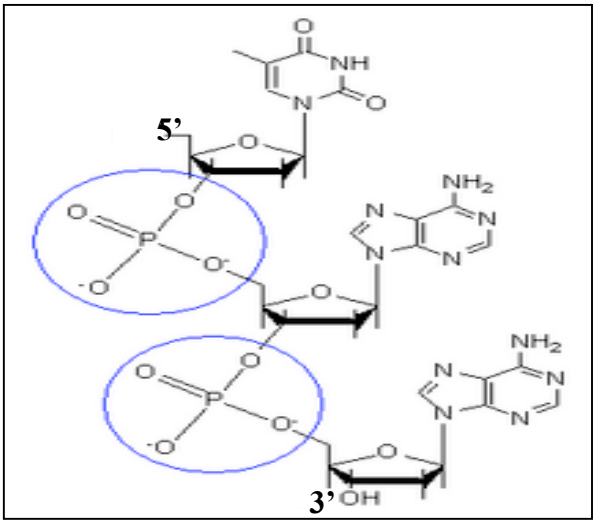
# Solution key - 7.012 Recitation 2 - 2010

**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?

*A nucleoside is comprised of a nucleic acid base (A, T, G, C, U) and ribose/deoxyribose sugar. In comparison, the nucleotide has a base and a 5 carbon sugar that has the phosphate groups.*

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

*The anti-parallel arrangement of the two strands in a DNA duplex allows the complementary bases to stack in a manner that allows them to hydrogen bond with each other. This arrangement also ensures that both the strands replicate in a 5′→3′ direction (you will learn more about this in your Molecular biology lectures).*

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

*The extra –OH group at the 2′C of the ribose sugar allows RNA to be more reactive compared to DNA.*

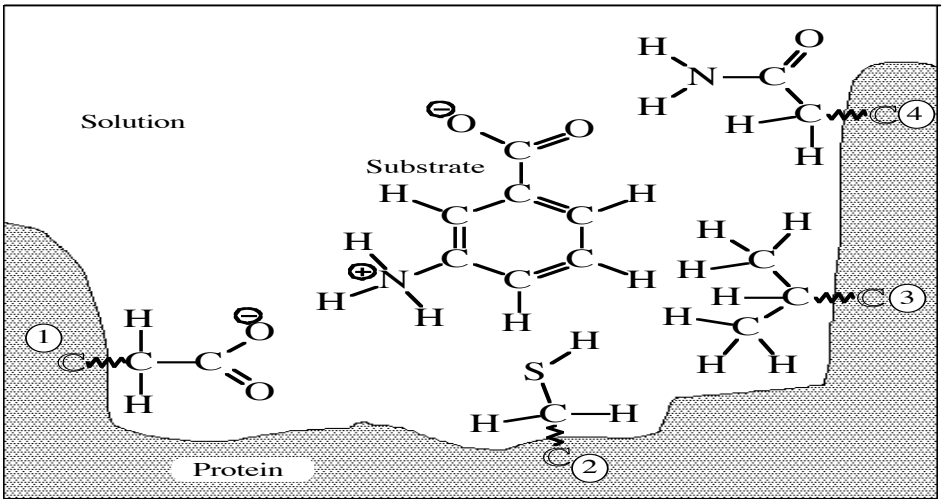
v. RNA is single stranded. However, it can have a very complex three-dimensional structure. Certain regions of RNA may show intra- molecular base pairing. Is the base pairing observed in RNA similar to or different from that in DNA?

*Yes, the intra-molecular base pairing in RNA follows the same complementary base-pairing rule as DNA where A forms two hydrogen bonds with U and C forms three hydrogen bonds with G.*

2. Some proteins act as enzymes that may be defined as biological catalysts. The active site of each enzyme binds to the substrate molecules. In each case, the active site is comprised of only 10-15 amino acids. Would you expect that these 10-15 amino acids that form the active site are immediately adjacent to each other in the primary structure? Explain your answer.

*No, an active site is formed in three dimensions. Different amino acids from various parts of the protein are brought in close proximity to each other to form the active site by the folding of the protein.*

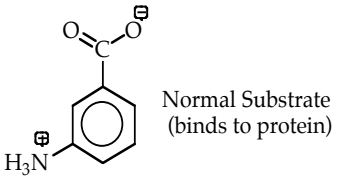
3. You have seen the following schematic of a substrate bound to the active site of an enzyme in your section 1 handout. You have also identified the amino acids located at positions 1-4 and stated their most likely mode of interaction with the substrate.

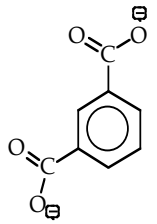



i. Describe the effect of the following substitutions on the enzyme substrate interaction.

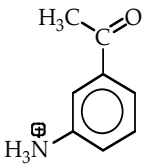
- Amino acid # 1 substituted to methionine: *Here Aspartic acid, which has a charged, polar, hydrophilic side-chain is being substituted by methionine that has an uncharged, non-polar, hydrophobic side-chain. The methionine will not be able to form the ionic bond with the substrate unlike aspartic acid thus preventing the enzyme substrate interaction.*
- Amino acid # 1 substituted to lysine: *Here cysteine, which has an uncharged, polar, hydrophilic side-chain is being substituted by lysine that has* ***positively charged****, polar, long hydrophilic side-chain. The lysine, being positively charged will be repelled by the* $NH_3$+ *group of the substrate.*
- Amino acid # 3 substituted to alanine: *Here Valine, which has an uncharged, nonpolar, hydrophobic side-chain is being substituted by alanine that also has an uncharged, nonpolar, hydrophobic side-chain. Therefore the hydrophobic interactions/VDW will most likely be maintained despite this substitution and the enzyme will be able to interact with the substrate.*

ii. One way to study the interactions between substrate and protein is to synthesize molecules similar to the substrate and see if they bind to the protein. Shown below are 3 "substrate analogs" along with the normal substrate. Explain, in terms of the interactions you described above, why each of the analogs binds or fails to bind to the protein.

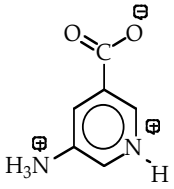


Analog 1
(does not bind)



Analog 2
(binds)



Analog 3
(does not bind)

*Analog #1 cannot bind since the two negative charges will repel each other. Analog #3 cannot bind since the polar groups interact unfavorably with the hydrophobic environment. The binding group of analog#2 is same as the normal substrate and it will therefore be able to bind.*

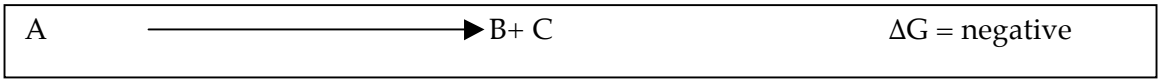
iii. There are four amino acids required for the binding of the substrate shown above to its enzyme. Why then do enzymes typically contain hundreds of amino acids? What are the other amino acids important for?

*The other amino acids help maintain the **active** 3D- conformation of enzyme.*

4. Enzymes, which are usually proteins, act as biological catalysts. Of the properties mentioned in the following table, state which do enzymes NOT change.

| **Properties** | **Does enzyme change this property? Yes or No.** |
|---|---|
| **Δ G of reaction** | *No* |
| **Rate of reaction** | *Increases* |

5. 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**.

*If you increase the substrate concentration, more substrate molecules will be available to bind to the active site of the enzyme and get converted to products B and C. This causes an initial increase in the rate of enzyme-catalyzed reaction. However, after some time, the active sites of all the available enzyme molecules are already saturated with the substrate molecules i.e. enzyme itself becomes a limiting factor. At this point, even if the substrate concentration is increased, there occurs no further increase in the rate of reaction i.e. reaction rate reaches a plateau phase.*