

## Organic Molecules Functional Groups

Dr. Ron Rusay

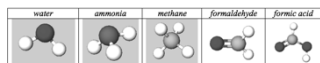
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## Elemental building blocks for all organic molecules

Los Alamos National Laboratory Chemistry Division

Periodic Table of the Elements

## Organic Molecules

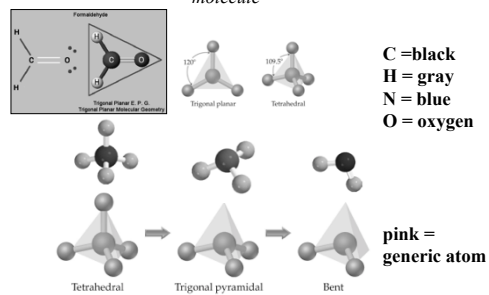


Shapes, Functions & Structural Analogies  
Water, Ammonia, Methane

Plus  $>C=O$  units

## Molecular Models for C, H, N, O

Fundamental repeating shapes found in every biological molecule



## Representing Organic Molecules

Representing Substances

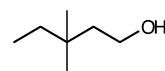
<http://chemconnections.org/general/movies/Representations.MOV>

## Representing Organic Molecules Common Formulas & Drawings

Molecular formula:  $C_7H_{16}O$  Empirical Formula:  $C_7H_{16}O$

Condensed Structure:  $CH_3CH_2C(CH_3)_2CH_2CH_2OH$  or  $CH_3CH_2C(CH_3)_2CH_2CH_2OH$

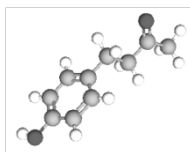
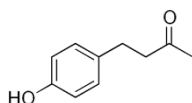
Bond-Line Structure:



## QUESTION

A compound that smells like fresh raspberries, the following structure,  $C_7H_7O_2$ , matches its calculated molar mass which is 164 g/mol.

- A) TRUE  
B) FALSE



## Organic Molecules Common Functional Groups

### Name

### General Formula

#### Alcohols

R'- or R-  
represents any  
generic carbon  
atom bonded in  
the functional  
group



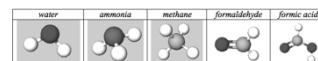
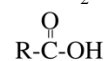
#### Ethers



#### Amines



#### Carboxylic Acids



## Organic Molecules Common Functional Groups

### Name

### General Formula

#### Aldehydes



#### Ketones

R'- or R-  
represents any  
generic carbon  
atom bonded in  
the functional  
group



#### Carboxylic Acids



#### Esters

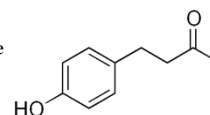


#### Amides



## QUESTION

Select the function(s) in the molecule

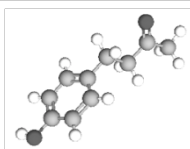


	Alcohol	R-OH
	Ether	R-O-R'
	Amine	R-NH <sub>2</sub>
	Aldehyde	R-C(=O)-H
	Ketone	R-C(=O)-R'
	Carboxylic Acid	R-C(=O)-OH
	Ester	R-C(=O)-OR'
	Amide	R-C(=O)-N(R')R''



## QUESTION

Select the function(s) in the molecule

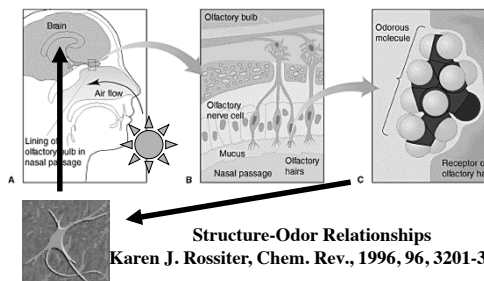


	Alcohol	R-OH
	Ether	R-O-R'
	Amine	R-NH <sub>2</sub>
	Aldehyde	R-C(=O)-H
	Ketone	R-C(=O)-R'
	Carboxylic Acid	R-C(=O)-OH
	Ester	R-C(=O)-OR'
	Amide	R-C(=O)-N(R')R''



## Detecting stuff we cannot see: the Sense of Smell Models, Theories & Interactions

<http://chemconnections.org/organic/chem226/Labs/Smell/smell-links.html>



Structure-Odor Relationships  
Karen J. Rossiter, Chem. Rev., 1996, 96, 3201-3240

Floral


Camphor-like

Ethanol

<http://chemconnections.org/organic/chem226/Labs/Smell/ChemComm.html>

[illegible]

Isoamyl acetate, also known as isopentyl acetate, is an ester formed from isoamyl alcohol and acetic acid. It is a colorless liquid that is only slightly soluble in water, but very soluble in most organic solvents. Isoamyl acetate has a strong odor which is also described as similar to both banana and pear.[3] Banana oil may be either pure isoamyl acetate, or flavorings that are mixtures of isoamyl acetate, amyl acetate, and other flavors.




Methyl salicylate (oil of wintergreen or wintergreen oil) is an organic ester naturally produced by many species of plants, particularly wintergreens. It is also synthetically produced, used as a fragrance, in foods and beverages, and in liniments.

The image displays four chemical representations of salicylic acid and its derivatives:

- Top:** A 2D chemical structure of salicylic acid, showing a benzene ring with an ortho-hydroxyl group and an ortho-acetate group.
- Middle Left:** A ball-and-stick model of salicylic acid, with carbon atoms in grey, oxygen in red, and hydrogen in white.
- Middle Right:** A space-filling model of salicylic acid, showing the relative sizes and spatial arrangement of the atoms.
- Bottom:** A ball-and-stick model of a salicylic acid dimer, formed by two salicylic acid molecules linked via hydrogen bonds, represented by dashed lines.



An extract of the cured, full-grown, unripe fruit of an orchid produces a popular flavoring. The natural extract sells for ~ \$1500/kg versus ~ \$20/kg for the synthetic version. The structure of the compound that is responsible for the smell/flavor is shown to the right. The Guinness Book of World Records once listed this compound as having the lowest smell detection limit of all chemicals ( $2 \times 10^{-11}$  g per 1,000 cm<sup>3</sup> of air).

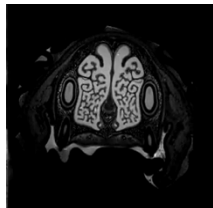


The figure displays the chemical structure and a space-filling model of 4-methoxybenzaldehyde. The chemical structure is shown on the left, featuring a benzene ring with a formyl group ( $\text{CHO}$ ) at the top position, a methoxy group ( $\text{OCH}_3$ ) at the para position (bottom), and a hydroxyl group ( $\text{OH}$ ) at the bottom position. The space-filling model on the right illustrates the three-dimensional arrangement of the atoms, with carbon atoms in grey, oxygen in red, hydrogen in white, and the formyl group in black.

The space (volume) of the Oakland Coliseum Arena, aka Oracle Arena, is approximately 90,000,000 ft<sup>3</sup>. If 1.00g of the compound were released at center court, and was completely and evenly dispersed throughout the building, would you smell it sitting in sec. 204, row H, seat 121? Show your calculation. (1 ft<sup>3</sup> = 0.0283 m<sup>3</sup>)

[https://www.youtube.com/watch?v=58U52IDTuvk&list=PLgawtcOBBjr9I-ND0UX-HmTQr\\_VN465G2&index=3](https://www.youtube.com/watch?v=58U52IDTuvk&list=PLgawtcOBBjr9I-ND0UX-HmTQr_VN465G2&index=3)

Inside the extraordinary nose of a search-and-rescue dog



<https://www.youtube.com/watch?v=FLH36ML8IEU>

Dogs Can Smell Cancer - Secret Life of Dogs - BBC



[https://www.youtube.com/watch?v=e0UK6kkS0\\_M](https://www.youtube.com/watch?v=e0UK6kkS0_M)

Turkey with Brown Sugar Glaze



### **Smell & memory:**

*Triggering Remembrances*

*Marcel Proust: À la recherche du temps perdu*

*In Search of Lost Time*

*aka*

*Remembrance of Things Past*

## **Functional Groups Continued:**

*Amino acids (Handout)*

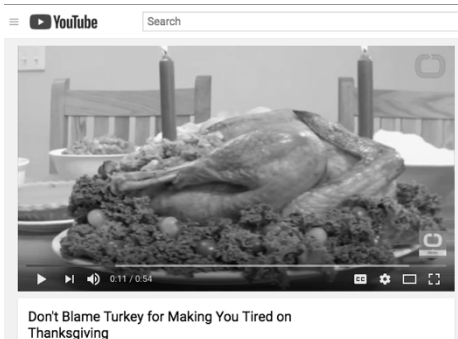
*Proteins-Enzymes*

*Carbohydrates*

*(sugars)*

*Synthesis of Aspirin*

<https://www.youtube.com/watch?v=geQnPq09IJY>

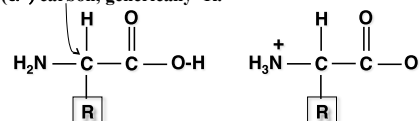


Don't Blame Turkey for Making You Tired on Thanksgiving

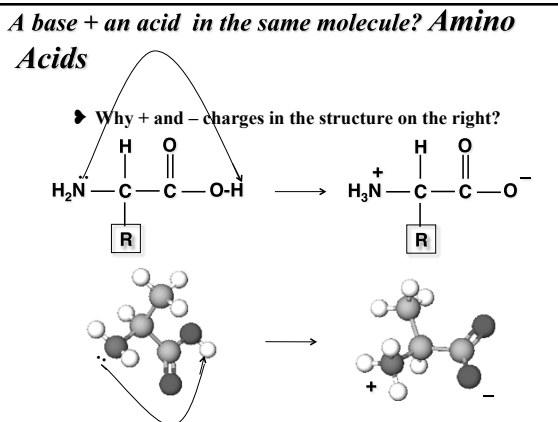
*A base + an acid in the same molecule?*

### **Amino Acids**

- ▶ More than 700 amino acids occur naturally, but 20 of them are particularly important.
- ▶ These 20 amino acids are the building blocks of proteins in humans and other organisms
- ▶ They differ in respect to the group attached to the alpha ( $\alpha$ -) carbon, generically -R.



- ▶ Why + and - charges in the structure on the right?



### Amino Acids

[https://chem.libretexts.org/LibreTexts/Diablo\\_Valley\\_College/DVC\\_Chem\\_106%3A\\_Rusay/Amino\\_Acids](https://chem.libretexts.org/LibreTexts/Diablo_Valley_College/DVC_Chem_106%3A_Rusay/Amino_Acids)

•Our bodies can synthesize about 10 amino acids.  
•“Essential” amino acids are the other 10 amino acids, which have to be ingested in our diet.

20 Amino Acids found in Proteins of Living Organisms

[https://chem.libretexts.org/LibreTexts/Diablo\\_Valley\\_College/DVC\\_Chem\\_106%3A\\_Rusay/Amino\\_Acids](https://chem.libretexts.org/LibreTexts/Diablo_Valley_College/DVC_Chem_106%3A_Rusay/Amino_Acids)

Name	I	R	R'	Essential Color	Function & Class
Alanine	Ala	A	H	CH <sub>3</sub>	Aliphatic, Hydrophilic
Arginine	Arg	R	H	<chem>CH2CH2NHC(=NH)NH2</chem>	Basic, Hydrophilic
Asparagine	Asn	N	H	<chem>CH2CONH2</chem>	Amide, Highly Hydrophilic
Aspartate	Asp	D	H	<chem>CH2COO-</chem>	Acidic, Hydrophilic
Cysteine	Cys	C	H	<chem>CH2SH</chem>	Sulfur-Containing, Hydrophilic
Glutamine	Gln	Q	H	<chem>CH2CH2CONH2</chem>	Amide, Highly Hydrophilic
Glutamate	Glu	E	H	<chem>CH2CH2COO-</chem>	Acidic, Hydrophilic

**Amino acids: two functions, an acid & a base, in the same mol**

Amines:  $R-NH_2$   
Carboxylic Acids:  $R-C(=O)OH$

	Alcohol	$R-OH$
	Ether	$R-O-R'$
X	Amine	$R-NH_2$
	Aldehyde	$R-C(=O)H$
	Ketone	$R-C(=O)R'$
X	Carboxylic Acid	$R-C(=O)OH$
	Ester	$R-C(=O)OR'$
	Amide	$R-C(=O)NR'$

### Amino Acids

**“Legos” of Chemical Biology**

All amino acids contain C, H, O, and N; two, C & M also have sulfur.

[http://chem.libretexts.org/LibreTexts/Diablo\\_Valley\\_College/DVC\\_Chem\\_106%3A\\_Rusay/Amino\\_Acids](http://chem.libretexts.org/LibreTexts/Diablo_Valley_College/DVC_Chem_106%3A_Rusay/Amino_Acids)

### 20 Amino Acids of Life

chiral: mirror images

Amino Acids:

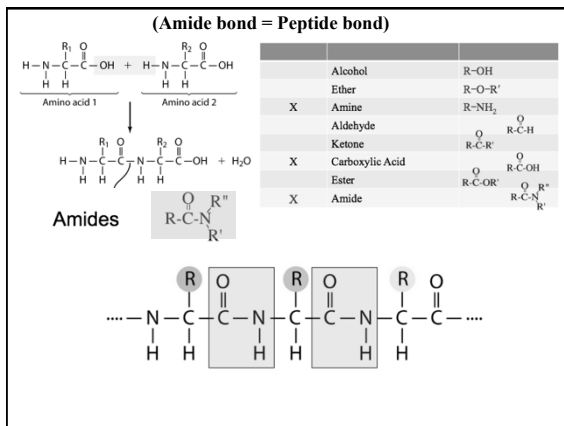
Name	I	R	R'	Essential Color	Function & Class
Methionine	Met	M	H	<chem>CH2CH2CH2SCH3</chem>	Aliphatic, Hydrophilic
Alanine	Ala	A	H	<chem>CH3</chem>	Aliphatic, Hydrophilic
Asparagine	Asn	N	H	<chem>CH2CONH2</chem>	Amide, Highly Hydrophilic
Aspartate	Asp	D	H	<chem>CH2COO-</chem>	Acidic, Hydrophilic
Cysteine	Cys	C	H	<chem>CH2SH</chem>	Sulfur-Containing, Hydrophilic
Glutamine	Gln	Q	H	<chem>CH2CH2CONH2</chem>	Amide, Highly Hydrophilic
Glutamate	Glu	E	H	<chem>CH2CH2COO-</chem>	Acidic, Hydrophilic
Glycine	Gly	G	H	<chem>H</chem>	Aliphatic, Hydrophilic
Histidine	His	H	H	<chem>CH2-4-imidazolyl</chem>	Basic, Hydrophilic
Isoleucine	Ile	I	H	<chem>CH(CH3)CH2CH3</chem>	Aliphatic, Hydrophilic

Leucine:  $CH_2CH(CH_3)CH_2CH_3$ , green, Aliphatic, Hydrophilic  
Lysine:  $CH_2CH_2CH_2CH_2NH_2$ , blue, Basic, Hydrophilic  
Methionine:  $CH_2CH_2CH_2SCH_3$ , yellow, Sulfur-Containing, Hydrophilic  
Phenylalanine:  $CH_2CH_2Ph$ , red, Aromatic, Hydrophilic  
Proline:  $CH_2CH_2N$ , red, Aliphatic, Hydrophilic  
Serine:  $CH_2CH_2OH$ , orange, Hydrophilic, Hydrophilic  
Threonine:  $CH(CH_3)CH_2OH$ , orange, Hydrophilic, Hydrophilic  
Tryptophan:  $CH_2CH_2Ind$ , pink, Aromatic, Hydrophilic  
Tyrosine:  $CH_2CH_2Ph$ , red, Aromatic, Hydrophilic  
Valine:  $CH(CH_3)CH_2CH_3$ , green, Aliphatic, Hydrophilic

**Amino acids: two functions, an acid & a base, in the same molecule**

Amines:  $R-NH_2$   
Carboxylic Acids:  $R-C(=O)OH$

Functions		
	Alcohol	$R-OH$
	Ether	$R-O-R'$
X	Amine	$R-NH_2$
	Aldehyde	$R-C(=O)H$
	Ketone	$R-C(=O)R'$
X	Carboxylic Acid	$R-C(=O)OH$
	Ester	$R-C(=O)OR'$
	Amide	$R-C(=O)NR'$



## Chemical Biology


### Reactions/Catalysts

### Globular Proteins / Enzymes

### Metabolism

Turkey with Brown-Sugar Glaze

★★★★☆ 1120



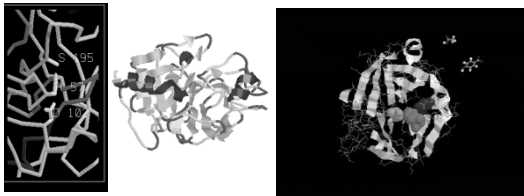
### Digestion

#### Globular Proteins / Enzymes

*Trypsin / α-Galactosidase / Invertase / Sucrase*

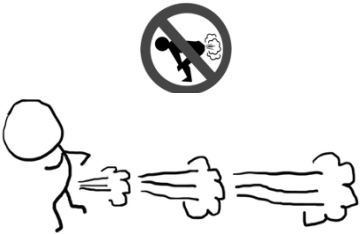
### Digestion

#### Trypsin Enzyme: Catalyzes Hydrolysis



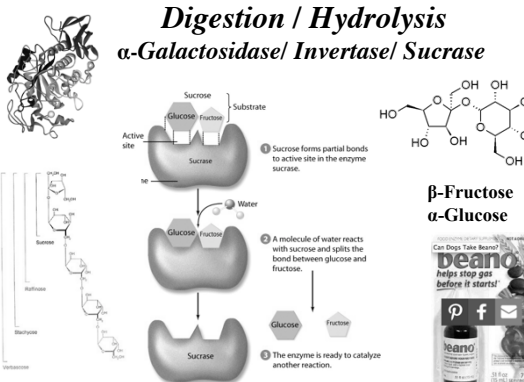
Trypsin, which catalyzes the digestion of proteins through hydrolysis, works in a similar way to acetylcholinesterase, but in breaking down other proteins instead of small molecules, acetylcholine - choline.

### Biprodut of Digestion



### Digestion / Hydrolysis

#### α-Galactosidase/ Invertase/ Sucrase



① Sucrose forms partial bonds to active site in the enzyme sucrase.

② A molecule of water reacts with sucrose and splits the bond between glucose and fructose.

③ The enzyme is ready to catalyze another reaction.

β-Fructose  
α-Glucose

Can Dogs Taste Beano?  
Helps stop gas before it starts!

Beano

## Organic Molecules Functional Groups *alcohols, ethers, aldehydes, ketones* Carbohydrates / Saccharides / Sugars

Name: \_\_\_\_\_

### Sugar Wordsearch

**Terry L. Heller**

Department of Chemistry, SUNY College at Oswego, Oswego, NY 13020-4015; [heller@oswego.edu](mailto:heller@oswego.edu)

This puzzle contains 29 names, terms, prefixes, and acronyms that describe sugars and their polymers. Find and highlight these words in the matrix below. "CARBOHYDRATE" is already done for you. Then, carefully transfer them to the blanks in the description below the matrix. Use the letters remaining in the matrix to complete the sentence describing these molecules. Your scores will be recorded. The answers to the Sugar Wordsearch are listed below. Good hunting!

N I E T O R P O C Y L G S U  
N I T I H C G L U C O S E G  
K E T O S E S S E S O D L A  
E A C H E X O S E I P E R  
S L S E S O I R A V S S  
O U Y T M P A M A M K R O N  
T G A R B O H Y D R A T E  
C A O R E N C L I F R C G  
A R L C C O E Y S W O U O  
L N I H A S E L P M I S R C  
A A P S E R E M O N A E F Y  
O N I C U D E R E T S E L  
E D D C E L L U L O S E T G

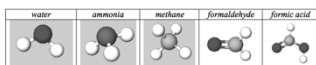
CARBOHYDRATE can be S....., A....., or K....., and an aldohexose S....., a ketohexose S....., or a D....., is a D..... of the R....., A....., and G..... in cyclic form, respectively L....., D....., and F....., in glucose linked to G...... Phosphoric acid is the....., which contains A..... and A...... The amino sugar is G....., and the only....., is in the alpha..... of glucose. Beta-linked glucose or N-acetylglucosamine makes C..... or C....., respectively. Both are structural polymers. Complex molecules like G....., and P....., have sugars attached. Finally, phospholipids....., which link R....., with in the backbone of....., converting the protein into the lipid form produces a..... strand.

Use the remaining letters to fill in the following sentence: \_\_\_\_\_

Wordsearch Due Next Week

### Sugars (Carbohydrates) Common Functional Groups

<u>Name</u>	<u>General Formula</u>
Alcohols	R-OH
Ethers	R-O-R'
Amines	R-NH <sub>2</sub>
Carboxylic Acids	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} \end{array}$



### Sugars (Carbohydrates) Common Functional Groups

<u>Name</u>	<u>General Formula</u>
Aldehydes	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{H} \end{array}$
Ketones	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{R}' \end{array}$
Carboxylic Acids	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} \end{array}$
Esters	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OR}' \end{array}$
Amides	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{N}^{\text{R}''}_{\text{R}'} \end{array}$

### Carbohydrate (-ose) Formation

- The chemical reaction of light, chlorophyll and two greenhouse gases, which also provide oxygen:



- Empirical formula = CH<sub>2</sub>O

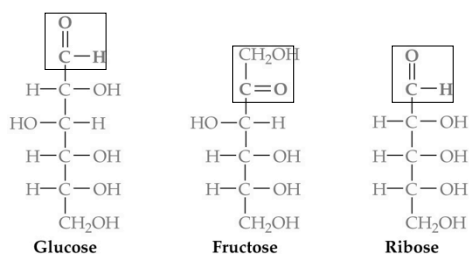
- Monosaccharides (simple sugars)

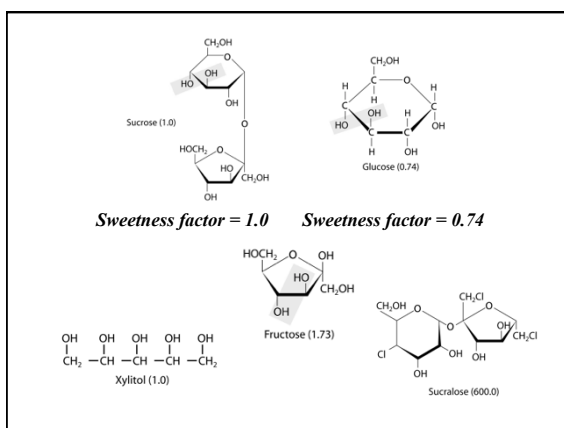
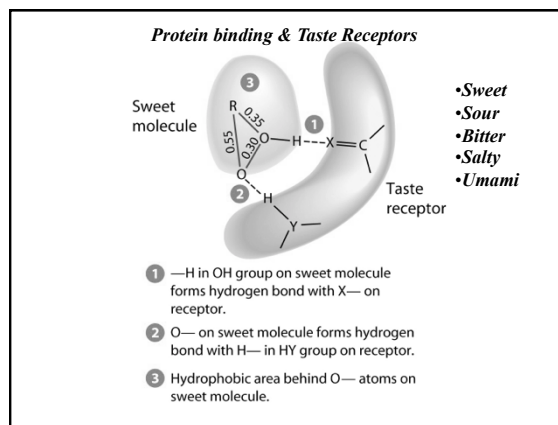
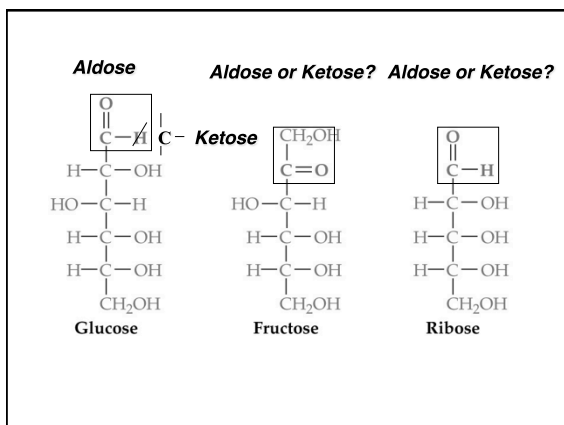
- C<sub>5</sub>: pentoses – *rib-ose*

- C<sub>6</sub>: hexoses – *fruct-ose, gluc-ose*

- Can be either an ald-ose (aldehyde + alcohols) or ket-ose (ketone + alcohols)

#### Aldose





**Relative Sweetness Scale - Sucrose = 1**

Compound	Rating
Saccharin	300 X
Cyclamate	30 X
Aspartame	180 X
Acesulfame	200 X
Sucralose	600 X

Sucralose (600.0)

