BE/APh 161: Physical Biology of the Cell, Winter 2023
Homework #8
Due at the start of lecture, 2:30 PM, March 8, 2023.

Problem 8.1 (Tensile strength of the ϕ29 capsid, 20 pts).
We have discussed the packaging of the ϕ29 viral capsid. Specifically, we used Fig. 1 to estimate packaging forces. Here, we will estimate a lower bound for the tensile strength of the capsid. Tensile strength, measured in units of force per area, is the maximum stretching stress a material can bear before rupturing. Based on that curve and our discussion in lecture, estimate the minimum that the tensile strength of the ϕ29 virus must be to contain the genome. How does this compare to the tensile strength of bone? *Hint*: It might be useful to read about the Young-Laplace Law, described in section 11.3.1 of *PBoC2*.

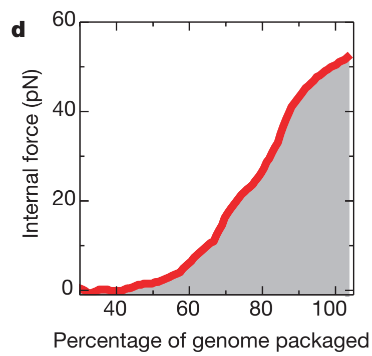

Figure 1: Force/fractional packaging curve for a ϕ29 virus. Figure taken from Smith, et al., *Nature*, **413**, 748, 2001.

Problem 8.2 (Antenna model for microtubule length control, 50 pts).
Do problem 15.7 of *PBoC2*.

Problem 8.3 (Polymerization as a force generator, 35 pts).
Imagine an actin filament is polymerizing against a compressive force. This might be the case if it polymerizes against a membrane, which can deform but nonetheless provides a compressive force on the filament.

a) Let K_d be the dissociation constant for binding an additional actin monomer to the end of an actin filament, as defined in lecture. Let δ be the increased length of an actin filament as a result of adding one monomer. Show that at equilibrium, the filament can exert a force of

$$F_\mathrm{eq} = \frac{k_BT}{\delta}\,\ln\frac{c_1}{K_\mathrm{d}}, \tag{8.1}$$

where c_1 is the concentration of actin monomer. Estimate F_eq for actin, given that cells typically have $c_1 \approx 20\ \mu\text{M}$. *Hint*: It might help to think about states and weights.

b) What is the maximal length of a filament such that it can polymerize against a compressive load without buckling? Derive an analytical expression and then plug in numbers for actin.

c) F_{eq} is the maximal force a filament can exert against a compressive load, as at equilibrium the polymerization force balances the compressive load. Experimentally, it is often the case that this force is never achieved, with polymerization essentially stalling at forces smaller than F_{eq}. Provide an intuitive explanation as to why this might be the case.