MSE/BioE C118 - Biological Performance of Materials

Prof. K. E. Healy
465 Evans Hall

Exam 1: October 17, 2002 **Closed Book Exam**
Please answer all of the questions clearly and box your final answer. Useful equations, data, and physical constants appear at the end of the exam.

NAME: HEALY (KEY)

ID NUMBER:

Prob. 1	Prob. 2	Prob. 3	Prob. 4	Total
Max = 25	Max = 25	Max = 25	Max = 25	Max = 100

Extra Credit (2 pts.)
Who is the mascot of the S.F. Giants baseball team?

Lou Seal

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1. Poly(L-lactide) is a semi-crystalline biodegradable polymer that has found widespread use in medical devices requiring strength (e.g., sutures, fracture fixation pins, etc...). You assume the Maxwell element can satisfactorily describe the viscoelastic behavior of the polymer. (25pts.)

    a. For the Maxwell element, derive an expression for the stress-relaxation experiment describing stress as a function of time. From your expression draw a graph of stress vs. time and define the relaxation time (λ) and indicate where it occurs on your graph.?

    b. You decide to heat treat the material to dramatically increase λ by a factor of 10. What happened to the microstructure of the material during your heat treatment?

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2. You are given two materials to evaluate for implantable biomedical devices. You decide to implant each of these materials in a well-established animal model to evaluate their biological performance. (25 pts.)

a) Describe the development of the interfacial hierarchy over time existing between the implant and the body's host tissue.

b) What type of long-term interactions can occur between the implant and the body?

c) One material shows poor biological performance as determine by chronic inflammation and fibrous tissue encapsulation. Examination of proteins bound to the materials surface indicates that they were responsible for the poor performance. How could the bound proteins influence the biological performance?

3. You can use DLVO theory to approximate the approach of a sphere toward a flat plate in ion-containing media. In class, we used DLVO theory to approximate the interaction free energy as a function of distance between a polymer (flat surface) and either proteins or cells in salt solution (e.g., NaCl). Assume a polymer surface potential of -20 mV; surface potential of -10 mV for the cell; surface potential of -10 mV for the protein; a 1:1 electrolyte with a concentration of 0.2M and a Debye length (κ^{-1}) of 1.48 nm; at body temperature (37 °C). (25 pts.)

a) Explain how you would calculate the total interaction free energy W(D) curve for both a protein and a cell approaching the polymer surface? Be sure to show which equations you would use for your calculation (see, end of exam).

b) Sketch representative curves for the total interaction free energy W(D) for both a protein and a cell approaching the surface. Make sure to include representative features of the curves and label them clearly.

c) Sketch how the representative curves for the total interaction free energy W(D) for both a protein and a cell approaching the surface are affected by independently decreasing the electrolyte concentration or increasing surface potential.

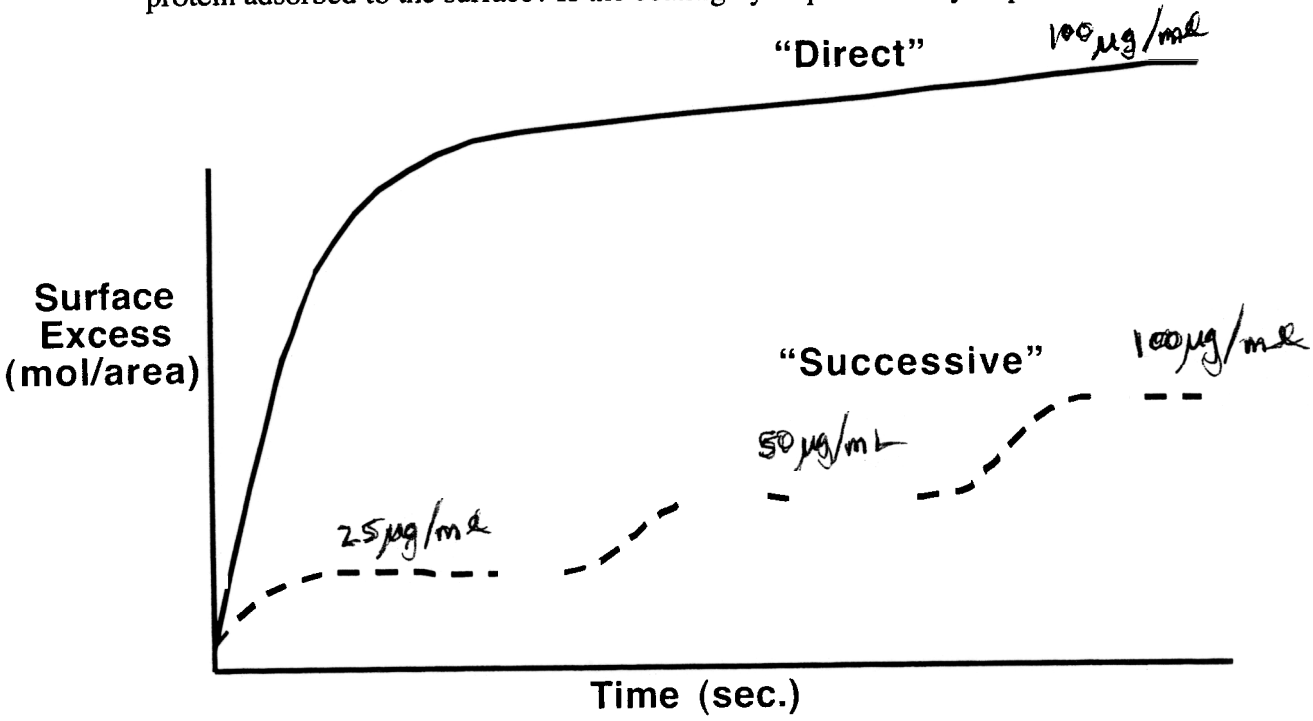
d) Based on these graphs and DLVO theory, describe initial events occurring at the surface after exposure of the polymer to a 1:1 electrolyte with a concentration of 0.2M solution containing both proteins and cells (e.g., serum).

4. You are asked to evaluate a coating that purportedly minimizes protein adsorption. (25 pts.)

a) What are the three key aspects of protein adsorption that affect the biological performance of a material?

b) You conduct a protein adsorption experiment to address the aspects defined in a) to determine the magnitude of protein adsorption. How would you perform this experiment and what would you measure? What would a typical protein adsorption curve look like? Make sure to identify appropriate regions of the curve.

c) You then decide to conduct a protein adsorption experiment where you increase the concentration of protein successively after the surface excess (mol/area) has reached equilibrium. You obtain the curves below comparing "direct" versus "successive" protein adsorption isotherms. Why does the successive experiment have much less protein adsorbed to the surface? Is the coating hydrophobic or hydrophilic?



d) What are the "new" themes for surfaces that resist protein adsorption? Does this coating meet all of these characteristics? Do you think this is a good coating to resist protein adsorption?

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4. You are asked to develop a coating for a sensor to measure blood oxygen levels. You perform a water contact angle study on the existing coating for the device and determine $\theta_{adv} \sim 100°$. You decide to develop a coating based on one of the three modifications discussed in the Prime and Whitesides (Science, 1991) paper. (25 pts.)

a) What were the three coatings addressed in the paper and what existing or native materials were they intended to model?

b) You choose one of these coatings for your sensor. You perform a water contact angle study on the *new* coating for the device and determine $\theta_{adv} \sim 30°$. What additional techniques would you perform to characterize the surface? Be sure to include what the technique measures and its limitations.

c) You then decide to conduct a protein adsorption experiment to determine the magnitude of protein adsorption and whether the adsorbed proteins change conformation as a function of time. How would you perform this experiment and what would you measure? What would a typical protein adsorption curve look like? Make sure to identify appropriate regions of the curve. Do proteins change conformation on this surface?

d) Based on your answer for c), would your surface work better as the new sensor coating?