Bioengineering 304: Physiology

Oct 11, 2009
Homework Assignment #1
Due: 16th Oct 2009

Points awarded for each question are indicated in square brackets. Return assignment with your name clearly indicated at the top of your answer sheet.

[25] **Question 1**. According to the random walk model, solute molecules move freely in a solvent solution. Assume that the dimensions of a red blood cell can be approximated by a cube of size 7 x 4 by 4 μm. If an adult human contains 2 x 10^{13} red blood cells and on average the collective amount of iron in red blood cells is 2.5 grams, then compute the following:

a) What is the volume of a single red blood cell expressed in liters and microliters?
b) On average, what mass of iron does each red blood cell contain?
c) Assuming that all this iron is located in the hemoglobin, estimate the concentration of hemoglobin in a red blood cell.
d) Estimate how many hemoglobin molecules are to be found in a single red blood cell.
e) What is the average distance between individual hemoglobin molecules?

[25] **Question 2.** Diffusion related questions.

a) Assuming that a hepatocyte is a spherical cell with diameter of 20 μm, how long on average would be take a protein with a diffusion constant of 7.7 $\mu m^2\ s^{-1}$ to diffuse from one end of the cell to the other?
b) How long would the same protein take to diffuse down the length on a nerve axon of length 3 mm? You can assume that the never axon is one dimensional.
c) Comment on your answer to b) and speculate what it might mean.

[50] **Question 3.** The random walk model is a good approximation of passive diffusion. We can easily simulate a random walk on a 2-D lattice. By starting a particle at an origin point (0,0), we can 'walk' the particle a given number of steps across the lattice. At each step we can throw a dice to determine whether the particle should move north, south, east or west. In this assignment you should implement a random walk simulation on a 2-D lattice using a suitable programming language. Using the simulation, you should answer the following questions:

a) For a given number of steps, N (say 50), show empirically that the average displacement in the x and y directions is zero, i.e $\langle x \rangle = 0; \langle y \rangle = 0$. You may need to run 10,000 trials to get good statistics. Plot a histogram of the distribution of x displacements.
b) Plot a histogram of the distribution of the squared distance ($x^2 + y^2$) travelled by each particle. Squaring the values eliminates any negative values. Do this for 10,000 trials and plot the distribution.
c) Plot the root-mean-squared distance travelled by a particle verses the square root of the number of steps. Show that the relationship is linear.