BP205 Molecular Dynamics of the Cell
Problem Set 2
Due January 27th in class

1. Distinguishing between ratchets and power strokes.

Consider a motor protein traveling in one dimension along a filament.

a. A power stroke with Brownian fluctuations.
In a power stroke, an external driving force causes a motor protein to move a fixed unit per unit time. In addition, the protein makes some number (n) of independent random moves forward or backward with equal probability per unit time due to Brownian fluctuations. In other words, the average velocity of the protein is $\Delta x/\Delta t$, but the motion is stochastic. For n = 10, what is the free energy consumption per unit filament length in terms of k_BT?

b. A Brownian ratchet that weakly biases fluctuations.
In a Brownian ratchet, there is no driving force, but instead internal barriers (fully or partially) block backward fluctuations, which makes the protein more likely to fluctuate forward. Suppose a protein makes 10 random moves of Δx per unit Δt, and that each time the object passes a multiple of 5 * Δx, a barrier of 1 k_BT is established at that location. At the barrier, what is the probability of forward and backward fluctuations? What is the free energy consumption per unit length?

c. A Brownian ratchet that strongly biases fluctuations.
Again the protein makes 10 random moves of Δx per unit Δt, but now each time it passes a multiple of 100 * Δx, a barrier of 20 k_BT is established at that location. Now what is the probability of forward and backward fluctuations at the barrier? What is the free energy consumption per unit length?

d. Sketch/discuss the expected trajectories (plot of x vs. time) and velocities for motor proteins **a, b** and **c**.

2. Binding on a cell surface.

A single receptor for a small ligand (D_L = 30 Å^2/ns) is embedded in a cell membrane. The ligand is all around with a concentration of 2 μM, but any ligand at the surface of the receptor is consumed immediately. Fick's law tells us that there is a flux of ligand toward the receptor. Assume that the radius of the receptor, 50 Å, is much larger than that of the ligand and that at 200nm away from the receptor, the ligand is at bulk concentration. Find and plot the full concentration profile for the ligand. What is the maximum number of ligand molecules per time that the receptor can consume?