Example of BIOE 150 Final Exam and Answer Key

1.) Define the following terms:

Green Fluorescent Protein: Protein originally derived from jelly fish that fluoresces green when exposed to blue light

Contact Angle: Angle between a liquid/gas interface and a surface. Used to determine the hydrophilicity/hydrophobicity of a surface.

Forster/Fluorescence Resonance Energy Transfer: Energy transfer from an excited donor chromophore to an acceptor chromophore. The transferred energy excites the acceptor chromophore. Occurs only when the donor and acceptor are in close proximity.

Bacterial auxotroph: A bacteria that is unable to synthesize a specific compound (e.g. an amino acid) that it requires for survival. Can be used as part of a strategy to incorporate unnatural amino acids

2.) True or False Questions

We can design a bio-inspired protein nanostructure using recombinant DNA techniques. When we design the protein sequence motifs with the sequence $[(GA)_MGE]_n$ linked with PEG at both the N and C terminus where n controls the width and m controls the height of the nanostructures. **TRUE**

Leucine Zipper Motifs are built of heptad amino acid repeats (*abcdefg*) with a leucine residue at almost every seventh position which can promote dimerization by specific hydrophobic interactions. **TRUE**

Bioluminescence is the chemical production and emission of light within an organism through a reaction that often involves GTP. **FALSE, ATP**

Because insects possess compound eyes, they can see high resolution images compared with those of single aperture eyes. **FALSE**

3) We can design a polypeptide, polyglutamate $[Glu]_{100}$ using both chemical and biological approaches with the same number average molecular weight. However, when we measured their weight average molecular weight, they are different from the number average molecular weight.

a. Define number average molecular weight and weight average molecular weight (Write the equations and define the variables)

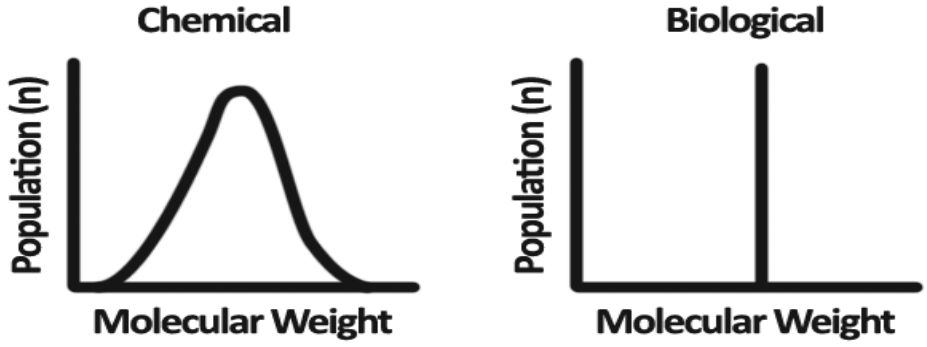
$$M_n = \frac{\sum M_i N_i}{\sum N_i}, M_w = \frac{\sum M_i^2 N_i}{\sum M_i N_i}$$

M_n - # average MW
M_i - Molecular weight
N_i - # of molecules with molecular weight M_i

b. Explain why there is a difference between the two weight average molecular weights depending on synthesis method

Chemical polypeptide polymerization always yields a distribution of different molecular weight products causing the weight average MW to be different from the number average molecular weight. Biological polypeptide synthesis yields a single, monodisperse product so the number average MW = weight average MW

c. Draw the MW distribution curves prepared by chemical and biological approaches.

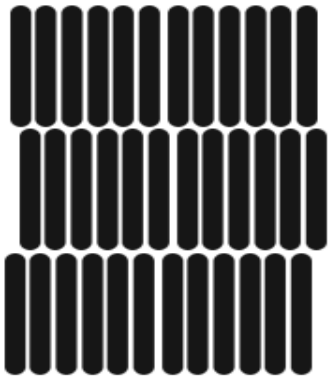


D. We can synthesize a polymer called PBLG (poly-gamma-benzyl-L-glutamate) through modification of a chemically or biologically synthesized polyglutamate using a benzylation reaction. After the reaction the polypeptide main chains become rigid rod-like structures. PBLG at high concentrations form liquid crystalline structures. Although both polypeptides initial products possessed the same number average MW, their self-assembled liquid crystalline structures exhibit very different morphologies. One forms a smectic phase and the other forms a nematic phase.

Which PBLG forms a smectic phase liquid crystalline structure? **Biologically synthesized**

E. Explain why the PBLG you chose forms the smectic phase and draw a schematic diagram of the ordered structure it possesses

The smectic phase has a layered structure with the liquid crystal aligned in the same direction in each layer. This phase is not favored by chemically synthesized product because having a distribution of MW prevents the formation of well organized layers



4. Elastin is a flexible connective protein found in the Extracellular matrices of tissues such as vascular walls. Polypeptides based on the pentapetide repeat $(G\underline{\mathbf{V}}GVP)_n$ display elastin-like properties and exhibit a structural transition at a specific temperature. The elastic properties are maintained as long as the glycine and proline residues are present. If we replace the underlined valine residue with lysines $(G\underline{\mathbf{K}}GVP)_n$ the temperature transition changes and becomes pH dependent.

Describe the temperature based structural transition. Does the temperature at which the transition occurs increase or decrease when comparing $(GKGVP)_n$ to $(GVGVP)_n$ at neutral pH. Finally, explain why the transition temperature varies with pH.

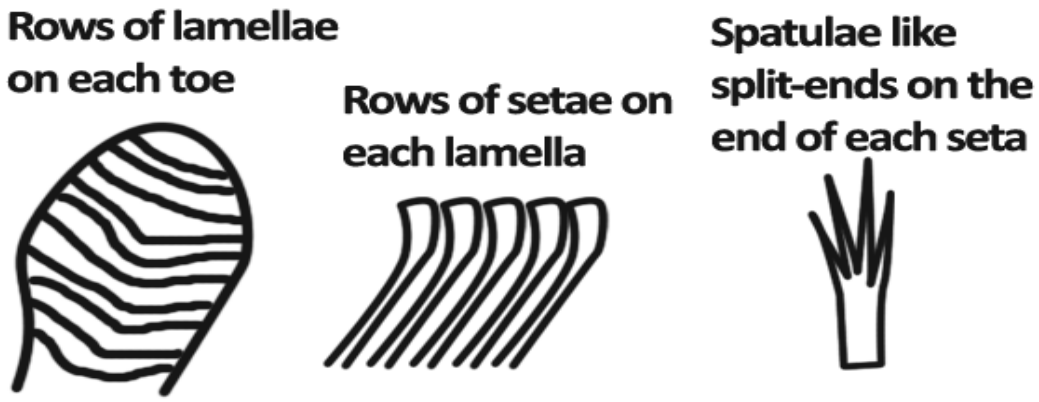
At low temperatures Elastin has a random coil conformation and is soluble. Above its transition temperature the elastin collapses into a beta-helix structure and becomes less solvated making it insoluble.

The transition temperature increases when changing to GKGVP because lysine residues are more hydrophilic and thus it is harder to transition to the hydrophobic phase

Lysine is an ionizable side chain $R\text{-}NH_3^+ \rightarrow R\text{-}NH_2 + H^+$ so the pH will control the degree of ionization. At lower pH it is more charged and so is solvated by more water, increasing the transition temperature.

5. Geckos are well known for their unique ability to climb vertical or even inverted surfaces. They can stick to a variety of surfaces ranging from smooth glass to rough brick.

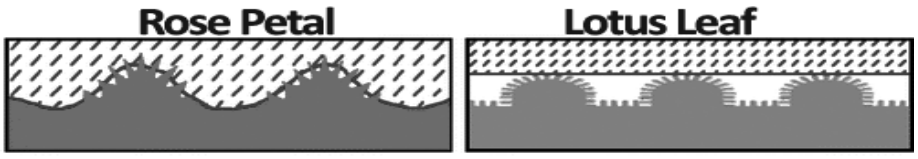
Draw the three different hierarchical structures of gecko feet from macro to nanoscale



Explain the mechanism of how it can attach and detach easily to/from many different surfaces

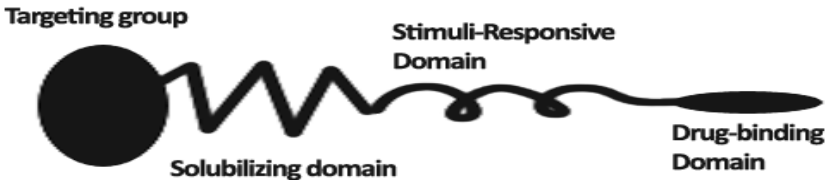
Geckos attachment occurs primarily through the additive effect of many Van der Waals forces. The geometry of the setae are such that they only adhere at a certain angle with the application of a force. Detachment occurs by peeling the toe away, resulting in a change to a non-adhesive angle.

6. Both lotus leaves and rose petals possess superhydrophobic surfaces. However, rose petals have a strong adhesion for water droplets compared to lotus leaves. Draw schematic diagrams of each wet structure and explain what causes the difference.



Both have chemical composition and nanoscale structure which lead to hydrophobicity but at larger scale the rose petal geometry is curved and spaced such that water impregnates into grooves leading to strong adhesion. The lotus leaf has grooves that prevent water from entering, leading to low adhesion.

7. Suppose we can develop a tumor targeting drug delivery micelle using polypeptides. Describe the four components needed and their purpose and draw a schematic of the polypeptide structure which reflects the surfactant number needed to form a micelle.



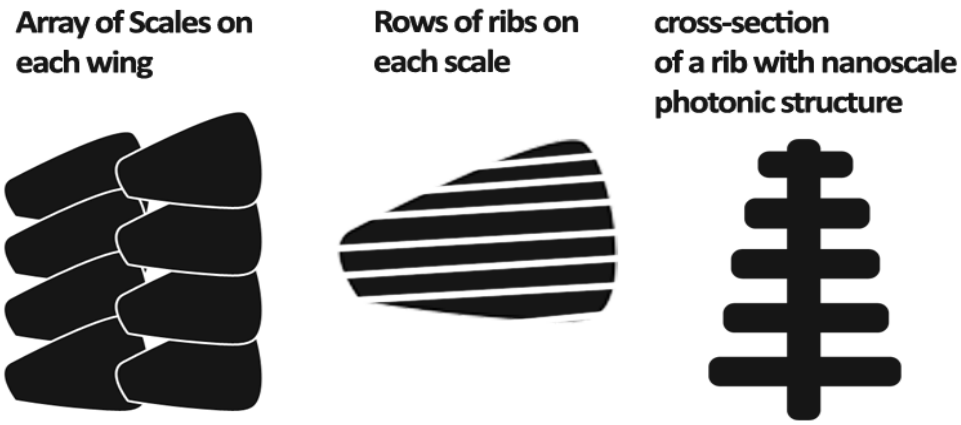
Targeting group: targets micelle to specific tissue/cell type
Solubilizing domain: hydrophilic domain
Stimuli-responsive domain: region responsible for stimuli-responsive breakdown or assembly of the micelle. For example responsive to pH
Drug-binding domain: site for drug attachment
Surfactant # < 1/3 for micelle

Describe a method to develop tumor targeting receptors using phage display that could be used as the headgroup of the polypeptide micelle.

Using a phage display, a library of phage expressing different amino acid sequences could be mixed with non-tumor cells. Those that do not bind would then be mixed with tumor cells. Those that do not bind could be washed away. Those that do bind could be eluted and amplified. The eluted phage could then be sequenced. If a consensus sequence is determined then that would be a possible tumor targeting sequence. Otherwise, the process would be repeated until a consensus was determined.

8. Many Morhpo butterflies are colored in metallic, shimmering shades of blue and green. These colors are not a result of pigmentation but are hierarchical structures.

Draw the hierarchical structures of butterfly wings



What is the periodic spacing of nanostructures to exhibit the blue color (~400nm) on the butterfly wing and explain why that spacing generates the blue color.

The blue color is the result of constructive interference due to the ~200nm spacing between the struts on each ridge.