PH549: Physics of Biological Systems
Assignment 1

1. **Two-dimensional FRAP**

   The goal of this problem is to simulate a two-dimensional FRAP process. Consider a cell as a circle of radius $R = 10\mu m$.

   - Write a code to simulate a diffusion process in 2D. Consider proteins as point particles (no excluded volume) diffusing with a diffusion constant of $D = 1\mu m^2/s$.
   - Now, simulate a FRAP process. Construct an initial condition such that there are no proteins inside a $r = 1\mu m$ circle at the center of the circle. This is the FRAP RoI (region of interest). Assume that the number of proteins is $N_p = 5000$, and these proteins are uniformly distributed . Now starting from this $t = 0$ initial condition, start the diffusion process, and count the number of proteins inside the RoI as a function of time, $N(t)$. Plot $N(t)$ vs t.
   - Can you estimate the diffusion coefficient from the above plot? Does it match with the chosen D value?
   - Repeat the simulation for $N_p = 10000$. Plot the new $N(t)$ vs t. Does the $t_{1/2}$ (time take to reach half-maximal number/intensity) change with protein concentration?
   - Repeat the simulation for $D = 2\mu m^2/s$. How does the new $t_{1/2}$ value compare with the one obtained for the earlier diffusion constant?

   Please attach all plots and (a link to the) code.

2. **Chemoreceptor clustering**

   There is strong evidence that chemoreceptors in E. coli tend to cluster near one pole as shown in the figure (Kentner and Sourjik (2006)). One hypothesis about the role of such clustering is that it might increase the ability of a bacterium to better detect molecules in its environment. Determine if this is the most efficient strategy for counting (absorbing) molecules of chemoattractant. Approximate E. coli as a sphere $a = 1\mu m$ in radius and neglect its motion. Then compare the diffusive current to $N = 1000$ receptors (absorbing patches of radius $s = 1nm$) scattered over the surface of the cell with the diffusive current to the same receptors incorporated into a single patch with the same total area. Make use of the result that the diffusive current onto a sphere of radius a with N absorbing patches of radius s spread uniformly over its surface is

$$I = \frac{4\pi Dac_\infty}{1 + \frac{\pi a}{Ns}}$$

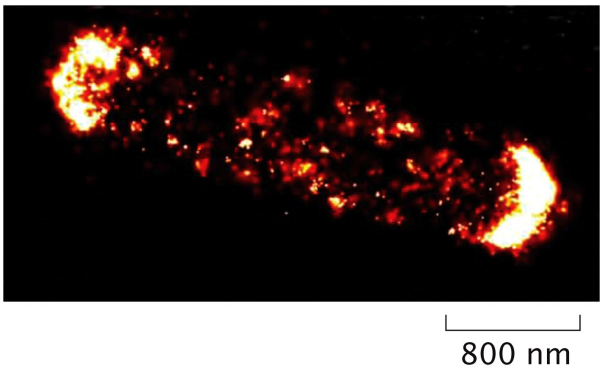

Figure 1: Clustering of *E. Coli* chemotaxis receptors at the poles, Greenfield *et. al.* PLoS Biol. 2009

where D is the diffusion constant of the molecules, while c_∞ is their concentration far from the cell.