Bi1X: The Great Ideas of Biology
Homework 1
Due Date: Monday, April 4, 2011

"The quality of a person's life is in direct proportion to their commitment to excellence, regardless of their chosen field of endeavor." - Vince Lombardi

This first set of exercises is intended to begin to familiarize you with the use of Matlab. Matlab is a powerful and simple computational tool that we will use on several occasions this term, often for the purposes of manipulating images that we take with our microscopes. With such images in hand, one of the tasks we will undertake is using Matlab to automatically identify objects in our images.

1) One of the important processes in biology is the binding together of some ligand (L) with its receptor (R). As the concentration of the ligand increases, it becomes ever more likely that the receptor will be bound. The functional form of the "binding curve" is given by

$$p([L]) = \frac{\frac{[L]}{K_d}}{1 + \frac{[L]}{K_d}}, \tag{1}$$

where $p([L])$ gives us the fraction of receptors that are occupied by ligands (or the probability that a given ligand will be occupied) and where K_d is known as the equilibrium dissociation constant. Notice that the units of K_d are concentration (i.e. moles per liter, for example). Given a dissociation constant of $K_d = 100\ nM$, make a plot of the probability of receptor occupancy as a function of ligand concentration. Make sure to label your axes and to put a title on the graph.

2) Manipulating images will be one of the most common activities we will resort to when analyzing the results of our microscopy experiments. Images are really giant matrices of the form I_{ij}, where i and j are integers that index the particular "pixel" of interest in our image. As a warm up for handling these matrices, in this exercise, we want you to create a 3×3 matrix of the

form

$$\mathbf{M} = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix}. \tag{2}$$

Show us how to obtain the elements M_{11} and M_{23} in the matrix using Matlab commands. Also, show how to print out just the first column and then, just the first row. Then, show how to multiply this matrix by the number π.

3) Often when performing tasks in Matlab we will want to repeat a task. For example, you might have taken a movie with the microscope and need to analyze a sequence of images. One of the ways we can repeat the same procedure over and over again is using a structure known as a "for loop". To explore the use of such loops, we will integrate a simple differential equation that is sometimes used to describe the growth of bacterial populations, the so-called logistic equation given by

$$\frac{dN}{dt} = rN(1-N). \tag{3}$$

For early times, the growth is exponential, but once the population gets large, the growth saturates. To integrate this equation, we are going to start with the initial condition that $N(0) = 0.01$ and use a simple time step scheme that comes from

$$\frac{N(t+\Delta t) - N(t)}{\Delta t} \approx rN(t)(1-N(t)), \tag{4}$$

which can be rewritten as

$$N(t+\Delta t) = N(t) + rN(t)(1-N(t))\Delta t. \tag{5}$$

What this means from the standpoint of the "m-file" you will write is that you need to repeatedly find the new N, given the previous one using a for loop. For simplicity, take $r = 1$. Your for loop structure should be of the form **"for i=step:step:totaltime"**. This basically makes a loop with a number of steps determined by how large your time step is and what the total amount of time you want to integrate for will be. Within the loop, you might find something like this useful **"N(m)=N(m-1)+rN(m-1)*(1-N(m-1))"**. Right after this within the loop put $\mathbf{m = m + 1}$. This increments the counter we are using to index the array $N(m)$. After the loop finishes, then construct a vector T of the various time instants and make a plot of $N(t)$.