7.013 Recitation 2 – Spring 2018

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

Summary of Lectures 2 (2/9) & 3 (2/12):

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 of atoms together in a molecule. **Hydrogen** forms a single bond with another atom. **Carbon** forms four bonds. **Nitrogen** makes three bonds – in this form the nitrogen is neutral. **Nitrogen** can also form four bonds – in this form the nitrogen is positively charged. **Oxygen** makes two bonds – in this form the oxygen is neutral. **Oxygen** can also form a single bond – in this form the oxygen will be negatively charged .The most common bonding to **Sulfur** in biomolecules is similar to **Oxygen**. **Phosphorous** likes to form 5 bonds.

- **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 (δ-) and the partial positive charge (δ+) on the H i.e. difference in the electronegativity of O and H atoms.

- **Hydrophobic interactions):** In aqueous environment, the hydrophobic molecules 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

Functional groups: Certain small groups of atoms called functional groups occur frequently in biological macromolecules. Each functional group has specific properties and when attached to a large molecule, the group confers its properties to the larger molecule. Since macromolecules are so large, they may contain diverse functional groups; some are polar and uncharged, others are polar and charged and some are nonpolar and hydrophobic. The attached functional groups confer different specific properties to the local sites within the macromolecules, regulate the overall 3D-structure of the molecule, and regulate the molecule's chemical properties and its interactions with other reactants.

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 release of water molecule(s) as a reaction byproduct.

Types of macromolecules: The following are the four major classes of biological macromolecules.

- **Carbohydrates:** Carbohydrates include monosaccharides, disaccharides, trisaccharide or polysaccharides. A monosaccharide is composed of carbons flanked by H atoms or -OH groups, is hydrophilic and can exist in a linear or cyclic structure. Monosaccharides are linked together by glycosidic bonds to form polysaccharides including starch, chitin and cellulose. The carbohydrates have C:H:O in the ratio of 1:2:1.

  Carbohydrates are used as an energy source, as a source for carbon, and can be attached to other macromolecules, including lipids and proteins, to serve as recognition markers for the cell. Proteins covalently attached to carbohydrates (glycans) are called **glycoproteins:** We have different **blood groups** due to the variation in the glycans that are attached to cell surface protein on mature red blood cells.

- **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.

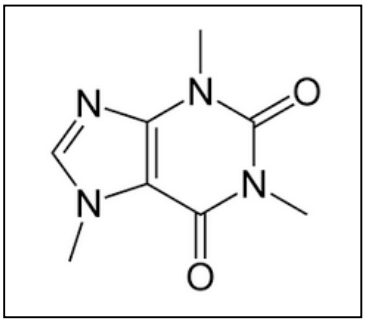
- **Nucleic acids (DNA & RNA):** Nucleic acids [Deoxyribonucleic acids (DNA)/Ribonucleic acids (RNA)] are biological macromolecules specialized for the storage, transfer and use of genetic information. They are built from basic building blocks called nucleotide triphosphates (deoxy-ribonucleotide or dNTP in DNA and ribonucleotides or rNTPs in RNA): **A**denosine triphosphate (ATP), **T**hymidine triphosphate (TTP), **G**uanosine triphosphate (GTP), **C**ytosine triphosphate (CTP) and **U**ridine triphosphate (UTP). The A and G are purine bases whereas the T, C and U are pyrimidine bases.

  Polymers of nucleic acid are formed by condensation or dehydration reaction that leads to the formation of a 3'->5' covalent phosphodiester bond. DNA in the cell is the hereditary material and is usually double-stranded. The two strands of DNA are complementary and anti-parallel.

  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. It is to be noted that the linear chain of proteins is made in an N->C direction with the C terminus being the receiving end for incoming amino acid. In comparison, the nucleic acids are made of nucleotides in a 5'->3' direction with the 3' end being the receiving terminus for the incoming nucleotide.

Questions

1. The following is the "line-angle" drawing of caffeine. **Note:** *The carbon (C) and the hydrogen (H) atoms are not shown but implied.*

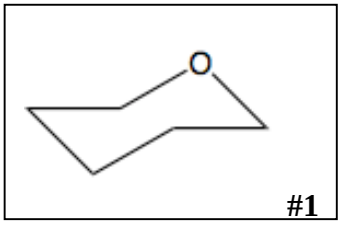


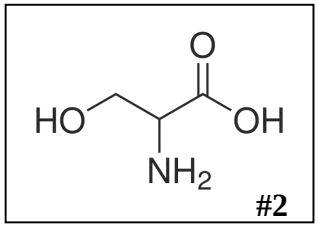
a) Clearly show the position of **ALL** C and H atoms on the drawing and give the **chemical formula** of caffeine.

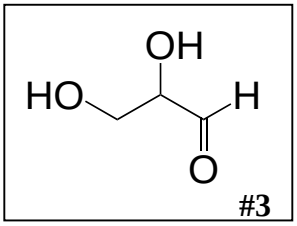
b) On the line angle drawing, **box** a **nonpolar** group and **circle all electronegative elements**.

c) Give the **strongest non-covalent interaction** that allows caffeine to dissolve in aqueous environment.

2. The following structures are shown as "line-angle" drawings of three chemical structures. For each structure, show the position of **all** of the carbon and hydrogen atoms as implied by the drawings.







a) Give the chemical formula of each structure based on the line angle drawings above.

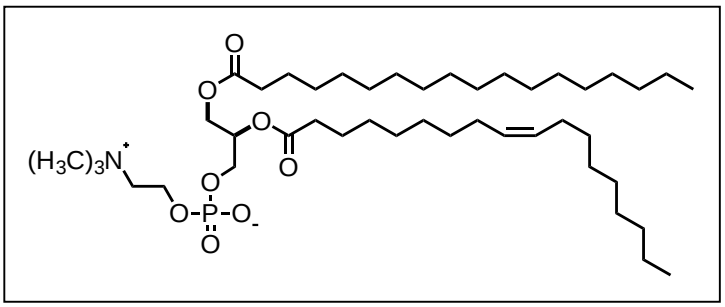
#1: _____ **#2:** _____ **#3:** _____

b) Circle the structure that can serve as a building block of carbohydrates and **box** a functional group in this structure.

c) Box the structure that can serve as a building block of proteins.

d) Underline the central carbon atom of the structure that you circled in part (c) and circle its side-chain. Based on its side-chain would you classify it as a polar or nonpolar amino acid?

3. The following is a line angle drawing of a biological molecule. Multiple copies of this molecule can arrange and form the plasma membrane of a cell.

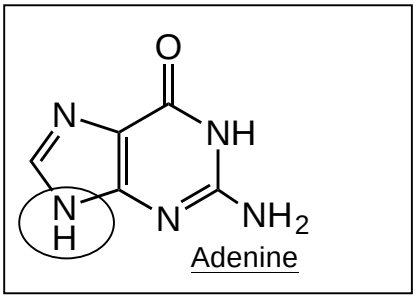


i. **Circle** the correct option. The above molecule belongs to the class of ***carbohydrates/ lipids/ proteins/ nucleic acids*.**

ii. **Circle** the part of the molecule that will be exposed to the aqueous (i.e. water filled) exterior or cytoplasm of the cell.

iii. **Box** the part of the molecule that will form the hydrophobic region of the plasma membrane.

4. The following is adenine base, which can covalently bond, through condensation reaction with ribose sugar to form a nucleotide (ATP).

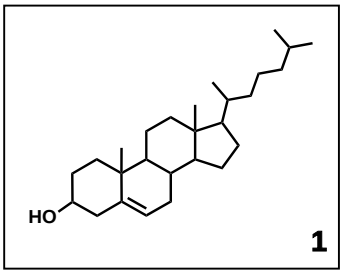


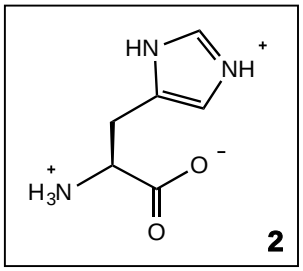
Adenine

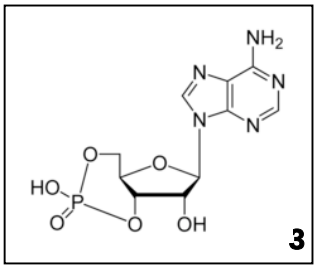
i. Which Carbon atom of the ribose sugar (choose from ***C1'/ C2'/ C3'/ C4'/ C5'***) would covalently bond with the circled region of adenine to form Adenosine triphoshphate (ATP)?

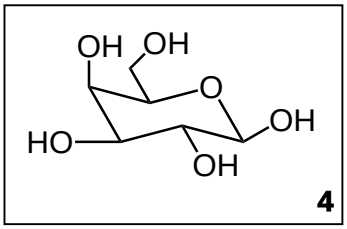
ii. Would you classify this base as purine or pyrimidine? **Explain** why you selected this option.

5. Four different structures are shown below.









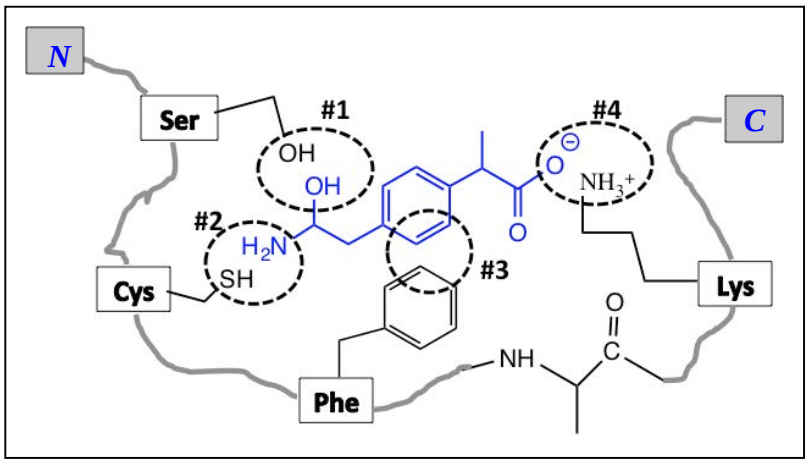
i. Which molecule (***1/ 2/ 3/ 4***) serves as a building block of proteins?

ii. Which molecule (***1/ 2/ 3/ 4***) is an example of steroids that may be found within the non-aqueous interior of the cell membrane?

iii. Which molecule (***1/ 2/ 3/ 4***) serves as a building block of polysaccharides (sugar polymers)?

iv. Which structure (***1/ 2/ 3/ 4***) is an example of a nucleotide?

6. This schematic shows the interaction between **Molecule 1** and **Enzyme X (dotted circles)**. *For simplicity, only the side-chains of the amino acids of Enzyme X that interact with the Molecule 1 are shown.*



Give the **STRONGEST** interaction (***hydrogen/ ionic/ hydrophobic***) at...

Position #1: _____

Position #2: _____

Position #3: _____

Position #4: _____

7.013 Introductory Biology

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