Reading Assignments for Week 7

- Monday, February 24: Section 7.1 (pp. 281–288).
- Wednesday, February 26: Section 7.2 but **skip** Section 7.2.3 and the MWC Model part of Section 7.2.4 (pp. 289–292, 298–299, 301–305).
- Friday, February 28: The MWC Model part of Section 7.2.4 (pp. 300–301) and Sections 7.3 and 7.4 (pp. 305–308).

Homework #5 — due Friday, February 28

From lecture of Friday, Feb 21

1. **Problem 6.3.** Replace part (a) with this:

   (a1) Consider *free* RNA polymerase (floating around the cell not on a DNA strand) that can bind with nonspecific (non promoter) sites of the DNA according to a reaction

   $$\mathrm{RNAP} + \mathrm{DNA}_{\mathrm{NS}} \rightleftarrows \mathrm{RNAP} \cdot \mathrm{DNA}_{\mathrm{NS}}$$

   with dissociation constant K_{NS}, or bind with promoter sites according to the reaction

   $$\mathrm{RNAP} + \mathrm{DNA}_{\mathrm{P}} \rightleftarrows \mathrm{RNAP} \cdot \mathrm{DNA}_{\mathrm{P}}$$

   with dissociation constant K_{P}. Find an expression for the probability of a promoter site having a bound RNA polymerase in terms of the concentrations of $\mathrm{RNAP}{\cdot}\mathrm{DNA}_{\mathrm{NS}}$, $\mathrm{DNA}_{\mathrm{NS}}$, and the dissociation constants.

   (a2) Use the value of K_{NS} given in part (b) and the concentration of DNA in *E. coli* to calculate the concentration ratio of free RNAP to $\mathrm{RNAP}{\cdot}\mathrm{DNA}_{\mathrm{NS}}$. Use this result to argue that most of the RNA polymerase is bound to the DNA.

   Part (b) then follows. Comparison to Eq. (6.23) is helpful.

2. **Problem 6.4ab.** I will show you part (c) in the solution set, but you don't have to do it.

From lecture of Monday, Feb 24

3. **Problem 6.7ab**
4. **Problem 7.1**

From lecture of Wednesday, Feb 26

5. **Problem 7.2**

6. **Problem 7.3.** Note that "canonical distribution" means Boltzmann distribution.

7. **Problem I: Carbon Monoxide Poisoning.** Hemoglobin's receptor sites can bind carbon monoxide (CO) as well as the desired oxygen (O_2). For multiple species, the grand partition function is given by

$$\mathcal{Z} = \sum_i e^{-\beta(E_i - \mu^{(1)} N_i^{(1)} - \mu^{(2)} N_i^{(2)} - \dots)}$$

where $\mu^{(j)}$ is the chemical potential of the jth species, and $N_i^{(j)}$ is the number of species j particles present in state i.

   (a) Consider a single binding site on hemoglobin and neglect cooperative effects. Determine an expression for the grand partition function of this site in terms of the binding energies ϵ_{CO} and ϵ_{O_2} and chemical potentials μ_{CO} and μ_{O_2}. Hint: your expression should be a sum of three terms.

   (b) The binding energies are roughly $\epsilon_{\mathrm{CO}} \approx -34 k_B T$ and $\epsilon_{\mathrm{O}_2} \approx -28 k_B T$ (note that CO binds more tightly than O_2) and in the lungs the chemical potential of oxygen is comparable its value in the atmosphere, so $\mu_{\mathrm{O}_2} \approx -24 k_B T$. Consider the case where CO is present at 1/100 the amount of O_2. Then its chemical potential, due to its $-k_B T \ln c$ term, will be smaller by an amount $k_B T \ln 100$. Use this information to calculate the probability of a hemoglobin site in the lungs being occupied by an oxygen molecule.

   (c) For comparison, consider the case where no CO is present. Find the modified grand partition function (which must have $N_{\mathrm{CO}} = 0$) and determine the probability of the hemoglobin site being occupied by an oxygen molecule. Your result, in comparison with (b), should illuminate the danger of being exposed to even low levels of carbon monoxide!