Molecular Cell Biology A

"Chemical principles and cellular biochemistry"

BIOX24ZL

Tuesdays 9-10:30

Ray LC

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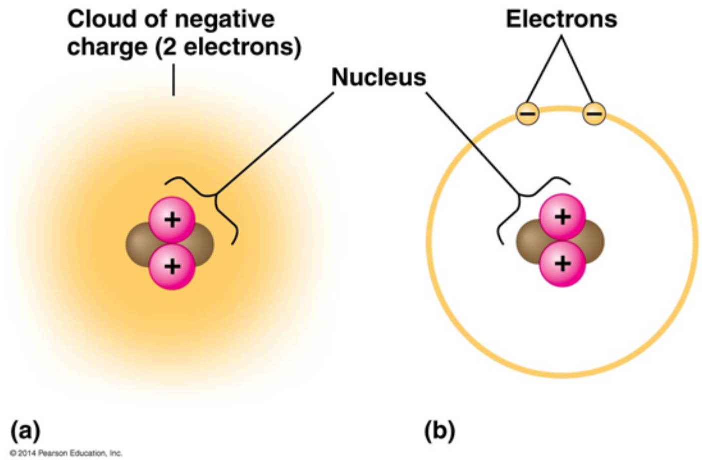
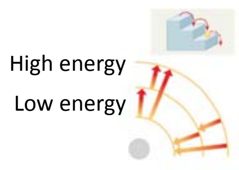
Atoms are made up of neutrons, protons (+), and electrons (-).



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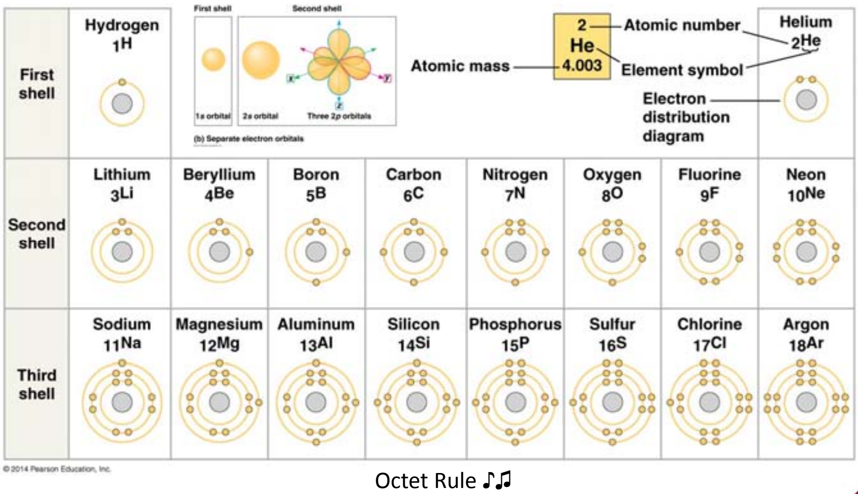
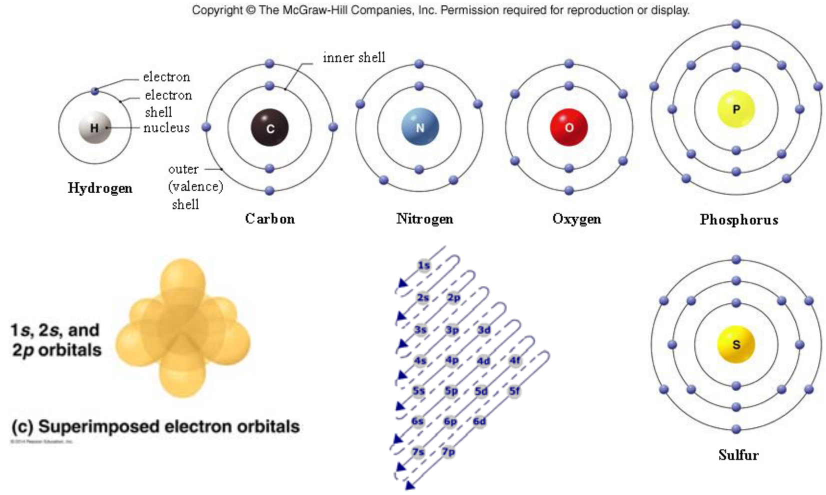
Chemistry is determined by number of protons and distribution of electrons.



Octet Rule ♪♫

The Octet rule governs reactivity of most chemical elements.

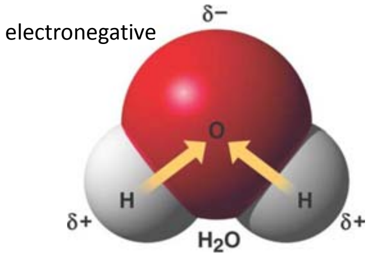


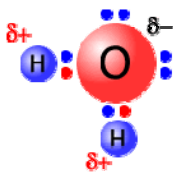
Things to ponder while lining up to get ramen (aka review).

- 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?

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

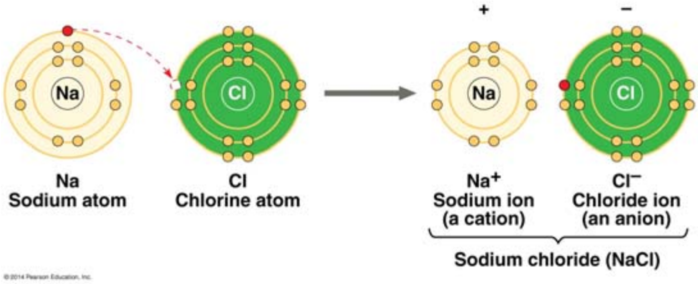
- **Covalent bonds** are made up of atoms sharing valence shell electrons in a molecule (H-H single bond, O=O double bond).
- Water: oxygen - two single bonds - hydrogen.



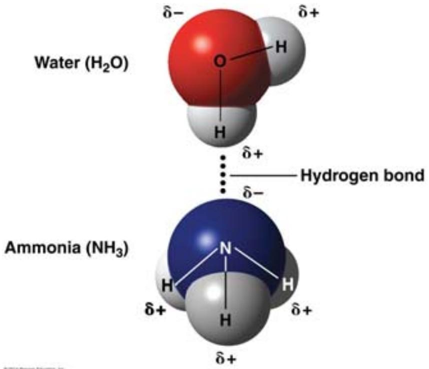


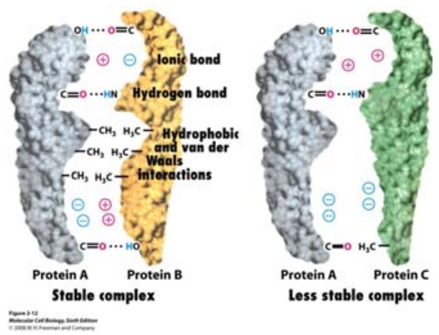
Chemical reactivity is dependent on the number of valence shell electrons.

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



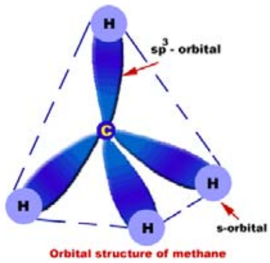
Other chemical interactions hold biological molecules together.

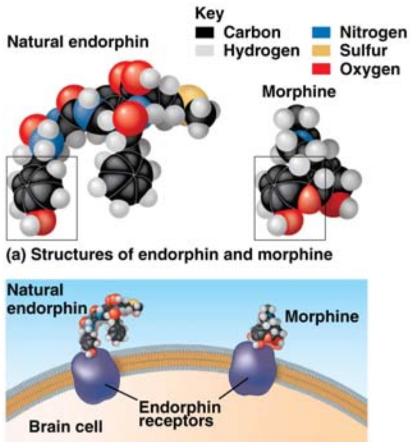




Hydrogen Bonds Hydrophobic Interactions Van der Waals forces

The 3D shape of molecules determines their biological reactivity.





(a) Structures of endorphin and morphine

(b) Binding to endorphin receptors

Chemical reactions preserve the number of atoms of each element.

- Acid-Base:

  $HCl + KOH \rightarrow KCl + H_2O$
- Combustion:

  $C_3H_8 + 5O_2 \rightarrow 4H_2O + 3CO_2 + \text{energy}$
- Photosynthesis:

  $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$
- Question: X and Y are? $2H_2 + XO_2 \rightarrow YH_2O$

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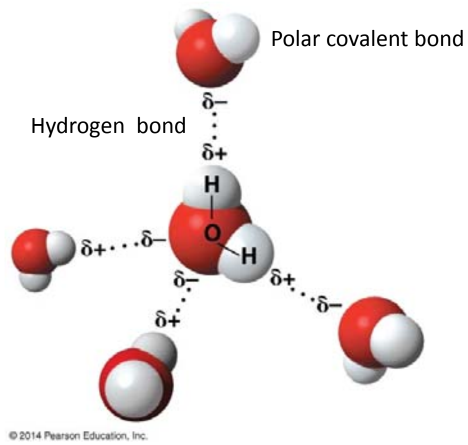
The polarity of the water molecule gives rise to hydrogen bonds.



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.

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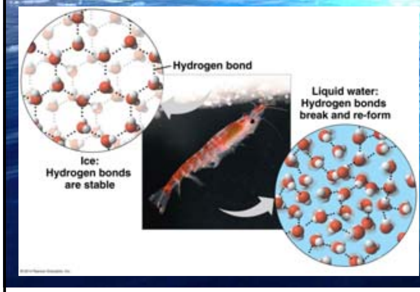
Ability of solid ice to float on liquid ice means lakes/seas won't freeze solid.



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

- Combustion:

  $C_3H_8 + 5O_2 \rightarrow 4H_2O + 3CO_2 + \text{energy}$
- 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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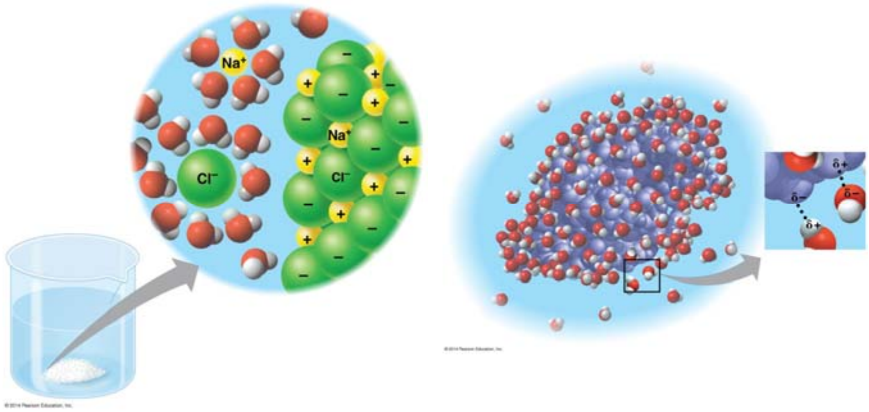
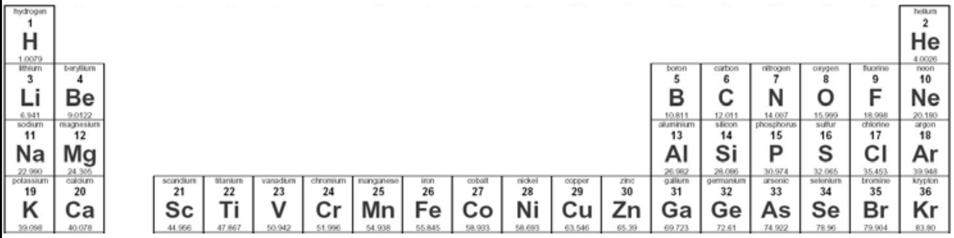
Water can dissolve almost anything due to its weak hydrogen bonding.



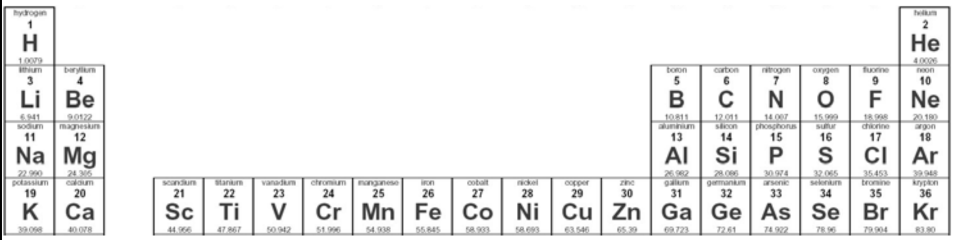
Calculating amount of materials using molar definition of mass.

- 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 x 1.0079g) + 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?

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

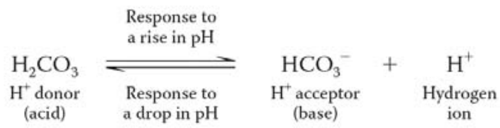


NaCl is one Na (22.99 g/mol) and
one Cl (35.453 g/mol).
So one mol of NaCl is 22.99+35.45 = 58.44 gram,
put that in one liter of water to give you
1M NaCl in H_2O.

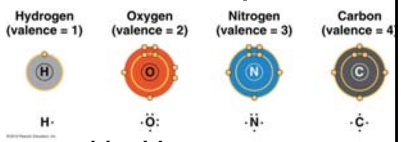


Acidic and basic solutions affect living conditions.

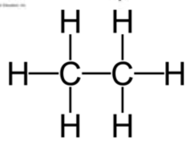
- At 25°C, $[H^+] = 10^{-7}M$, $[OH^-] = 10^{-7}M$.
- $pH = -\log [H^+]$, inversely related to hydrogen concentration.
- Neutral solution has pH 7.
- Acidic solution has pH < 7, basic has pH > 7.
- Biological buffers reduce the effect of pH changes:



The study of carbon based "life" compounds is organic chemistry.



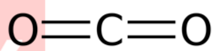
- **Miller and Urey** (12-11).
- 4 valence electrons of C:
- Single bonds (ethane C_2H_6)



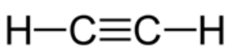
109.5°

- Double bonds (carbon dioxide CO_2)

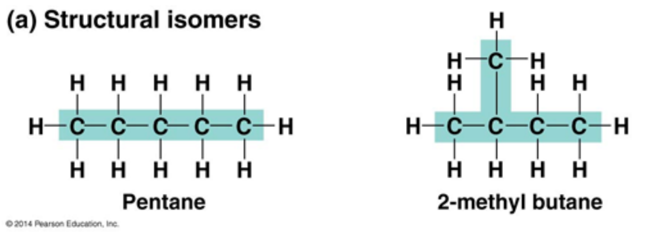
180°

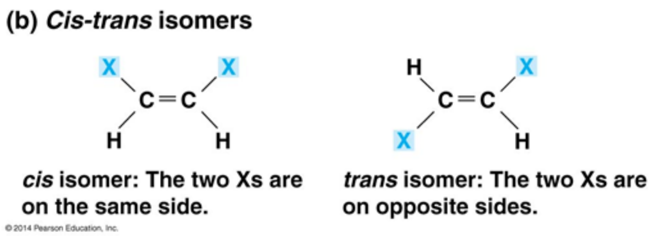


- Triple bonds (acetylene C_2H_2)



Isomers have the same number of atoms of each element.





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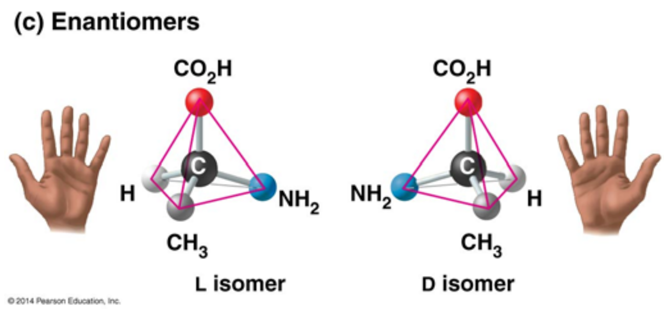

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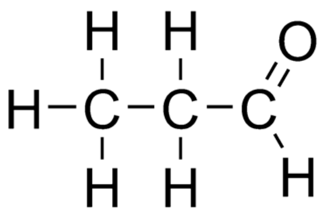
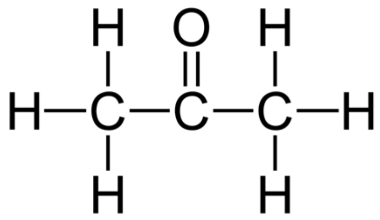
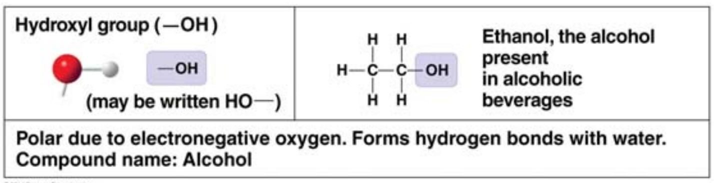
Isomers have the same number of atoms of each element.

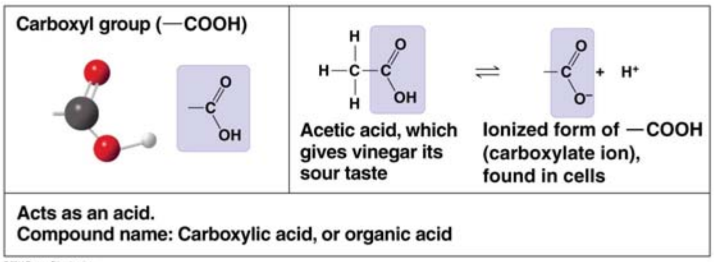
- Question: what kind of isomers are propanal and acetone?





Functional groups give “personalities” to biological molecules.





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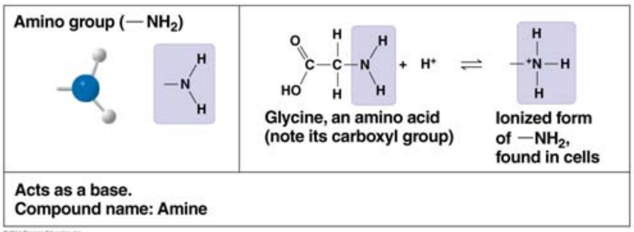

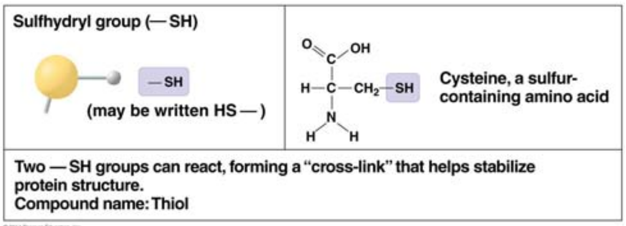

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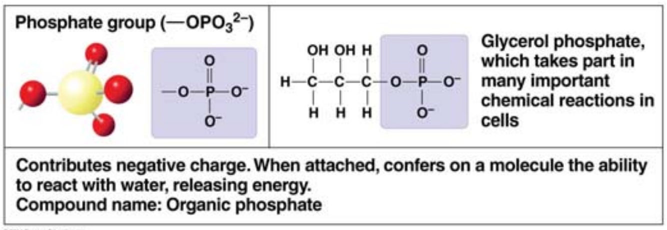
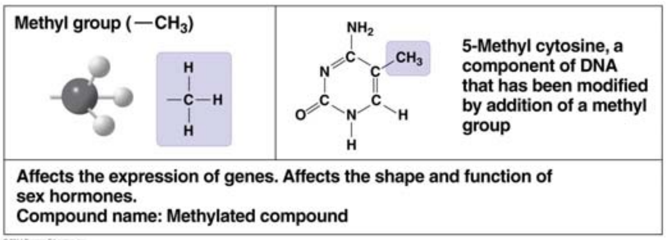
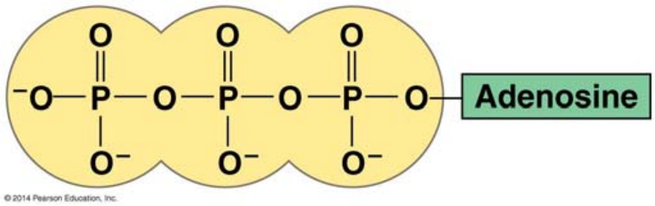
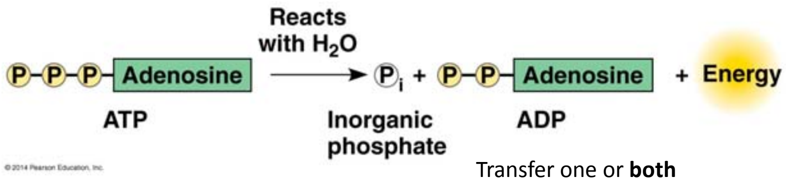




ATP is the energy "currency" of the cell.



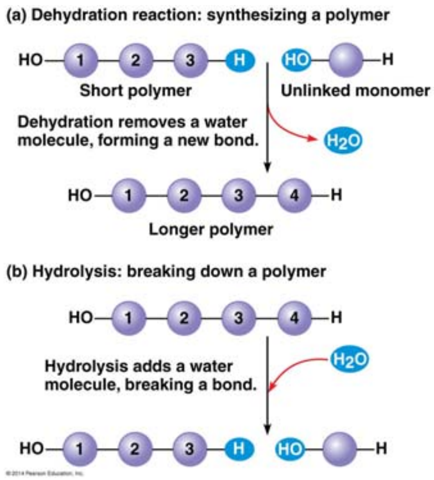


Transfer one or **both** phosphates for energy

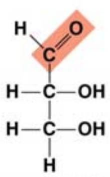
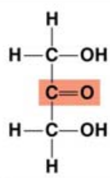
Life has three main classes of macromolecules.

- 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).

Monomers are built into polymers in dehydration reactions.

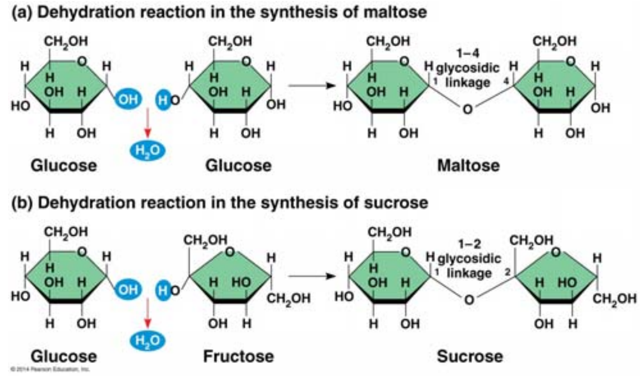


Carbohydrates are chains of sugars with carbonyl and hydroxyl groups.

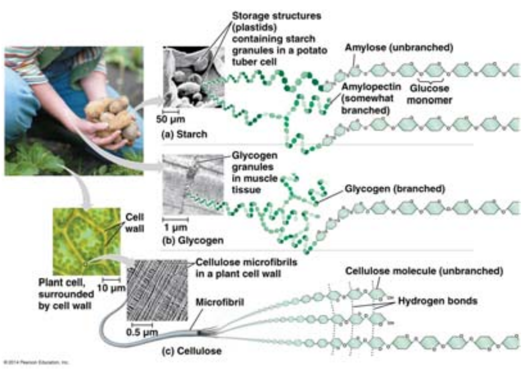
Aldose (Aldehyde Sugar)	Ketose (Ketone Sugar)
Trioses: 3-carbon sugars ($C_3H_6O_3$)	
	
Glyceraldehyde	Dihydroxyacetone

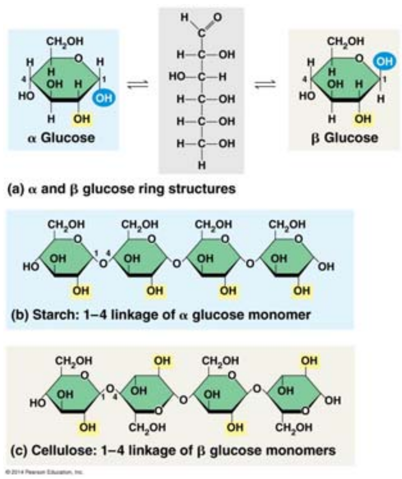
Carbohydrates monomers are joined together by glycosidic bonds.

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



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





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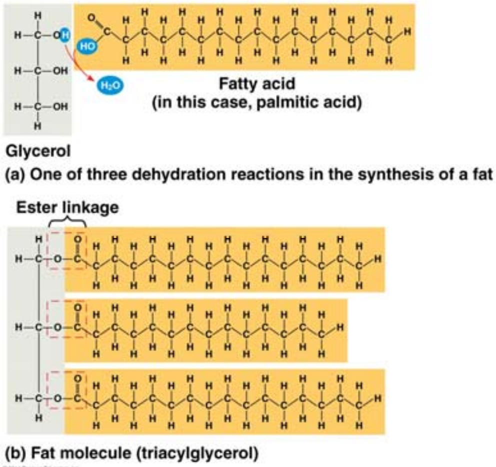
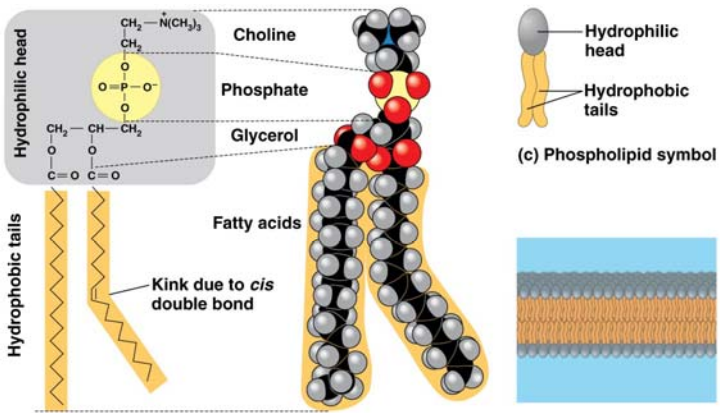
Fats are made up of glycerol and three fatty acids joined together.



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

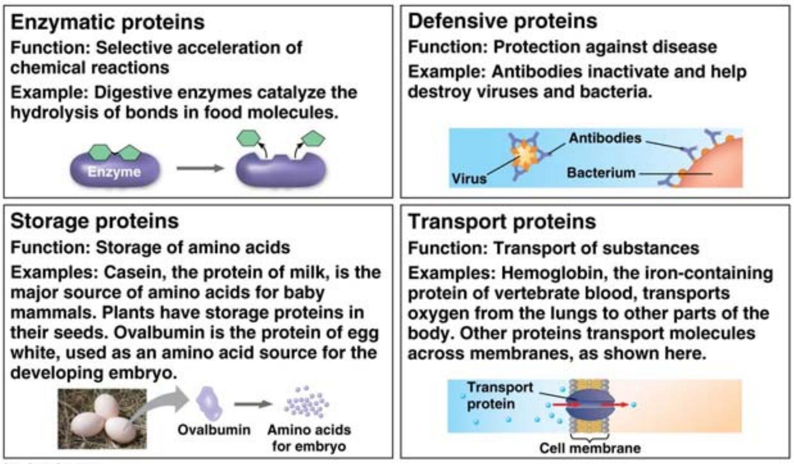
(b) Fat molecule (triacylglycerol)

Phospholipids form the (bilayer) membranes of cells.



(a) Structural formula (b) Space-filling model (c) Phospholipid symbol (d) Phospholipid bilayer

Proteins are required for diverse functions of cells.



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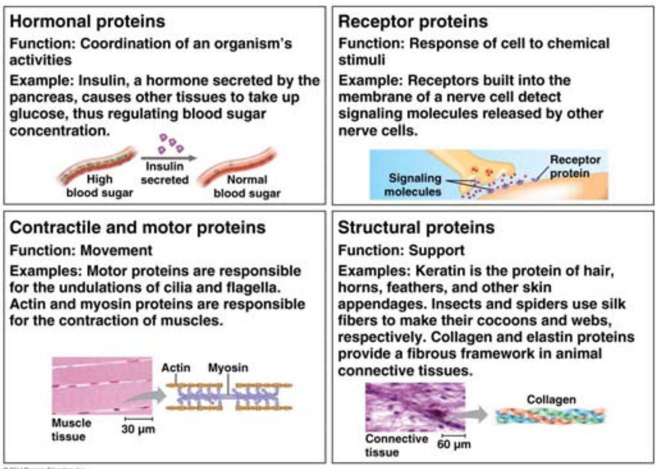
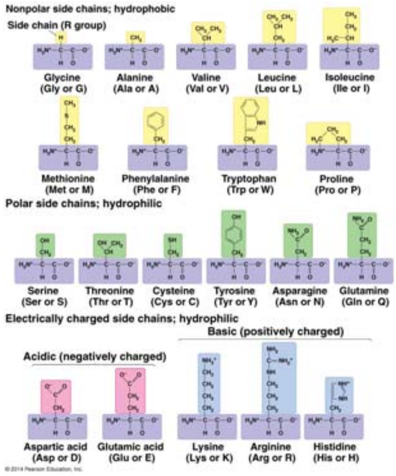
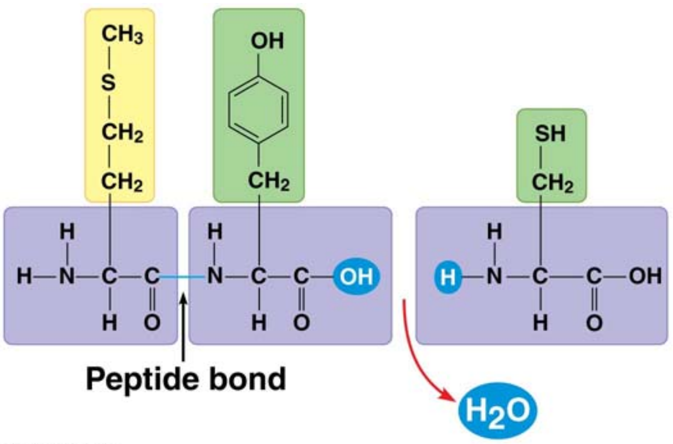


Proteins are made up of amino acids characterized by different side chains.



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.