

Chapter 2: The Chemical Context of Life

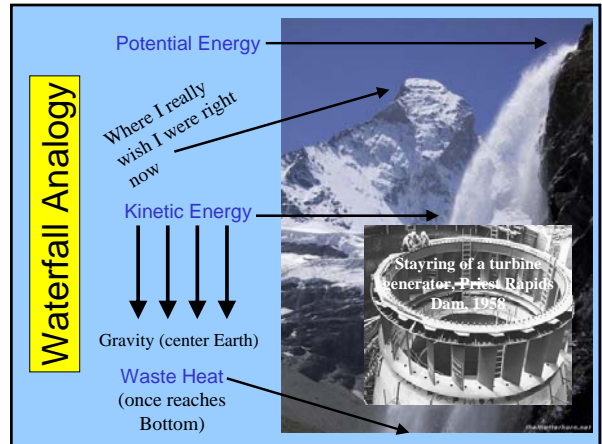
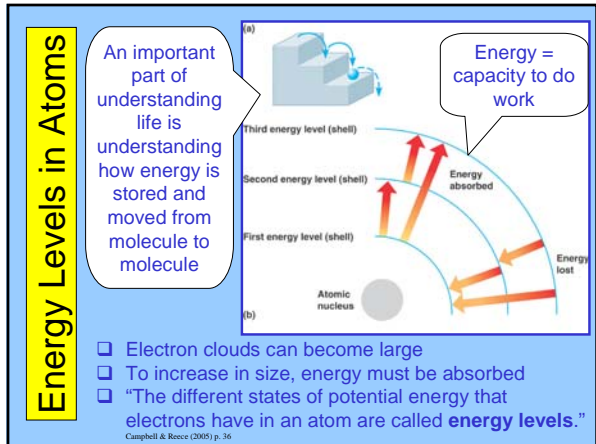
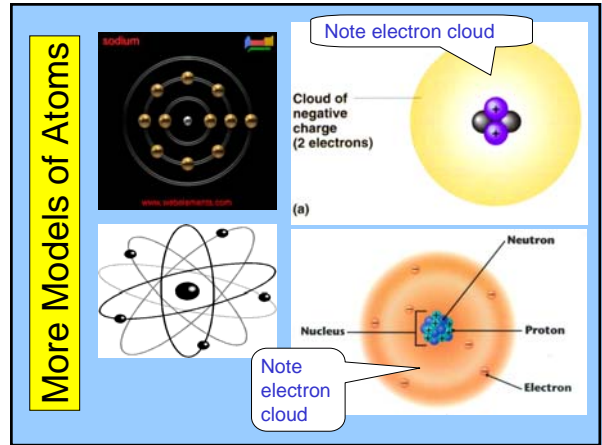
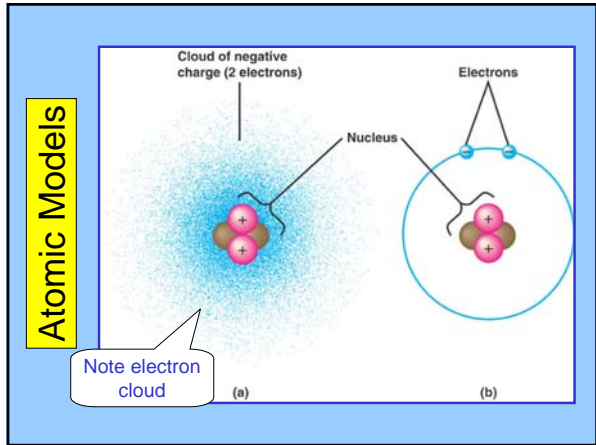
Elements in Body

Table 2.1 Naturally Occurring Elements in the Human Body

Symbol	Element	Atomic Number (See p. 34)	Percentage of Human Body Weight
O	Oxygen	8	65.0
C	Carbon	6	18.5
H	Hydrogen	1	9.5
N	Nitrogen	7	3.3
Ca	Calcium	20	1.5
P	Phosphorus	15	1.0
K	Potassium	19	0.2
S	Sulfur	16	0.2
Na	Sodium	11	0.1
Cl	Chlorine	17	0.05
Mg	Magnesium	12	0.05

Trace elements (less than 0.01%): boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn).

Trace elements are found in smaller amounts but nevertheless are essential to a healthful existence



Electrons Store Energy

Chemical potential energy is locked within chemical bonds!

The transduction of energy from one form to another, and the use of that energy to move or to create complex structures (particularly babies) is what life is all about

(a) Third energy level (shell)
Second energy level (shell)
First energy level (shell)

(b) Atomic nucleus

Electron Orbitals

Electrons exist within specific energy levels or electron shells which are probabilistic clouds surrounding nuclei; it is the quantum changes in the shape (e.g., size) of these clouds that correspond to changes in the energy associated with an electron

(a) 2p orbitals
1s, 2s, and 2p orbitals

(b) Second shell (maximum 8 electrons)
(c) Neon, with two filled shells (10 electrons)

Energy Stored in Chemical Bonds

An electron with greater energy is found at a greater distance from the nuclei the electron is associated with

Glucose
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Valence Electrons

- ❑ The electrons found in the outer "shell" of an atom are known as valence electrons
- ❑ The valence of an atom is the number of electrons an atom must receive to become chemically stable (i.e., less reactive)
- ❑ For many atoms Valence = 8 - # valence electrons
 - Oxygen: 6 valence electrons, valence = 2
 - Nitrogen: 5 valence electrons, valence = 3
 - Carbon: 4 valence electrons, valence = 4
- ❑ In Biology (even in chemistry) there are always exceptions:
 - Hydrogen: 1 valence electron, valence = 1
 - Phosphorus: 5 valence electrons, valence = 5
- ❑ These ideas of valence electrons and an atom's valence will take on more meaning as we discuss chemical bonds and molecular structure

Valences of Various Elements

1 Hydrogen ${}^1_1\text{H}$

2 Helium ${}^2_2\text{He}$

4 Boron ${}_{11}\text{B}$

3 Carbon ${}_{12}\text{C}$

2 Nitrogen ${}_{14}\text{N}$

Oxygen ${}_{16}\text{O}$

Fluorine ${}_{17}\text{F}$

Neon ${}_{18}\text{Ne}$

Sodium ${}_{11}\text{Na}$

Magnesium ${}_{12}\text{Mg}$

Aluminum ${}_{13}\text{Al}$

Silicon ${}_{14}\text{Si}$

Phosphorus ${}_{15}\text{P}$

Sulfur ${}_{16}\text{S}$

Chlorine ${}_{17}\text{Cl}$

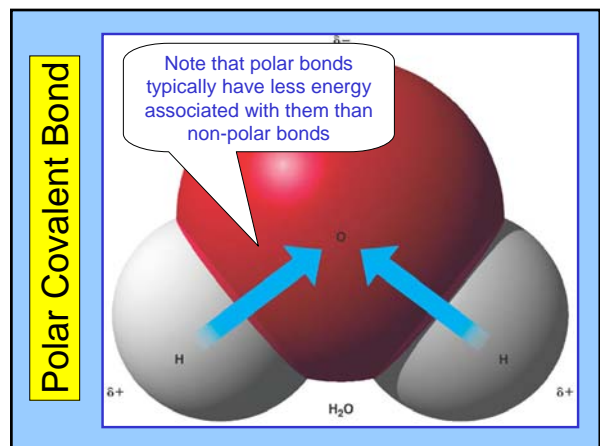
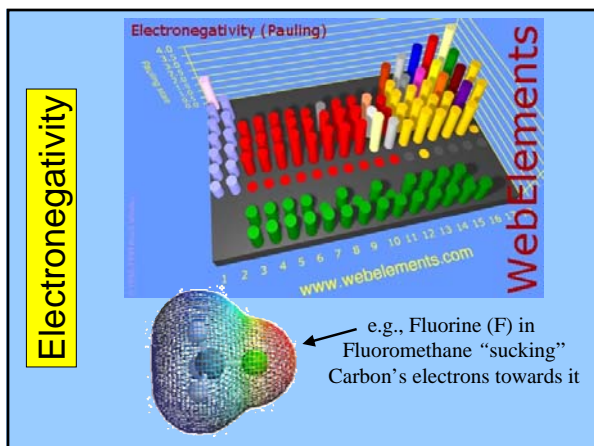
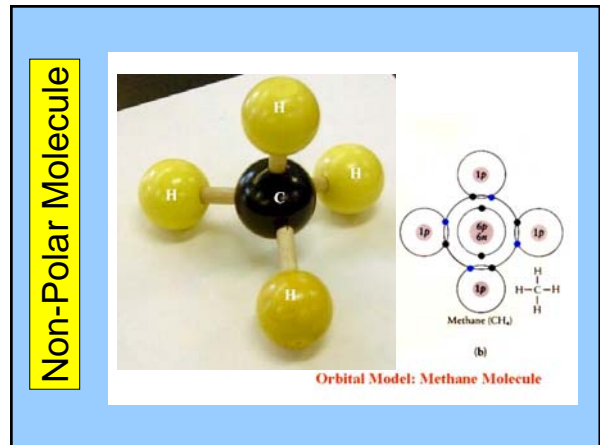
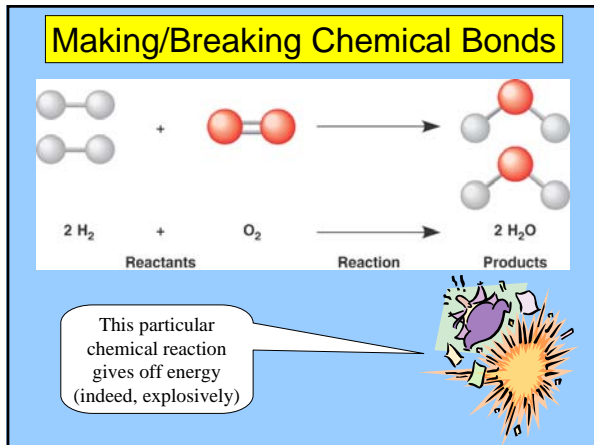
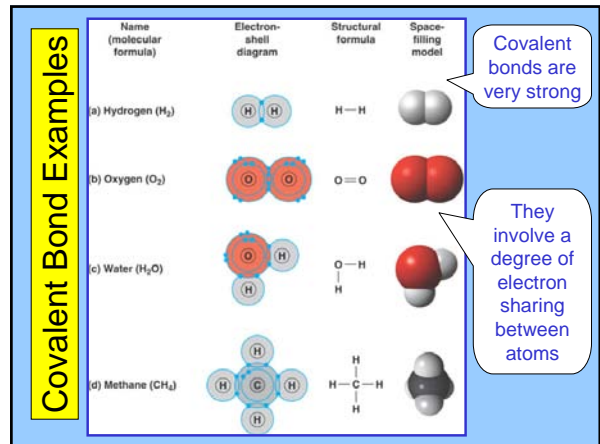
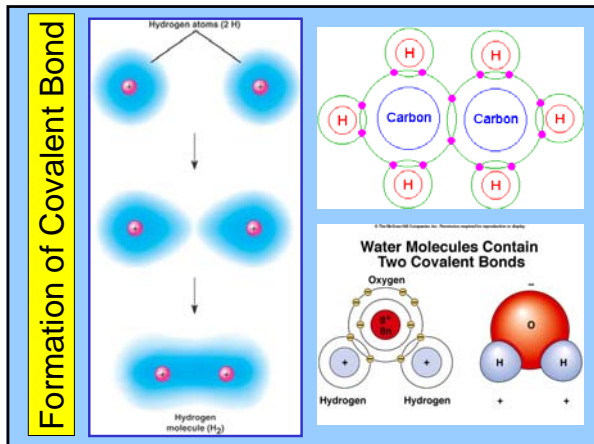
Argon ${}_{18}\text{Ar}$

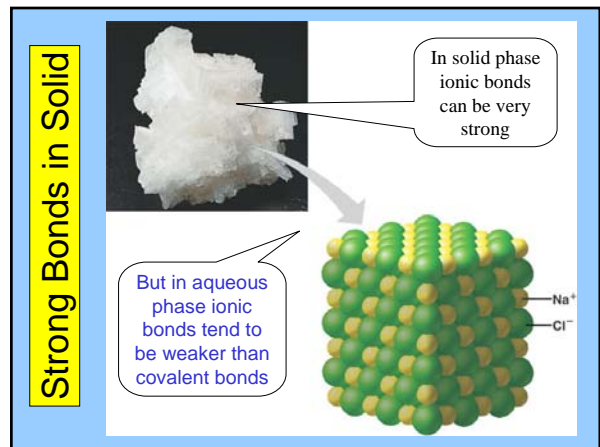
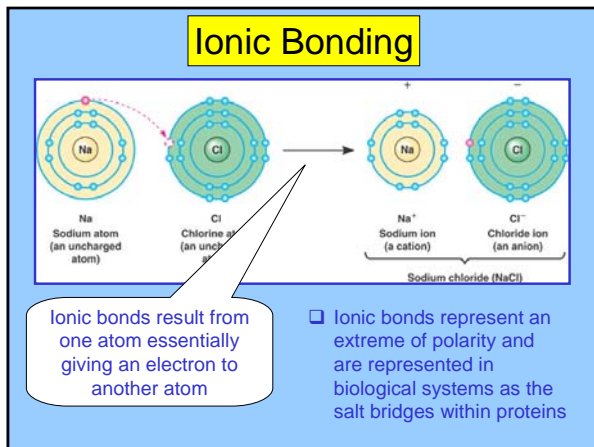
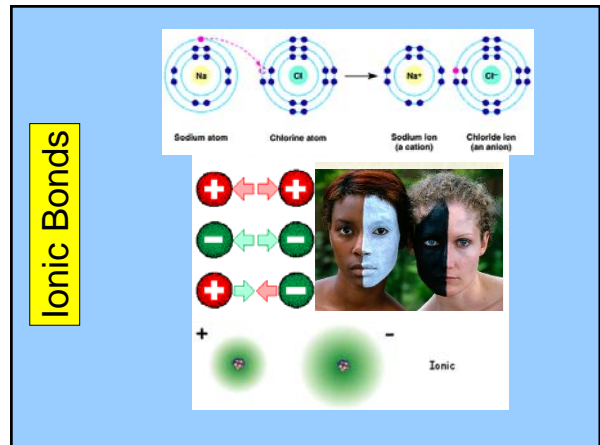
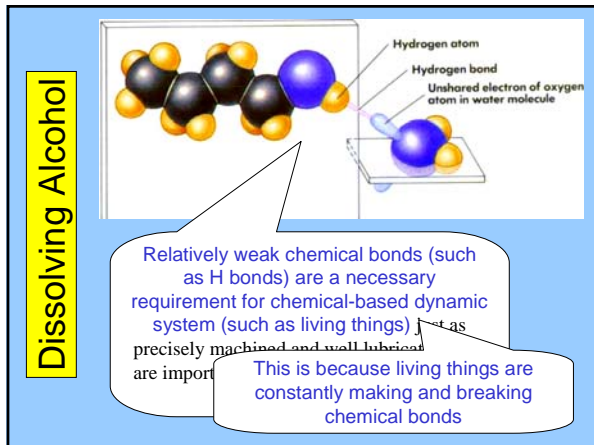
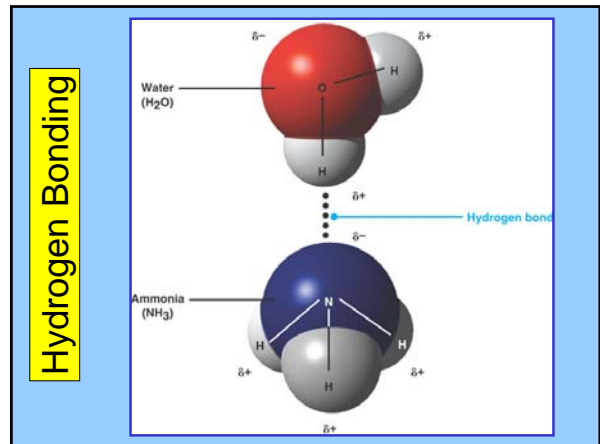
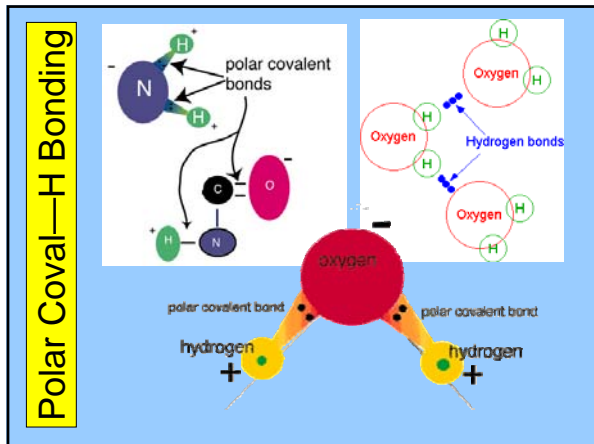
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Chemical Bonds

- ❑ When a chemical reaction occurs, what is happening is the making or breaking (or both) of chemical bonds
- ❑ Chemical bonds consist of electrons that are shared, more-or-less, between the nuclei of the bonded atoms
- ❑ The degree of sharing impacts on the energy associated with a chemical bond (and living things store most of their energy within chemical bonds)
- ❑ Greater "hogging" by one atom relative to another results in a decrease in the electron's distance from an atomic nuclei (relatively so, at least) and therefore a decrease in the amount of energy stored by the electron
- ❑ We will consider covalent bonds, polar covalent bonds, ionic bonds, and hydrogen bonds





Problem: Too Strong Bonds

If chemical bonds were universally too strong, then this making and breaking of bonds would require too much energy for life to exist (i.e., we would all be rocks)

Importance of Shape

Organisms "work" to a large extent because their molecules have specific shapes (just as their bodies have specific shapes)

Here as some simple examples of molecule shapes

FFF Morphine/Endorphin

"Molecular shape is crucial in biology because it determines how biological molecules recognize and respond to one another with specificity." Campbell & Reece (2005) p. 43

(a) Structures of endorphin and morphine

Form Follows Function

(b) Binding to endorphin receptors

FFF Phospholipids

"Only molecules with complementary shapes are able to bind to each other by weak bonds." Campbell & Reece (2005) p. 43

Van der Waals interactions

Metabolism

Coupled Reactions

$$A + B \rightarrow C + D + \text{Energy}$$

$$E + F + \text{Energy} \rightarrow G + H$$

Reactants

Products

Metabolism is the sum of all chemical reactions that go on inside of an organisms

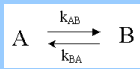
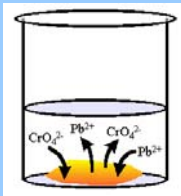
Reversible Reactions

Many (most?) biologically important reactions are readily reversible.

Often the energy required to make or break these bonds may be supplied solely by the ambient heat of the environment (e.g., your body temperature)

If the free energy difference between reactant(s) (A + B) and product(s) (D) is sufficiently small then the energy associated with ambient heat (i.e., local temperature) alone may be enough to drive a reaction backward, then the reaction is reversible.

Equilibrium



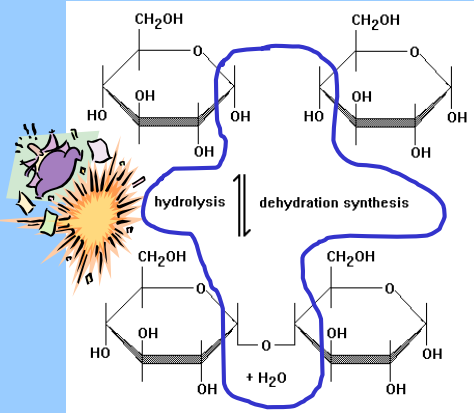
At Equilibrium the Rate of the Forward Reactions is equal to the Rate of the Reverse Reaction (note saturated solution to left)

Note that rate of Forward Reaction equals product of number of Reactant molecules (A) times the Rate Constant (K_{AB}) and vice versa (so if you have more A then equilibrium is further to right)

Equilibrium represents Maximum Disorder!

Equilibrium does not mean $[A] = [B]$!!!!

Hydrolysis/Dehydration



The End

