بسم الله الرحمن الرحيم

King Saud University

College of Science

Department of Biochemistry

General Biochemistry-I (BCH 201)

Chapter 1:

Introductory Biochemistry

Prepared by Dr. Farid Ataya

http://faculty.ksu.edu.sa/75112

BCH 201

General Biochemistry-1

- Course Symbol & No. : BCH 201
- Credit Hours : 3 (3+0)
- Prerequisite : CHEM103
- Class schedule : Sunday, Tuesday, Thursday
  1:00 pm to 1:50 pm.
- Class location : AA35 building No. 5
- Examinations : Continuous Assessment Tests (CAT)
  - First (30 Marks) Sun, 10/05/1436h – 01/03/2015
  - Second (30Marks) Tues, 07/6/1436h – 26/4/2015
  - Final (40 Marks)

Course Objectives

- **To familiarize students with knowledge of:**

i. basic biochemistry needed for higher level courses
ii. chemical concepts with particular reference to chemical process found within living cells (chemical bonds, functional groups, equilibrium, and energy)
iii. structure and properties of water and buffers
iv. building blocks of cellular components
v. structure and properties of amino acids, peptide bond
vi. structure and properties of proteins and structural & functional classification of proteins
vii. introduction to enzymes and metabolism
viii. Introduction to sugars and carbohydrates
ix. Introduction to fatty acids and lipids

Course Description (1_cont.)

Topics	Weeks	Lectures
Definition and Introduction: General introduction to Biochemistry Elements: Atoms (C, O, H, etc) and essential elements (Mg, Ca, etc), versus earth composition. Biomolecules: H_2O, amino acids, saccharides, nucleic acids, lipids, vitamins, and heme) Assembly of molecules (proteins, DNA, RNA, carbohydrates, membranes) Biochemistry pathways: information (molecular biology) versus Structural (chemistry); Living versus nonliving Organelles, cells and organisms	2	1-6
Chemical Concepts- importance to biochemistry: Chemical bonds: Covalent, ionic, hydrogen bond, hydrophobic interactions, Van der Waals interactions. Functional groups. Chemical Equilibrium Free Energy	2.66	7-14
Structure and Properties of water: Structure of water. Hydrogen bonding and solubility of molecules. Surface tension. Expansion upon freezing. High boiling point. Ionization of H_2O Weak acids and bases (pH and pK and Handerson Hasselbalch equation Buffer systems	1.66	15-19
1st Continuous Assessment Test	**0.33**	**20**

Course Description (2_cont.)

Topics	Weeks	Lectures
Amino acids: Definition and types of amino acids Function of amino acids Functional groups in amino acids Structure and classification of standard amino acids Properties of amino acids (polarity; stereoisomerism; light absorption; ionization) Modification (hydroxylation; phosphorylation; methylation; disulfide bridges etc)	2	21-26
Proteins: Peptide Bonds (formation, structure and properties) and terminology; Amino acids residues versus polypeptide and proteins. Protein structure (primary, secondary, tertiary, and quaternary) Protein folding (amino acids → secondary elements → motifs→ domains→ subunits) Protein denaturation Structural classification of proteins (fibrous and globular proteins: representatives of all-alpha, all-beta and alpha/beta proteins) Functional classification of proteins: enzymes, immunoglobulins; transport (O_2, fatty acids), regulatory (hormones etc), structural and movement, with examples Simple and complex proteins (metal ions, cofactors, lipids, carbohydrates etc) Introduction to enzymes and metabolism	2	27-32
2nd Continuous Assessment Test	**0.33**	**33**

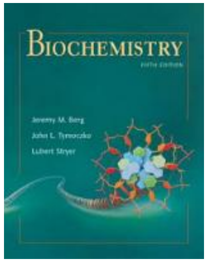
Course Description (3_cont.)

Topics	Weeks	Lectures
Carbohydrates: Definition and types of sugars Structure of monosaccharides and disaccharides Differences between polysaccharides (starch, glycogen and cellulose)	2	34-39
Lipids: Structure of fatty acids (saturated vs unsaturated f.a.) Types of lipids Chemical properties of fatty acids Physical properties of fatty acids Structure of cell membrane	1	40-42
Final exam	**--**	**--**

Books

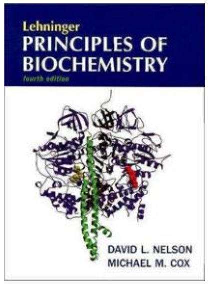
- **Biochemistry** by Stryer

(latest edition)



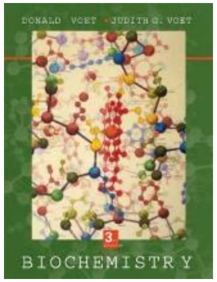
- **Lehninger: Principles of Biochemistry**

by DL. Nelson and MI. Cox (latest edition)



- **Biochemistry.**

by D. Voet and J. Voet (latest edition)



What is Biochemistry?

- Biochemistry is the chemistry of the living cell.
  - It describes in molecular terms the structures, mechanisms, function and chemical processes shared by all living organisms.
  - It provides fundamental understanding of the molecular basis for the function of living things.
  - It provides a broad understanding of the molecular basis of life.
  - It explains what goes wrong to produce a disease.
- Examples:
  - The chemical structures of biomolecules.
  - Interactions leading to formation of supermacro-molecules , cells, multi-cellular tissues, and organisms.
  - Bioenergetics of the reactions in the cell.
  - Storage and transmission of information.
  - Chemical changes during reproduction, aging, and death of cells.
  - Regulation of chemical reactions inside living cells.

Principal Areas of Biochemistry

- **Structure-function relationship:**
  - Structural Chemistry for proteins, carbohydrates, DNA/RNA, lipids, and every other component in the cell.
  - Functions of these components
  - Relationship between structure and function.

- **Metabolism**:
  - Catabolism: Pathways of chemical reactions leading to the breakdown of molecules
  - Anabolism: pathways of chemical reactions leading to synthesis of molecules.
  - Bioenergetics of reaction as well as management of cellular Energy.

- **Cellular communication**
  - Storage, transmission, and expression of genetic information
    - DNA replication and protein synthesis.
  - Cell-cell communication & interaction
  - Signal transduction

History of Biochemistry

Biochemistry is only about 100 year-old science:
Some major events in its history.

1990 — Gene Therapy

1970 — PCR & Recombinant DNA

1966 — Genetic codes unveiled.

1959 — 3-D structure of hemoglobin

1953 — Watson and Crick proposed the double helix for DNA

1944 — Avery, MacLeod, and McCarty showed DNA to be the agent of genetic transformation.

1937 — Krebs elucidated the citric acid cycle.

1926 — Sumner crystallized urease.

1925 — The glyclolytic pathway revealed

1897 — Buchner : in-vitro experiment with cell extracts.

1869 — Miescher isolated nucleic acids.

1828 — Wohler synthesized urea from ammonium cyanate

Inorganic → organic

$NH_4CNO \rightarrow CO(NH_2)_2$

What is the matter?

- **The matter** is anything that has mass and volume (occupies space).
  - -In chemical point of view matter is made up of atoms.
  - -Atoms are formed from nucleus (having protons and neutrons) and circulating negatively charges electrons.
  - -Atoms having specific numbers of protons form elements
  - -There are 118 elements on the periodic table 92 of them are natural.
  - -All living and non-living matter are made of elements.
  - -Group of elements can form molecules of compounds.

In biochemistry, we are interested in the chemical structure and reactions in living cells.

So, the introduction for biochemistry is the study of the living cell.

The origin of Life

- Living matter consists of some chemical elements.
- Those elements bind together to form molecules.
- Most of compounds in Biological systems are organic compounds (have Carbon)
- Chemical compounds have reactive functional groups that participate in biological structure and biochemical reactions.
- Polymerization of organic molecules form more complex structure by the mean of condensation reaction with the removal of water.
- The key of origin of living matter is the formation of membranes that separate the critical molecules required for replication and energy capture.
- Larger polymers of molecules form macromolecules that all together provide biological specificity of the living matter. E.g. carbohydrates, proteins, lipids, genetic material (DNA and RNA) etc.

Biological Hierarchies

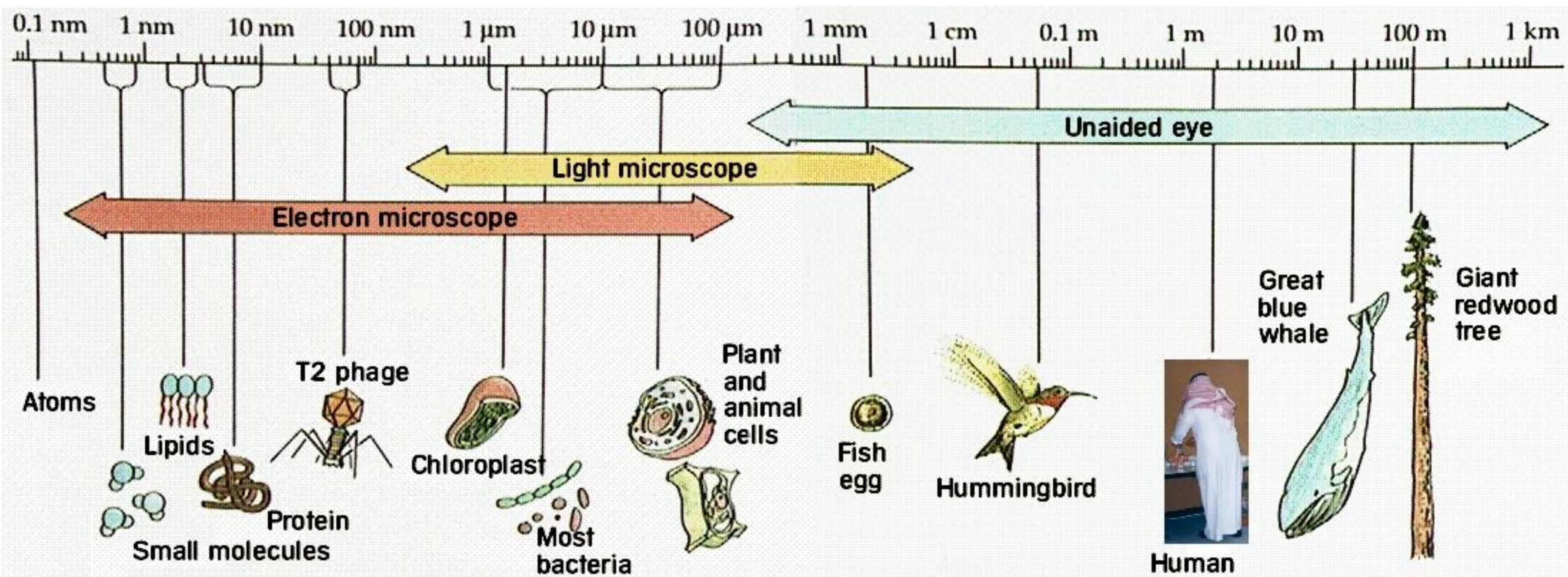
- Biological Hierarchy: Simple Molecules are used to Build Complex Structures

Elements → Molecule → Cell → Tissue → Organ → Organism → Population →Species → Biosphere

- Relative sizes (or ranges) for some biological things, and the resolving power of available tools!

▪Note that the scale is logarithmic.

▪Remember: 1 m = 10 dm = 100 cm = 1000mm = 10^6 µm =10^9 nm = 10^{10} A°



Cell Theory

The cell theory is proposed and developed in the 1600-1800s. The main parts of the cell theory today are:

- Cell is the smallest unit of living matter.
  - Don’t confuse this with electrons, protons, atoms, proteins, DNA, etc. These are lifeless molecules
- Cell is the structural & functional unit of all organs and/or organisms.
- All organisms are composed of one or more types of cells.
- All cells come from pre-existing cells by division.
  - Spontaneous generation does not occur.
  - Cell is capable of reproduction.
- Cells contains hereditary information which is passed from cell to cell during cell division.
- All energy flow (metabolism & biochemistry) of life occurs within cells.

Typical Cells

- Cells from different organisms have different shapes, structures, and sizes.
- All cells have protoplasm.

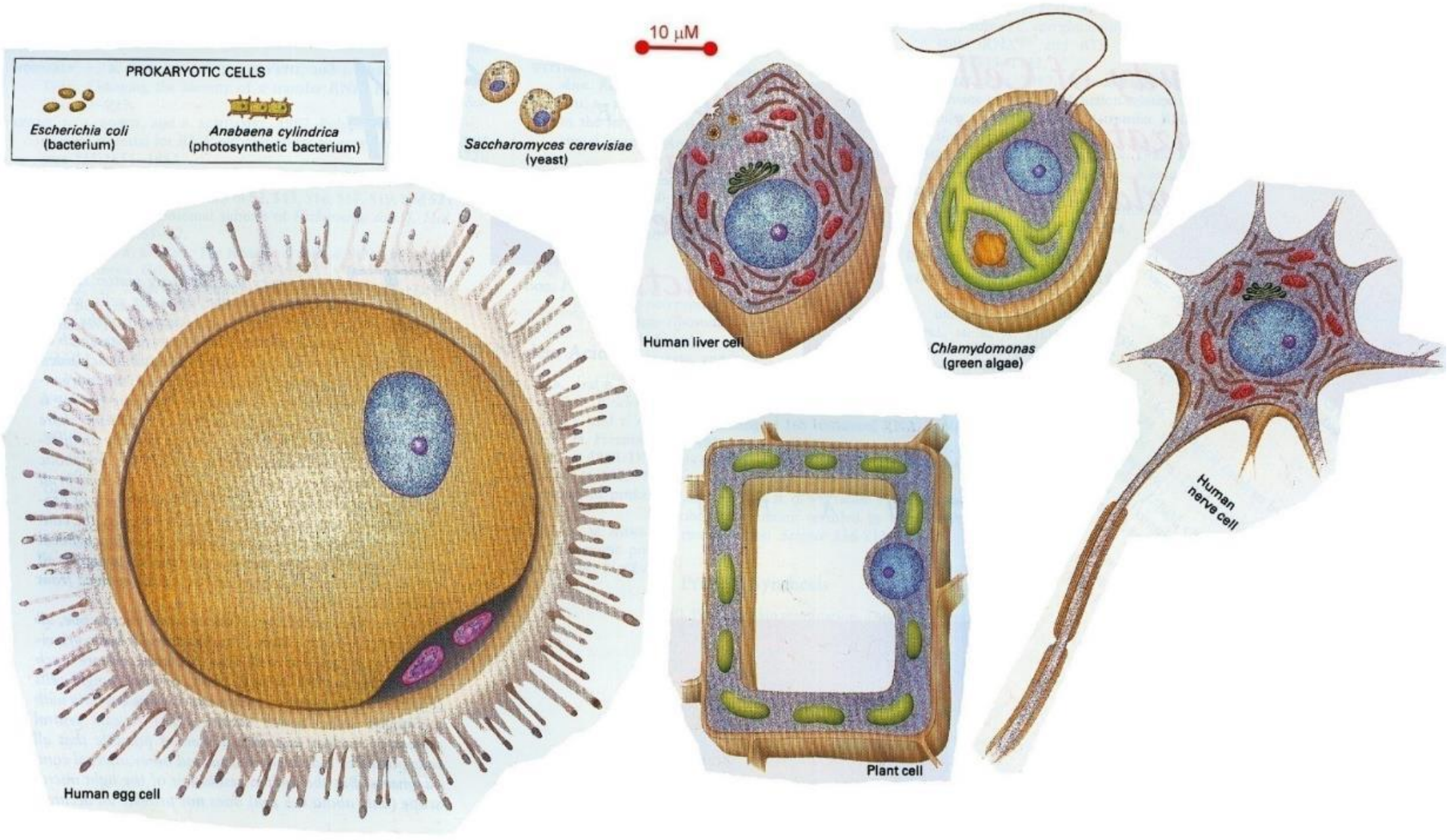
- They are usually divided into two broad groups: Eukaryotes and Prokaryotes.
  - Eukaryotic cells (Eu = true; kary = nucleus): have a membrane-bound nucleus and a variety of organelles and internal membranes.

  - Prokaryotic cells (Pro = before) are smaller (a general rule) and lack much of the internal compartmentalization and complexity of eukaryotic cells; No membrane-bound nucleus or other organelles.

  - Viruses do not always conform to cell theory:
    - one or more of the basic cell components is missing.
    - Inside the host cell, viruses are living matters.

Sizes and Shapes of Cells

Notice: Cells in the figure is represented according to the proportion of its size using the suitable scale.



Prokaryotes

- Prokaryotes; all in one!!
  - It shows a limited range of morphologies but very diverse metabolic capabilities.
- Prokaryotes are often single-celled organisms.
  - Do NOT have true nucleus or organelles.
  - Most have circular or “looped” DNA
  - lack much of the internal membranous compartmentalization
  - Mainly unicellular organisms
- Prokaryotes are divided into two major lineage:
  - Eubacteria (true bacteria): inhabit soils, surface waters, and the tissues of other living or decaying organisms. Most of the well studied bacteria, including *Escherichia coli*, are eubacteria.
  - Archeabacteria (Greek *arche*-, “origin”): most inhabit extreme environments—salt lakes, hot springs, highly acidic bogs, and the ocean depths. It includes:
    - Methanogens (oxygen-free milieus)
    - Halophiles (require high concentrations of salt)
    - Thermophiles (live in hot regions, 80^{o}C, in a pH< 2)

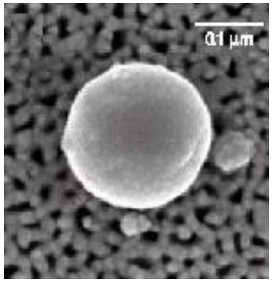
Prokaryotic Cells

Prokaryotes have different shapes:

- Rode-like (Bacillus)
- Round (Coccus)
- Thread-like (Spirillum)

Bacillus-

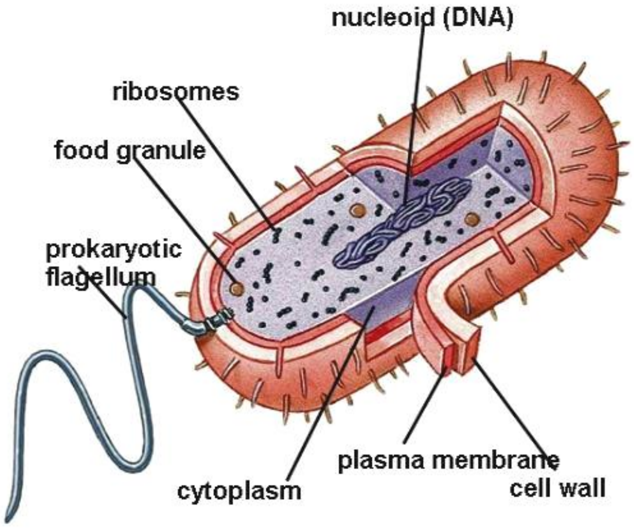
Coccus-



Spirillum-

The typical model of prokaryotes has:

- cell wall (capsule or pili),
- cell membrane,
- nucleoid region, Contains a single, simple, long circular DNA.
- Ribosomes (site of protein synthesis)
- Flagella (for movement)



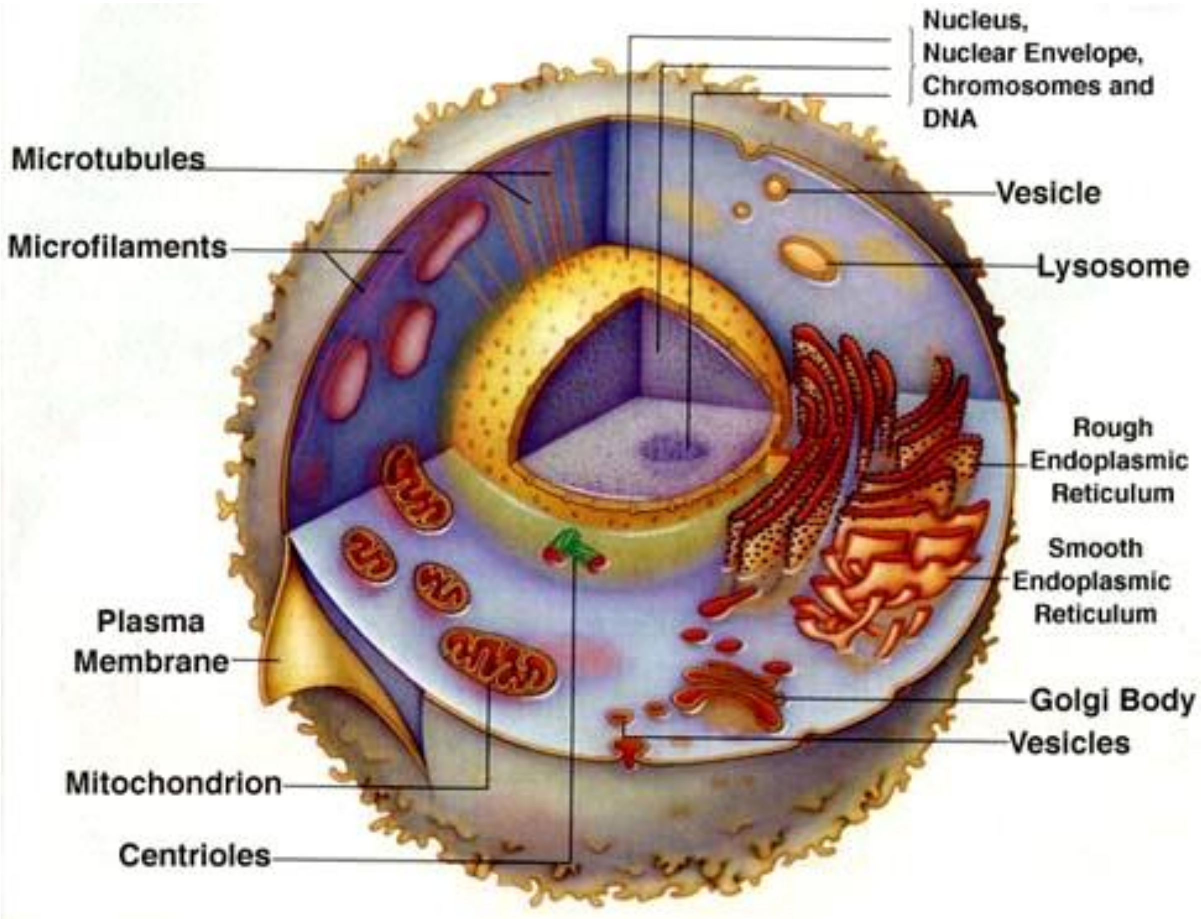
Eukaryotic Cells

- Eukaryotes are found in Animal, Plant, Protists, and Fungi kingdoms
  - Few eukaryotes are single-cell but the majority are multicellular organisms
    - So, not all unicellular organisms are eukaryotes because bacteria are unicellular prokaryotic organisms
    - On contrary, all multicellular organisms are eukaryotes

- Eukaryotic cells are complex cells (different sizes, shapes, and structures) and specialized but they all have:
  - Membrane-bound nucleus which contains the cell's genetic material; DNA
  - Organelles, each is surrounded by a membrane or two like lysosome, Golgi bodies, endoplasmic reticulum, mitochondria, etc
  - Eukaryotic DNA is organized in linear structures (chromosomes), associated with proteins (histones)

Generic Animal Cell (cont.)

- Animals have a variety of cells that differ in shapes, structures, and sizes.
- A model structure is shown as follow:



Generic Animal Cell (Cont.)

- The animal cell is surrounded by lipid bilayer plasma membrane.
- The content inside the plasma membrane is called protoplasm. It contains many organelles and subcellular structures as:
  - **Nucleus:** contain the genetic materials and surrounded by porous nuclear membrane. It contains liquid called neucleoplasm.
  - **Ribosome:** the site of protein synthesis. It is a group of protein subunits and ribosomal RNA.
  - **Mitochondria:** the site of energy production. It is a double –walled organelle having many enzymes for energy production (The Power House). The inner membrane is highly folded to increase the area of energy production. The number of mitochondria increases as the energy needs increases.
  - **Lysosome:** the site of removal of cell degraded waste substances. It contains many digestive enzymes and it is known as suicide bag as it burst and its contents release to lyse the cell when the cell die.
  - **Golgi Bodies,** a membranous structure. It packages proteins into membrane-bound vesicles inside the cell before the vesicles are sent to their destination.
  - **Endoplasmic reticulum (ER);** a network of membranes that may carry ribosomes or not. It share in the synthesis and export of proteins and membrane lipids.
  - **Centrosome; It presents only in animal cells** and serves as the main microtubule organizing center of the animal cell as well as a regulator of cell-cycle progression.

Generic Plant Cell

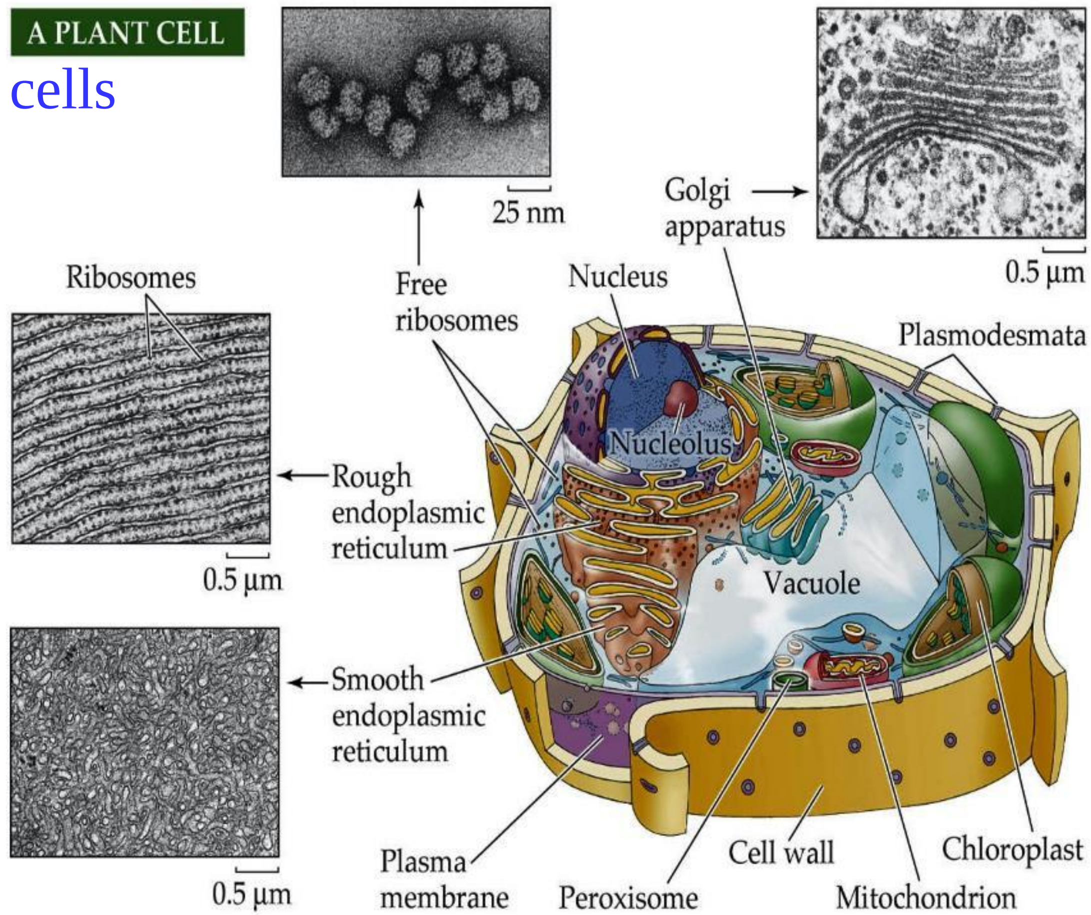
Plant cells is larger that animal cells and have some similarity with animal cells and differ in some specific plant structures like:

Organelles that present in plant cells but not in animal cells:

- External cell wall
- Chloroplast (for photosynthesis)
- Vacuoles (instead of lysosomes)
- Starch granules
- Thylakoids for ATP synthesis and
- Glyoxysome for glyoxylate cycle
- It DOESN'T have centrosome

Compare and contrast between animal and plant cells (Similarities and differences)

Compare and contrast between prokaryotes and eukaryotes (Similarities and differences)

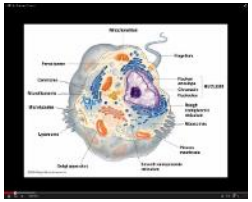


video

Cell, tissue, organ
https://www.youtube.com/watch?v=HBvfBB_oSTc

https://www.youtube.com/watch?v=B_zD3NxSsD8&x-yt-ts=1422411861&x-yt-cl=84924572

https://www.youtube.com/watch?v=g4L_QO4WKtM



Quiz

http://quizlet.com/10449142/study-guide-exam-2-cells-flash-cards/

Plant cells differ from animal cell in

contains plastids b- contain cell wall c- contain cellulose d- all of the above

Which organelle will use up oxygen and give off carbon dioxide AND water?

a) lysosome b) Golgi c) mitochondria d) chloroplasts

Which organelle will give off oxygen and use up carbon dioxide?

a) chloroplasts b) rough ER c) lysosomes d) mitochondria

The origin of cell organelles in eukaryotes is not possibly attributed to:

a) invagination of the plasma membrane to form Endoplasmic reticulum
b) incorporation of engulfed bacteria to form mitochondria
c) an elongated bacterium that became attached to a host
d) groups of prokaryotic cells begin to live in a small group sharing products of metabolism

Which organelle forms a membranous system of CHANNELS for intracellular transport?

a) ER b) mitochondria c) golgi apparatus d) lysosome

The _________ will mostly produce vesicles:

a) rough ER b) lysosome c) mitochondria e) Golgi

The eukaryotic cell is different from prokaryotic cell division in all the following ways except:

a) the amount of DNA present in the cells b) how the DNA is packaged
c) in the production of daughter cells d) the involvement of microtubules

Mitochondria are/synthezise:
A) structures involved in the breakdown of ATP
B)organelles involved in the synthesis of proteins
C) involved in producing ATP for cellular energy
D) synthesize proteins for use outside the cell

Lysosomes:
A)have a highly alkaline internal environment
B) are used mainly for the cell to "commit suicide"
C) contain digestive enzymes used to break down pathogens, damaged organelles, and whole cells

The major functions of the endoplasmic reticulum are ________.
A) hydrolysis, osmosis
B) detoxy, packaging
C) synthesis, storage, transport
D) pinocytosis, phagocytosis

According to cell theory:
A) all organisms are composed of tissues.
B) the smallest unit of life is a nucleus.
C) animals, not plants, are composed of cells.
D) multicellular organisms hve many cells.
E) new cells arise only from preexisting cells.

Compared with a eukaryotic cell, a prokaryotic cell:
A) lacks organelles
B) is larger.
C) does not require energy.
D) is not alive

Which of the following is a prokaryotic cell?
A) plant cell
B) liver cell
C) muscle cell
D) bacterium

Which structure regulates passage of molecules into and out of the cell?
A) plasma membrane
B) nucleus
C) mitochondria
D) chloroplast

Organisms, Organs, & Organelle

- Organism is a complete living entity
  - Unicellular organisms such as Bacteria, Protists, etc (mostly prokaryotic).
  - Multicellular organisms such as all animals and most plants. These organisms have different Levels of Cellular Organization, (mostly eukaryotic).

  - The Level of Cellular Organization is arranged from lower to higher level as follows:
    1. Cells
    2. Tissues (Epithelia, Connective, Muscle, Nerve Tissue)
    3. Organs (Heart, skin, kidney, etc.)
    4. Organ systems (circulatory, respiratory, digestive, etc)
    5. Organisms (Human, bovine, etc)

Characteristics of Living Organisms

There are 6 main Characteristics:

1- The highly organized Cells

2- Relation with energy

3- Grow and Reproduce with high fidelity

4- Interact with environment

5- Movement

6- Homeostasis

Characteristics of Living Organisms

1-The highly organized Cells

- The cell is the building block of the living organisms.
- It is structurally complicated and highly organized.
- Cell group together to form tissue or organ to perform specific function.
  - **Cell intricate internal structures like:**
    - Biological structures that serve functional purposes, e.g.:
      - Nucleus:
      - Ribosome:
      - Mitochondria:
      - lysosome:

State the function of each organelle.

    - Many kinds of complicated chemical molecules like:
      - Proteins, DNA, RNA, carbohydrates, lipids, etc.

Properties of living Organisms

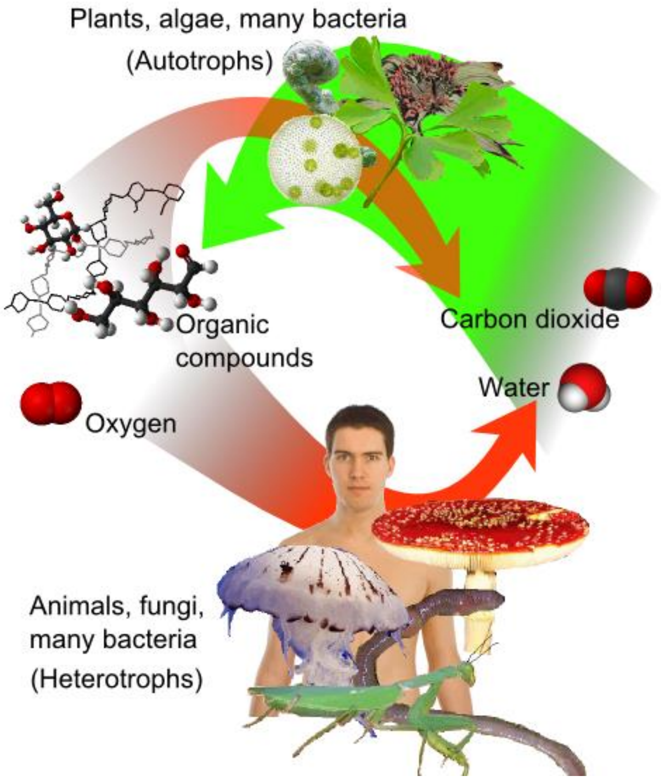
2- Relation with energy

Living organisms operate within the same laws of Thermodynamics that apply to physics and chemistry

All living organisms have the ability to:

Extract, Transform, Store, and Use ENERGY.

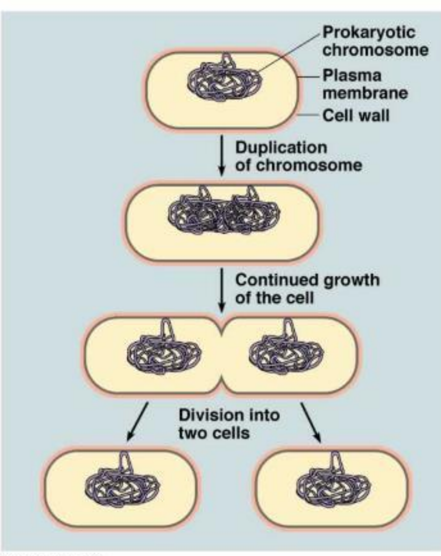
- First Law of Thermodynamics: “Energy can not be created or destroyed, but can be transformed”.
  - Sun is the ultimate source of energy for all living things.
  - The energy in the sunlight is transformed into usable form by autotrophs (photosynthesis).
  - Other living things extract energy from autotrophs, directly or indirectly (herbivores, carnivores or omnivores).
  - Energy is stored in chemical bonds: e.g. ATP, GTP, NADH, etc. and releases when these bonds are broken,
- Second Law of Thermodynamics – Spontaneous processes are characterized by an increase in the **entropy** of the universe by the conversion of order and disorder.



Properties of living Organisms

3- Grow and Reproduce with high fidelity

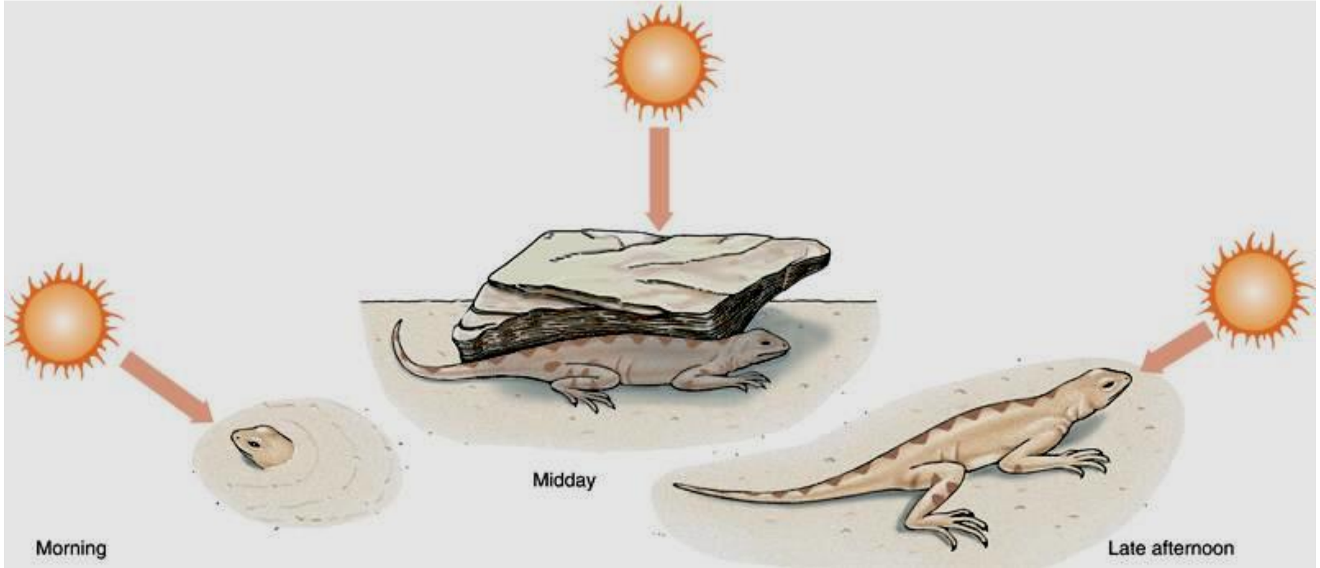
- All living organisms grow and undergo development
- The most characteristic attribute is the near- perfect fidelity of self- replication and self assembly
  - Cells divide to produce new cells.
  - Organisms reproduce to produce new generations.



Properties of living Organisms

4- Interact with environment

- Living organisms interact with their environments.
- It undergoes accommodation, hibernation and/or adaptation.
- **Ecology** is the study of
  - interaction between organisms
  - Interaction between organisms and their environment



Properties of living Organisms

5- Movement

- **Movement** – Living systems and their parts can have precise and controlled movements.
- Movements are required for:
    - Extraction of energy from their environments.
    - Responses to stimuli
    - Reproduction
    - Growth
    - Development in multicellular organisms

- On contrary, the nonliving matter often needs external forces to be moved and is Not precisely controlled by the moving objects.

Properties of living Organisms

6- Homeostasis

- Homeostasis is a characteristic of living organisms in which the internal conditions remain stable and relatively constant and regulated regardless the different biological and environmental factors affecting the organism.
- Examples of homeostasis include the regulation of temperature and the balance between acidity and alkalinity (pH).

Quiz

1. All organisms are composed of one or more types of cells .... (   )
2. Living cells can be generated spontaneously ....…....... (   )
3. Ribosomes contains hereditary information which is passed from cell to cell ...... (   )
4. Prokaryotes are often single-celled organisms .... (   )
5. Mitochondria is responsible for cytoplasmic protein synthesis .... (   )

6. Living organisms operate within the same laws that apply to physics and chemistry (   )

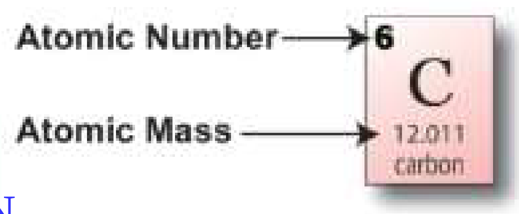
7.Angestrom is larger than micrometer .... (   )

8.Lysosome is an cellular organelle responsible for digestion of cell component and is called Suicide Bag .... (   )

For more training visit http://quizlet.com/10449142/test

The matter versus element and molecule?

- **The matter** is anything that has mass and volume (occupies space).
  - There are 118 elements on the periodic table 92 of them are natural.
  - An element consists of atoms of the same kind.
  - Any element consist of atoms. The atom is formed from nucleus (having protons and neutrons) and circulating negatively charges electrons.
  - The atomic number of each element represent the number of protons in its nucleus.



For example,

- the element that has 6 protons in its atom is CARBON
- The atom that has 7 protons is NITROGEN
- The atom that has 8 protons is OXYGEN
- Molecule is a group of two or more elements.

Periodic table of elements

metals

- alkali metals
- alkaline earth metals
- transition metals
- rare earth metals
- other metals

nonmetals

- halogens
- noble gases
- other nonmetals

metalloids

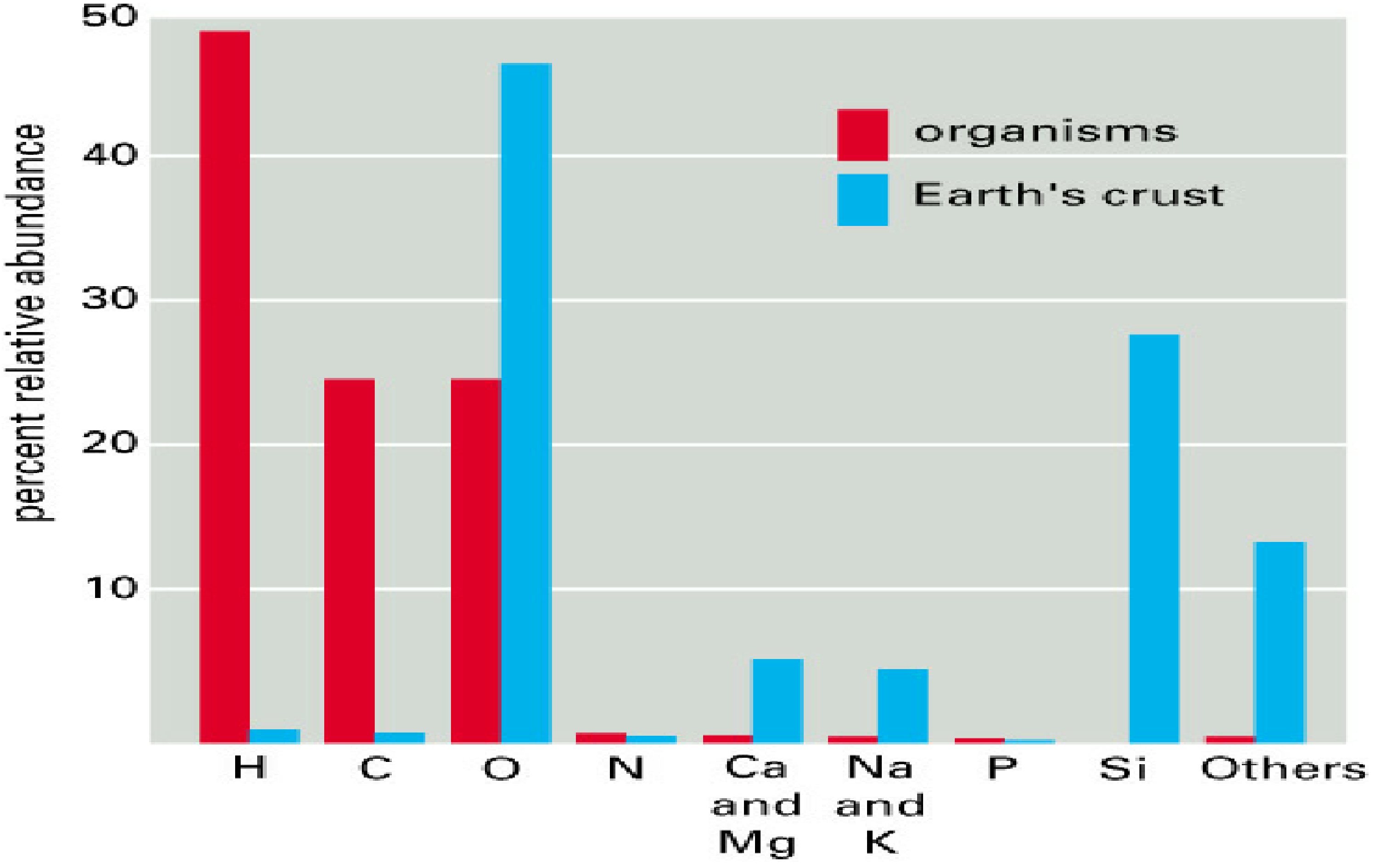
- metalloids

group 1	group 2	group 3	group 4	group 5	group 6	group 7	group 8	group 9	group 10	group 11	group 12	group 13	group 14	group 15	group 16	group 17	group 18
1 H 1.0079 hydrogen																	2 He 4.0028 helium
3 Li 6.941 lithium	4 Be 9.0122 beryllium											5 B 10.811 boron	6 C 12.011 carbon	7 N 14.007 nitrogen	8 O 15.999 oxygen	9 F 18.998 fluorine	10 Ne 20.180 neon
11 Na 22.990 sodium	12 Mg 24.305 magnesium											13 Al 26.982 aluminum	14 Si 28.086 silicon	15 P 30.974 phosphorous	16 S 32.065 sulfur	17 Cl 35.453 chlorine	18 Ar 39.948 argon
19 K 39.098 potassium	20 Ca 40.078 calcium	21 Sc 44.956 scandium	22 Ti 47.867 titanium	23 V 50.942 vanadium	24 Cr 51.996 chromium	25 Mn 54.938 manganese	26 Fe 55.845 iron	27 Co 58.933 cobalt	28 Ni 58.693 nickel	29 Cu 63.546 copper	30 Zn 65.38 zinc	31 Ga 69.723 galium	32 Ge 72.61 germanium	33 As 79.922 arsenic	34 Se 78.96 selenium	35 Br 79.904 bromine	36 Kr 83.80 krypton
37 Rb 85.468 rubidium	38 Sr 87.62 strontium	39 Y 88.906 yttrium	40 Zr 91.224 zirconium	41 Nb 92.906 niobium	42 Mo 95.96 molybdenum	43 Tc (98) technetium	44 Ru 101.07 ruthenium	45 Rh 102.91 rhodium	46 Pd 106.42 palladium	47 Ag 107.87 silver	48 Cd 112.41 cadmium	49 In 114.82 indium	50 Sn 118.71 tin	51 Sb 121.76 antimony	52 Te 127.60 tellurium	53 I 126.90 iodine	54 Xe 131.29 xenon
55 Cs 132.91 cesium	56 Ba 137.33 barium	71 Lu 174.97 lutetium	72 Hf 178.49 hafnium	73 Ta 180.95 tantalum	74 W 183.84 tungsten	75 Re 186.21 rhenium	76 Os 190.23 osmium	77 Ir 192.22 iridium	78 Pt 195.08 platinum	79 Au 196.97 gold	80 Hg 200.559 mercury	81 Tl 204.38 thallium	82 Pb 207.2 lead	83 Bi 208.98 bismuth	84 Po (209) polonium	85 At (210) astatine	86 Rn (222) radon
87 Fr (223) francium	88 Ra (226) radium	103 Lr (262) lawrencium	104 Rf (267) rutherfordium	105 Db (268) dubnium	106 Sg (271) seaborgium	107 Bh (272) bohrium	108 Hs (270) hassium	109 Mt (276) meitnerium	110 Ds (281) darmstadtium	111 Rg (280) roentgenium	112 Uub (285) ununbium	113 Uut (284) ununtrium	114 Uuq (289) ununquadium	115 Uup (288) ununpentium	116 Uuh (293) ununhexium		118 Uuo (294) ununoctium

57 La 138.91 lanthanum	58 Ce 140.12 cerium	59 Pr 140.91 praseodymium	60 Nd 144.24 neodymium	61 Pm (145) promethium	62 Sm 150.36 samarium	63 Eu 151.96 eruopium	64 Gd 157.25 gadolinium	65 Tb 158.93 terbium	66 Dy 162.50 dysprosium	67 Ho 164.93 holmium	68 Er 167.26 erbium	69 Tm 168.93 thulium	70 Yb 173.06 ytterbium
89 Ac (227) actinium	90 Th 232.04 thorium	91 Pa 231.04 protactinium	92 U 238.03 uranium	93 Np (237) neptunium	94 Pu (244) plutonium	95 Am (243) americium	96 Cm (247) curium	97 Bk (247) berkelium	98 Cf (251) californium	99 Es (252) einsteinium	100 Fm (257) fermium	101 Md (258) mendelevium	102 No (259) nobelium

Chemical elements of cell

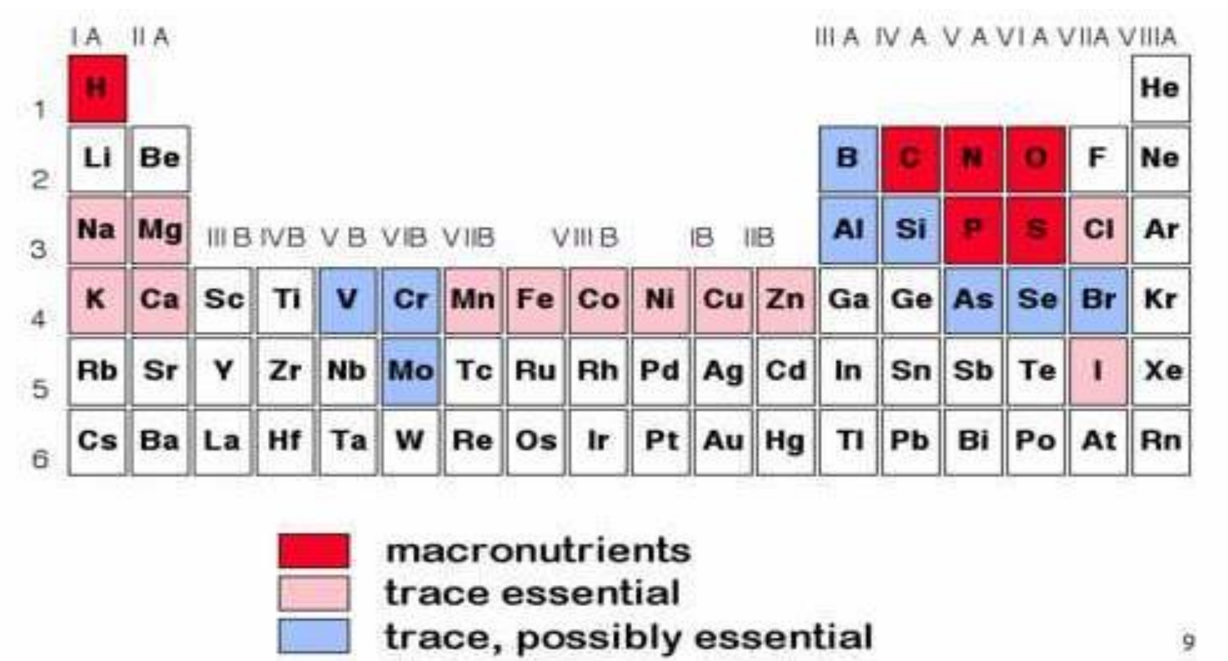
Chemical elements of a living cell are the same as in the Earth's crust, but in diferent proportions.



Elements in living cells

There are many classifications of elements regarding its distribution in living cells. The most used one is as follow:

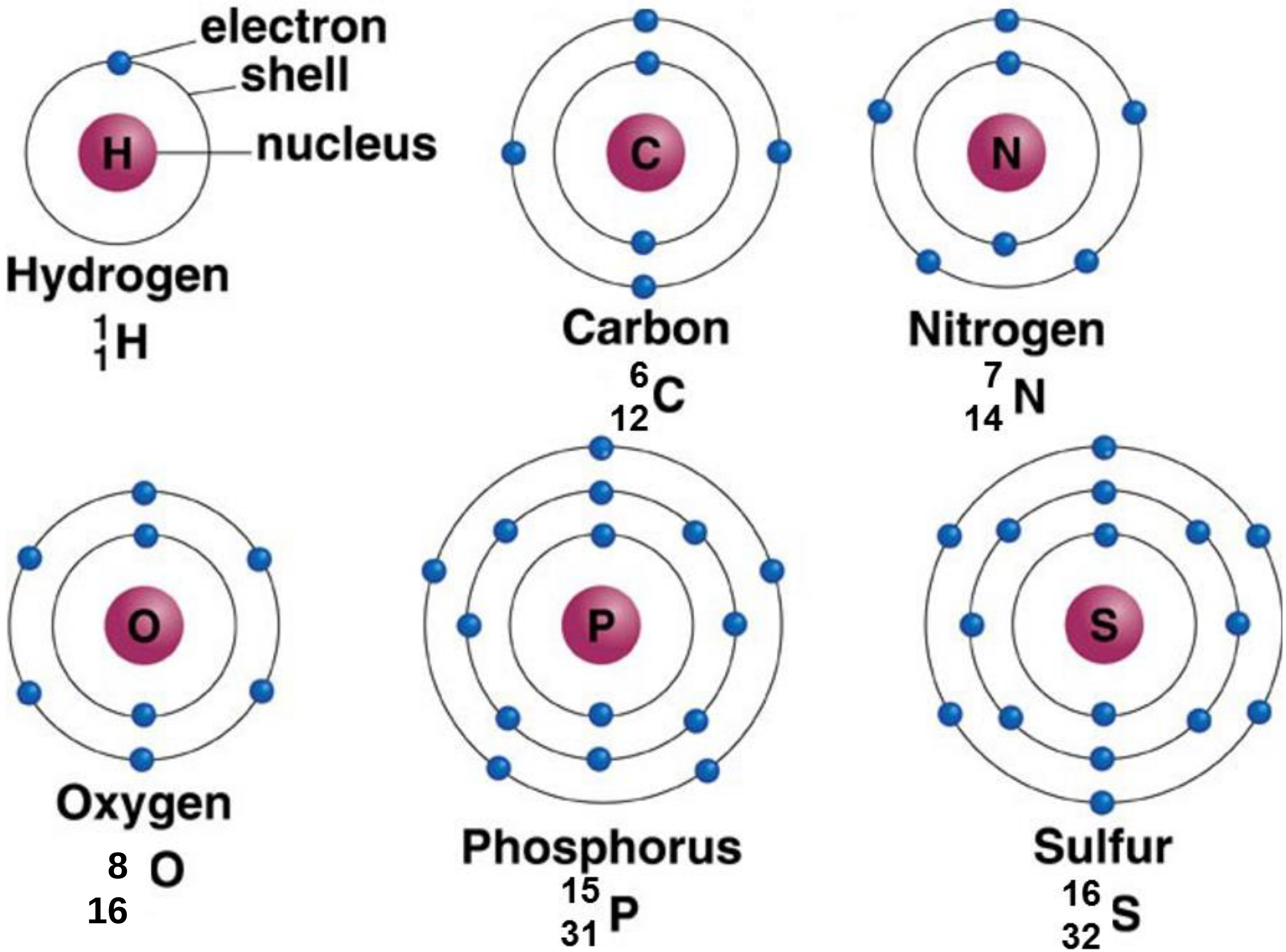
- **Macronutrients** are elements that are most abundant in the cell, **(C, H, N, O, P, S)**
- **Essential elements** are found in small amounts, but essential (Na, Mg, K, Ca, Mn, Fe, Co, Ni, Zn, Cu, Cl, I).
- **Trace Possibly Essential elements**: some are common, others are less common (V, Cr, Mo, B, Al, Si, As, Se, Br).



Chemical Elements of Life

- C H N O P S: are the most abundant elements in cell.
  - They account for more than 99% of atoms in the human body
- H, O, N and C have common properties that are important to the chemistry of life.
  - They all:
    - have relatively low atomic numbers
    - capable of forming one, two, three and four bonds (for H, O, N and C , in order).
    - form the strongest covalent bonds in general.

Write the atomic number and the atomic mass of each element (CHNOPS)


electron
shell
nucleus
H
Hydrogen
1
1
H
C
Carbon
6
12
C
N
Nitrogen
7
14
N
O
Oxygen
8
16
O
P
Phosphorus
15
31
P
S
Sulfur
16
32
S

Chemistry and Life

Living organisms operate within the same laws that apply to physics and chemistry:

- Conservation of mass, energy
- Laws of thermodynamics
- Laws of chemical kinetics
- Principles of chemical reactions

Chemistry Review

There are 5 major forces that maintain the structure of biomolecules:

- Only one is a strong force: The covalent bond
- The others are considered weak forces:
  1. The ionic bond
  2. The hydrogen bond
  3. Hydrophobic interaction (not chemical bond)
  4. Van Der Waals attraction (not chemical bond)

Ionic bond (Cont.)

Formed by complete transfer of valence electrons between two atoms

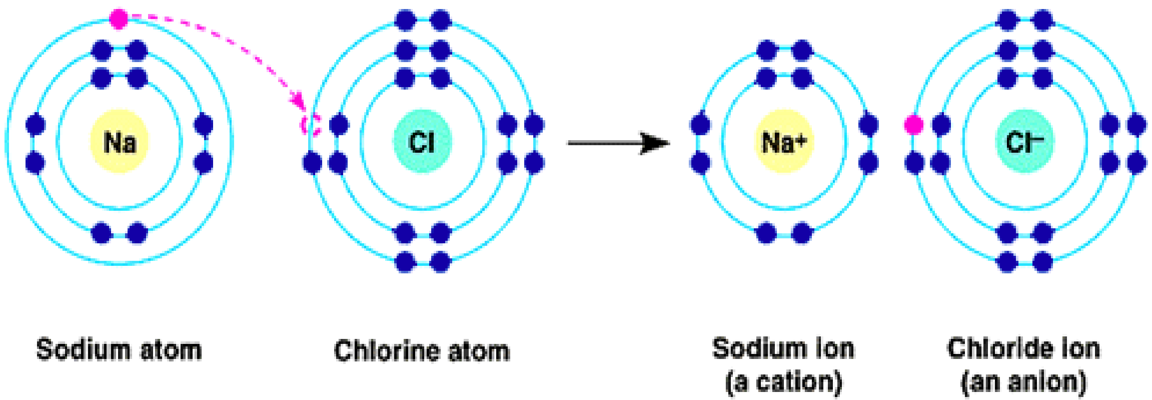
Strength is governed by a general law:

$$F = K * \frac{Q_1 * Q_2}{R^n * D}$$

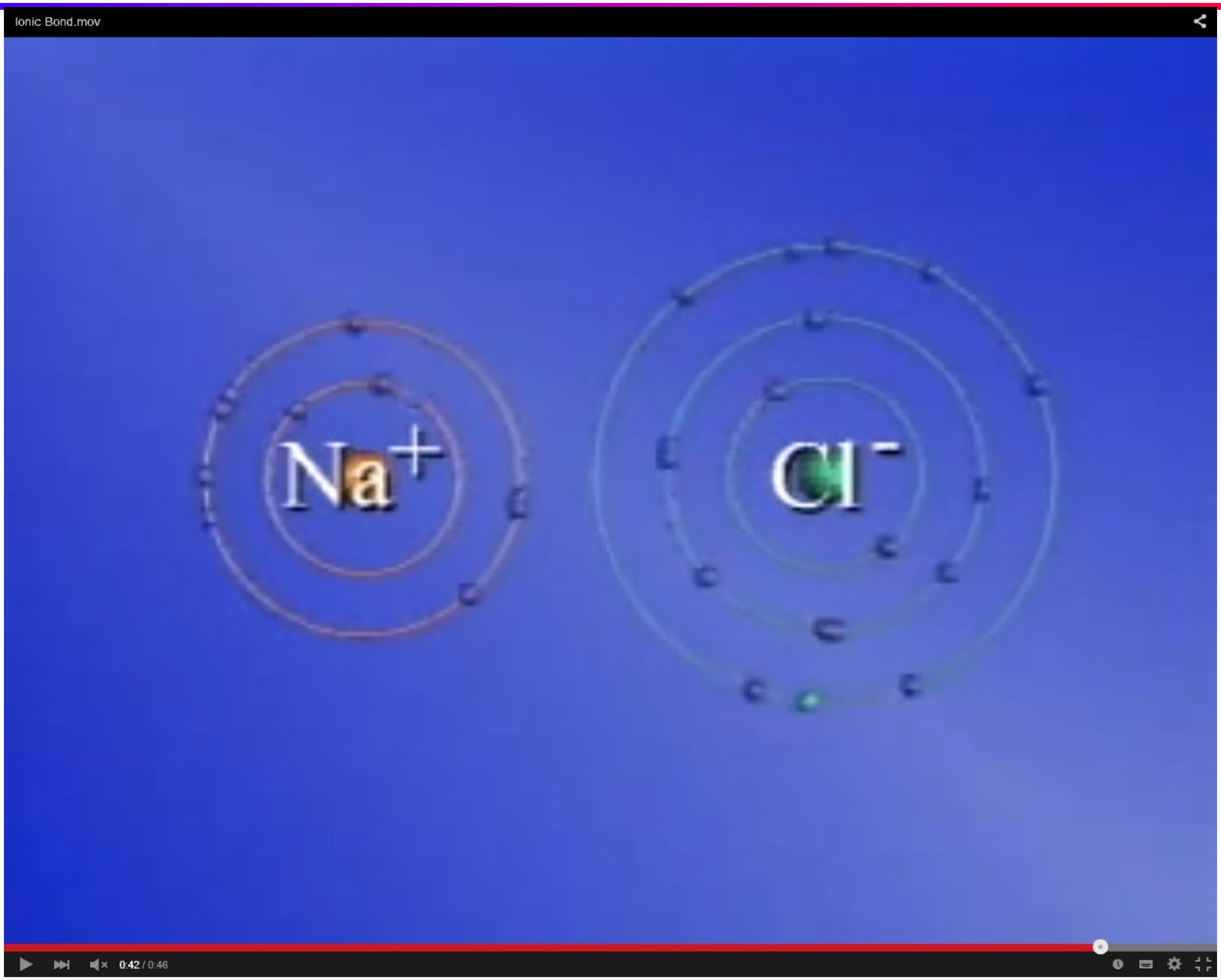
Qs are charges, R is distance between them, D = dielectric of the medium, k =constant, and n=1 or 2, depending on the nature of interaction.

D = 1 in vacuum, 2- 3 in grease, and 80 in water

Electrostatic interaction is responsible for ionic bonds, salt linkages or ion-pairs, and hydrogen bonding



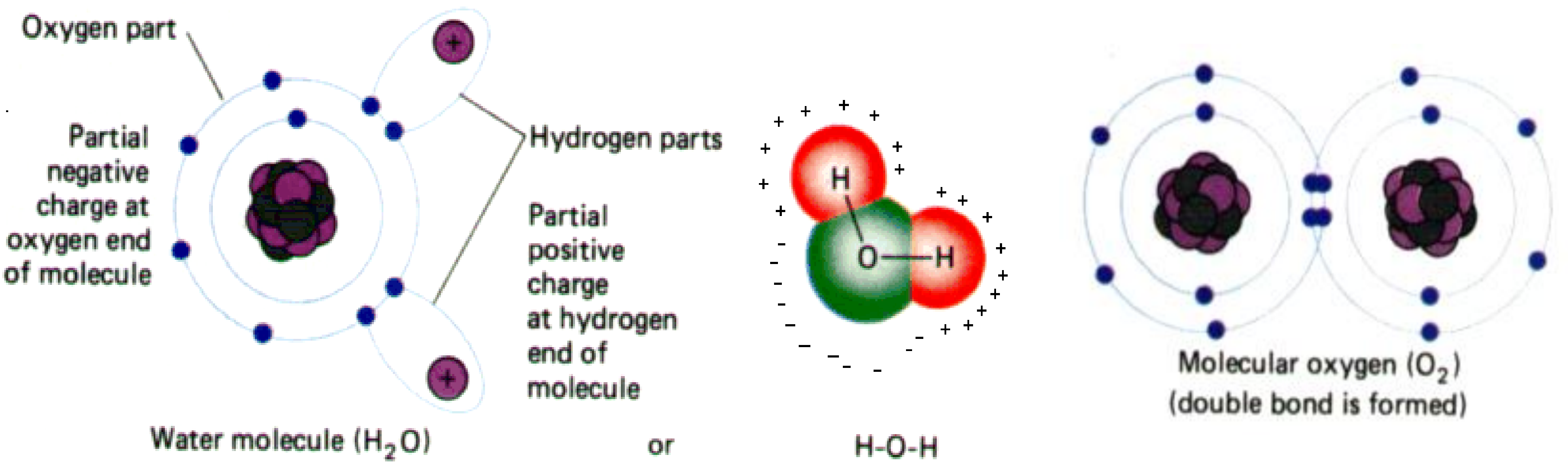
Ionic bond

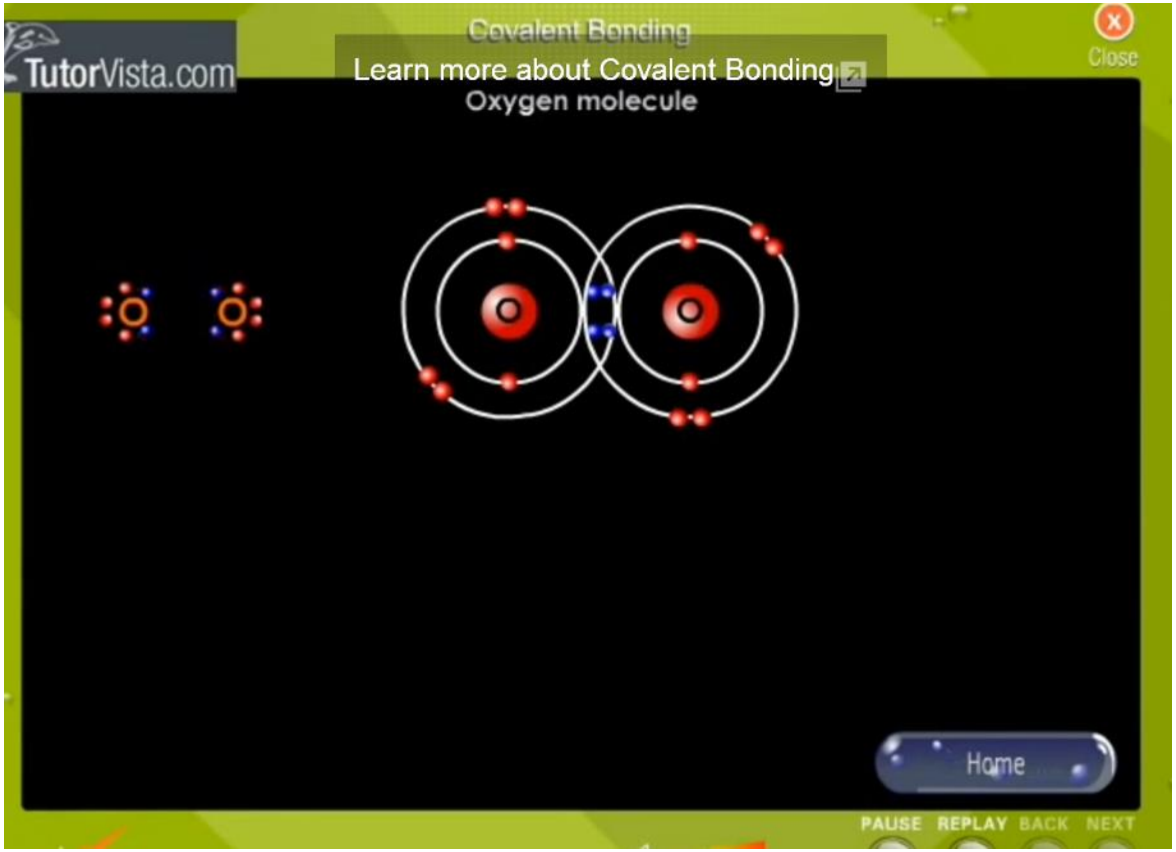


https://www.youtube.com/watch?v=lODqdhxDtHM

The Covalent Bond (Cont.)

- The strongest bond in biochemistry
- Does not dissociate or break in H_2O
- Formed by sharing of valence electrons
  - If partners are unequal, asymmetrical distribution of electrons creates partial electrical charges and therefore polar molecules





https://www.youtube.com/watch?v=20AbmhCk-RI
https://www.youtube.com/watch?v=MlgKp4FUV6I
https://www.youtube.com/watch?v=X9FbSsO_beg

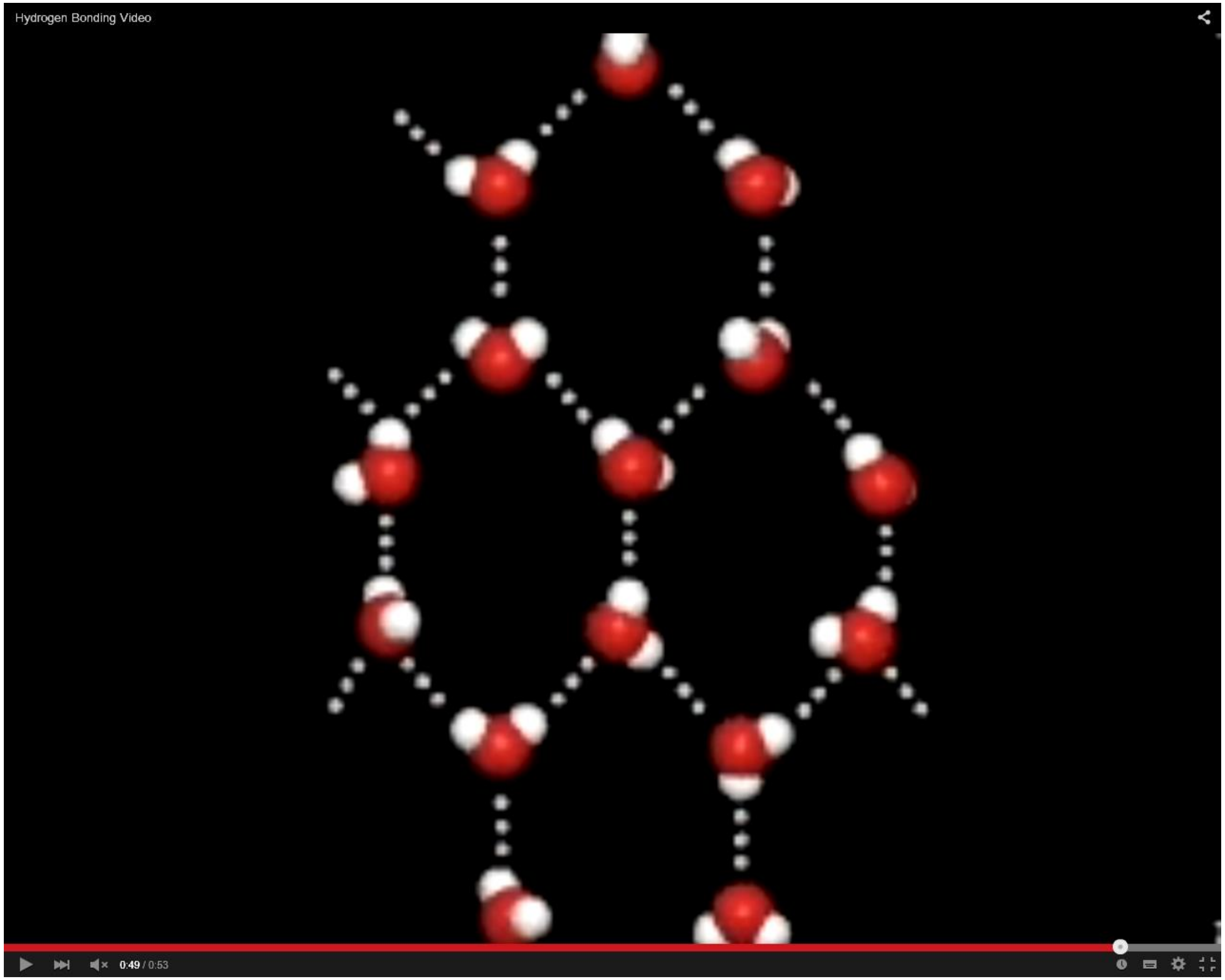
The Hydrogen Bond (Cont.)

- The hydrogen bond is weak, but very important in biochemistry
- The general formula for H-bond is

$$\overset{\delta^-}{-D}-\overset{\delta^+}{H}\cdots\cdots\overset{\delta^-}{A}-$$

- (D) is the donor atom
- (A) is the acceptor atom which must have at least one-pair of free electrons
  - Important atoms in Biochemistry are O and N
  - Carbon can neither donate nor accept H-bonding

The Hydrogen Bond



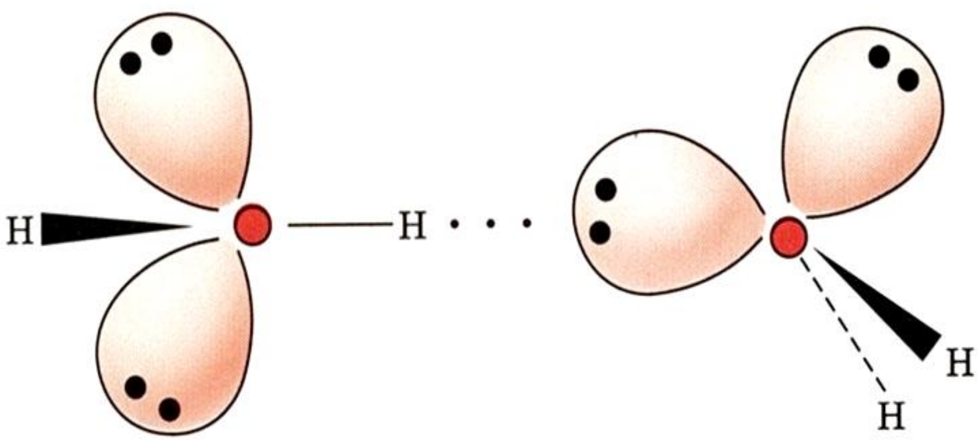
https://www.youtube.com/watch?v=lkl5cbfqFRM

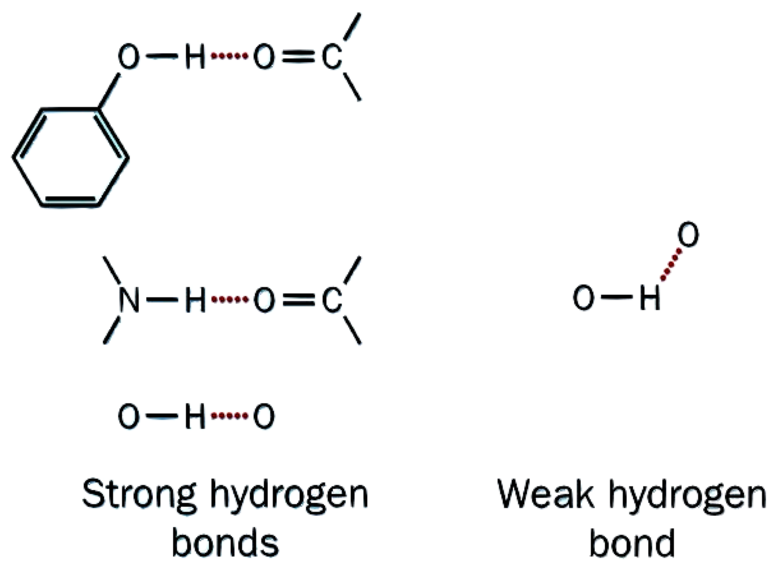
Strength of H-bond

- H-Bond is a type of dipole-dipole interaction, but can be considered as a weak ionic bond:
  - Distance (R3) is a major factor
  - D is also a major contributor in biological systems
  - Very strong angle dependence

$$F = K * \frac{Q_1 * Q_2}{R^3 * D}$$

Lone-Pair Electrons of Water





Hydrophobic Interactions

Non- polar groups cluster together

$$\Delta G = \Delta H - T\,\Delta S$$

- The most important parameter for determining the stability of proteins, membrane, nucleic acids
- Very important consideration for many biochemical methods and interactions
- Entropy order- disorder. Nature prefers to maximize entropy "maximum disorder"
- Structure formations are driven by water interactions

Van Der Waals Attraction

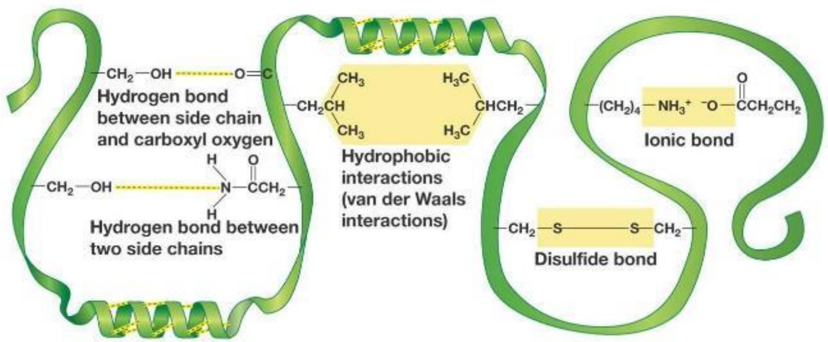
Non-specific attractions (induced dipole-induced dipole) most effective near the contact distances. $F \sim 1/R^6$

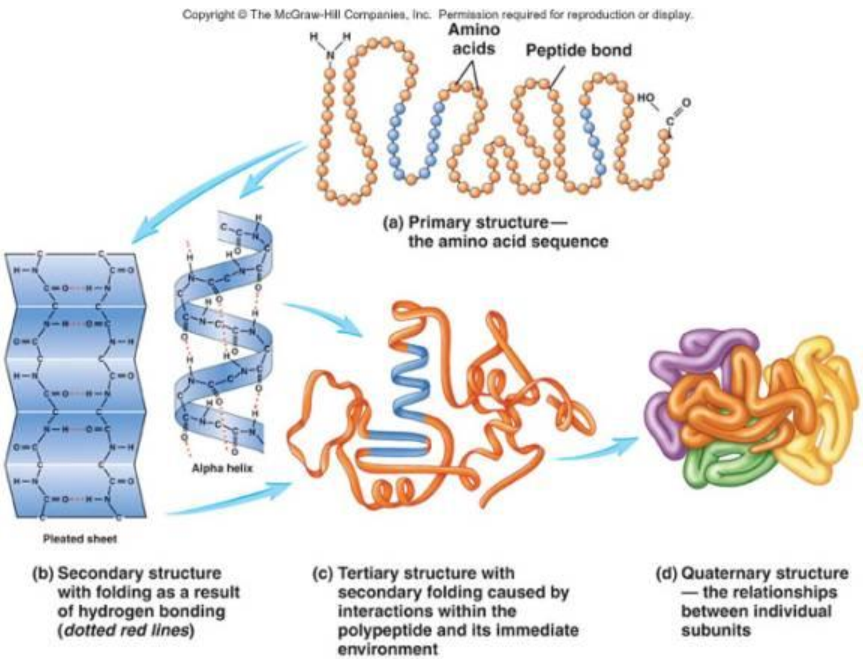
Atom	contact Distance	Atom	contact Distance
H	1.2 Å	C	2.0 Å
N	1.5 Å	O	1.4 Å
S	1.85 Å	P	1.9 Å

Weak interaction; About 1.0 kcal/mol

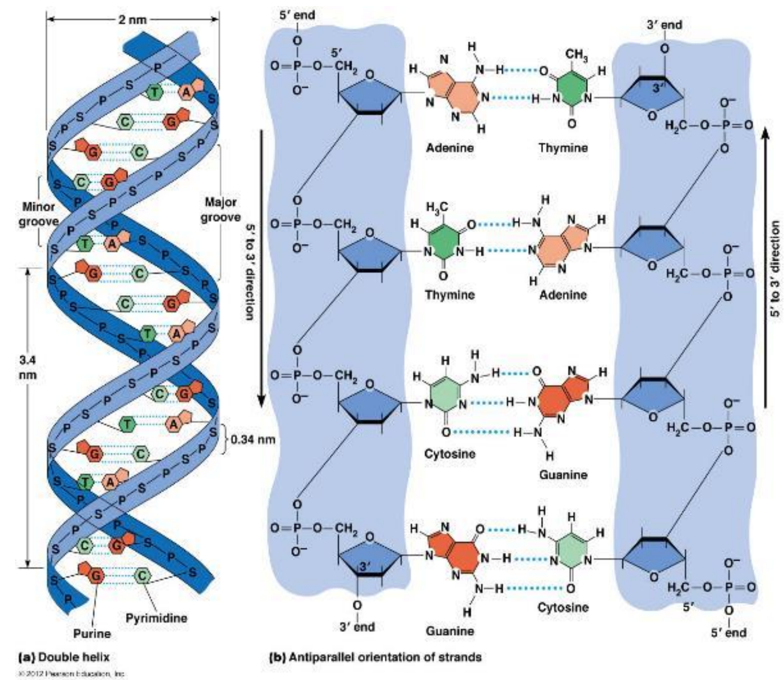
- Becomes important when many atoms come in contact as in steric complementarities as in:
  - a) antibodies
  - b) enzyme substrate

Example of macromolecule having different types of bonds





Protein structure



DNA structure

Dimensions

- Dimensions in Biochemistry are often expressed as angstrom (Å), nanometer (nm), or micrometer (μm).

You must know this and be comfortable using them.

1 Å = 10^{-10} m, 1 nm=10 Å 1 μm=10,000 Å

Length is very important!!

- C - C bond is 1.54 Å
- Hemoglobin 65Å
- Ribosome 300Å
- Viruses 100 - 1000Å
- Cells 1-10 μm or 10,000- 100,000 Å

1 mm= 10^{-3} m
1 μm = 10^{-6} m
1 nm = 10^{-9} m
1 Å = 10^{-10} m

Information about structure come from:
light microscope: range of 2000 Å or 0.2μm
X-ray crystallography, electron microscope or NMR: 1 Å ⇒ 10^4 Å range

Time scale

Life is in Constant Flux

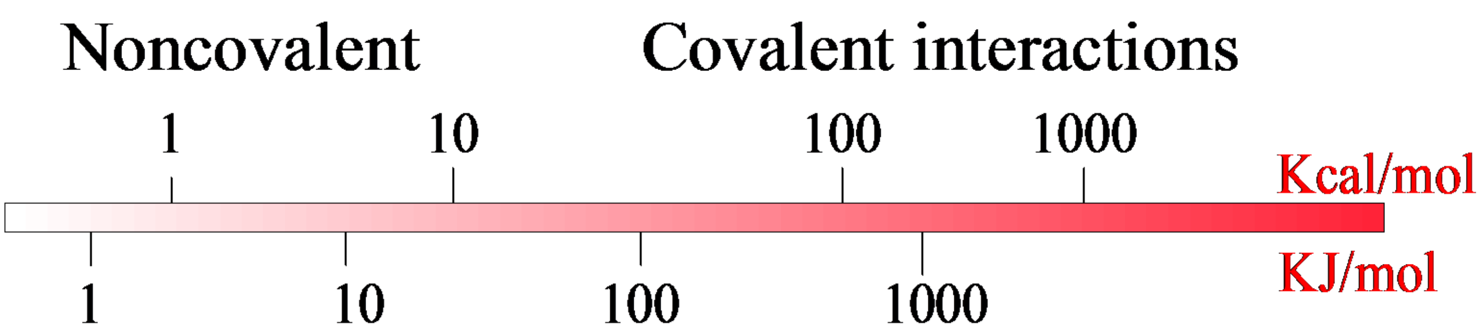
- Substrates to products in 10^{-3} sec (ms)
- Unwinding of DNA in 10^{-6} sec (μs)

10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	1	10^{3}	10^{6}	10^{9}	10^{12}
femto	pico	nano	micro	milli	Base Unit	kilo	mega	giga	tera
f	p	n	μ	m		K	M	G	T

femto fs	excitation of chlorophyll
pico ps	charge separation in photosynthesis
nano ns	hinge protein action
micro μs	DNA unwind
milli ms	enzymatic reactions
10^{3}	generation of bacteria
2.3×10^{9} sec	average human life span

Energy

- Ultimate source of energy is the sun: E = hν
- where E is the energy of a bit of light called a quantum or photon of light.
- h is a very small constant called “Planck’s constant” (6.626068×10^{-34} J s) and
- “n” is the frequency of the radiation.
  - photons of green light have E of 57 Kcal/mol
- 1 cal = 4.184 joules or 1 J= 0.239 cal; You must know this.
- Covalent interactions are stronger than noncovalent ones
  - The carbon skeleton of a molecules is thermally stable
    - e.g. C - C bond = 83 Kcal/mol or 346 KJ/mol
- The shape and interactions of molecules are governed by noncovalent interactions
  - Biomolecules shape can be modified by thermal energy.
    - Boil an egg, fry a steak or get a sunburn.

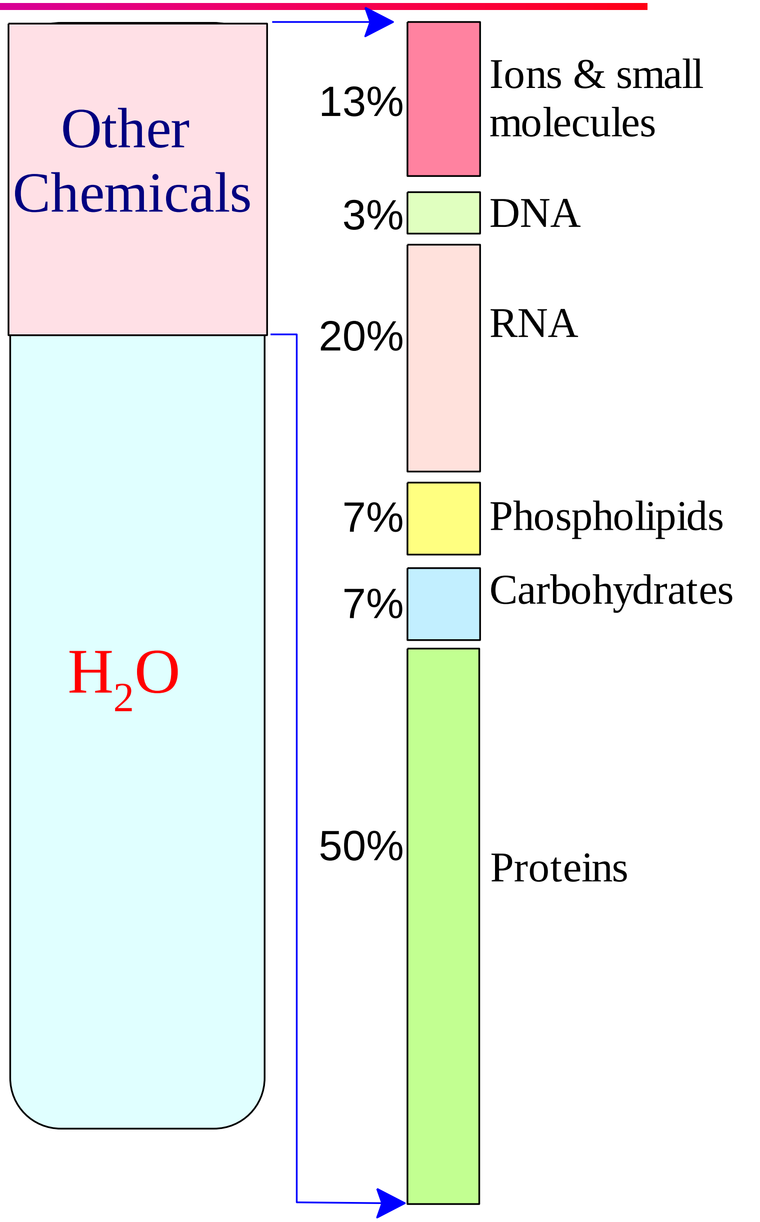


Basic Materials in Cell

All cells have these basic common materials:

- H_2O: The solvent of life. All cellular reactions are carried out in aqueous environment.
  - All chemical reactions in a cell make up its METABOLISM.
- And 4 Major macromolecules:
  1. Proteins (the cell work horses)
  2. Nucleic Acids (genetic materials)
  3. Carbohydrates (many functions)
  4. Lipids (membrane and energy source and depot)

  Notice that all macromolecules are organic compounds (i.e. contain carbon).
- Plus ions & metabolites (small amounts)

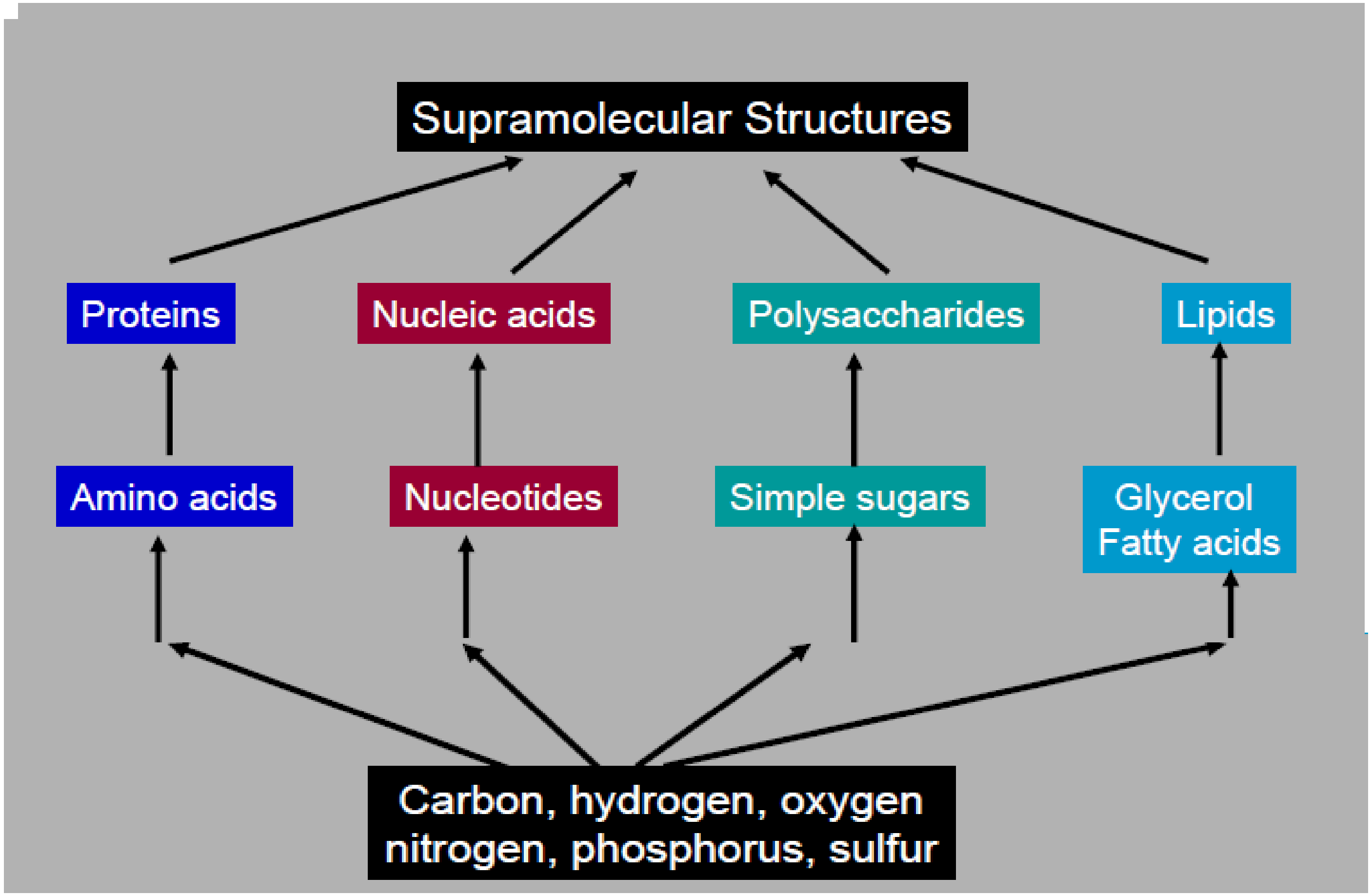


The 4 Major macromolecules

There are 4 major macromolecules (polymers) in the cell formed by condensation of smaller building blocks (monomers) by the removal of H_2O (dehydration):

Macromolecule (polymers)	Building blocks (monomers)	Name of bond
Carbohydrate	Monosaccharides	Glycosidic bond
Proteins	Amino acids	Peptide bond
Nucleic acids	Nucleotides	Phospho diester bond
Lipids	Fatty acids + alcohol	Ester bond

CHNOPS vs monomer vs macromolecules

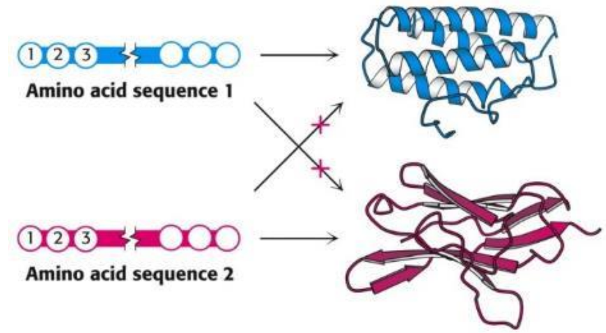


Characteristics of biological molecules

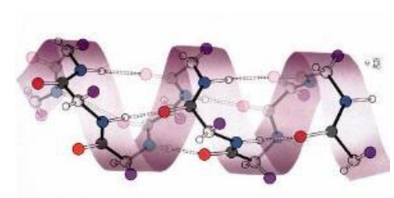
- All macromolecules have a “Sense” or Directionality
  - DNA : -ATC- ≠ -CTA-
  - Protein: -Gly-ser- ≠ -Ser-Gly-
  - Carbohydrate: -Glu-Gal ≠ -Gal-Glu-

- Macromolecules are Informational:
  - Examples: AUC=Ile; ACU=Thr; UAC=Tyr

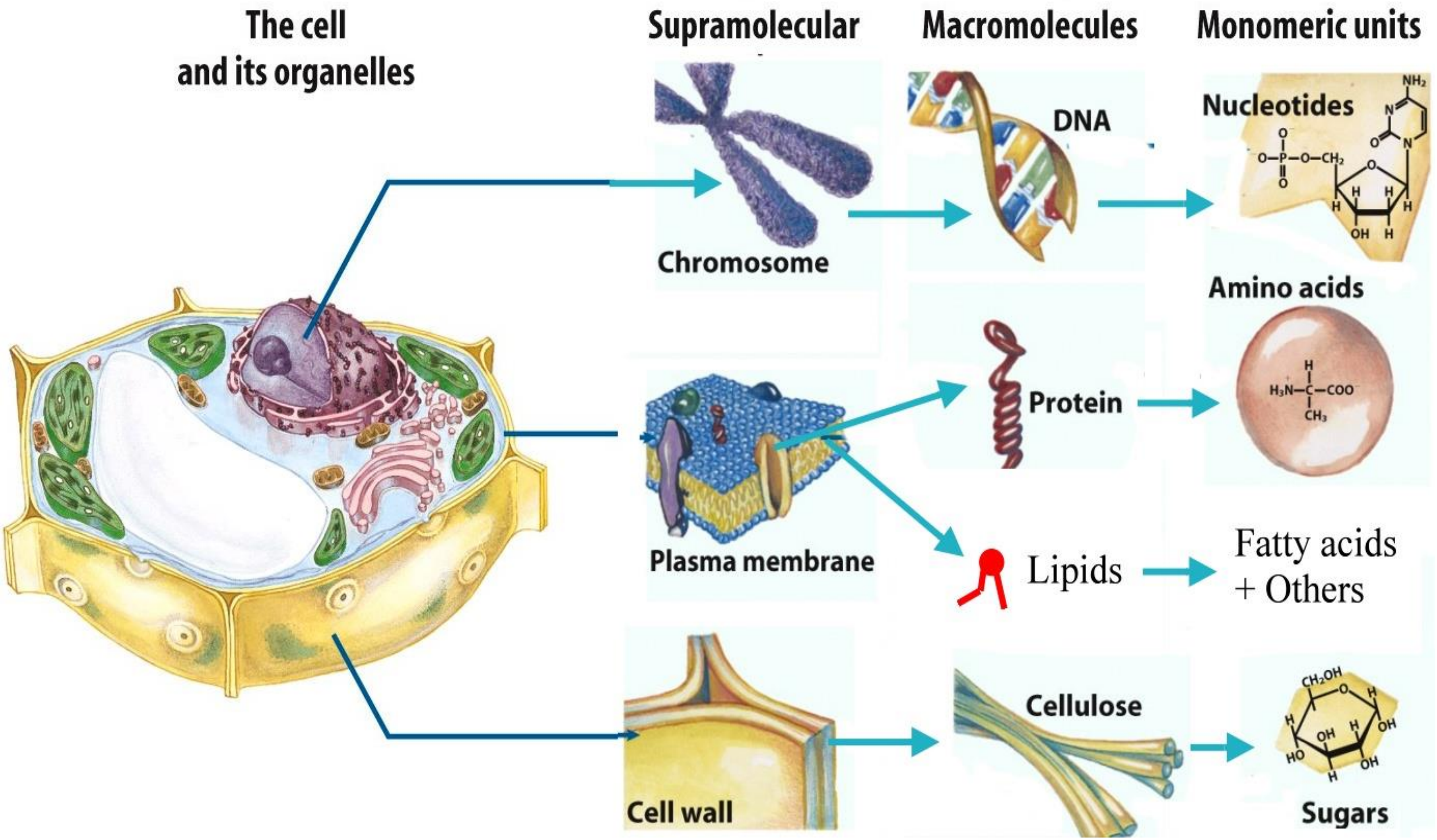
- Macromolecules Have Characteristic Three-Dimensional Architecture



- Weak forces maintain biological structure and determine biomolecular interactions



Structural Levels of Cell Molecules



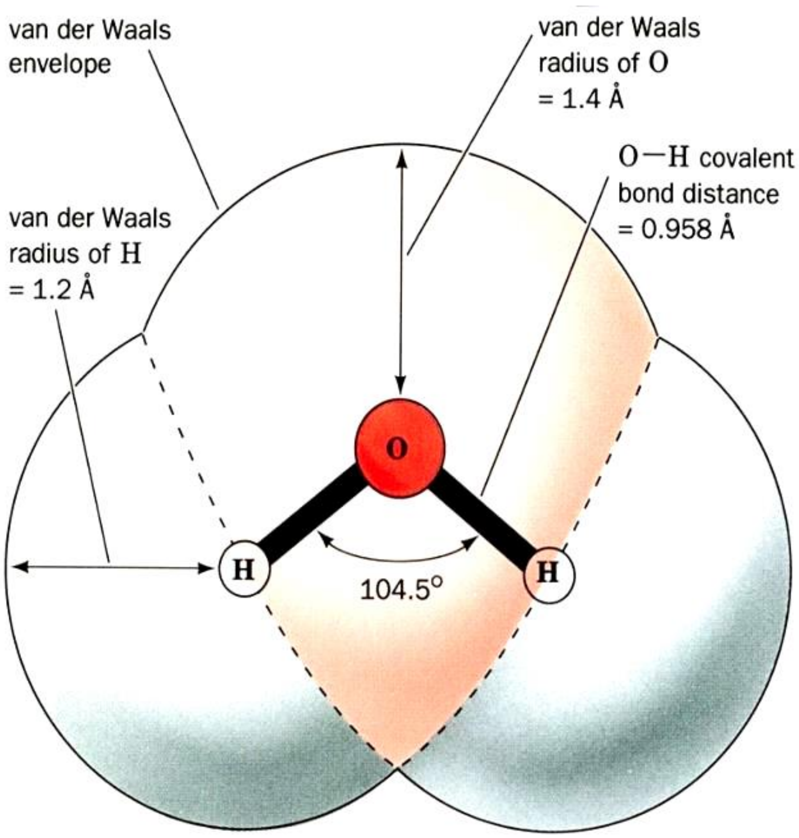
The Solvent of Life

- We are ~ 70% Water

- H_2O is key to the behavior of macromolecules.
  - All life transformations occur in aqueous media
  - Most biochemical reactions take place in water
  - Water is a reactant in a number of reactions, usually in the form of H^+ and OH^-.

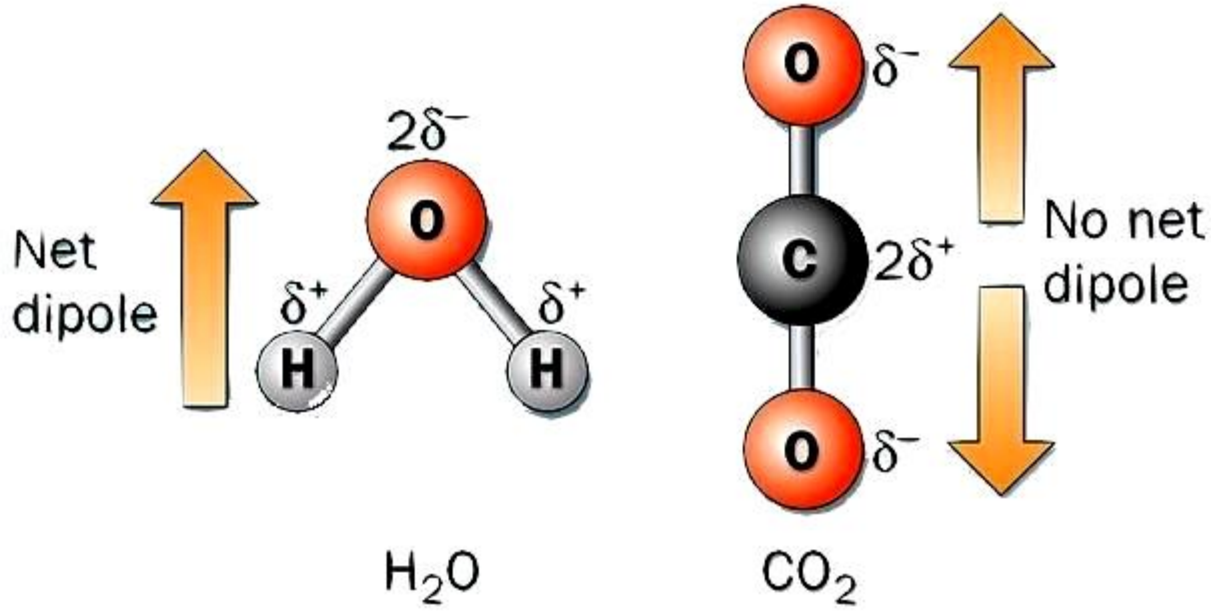
- Even water insoluble compounds such as lipid membranes derive their structure and function by interaction with H_2O
  - Biomolecules assume their shapes in response to the aqueous medium

Structure of Water



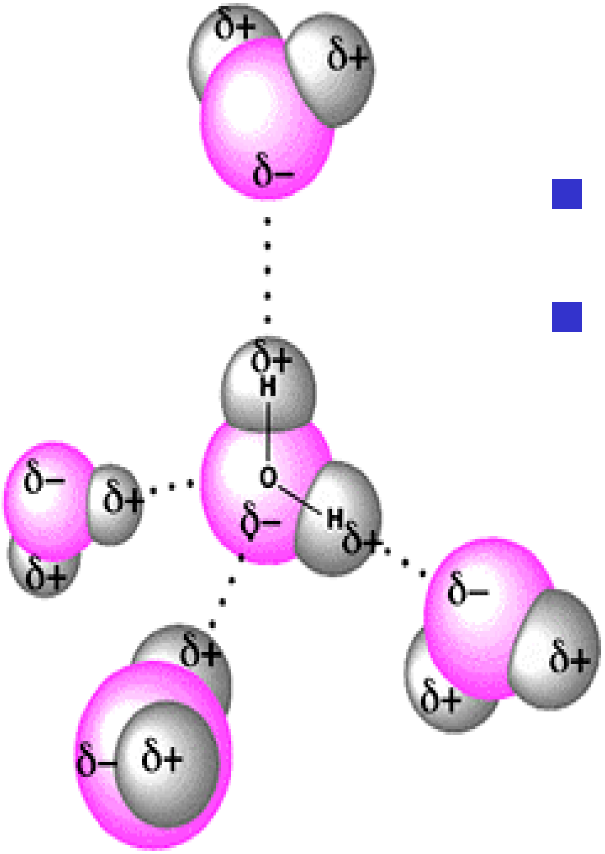
- The difference between O and H in electronegativity creates polar bonds
  - -OH is a very polar bond
  - H_2O can donate and accept hydrogen bonds
  - H_2O can function as an acid or a base
- Structure: water is a bent molecule (geometry & polarity)

Geometry Determines Polarity



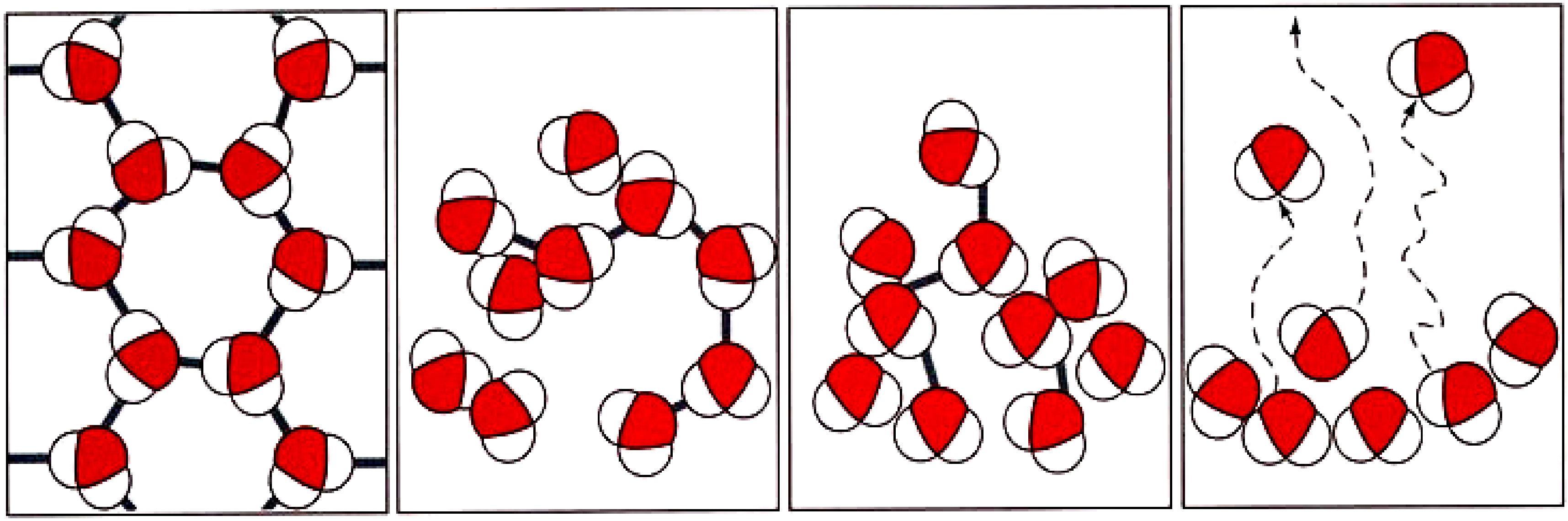
While both bonds O-H and C-O are polar,
the sum of vectors in CO_2 is zero, and therefore, CO_2 is nonpolar molecule
while H_2O is polar molecule

Hydrogen Bonding in Water



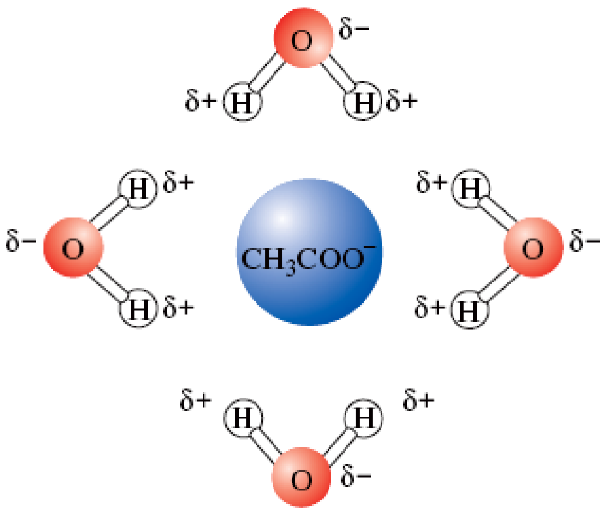
- Partial charges cause electrostatic attractions between O and H
- Each H_2O can bind 4 other H_2O 's.
- H-bonding among its molecules gives water:
  - a) high boiling point
  - b) high surface tension or capillary action
  - d) expansion upon freezing
  - e) solvent for polar molecules

Water: Ice, Liquid, and Vapor

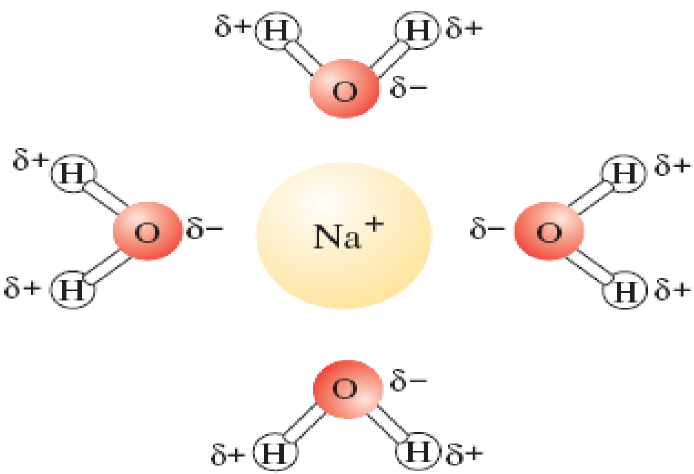


	H_2O	NH_3	CH_4	H_2S
Molecular weight	**18**	**17**	**16**	**32**
Boiling point (° C)	**100**	**-33**	**-161**	**-60.7**
Melting point(° C)	**0**	**-78**	**-163**	**-65.5**
Viscosity (centipoises)	**1.01**	**0.35**	**0.10**	**0.15**

Water As a Solvent: Ionic Interactions

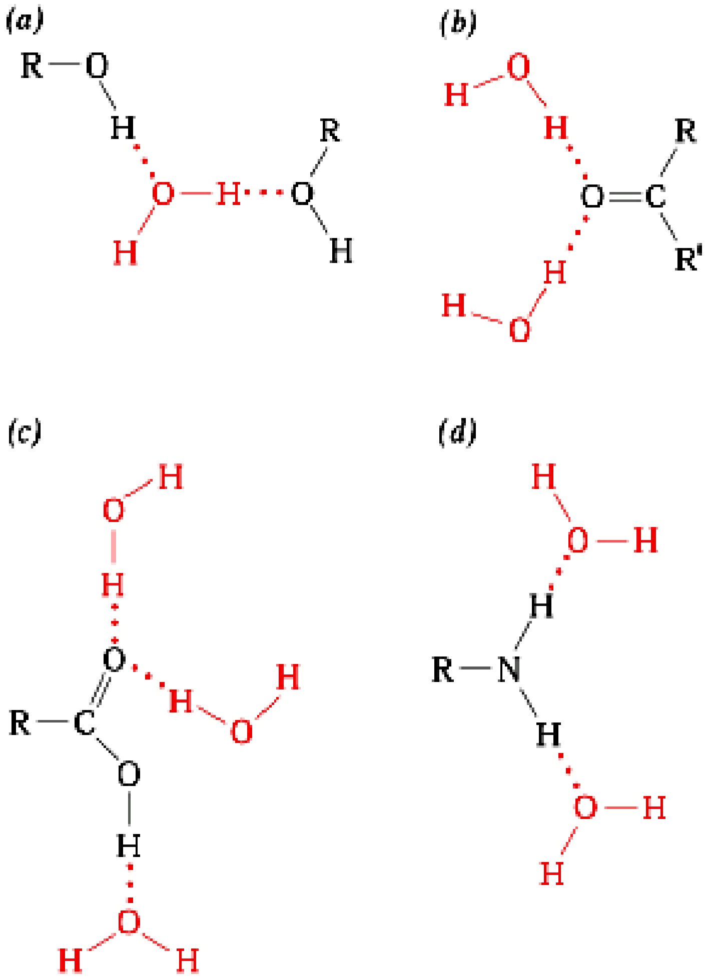


- Water can solvate charged molecules (both cations & anions)
- Water projects its partially positive hydrogens towards negatively charged ions.
- Water projects its partially negative oxygen towards positively charged ions



- Notice the opposite orientation of water molecules around a cation versus anion.
- This type of interaction is called ion–dipole interactions.

Water as a solvent: H-bonding



Based on their interaction with H_2O, Molecules are divided into two types:

- **Hydrophobic molecules**: do not interact with H_2O
- **Hydrophilic molecules**: able to interact with H_2O via polar functional groups or charged groups

Which chemical groups are hydrophilic????

- All charged groups are hydrophilic
- Uncharged polar molecules have functional groups that form H-bonds with H_2O.
- Examples: Alcohols, amines, carbonyls (aldehydes & ketones)

Quiz

Answer by marking true (T) or False (F)

1. The most abundant elements in cell are C H N O P S .... (   )
2. Molybdenum, bromide and boron are examples of trace elements .... (   )
3. Water represents 50% of the living cell .... (   )
4. Covalent bond is the strongest bond in biochemistry .... (   )
5. Hydrogen bond can be dissociated by heating or changing pH .... (   )
6. The difference between O and H in electronegativity creates covalent bonds .... (   )
7. Most of the water soluble compounds have polar or charged groups .... (   )
8. Each H_2O molecule can bind 3 other H_2O to form complex of $4H_2O$ .... (   )
9. The Oxygen in water molecule has one partial negative charge .... (   )

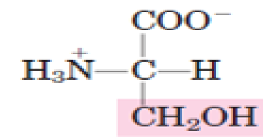
Functional Groups in Biochemistry (Cont.)

Examples from biochemistry

R-OH
Alcohol

—OH
Hydroxyl

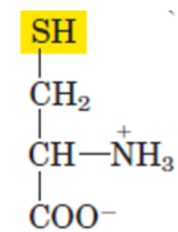
Example:
amino acid
(serine)



R-SH
Thiol

—SH
Sulfahydryl

Example:
amino acid
(cysteine)



$R{-}C({=}O){-}OH$
Carboxylic acid

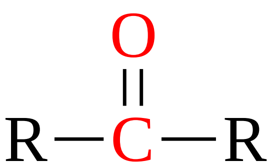
$-C({=}O){-}OH$ $\quad$ $R{-}C({=}O){-}O^{-}$
Carboxylate

Example:
fatty acid
(Palmitic acid)

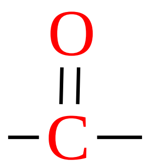
$CH_3(CH_2)_{16}COOH$

Functional Groups in Biochemistry (Cont.)

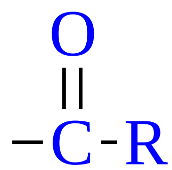
Examples from biochemistry



Ketone

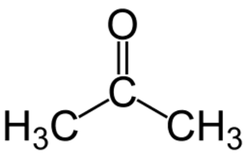


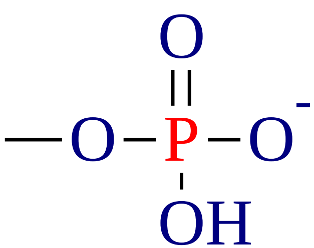
Carbonyl



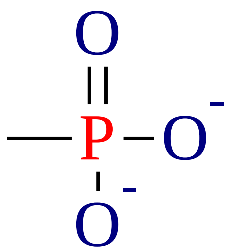
Acyl

Example:
acetone



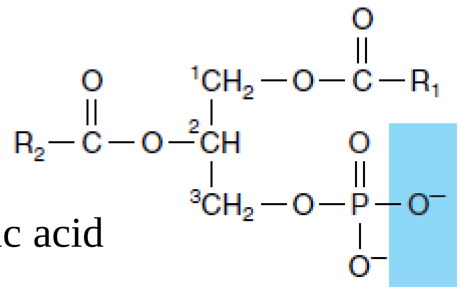


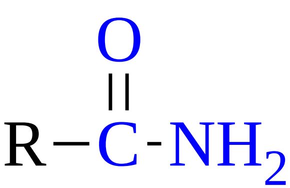
Phosphate



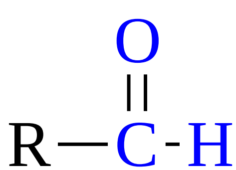
Phosphoryl

Example:
Phosphatetic acid



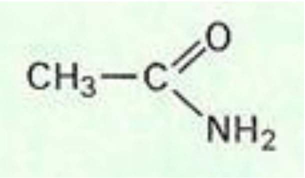


Amide



Aldehyde

Example:
acetamide



Functional Groups in Biochemistry (Cont.)

Examples from biochemistry

$R{-}NH_2$ — Primary

$R{-}N(R_1){-}H$ — Secondary

$R{-}N(R_1){-}R_2$ — Tertiary

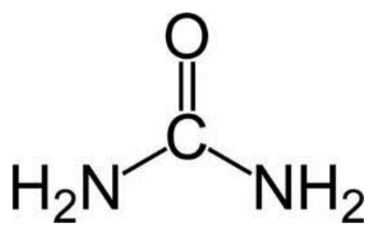
Amines

$-NH_3^+$

$-NH_2$

Amino

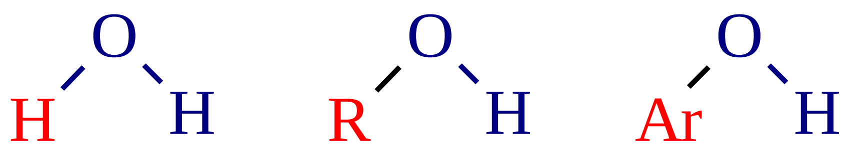
Example:
Urea



Alcohols & Phenols

- Alcohols:
  - Any molecule having –OH group (Hydroxyl) bound to an alkyl chain.
    - Primary, secondary, and tertiary alcohols based on what's bound to the C-OH group.
  - Important in many biological molecules
    - Some Amino acids, carbohydrates, and certain lipids
- Phenols
  - A hydroxyl group bound to an aryl or aromatic group (e.g., phenyl)

- **Both can be viewed as a substituted water.**



Properties of Alcohols

The -OH in alcohols has properties like H_2O

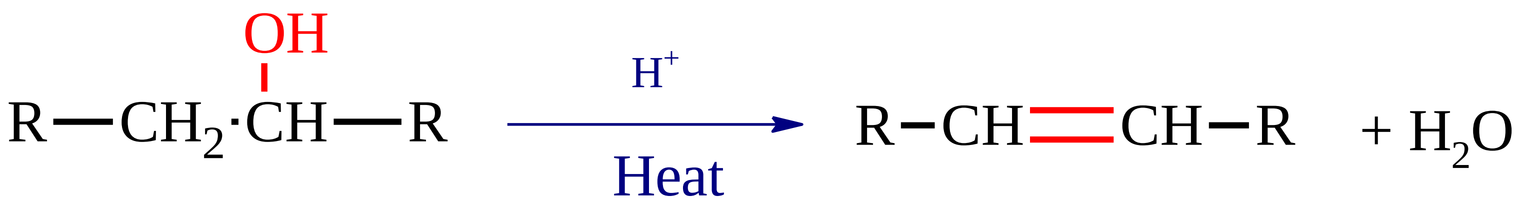
- Can participate in H-bonding (acceptor & donor)
- Polar group
- Water soluble
- but long carbon chain reduces solubility: R-OH

$$\overset{\delta^-}{\text{-O}}\text{-}\overset{\delta^+}{\text{H}}\cdots\cdots\overset{\delta^-}{\text{A}}\text{-}$$

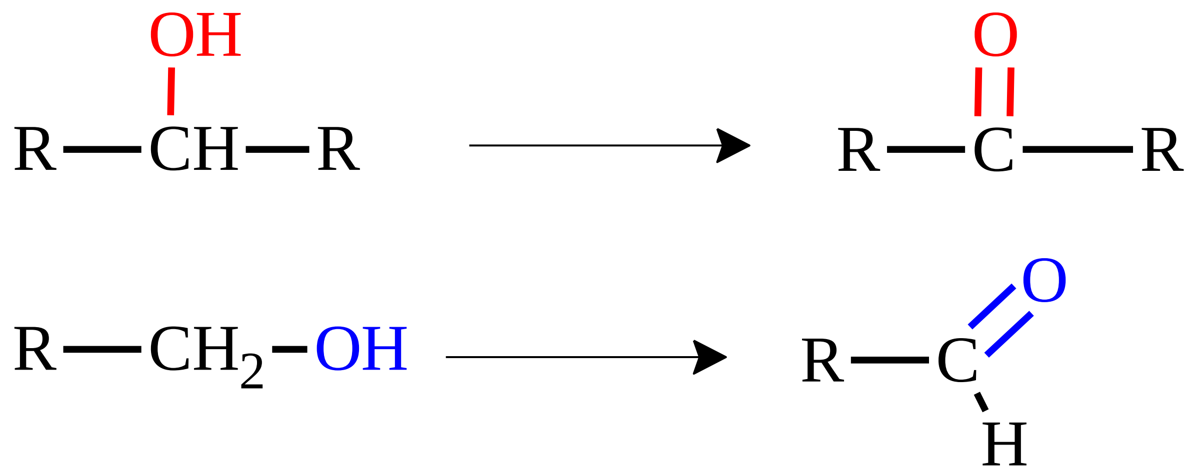
  - C_1 - C_5 Highly soluble
  - C_5 - C_7 Moderately soluble
  - C_8 and above Slightly soluble/insoluble

Reactions of alcohols

- Dehydration: removal of a water



- Oxidation: conversion of OH to =O.

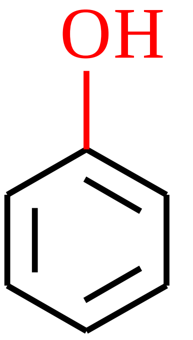


Ketone

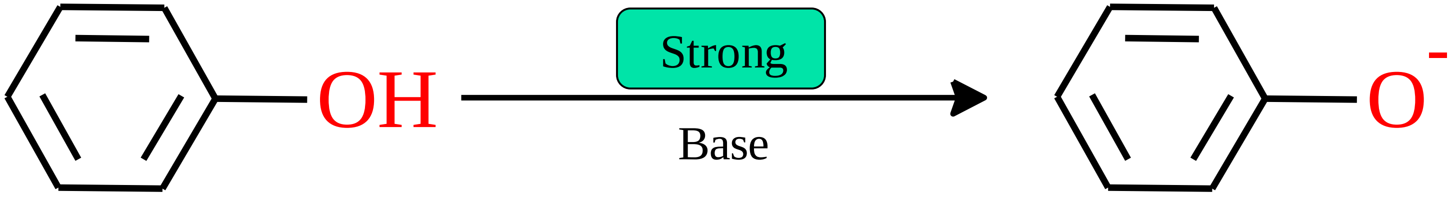
Aldehyde

- Remember OIL RIG
  - Oxidation Is Loss of electron (before, the gain of oxygen)
  - Reduction Is Gain of electron (before, the loss of oxygen)

Phenols



- Compounds with hydroxyl group bound to a benzene ring
- They are weak acids
  - Can lose a proton to strong bases.
    - Aliphatic alcohols do not act as acids.
      - The anion formed is not stable.



- The ring of phenol is easily oxidized.
  - In vivo, special enzymes can accomplish this.
    - *In vivo* means “in life” or “in a living cell”
    - *In vitro* means “in glass”

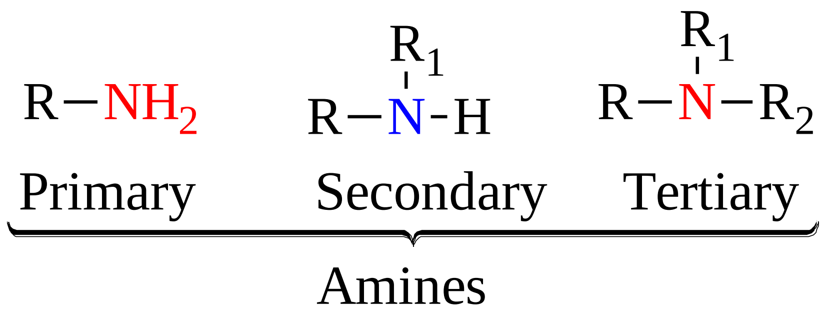
Thiols

- Similar to alcohols but contain S instead of O = R-S-H
  - The -SH can be called the thiol, mercaptan, or sulfhydryl group.
- S is less electronegative than O →
  - Less polar than alcohols
  - Weaker H-boding capability
  - Less water solubility

- Have some of the strongest & unpleasant odors

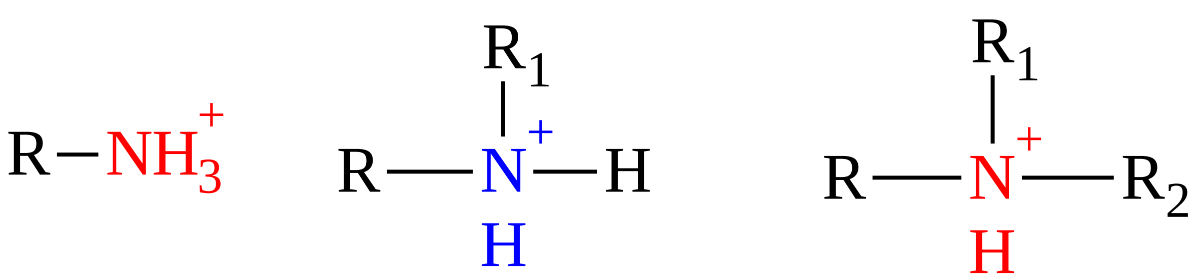
Amines

- Many biological molecules contain amino groups.
  - amino acids, DNA, RNA bases, alkaloids (e.g., caffeine, nicotine)
- General formula



  - R's are not necessarily identical.
  - Can be considered as substituted ammonia molecules.

- Amines are basic groups and can accept protons to become acidic.



Properties of Amines

- Nitrogen is very electronegative
  - but not quite as electronegative as oxygen.

$$\overset{\delta^-}{-N}-\overset{\delta^+}{H}\cdots\cdots\overset{\delta^-}{A}-$$

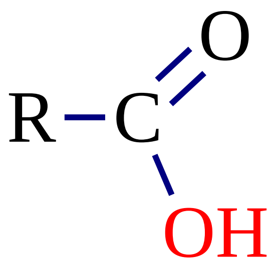
Thus:

- Amino group are polar groups
- Can participate in H-bonding (acceptor & donors)
  - Amines can also share H bonds with water, so they are more soluble in water than alkanes.
  - H bonds are not as strong as in alcohols
- Weak bases (similar to ammonia, a common weak inorganic base).

Carboxylic acids

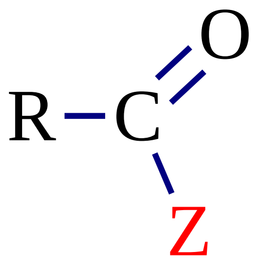
- Many biological molecules contain carboxylic group or one of its derivatives.
  - Proteins, amino acids, fatty acids, lipids, sugar, carbohydrates, and many others.

General Formula: -COOH (carboxyl)



- Any R possible: H, alkyl or aromatic chain

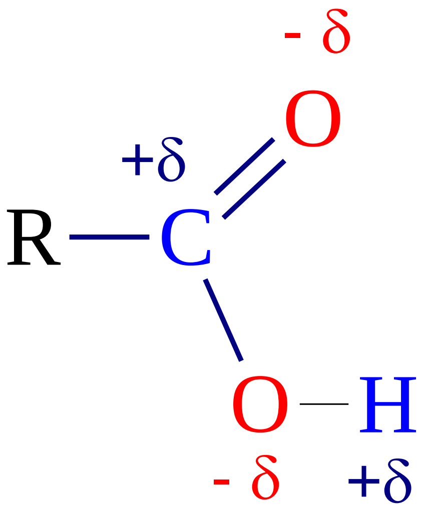
Derivatives Formula, where Z = could be:



- -Cl (Acid chloride)
- -OR, -OAr (Ester)
- $-NH_2$, -NHR (Amide)

Properties of Carboxylic Acids

- The carboxylic group is one of the most polar groups in biochemistry
- Both parts of the group are polar
  - -C=O
  - -O-H
    - –O-H is so polar, it is nearly ionic bond



- Presence of carboxylic group:
  - increases the solubility in water
    - Solubility decreases rapidly as MW increases.
  - Adds acidic character

Acidity of Carboxylic Acids

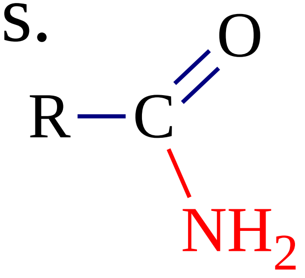
- All carboxylic acids are weak acids.

$$R-COOH \rightleftharpoons R-COO^{-} + H^{+}$$

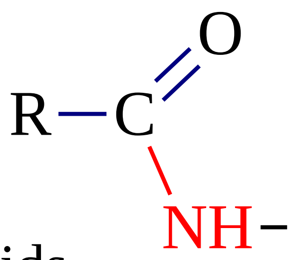
- They can ionize into H^+ and an anion.
  - Strong acids drive the reaction to the right
- Carboxylic acids occur largely as their anions in living cells and body fluids.
- The carboxylates are salts, example, sodium acetate .

Amides

- One of the important bonds in Biochemistry
  - Amides are derivatives of carboxylic acids.



- General formula:
  - Can be prepared from acids
    - + ammonia → simple amides
    - + amine →Substituted amides
      - Peptide bond is an amide bond between amino acids

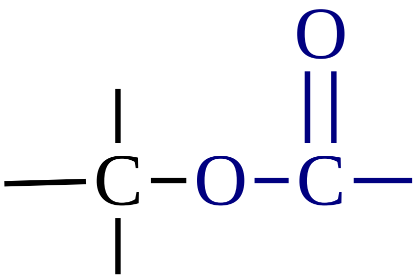


- The C-N bond is the amide bond.
  - One of the strongest bonds in biochemistry .
  - It can be broken but require strong acid or base + high temperatures.

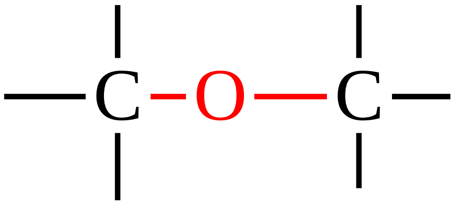
Amide Properties

- Amide molecules are polar.
  - They can participate in H-bonding as donor or acceptor
  - The forces among simple amides are so great that all except are solids at room temperature, except methanamide (formamide).
- Amides are NOT basic molecules.
  - The amine group of amide can not accept protons or get ionized
  - They are neutral in an acid-base sense.

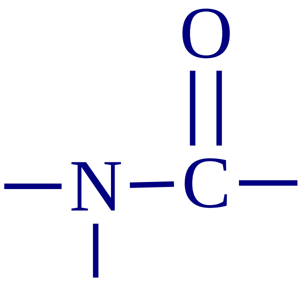
Common Linkages in biochemistry



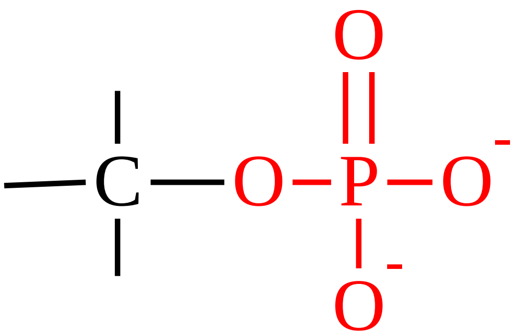
Ester



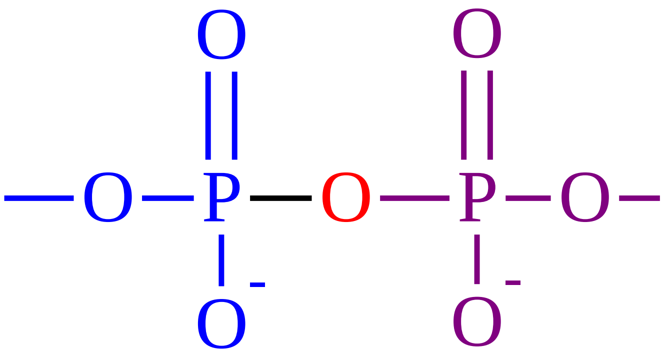
Ether



Amide



Phosphate Ester



Phosphodiaester
(phosphoanhydride)

Ionization of Water

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

H^+ (proton), HO^- (hydroxide), H_3O^+ (hydronium ion)

$$K_a = \frac{[H+][OH-]}{[H_2O]}$$

- K_a is a dissociation constant, and the brackets represent the concentrations of the species.

- $[H_2O]$ is constant by definition, so the equation simplifies to:

$$K_a(w) = [H][OH] = 10^{-14} At + 25^o C$$

Ionization of Water: pH Scale

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

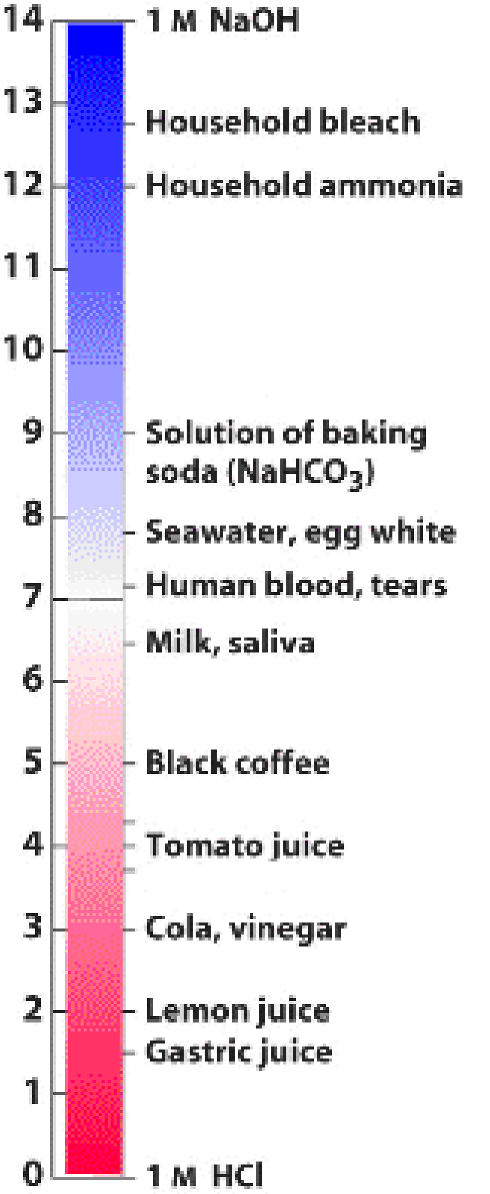
- Pure water has equal concentrations of H^+ and HO^-

$[H^+]=[HO^-] = 10^{-7}$ M for a neutral solution

If $[H^+] > 10^{-7}$ M, then the solution is acidic

If $[H^+] < 10^{-7}$ M, then the solution is basic

pH = -log[H^+]



Bronsted-Lowry Acids

$$HA + H_2O \rightleftharpoons H_3O^+ + A^-$$

- An acid is a substance that can donate a proton
- A base is a substance that can accept a proton
- In the above equation, HA is the acid and H_2O is the base
- A^- is the conjugate base of HA, and H_3O^+ is the conjugate acid of H_2O

$$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$$

Acid   Conjugate base

Quiz

Answer by marking true (T) or False (F)

1.H_2O can function as an acid or a base .... (   )

2.The structure of H_2O is a linear molecule .... (   )

3.Phenols act as a weak acid as it gives protons to a strong base .... (   )

4.Sulpher is less electronegative than Oxygen .... (   )

5.An acid is a substance that can accept a proton .... (   )

تعريف بالحموض والقواعد وثوابت التفكك الخاصة بها

Definition of acids and bases and its dissociation constants

تعريف الأحماض والقلويات

- *تعريف أرهينيوس* ***Arrhenius (1884)***

الأحماض هي المركبات التي تأين في المحاليل المائية لتعطي أيونات هيدروجين H^+.

القواعد هي المركبات التي تأين في المحاليل المائية لتعطي أيونات هيدروكسيل OH^-.

- *تعريف برونستد – لوري* ***Bronsted-Lowry (1923)***

هذا التعريف أكثر شمولية واستخداماً في الأوساط العلمية

الأحماض هي التي تأين لتعطي بروتونات Proton donor.

القواعد هي التي تستقبل بروتونات Proton acceptor.

$$BH \rightleftharpoons H^+ + B^-$$

حمض ... بروتون ... قاعدة

- كل من الحمض والقاعدة مرافق للآخر Conjugate
- فمثلاً B^- هي القاعدة المرافقة للحمض BH
- و BH هو الحمض المرافق للقاعدة B^-.

قاعدة (B1) + حمض (A2) ⇌ قاعدة (B2) + حمض (A1)

$$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$$

$$HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$$

$$HSO_4 + H_2O \rightleftharpoons H_3O^+ + SO_4^-$$

$$HBr + H_2O \rightleftharpoons H_3O^+ + Br^-$$

(مستمر): الأحماض والقويات

يمكن للماءِ أن يتأين ذاتياً ليعمل كحمض وكقاعدة في نفس الوقت

$$H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$$

(A1) حمض + (B2) قاعدة ⇌ (A2) حمض + (B1) قاعدة

- الأحماض الضعيفة تتأين (تتفكك) بدرجة ضعيفة لأن القاعدة المرافقة قوية فترتبط بقوة مع الهيدروجين
- الأحماض القوية تتأين كلياً فهي تتميز بميلها الشديد لإعطاء (فقد) بروتونات نظراً لضعف القاعدة المرافقة
- القواعد القوية تتميز بميلها الشديد لاستقبال بروتونات

وبحساب ثابت التأين للحمض K_a

$$HA \rightleftharpoons H^+ + A^-$$

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$K_a = \frac{[H_3O^+][OH^-]}{[H_2O]}$$

$$K_a = \frac{[10^{-7}][10^{-7}]}{[55.56]}$$

$$K_a = 1.8x10^{-16}$$

(مستمر): الأحماض والقويات

تعتمد قوة الحمض أو القاعدة على قدرة المذيب solvent على الارتباط بأيون الهيدروجين.
فممكن لحمض أن يكون قوياً في أحد المذيبات وضعيفاً في مذيب آخر.

فمثلاً حمض الأسيتيك (الخليك) يكون ضعيفاً في الوسط المائي ويكون قوياً في محلول الأمونيا.

القاعدة المرافقة للحمض القوي تكون ضعيفة والعكس صحيح.
فمثلاً الماء حمض ضعيف ولكن قاعدته المرافقة قوية (الهيدروكسيل OH)
أحماض HCl, HBr, HNO_3 هى أحماض قوية (سريعة التأين) وقواعدها المرافقة ضعيفة NO_3^-، Br^-, Cl^-.

تعريف الـ pH

هو اللوغاريتم السالب للتركيز الجزيئي لأيون الهيدرونيوم $[H_3O^+]$

$$pH = -\log [H_3O^+]$$

وتكتب غالباً بالصيغة التالية

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

وعند درجة حرارة ٢٥ °م تكون pH للماء النقي = ٧

$$pH = -\log [H^+] = -\log 10^{-7} = -(-7) = 7.0$$

بالمثل يمكن تعريف الـ pOH

$$pOH = -\log [OH^-]$$

$$pH + pOH = 14.00$$

معادلة هندرسون - هاسلبالخ
Henderson-Hasselbalch Equation

وضعت هذه المعادلة للتعبير عن الأحماض والقواعد الضعيفة وليس الأحماض القوية المخففة
إن الأحماض والقواعد الضعيفة لا تتأين كلياً، وتوجد في حالة اتزان بين تركيز الحمض الغير متأين وأيوناته (البوتون + القاعدة المرافقة)

$$HA \longleftrightarrow H^+ + A^-$$

يمكن حساب ثابت الاتزان كما يلي:

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

(مستمر): معادلة هندرسون – هاسلبالخ

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$-\log[H^+] = -\log K_a - \log\frac{[HA]}{[A^-]}$$

$$[H^+] = K_a \bullet \frac{[HA]}{[A^-]}$$

$$pH = pK - \log\frac{[HA]}{[A^-]}$$

$$\log[H^+] = \log(K_a \bullet \frac{[HA]}{[A^-]})$$

$$pH = pK + \log\frac{[A^-]}{[HA]}$$

$$\log[H^+] = \log K_a + \log\frac{[HA]}{[A^-]}$$

عندما يكون الحمض نصف متأين (يتساوى تركيز الحمض مع تركيز قاعدته المرافقة) يكون: pH = pK

$$[A^-] = [HA]$$

$$pH = pK + \log\frac{[A^-]}{[HA]} = pK + \log\frac{1}{1} = pK + 0 = pK$$

$$pH = pK$$

المحاليل الحيوية المنظمة

- تعريف المحلول المنظّم **Buffer**:

هي محاليل تتغيّر قيمة الرقم الهيدروجيني لها تغيراً طفيفاً عند إضافة حمض أو قاعدة إليها بكميات قليلة.

(أي أنها محاليل تقاوم التغيرات في قيمة **pH** عند إضافة حمض أو قاعدة إليها).

- ممّ يتكوّن المحلول المنظّم؟

- يتكوّن من حمض ضعيف وقاعدته المرافقة (ملح الحمض) أو قاعدة ضعيفة وحمضها المرافق (ملح القاعدة)

- أمثلة المحاليل المنظمة:

(CH_3COOH ، CH_3COO^-)

(NH_3 ، NH_4Cl) (HCN ، $NaCN$)

(HNO_2 ، KNO_2) (H_2CO_3 ، $NaHCO_3$)

آلية عمل المحاليل المنظمة

يحتوى المحلول المنظم على مواد تتفاعل مع أيونات H^+ ومواد أخرى تتفاعل مع أيونات OH^- المضافة أو الناتجة من أي تفاعل وبذلك يقل تأثير تلك الأيونات على الوسط

مثال: المحلول المتكون من حمض الأستيك + أسيتات صوديوم

– يقاوم التغير في الـ pH إذا أضيف إليه حمض قوي مثل HCl لأن الحمض المضاف يتحلل إلى أيونات Cl^- و H^+

– ترتبط أيونات Cl^- مع الصوديوم مكوناً ملح الطعام NaCl لا يؤثر في الـ pH

– ترتبط أيونات الأسيتات مع H^+ فيتكون حمض الأستيك ضعيف التحلل الذي لا يغير بدوره الـ pH

السعة التنظيمية Buffering Capacity

تتناسب قدرة المحلول المنظم على مقاومة التغير في الا pH طردياً مع تركيز مكوناته وتبلغ السعة التنظيمية أقصاها عندما يتساوى تركيز الحمض مع قاعدته المرافقة

مثال acetate buffer

$$pH = pK_a = -\log K_a$$

$$\log K_a = -\log 1.8 \times 10^{-5}$$

$$= 4.74$$

هذا معناه أن السعة القصوى لهذا المحلول تقع عند $4.74 = pH$ وتقل القدرة على مقاومة التغير كلما بعدنا عن هذا الرقم في حدود $\pm$ ١

أهمية المحلول المنظم

- ضرورية لضمان نشاط الإنزيمات
- ضرورية لنقل الغازات في الدم pH optima = 7.4
- تعالج التربة الزراعية بمحاليل منظمة حتى تصبح صالحة لزراعة محاصيل معينة.

أمثلة للكواشف على درجة الـ pH

الكاشف	لونه في الوسط القاعدي	لونه في الوسط الحمضي
فينول فثالين **Phenol phthaline**	وردي	عديم اللون
الميثيل البرتقالي **Methyl orange**	أصفر	أحمر
المثيل الأحمر **Methyl red**	أصفر	أحمر
دوار الشمس **Litmus paper**	أزرق	أحمر

أمثلة على pH لبعض السوائل

المادة أو المحلول	الأس الهيدروجيني pH
-عصير الليمون	2 . 40 –2.2
- الخل	3.0
- عصير الطماطم	4.0
- الجبنة	6.4-4.8
- ماء الشرب	8.0 – 5.5
- ماء البحر	8 .3
- بول الانسان	8 . 4 – 4 . 8
- حليب الأبقار	6 .6 – 6 .3
- لعاب الانسان	7 .5 – 6 .5
- دم الانسان	7 . 5 – 7 . 3