Human Biology- Bio 107
Chapter 2- Chemistry of Living Things

I. Basic Chemistry

A. All matter is made of elements.
Matter- anything that has mass and occupies space

1. element- pure substance that cannot be broken into simpler substance by ordinary chemical means (rxn w/ acids, heat, cooling, chemical rxns)

a. 92 naturally occurring elements Fig 2.2

b. ~90% of the Human Body consist of: See Table 2.2

Element	Symbol
Carbon	C
Hydrogen	H
Nitrogen	N
Oxygen	O
Phosphorus	P
Sulfur	S

Symbol for an element comes from the Greek:
Gold is Au (Aurum), Sodium is Na (Natrium)

B. Atom- smallest unit of an element that retains the property of that element Fig 2.3

1. Inside the Nucleus- neutrons/protons

a. neutrons- nuclear particle with no electrical charge, and an atomic mass of "1"
b. protons- nuclear particle with a positive electrical charge, and an atomic mass of "1"

The chemical identity of an atom depends upon the number of protons in its nucleus!

2. Orbiting outside the nucleus (in an electron "cloud")

a. electrons- negatively charged atomic particle

3. <u>Atomic Number</u> = the number of protons in an atoms nucleus

4. <u>Atomic Mass</u> = the number of neutrons + number of protons in an atoms nucleus

Proton = 1 Atomic Mass Unit (AMU)
Neutron = 1 AMU
Electron = 0 AMU (actually weighs 1/1837 of a proton)

What is the shorthand method for designating an element w/ it's Atomic # and mass?

C

5. Electrons exist in energy clouds around the nucleus (applies to elements in the first three energy levels only!)

Energy level	Number of Electrons Held
#1	2
#2	8
#3	8

<u>*The number of electrons that an atom has equals the number of protons in an electrically neutral atom.</u>

<u>The number and arrangement of an atoms electrons effects its chemical reactivity.</u>**

C. The Periodic Table- a reference tool for keeping track of repeating patterns of atomic reactivity and electron configuration. Fig 2.2

1. Period- horizontal rows on the periodic table
the period number corresponds with the energy shells where you find the electrons.

2. Group- vertical column on the periodic table

The "A" group numbers correspond with an atoms number of valence electrons

a. <u>Valence electrons</u>- electrons in the outer most shell of an atom.

3. **Information on the table:**
   Chemical Symbol
   Name of element
   Atomic Number = # protons (or electrons)
   Atomic Mass = # p + #n
   # Valence electrons
   Number of Energy Shells
   Number of covalent bonds it forms
   Location of metals and non-metal elements

DETERMINE the above mentioned information for the following elements:

Chemical Symbol	**Na**	**O**
Name of element		
Atomic Number = # protons		
Atomic Mass = # p + #n		
# Valence electrons		
Number of Energy Shells		
Number of covalent bonds		
metals and non-metal		

D. <u>Isotopes</u>- have the same number of protons but a different number of neutrons

Examples:

1. **The number of neutrons will affect the stability of an atoms nucleus. Atoms with unstable nuclei can break apart and emit <u>radiation.</u> Elements that emit radiation are called radioactive isotopes (radioisotopes).**

a. low level radiation- used in imaging, medical diagnostics

b. high level radiation- can harm cell by damaging DNA or other important molecules in the body.
1) used in cancer treatment

II. Molecules and Compounds

A. molecule- two or more atoms held together with a chemical bond

B. Compound- two or more different elements held together with a chemical bond

C. Two types of Chemical Bonds: Table 2.1

1. Ionic Bonds- bond between atoms with opposite electrical charges Atoms develop an electrical charge by either giving up or adding electron(s). Fig 2.6

Atoms give up or add electrons in order to have a completely filled outer energy shell!

a. ion- an atom with an electrical charge

Example: Sodium Chloride (Table Salt)

2. Covalent Bonds- bonds formed from the sharing of electrons Fig 2.5

Atoms will share electrons to get a completely filled outer energy shell. Share electrons to have an "octet" (8). (Except H, He- which only can hold 2 e-)

Two Kinds:
a. Non-polar covalent Bonds- equal sharing of electrons

Structural Formula:

H - H **O = O** **Cl-Cl**

Molecular Formula: H_2 O_2 Cl_2

Hydrogen **Oxygen** **Chlorine**

<u>A bond "-" represents a shared pair of electrons</u>.

One, two, or three pairs of electrons may be shared
(Single, double or triple bonds)

Same element on each side of a bond means equal sharing!

b. <u>Polar Covalent Bonds</u>- unequal sharing of electrons

Different elements on each side of a bond means polar bond.
Structural Formula:

```
   O
  /  \
 H    H
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O = C = O

Molecular Formula:

H_2O **CO_2**

Water **Carbon Dioxide**

III. Water – most abundant molecule in living things (60-70% total body weight)

A. Water has <u>polar bonds</u> but is also a <u>polar molecule</u>.

B. Molecular polarity: To determine the polarity of a molecule you must examine the bond polarity as well as the molecules shape. (Molecular polarity has a tremendous influence on numerous factors important for life to exist.)

1. <u>Non-polar Molecule</u>- the sum of the partial positive and partial negative charges occur at the same place in the molecule.

2. <u>Polar Molecule</u>- the sum of the partial positive and partial negative charges occur at different places in the molecule.

C. <u>Hydrogen Bonds</u>- occurs when the partial negative charge of the oxygen atom on a water molecule is attracted to a partially positive charge of a hydrogen atom on a different water molecule. Fig 2.7

Has a huge influence on properties of water!

D. Properties of water:

1. liquid @ room temp. most molecules w/ similar molecular mass are gases @ room temp.

2. good solvent (for other polar molecules and ionic compounds) Fig 2.8
Hydrophilic- (water loving) readily dissolve in water
Hydophobic- (water fearing) do not mix with water

3. water molecule are cohesive (attracted to each other). Why?

4. liquid water temperature raises and lowers slowly.
Calorie- amount of heat needed to raise 1 g of water 1 degree Celsius
Important in maintaining homeostasis

5. High heat of vaporization- allows for evaporative cooling

6. Frozen water is less dense than liquid water

IV. Acids/Bases/pH Fig 2.11

Water molecules can break apart into ions.

$H_2O \leftrightarrow H^+ + OH^-$

A. $pH = - \log [H^+]$

[H+]		pH
$1 \times 10^{-1} =$	0.1	1
$1 \times 10^{-2} =$	0.01	2
$1 \times 10^{-3} =$	0.001	3
$1 \times 10^{-4} =$	0.0001	4
$1 \times 10^{-5} =$	0.00001	5

1×10^{-10} = 0.0000000001 10
1×10^{-14} = 0.00000000000001 14

The concentration is Expressed in MOLARITY!

a "MOLE" is a qty of atoms or molecules.
1 MOLE = 6.02×10^{23}

B. Acids- produce H^+ in solution.
$[H^+] > [OH^-]$

C. Bases- produce OH^- in solution.
$[H^+] < [OH^-]$

D. pH Scale- runs from 0-14 Fig 2.10

1. pH 7 is neutral

2. pH < 7 is acidic

3. pH > 7 is basic (alkaline)

E. <u>Buffers</u>- molecules that in solution absorb or produce H^+ or OH^- in order to resist changes in pH.

There are many Biologically important buffers:
Bicarbonate Buffer in blood

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- + H^+$$

V. Organic/Inorganic Molecules Table 2-2

A. <u>Organic Molecules</u>-
a. consist mainly of carbon and hydrogen
b. linked by covalent bonds
c. often very large molecules with many atoms

B. <u>Inorganic Molecules</u>
a. may consist of ions
b. may have ionic or covalent bonds

c. always have small numbers of atoms

C. Isomer- same chemical formula but different structural formula.

C_2H_6O

VI. Molecules of Life-

Organic Molecules- formed from molecules w/ carbon backbones Fig 2.12

A. macromolecules Fig 2.13

1. Dehydration synthesis rxns form them

a. polymers are constructed by linking many similar subunits (monomers)

2. hydrolysis rxns break them down

a. polymers are broken down into monomers

B. Carbohydrates $(CH_2O)_n$

1. Simple Carbohydrates Fig 2.14

a. monosaccharides- glucose, fructose, galactose

b. disaccharide- sucrose (glucose + fructose), lactose (glucose + galactose), maltose (glucose + glucose)

c. oligosaccharides- 2-15 monosaccharides linked together

2. Complex Carbohydrates (polysaccharides)- long chains of glucose (branching of the chains varies) act as E storage molecules Fig 2.15

a. glycogen- E storage molecule in animals

b. starch- E storage molecule in plants

c. cellulose- structural component in plants

d. conjugated- contain carbs and other molecules as well

1. glycolipids, glycoproteins

B. Lipids- (fats, oils, fatty acids (FA's)) contain C, H, O and are Hydrophobic. Fig 2.16, 2.17

Contain more E gram/gram than any other biological molecule!

1. **<u>Triglycerides</u>- three FA chains attached to a 3 carbon glycerol molecule**

2. **<u>Saturated FA's</u>- contain no double bonds, all carbons are saturated w/ hydrogens**

3. **<u>Unsaturated FA's</u>- contain one or more double bonds, "bent"**

4. **<u>Phospholipids</u>- triglyceride w/ two FA chains and one phosphate groups attached Fig 2.17**
   1. **phosphate head is hydrophilic (polar)**
   2. **FA tail is hydrophobic (non-polar)**

5. **<u>Steroids</u>- examples: fats that act as sex hormones, cholesterol Fig 2.18**

C. <u>Proteins</u>- polymer made of monomers of amino acids (AA's)
(Peptide bond- a bond between two amino acids formed thru dehydration synthesis! Fig 2.20)
(20 different kinds of AA's- Fig 2.19)

oligopeptide: <15 AA's polypeptide: > 15 AA's

1. **<u>Protein organization</u>- proteins have complex folded structures that dictate their function Fig 2.20, 2.21**

   FOUR PROTEIN STUCTURES:
   a. <u>Primary</u>- a simple chain ofAA's linked together w/ peptide bonds

   b. <u>Secondary</u>- a more complex folding of the primary structure due to bonding between AA's that forms sheets, helixes, and coils.

   c. <u>Tertiary</u>- additional complex 3-D folding of the protein.

   d. <u>Quartenary</u>- combining of numerous tertiary proteins into a single large functional mass.

Require specific conditions to function- i.e.- pH, temps- (Otherwise the may "denature")

c. <u>Enzymes are a special type of protein that facilitates chemical rxns</u> (regulate metabolism) Fig 2.22

1. Protein Quaternary structure forms an enzymes "active site"
2. "substrate molecules" can bind to this active site.
3. enzyme changes shape and can cause bonds to form (or break) in a substrate molecule.
4. enzyme releases new substrate product
5. enzyme can then repeat the process.
Enzymes are not "used up" in a chemical rxn!
They are used again and again. They "catalyze" chemical rxns!

3. metabolic pathways- series of enzymes that work in sequence

D. <u>Nucleotides, Nucleic Acids, and ATP</u>

1. <u>ATP</u> (adenosine triphosphate) – carries energy for the cell Fig 2.26

a. product of "cellular respiration" (aerobic and anaerobic) (break down of sugars into energy)

b. E stored in the bonds between the phosphate groups
Break a phosphate bond? Energy is released to do cellular work!

2. <u>Nucleic Acids</u>- polymers composed of monomers of <u>nucleotides</u> (store genetic information)

1. <u>DNA</u>- (deoxyribonucleic acid) holds genetic information

Four nucleotides named for their bases:
Adenine, Thymine, Guanine, Cytosine Fig 2.23
A-T and C-G
a. contains nitrogen base, deoxyribose sugar, phosphate group
b. DNA is "double stranded" Fig 2.24
1. runs in opposite directions- "antiparallel"

2. RNA- (ribonucleic acid) transfers genetic information from nucleus to cytoplasm so proteins can be made

Four nucleotides named for their bases:
Adenine, URACIL, Guanine, Cytosine Fig 2.25

a. contains nitrogen containing base, ribose sugar, phosphate
b. single stranded