BIOCHEMISTRY

Analysis of Biological System

- Despite of all their complexity, an understanding of biological system can be simplified by analyzing the system at several different levels:
  - the cell level: microbiology, cell biology;
  - the molecular level: biochemistry, molecular biology;
  - the population level: microbiology, ecology;
  - the production level: bioprocess.

Biochemistry

- **Introduction of the biological system at molecule level.**
- This section is devoted mainly to the structure and functions of biological molecules.
- Contents: ***Cell construction***
  - Protein and amino acids
  - Carbohydrates
  - Lipids, fats and steroids
  - Nucleic acids, RNA and DNA

Cell Construction

- Living cells are composed of high-molecular-weight polymeric compounds such as:
  - Proteins
  - Nucleic acid
  - Polysaccharide and carbohydrate
  - Lipids and other storage materials (fats, polyhydroxbutyrate, glycogen)

  Bioplymers

  - Metabolites in the form of inorganic salt (NH^{4+}, PO_4^{3-} , K^+, Ca^{2+}, Na^+, SO_4^{2-})
  - Metabolic intermediates (e.g. acetate)
  - vitamins

Cell Construction

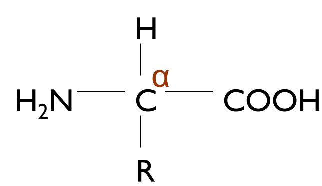
- Biopolymers constitute the major structural elements of living cells.
  - Bacterial cell wall = polysaccharide + proteins + lipids
  - Cell cytoplasm = proteins (mostly in the form of enzymes)
  - In eukaryotes, cell nucleus contains nucleic acid in the form of DNA

PROTEINS AND AMINO ACIDS

Amino Acids and Protein

- **<u>Proteins</u>** are the most abundant organic molecules in living cells, constituting 40% - 70% of their dry weight.
- Proteins are polymers built from **amino acid** monomers.
- **<u>Amino acid</u>** is any molecule that contains both carboxyl (–COOH) and amino (H_2N–) functional groups.

Amino Acids

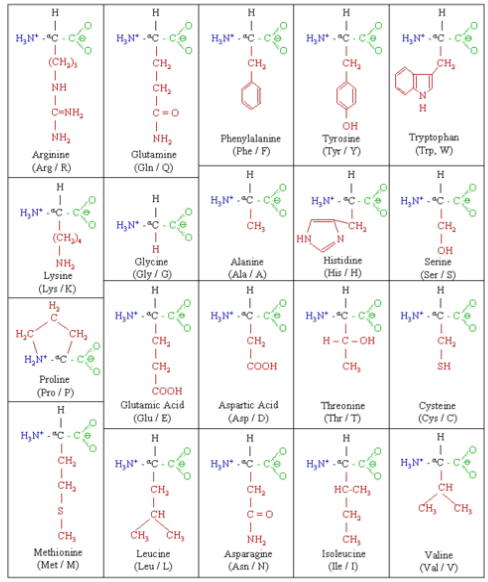


- "R" represents a side chain specific to each amino acid.
- Amino acids are usually classified by properties of the side chain into four groups:
  - Acidic
  - Basic
  - Hydrophilic (polar)
  - Hydrophobic (nonpolar)

- **<u>α-amino acid</u>** are amino acid in which the amino and carboxylate functionalities are attached to the same carbon, the so-called α–carbon.
- They are the building blocks of proteins.

Standard Amino Acids

- There are 20 standard amino acids that are commonly found in proteins.



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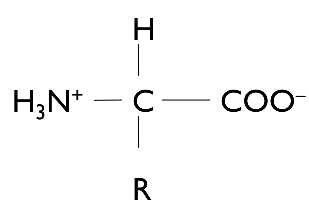
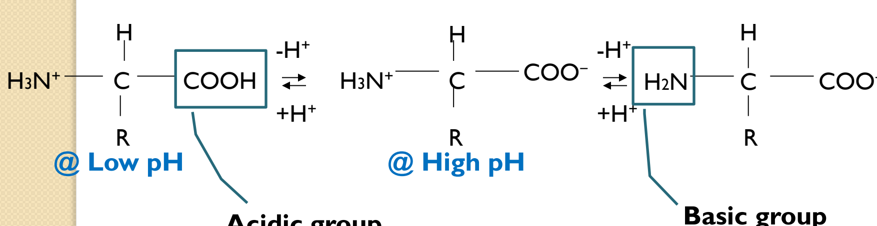


- An amino acid having positively and negatively charged groups, a dipolar molecule.

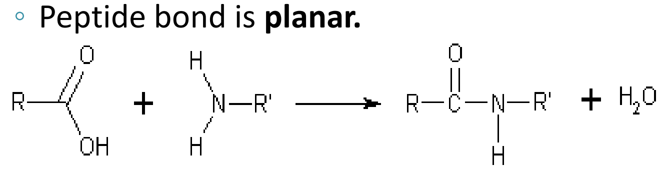


Isoelectric Point (IEP)

- The pH value at which amino acids have no net charge.
- IEP varies depending on the R group of amino acids.
- At IEP, an amino acid does not migrate under the influence of an electric field.
- Knowledge of IEP can be used in developing processes for protein purification.

Peptides

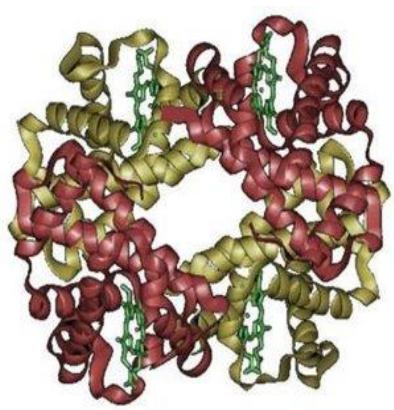
- **Peptide bond** is a chemical bond results from the condensation reaction between two amino acids.
  - The carboxyl group of one amino acid reacts with the amino group of the other amino acid, releasing a molecule of water.
  - Peptide bond is **planar.**



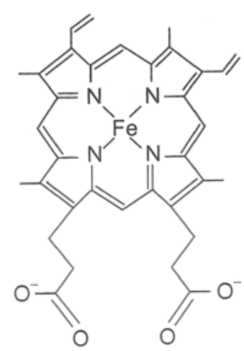
- **Peptides** contain two or more amino acids linked by peptide bonds.

Proteins

- **Polypeptides** usually contain fewer than 50 amino acids.
- Larger amino acid chains are called **proteins.**
  - Protein constitutes 40 - 70% of dry weight of cell.
  - Its molecular weight is from 6000 to several hundred thousand.
- **Prosthetic groups**: organic or inorganic components other than amino acids contained in many proteins.
- **Conjugated proteins**: proteins containing prosthetic groups.



Conjugated protein: **hemoglobin**
Prosthetic groups: heme in green (4)
Amino acid units in red and yellow

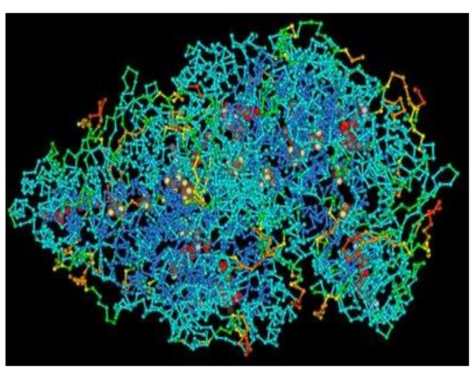


Heme group: iron containing organometallic complex

Proteins Classification

- Proteins have diverse biological functions, which can be classified into:
  - Structural protein: glycoprotein, collagen, keratin
  - Catalytic protein: enzymes
  - Transport protein: hemoglobin
  - Regulatory protein: hormones (insulin, growth hormone)
  - Protective proteins: antibodies

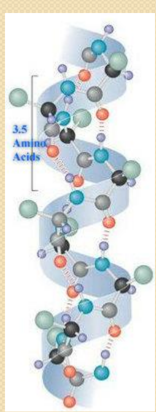
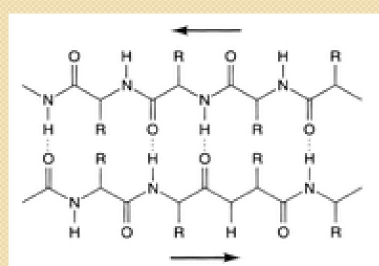
Protein 3-D Structure



Proteins are amino acid chains that fold into unique 3-dimensional structures.
The shape into which a protein naturally folds is known as its native state, which is determined by its sequence of amino acids and interaction of groups.

Protein 3-D Structure

- Protein has three-dimensional structure at four level:
  - **Primary structure:** the unique linear sequence of amino acids, held together by covalent peptide bonds
  - **Secondary structure:** the way the polypeptide chain is extended and is a result of H-bonding between residues.
    Two major types of secondary structure are α-helix and β-pleated sheet.

α-helix	**β-pleated sheet**
	

Protein 3-D Structure

Protein 3-D Structure

- Protein has three-dimensional structure at four level:
  - **Tertiary structure:** the overall shape of a protein molecule and the result of interaction between R groups mainly through hydrophobic interaction. The tertiary structure has a profound effect on protein function.
  - **Quaternary structure:** the interaction between different polypeptide chains of protein. This structure is important to the active function of protein especially enzyme.

Protein Denaturation

- Protein can be denatured at its three dimensional structure. Protein denature could be reversible or irreversible.
- Proteins denature when they lose their three-dimensional structure - their chemical conformation and thus their characteristic folded structure.
- This change is usually caused by heat, acids, bases, detergents, alcohols, heavy metal salts, reducing agents or certain chemicals such as urea.

CARBOHYDRATES

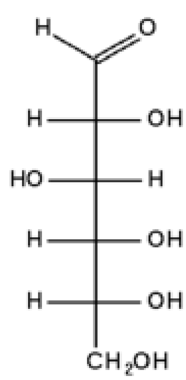
Carbohydrates

- Carbohydrates are synthesized from carbon dioxide and water through photosynthesis, $(CH_2O)_n$ ($n \geq 3$), or $C_n(H_2O)_{n-1}$.
- Carbohydrates play critical roles as structural and storage compounds in cells.
- Carbohydrates are classified by the number of sugar units:
  - monosaccharides
  - disaccharides
  - polysaccharides

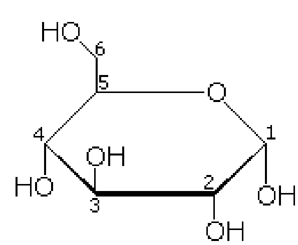
Carbohydrates

- Monosaccharides are the simplest form of carbohydrates containing three to nine carbon atom $(CH_2O)n$.
- They consist of one sugar and are usually colorless, water-soluble, crystalline solids.
- Important monosaccharides include **glucose**, **D-ribose** and **deoxyribose**.

Glucose



D-Glucose as a straight chain



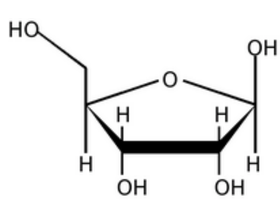
D-Glc in ring structure

Glucose

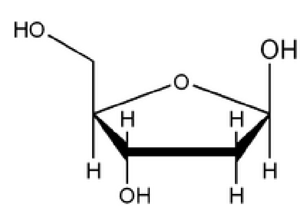
- Glucose (Glc) is one of the main products of photosynthesis and starts cellular respiration.
- The cell uses it as a source of energy and metabolic intermediate.
- Glucose is the source for glycolysis and citric acid cycle in metabolic pathway.
- Glc is produced commercially via the enzymatic hydrolysis of starch.

D-Ribose and Deoxyribose

- D-Ribose and deoxyribose are pentose containing five carbon ring-structure sugar molecules



D-ribose



deoxyribose

D-ribose and Deoxyribose

- D-Ribose is a component of the ribonucleic acid (RNA) that plays central role for **protein synthesis**.
- Ribose is critical to living creatures. It is also a component of adenosine triphosphate (ATP).
- Deoxyribose is a component of deoxyribonucleic acid (DNA) that is **important genetic material**.

Disaccharides

- Formed by the condensation of two monosaccharides.
- e.g. Maltose is formed by the condensation of two glucose molecules via 1, 4-glycosidic linkage.

Maltose

Disaccharides

- Common disaccharides:
  - Sucrose (known as "table sugar", "cane sugar") = β-D-glucose + β-D-fructose
  - Lactose (milk sugar) = β-D-glucose + β-D-galactose

Polysaccharides

- Formed by the condensation of more than two monosaccharides by glycosidic bonds.
- Polysaccharides have a general formula of $C_n(H_2O)_{n-1}$ where n is usually a large number between 200 and 500.
- They are very large, often branched, molecules.
- They tend to be amorphous, insoluble in water, and have no sweet taste.
- Examples include
  - **storage polysaccharides** such as **starch**, and
  - **structural polysaccharides** such as **chitin**.