

Molecular, Cellular & Tissue Biomechanics

Spring 2015

Problem Set # 1 – Additional Questions

Distributed: Thursday February 12, 2015

Due: Wednesday, February 18, 2015

1. Proteins inside cells. Hemoglobin is the major Fe-containing protein found inside red blood cells, which mammals use for oxygen transport (Fig. Q1.1).

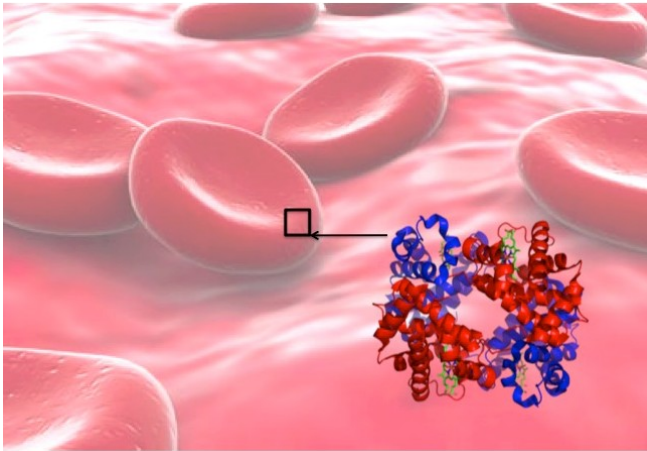


Fig Q1.1. Hemoglobin protein is located inside red blood cells. (Black box not to scale). Quaternary structure shows four globular subunits, with Fe “heme group” in green.

- (a) This protein is of molecular weight 68 kDa (kg/mol) and exhibits diffusivity $D = 7 \times 10^{-7} \text{ cm}^2/\text{sec}$ at 300K in water. Based on this information, estimate the radius of hemoglobin, stating any assumptions. Comment on the reasonableness of your estimate, given that this is a protein found in a red blood cell.
- (b) Will the diffusivity of hemoglobin in the blood of a living human be higher or lower than D stated in part (b)? Explain why, stating any assumptions or estimates.

2. Proteins outside cells. Fibronectin is a multidomain, extracellular matrix protein produced by cells such as fibroblasts, which can be mechanically unfolded (Figure Q1.2).

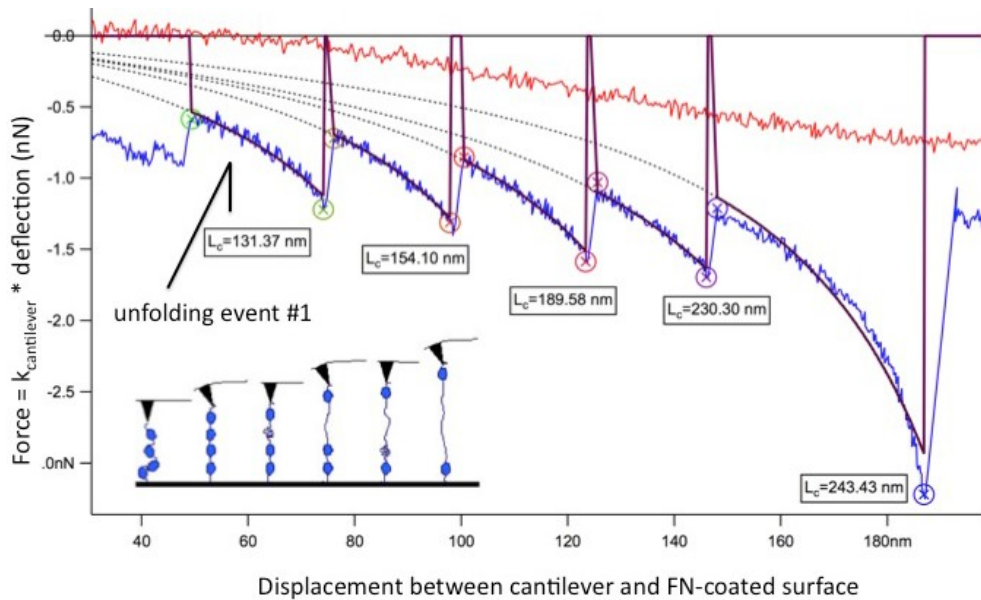


Fig Q1.2. Force vs. extensional displacement to unfold 5 domains of fibronectin via Atomic Force Microscope---measured molecular force spectroscopy, at a loading rate of 10 pN/sec and $T = 300\text{K}$. Blue trace is retraction of the cantilever during unfolding events. (Red trace is approach of the cantilever to the fibronectin (FN)-coated surface.)

- (a) Unfolding is a rare event, facilitated here by forced chain extension. L_c was obtained by fitting the wormlike chain (WLC) model to each unfolded domain's extension. Average persistence length was also found through this fitting to be 1 nm. Using L_c computed from just the first unfolding event, what is the force required to extend the unfolding domain by $r = 10\text{ nm}$? Here, r is the distance between the ends of the unfolding domain, not the entire fibronectin protein.
- (b) In this experiment at 300K, the force required to fully extend this first domain was 750 pN at a loading rate of 10 pN/sec. Will the force required to fully extend this domain at body temperature increase or decrease? What are the physical reason(s) for the change in this force magnitude?

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