3.052 Nanomechanics of Materials and Biomaterials: Spring 2007
Assignment #5

Due Date: Tuesday 05.01.07

You are encouraged to use additional resources (e.g. journal papers, internet, etc.) but please cite them (points will be deducted for not doing so). You will need to research additional sources to answer some questions. Everything must be answered in your own words; also, do not copy phrases or sentences from the paper or podcast.

+ 5 extra credit for posting a message on one of the podcast message boards.

1. **Nanomechanics of Chondrocytes Podcast.** Ng, et al. *J. Biomech.*, Vol. 40, Issue 5, 1011-1023, **2007**. (Note : nanoindentation will be covered in more detail later on the course, but this podcast was included at this time to correlate with the cartilage lectures).

   a. The data presented in this paper has alot of relevance to understanding the fundamentals of cartilage tissue engineering. Why doesn't injection of cartilage cells into a damaged tissue result in regeneration? Why is it more advantageous to use young immature chondrocytes for tissue engineering? Look up one journal article published in the last year on cartilage tissue engineering, post the PDF for this journal article along with your assignment, give the full citation in your assignment solutions, and summarize what you feel was the most important /interesting discovery in this paper in a few sentences / short paragraph (do not copy abstract). You are not allowed to use any papers posted by classmates on the class message boards (i.e. you need to look up your own).

   b. The original AFM image for Fig. 2d has been posted on the MIT Server. Using WSXM software (http://www.nanotec.es/imagenes/titu_wsxm.gif), measure the banding periodicity and diameter of 5 different individual fibrils (show an image and section profile for one of these) and report a mean and standard deviation for the measured values. Comment on the relationship of these experimentally measured values to the specific type of collagen expected in the pericellular matrix (cite appropriate references).

   c. Name 5 major experimental differences between the AFM-based single cell mechanics experiments presented in this paper compared to the previous podcast by Suresh, et al. *Acta Biomaterialia* **2005** 1, 15 using optical tweezers.

   d. The data in Figure 6 have been digitized and are posted on the MIT Server. Calculate and compare the energy dissipated for the nanosized and micron-sized probe. Suggest a hypothesis for any similarities / differences in terms of the deformation of the cell.

   e. What is the explanation given in this paper/podcast for why the chondron (Day>0) is less stiff than the Day 0 chondrocyte?

2. **Nanomechanics and Biocompatibility : Protein-Biomaterial Interactions.** Halperin, *Langmuir* **1999**, 15, 2525-2523.

   a. Explain what the following parameters defined in the paper are physically; U_{eff}, U^*, U_{brush}, U_{in}, U_{out}, U_{bare}, U_{ads}

   b. Plot $U_{eff}(z)$ in units of $k_B T$ for the compressive mechanism for a typical large protein (cite references for protein property values needed) using the following polymer brush properties; monomer size, a ~ 1 nm, equilibrium brush height, L_o ~ 5 nm, grafting density σ^{-1}~ 0.2 nm^{-2}, N=10 monomers per polymer chain, and Hamaker constant, A = 0.1×10^{-19} J. Explain how the form U_{eff} changes with variations in the Hamaker constant.

   c. Calculate a numerical value for k_{ads} for the same protein chosen in part b using values extracted from your plot in part b. Explain what k_{ads} means physically.

3. **Elasticity of Fibronection Podcast.** Abu-Lail, et al. *Matrix Biology* **2006** 25 175.

   a. Locate a reliable source for the 3D structure of fibronectin, copy it into your assignment solutions, research and explain in ~1 paragraph the important details of this structure. Professor Zauscher refers to the fibronectin modules as "homologous." Explain what is meant by this.

   b. The data in Figure 1c (pulling rate of 580 nm/s) has been digitized and is posted on the MIT Server as an Excel file. Prof. Zauscher stated that one proof that single molecules are being probed is that when the data from each individual peak in a force-separation curve is normalized by the contour length estimated by the worm-like chain (WLC) model, all of the data should overlay and produce a single master curve representing the elasticity of the molecule. Prove this by taking the following steps.

   > i) Fit each peak in this digitized dataset to the WLC model, as Zauscher has done, plotting all of the model fits on a single graph. Make a table summarizing the fitting parameters for each simulation (corresponding to each peak) and the corresponding contour lengths calculated from these fitting parameters, as well as the mean and standard deviations for the fitting parameters and contour length for FN-III and GFP. Is any difference observed in the estimated persistence length for FN-III and GFP?

   > ii) From the values obtained in i), create two separate master elasticity curves, i.e. two plots; one for FN-III and one for GFP. Does this analysis support Zauscher's assertion that single molecules are being probed?

   c. Calculate the theoretical contour lengths based on known peptide bond angles for FN-III and GFP and compare to the values obtained in 3a.

   d. Section 2.2 on page 177 is entitled "Fingerprints of FN-III and GFP Domains"- what do the authors mean by "fingerprints"?

   e. How did Prof. Zauscher link his single molecule data presented in the paper to the two possible mechanisms of fibronectin deformation? Did you find his argument convincing? Why or why not?