Biochemistry

- The study of molecules and reactions that occur in living organisms.
- Explains the development, maintenance, reproduction and destruction of life forms.
- These biological processes require specific interactions between thousands of ‘biochemicals’.
Biomolecules

- All living matter is considered ‘organic’.
- Organic compounds are made up of C, H, O with significant amount of N, P and S.
- Trace elements include Ca, Fe, I, Na, Mg, etc.
- Biologically important small molecules: water, vitamins, some hormones, heme etc.
Biomolecules

- Macromolecules divided into 4 classes:
  Nucleic acids: DNA and RNA (polynucleotides)
  Proteins: polymers of aminoacids (polypeptides)
  Carbohydrates: polymers of sugars (polysaccharides)
  Lipids: water-insoluble biomolecules. (not polymers)
Biochemical Reactions

• Enzyme catalyzed
• Together they are called ‘Metabolism’
• 2 categories:
• Anabolism make up the synthetic reactions
• Catabolism is the degradation reactions
Reaction Compartments

• Biochemical reactions occur inside the cell
• The cell is compartmentalized into organelles.
  (review your biology)
• Main reaction sites: mitochondria, cytosol, ER
• Compartments allows reactants to remain separated until reaction time.
• Pumps and transporters that facilitate entry of biomolecules into organelles.
• Biochemical signals target molecules to correct site.
Genetic Information

- Genetic information is contained in DNA.
- The complete human genome is sequenced.
- Need to identify the functions of each gene.
- Which genetic errors cause disease?
- Gene expression during development.
- Genetic changes during evolution.
Flow of Information

• Genetic information flows from DNA→DNA→RNA→Protein→Function
• DNA is the Blueprint
• RNA is the Messenger
  (RNA also has structural and adapter roles)
• Protein is the Performer
• DNA and RNA sequences are made up of only 4 bases each
• Protein sequences contain 20 amino acids.
Structure-Function Relationship

• Underlying principle throughout Biochemistry: Structure determines function.
• The structure (sequence) and therefore, the function, of each gene is unique.
• In the double helix, A-T and G-C pairing is based on chemical structure of A, T, G, and C.
• In proteins, not only the sequence of amino acids, but also the 3D folding patterns affect function.
Biochemical Evolution

• The genetic code is universal.
• Diverse organisms share the same biomolecules.
• These similarities point to a common ancestry for all organisms on earth. (Tree of Life)
• The diversity stems from:
  adaptation of biomolecules to new roles
  variable complexity
  macromolecular interactions.
• One can understand evolutionary progress by comparing genetic and biochemical characteristics of various organisms.
Life Started with Chemical Synthesis of Key Biomolecules

- Water
- Amino acids and Proteins
- Carbohydrates (carbon/energy source/store)
- Lipids (also for energy)
Biochemistry of Evolution

- Prebiotic chemicals evolved into organized complexes capable of growth and duplication (chemistry merged with biology)
- Prehistoric life forms adapted to the environment by using sunlight and chemical energy for physiological functions.
- Stability of these chemical compounds is dependent on covalent bonds; their reactivity depends on non-covalent interactions.
Chemical Bonds in Biochemistry

Irreversible Bonds

- Covalent bonds
  - Single bonds
  - Double and triple bonds
  - Resonance structures

- Chemical reactions require making and breaking covalent bonds
Reversible Bonds

• Noncovalent bonds
  Electrostatic interactions (electrical charge)
  Hydrogen bonds (H and $\delta^-$ atom)
  van der Waals interactions
    (transiently $\delta^-$ and $\delta^+$ atoms)
  Hydrophobic interactions (nonpolar domains)
• Reversible bonds are the basis for macromolecular 3D structure.
Hydrogen donor → 0.9 Å → NH → 2.0 Å → Hydrogen acceptor

180°
van der Waals contact distance

Energy

Repulsion

Attraction

Distance

0
Hydrophobic Interactions

Nonpolar molecule

Nonpolar molecule

Nonpolar molecule