Josh Whitehead

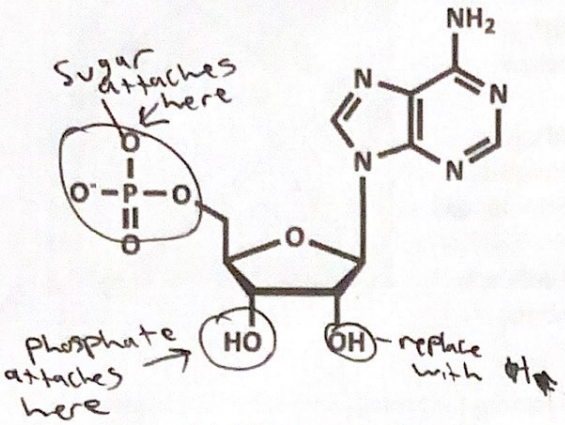
CHEN 5103 - Biochemical Engineering

Homework Assignment #2

Due January 28, 2022 at 11:59 pm

Question 1

The following diagram represents a nucleotide that serves as a monomer for ribonucleic acid (RNA).



a. Label the group or atom that you would remove, so that the nucleotide drawn above can serve as a monomer for DNA.

b. What type of bonds would hold two such adjacent nucleotides together in a growing nucleic acid chain? Circle the group(s) that would participate in the formation of this bond if the nucleotide shown above, was added to the growing nucleic acid chain.

Covalent bonds hold them together

c. Name the type of bonds that the above nucleotide will form with its complementary nucleotide. How many of these bonds would you expect between this nucleotide pair?

Hydrogen bond, Uracil, two hydrogen bond

d. The nucleotide (N) shown above is a part of the following nucleic acid sequence.

5'AGCCAAACCG3'

For the nucleic acid sequence that is given above,

Which nucleotide base (A/T/G/C/U) has a free phosphate group?

The first A has a free phosphate group

Which nucleotide base (A/T/G/C/U) has a free hydroxyl group? The last G has a free 1' hydroxyl group

If adenosine (A) is added to the above nucleic acid sequence in a cell, would it be added to the 5' end or the 3' end?

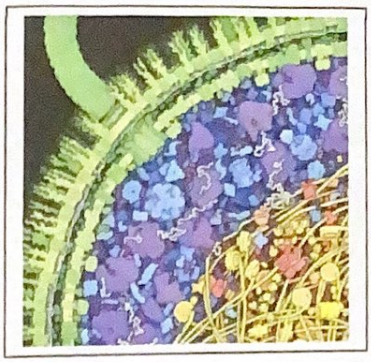
3' end Builds 5' → 3'

e. The nucleic acid sequence shown above interacts with a specific protein. Of the following amino acids that are a part of this protein, circle those whose side-chains are most likely to

interact with the phosphates of the sugar-phosphate backbone of nucleic acids. Explain why you selected these amino acids.

Methionine, Lysine, Alanine, Leucine, Arginine

Met will not interact with phosphates because it is the "start" codon



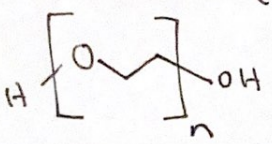
Question 2: In lectures, we discussed water is one of the main molecular components of living organism. However, the cellular environment is not a diluted water solution (for example, the amount of highly condensed DNA molecules inside of the cell). Inside of the cells contains high concentrations of macromolecules (sugar, protein, and nucleotides….). This effect is called macromolecular crowding. Please read the short commentary published in PNAS (A model of intracellular organization https://www.pnas.org/content/102/17/5901#ref-4) and conduct some literature research to answer the following questions.

a. Explain the importance of macromolecular crowding for protein structure/functionality

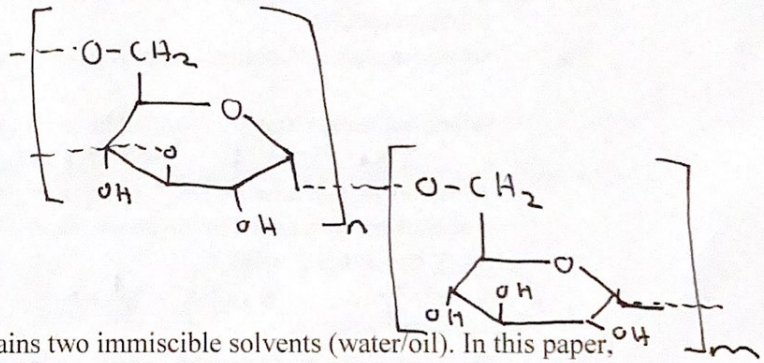
Proteins are only active when they are folded in the right shape so macromolecular crowding helps them to maintain their correct shape/size. without macromolecular crowding, the proteins could more easily denature and become inactive

b. In the commentary, the author described two-phase system in water (egg white/egg yolk). What molecules does the paper use to create a two-phase system in water and draw the molecular structure of the molecules.

Poly ethylene Glycol (PEG) (white)



Dextran (yolk)

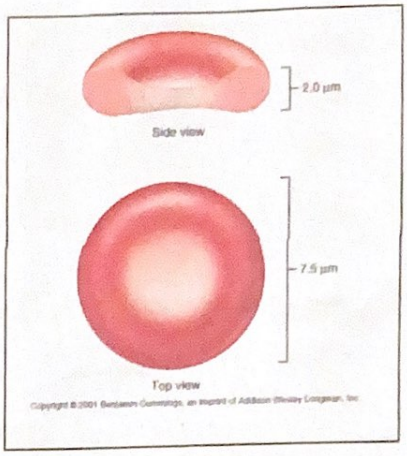


c. In general, two-phase system contains two immiscible solvents (water/oil). In this paper, the two-phase system is created in the same solvent (water). Biology uses this

phenomenon to create different phases and partition the cellular space. Explain the aqueous two-phase system

when in the lipid bylayer shell, PEG and Dextran can form a n aqueous two-phase system by changing the temperature or osmotic pressure outside the shell.

Question 3. a. In lecture, we discussed the amount of DNA molecules in the cell. Now, let's estimate the number of proteins in a red blood cell. Protein hemoglobin is the major protein in red blood cells. It accounts for 95% of the total protein in a red blood cell. It was estimated the protein concentration in a cell could be as high as 350mg/ml. What is the number of hemoglobin molecules in a red blood cell? (hemoglobin is a globular protein that has a molecular weight of 67,000 Da., approximate red blood cell as a cylinder) Show calculation.



assume Cylinder

$\therefore V = \pi r^2 h = \pi \cdot \frac{7.5^2}{4} \cdot 2 = 8.8357 \times 10^{-5}\ m^3$

$C = 350\ \frac{g}{L} = 350000\ \frac{g}{m^3} \rightarrow m_H = 0.95 \cdot C \cdot V = 29.38\ g$

$n = \frac{m_H}{M_H} = \frac{29.38\ g}{67000\ \frac{g}{mol}} = 4.3849 \times 10^{-4}\ mol$

$\#\text{molecules} = 4.3849 \times 10^{-4}\ mol \cdot \frac{6.022 \times 10^{23}}{1\ mol} = 2.64 \times 10^{20}$ molecules

b. The hemoglobin molecule is nearly spherical with a diameter of 55 Å. What is its volume? and can the number of hemoglobin molecules you calculated above fit in one red blood cells

$V = \frac{4}{3}\pi r^3 = 8.71 \times 10^{4}\ Å^3 = 8.71 \times 10^{-26}\ m^3$

$8.71 \times 10^{-26} \cdot 2.64 \times 10^{20} = 6.53 \times 10^{-5}\ m^3 < 8.84 \times 10^{-5}\ m^3$ ∴ they can fit

Question 4: Describe the main functionality of the following cellular components: (in relationship with the central dogma of molecular biology)

Endoplasmic reticulum (ER)

Site of protein synthesis and modifies protein structure after synthesis

Golgi apparatus:

modifies proteins and packages them for transportation

Chaperone Proteins:

Guide Poly Peptide Chains to Fold into the Correct Shape

Nucleus:

Contains DNA and doesn't let it leave so it's Protected

Comparing the transcription and translation process of prokaryotes and eukaryotes, what are unique to eukaryotes?

In a Prokaryote the transcription and translation occur in the cytoplasm simultaneously but Eukaryotes have a nucleus and other organelles where the process takes place