University of Houston

BCHS 3304: General Biochemistry I - Fall 2009
Section 21734
Tuesday/Thursday 11:30 AM – 1:00 PM 102 SW

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Office hours:
Tuesday and Thursday (1:00-2:00 PM) or by appointment

Course web page:
http://www.bchs.uh.edu/~glegge/teaching/

The lecture notes and homework will be posted on the Web

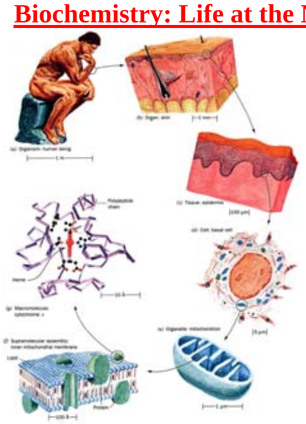
http://www.bchs.edu/~glegge/teaching/

These notes are not a substitute for class participation. These notes are posted on the web, although they may be altered before class. They are intended to make you pay attention in class, so take these notes with you. Don't just sit in class and just copy notes!!

Read the assigned material before the lecture.

Collect Homework 1 and START IT!!!

Biochemistry: Life at the Molecular Level



Biochemistry is the study of biological processes at a chemical level

Foundations of Biochemistry

Chapter 1: Life

Biochemistry is the study of the chemistry of life.
Biochemistry is an interdisciplinary science overlapping with chemistry, cell biology, genetics, immunology, microbiology, pharmacology, and physiology.

Main issues of Biochemistry

1. What are the chemical and three-dimensional structures of biological molecules?
2. How do biological molecules interact with each other?
3. How does the cell synthesize and degrade biological molecules?
4. How is energy conserved and used by the cell?
5. What are the mechanisms for organizing biological molecules and the coordinating of their activities?
6. How is genetic information stored, transmitted, and expressed?

Introduction to the Chemistry of Life

THE ORIGIN OF LIFE

•Universe is 15-20 billion years old –BIG BANG
•Initially H_2 was made then condensed to He
•Over the billions of years under the right conditions complex molecules formed.
•Complicated chemical reactions started occurring - intermolecular interactions and carbon based chemistry developed.

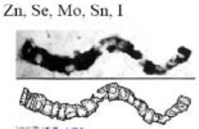
From this milieu sprang the property of

LIFE

Prebiotic World

Living matter consists of a small number of elements (see Table 1-1, p.3)
Elemental composition of the human body (98%)
•Carbon (C) – 61.7%; Nitrogen (N) – 11.0%; Oxygen (O) – 9.3%
•Hydrogen (H) – 5.7%; Calcium (Ca) – 5.0%; Phosphorous (P) – 3.3%
•Potassium (K) – 1.3%; Sulfur (S) – 1.0%; Chlorine (Cl) – 0.7%
•Sodium (Na) – 0.7%; Magnesium (Mg) – 0.3%
•Trace: B, F, Si, V, Cr, Mn, Fe, Co, Cu, Zn, Se, Mo, Sn, I

•Most organisms are ca. 70% water
•The earth is ca. 4.6 billion years old.



•Earliest known fossil is ca. 3.5 billion years old (filamentous bacterium).

The Physical Laws of Life

•Philosophers thought life contained a “vital force” or vitalism but this has been rejected by modern science.

•Haldane – simple organic compounds from H_2O, N_2 and CO_2
•Urey – chemical synthesis of urea

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

•Conservation of Mass, Energy
•Laws of Thermodynamics
•Laws of Chemical Kinetics
•Principles of Chemical Reactions

Molecular Logic of Life

These physical laws describe several axioms that make up the Molecular Logic of Life. These axioms define:

•Energy converted to work
•Catalytic chemical transformations
•Assembly of molecules with great complexity from simple subunits.
•Complex molecules combine to form supra molecular components, organelles and finally assemble into a cell.
•Store and pass on instructions for the assembly of all future generations from simple non-living precursors

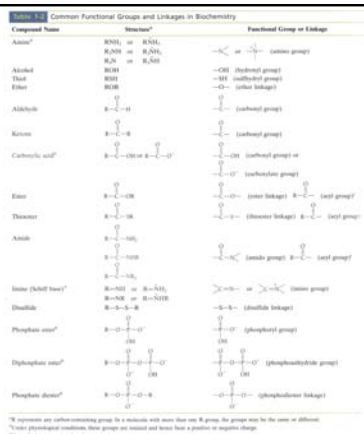


Table 1-2 Common Functional Groups and Linkages in Biochemistry

Compound Name	Structure	Functional Group or Linkage

Life is in constant flux

Enzyme catalyzed reactions- Substrates ⇒ Products 10^{-3} sec - milli sec
Unwinding of DNA 10^{-6} sec - micro sec

10^{-15} s	10^{-12} s	10^{-9} s	10^{-8} s	10^{-6} s	10^{-3} s	10 s	10^{3}s
femto	pico	nano		micro	milli	sec	

•femto fs	excitation of chlorophyll
•pico ps	charge separation in photosynthesis
•nano ns	hinge protein action
•10^{-8} 10 ns	fluorescence lifetime
•micro µs	DNA unwind
•milli ms	enzymatic reactions
•10^{3}	generation of bacteria
•2.3 x 10^{9} sec	average human life span

What distinguishes living organisms?

1) Structurally complicated and highly organized
   a. intricate internal structures
   b. many kinds of complicated molecules

proteins, DNA, RNA, starches, and lipids etc. (inanimate objects sand clay are mixtures of simple compounds)

2) Living organisms:

a. extract
b. transform → ENERGY
c. store
d. use

Living things can extract energy from the environment

Chemical: Chemoautotrophs or lithoautotrophs

$H_2S \rightarrow 2H^+ + S\downarrow + 2e^-$
$2NH_3 + 4O_2 \rightarrow 2HNO_3 + 2H_2O$
$4FeCO_3 + O_2 + 6H_2O \rightarrow 4Fe(OH)_3 + 4CO_2$
or

Sunlight: Photoautotrophs
$nCO_2 + nH_2O + h\upsilon \rightarrow (CH_2O) + nO_2$

Energy is needed to build and maintain structures

a) mechanical energy	- muscles
b) chemical energy	- electric eel
c) osmotic energy	- plant turger
d) light energy	-bioluminescence

3) Most characteristic attribute of living things is self-replication and self assembly

it is the quintessence of the living state

1 single bacteria → 10^9 in 24 hr

With near-perfect fidelity during replication!

A crystal at equilibrium grows but life at equilibrium is death!

Life is a set of relationships characterizing the nature, function and interaction of biomolecules.

The Essential Role of Water

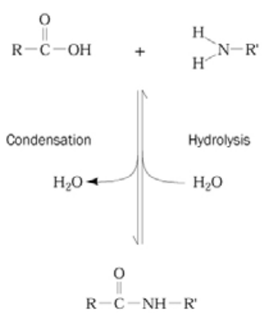
•H_2O is the key to understanding the behavior of macromolecules. It is the solvent of life and all living transformations occur in an aqueous media-

Life is thought to have arisen from the sea.

•Even water-insoluble compounds such as lipid membranes derive their nature and function by their interactions with H_2O.

Condensation reactions

•Chemical Evolution, simple molecules condense to form more complex forms (polymers)



Reaction of a carboxylic acid with an amine

Replication through complementarity

- Specific pairing of functional groups gives rise to complementarity
- More complex molecules increases chemical versatility
- Complementarity makes it possible for macromolecules to replicate
- Over time natural selection favored molecules that made accurate copies of themselves

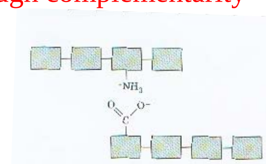
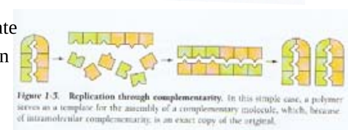
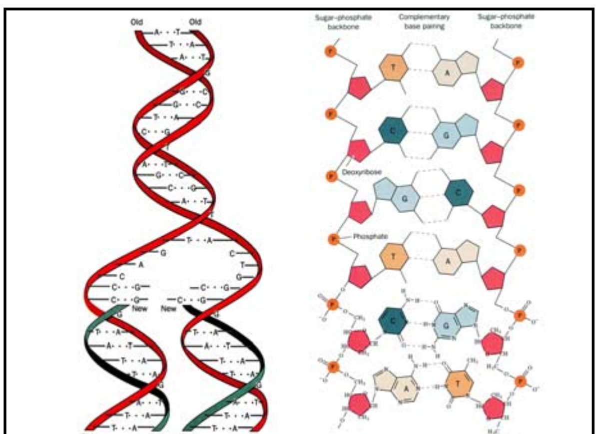
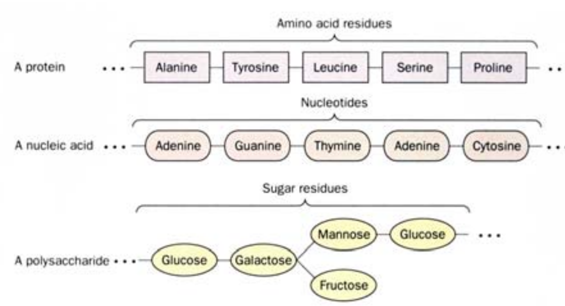


Figure 1-4. Association of complementary molecules.







How did organisms evolve?

- Blind watchmaker principle, small mutations arise at random.

1. Evolution is not directed
2. Evolution requires built-in sloppiness
3. Evolution is constrained by the past
4. Evolution is ongoing

Table 1-2 Common Functional Groups and Linkages in Biochemistry

Compound Name	Structure[a]	Functional Group or Linkage
Amine[b]	RNH_2 or $R\overset{+}{N}H_3$ R_2NH or $R_2\overset{+}{N}H_2$ R_3N or $R_3\overset{+}{N}H$	—N< or —N⁺— (amino group)
Alcohol	ROH	—OH (hydroxyl group)
Thiol	RSH	—SH (sulfhydryl group)
Ether	ROR	—O— (ether linkage)
Aldehyde	R—C(=O)—H	—C(=O)— (carbonyl group)
Ketone	R—C(=O)—R	—C(=O)— (carbonyl group)
Carboxylic acid[b]	R—C(=O)—OH or R—C(=O)—O^-	—C(=O)—OH (carboxyl group) or —C(=O)—O^- (carboxylate group)
Ester	R—C(=O)—OR	—C(=O)—O— (ester linkage) R—C(=O)— (acyl group)[c]
Thioester	R—C(=O)—SR	—C(=O)—S— (thioester linkage) R—C(=O)— (acyl group)[c]
Amide	R—C(=O)—NH_2 R—C(=O)—NHR R—C(=O)—NR_2	—C(=O)—N< (amido group) R—C(=O)— (acyl group)[c]
Imine (Schiff base)[b]	R=NH or R=$\overset{+}{N}H_2$ R=NR or R=$\overset{+}{N}$HR	>C=N— or >C=N⁺< (imino group)
Disulfide	R—S—S—R	—S—S— (disulfide linkage)
Phosphate ester[b]	R—O—P(=O)(OH)—O^-	—P(=O)(OH)—O^- (phosphoryl group)
Diphosphate ester[b]	R—O—P(=O)(O^-)—O—P(=O)(OH)—O^-	—P(=O)(O^-)—O—P(=O)(OH)—O^- (phosphoanhydride group)
Phosphate diester[b]	R—O—P(=O)(O^-)—O—R	—O—P(=O)(O^-)—O— (phosphodiester linkage)

[a] R represents any carbon-containing group. In a molecule with more than one R group, the groups may be the same or different.
[b] Under physiological conditions, these groups are ionized and hence bear a positive or negative charge.
[c] If attached to an atom other than carbon.

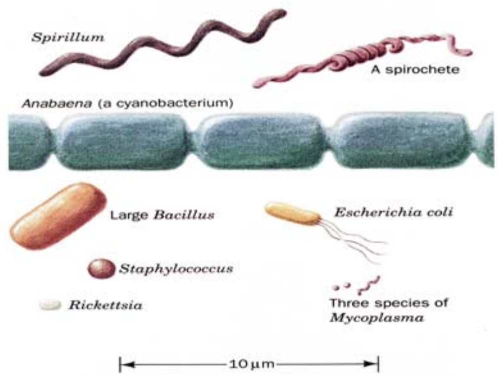
•Cell → multi cell, varied and diverse and evolutionary processes lead to diversity but life has many common themes and processes.

Organic compounds found in living organisms are a product of Biological Activity

Biomolecules are selected by evolution- the fit are kept, the not fit are discarded.

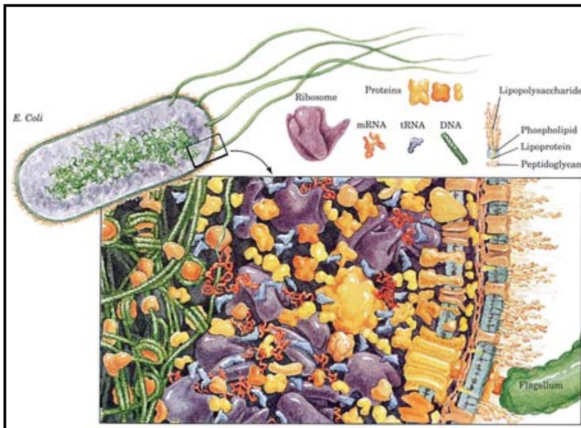
The more fit remain and continue to evolve.

The Evolution of Cells Provided the Advantage of COMPARTMENTATION



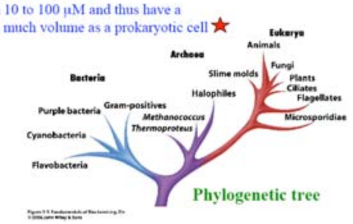
Cellular Architecture

- Vesicles (fluid-filled sacs) are thought to be the precursors to cells
- These entities would have had the ability to shield self-replicating chemical reactions and catalyzed reactions so that they were taking place in a sheltered environment, giving them a competitive advantage
- This process is called compartmentation
- This compartment then has the opportunity to further evolve in order to enhance its advantage.
  - It may do so my hoarding nutrients and ions
- A typical animal cell contains as many as 100,000 different types of molecules
- A common bacterium, *E. coli*, contains millions of molecules, representing 3000-6000 different compounds.

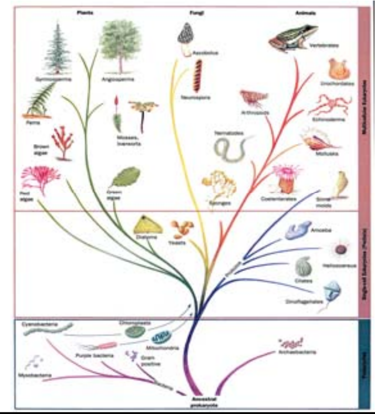


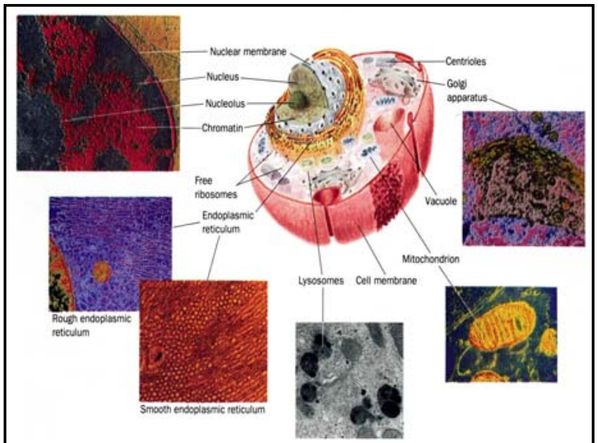
Prokaryotes and Eukaryotes

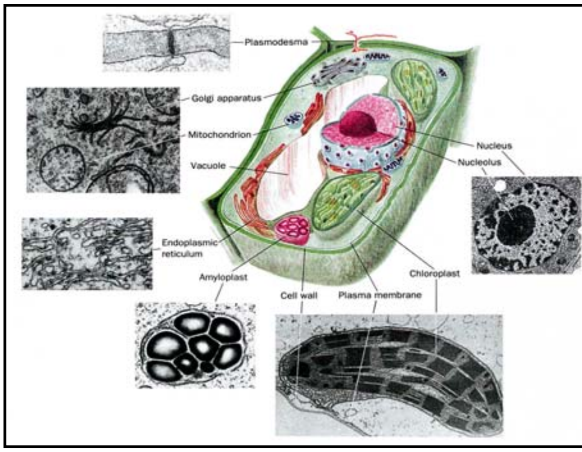
- All modern organisms are based on the same morphological unit, the cell
- Prokaryotes – lack a nucleus (e.g., bacteria) ★
- Eukaryotes – membrane enclosed nucleus encapsulating their DNA ★
- Viruses are not cells and are not living since they lack the apparatus to reproduce outside of their host cells ★
- Prokaryotes range in size from 1 to 10 μM ★
- Eukaryotes range in size from 10 to 100 μM and thus have a thousand to a million times as much volume as a prokaryotic cell ★



Phylogenetic Tree of Showing Three domains of Organisms







Lecture 2
Thursday 8/27/09
Units and Thermodynamics