\nu} CH_3Cl + HCl$$

$$CH_3Cl + Cl_2 \xrightarrow{h\nu} CH_2Cl_2 + HCl$$

$$CH_2Cl_2 + Cl_2 \xrightarrow{h\nu} CHCl_3 + HCl$$

$$CHCl_3 + Cl_2 \xrightarrow{h\nu} CCl_4 + HCl$$

- Mechanism

$$Cl_2 \xrightarrow{h\nu} 2Cl\cdot$$

$$CH_4 + Cl\cdot \longrightarrow \cdot CH_3 + HCl$$

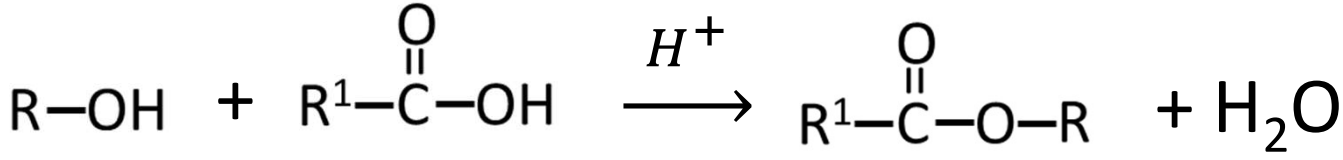
$$\cdot CH_3 + Cl\cdot \longrightarrow CH_3Cl$$

**Note:** A dot represents a single $e^-$. Structures will single $e^-$ are called radicals.

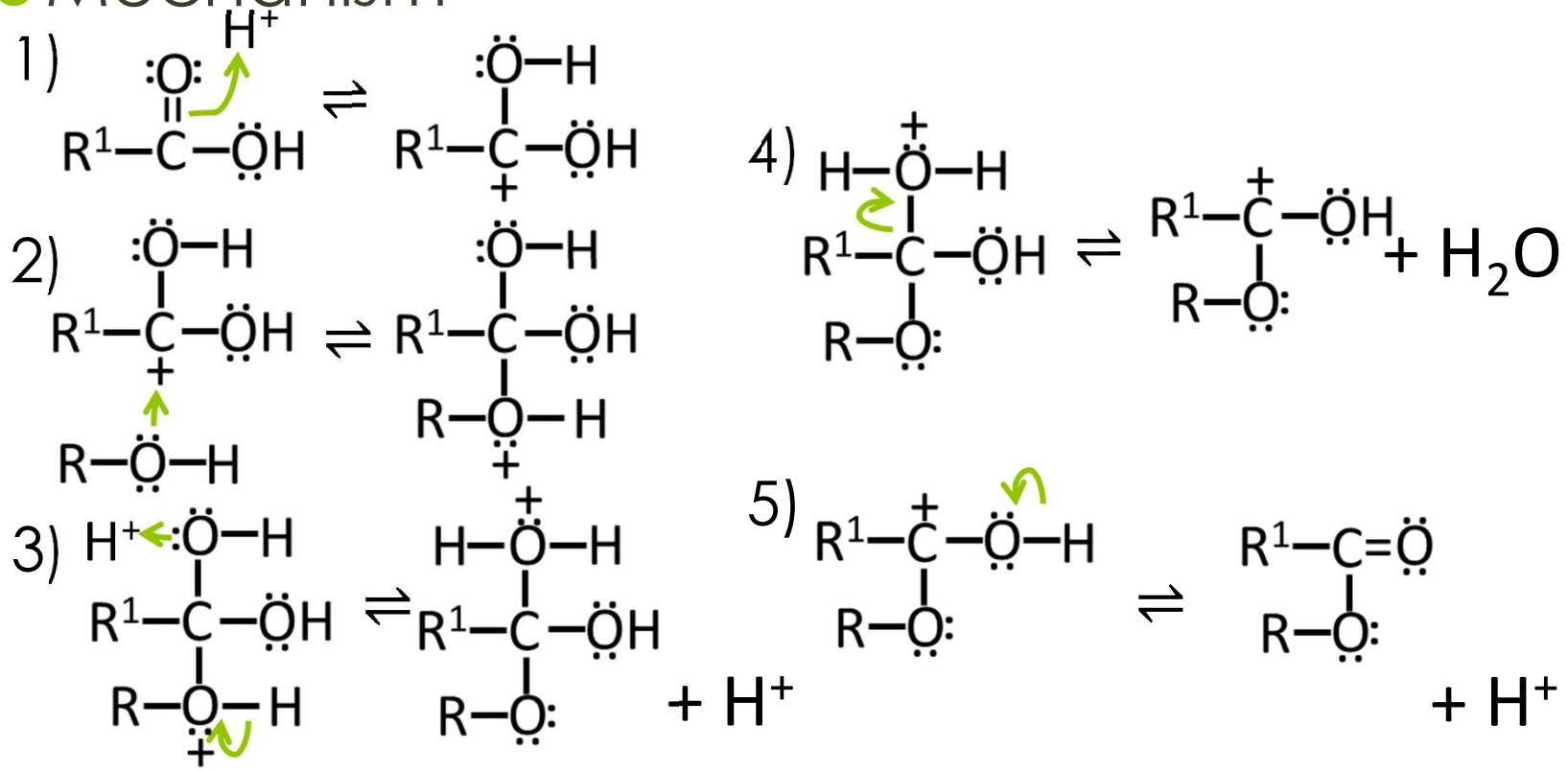
# Organic Reactions

## Esterification

- Overall Reaction

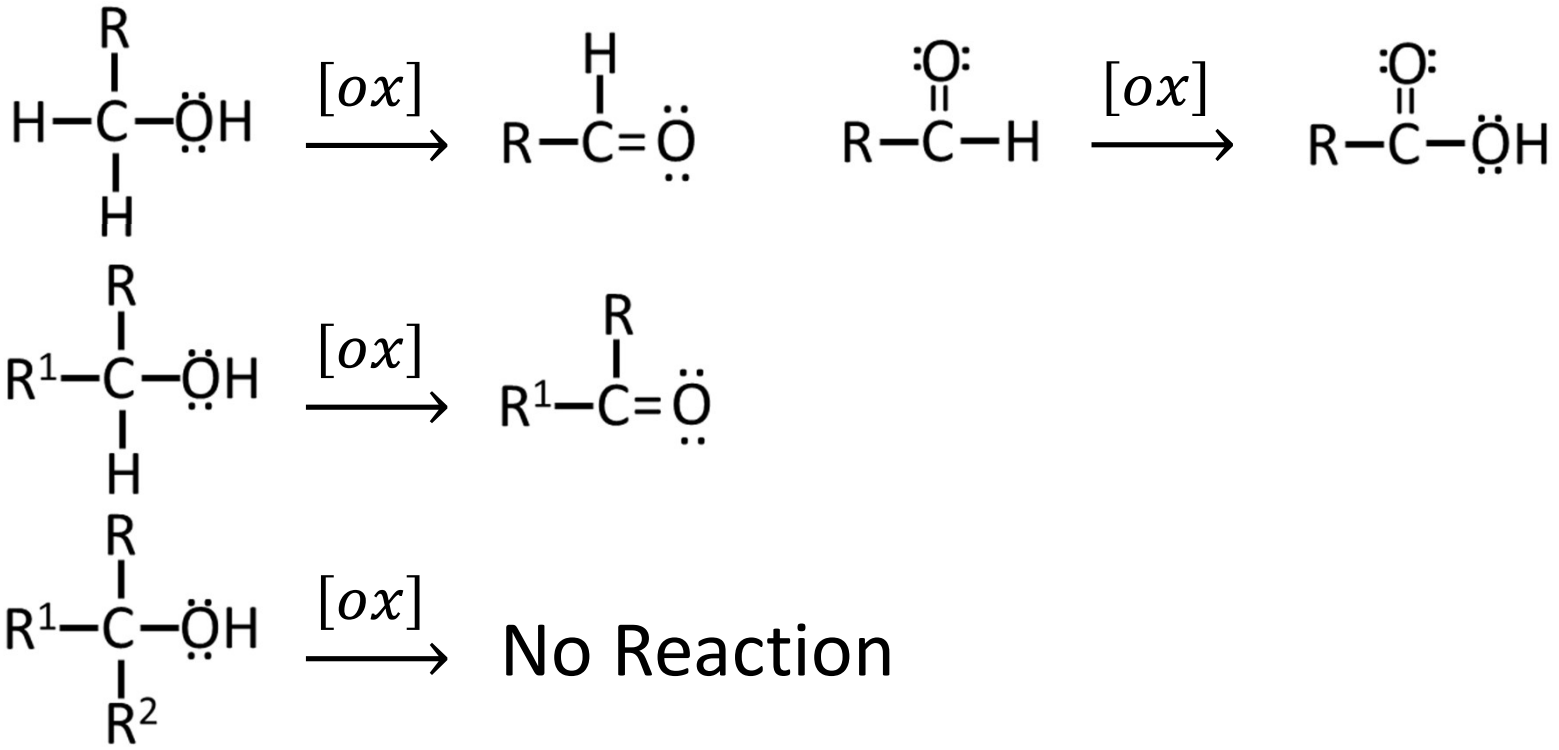



- Mechanism



# Organic Reactions

- **Oxidation:** Addition of electronegative atoms to carbon or removal of hydrogen atoms from carbon.
- **Reduction:** Removal of electronegative atoms from carbon or addition of hydrogen atoms to carbon.



# Organic Reactions

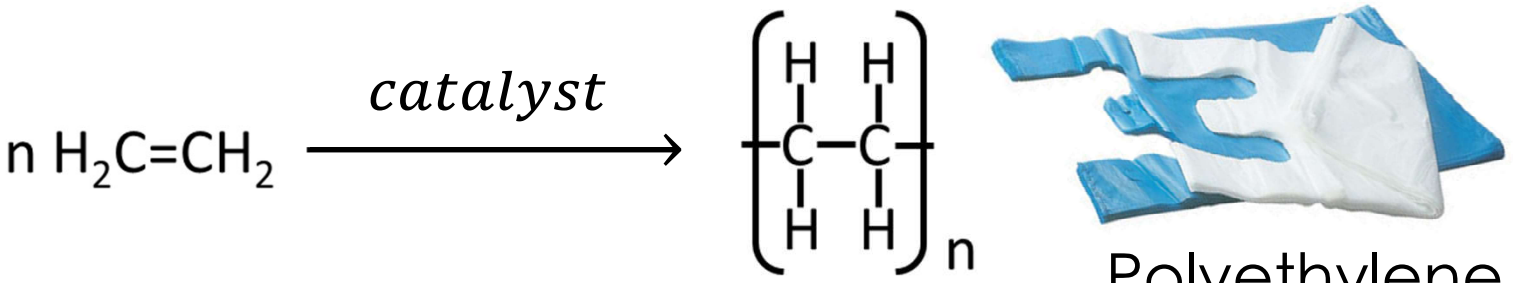
*Student Question*

What might be the product of the oxidation of 2-methyl-1-butanol?

a) 2-methyl-1-butanone
b) 2-methylbutanal
c) 2-methylbutanoic acid
d) Both b and c
e) Both a and c

# Polymers

- **Polymers:** Compound in which chains or networks of small repeating units form giant molecules.
- **Addition Polymer:** A polymer formed by adding monomer units together (usually by reacting double bond).






Polyethylene

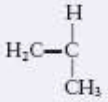
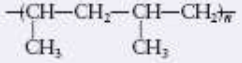
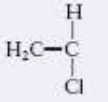
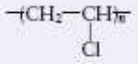
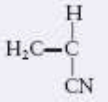
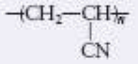
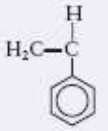
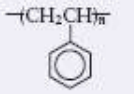
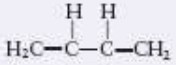
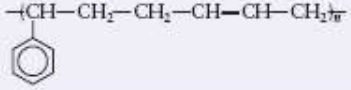
- **Homopolymer:** A polymer formed from a single monomer.

# Polymers

- Other Addition Polymers

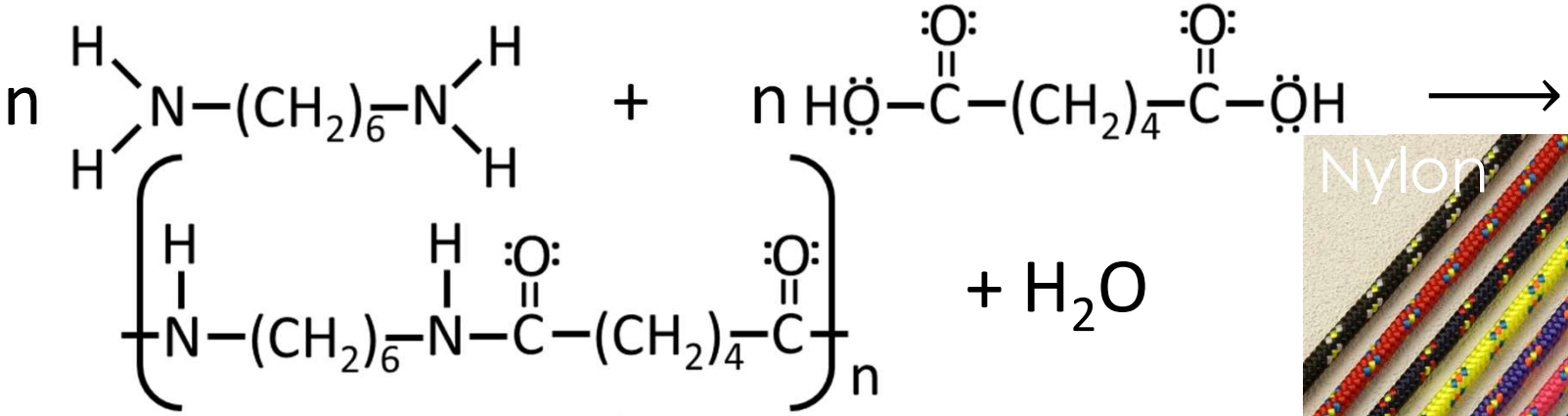
**TABLE 21.7**

Some Common Synthetic Polymers, Their Monomers, and Applications

| Monomer | | Polymer | | |
|---|---|---|---|---|
| Name | Formula | Name | Formula | Uses |
| Ethylene | $H_2C{=}CH_2$ | Polyethylene | $-(CH_2{-}CH_2)_n-$ | Plastic piping, bottles, electrical insulation, toys |
| Propylene |  | Polypropylene |  | Film for packaging, carpets, lab wares, toys |
| Vinyl chloride |  | Polyvinyl chloride (PVC) |  | Piping, siding, floor tile, clothing, toys |
| Acrylonitrile |  | Polyacrylonitrile (PAN) |  | Carpets, fabrics |
| Tetrafluoro-ethylene | $F_2C{=}CF_2$ | Teflon | $-(CF_2{-}CF_2)_n-$ | Cooking utensils, electrical insulation, bearings |
| Styrene |  | Polystyrene |  | Containers, thermal insulation, toys |
| Butadiene |  | Polybutadiene | $-(CH_2CH{=}CHCH_2)_n-$ | Tire tread, coating resin |
| Butadiene and styrene | (See above.) | Styrene-butadiene rubber |  | Synthetic rubber |

# Polymers

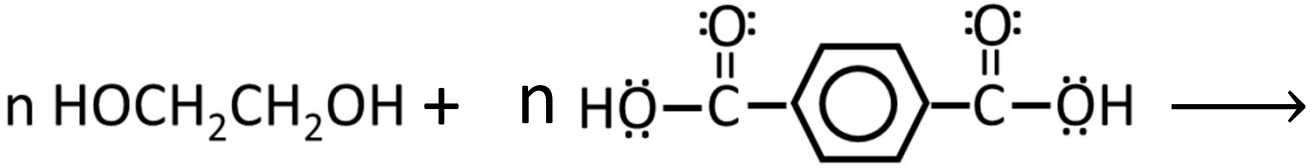
- **Condensation Polymer:** A polymer that forms when two monomers combine by eliminating a small molecule (usually $H_2O$ or HCl)

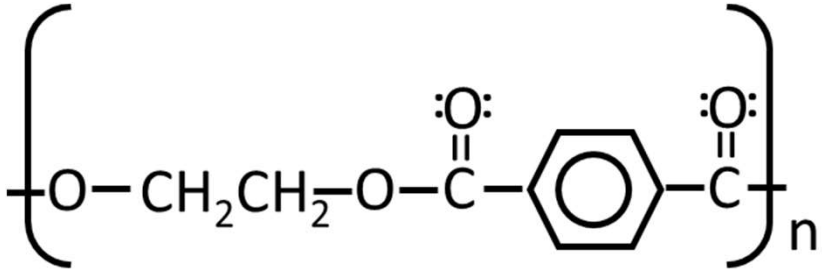



- **Copolymer:** A polymer formed from a mixture of different monomers.
- **Polyamide:** A polymer in which the monomers are linked by amide functional group (nitrogen next to double bonded oxygen) formed by condensation.

# Polymers

- **Polyester:** A polymer in which the monomers are linked by ester groups formed by condensation.



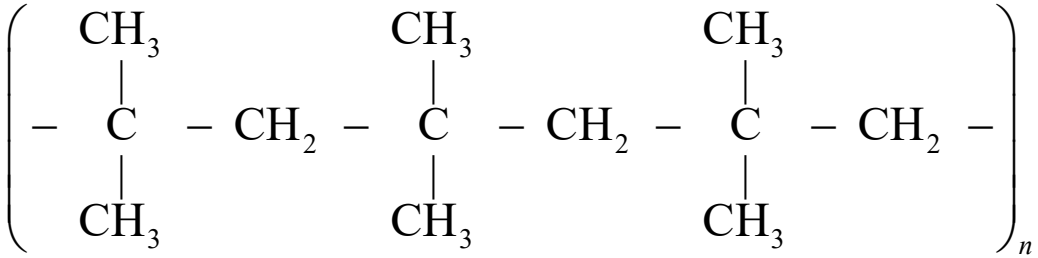




Dacron

# Polymers

## *Student Question*

Consider the polymer:

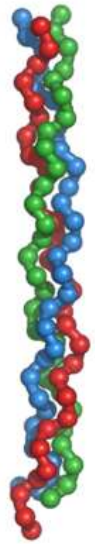


What monomer(s) is/are needed to produce the above polymer?

a) $CH_2=CH_2$ and $CH_3CH = CH_2$
b) $CH_2=C(CH_3)_2$
c) $CH_3CH=CHCH_3$
d) CO and $CH_2=CH_2$
e) None of the Above

# Biochemistry

- **Protein:** A natural high-molecular-weight polymer formed by condensation reactions between amino acids.

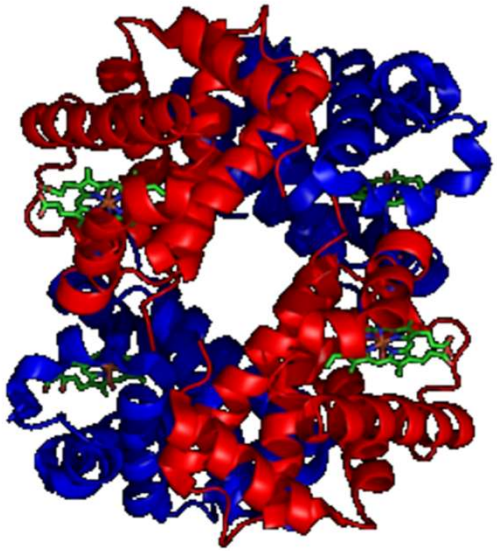


**Fibrous Proteins**

- Non soluble
- Provide structure integrity and strength

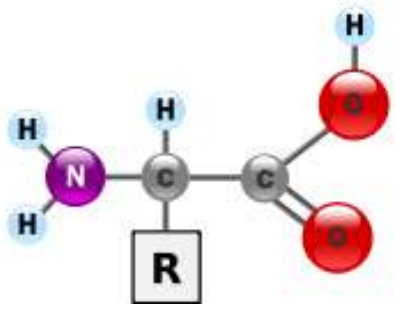
**Globular Proteins**

- Soluble in Water
- Transport of oxygen and nutrients and act as catalyst to reactions

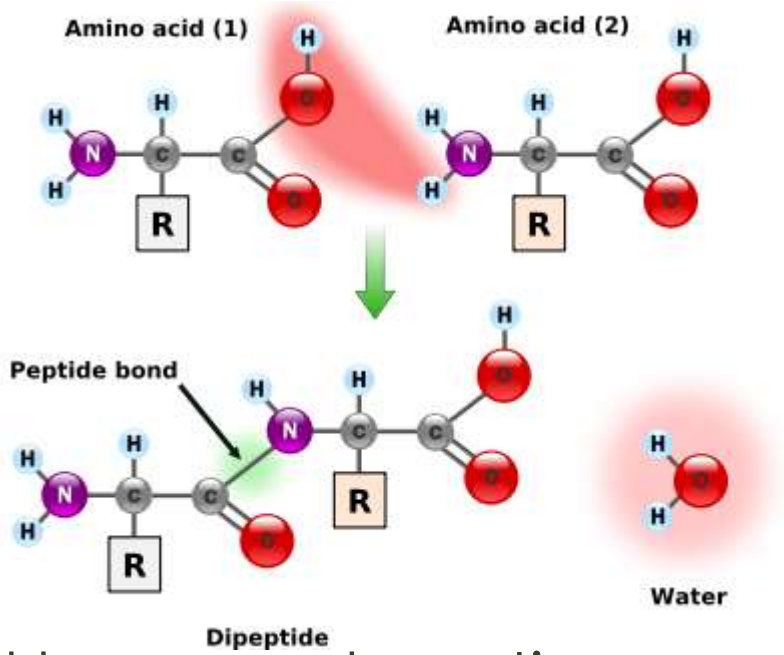


# Biochemistry

- **Amino Acids:** Monomers of proteins




R is the Side Chain



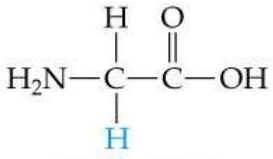

- **Peptide:** Molecule formed by a condensation reaction between amino acids.

**Note: Often peptides are described in terms of the number of units.**
**Ex. dipeptide or polypeptide.**

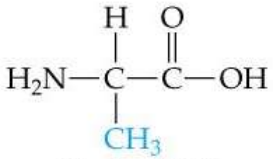
- **Peptide Bond:** The –CONH- group.

# Biochemistry

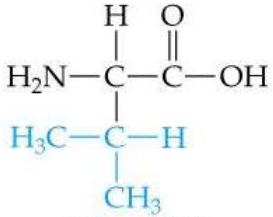
- Amino Acid with Nonpolar R Groups (hydrophobic)



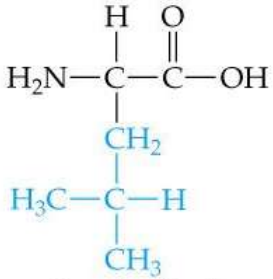
Glycine (Gly)



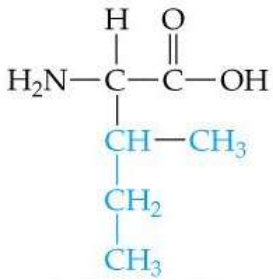
Alanine (Ala)



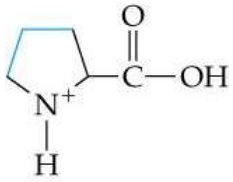
Valine (Val)



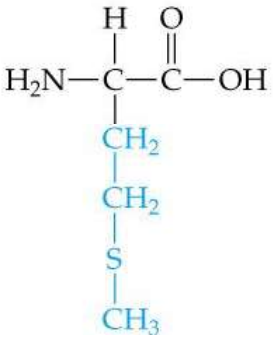
Leucine (Leu)



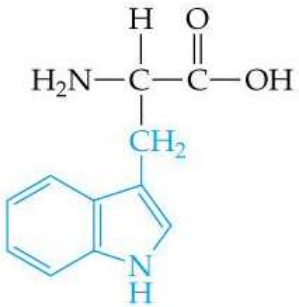
Isoleucine (Ile)



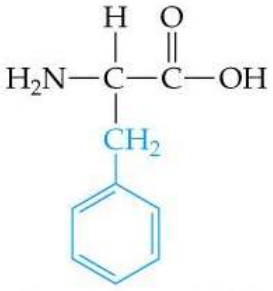
Proline (Pro)



Methionine (Met)



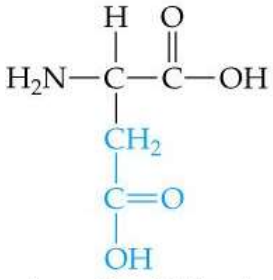
Tryptophan (Trp)

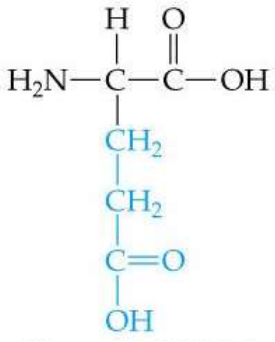


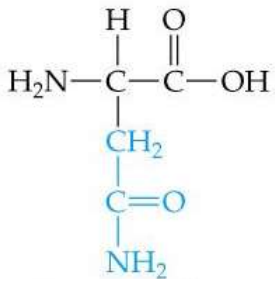
Phenylalanine (Phe)

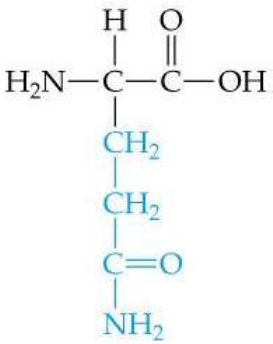
# Biochemistry

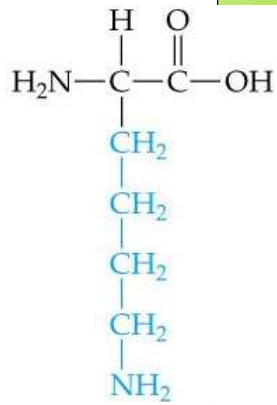
- Amino Acid with Polar R Groups (hydrophilic)

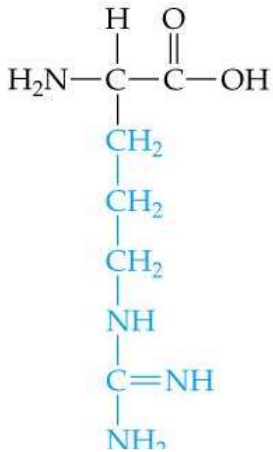

Aspartic Acid (Asp)

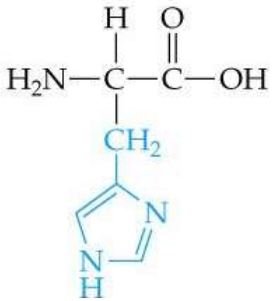

Glutamic Acid (Glu)

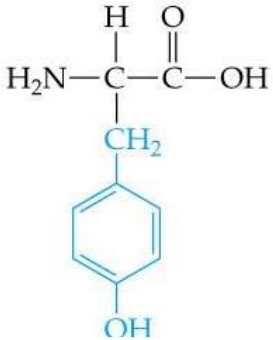

Asparagine (Asn)

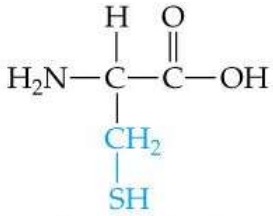

Glutamine (Gln)

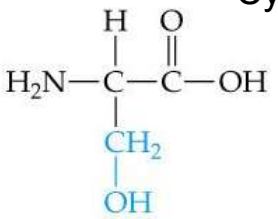

Lysine (Lys)

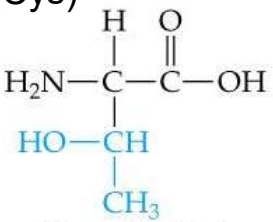

Arginine (Arg)


Histidine (His)

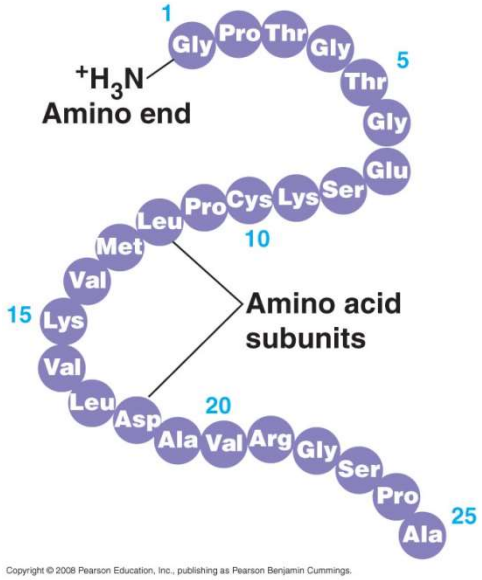

Tyrosine (Tyr)


Cysteine (Cys)


Serine (Ser)


Theronine (Thr)

# Biochemistry

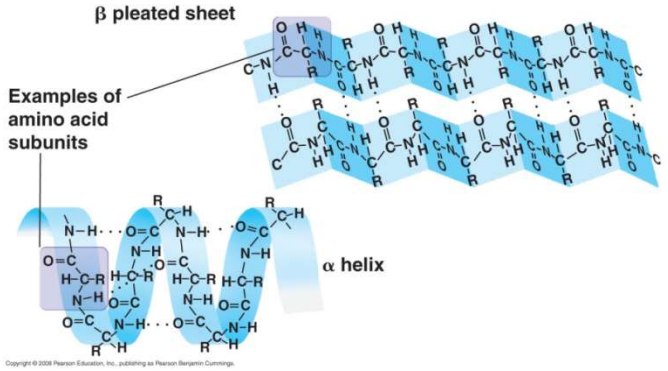



**Primary Structure:**

- The sequence of amino acids in the polypeptide chain of a protein.

**Secondary Structure:**

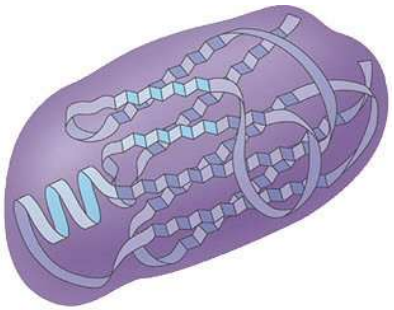
- The manner in which a polypeptide chain is coiled. (Short range structure).




**Note: Secondary structure usually a result of H-Bonding**

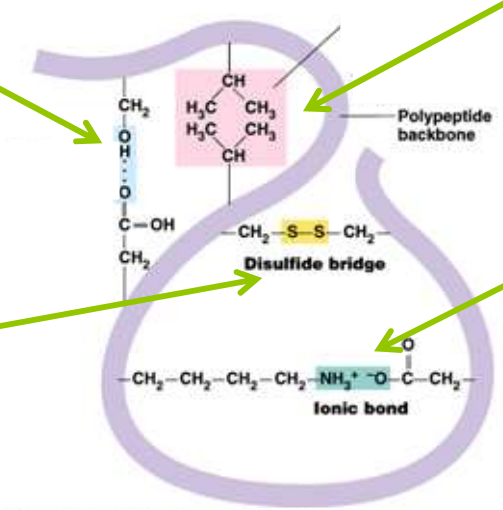
# Biochemistry

- **Tertiary Structure:** The shape into which the α–helix and β–sheet sections of a polypeptide are twisted as a result of interactions between peptide groups lying in different parts of the primary structure. (Long range order)



**H-Bonds**:
Needs each amino acid R group to contain groups that can H-Bond

**London Dispersion:**
Needs each amino acid R to be nonpolar




**Disulfide Bridge:**
Needs each amino acid R group to contain sulfur

**Ionic:**
Needs the amino acid R groups to contain either COOH or $NH_2$

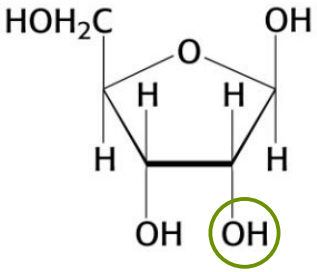
# Biochemistry

- **DNA (deoxyribonucleic acid):** A huge nucleotide polymer having a double-helical structure with complementary bases on the two strands. Its major functions are protein synthesis and the storage and transport of genetic information.
- **RNA (ribonucleic acid):** A nucleotide polymer that transmits the genetic information stored in the DNA to the ribosomes for protein synthesis.

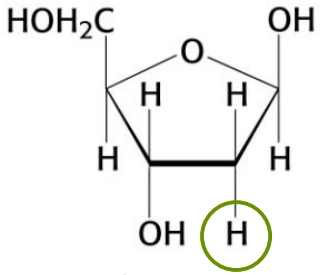
# Biochemistry

## Nucleotides

- Contain 5-carbon sugar



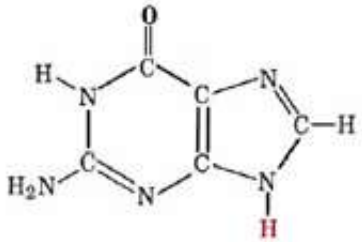
RNA (ribose)

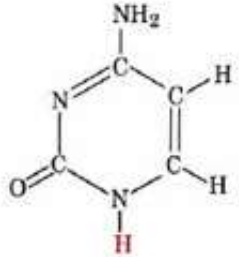


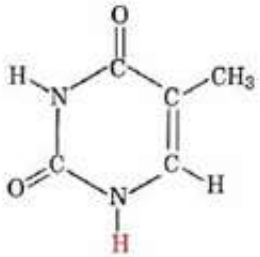
DNA (deoxyribose)

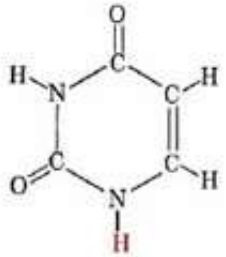
- Contain nitrogen-containing organic base


Adenine (A)
(DNA and RNA)


Guanine (G)
(DNA and RNA)


Cytosine (C)
(DNA and RNA)

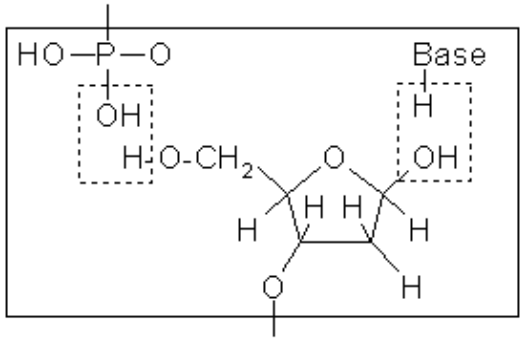

Thymine (T)
(DNA only)

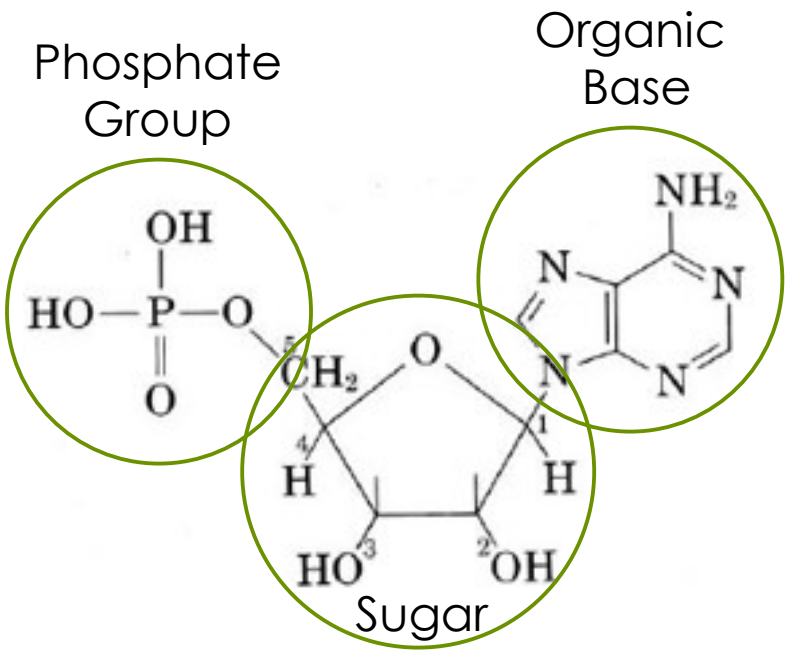

Uracil (U)
(RNA only)

# Biochemistry

## Nucleotides

- Contain a phosphoric acid molecule ($H_3PO_4$)



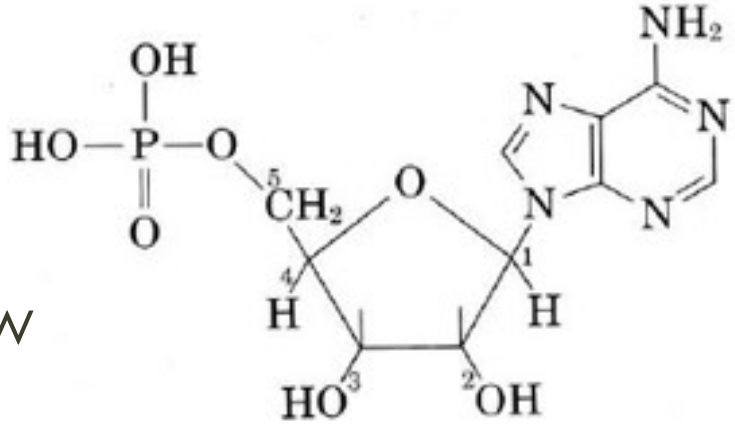



# Simple Organic Molecules

## *Student Question* (ADDITION)

This is a _____ nucleotide?

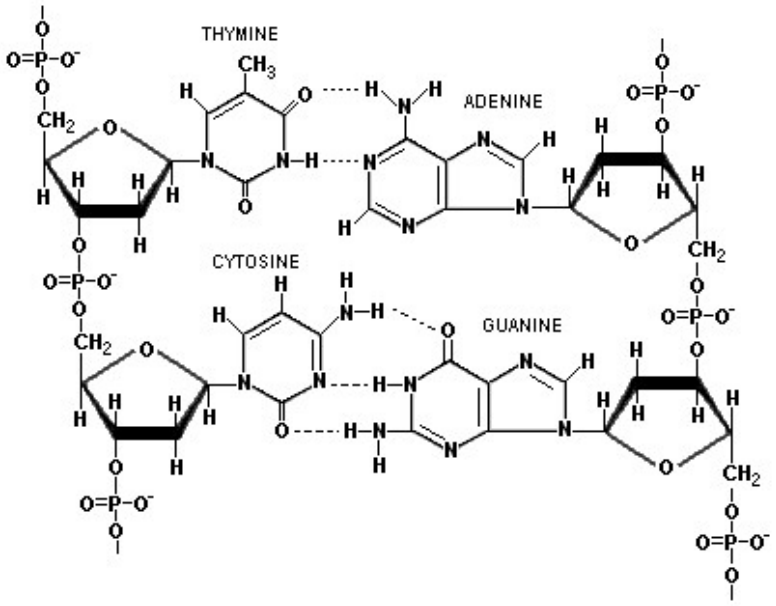
a) DNA
b) RNA
c) Either
d) Do not know

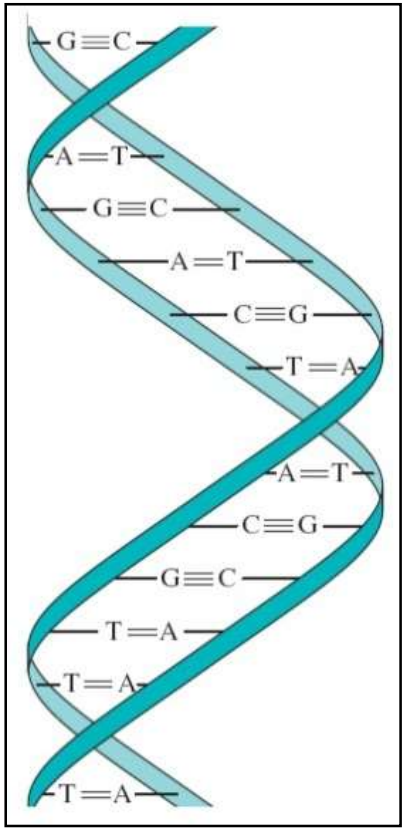


# Biochemistry

## DNA structure

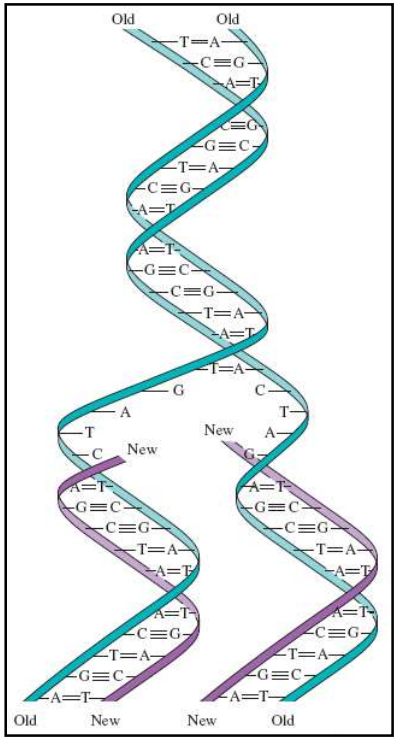
- Contain two strands with complementary bases
  - Thymine and Adenine
  - Cytosine and Guanine



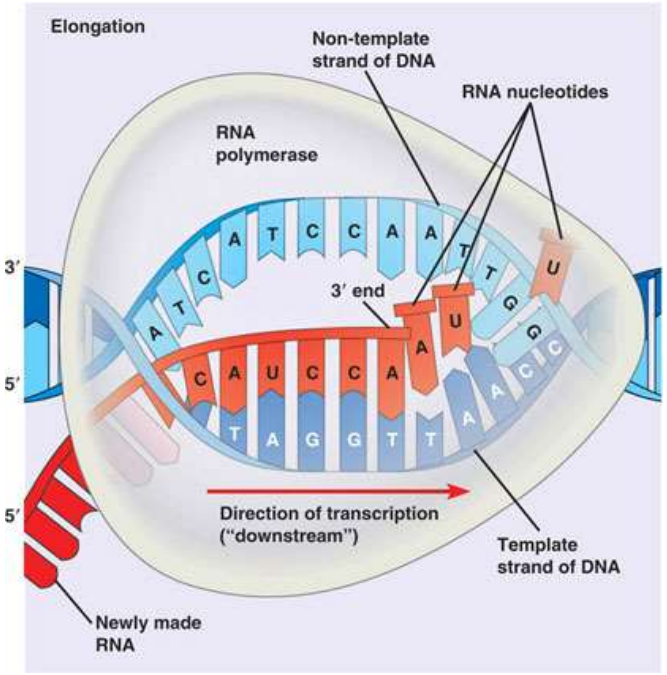
# Biochemistry

DNA is located in the cell nucleus. When cells divides, the DNA unwinds and new complimentary strands are constructed.



# Biochemistry

**RNA Transcription:** Process of creating an equivalent RNA copy from a sequence of DNA.




RNA Complimentary Bases

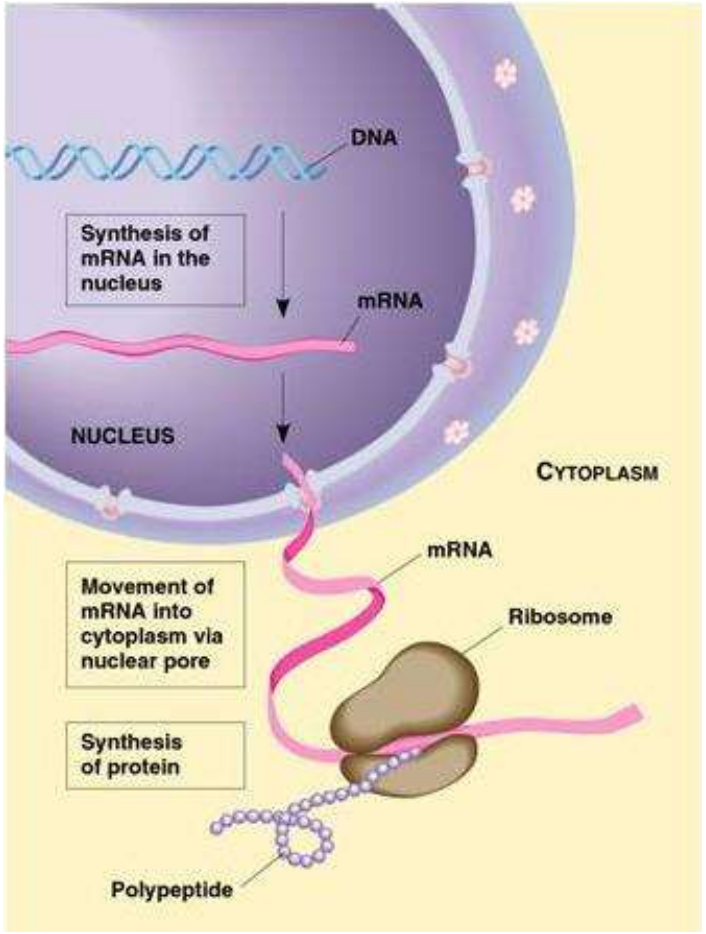
| DNA Bonding Site | RNA Nucleotide |
|---|---|
| Thymine | Adenine |
| Adenine | Uracil |
| Cytosine | Guanine |
| Guanine | Cytosine |

# Biochemistry

**mRNA** *(messenger RNA)*: Template for protein synthesis.

**tRNA** *(transfer RNA)*: RNA molecules that transfer specific amino acids to a growing protein.

**RNA Translation:** The process in which the genetic code carried by mRNA directs the production of proteins from amino acids.



# Biochemistry

**Carbohydrate:** An organic compound containing only carbon, hydrogen and oxygen with the general formula $C_m(H_2O)_n$.

- Purpose of Carbohydrates
  - Food sources
  - Structural material (plants)
  - DNA backbone

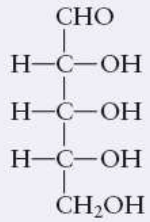
**Monosaccharides** *(simple sugars)*: An individual unit from which carbohydrates are considered to be composed.

**TABLE 21.8**

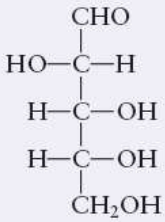
Some Important Monosaccharides

Pentoses

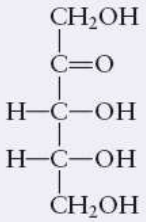
D-Ribose




D-Arabinose

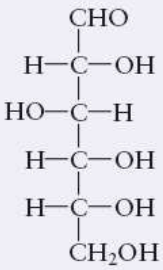



D-Ribulose

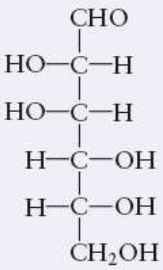



Hexoses

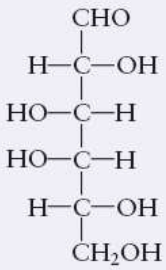
D-Glucose



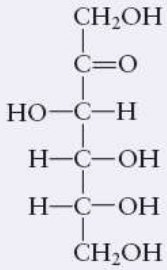

D-Mannose



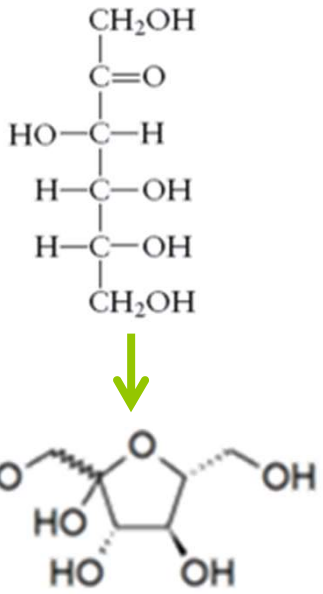

D-Galactose




D-Fructose

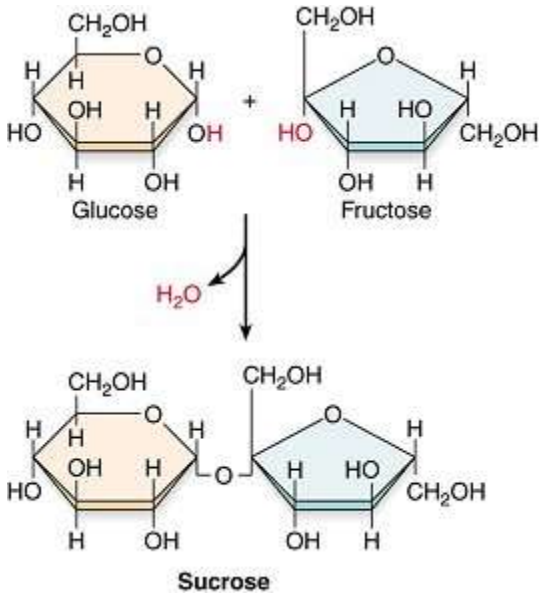



D-frutose




**Note:** Many monosaccharides are more stable in ring structures.

# Biochemistry




**Glycoside Linkage:** Carbon-Oxygen-Carbon linkage that join rings together.

**Disaccharide:** A carbohydrate formed from to monosaccharides.

# Take Away From Chapter 21

**Big Idea:** The large number of hydrocarbons arise from the ability of carbon atoms to form long chains and rings with one another. The properties of hydrocarbons are dominated by the functional groups present. Functional group's properties are independent of their bonding environment.

- **Simple Organic Molecules**
  - Know how to draw fisher projections (3D representations of 2D) and skeletal formula (line structures) or organic compounds.
  - Know how to name branching alkanes, alkene, and alkynes. (9,11,13,14)
  - Know how to name cyclic hydrocarbons (12,15)
  - Know fundamental properties of organic molecules (7,132)
    - Cyclic hydrocarbon rings
      - 5 and 6 member rings are commonly found.
      - 5 membered rings are flat while 6 membered rings exist in the chair or boat configuration.
  - Know how to name aromatic compounds (benzene and toluene)(16)

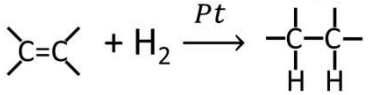
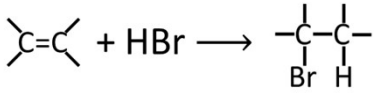
Numbers correspond to end of chapter questions.

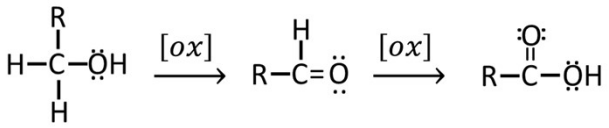
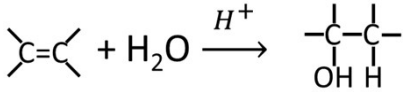
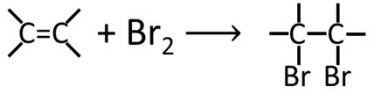
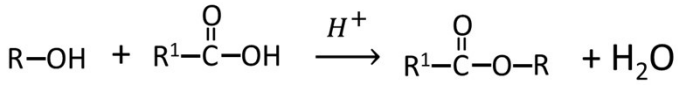
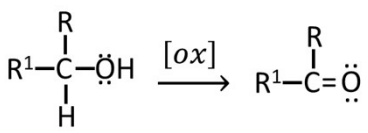
# Take Away From Chapter 21

- **Isomers** (27,28,30)
  - Be able to determine the number of structural isomers for a given chemical formula. (5,8,29)
  - Be able determine if geometric isomers exist. (21,25,26)
    - Double bond or ring structure.
    - 2 different substituents on both atoms of interest.
  - Be able to determine if a compound has an optical isomer (106,112,113,114,116)
    - 4 different groups bonded to a carbon.
- **Functional Groups** (39,40)
  - Be able to recognize and name the following functional groups (37,38,43,44,45,46,49)
    - Alcohol (OH), Carboxylic acid (COOH), Aldehyde(COH), Ketone (CO), Ester (COO), Amine (contain N),Amides (double bonded O next to N, do not need to name) and Ether (COC)

Numbers correspond to end of chapter questions.

# Take Away From Chapter 21

- **Functional Groups**
  - Know fundamental properties of the functional groups. (40)
    - Which functional group is most soluble in water, polar, etc.
  - Be able to recognize primary, secondary and tertiary alcohols and amines. (41,42)
- **Organic Reactions** (56,61,65)
  - Know the following reactions
    - 
    - 
    - 

      this reaction can continue until all H are replaced by Cl
    - 
    - 
    - 
    - 
    - 

Numbers correspond to end of chapter questions.

# Take Away From Chapter 21

- **Polymers** (69)
  - Know the difference between addition polymers and condensation polymers.
  - Be able to determine the structure of the polymer based on the monomers and the monomer based on the structure of the polymer. (72,75,76,77,84)
- **Biochemistry**
  - Know the basic properties of proteins (89,99)
    - Types of structure (primary, secondary, tertiary)(88)
    - Know how to draw the structure of peptides (95,96)
  - Know the basic properties of DNA and RNA (117,119)
  - Know the basic properties of carbohydrates (111)

Numbers correspond to end of chapter questions.