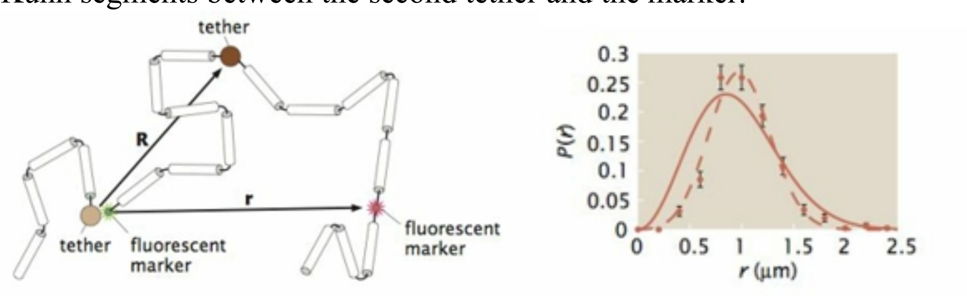
PHYS3511-Biological Physics
Fall 2018, Assignment #8 Due Monday, December 3 2018

Exercise 1) Now suppose you purify a DNA sample of an organism, consisting of double-stranded DNA molecules each of length 2000000 basepairs, and suspended in a salt solution. Using a light scattering microscope, with resolution of $0.2\mu m$, each molecule appears to be a blob of diameter $1.2\mu m$.

a) Using the appropriate equation estimate the length of one basepair. Compare your results with the known size of $0.34nm$per basepair.
b) Consider the DNA of a particular strain of E. Coli, which is a single-stranded DNA of length 5386 basepairs. Would this DNA be visible using the same light microscope as part a)? If your answer is no, what is the minimum resolution of a microscope that can resolve this DNA blob?

Exercise 2) Consider equation 8.36 for a free-polymer distribution, and 8.37 for a tethered polymer. The result is shown in the plot of figure 8.12 (see below), for distance 100 kb between the two fluorescent tags, and $N^{/}a^2 = 0.5\mu m^2$, $R\sim 0.9\mu m$, usually the Kuhn is taken to be about a = 300 bp, with the length of a base pair being $\sim\frac{1}{3}nm = 0.34nm$. In the equation N is the Kuhn segments between the two markers, and $N^{/}$ is the Kuhn segments between the second tether and the marker.



$$P(r) = \left(\frac{3}{2\pi Na^2}\right)^{3/2} 4\pi r^2 e^{-3r^2/2Na^2}, \qquad (8.36)$$

for the free-polymer case, and

$$P(r) = \left(\frac{3}{2\pi N'a^2}\right)^{1/2} \frac{r}{R}\left(e^{-3(r-R)^2/2N'a^2} - e^{-3(r+R)^2/2N'a^2}\right) \qquad (8.37)$$

A) Reproduce the plot above
B) Double the number of segments $N^{/}$, and plot the result and compare with A).

Exercise 3)

A) Using Stirling's approximation derive equation 14.3, where the values of L and C are not negligible. Reproduce the plot of 14.7, but using one lattice volume being $V_{box} = 1nm^3$, with P_{bound}vs. $[L]$ in M.
B) Consider the opposite of Figure 14.9, where a crowding molecule occupy **four lattices**, while a ligand occupies **one lattice**. Derive an equation similar to 14.4.

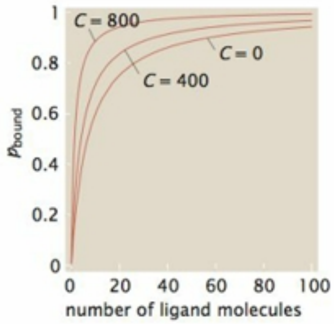


Figure 14.7: Probability of a protein binding site being occupied by a ligand for a number of different concentrations of the crowding molecules. The reaction volume is $\Omega = 1000$ and $\Delta\varepsilon_L = -5\, k_B T$.

$$p_{\mathrm{bound}} = \frac{1}{1 + \frac{\Omega - L - C}{L} e^{\beta \Delta \varepsilon_L}}, \tag{14.3}$$

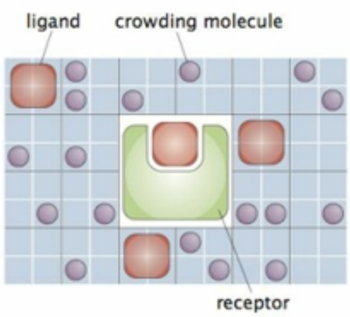


Figure 14.9: Lattice model for large ligands. This lattice model describes binding in the presence of crowding agents where the size of the crowder is different from that of the ligands. This is represented by using different-size boxes for the crowder and the ligand.

$$p_{\mathrm{bound}} = \frac{1}{1 + \frac{Z_{\mathrm{sol}}(L, C)}{Z_{\mathrm{sol}}(L-1, C)} e^{\beta \Delta \varepsilon_L}} = \frac{1}{1 + \frac{\Omega}{L}(1 - \phi_C)^r e^{\beta \Delta \varepsilon_L}}$$

Exercise 4) Chapter 14, Problem 14.1

Exercise 5) Chapter 14, Problem 14.3