

Molecular Cell Biology A

“Chemical principles and cellular biochemistry”

BIOX24ZL

Tuesdays 9-10:30

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Everything in life and elsewhere are made up of atoms.

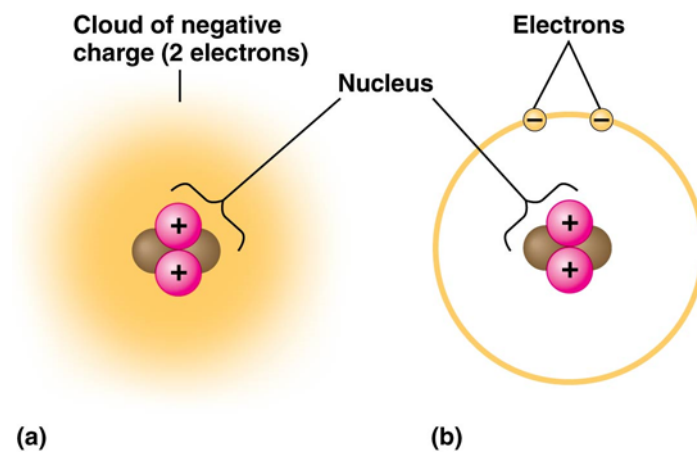
- We are made up mostly of elements oxygen, carbon, hydrogen, and nitrogen (96%).
- Compounds are combinations of elements: water H_2O , salt $NaCl$, methane (gas) CH_4 .
- Atom is an unit of matter of a single element.
- Question: The human body, which has 7×10^{27} atoms, is composed mostly of which element?

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Atoms are made up of neutrons, protons (+), and electrons (-).



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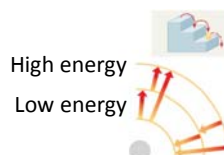
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Atoms are made up of neutrons, protons (+), and electrons (-).

- Atomic mass = # protons + # neutrons.
- Atomic number = # protons = # electrons.
- Isotopes have the same atomic number but different atomic mass (carbon 13).
- Radioactive isotopes used for dating. ❤️
- Electrons occupy different levels of energy.



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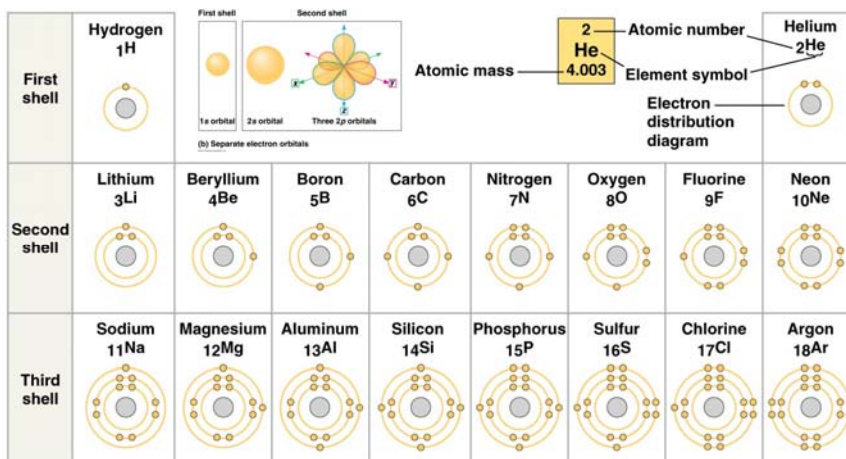
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Chemistry is determined by number of protons and distribution of electrons.



Octet Rule 🎵

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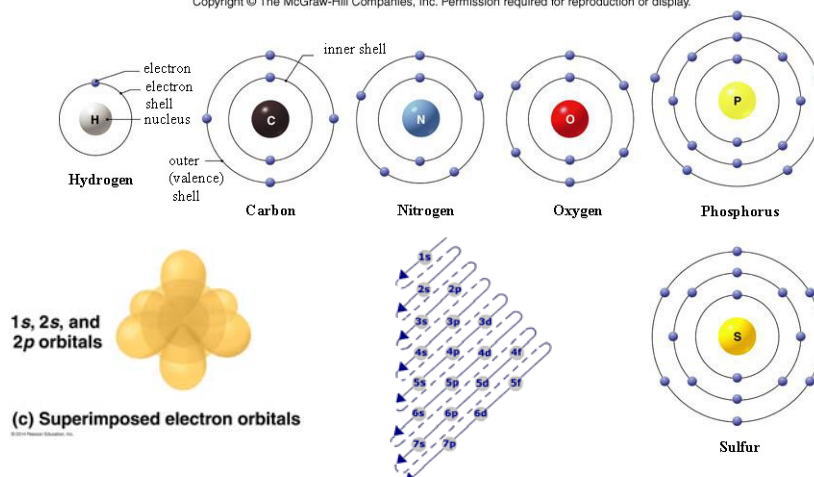
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The Octet rule governs reactivity of most chemical elements.

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Things to ponder while lining up to get ramen (aka review).

- Question: titanium has atomic number 22, an isotope of titanium with mass of 48 has how many neutrons?
- Question: how many electrons does chlorine (atomic number 17) have in its outermost (valence) shell?

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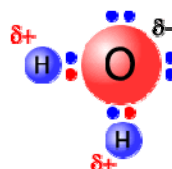
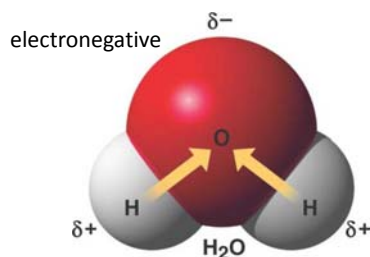
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Chemical reactivity is dependent on the number of valence shell electrons.

- **Covalent bonds** are made up of atoms sharing valence shell electrons in a molecule (H-H single bond, O=O double bond).
- Water: oxygen - two single bonds - hydrogen.



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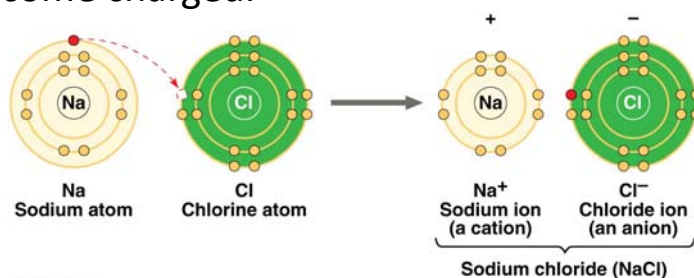
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Chemical reactivity is dependent on the number of valence shell electrons.

- **Ionic bonds** are formed from atoms with such differing electronegativity that one pulls electron away from the other and both become charged.



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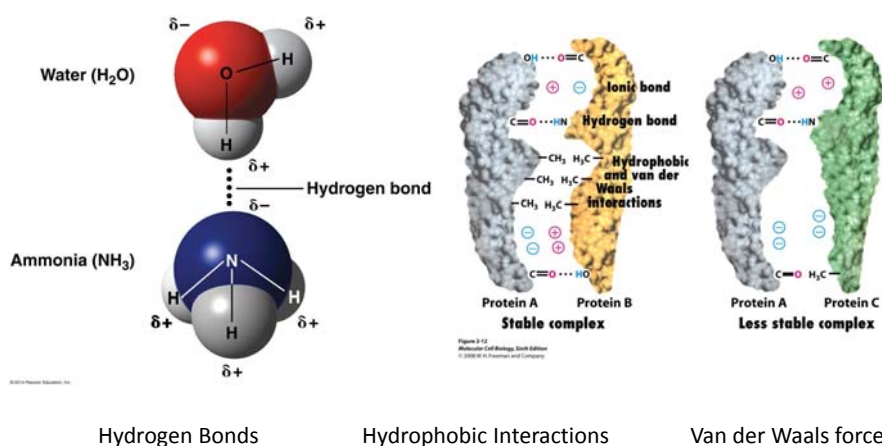
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Other chemical interactions hold biological molecules together.



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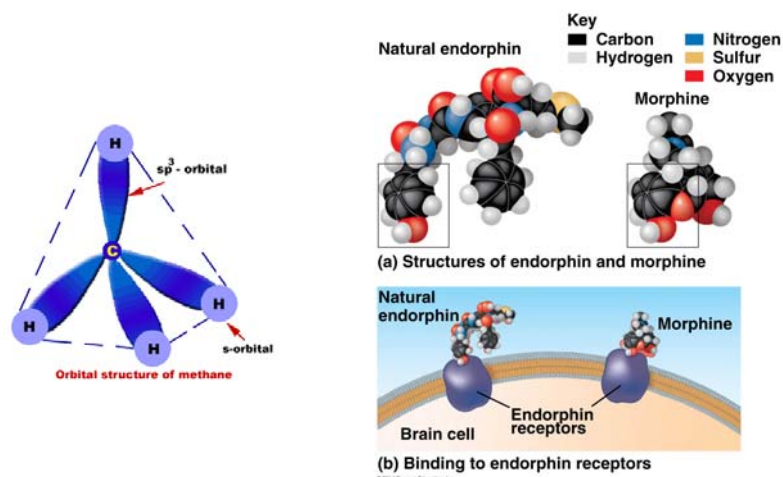
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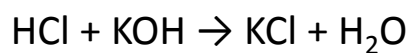


The 3D shape of molecules determines their biological reactivity.

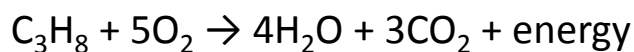


Chemical reactions preserve the number of atoms of each element.

- Acid-Base:



- Combustion:

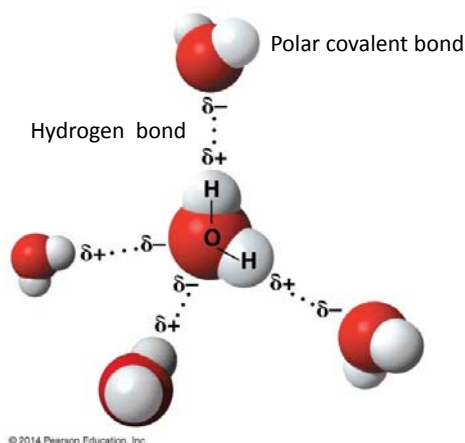


- Photosynthesis:



- Question: X and Y are? $2\text{H}_2 + \text{XO}_2 \rightarrow \text{YH}_2\text{O}$

The polarity of the water molecule gives rise to hydrogen bonds.





Properties of water sustain life on Earth.

- Adhesion to water allows transport up thin vesicles; surface tension allows floatation.
- Water can absorb heat when it's hot and release heat when it's cold; high specific heat.
- Water that evaporates as steam leaves behind a cooler reservoir of liquid to prevent overheating; high heat of vaporization 580 cal.



Ability of solid ice to float on liquid ice means lakes/seas won't freeze solid.





Hydrogen bond

Ice: Hydrogen bonds are stable

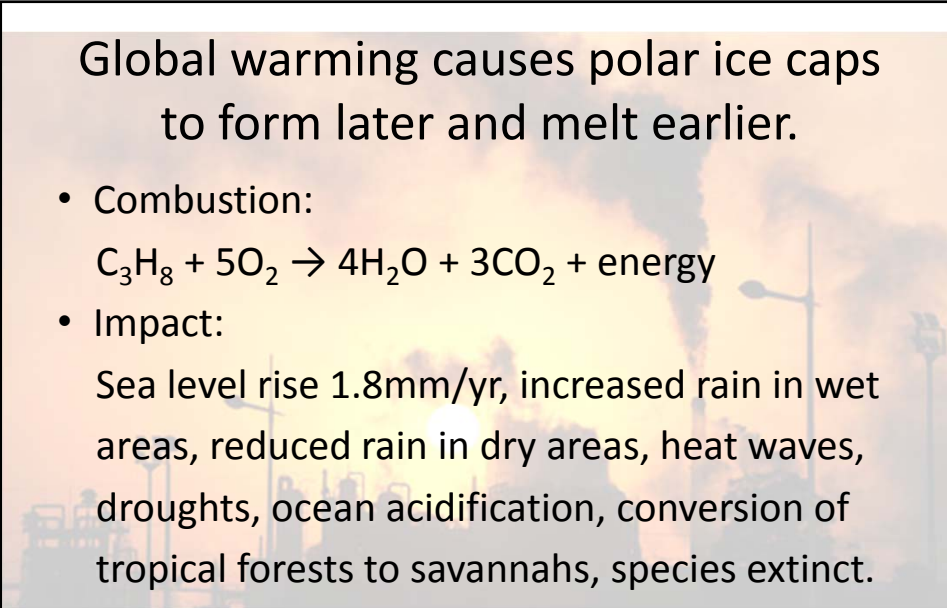
Liquid water: Hydrogen bonds break and re-form

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Global warming causes polar ice caps to form later and melt earlier.

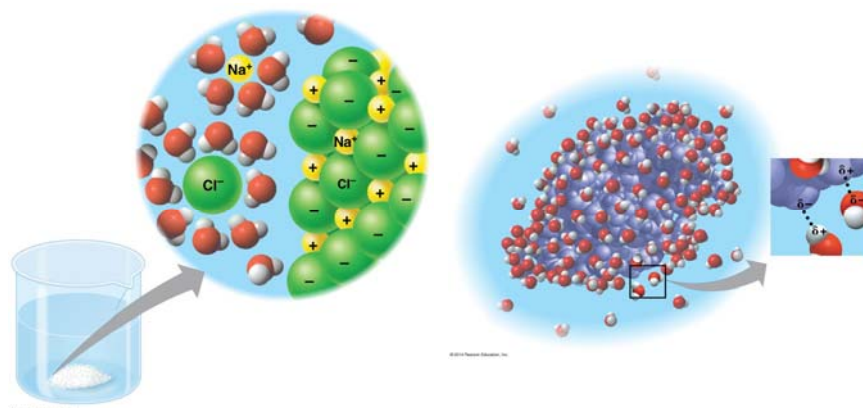
- Combustion:

$$\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 4\text{H}_2\text{O} + 3\text{CO}_2 + \text{energy}$$
- Impact:
 Sea level rise 1.8mm/yr, increased rain in wet areas, reduced rain in dry areas, heat waves, droughts, ocean acidification, conversion of tropical forests to savannahs, species extinct.



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Water can dissolve almost anything due to its weak hydrogen bonding.



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Calculating amount of materials using molar definition of mass.

- A mole of a compound has its molecular mass expressed in grams (for 6.02×10^{23} molecules).
 - One mole of water weighs 18 grams:
 - 2 hydrogens ($2 \times 1.0079\text{g}$) + 1 oxygen (15.9994g)
- Concentration is moles per liter of solution.
- **Question: How many grams of salt (sodium chloride) should you add to one liter of water to get one molar concentration salt solution?**

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NaCl is one Na (22.99 g/mol) and
one Cl (35.453 g/mol).

hydrogen 1 H 1.0079																	helium 2 He 4.0026				
lithium 3 Li 6.941	beryllium 4 Be 9.0122															boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305															aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	seleเนียม 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80				

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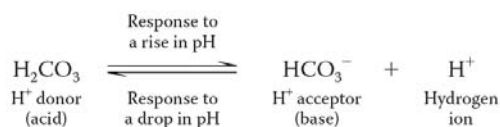
So one mol of NaCl is $22.99 + 35.45 = 58.44$ gram,
put that in one liter of water to give you
1M NaCl in H₂O.

hydrogen 1 H 1.0079																	helium 2 He 4.0026				
lithium 3 Li 6.941	beryllium 4 Be 9.0122															boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305															aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	seleเนียม 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80				

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Acidic and basic solutions affect living conditions.

- At 25°C, $[H^+] = 10^{-7}M$, $[OH^-] = 10^{-7}M$.
- $pH = -\log [H^+]$, inversely related to hydrogen concentration.
- Neutral solution has pH 7.
- Acidic solution has $pH < 7$, basic has $pH > 7$.
- Biological buffers reduce the effect of pH changes:



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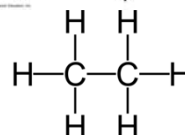
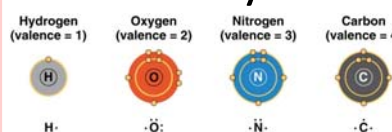
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The study of carbon based “life” compounds is organic chemistry.

- **Miller and Urey** (12-11).
- 4 valence electrons of C:
- Single bonds (ethane C_2H_6)
109.5°
- Double bonds (carbon dioxide CO_2)
180°
- Triple bonds (acetylene C_2H_2)



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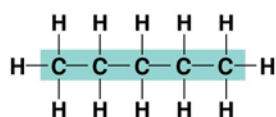
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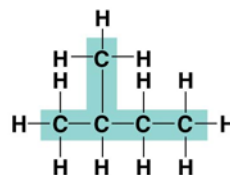


Isomers have the same number of atoms of each element.

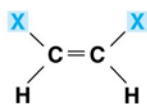
(a) Structural isomers



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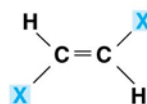


(b) *Cis-trans* isomers



cis isomer: The two Xs are on the same side.

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trans isomer: The two Xs are on opposite sides.

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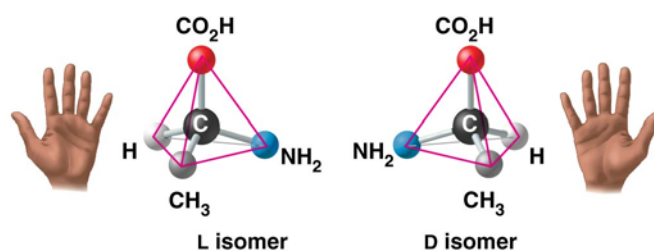
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Isomers have the same number of atoms of each element.

(c) Enantiomers



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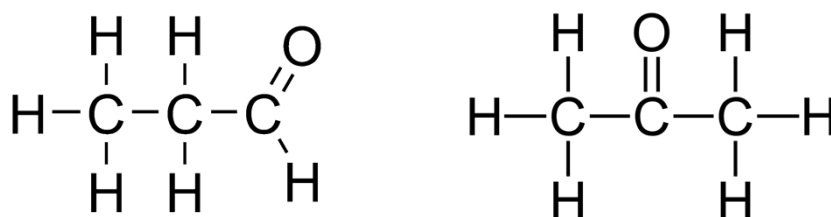
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Isomers have the same number of atoms of each element.

- Question: what kind of isomers are propanal and acetone?



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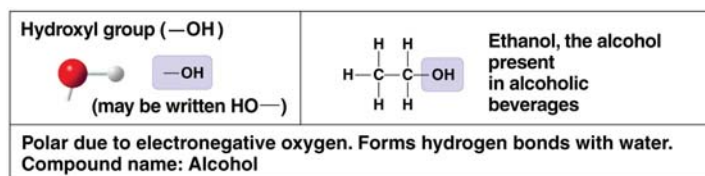
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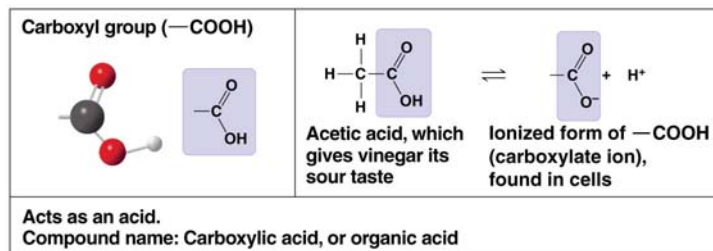
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Functional groups give “personalities” to biological molecules.



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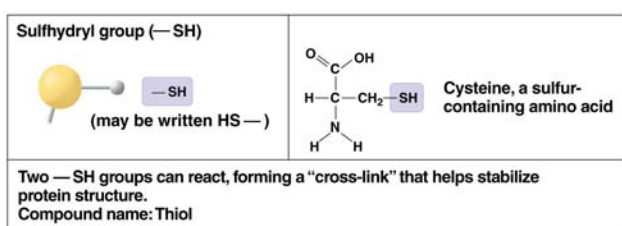
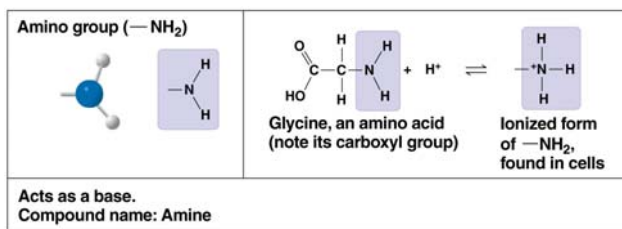
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Functional groups give “personalities” to biological molecules.



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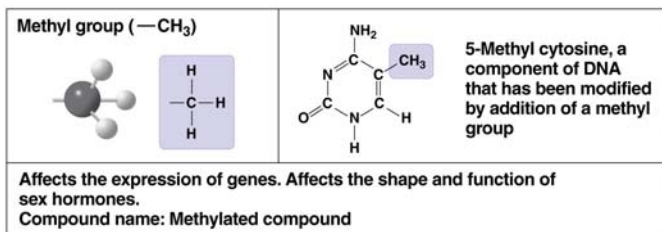
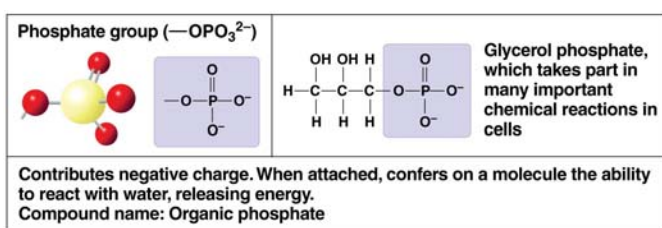
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Functional groups give “personalities” to biological molecules.



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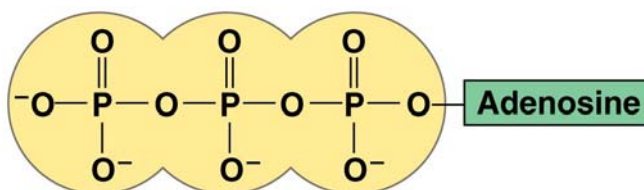
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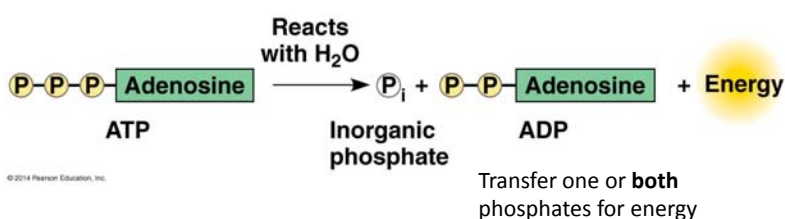
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ATP is the energy “currency” of the cell.



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Life has three main classes of macromolecules.

- Carbohydrates store energy (starch, glycogen) and form structures (cellulose, chitin) and make up the backbones of DNA (ribose).
- Proteins catalyze reactions and bind important substrates like oxygen.
- Nucleic acids carry genetic information and information about making proteins (DNA, RNA).

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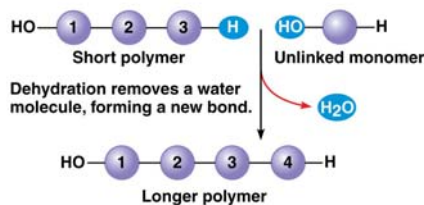
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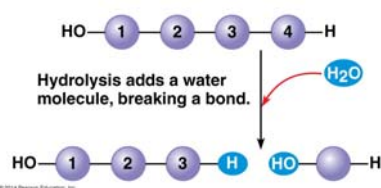


Monomers are built into polymers in dehydration reactions.

(a) Dehydration reaction: synthesizing a polymer



(b) Hydrolysis: breaking down a polymer



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Carbohydrates are chains of sugars with carbonyl and hydroxyl groups.

Aldose (Aldehyde Sugar)	Ketose (Ketone Sugar)
Trioses: 3-carbon sugars (C₃H₆O₃)	
<p>Glyceraldehyde</p>	<p>Dihydroxyacetone</p>

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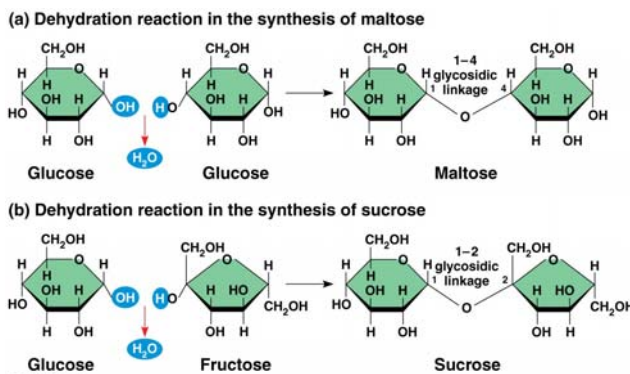
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Carbohydrates monomers are joined together by glycosidic bonds.

- In solution, each monosaccharide form rings of (usually) 5 or 6 carbons.



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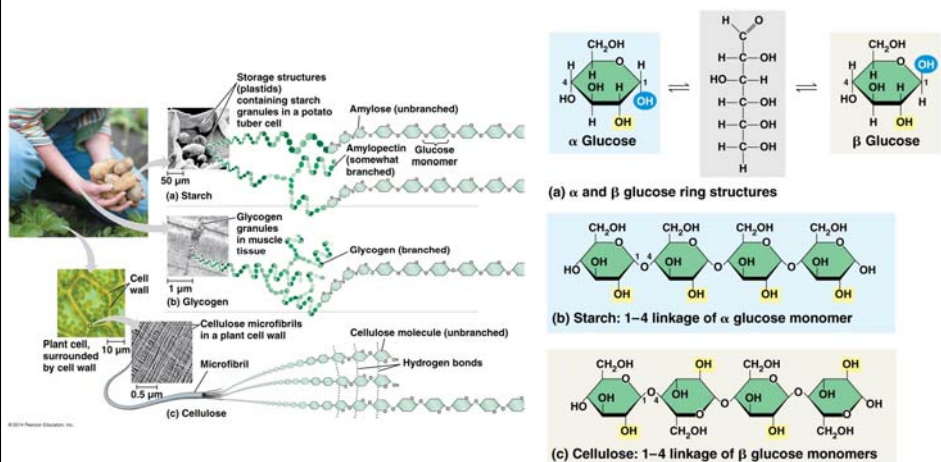
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Starch (α glucose) and cellulose (β glucose) link monomers differently.



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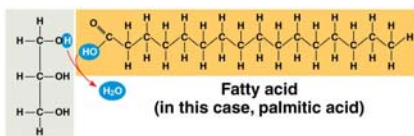
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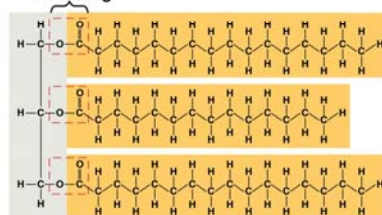
Fats are made up of glycerol and three fatty acids joined together.



Glycerol

(a) One of three dehydration reactions in the synthesis of a fat

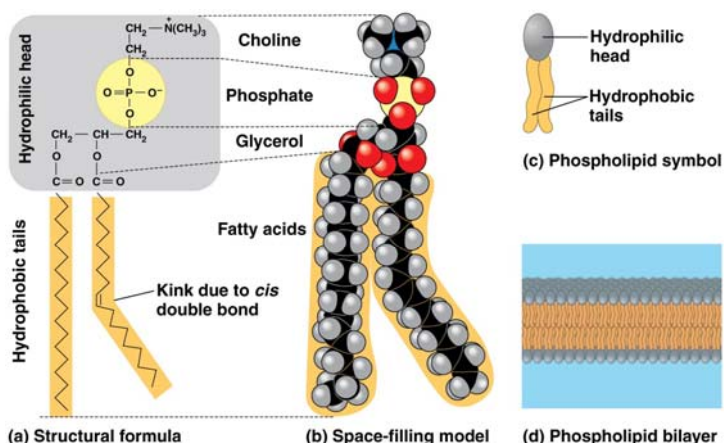
Ester linkage



(b) Fat molecule (triacylglycerol)




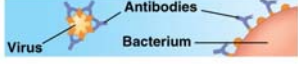


Phospholipids form the (bilayer) membranes of cells.



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Proteins are required for diverse functions of cells.

<p>Enzymatic proteins Function: Selective acceleration of chemical reactions Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.</p> 	<p>Defensive proteins Function: Protection against disease Example: Antibodies inactivate and help destroy viruses and bacteria.</p> 
<p>Storage proteins Function: Storage of amino acids Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.</p> 	<p>Transport proteins Function: Transport of substances Examples: Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across membranes, as shown here.</p> 

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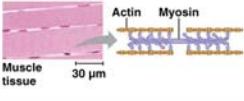
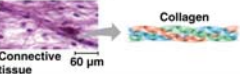
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Proteins are required for diverse functions of cells.

<p>Hormonal proteins Function: Coordination of an organism's activities Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.</p> 	<p>Receptor proteins Function: Response of cell to chemical stimuli Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.</p> 
<p>Contractile and motor proteins Function: Movement Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.</p> 	<p>Structural proteins Function: Support Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.</p> 

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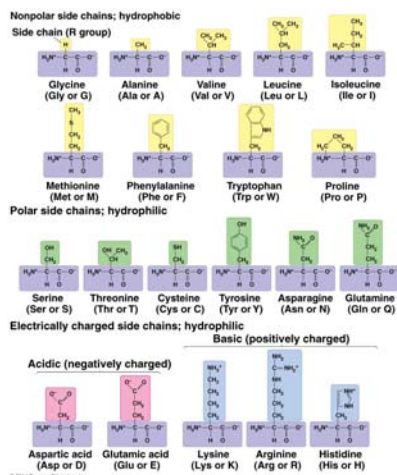
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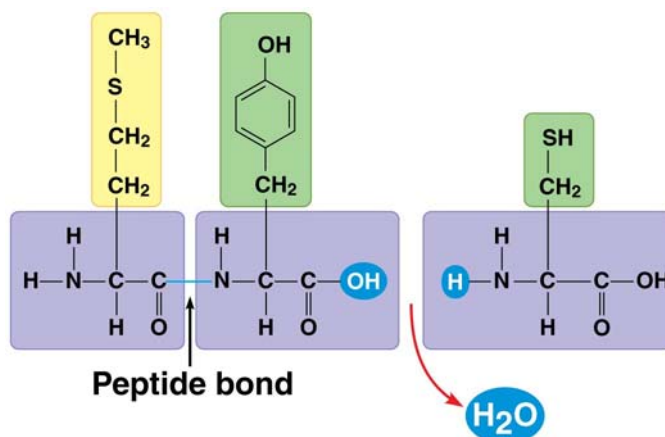
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Proteins are made up of amino acids characterized by different side chains.



Individual amino acids are joined together by peptide bonds.



Team work.

Which of the following chemicals do you NOT expect to be readily dissolved in water?

- A. Uric acid
- B. Hexane
- C. Glycerol
- D. Ethanol
- E. Potassium chloride

ATP is the main energy currency in cells, and it can especially be used to drive condensation reactions that produce macromolecular polymers. How does ATP normally catalyze the condensation reaction, which by itself is energetically unfavorable?

- A. It transfers its terminal phosphate to an enzyme and is released as ADP.
- B. It transfers its two terminal phosphates to an enzyme, and is released as AMP.
- C. It covalently attaches to both of the substrates.
- D. It transfers either one or two terminal phosphate(s) to one of the substrates and is released as either ADP or AMP.
- E. It covalently attaches to the enzyme, forming an enzyme-AMP adduct.

