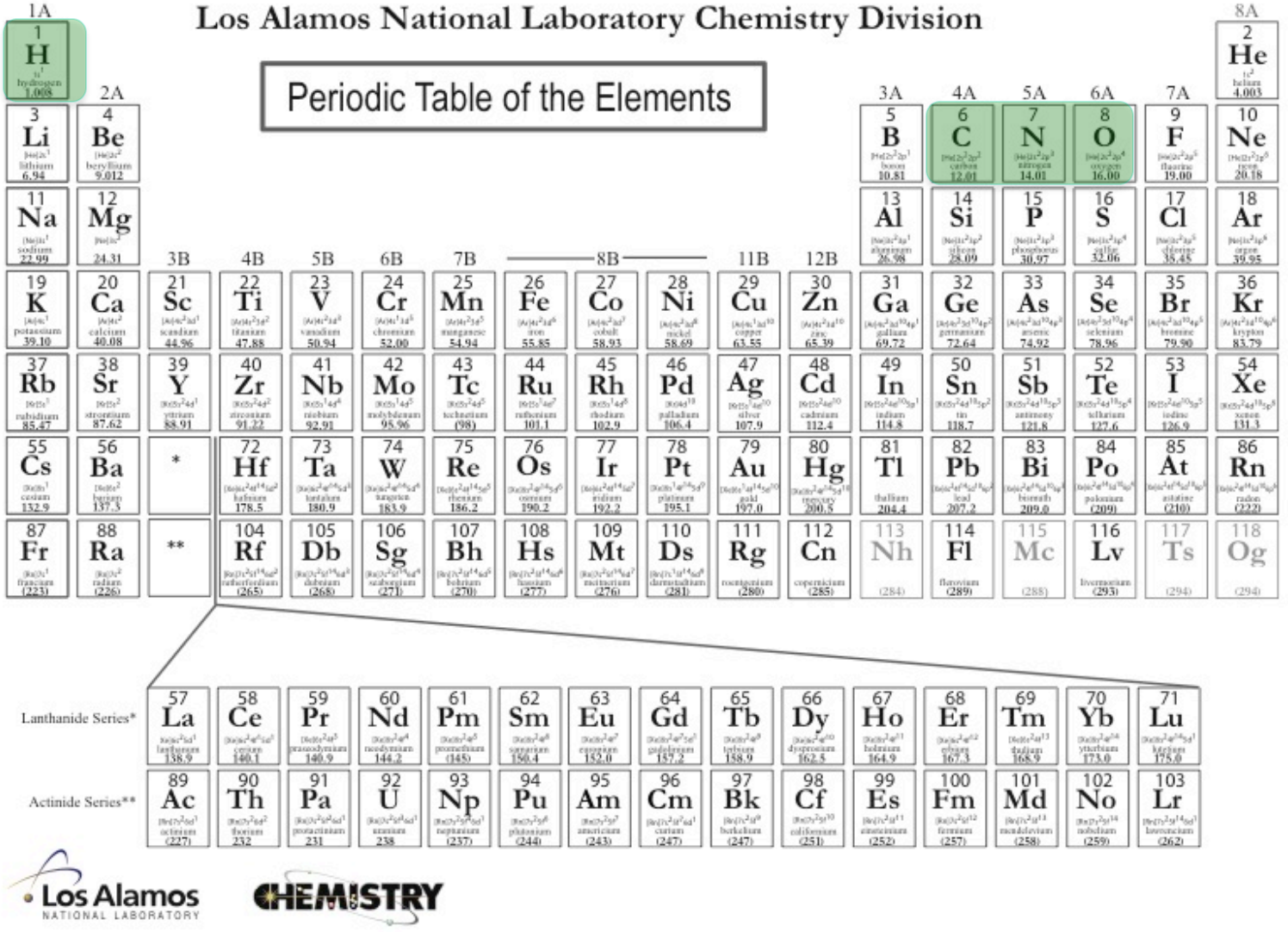
Organic Molecules
Functional Group Overview

Dr. Ron Rusay

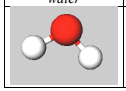
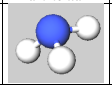
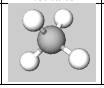
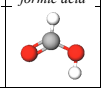
Elemental building blocks for all organic molecules



Functional Groups & Amino Acids

Organic Molecules & Functional Groups

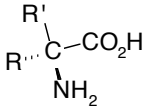
The following simple molecules: water, ammonia, methane, formaldehyde and formic acid can be used as "lego-like" building blocks to construct the vast majority of organic and biological molecules. Simply replace a hydrogen from each of any two molecules with a bond to the central atom, and if joining three molecules replace 4 hydrogens with 2 bonds.

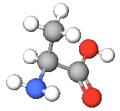
water	*ammonia*	*methane*	*formaldehyde*	*formic acid*
				

Name	**General Formula**
Alcohols	R−OH
Ethers	R−O−R′
Amines	$R-NH_2$
Carboxylic Acids	
Aldehydes	
Ketones	
Carboxylic Acids	
Esters	
Amides	

Chem 108 / Dr. Rusay

20 Amino Acids found in Proteins of Living Organisms

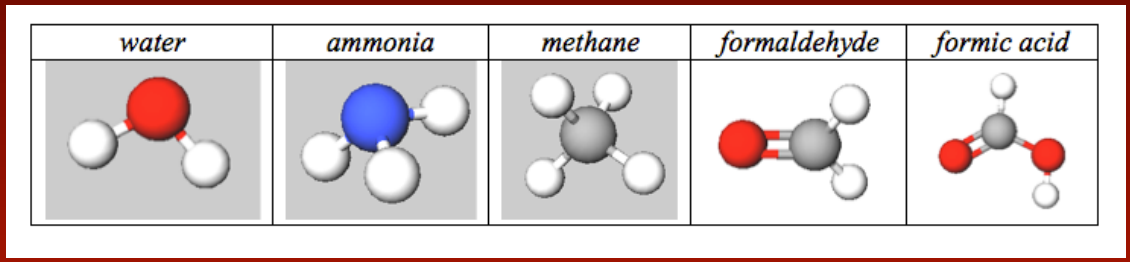




https://chem.libretexts.org/LibreTexts/Diablo_Valley_College/DVC_Chem_106%3A_Rusay/Amino_Acids

Name	I	II	R-	R'-	Rasmol Color	Function & Class
Alanine	Ala	A	H-	CH_3-	dark gray	Aliphatic Hydrophobic
Arginine	Arg	R	H-		blue	Basic Hydrophilic
Asparagine	Asn	N	H-		cyan	Amide Highly Hydrophilic
Aspartate	Asp	D	H-		bright red	Acidic Hydrophilic
Cysteine	Cys	C	H-	$-CH_2SH$	yellow	Sulphur Containing Hydrophobic
Glutamine	Gln	Q	H-		cyan	Amide Highly Hydrophilic
Glutamate	Glu	E	H-		bright red	Acidic Hydrophilic
Glycine	Gly	G	H-	H-	light gray	Aliphatic Hydrophobic
Histidine	His	H	H-		pale blue	Basic Hydrophilic
Isoleucine	Ile	I	H-		green	Aliphatic Hydrophobic
Leucine	Leu	L	H-		green	Aliphatic Hydrophobic

Organic Molecules



Shapes, Functions & Structural Analogies

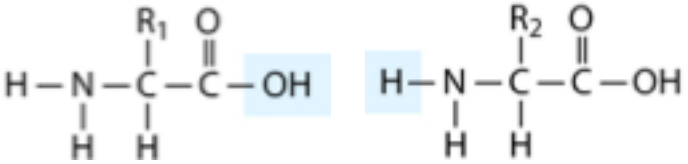
Water, Ammonia, Methane

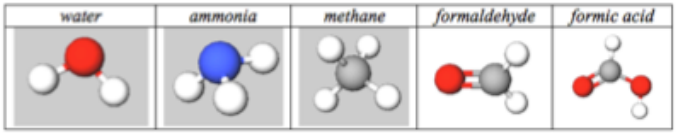
Plus  C=O “carbonyls”

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

Amines $R-NH_2$

Carboxylic Acids $R\text{-}C(=O)\text{-}OH$



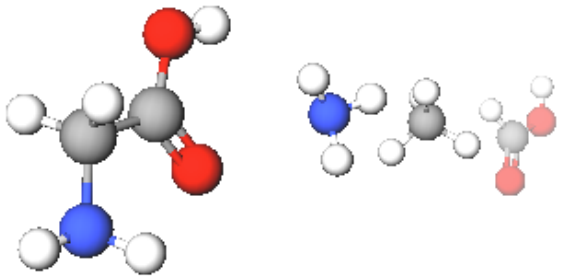


	Functions	
	Alcohol	$R-OH$
	Ether	$R-O-R'$
X	Amine	$R-NH_2$
	Aldehyde	$R\text{-}C(=O)\text{-}H$
	Ketone	$R\text{-}C(=O)\text{-}R'$
X	Carboxylic Acid	$R\text{-}C(=O)\text{-}OH$
	Ester	$R\text{-}C(=O)\text{-}OR'$
	Amide	$R\text{-}C(=O)\text{-}N(R'')R'$

https://www.youtube.com/watch?v=JQZQiEdOPJY

Amino Acids
Legos of Chemical Biology

Amino acids containing carbon, hydrogen, oxygen, and nitrogen, which resemble the following shapes & structural components



- **20 different amino acids are encoded in humans' genetic code, which is archived in DNA.**

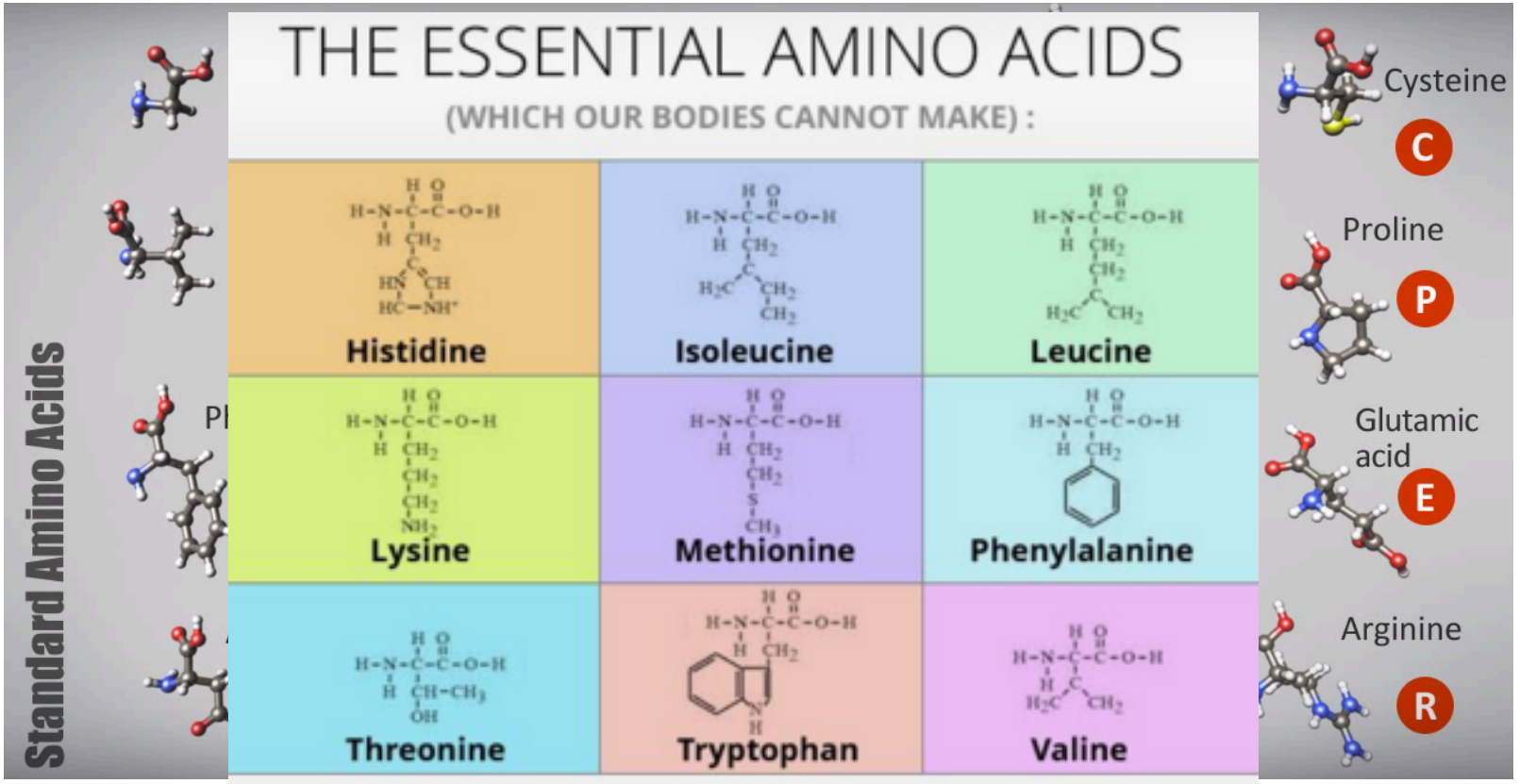
- **Hundreds of amino acids link together with amide (peptide) bonds to form proteins, which provide the machinery and molecular structures for the chemistry of life.**

- **There are less than 20,000 total proteins produced from humans' entire genome, each coded by a specific gene in DNA's ~3 billion genetic bases.**

http://chem.libretexts.org/LibreTexts/Diablo_Valley_College/DVC_Chem_106%3A_Rusay/Amino_Acids

Amino Acids
Legos of Chemical Biology

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



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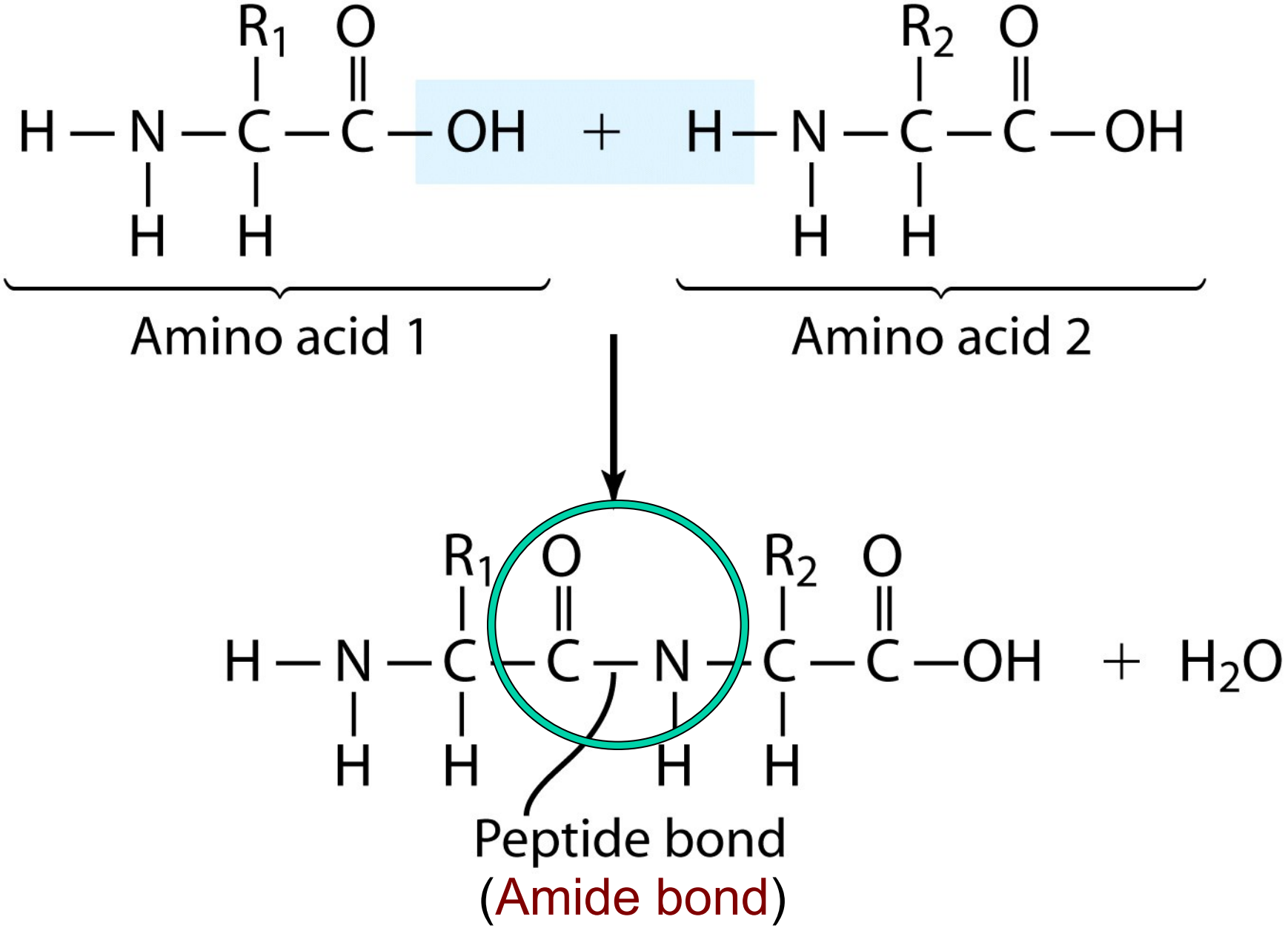
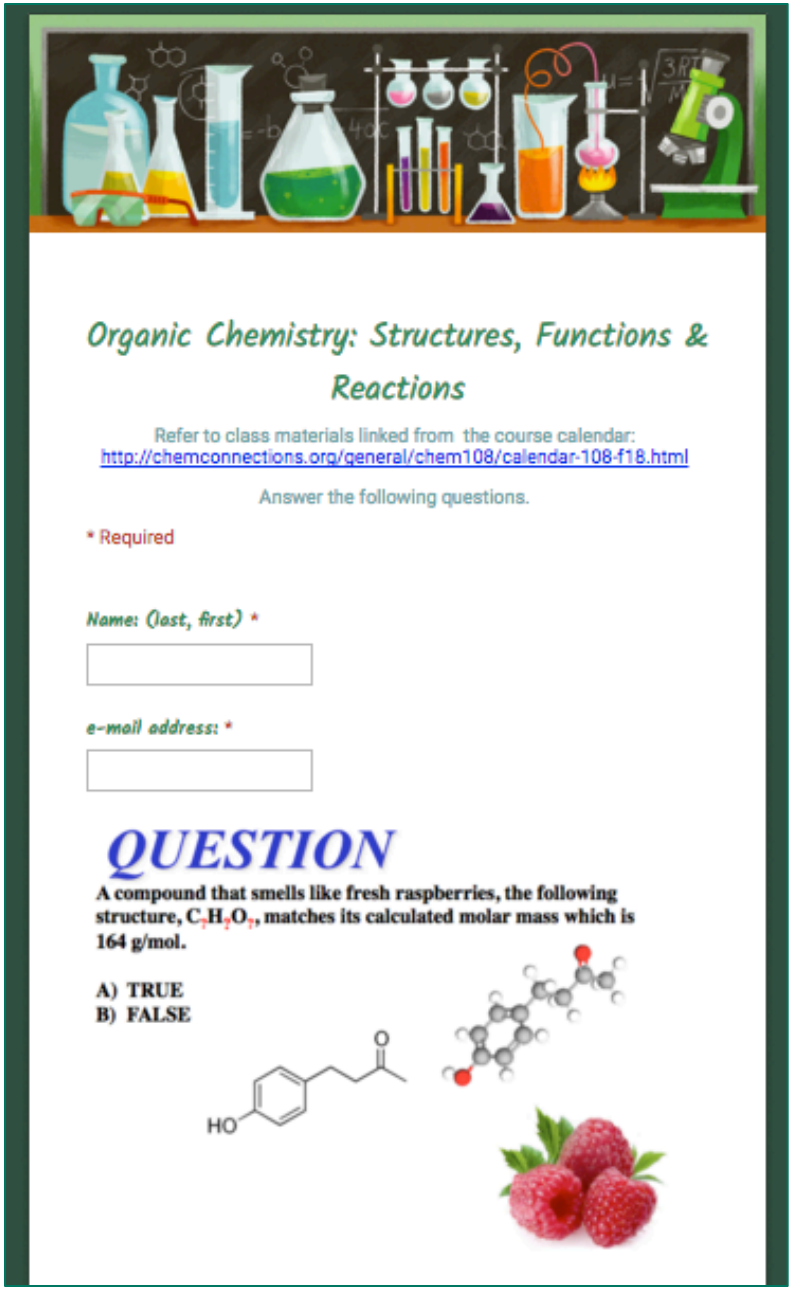

Amino acid 1
Amino acid 2
Peptide bond
(Amide bond)

http://chemconnections.org/general/chem108/Organic%20Chemistry%20Guide.html



Organic Chemistry: Structures, Functions & Reactions

Refer to class materials linked from the course calendar:
http://chemconnections.org/general/chem108/calendar-108-f18.html

Answer the following questions.

* Required

Name: (last, first) *

e-mail address: *

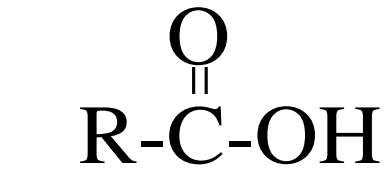
QUESTION

A compound that smells like fresh raspberries, the following structure, $C_7H_7O_7$, matches its calculated molar mass which is 164 g/mol.

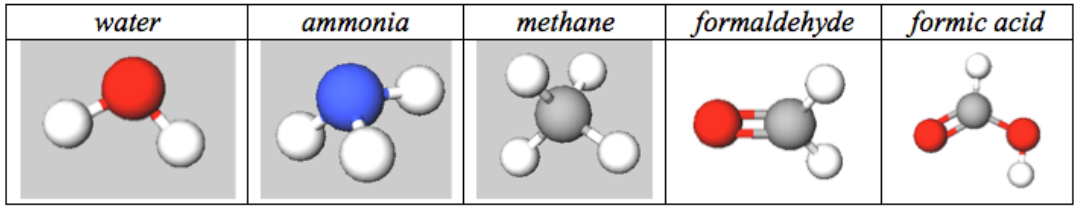
A) TRUE
B) FALSE

Organic Molecules

Common Functional Groups

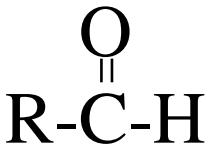
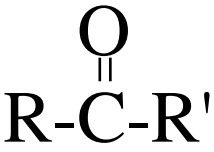
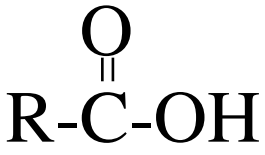
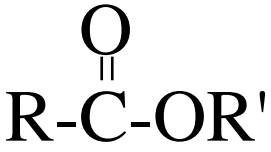
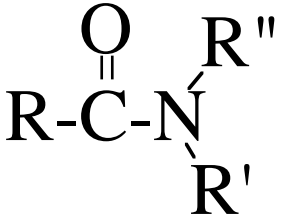
Name	General Formula
Alcohols	R−OH
Ethers	R−O−R′
Amines	$R-NH_2$
Carboxylic Acids	

R′− or R− represents any generic carbon atom bonded in the functional group



Organic Molecules

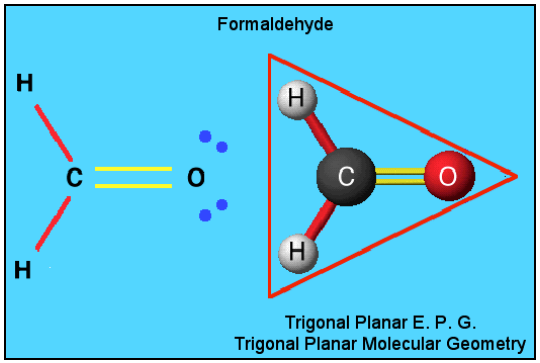
Common Functional Groups

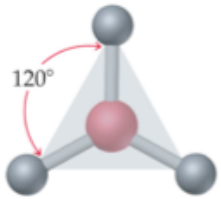
Name	General Formula
Aldehydes	
Ketones	
Carboxylic Acids	
Esters	
Amides	

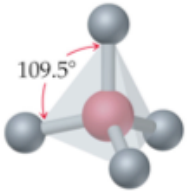
R′− or R− represents any generic carbon atom bonded in the functional group

Molecular Models for C, H, N, O

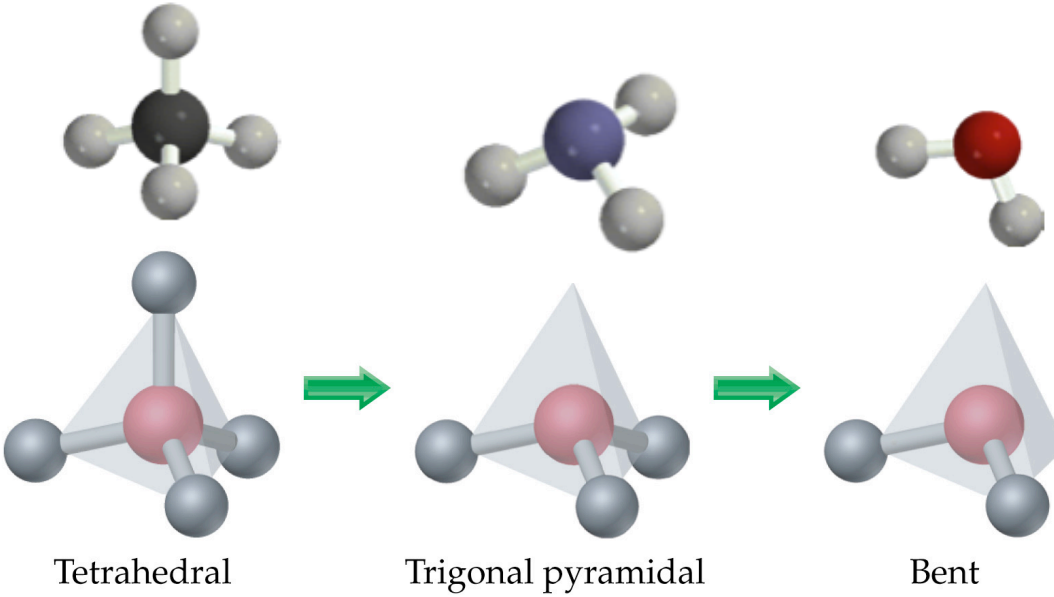
Fundamental repeating shapes found in every biological molecule







C =black
H = gray
N = blue
O = oxygen



pink = generic atom

Representing Organic Molecules

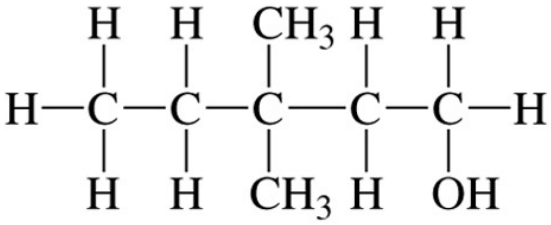
http://chemconnections.org/general/movies/Representations.MOV

Representing Organic Molecules

Common Formulas & Drawings

Molecular formula: $C_7H_{16}O$

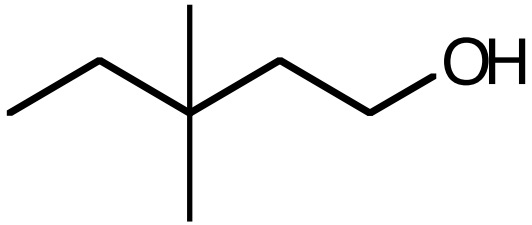
Empirical Formula: $C_7H_{16}O$



Condensed Structure:

$CH_3CH_2C(CH_3)_2CH_2CH_2OH$ or $CH_3CH_2\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{C}}CH_2CH_2OH$

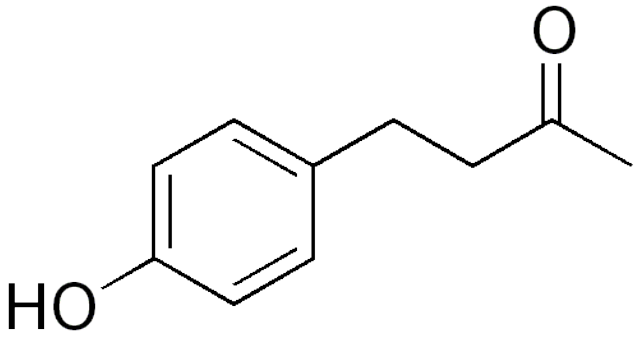
Bond-Line Structure:

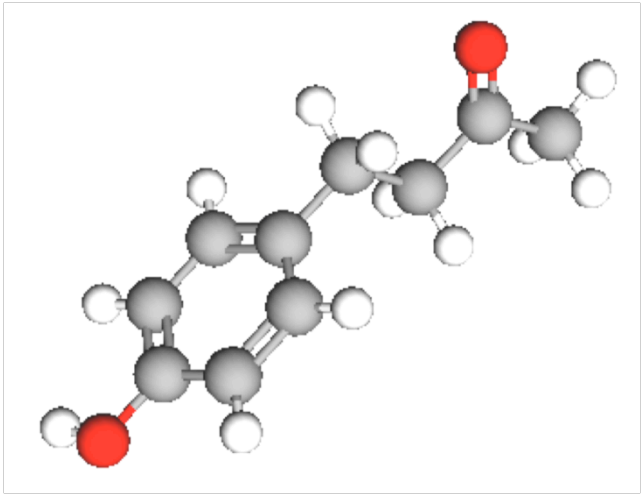


QUESTION

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

A) TRUE
B) FALSE



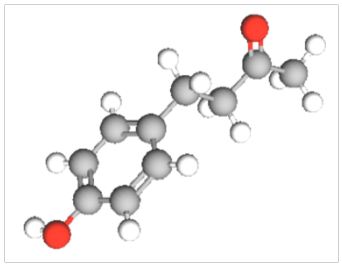


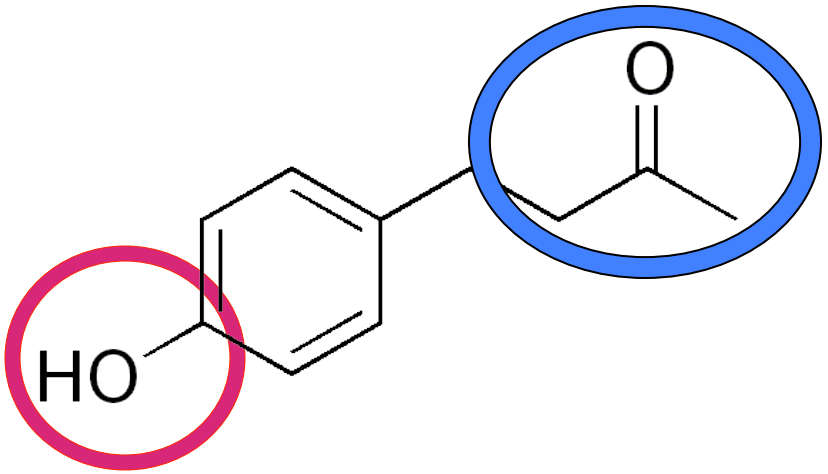
Organic Chemistry: Structures, Functions & Reactions

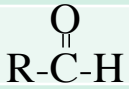
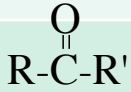
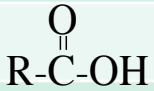
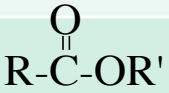
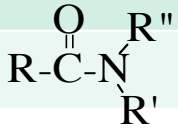
http://chemconnections.org/general/chem108/Organic%20Chemistry%20Guide.html

QUESTION

Select the function(s) in the molecule



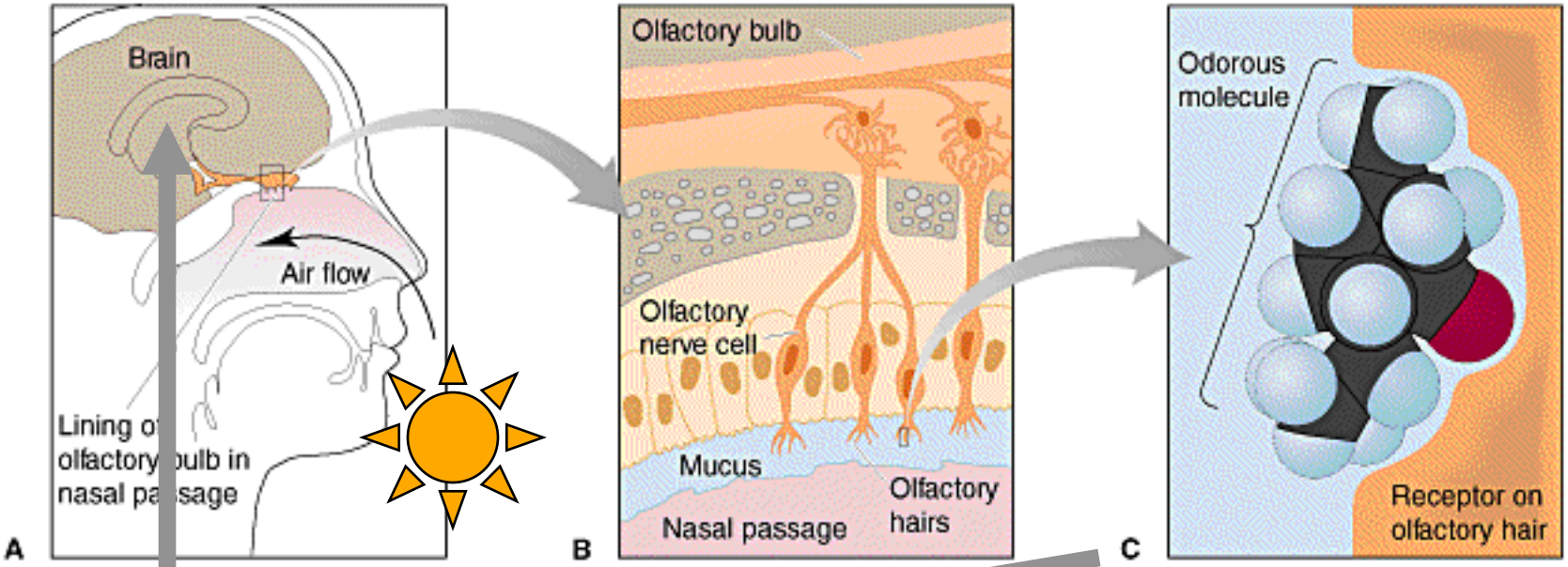


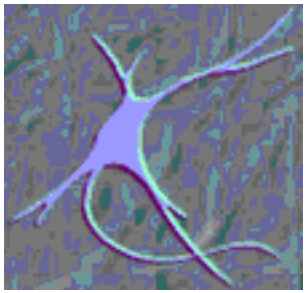
	Alcohol	R−OH
	Ether	R−O−R′
	Amine	$R-NH_2$
	Aldehyde	
	Ketone	
	Carboxylic Acid	
	Ester	
	Amide	

Detecting stuff we cannot see: the Sense of Smell

Models, Theories & Interactions

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

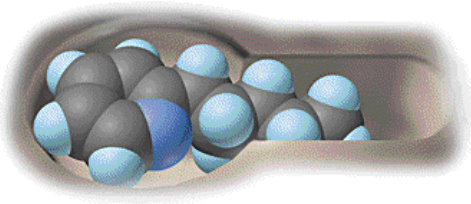




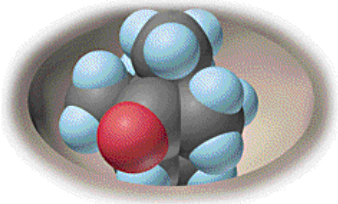
Structure-Odor Relationships

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

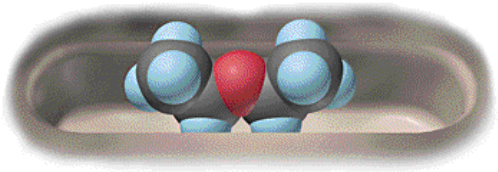
Historical view of a few smell receptors.



Floral



Camphor-like



Ethereal

4 October 2004

The Nobel Assembly at Karolinska Institutet has today decided to award

The Nobel Prize in Physiology or Medicine for 2004

jointly to

Richard Axel and Linda B. Buck

for their discoveries of

"odorant receptors and the organization of the olfactory system"

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

Organic Functions & Smell Receptors.

Organic Chemistry

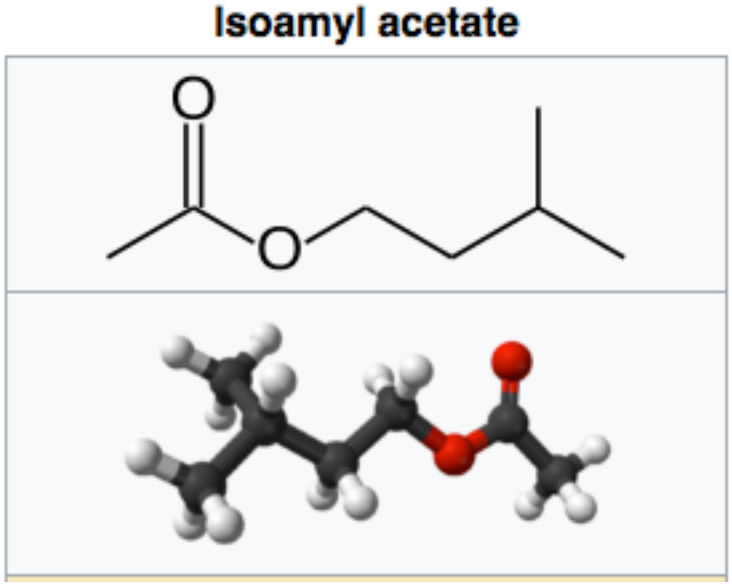
Table of organic compounds and their smells

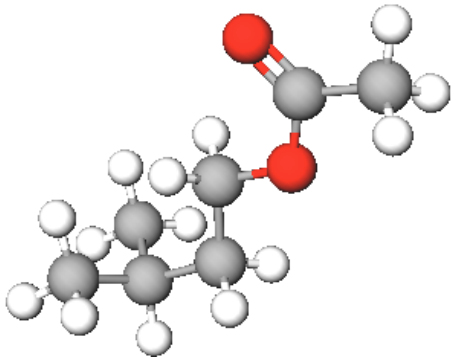
	ALKANES		ALKENES	ALCOHOLS		ALDEHYDES				KETONES		CARBOXYLIC ACIDS		HALOALKANES			THIOLS	AMINES		NITRILES	LACTONES
	-ane	cyclo -ane	-ene	-anol	-an-2-ol	-anal	2-methyl -anal	3-(4-t-butylphenyl) -anal	-enal	-an-2-one	methyl -an-2-one	-anoic acid	-enoic acid	chloro -ane	bromo -ane	iodo -ane	-anethiol	-anamine	diamino -ane	-anenitrile	-anolide
meth- 1 carbon	none	doesn't exist	carbene is too unstable to smell	ABSOLUT VODKA	doesn't exist	DANGER FORMALDEHYDE	doesn't exist	doesn't exist	doesn't exist	doesn't exist	doesn't exist	PUNGENT & PENETRATING	doesn't exist	TOXIC & MILDLY SWEET	LIKE CHLOROFORM	SWEET, ACRID			?		doesn't exist
eth- 2 carbons	none	doesn't exist		ABSOLUT VODKA	doesn't exist	FRUITY, ETHEREAL	doesn't exist	doesn't exist	doesn't exist	doesn't exist	doesn't exist	VINEGAR	doesn't exist	MILDLY SWEET	SWEET, ACRID	ETHEREAL	SKUNK			ETHEREAL	doesn't exist
prop- 3 carbons	none			ABSOLUT VODKA	RUBBING ALCOHOL	IRRITATING GREEN COFFEE	WET CEREAL	ATTRACTS SPERM	BURNED GREASE	NAIL VARNISH REMOVER	doesn't exist	SLIGHTLY RANCID	SHARP	MILDLY SWEET	SWEET	SHARP, UNIQUE				ETHEREAL	none
but- 4 carbons	none				WINE	PUNGENT BANANA		LILY	PUNGENT & SUFFOCATING	BUTTERSCOTCH	LIKE NAIL VARNISH REMOVER	RANCID BUTTER	BROWN SUGAR	SHARP	PLEASANT, SWEET	SHARP, UNIQUE			DEAD ANIMALS	SUFFOCATING	
pent- 5 carbons	STARTING FLUID	PLEASANT		STRONG SWEET	(S)- and (R)- enantiomers	PUNGENT NUTS & CHOCOLATE	FRESHLY CUT GRASS	?		&	MINT (4-methyl-)	DISGUSTING		MILD	PLEASANT, SWEET		ROASTED GARLIC		DEAD ANIMALS & URINE		HERBAL
hex- 6 carbons	STARTING FLUID	SWEET		FRESHLY CUT GRASS		FRESHLY CUT GRASS	FRESHLY CUT GRASS	?		ATTRACTS MICE	(3-methyl-)	GOATS	ARMPITS (WHEN 3-METHYLATED)	AROMATIC	SLIGHTLY SWEET	?	BURNED		ROTTING FISH		&
benzene different naming system is used	n/a	n/a	Benzene	SICKENINGLY SWEET AND TARRY Phenol	doesn't exist			?	doesn't exist	doesn't exist	Acetophenone	BALSAMIC	doesn't exist		AROMATIC			Aniline	TOXIC, AROMATIC	Benzonitrile	doesn't exist
hept- 7 carbons				FRESHLY CUT GRASS	(S)- and (R)- enantiomers	STRONG, FRUITY COGNAC	(2,6-dimethyl-heptanal)	?	ALMOND BUTTER	&	BAD (6-methyl-)	RANCID	ARMPITS (WHEN 3-METHYLATED)	none	SLIGHTLY SWEET	none			&		CARAMEL &
oct- 8 carbons	PETROL			PENETRATING, SWEET	(S)- and (R)- enantiomers	STRONG, CITRUS-LIKE	?	?		-2-one petrol -3-one herb butter	?	&	ARMPITS	none		SEAWEED	STENCH				
non- 9 carbons	DIESEL			CITRUS		ATTRACTS MOSQUITOES		?	OLD PEOPLE	MILK	?	RANCID	ARMPITS	none	none	none	OBNOXIOUS				
dec- 10 carbons	JET FUEL			CITRUS FLOWERS	?	BUCKWHEAT		?	ATORA TALLOW	?	?		ARMPITS	none	none	none	OBNOXIOUS				
undec- 11 carbons	NEW JET FUEL ALSO ANT 'PANIC' PHEROMONE	?		CITRUS FLOWERS	?	MAKES SPERM UNABLE TO FIND THE EGG	KUMQUATS	?	&	ALGERIAN OIL OF RUE	?	WAXY	PUNGENT & PENETRATING	UNIQUE & UNPLEASANT	none	MOUSE PHEROMONE	OBNOXIOUS				&
dodec- 12 carbons		MUSTY		FLOWERS	?		?	?	&	?	?	BAY OIL	FATTY	UNIQUE & UNPLEASANT	none	?	OBNOXIOUS				&
tridec- 13 carbons	STINK BUG PHEROMONE	UNIQUE; FOUND IN ROSES		PLEASANT	?	GRAPEFRUIT PEEL	ROASTED	?	?	WAXY	?		?	UNIQUE & UNPLEASANT	none	?	OBNOXIOUS		none		ANGELICA ROOT
tetradec- 14 carbons	KAPOK BUSH FLOWERS	none			?		?	?	?	?	?	WAX & NUTMEG	?	UNIQUE & UNPLEASANT	none	?	OBNOXIOUS		none		CEDAR WOOD
pentadec- 15 carbons	TAMARIND (ANT-CALMING PHEROMONE)	?		ABSOLUT VODKA	?	FRESH	?	?	CORIANDER	CELERY	?	BIOMARKER FOR DAIRY CONSUMPTION (No smell)	?	UNIQUE & UNPLEASANT	none	?	OBNOXIOUS		none		MUSK

Version 1.2 Produced by James at jameskennedymonash.wordpress.com. Visit website for more infographics. Free to use!

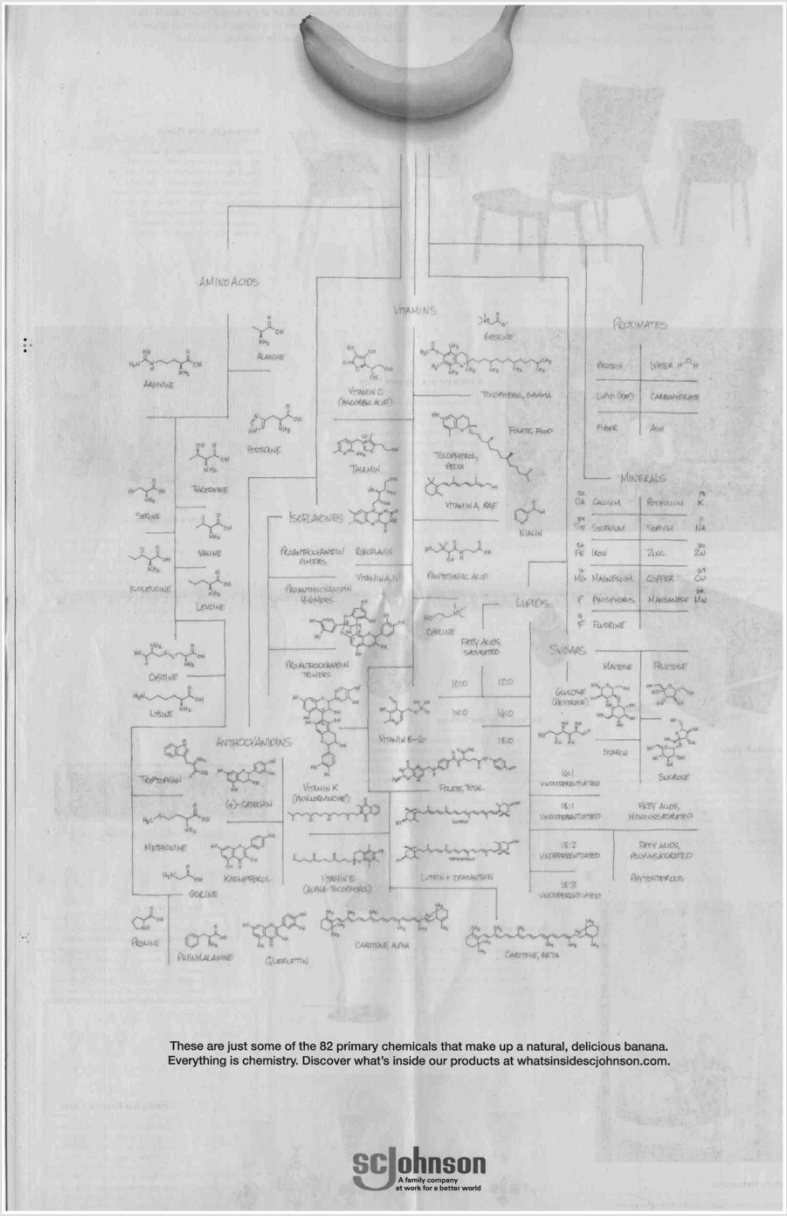
One molecule, one function: One Smell Receptor

Isoamyl acetate, also known as isopentyl acetate, is 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.

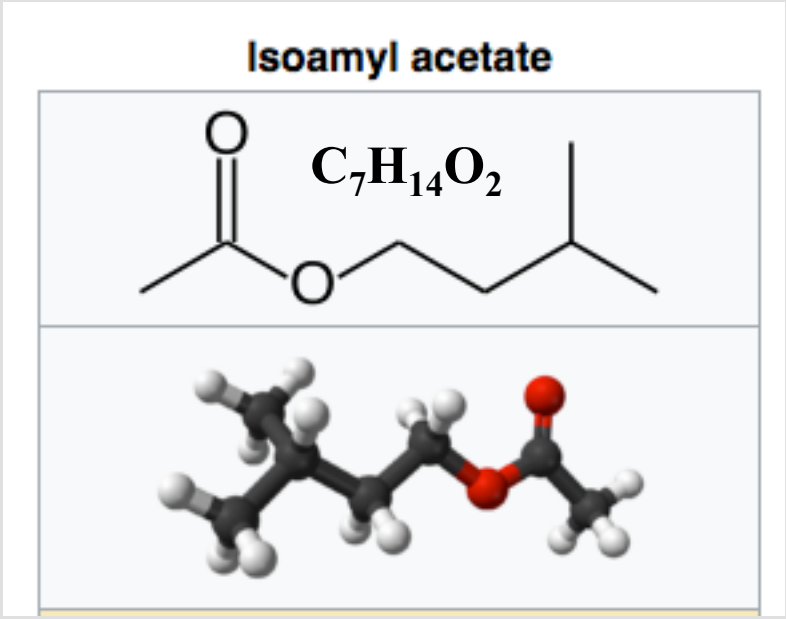




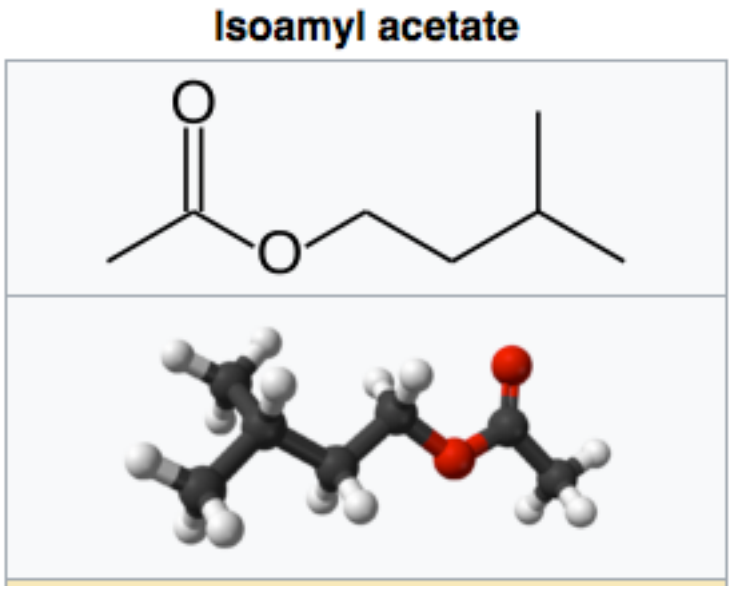
$C_7H_{14}O_2$

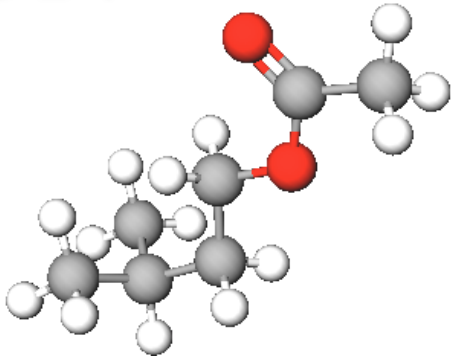


One molecule among 82 primary chemicals found in bananas:



QUESTION





$C_7H_{14}O_2$

The function in isoamyl acetate's structure is a(n):

A.Alcohol

B.Aldehyde

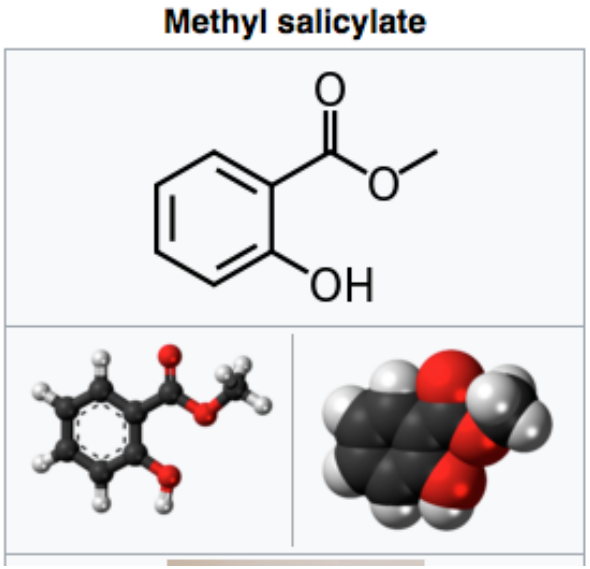
C.Ketone

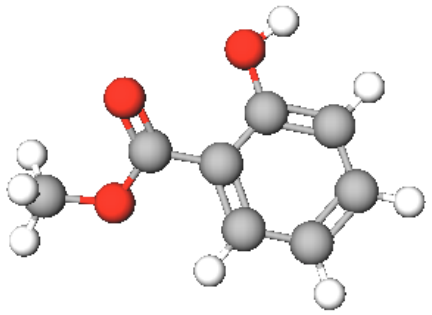
D.Ester

E.Carboxylic Acid

One molecule, two functions: One Smell Receptor

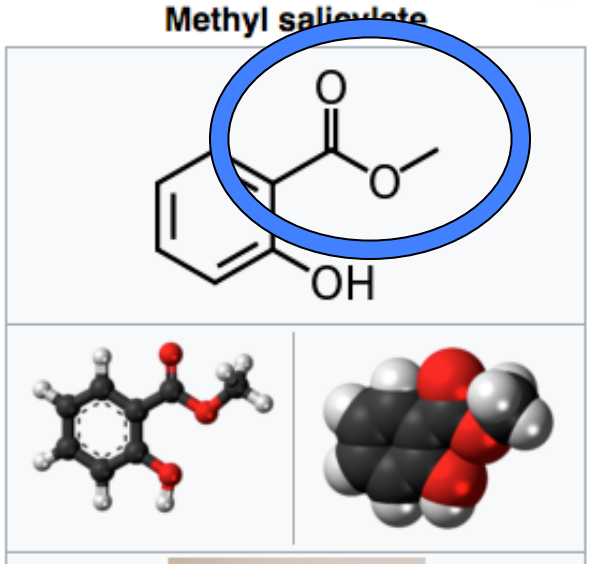
Methyl salicylate (oil of wintergreen or wintergreen oil) is naturally produced by many species of plants, particularly wintergreens. It is also synthetically produced, used as a fragrance, in foods and beverages, and in liniments.

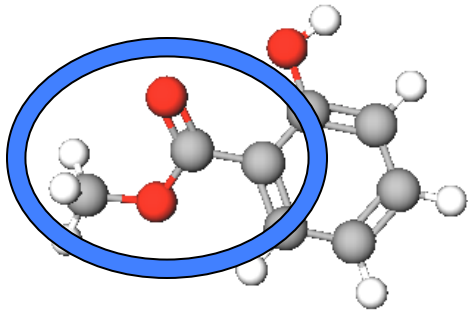




$C_8H_8O_3$

QUESTION





$C_8H_8O_3$

One of the functions, an ester, is circled. What is the other function?:

A.Alcohol

B.Ether

C.Ketone

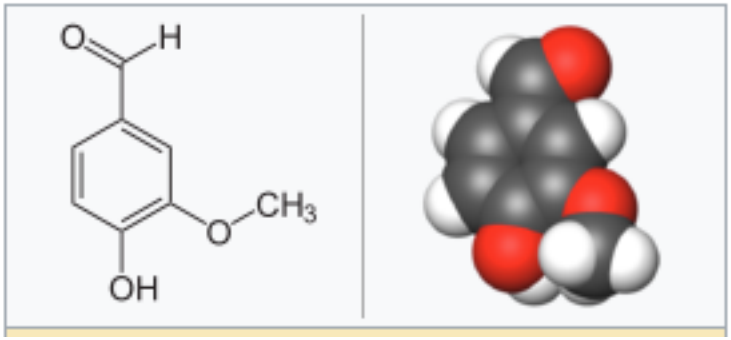
D.Aldehyde

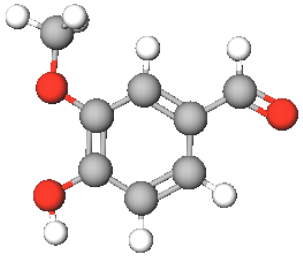
E.Carboxylic Acid

One molecule, three functions: One Smell Receptor

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 (2×10^{-11} g per 1,000 cm^3 of air).

Vanillin

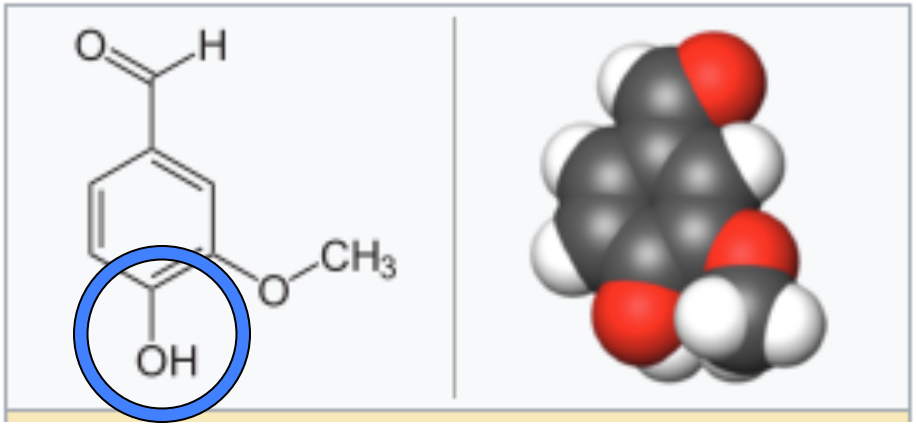


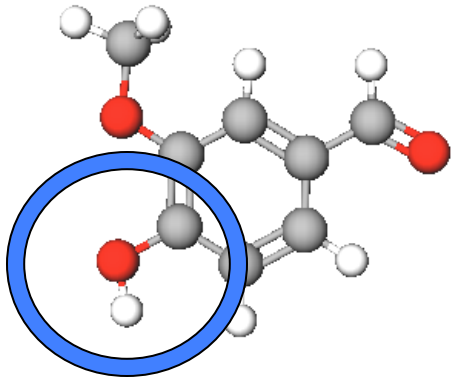


Bonus:
The space (volume) of the Oakland Coliseum Arena, aka Oracle Arena, is approximately 90,000,000 ft^3. If 1.00g of the compound were released at center court, and was completely and evenly dispersed throughout the building, would you smell it sitting in sec. 204, row H, seat 121? Show your calculation.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

QUESTION

Vanillin





One of the functions, an alcohol, is circled.
What are the other two functions?:

A.Aldehyde + Ketone

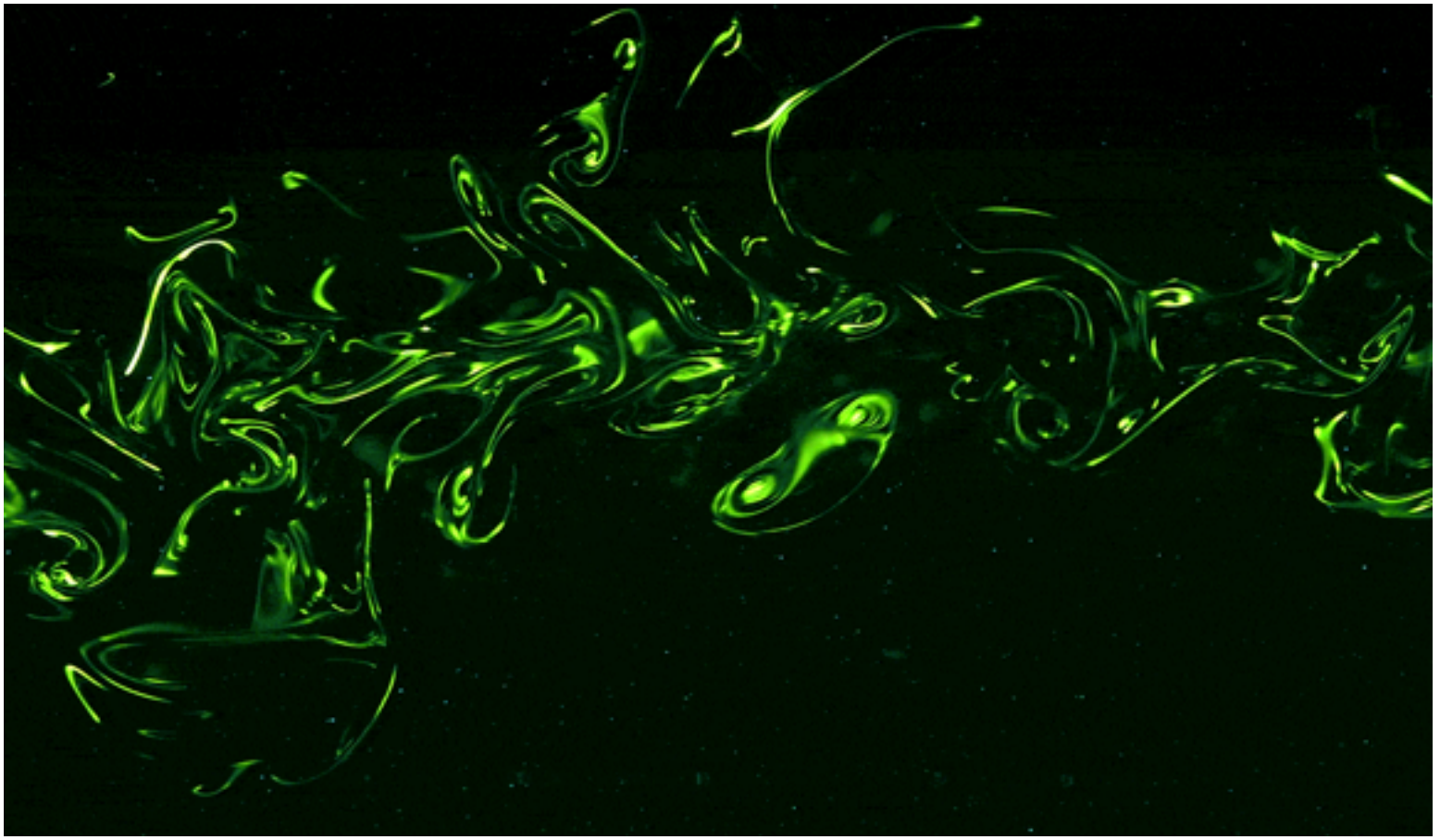
B.Carboxylic Acid + Ester

C.Ketone + Ether

D.Aldehyde + Ether

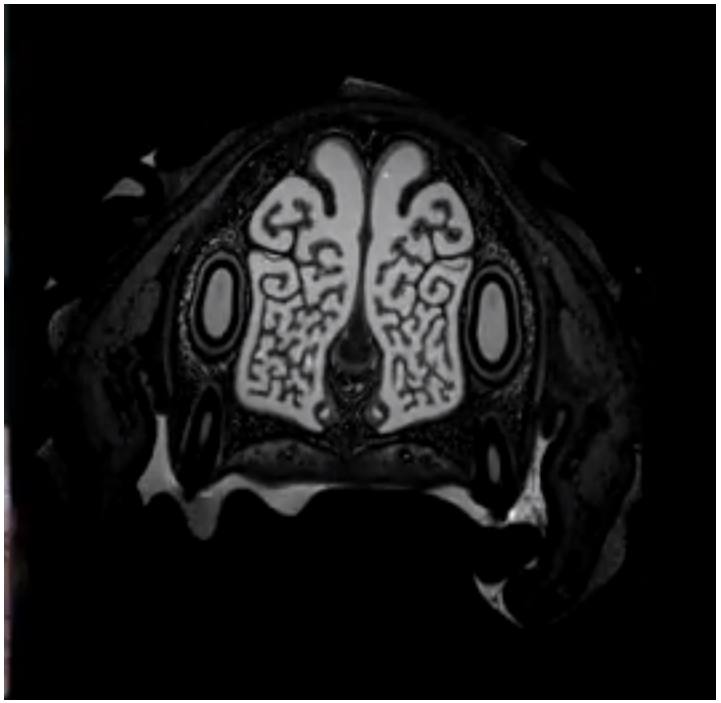
E.Carboxylic Acid + Aldehyde

What a smell looks like



https://www.youtube.com/watch?v=58U52lDTuvk&list=PLgawtcOBBjr9I-NDoUX-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

Name: _____

Organic Functional Group Sudoku Puzzle

adapted from

Crute, Thomas D.; Myers, Stephanie A., *J. Chem. Educ.* 2007, **84**, 612

The precursor of the sudoku puzzle was first published in the United States in 1979 by Howard Garns, a retired architect and freelance puzzle constructor. In April 1984, the puzzle was introduced in Japan and the name "sudoku" was assigned to the puzzle. "Suuji wa dokushin ni kagiru" may be translated as "the numbers must be single" or "the numbers must occur only once". Later the name was abbreviated to sudoku (pronounced SUE-dough-coo; "su" means number, "doku" means single). In April 2005, The *New York Post* published sudoku puzzles as a regular feature and by July 2005, the puzzle surged in popularity all over the country *(1, 2)*.

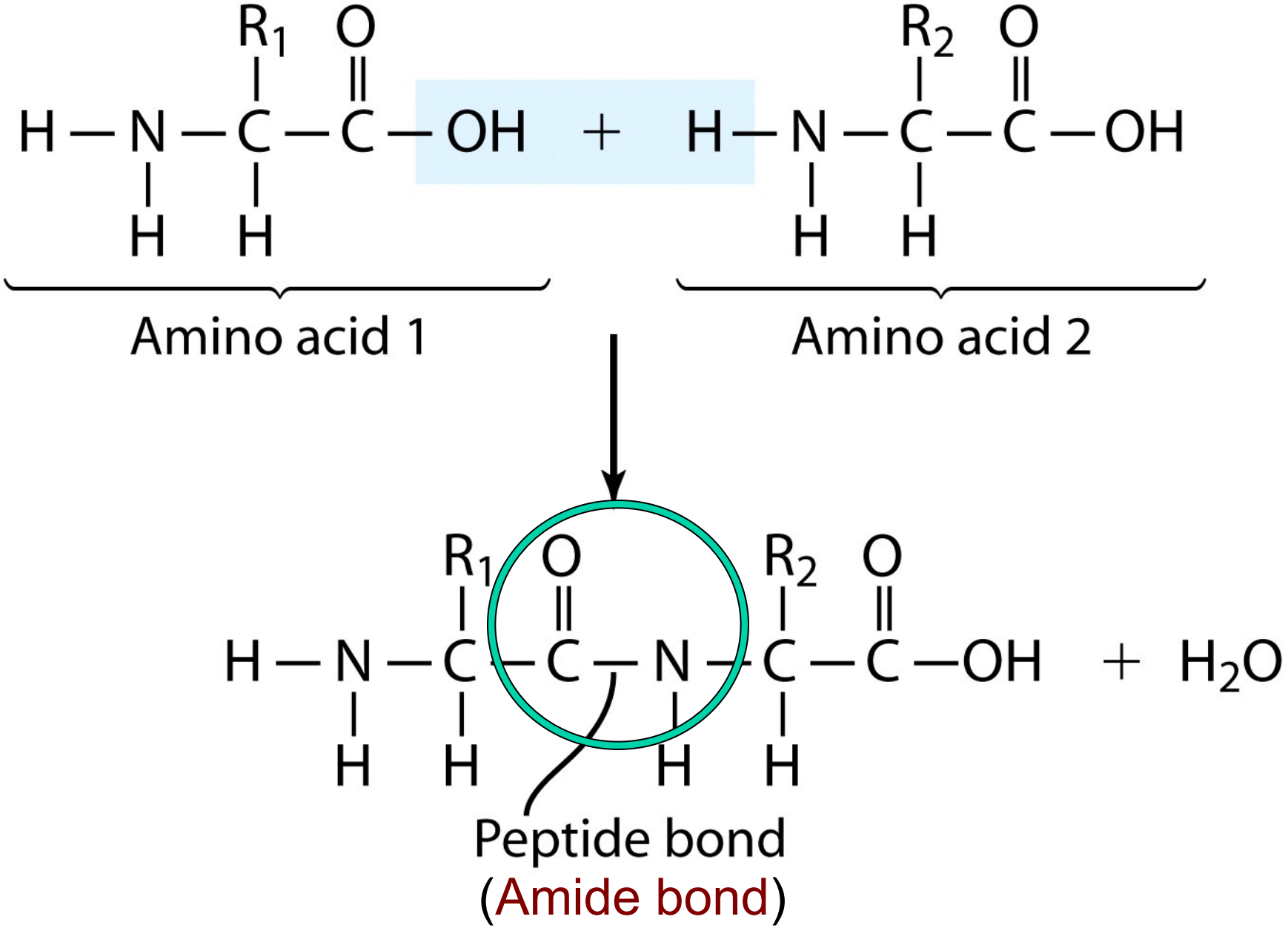
The following Sudoku puzzle deals with the names and generic structures of organic functional groups found in organic molecules. They do not deal directly with numbers as

	R-COOH					$R\text{-}CONH_2$	$R\text{-}NH_2$	R-CO-R′
$R\text{-}NH_2$	R-Cl	R-CO-R′	R-OH			R-O-R′		
R-O-R′					R-COO-R′		R-Cl	R-OH
R-CO-R′								
R-COO-R′	R-OH		R-O-R′	$R\text{-}NH_2$	R-CO-R′		R-COOH	$R\text{-}CONH_2$
								R-O-R′
$R\text{-}CONH_2$	R-CO-R′		R-COOH					R-Cl
		$R\text{-}NH_2$			R-Cl	R-OH	$R\text{-}CONH_2$	R-COO-R′
R-Cl	R-COO-R′	R-CHO					R-O-R′	

Organic Molecules
Functional Groups

Proteins
Amines, Carboxylic Acids
Amides (Peptides)

Physiological reactions (metabolism) of one gram of protein produces 4 to 5 Calories (kcal), which is enough energy to raise the water in your body about 1 ^{o}C.


Amino acid 1
Amino acid 2
Peptide bond
(Amide bond)

Proteins: Macromolecular Biopolymers

- **Structural proteins**: ***Collagen***

  ***Connectin proteins*, β - MW of 2.1 million g/mol; length = 1000 nm; can stretch to 3000 nm.**

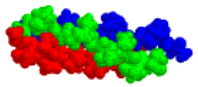
- **Mechanical (Contractile) proteins**: ***Actin, Myosin***
- **Transport proteins**: ***Hemoglobin***
- **Enzymes**: ***Glutamine synthetase* - 12 subunits of 468 residues each; total mol. wt. = 600,000 daltons**
- **Regulatory proteins**: ***Insulin* - α -alpha chain of 21 residues, β - beta chain of 30 residues; total mol. wt. of 5,733 amu**
- **Specialized proteins**: ***Antifreeze in fish***

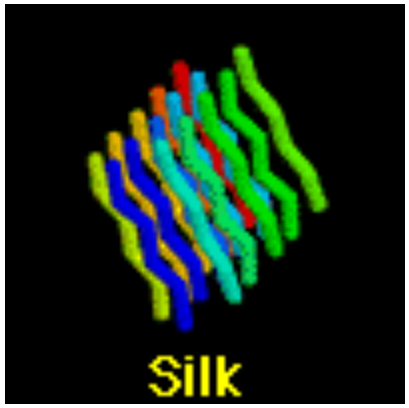
A gene was first defined as: one piece of DNA that codes for one protein. (The definition is being expanded beyond proteins to include certain types of RNA.)

Proteins: Macromolecular Biopolymers

Examples of Structural Proteins

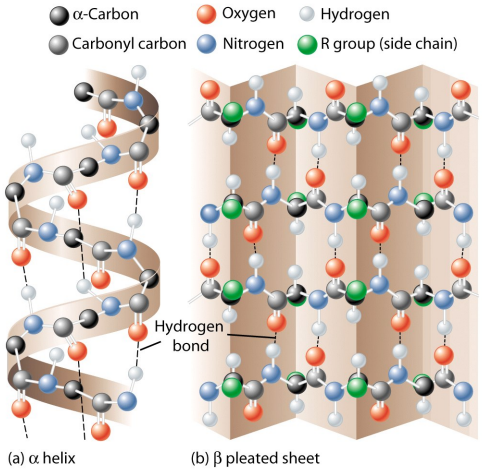
Collagen: connective tissue





Structural Proteins:

Silk



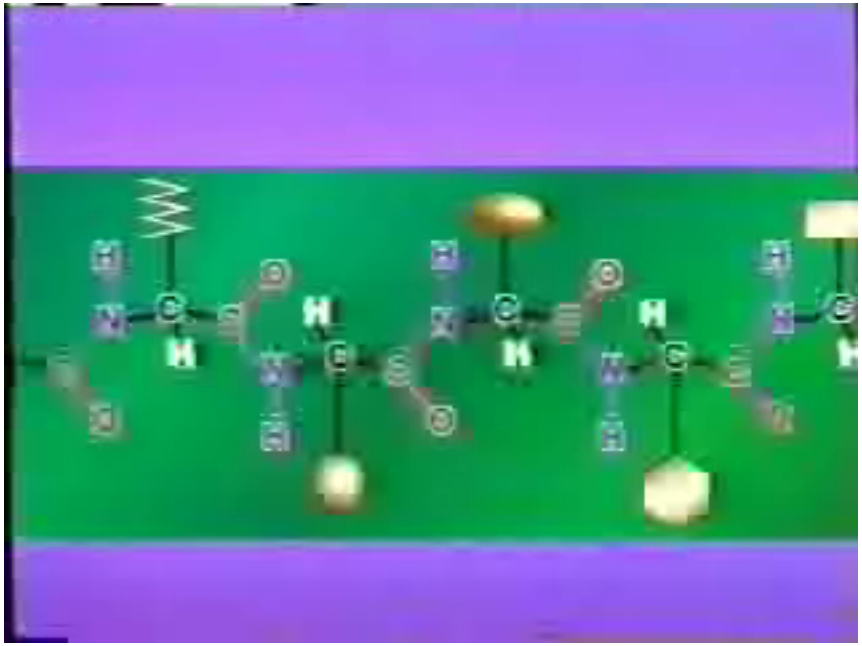
β-Sheets

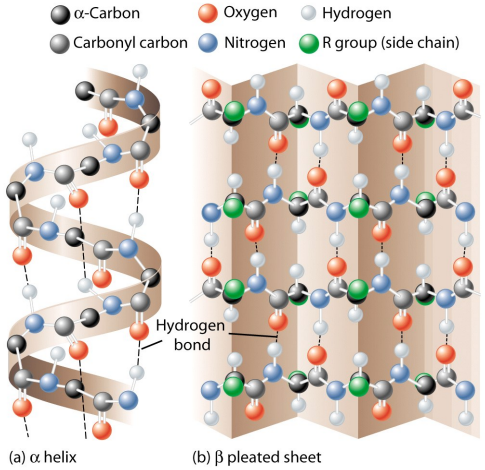
http://chemconnections.org/general/movies/proteins-silk-2.mov

Structural Proteins:

α-Helix

Curly Hair





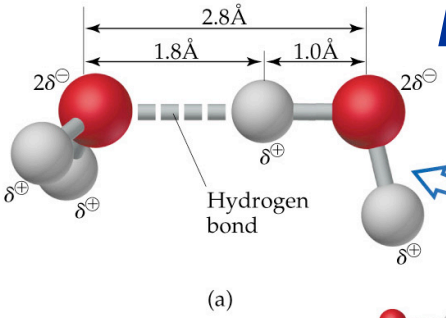
http://chemconnections.org/general/movies/protein-hair-2.mov

Annenberg World of Chemistry

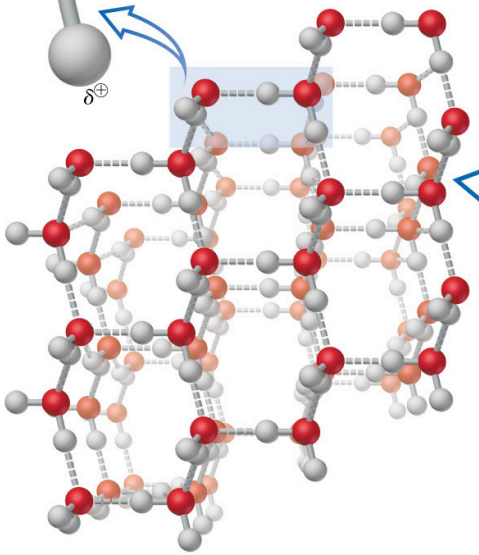
#23 Proteins *:* http://www.learner.org/resources/series61.html

Intra- & Inter-molecular

Hydrogen Bonding



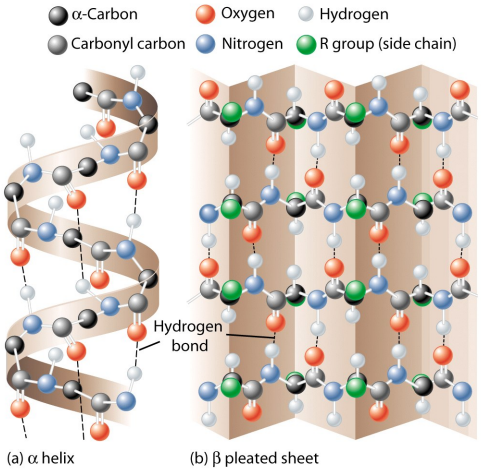
(a)



(b)

(c)

Inter-molecular Hydrogen Bonds



α-Helix β-Sheets

Intra-molecular Hydrogen Bonds

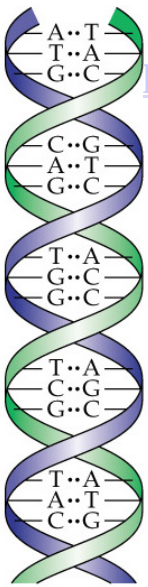
http://chemconnections.org/general/movies/ice-structure.MOV

http://chemconnections.org/general/movies/HydrogenBonding.MOV

DNA: Shape & Hydrogen Bonding

http://www.umass.edu/microbio/chime/beta/pe_alpha/atlas/atlas.htm

Views & Algorithms



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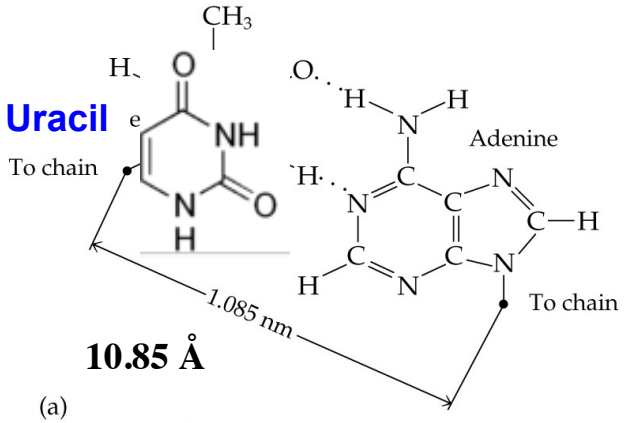
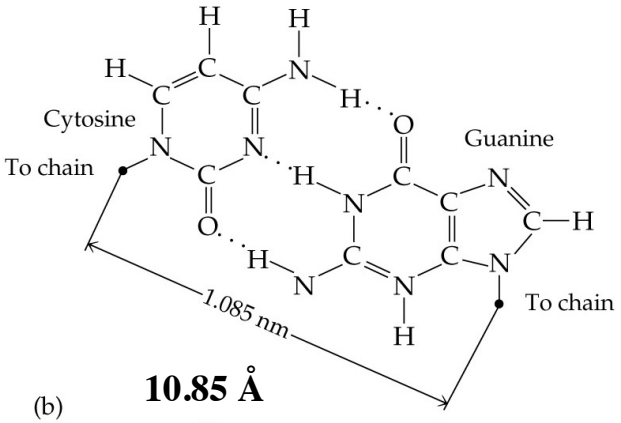


(a)



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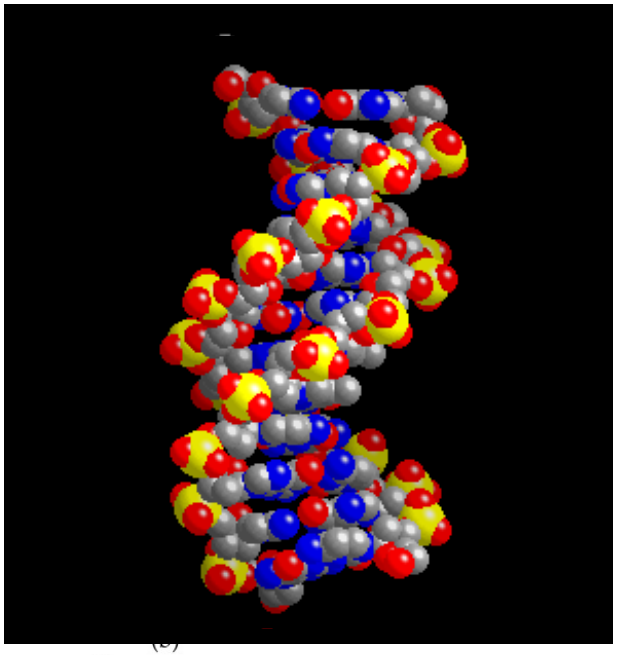
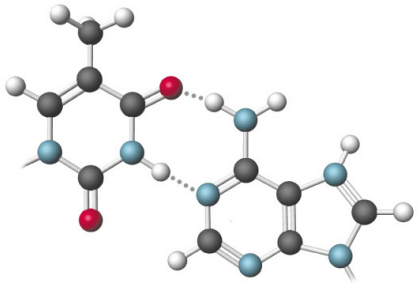
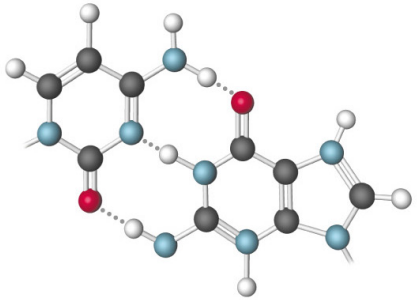


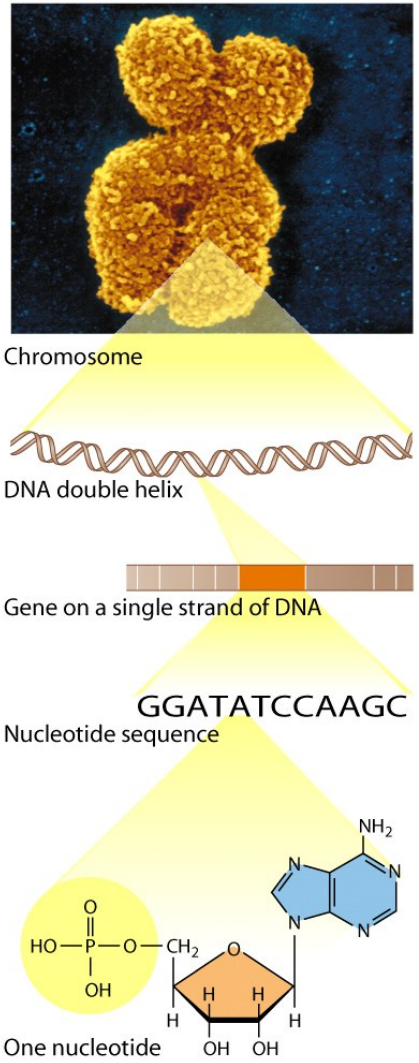




Chemical Biology

DNA ⇆ RNA ⇆ Proteins

Uracil



https://www.youtube.com/watch?v=gG7uCskUOrA

Chemical Biology

DNA ⇆ RNA ⇆ Proteins

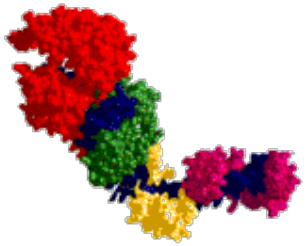
https://www.youtube.com/watch?v=X_tYrnv_o6A

Mechanical proteins:

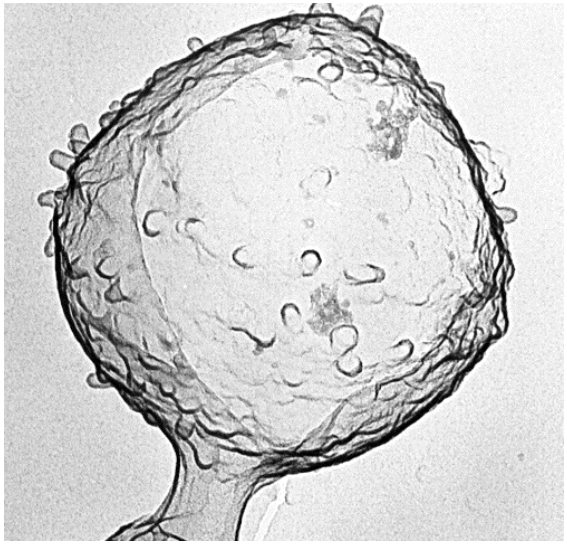
Pathogens & Cell Invasion

http://chemconnections.org/organic/chem226/Announcements-info/Staph-infection/infection.html

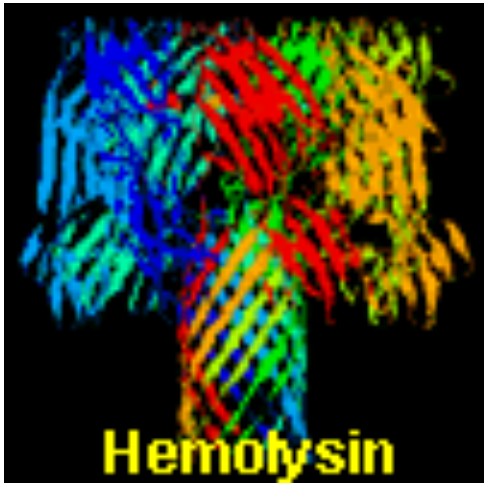
myosin-actin: muscle

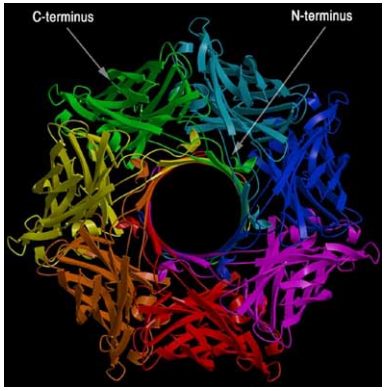


Michael Ferenczi

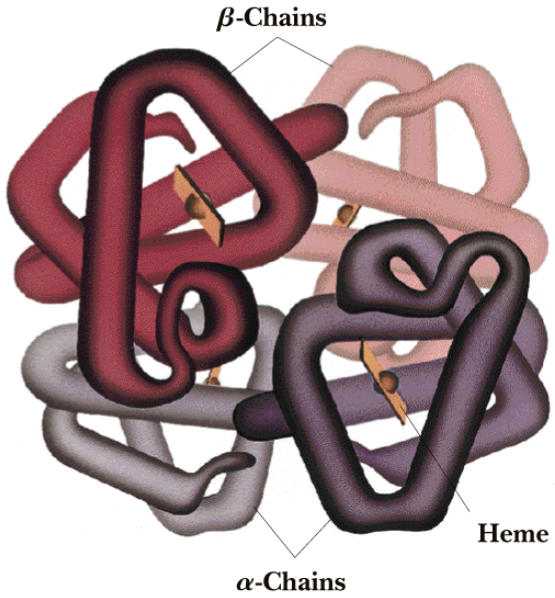


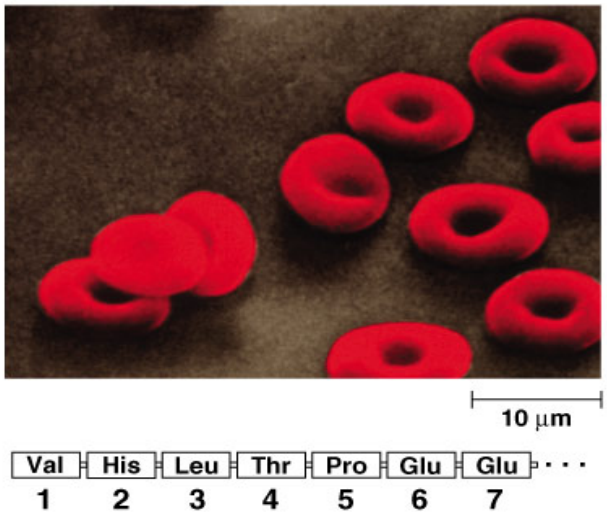
Streptococcus pyogenes
96,000 x
Vincent A. Fischetti Ph.D., Rockefeller University
http://www.chm.bris.ac.uk/motm/motm.htm



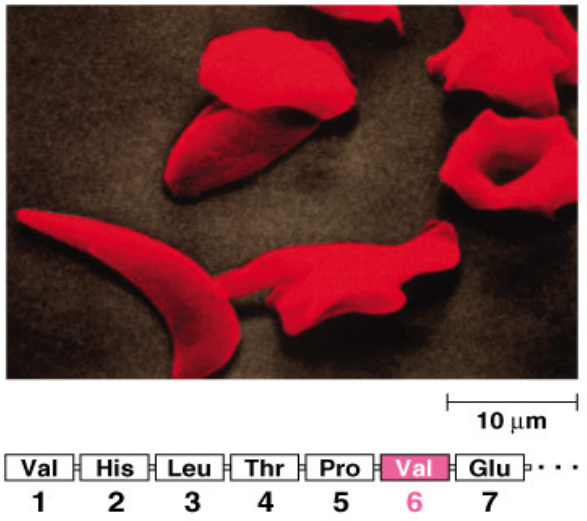


Transport Proteins: *Hemoglobin & Oxygen*



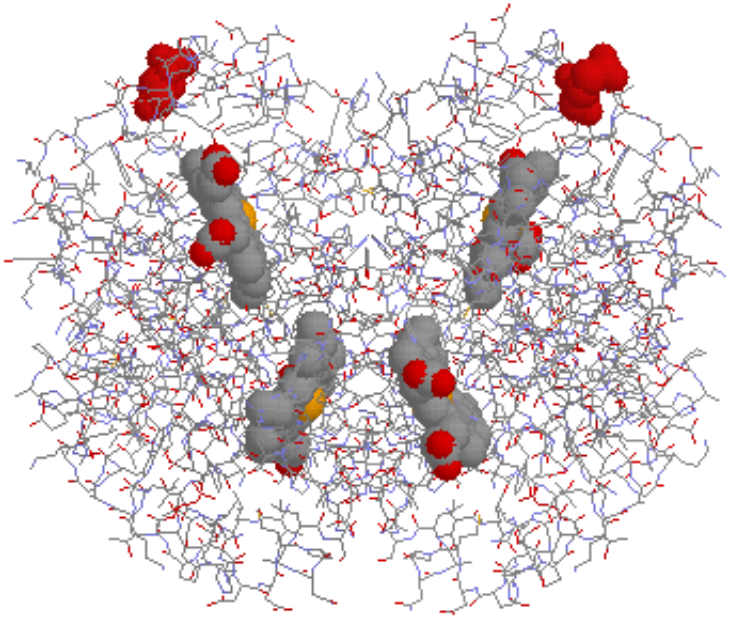


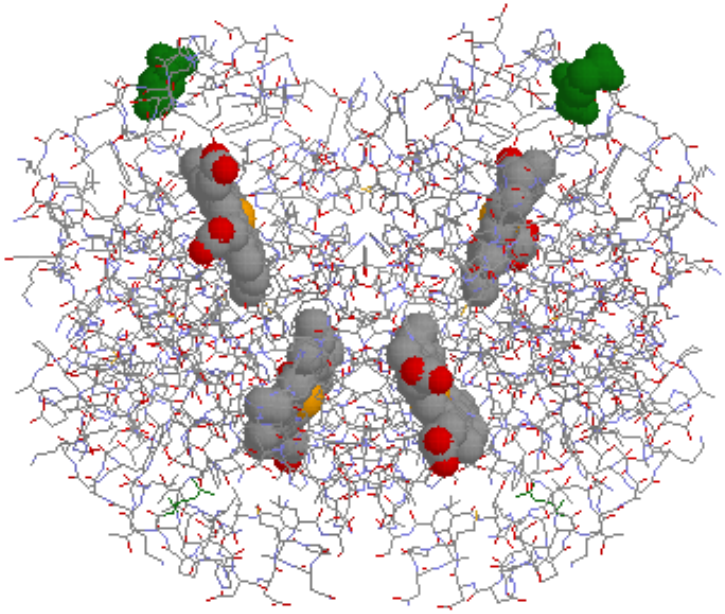
(a) Normal red blood cells and the primary structure of normal hemoglobin



(b) Sickled red blood cells and the primary structure of sickle-cell hemoglobin

Normal hemoglobin vs sickle cell hemoglobin





Valine replaces Glutamate

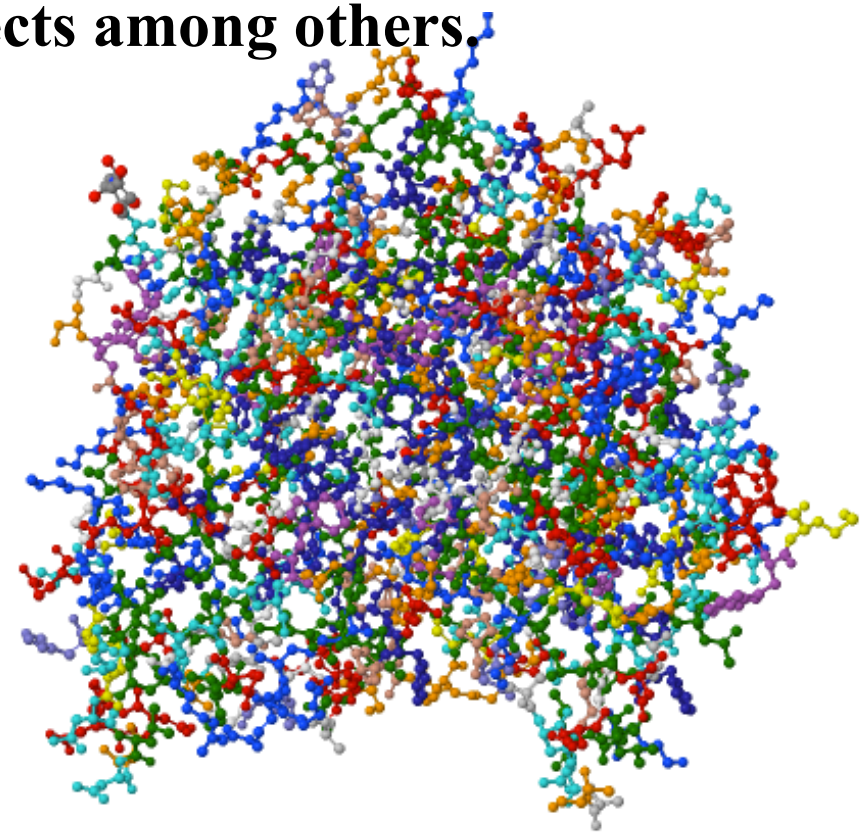
http://chemconnections.org/Presentations/Columbia/slide8-3.html

Firefox to listen

Catalytic Proteins: Enzymes

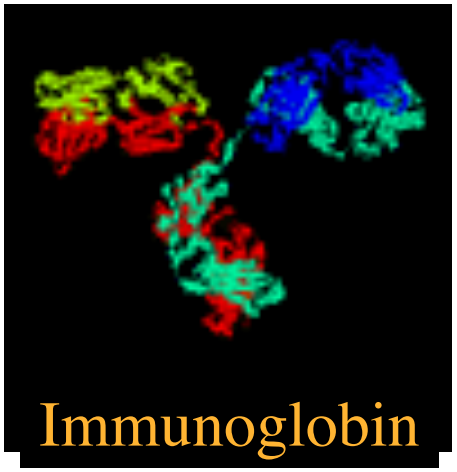
Acetylcholinesterase (ACE)

***ACE*, an enzyme, which catalyzes a key reaction in a repetitive biochemical cycle that is crucial to neurological and physiological functions in humans…. and insects among others.**



4,496 atoms;
4,404 bonds
574 amino acid residues

Protective Proteins



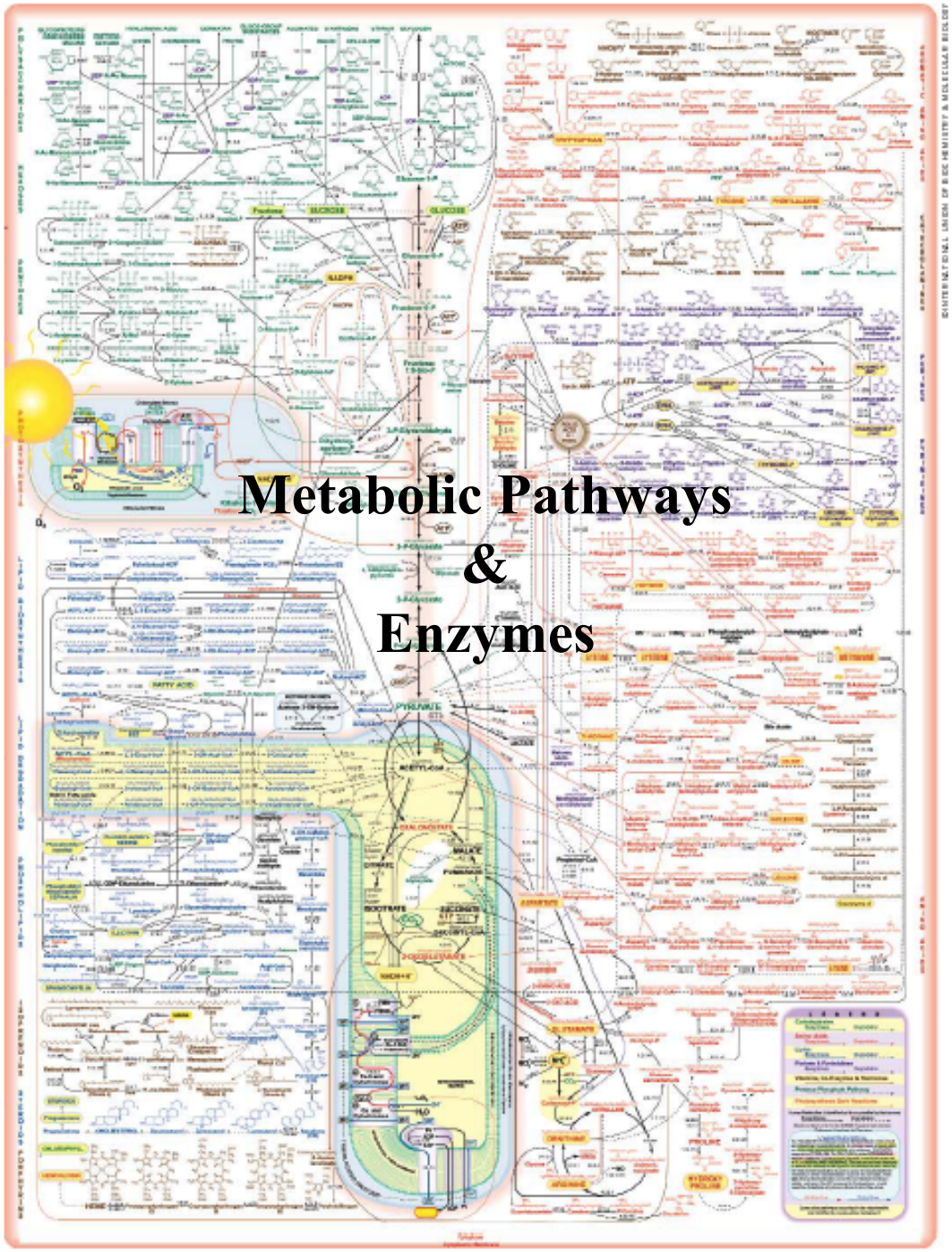
Antibodies

Prolific Immunoproteins

Human's total ~ 100 x 10 ^{6} immunoproteins

Combinatorial syntheses from libraries of 250, 10, and 6 possible contributors

Human Genome ~20,000 proteins


Metabolic Pathways
&
Enzymes

Name: _____

Organic Functional Group Sudoku Puzzle

adapted from

Crute, Thomas D.; Myers, Stephanie A., *J. Chem. Educ.* 2007, **84**, 612

The precursor of the sudoku puzzle was first published in the United States in 1979 by Howard Garns, a retired architect and freelance puzzle constructor. In April 1984, the puzzle was introduced in Japan and the name "sudoku" was assigned to the puzzle. "Suuji wa dokushin ni kagiru" may be translated as "the numbers must be single" or "the numbers must occur only once". Later the name was abbreviated to sudoku (pronounced SUE-dough-coo; "su" means number, "doku" means single). In April 2005, The *New York Post* published sudoku puzzles as a regular feature and by July 2005, the puzzle surged in popularity all over the country *(1, 2)*.

The following Sudoku puzzle deals with the names and generic structures of organic functional groups found in organic molecules. They do not deal directly with numbers as

	R-COOH					$R\text{-}CONH_2$	$R\text{-}NH_2$	R-CO-R′
$R\text{-}NH_2$	R-Cl	R-CO-R′	R-OH			R-O-R′		
R-O-R′					R-COO-R′		R-Cl	R-OH
R-CO-R′								
R-COO-R′	R-OH		R-O-R′	$R\text{-}NH_2$	R-CO-R′		R-COOH	$R\text{-}CONH_2$
								R-O-R′
$R\text{-}CONH_2$	R-CO-R′		R-COOH					R-Cl
		$R\text{-}NH_2$			R-Cl	R-OH	$R\text{-}CONH_2$	R-COO-R′
R-Cl	R-COO-R′	R-CHO					R-O-R′	

Organic Molecules

Functional Groups

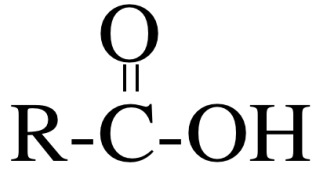
alcohols, ethers, aldehydes, ketones

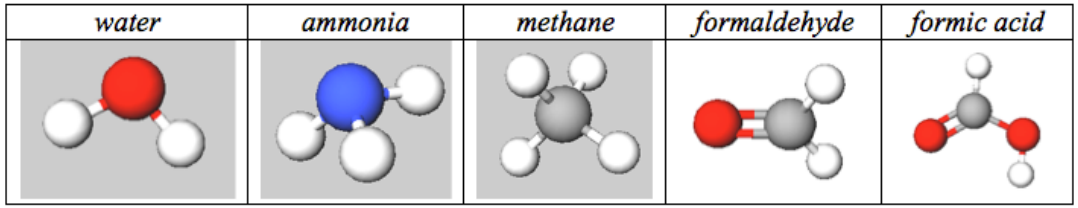
Carbohydrates / Saccharides / Sugars

Physiological reactions (metabolism) of one gram of carbohydrate produces about the same energy as 1 gram of protein: 4 to 5 Calories (kcal); enough to raise the water in your body about 1 °C.

Sugars (Carbohydrates)

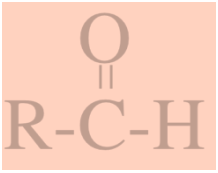
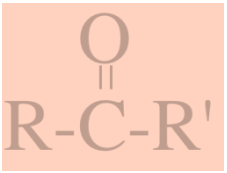
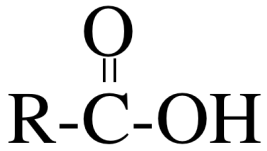
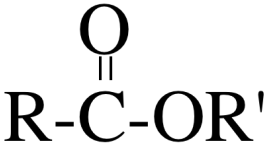
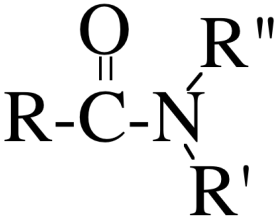
Common Functional Groups

Name	General Formula
Alcohols	R−OH
Ethers	R−O−R′
Amines	$R-NH_2$
Carboxylic Acids	



Sugars (Carbohydrates)

Common Functional Groups

Name	General Formula
Aldehydes	
Ketones	
Carboxylic Acids	
Esters	
Amides	

Carbohydrate ("-ose") Formation

Photosynthesis

Light + chlorophyll an + two greenhouse gases, which provide oxygen & sugars

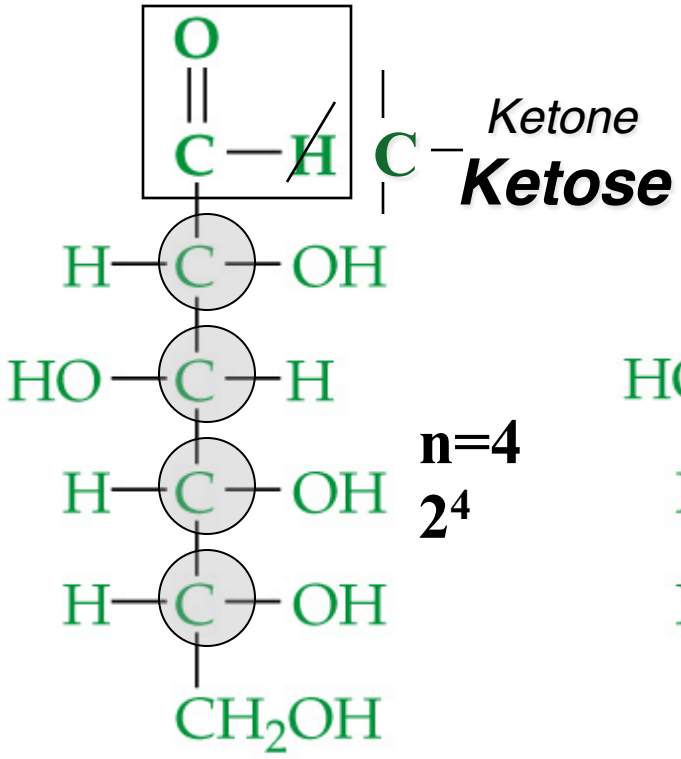
$$n\ CO_2 + n\ H_2O \longrightarrow C_n(H_2O)_n + n\ O_2$$

- **Empirical formula = CH_2O**
- **Monosaccharides (simple sugars)**
- **C_5 : pent-oses – *rib-ose***
- **C_6 : hex-oses – *fruct-ose, gluc-ose***

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

Aldehyde

Aldose



Ketone

Ketose

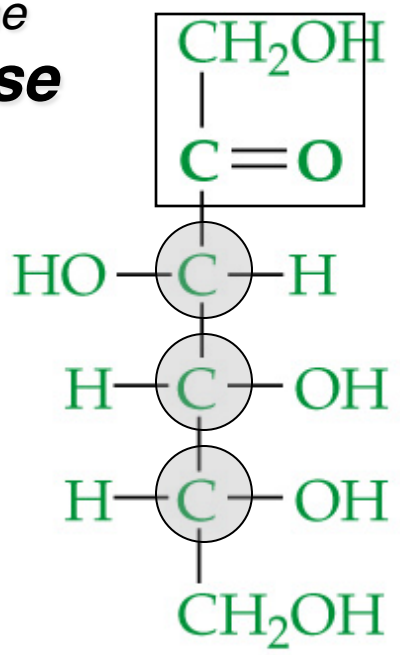
n=4

2^4

Glucose

Aldose or Ketose?

Ketose



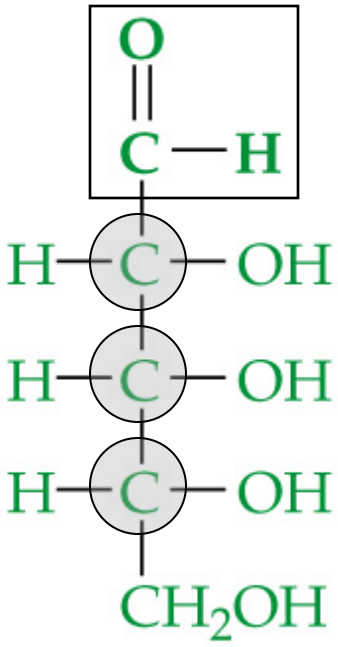
n=3

2^3

Fructose

Aldose or Ketose?

Aldose



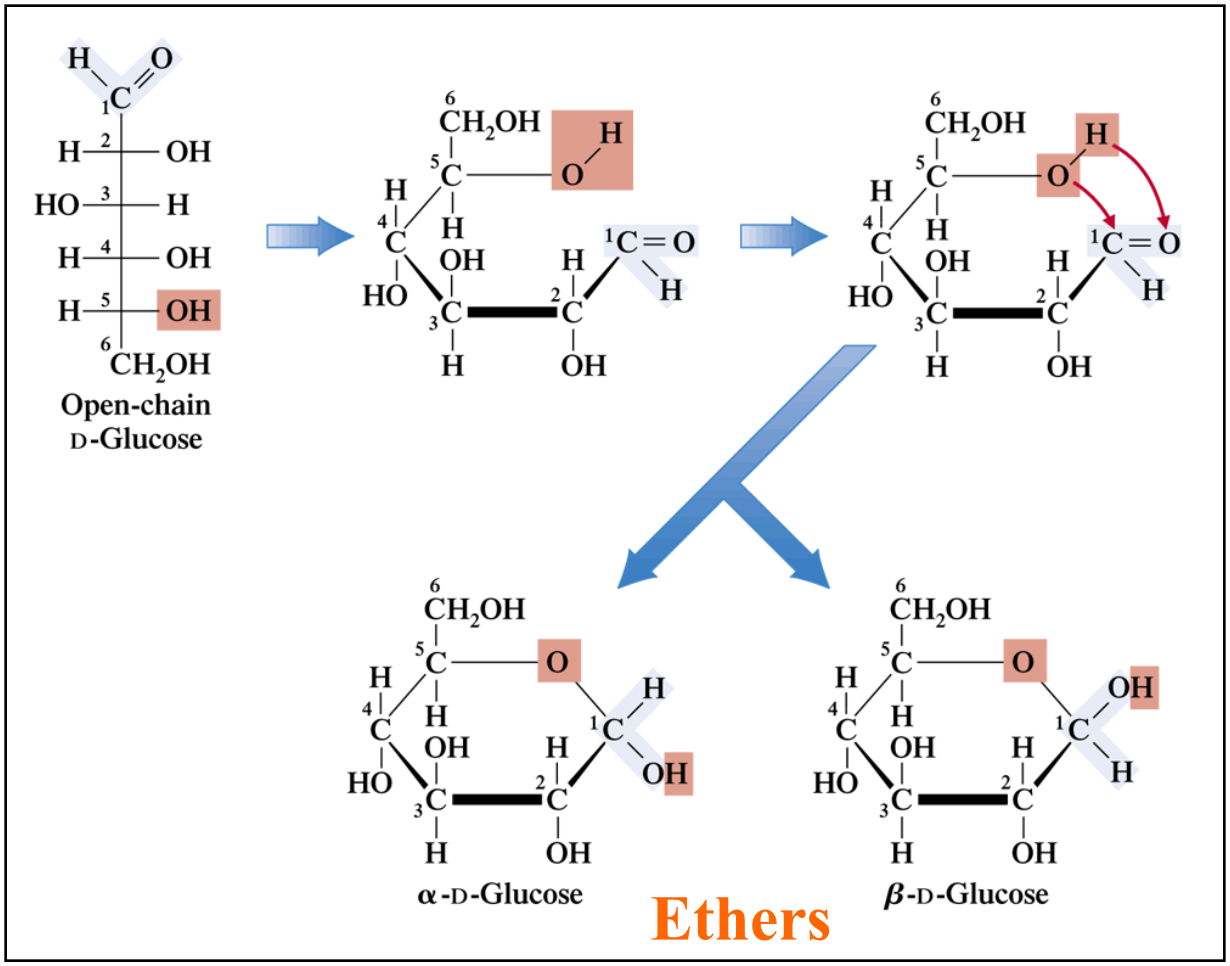
Ribose

There are 2^n possible stereoisomers, where n = the number of chiral atoms (alcohols).

Glucose? Fructose? Ribose?

Plus the cyclized forms of each of the sixteen, which adds a chiral carbon, D-Glucose for example:

D-glucose can cyclize intramolecularly



Sugar Wordsearch

Terry L. Helser

Department of Chemistry, SUNY College at Oneonta, Oneonta, NY 13820-4015; *helsertl@oneonta.edu*

This puzzle contains 29 names, terms, prefixes, and acronyms that describe sugars and their polymers. Find and highlight these terms in the matrix below. "CARBOHYDRATE" is already done for you. Then, correctly 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 success will be rewarded. The answers to the Sugar Wordsearch are found 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	G	C	H	E	X	O	S	E	I	P	E	R
S	S	L	S	E	S	O	B	I	R	A	Y	S	S
O	U	Y	T	M	P	A	M	A	M	K	R	O	N
T	G	C	A	R	B	O	H	Y	D	R	A	T	E
C	A	O	R	E	N	C	L	L	I	F	N	C	G
A	R	L	C	O	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
G	N	I	C	U	D	E	R	E	T	S	E	E	L
E	D	D	C	E	L	L	U	L	O	S	E	T	G

CARBOHYDRATEs can be S_____ S____s that are either A______ or K______ and are therefore R_______ sugars. Table sugar, S______, is a D___________ of the H_____s F_______ and G______ in cyclic furanose and P_______ forms, respectively. L______ is glucose linked to G________. Plants store energy in the ____saccharide S_____, which contains A______ and A__________. The animal equivalent is G_______. The only ____mer in them is the alpha A_____ of glucose. Beta-linked glucose or *N*-acetylglucosamine makes C________ or C_____, respectively. Both are structural polymers. Complex molecules like G_________s and _____P______s have sugars attached. Finally, phosphodi_____ bonds link R_____ units in the backbone of ___. Converting the pentose into the deoxy form produces a ___ strand.

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

Name: _____

Organic Functional Group Sudoku Puzzle

adapted from

Crute, Thomas D.; Myers, Stephanie A., *J. Chem. Educ.* 2007, **84**, 612

The precursor of the sudoku puzzle was first published in the United States in 1979 by Howard Garns, a retired architect and freelance puzzle constructor. In April 1984, the puzzle was introduced in Japan and the name "sudoku" was assigned to the puzzle. "Suuji wa dokushin ni kagiru" may be translated as "the numbers must be single" or "the numbers must occur only once". Later the name was abbreviated to sudoku (pronounced SUE-dough-coo; "su" means number, "doku" means single). In April 2005, The *New York Post* published sudoku puzzles as a regular feature and by July 2005, the puzzle surged in popularity all over the country *(1, 2)*.

The following Sudoku puzzle deals with the names and generic structures of organic functional groups found in organic molecules. They do not deal directly with numbers as

	R-COOH					$R\text{-}CONH_2$	$R\text{-}NH_2$	R-CO-R′
$R\text{-}NH_2$	R-Cl	R-CO-R′	R-OH			R-O-R′		
R-O-R′					R-COO-R′		R-Cl	R-OH
R-CO-R′								
R-COO-R′	R-OH		R-O-R′	$R\text{-}NH_2$	R-CO-R′		R-COOH	$R\text{-}CONH_2$
								R-O-R′
$R\text{-}CONH_2$	R-CO-R′		R-COOH					R-Cl
		$R\text{-}NH_2$			R-Cl	R-OH	$R\text{-}CONH_2$	R-COO-R′
R-Cl	R-COO-R′	R-CHO					R-O-R′	

Organic Molecules
Functional Groups

Lipids:
fats, oils, waxes, steroids,
plant natural products (terpenes)

Fats produce 9 to 10 Calories per gram; More than twice the energy of sugars or proteins, which produce 4 to 5 Calories.

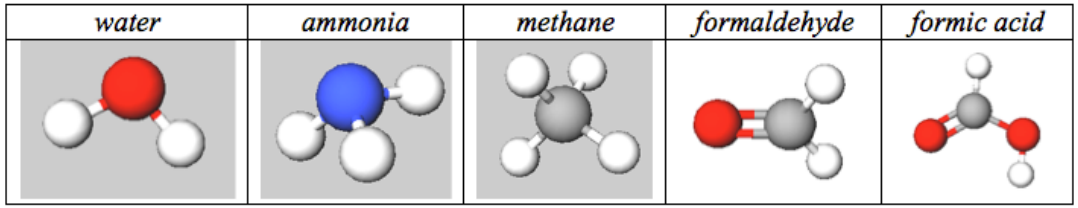
Lipids: Fats & Oils

Lipids are natural plant & animal products more soluble in non-polar solvents like gasoline than in water.

Lipids

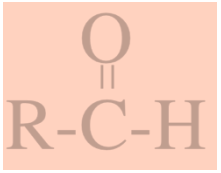
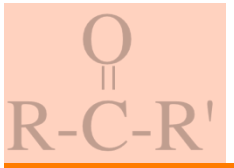
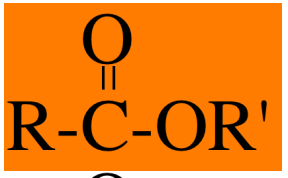
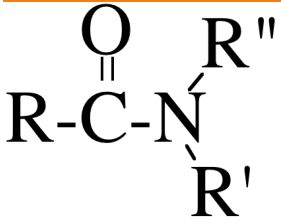
Common Functional Groups

Name	General Formula
Alcohols	R−OH (R is very large, note: glycerol is not a lipid)
Ethers	R−O−R′
Amines	$R-NH_2$
Carboxylic Acids	 (R is very large)



Lipids

Common Functional Groups

Name	General Formula
Aldehydes	
Ketones	
Carboxylic Acids	 (R is very large)
Esters	 (R is very large)
Amides	

Lipid Wordsearch

Terry L. Helser
Department of Chemistry, SUNY College at Oneonta, Oneonta, NY 13820-4015; helsertl@oneonta.edu

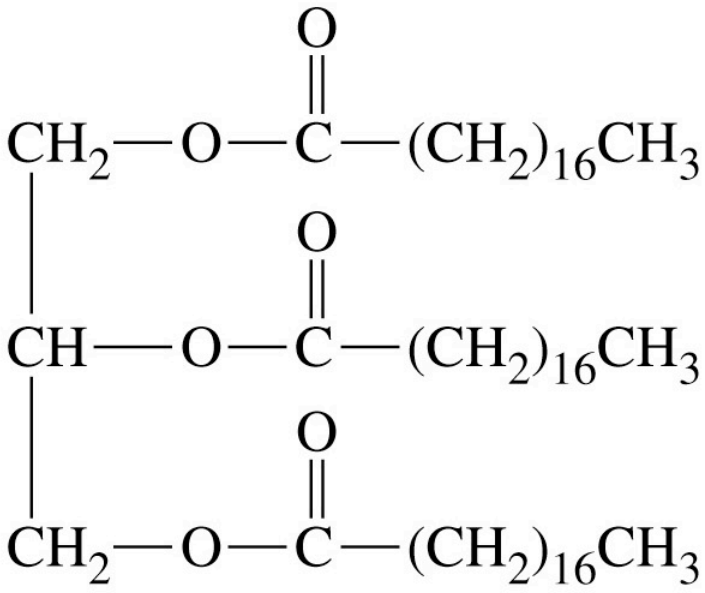
This puzzle contains 37 names, terms, prefixes and acronyms that describe lipids. They may be in any linear direction. Find and highlight these terms in the matrix below. "TRIACYLGLYCEROL" is already done for you. Then, correctly transfer them to the blanks in the description below the matrix. Use the letters remaining in the matrix to complete the sentence describing these molecules. Your success will be rewarded. The answers to the Lipid Wordsearch are found below. Good hunting!

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

TRIACYLGLYCEROLs are E____s of P_________,
S_______, and O_____ with glycerol. S_______ them
to make S___. B___ O_________ cleaves their ____-
C__s into A_ _ _ _ _ _-_ _ _ _s. The E_ _ _ _ _ _ _ _ F_ _ _ _
A___s include _________ and ______N___, which
are P___U__________ with 2 or 3 C__ double bonds.
They are precursors for P_____________ hormones and
maintain F_ _ _ _ M_ _ _ _ _ membranes as part of
P_____________ and S_____M_____. Hydrogenating
such L_____ makes O___, which can contain T____
double bonds. L_____ is a W__. Polymers of I_____
form the T_____s and other simple L_____ like the
S_____, C_____, and _____D hormones.
Use the remaining 16 letters to fill in the following sentence:
_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ for _ _ _ _ .

Molecular Formula: $C_{57}H_{110}O_6$
Molecular weight: 891 amu; MM= 891 g/mol

Examples of complex lipids

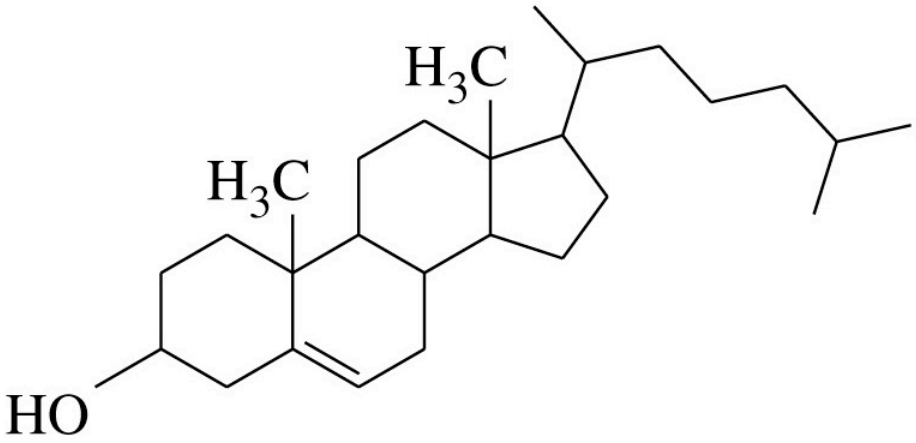


tristearin, a fat

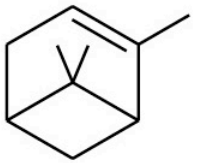
$\Delta_c H°_{solid}$	-35806.7 ± 1.8

kJ/mol

Examples of simple lipids



cholesterol, a steroid

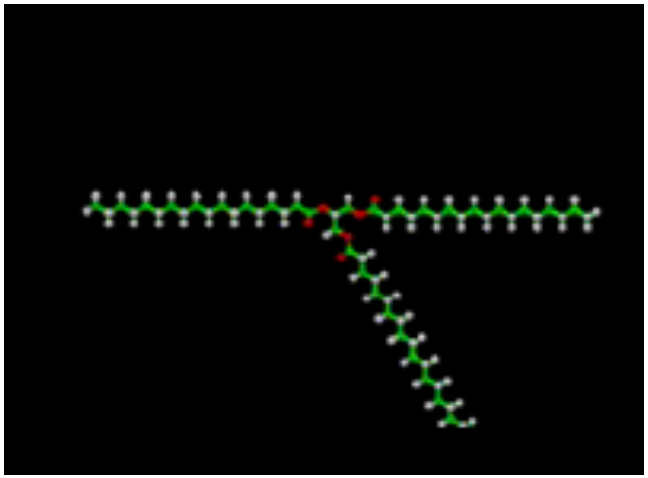


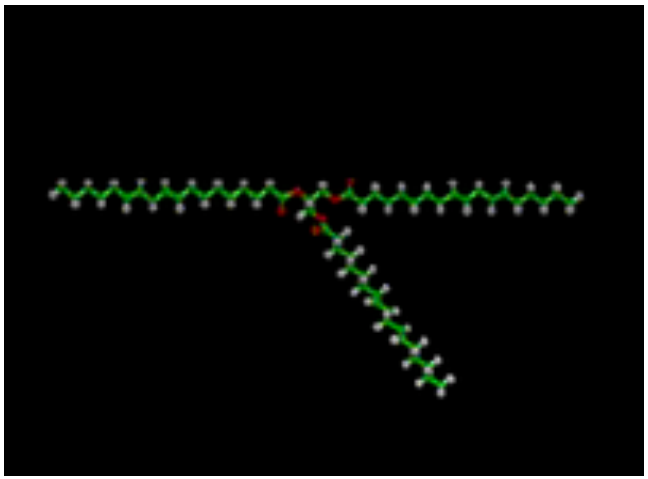
α-pinene, a terpene

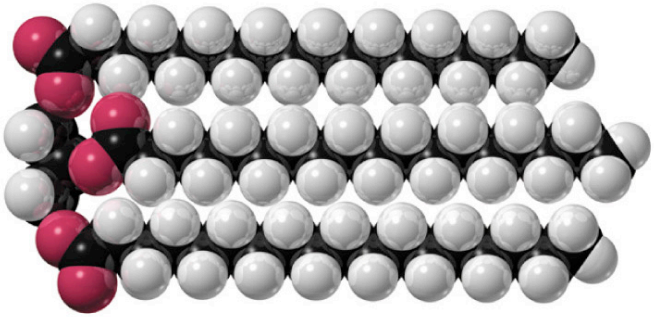
C_{10} , C_{15} , C_{20} , etc.

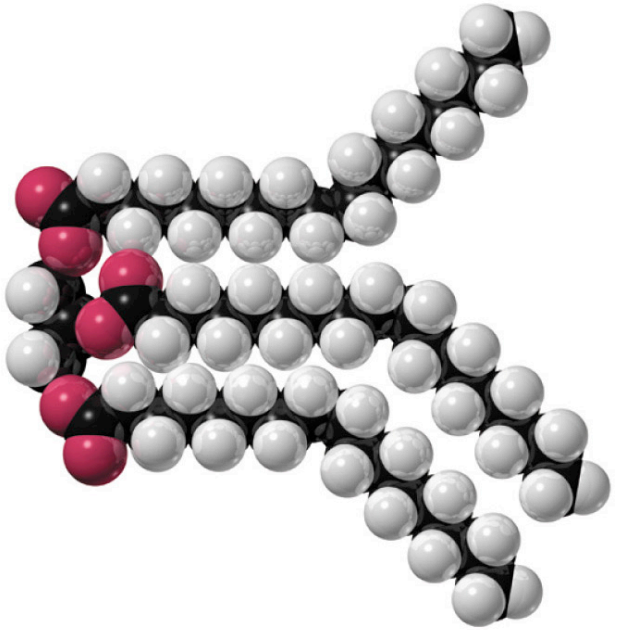
http://chemconnections.org/general/movies/fat-satd.MOV

FATS:









http://chemconnections.org/general/movies/fat-unsatd.MOV

Name: _____

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$R\text{-}NH_2$	R-Cl	R-CO-R′	R-OH			R-O-R′		
R-O-R′					R-COO-R′		R-Cl	R-OH
R-CO-R′								
R-COO-R′	R-OH		R-O-R′	$R\text{-}NH_2$	R-CO-R′		R-COOH	$R\text{-}CONH_2$
								R-O-R′
$R\text{-}CONH_2$	R-CO-R′		R-COOH					R-Cl
		$R\text{-}NH_2$			R-Cl	R-OH	$R\text{-}CONH_2$	R-COO-R′
R-Cl	R-COO-R′	R-CHO					R-O-R′	