

Molecular Structure of Biological Materials: Structure, Function & Self-assembly

Take-home Midterm Exam (**Due Thursday, Nov. 17**) 30% of the total grade. Please write a short description for each of the questions (10 point each). You need to think carefully and creatively, study the textbooks and lecture notes.

1. What is the structure of water in different temperatures? Why is the structure of water very important in the formation of protein secondary structures and protein-protein interaction? Why is hydration important in keeping protein soluble?
2. Please draw the structures of 20 L-amino acids and 4 nucleotides. Write their full names, three-letter code and one letter code. Please arrange amino acids in the order of hydrophobic, hydrophilic, polar and nonpolar groups. Explain briefly their side chain's tendency to interact with water. Please draw **all possible hydrogen bonds on the side chains of amino acids** and explain how they interact with water. **Draw all possible hydrogen bonds for the nucleic acid bases** (follow the books).
3. Describe in detail the basic characteristics of several secondary structural construction motifs and explain their functions in determining the structures of protein and protein-materials.
 - a) Alpha-helix (Describe possible helices from different amino acids, hint: the book)
 - b) 3₁₀ helix, c) π helix, d) beta-helix, e) beta-sheet, f) turns and loops, g) collagen helix.
4. Describe the peptide bond formation and its structure in great detail. Can you deduce other structure formations based on the peptide bond structure?
5. What is the characteristic of coiled-coil? Describe two, three and four strands of coiled coils. Where do you find such coiled coils in nature and can use improve the coiled-coil based materials?
6. Explain the significance of the high-resolution crystal structure of collagen. What have you learned from the single crystal structure? Explain why glycines and prolines are important in forming the structure of collagen? How does collagens undergo self-assembly?
7. Describe the molecular structures of silkworm silk and the spider silk. Both proteins have a high content of glycine. How are these glycines arranged in both silkworm silk and spider silk structures?
8. Briefly explain X-ray crystallography used in determination of the molecular structure of biological materials. Briefly explain both solution and solid state NMR in determination of the molecular structure of biological materials.
9. Describe how nature makes various types of biominerals. How can you make one?
10. Use the knowledge you have learned in the class to design an interesting building structural motif (hint: use various repeating sequences). Please describe how do you know what you designed it what you have in real materials, how do you characterize them at each steps and what tools and instruments to use.