

7.013 Recitation 3 - 2013

Summary of Lecture 4:

Biological macromolecules- Nucleic acids and Proteins: Nucleic acids [Deoxyribonucleic acids (DNA) / Ribonucleic acids (RNA)] are polymers specialized for the storage, transfer and use of genetic information. They are comprised of nucleotides (A, T, G, C and U) each of which has phosphate group, a pentose sugar and a nitrogenous base. Polymers of nucleic acid are formed by linking the 5' phosphate group of incoming nucleotide to the 3' hydroxyl group on the pentose sugar of last nucleotide in the growing nucleic acid strand. DNA is the hereditary material in the cell and is usually double-stranded. The RNA is usually single-stranded and is of three major types: ribosomal (rRNA), transfer (tRNA) and messenger (mRNA). The mRNA gets translated to proteins. In comparison, the tRNA and rRNA are involved in the synthesis of proteins. Nucleotides also serve as energy sources (ATP and GTP) and second messengers (cAMP) during intracellular or cell-cell signaling.

Proteins are linear chains of amino acids of which there are 20 distinct types. The order of the amino acids in the chain dictates the shape that the protein will take and therefore the function of the protein in the cell. There are 4 levels of protein structure: primary, secondary, tertiary and quaternary. The precise sequence of amino acids in a polypeptide chain constitutes the primary structure of proteins. A protein's secondary structure (α -helix and β -pleated sheets) is comprised of regular repeated spatial patterns in different region of polypeptide chains and is predominantly stabilized by hydrogen bonds. The different interactions between the side chain groups of the amino acids determine the 3-dimensional tertiary structure of proteins. Quaternary structure results when two or more polypeptide chains in a protein bind to and interact with each other. Proteins perform all possible functions within a cell except storage of hereditary information. Proteins can be structural, can be used to transport materials, can be used for locomotion of cells and be used as enzymes or biological catalysts. It is worth mentioning that the RNA may also have enzymatic activity.

Enzymes and energy: An endergonic reaction (one with a positive ΔG) cannot occur spontaneously, although it may be coupled to an exergonic reaction. An exergonic reaction (one with a negative ΔG) can proceed spontaneously. Exergonic reactions do not necessarily proceed quickly; this highlights the difference between thermodynamics and kinetics. The thermodynamics of the reaction are dictated by the difference in free energy between the substrate and the products. The kinetics of the reaction is determined by the transition stage and how much energy must be added to form the intermediate. Enzymes lower the activation energy needed for a reaction to proceed, but do not change the free energy of either the reactants or the products.

Enzymes are biological catalysts. They catalyze specific reactions and act by lowering the activation energy of their reaction. Each enzyme has a specific 3-dimensional conformation and an active site to which the substrate molecules can bind. The complex then gives rise to product (P) and the enzyme is released in its original form to catalyze the reaction once again. Each enzyme is specific for a particular reaction. Enzyme functioning may be regulated by various factors. These factors may include i.e. prosthetic groups, metal ions / cofactors, coenzyme, substrate concentration, pH, temperature, inhibitors, allosteric modulators and the feedback inhibition by the end product.

Questions:

1. Nucleic acids are of two major types: double helical DNA and single stranded RNA.

- i. Draw the chemical structure of a DNA molecule composed of three deoxy-ribonucleotides. Label the 3' and 5' ends.

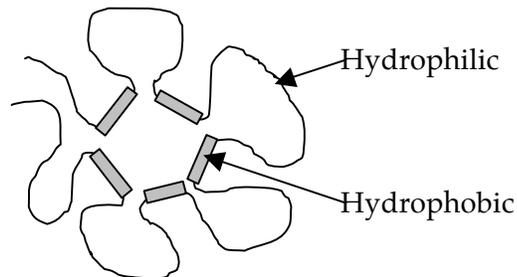
- ii. How is a nucleotide different from a nucleoside?

- iii. Why the two strands of DNA are anti-parallel to each other?

- iv. Why is RNA more reactive compared to a DNA?

- v. RNA is single stranded. However, it can have a very complex three-dimensional structure. Certain regions of RNA may show intra- molecular base pairing. Is the base pairing observed in RNA similar to or different from that in DNA?

2. A certain protein has this structure, where a line indicates a hydrophilic region and a box represents a hydrophobic region.



- i. Why do you think the protein might fold this way when dissolved in salt water?

- ii. How do you think the protein might fold differently if it were dissolved in cooking oil?

3. You are studying a protein that comes from a bacterial species that lives in your gut. This protein also has enzymatic function. If you boil this protein, you will disrupt Hydrogen bonds and ionic bonds, but not covalent bonds. If this enzyme is most active (100% active) in the cytoplasm of a bacterial cell (37°C) in your gut, what would be the effect of protease treatment on the activity of this protein?

4. Pepsin is a digestive enzyme that acts on proteins in stomach. This requires the presence of HCl for its normal functioning.

- i. What may be the type of reaction catalyzed by pepsin?
- ii. Pepsin functions well in the stomach but it ceases to function in the intestine. Explain why pepsin does not function in the intestine?

5. The formation, maturation and folding of secreted proteins takes place in the endoplasmic reticulum and the golgi body. These steps normally occur without any error. However, very rarely a misfolded protein may be produced which (if not destroyed) can lead to severe, life threatening diseases. How do the cells normally get rid of these misfolded proteins?

6. Enzymes, which are usually proteins, act as biological catalysts. Of the properties mentioned in the following table, state which are not changed by the enzymes.

Properties	Does enzyme change this property (Yes/No)?
ΔG of reaction	
Rate of reaction	

7. Working in a research lab you happen to identify a novel protein. This protein serves as an enzyme, which catalyses the following reaction.



You observe that if you increase the concentration of substrate A, there occurs a simultaneous increase in the rate of reaction, but only up to a certain point. Explain **why**.

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