7.016 Recitation 2 – Fall 2018

*(**Note:** The recitation summary should NOT be regarded as the substitute for lectures)*

Summary of Lectures 2 (9/7) & 3 (9/10):

Major elements of the biological macromolecules: Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Phosphorous (P) and Sulphur (S) are the six major elements found in biological macromolecules. The number of electrons regulates the chemical bonding and geometry of an atom.

Bonding: A chemical bond is an attractive force that links two electrons together in a molecule. There are many types of bonds that hold molecules together.

- **Covalent bonds** are the strongest of all the types of bonds. This results when two atoms attain stable electron numbers in their outermost shells by equal or unequal sharing one or more pairs of electrons between them, such as the bonds between C and H in methane.

- **Ionic bonds** occur between atoms with a very high difference in electronegativity. This results in a complete transfer of one or more electrons from one atom to another that has a higher electronegativity. For example, in table salt (NaCl), the sodium acquires a positive change (Na^+) by donating its electron to chlorine, which now acquires a negative charge (Cl^-).

- **Hydrogen bonds:** occur between polar molecules, such as molecules of water, because of the partial negative charge on the O and the partial positive charge on the H i.e. difference in the electronegativity of O and H atoms. In biological systems you most often see the formation of hydrogen bonds if the Hydrogen is between two O atoms or two N atoms or an O and N.

- **Hydrophobic interactions):** In aqueous environment, the hydrophobic molecules tend to aggregate with one another rather than interact with polar water molecules. This is hydrophobic interaction. It promotes association of hydrophobic molecules together in order for them to avoid water and thereby increase entropy.

- **Van Der Waals forces (VDW)** occur when atoms of two molecules are in close proximity. These brief interactions result from the random variations in the electron distribution in one molecule, which creates opposite charge distribution in the adjacent molecule. Although a single VDW is brief and weak, the sum of many such interactions over the entire span of a large nonpolar molecule can result in substantial attraction.

http://www.kentchemistry.com/links/bonding/bondingflashes/bond_types.swf

Biological macromolecules: All the cells have lipids, carbohydrates, nucleic acids and proteins. With the exceptions of lipids, the biological macromolecules are polymers made by the covalent bonding of small monomers through dehydration/condensation reactions. The polymers may be hydrolyzed to individual monomers with the addition of water molecule(s).

Lipids: Lipids or fats are predominately hydrocarbon chains that are used as energy storage and insulation. Lipids are hydrophobic in nature. Modified lipids form phospholipids, steroid hormones, cholesterol and some vitamins. Cell membranes are composed of lipid bilayers, which separate the aqueous inside of the cell (the cytoplasm) from the aqueous outside of the cell (the extra cellular environment).

Animations/ articles/ videos: http://www.johnkyrk.com/cellmembrane.html

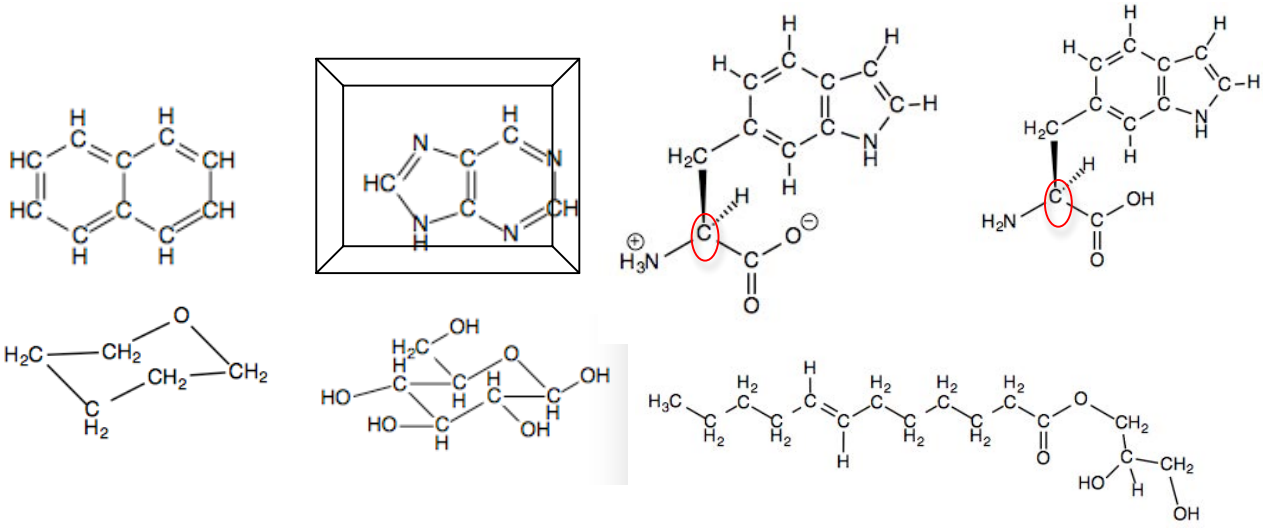
Proteins: Proteins are linear chains of amino acids of which there are 20 distinct types. The order of the amino acids in the chain dictates the shape and the function of the protein in the cell. There are 4 levels of protein structure: primary, secondary, tertiary and quaternary. The polypeptide chain of a protein is always WRITTEN in an N-> C direction and – as we shall see later it is also biosynthesized in an N-> C direction.

Animation on protein folding: https://www.youtube.com/watch?v=swEc_sUVz5I

Proteins perform all possible functions within a cell except storage of hereditary information. Each protein has a unique 3D-conformation, which is maintained under optimal conditions i.e. specific pH, salt concentration and temperature conditions. The protein 3D structure is crucial for function. Alteration in synthesis or functioning of proteins can result in diseases.

Questions:

1. Of the five structures given below



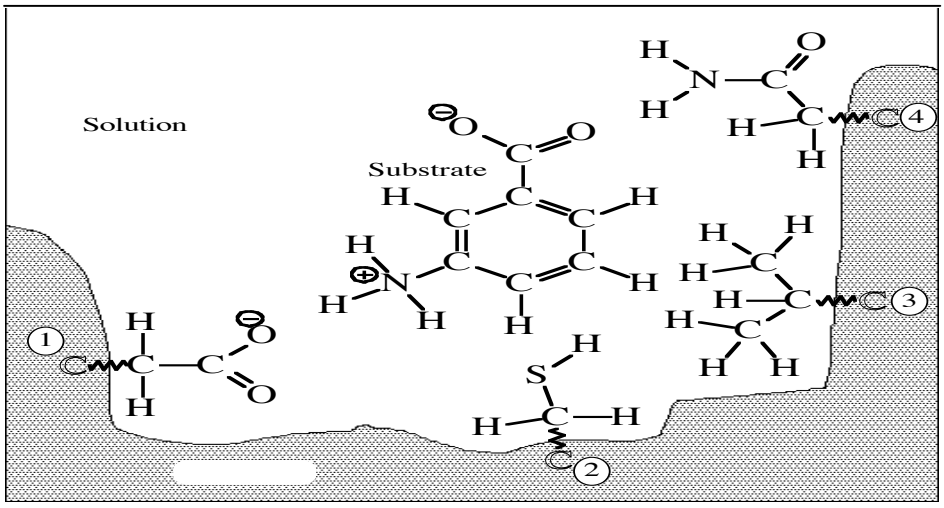
a) Circle the structure(s) that can serve as a building block of proteins. Underline the central carbon atom of this structure and classify the side- chain as **polar/ nonpolar**, **charged/ *uncharged*, *hydrophobic*/ hydrophilic**.

b) Box the structure(s) that can serve as a building block of carbohydrates.

c) Shade the structure(s) that can serve as a building block of nucleotide.

2. Patients with a high blood cholesterol levels do not benefit very significantly if they follow a cholesterol free dietary regimen. Briefly **explain** why is this so.

3. The following diagram represents a substrate molecule bound to the active site of a protein. The R groups from the amino acids in the protein's substrate-binding region are shown. Each of the four R groups from the protein that interacts with the substrate is numbered on the figure below. For each side chain, state the strongest type of interaction it could have with the substrate in the configuration shown below. *Your choices are: Covalent, Hydrophobic/ VDW, Ionic and Hydrogen.* Also classify each R group as *hydrophobic, polar or charged*.



a) Complete the following table.

R Group	Interaction(s) of R Group with Substrate	Classification of R Group
(1)		
(3)		
(4)		

b) The amino acid at position (2) is special and can form a disulphide (S-S) bonds with another cysteine. In terms of bond energy, how is a disulphide bond different from the interactions that you filled in the table above?

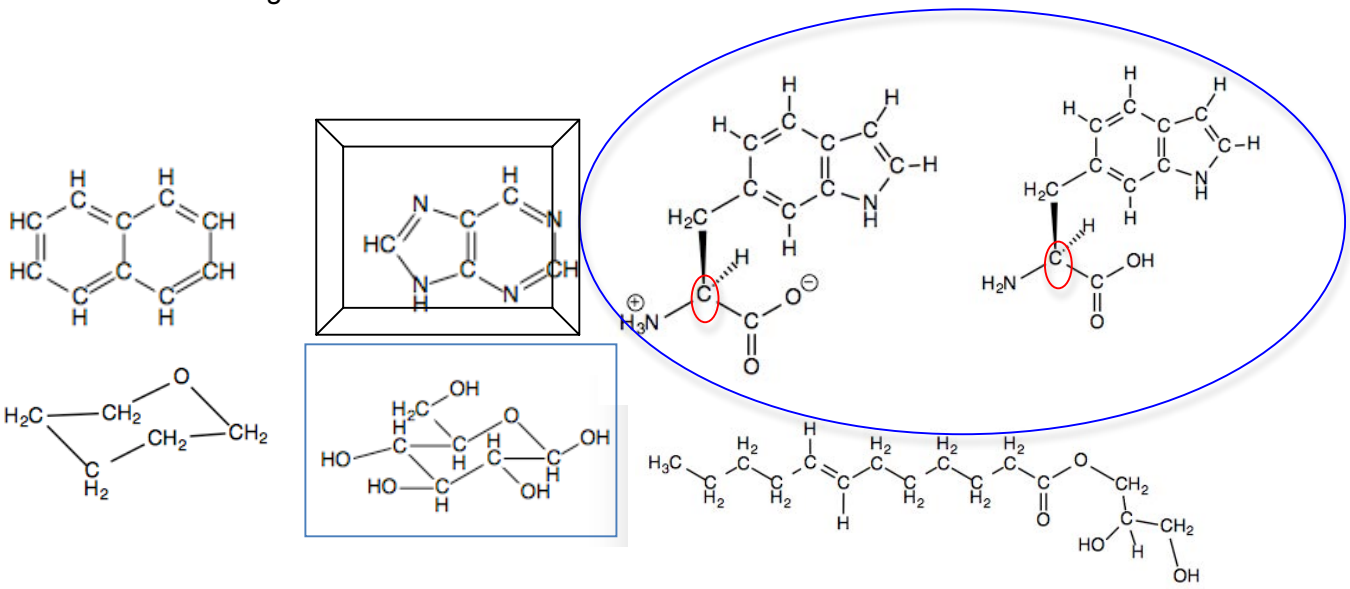
4. Pepsin is a digestive enzyme that acts on proteins in stomach. This requires the presence of hydrochloric acid (HCl) for its normal/ optimal function.

a) What may be the type of reaction catalyzed by pepsin?

b) Pepsin functions well in the stomach but it ceases to function in the intestine. **Explain** why pepsin does not function in the intestine?

Solutions to the Questions:

1. Of the five structures given below



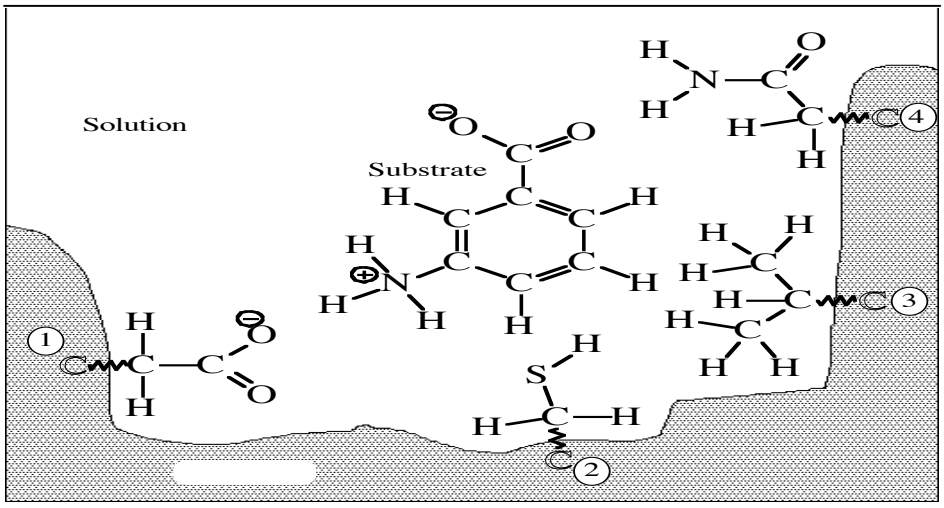
a) Circle the structure(s) that can serve as a building block of proteins. Underline the central carbon atom of this structure and classify the side- chain as polar/ ***nonpolar***, charged/ *uncharged*, ***hydrophobic***/ hydrophilic.

b) Box the structure(s) that can serve as a building block of carbohydrates.

c) Shade the structure(s) that can serve as a building block of nucleotide. *2nd structure within the top row*

2. Patients with a high blood cholesterol levels do not benefit very significantly if they follow a cholesterol free dietary regimen. Briefly **explain** why is this so.
Cholesterol is a part of membranes in all cells. It also serves as a precursor for vitamin D, bile acids, steroid hormones clearly reflecting that this is an important molecule that is made my our cells. Since the body makes cholesterol, you don't see a significant decrease in the blood cholesterol level even if you strictly follow a cholesterol free dietary regimen.

3. The following diagram represents a substrate molecule bound to the active site of a protein. The R groups from the amino acids in the protein's substrate-binding region are shown. Each of the four R groups from the protein that interacts with the substrate is numbered on the figure below. For each side chain, state the strongest type of interaction it could have with the substrate in the configuration shown below. *Your choices are: Covalent, Hydrophobic/ VDW, Ionic and Hydrogen.* Also classify each R group as *hydrophobic, polar or charged*.



a) Complete the following table.

R Group	Interaction(s) of R Group with Substrate	Classification of R Group
(1)	*Ionic, (Hydrogen bonding also possible)*	*Charged, polar, hydrophilic*
(3)	*Hydrophobic /*	*Nonpolar, hydrophobic*
(4)	*Hydrogen bonding*	*Polar, hydrophilic*

b) The amino acid at position (2) is special and can form a disulphide (S-S) bonds with another cysteine. In terms of bond energy, how is a disulphide bond different from the interactions that you filled in the table above? *It has very high bond energy since this is a covalent bond.*

4. Pepsin is a digestive enzyme that acts on proteins in stomach. This requires the presence of hydrochloric acid (HCl) for its normal/ optimal function.

a) What may be the type of reaction catalyzed by pepsin?
Pepsin digests the proteins to small polypeptides at acidic pH by breaking the peptide bonds. So it is a hydrolysis reaction.

b) Pepsin functions well in the stomach but it ceases to function in the intestine. **Explain** why pepsin does not function in the intestine?
Each enzyme maintains its active three-dimensional conformation at a specific pH. The acidic pH in the stomach is the required pH for pepsin's structure and therefore its activity.

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