

Name: _____

7.013 EXAM 1

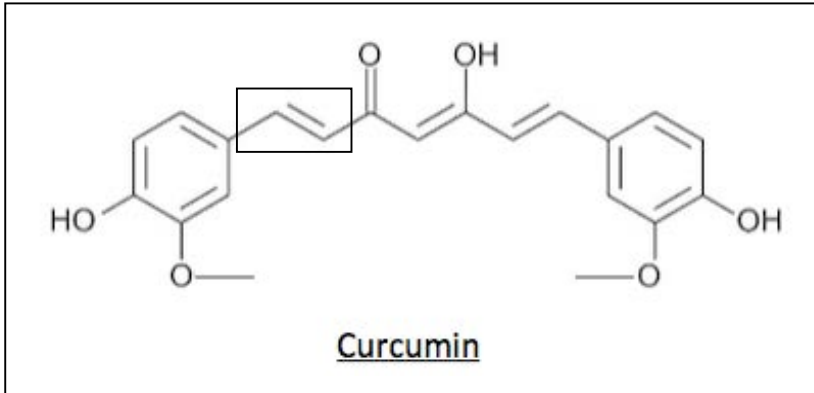
Write your name on this page and your initials on all the other pages in the space provided. This exam has 5 pages including the coversheet. Check that you have all the pages **1-5**.

Only writing on the **FRONT** of every page will be graded. You may use the backs of the pages, but only as scratch paper.

Questions	Points	Score
1	14	
2	14	
3	24	
4	22	
5	12	
6	14	
TOTAL	100	

Question 1 (14 points)

Anemia is a very common condition in which the body does not have sufficient number of red blood cells (RBC) or hemoglobin protein (Hb). The following is the line angle drawing of **curcumin**, an ingredient derived from turmeric plant, which is often given to patients with pernicious anemia (PA).



a) Clearly write in the position of **ALL** carbon (C) and hydrogen (H) atoms that are implied in the line angle drawing.

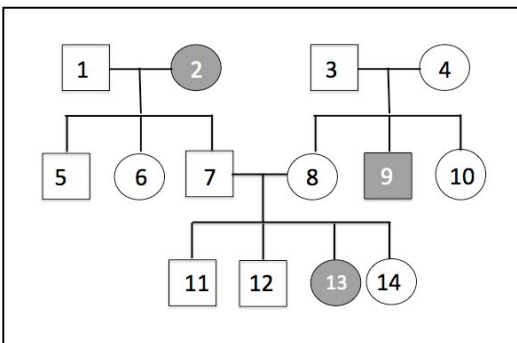
b) Circle an **intramolecular hydrogen bond** (an H-bond within the curcumin molecule) and label the proton donor (as δ^+) and proton acceptor (as δ^-) on the appropriate atoms of the circled groups.

c) Explain, in terms of the possible non-covalent interaction, why curcumin dissolves in water.

d) What does the boxed region in the line angle drawing above represent: **saturated or unsaturated** hydrocarbons? Explain why you selected this option.

Question 2 (14 points)

The following pedigree represents the mode of inheritance of a juvenile form of PA. **Note:** The circles represent females and squares represent males. Filled squares or circles represent PA patients. Assume that no other mutation arises within the pedigree. Assume complete penetrance.



a) Give the mode of inheritance of juvenile PA:

b) Give all the possible genotypes of **Individual 11** using “A” for the allele regulating the dominant phenotype and “a” for the allele regulating the recessive phenotype.

c) Individual 10 marries a male who has the same genotype as Individual 7. Together they have a son.

i. What is the probability that their son will have the same genotype as his father? **Show your work.**

ii. If their son has juvenile PA what is the probability that their second child will have juvenile PA?

Question 3 (24 points)

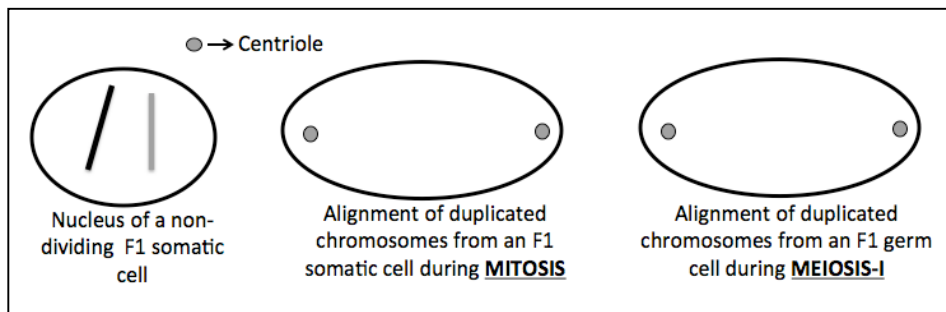
You decide to study two traits in a variety of turmeric plant: **powdered root color (regulated by autosomal Gene A)** and **taste (regulated by autosomal Gene B)**.

You cross true breeding **P1 (yellow powdered roots that taste sweet)** and **P2 (white powdered roots that taste bitter)** and obtain F1 plants (**yellow powdered roots that taste bitter**) Give the genotypes of the following plants for both traits, using "A" and "B" for the alleles regulating the dominant phenotype and "a" and "b" for the alleles regulating the recessive phenotypes.

a) Fill in the **genotypes of P1, P2 and F1** plants.

- i. Genotype of P1 (yellow powdered roots that taste sweet): _____
- ii. Genotype of P2 (white powdered roots that taste bitter): _____
- iii. Genotype of F1 (yellow powder roots that taste bitter): _____

b) Assume that Gene A and Gene B are located on the **same** autosome. In the diagram below, draw in the configuration of alleles of Gene A and Gene B for the following.



c) You cross an **F1 progeny (yellow powdered roots that taste bitter)** with another plant that gives **white powdered roots that taste sweet**. If Gene A and Gene B are **10cM** apart ...

- i. Complete the table below for each class of F2 plants (Total = 100).
- ii. Circle the non-recombinant / parental classes in the F2 generation in the table.

Genotypes?	Corresponding phenotype?	Estimated numbers?

d) You also want to study Gene D in the same plant variety. Experiment shows that Gene A in this variety of turmeric plant is completely linked to Gene D. You cross a P1 plant (genotype: AADD) with P2 plant (genotype: aadd) to get an F1 plant (Genotype AaDd). If you cross two F1 plants, what would be the genotypes and corresponding ratios of the plants in F2?

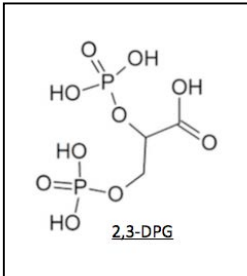
- i. **Genotypes:** _____
- ii. **Expected genotype ratios:** _____

Question 4 (22 points)

Hemoglobin protein (Hb) is found in mature RBC.

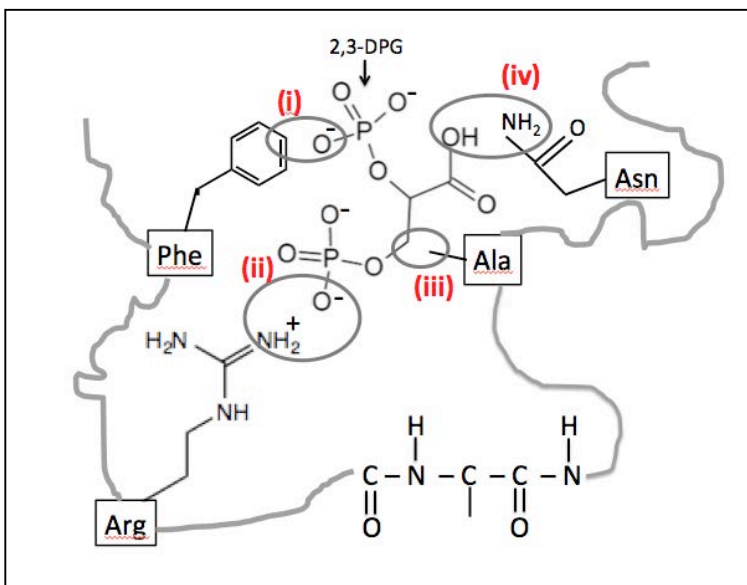
a) The Hb has two α - and two β - globin polypeptide chains. What is the highest order of protein structure for the Hb tetramer: **primary/ secondary/ tertiary/ quaternary**?

b) Each globin chain binds reversibly to one oxygen molecule (O_2) to form oxyhemoglobin (Oxy-Hb). Experiments show that the **non-covalent binding** of 2,3-diphosphoglycerate (2,3-DPG) prevents the binding of Hb to O_2 . Furthermore, increasing the concentration of O_2 cannot reverse the effect of 2,3-DPG.



Based on this observation, would you classify 2,3-DPG as a **competitive/ allosteric/ uncompetitive/ reversible/ irreversible inhibitor** of Hb? Circle **all** that apply and **explain** why you selected these options.

c) The binding of 2,3-DPG to Hb protein is shown below. **Note:** Each circled interaction is critical for 2,3-DPG mediated inhibition of Hb.



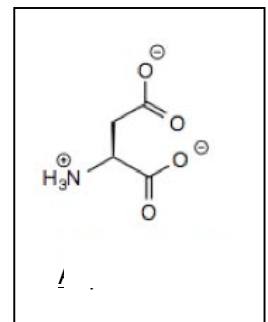
i. For each of the positions below, write the **strongest non-covalent interaction** between 2,3-DPG and Hb protein by choosing from the *hydrogen bond/ ionic interaction/ VDW forces/ hydrophobic interaction*.

- **Position (i):** _____
- **Position (ii):** _____
- **Position (iii):** _____
- **Position (iv):** _____

ii. **Box** all **peptide bonds** on the drawing.

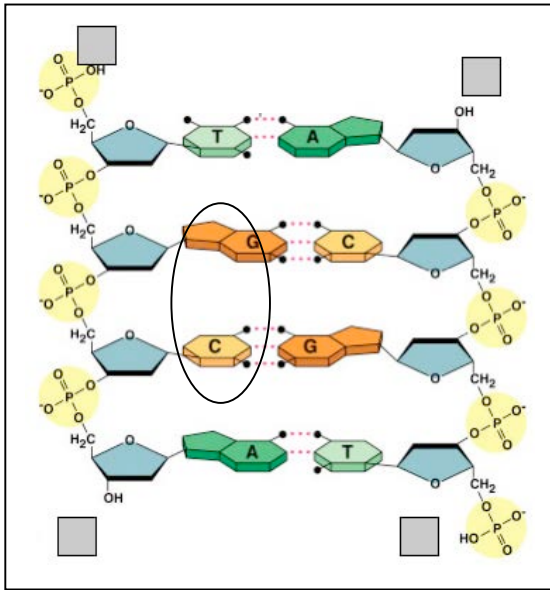
iii. In the diagram above, which amino acid was first added to the globin chain as it was being translated from the globin mRNA: **Phe or Asn**? Provide an **explanation** for selecting this amino acid.

d) You identify a mutant version of globin chain in a PA patient where the Arg shown in the diagram in part (c) is replaced by Aspartic acid. Would the Hb protein in this patient be able to transport O_2 even in the presence of 2,3-DPG? **Why or why not?**



Question 5 (12 points)

Below is a small portion of the gene that encodes the Globin chain of Hb protein. On the drawing...

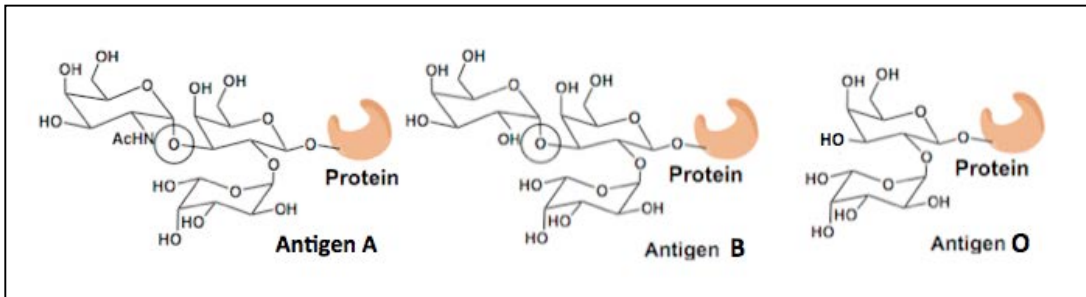


- Label the 5' and 3' ends by filling in the shaded boxes.
- Show the direction of synthesis of each strand by drawing arrows.
- To which end would the incoming nucleotide be added: 3' or 5'?
- Circle the group that may interact with the histone proteins that are rich in amino acids with positively charged side-chains.
- Put a "star" next to the carbon atom of the sugar that would differ between the nucleotides of DNA and RNA.
- Name the circled non-covalent interactions between the bases of a DNA strand: _____

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Question 6 (14 points)

PA patients often need blood transfusions. We have four major blood groups based on the type of antigen located on the surface of circulating RBCs: Type A, Type B, Type O (universal donor) and Type AB (universal acceptor). The structure of A, B and O antigens are shown below. Matching blood groups is critical for successful blood transfusions.



- Classify Antigens A/ B/ O as: **Lipids/ carbohydrates/ proteins/ Nucleic acid.**

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- Name an organelle where the antigens A/ B/ O would be covalently linked to the protein: _____
- You want to use a specific enzyme(s) to hydrolyze the circled bonds in antigens A and B. Assuming that the hydrolysis reaction has a $\Delta G = -4 \text{ kcal/mole}$, classify this reaction as **endergonic or exergonic** and **explain** why you selected this option.
- Propose a mechanism that allows the enzyme to generate the transition state (TS) complex and **explain** why generating TS complex is critical for the reaction.
- Assuming you are successful in hydrolyzing the circled bonds, can you give the modified RBCs to patient of any blood type? **Why or why not?**

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