BE/APh 161: Physical Biology of the Cell, Winter 2014
Homework #1
Due at the start of lecture, 1PM, January 15, 2014.

Note from JB: This problem set is largely about estimation. You should be able to do these estimates on a cocktail napkin. Please try to do complete this homework without the use of a calculator or computer to do calculations. Remember that we're just estimating, so π is about 3, etc. Be sure to comment on what parts of your estimates are most suspect and why. After you come up with your estimates, you may look them up at BioNumbers or elsewhere. And of course, try to have fun!

Problem 1.1 (Comments on *Cell Biology by the Numbers*, 10 pts)**.**
Rob Phillips and Ron Milo are working on a new book called *Cell Biology by the Numbers*. Download the book from the course website. Read their comments on page 2 addressed to you, a reader of the draft of the book. Also read the introduction, from pages 7–11.

Chapter 1, pages 12–73, has a set of 17 vignettes about the size and geometry of objects pertinent to cell biology. I encourage you to read all of them. Choose two of them to read carefully and write a short set of comments about each. What did you think was especially well-explained? What was confusing? What could be done to make it less confusing? Was there anything superfluous in the vignette? Is there anything you would add?

For this problem, please print your responses and hand them in with your problem set and also email your answers to me. I intend to share your comments with the authors. Indicate in your email if you would like to remain anonymous when I share them. Otherwise, they will know the names of the writers of the comments I share.

Problem 1.2 (Exploring biology with numbers, 12 pts)**.**
Spend some time on the BioNumbers website (`http://www.bionumbers.org/`), looking at various numbers. Pick three that are particularly interesting to you, give their BNIDs, and write a few sentences about why you find each one interesting.

Problem 1.3 (Sizing up yourself, 10 pts)**.**
Perhaps the biological system you are most familiar with is your own body. Estimate the quantities listed below. You can probably look up most of these numbers, but I would like you to practice your estimation skills. Carefully explain your reasoning for arriving at your estimate.

a) How many cells are in your body?

b) How many hairs are on your head?

c) What is the total mass of DNA in your body?

d) What volume of air passes through your lungs each day?

e) On average, how many molecules from Julius Caesar's last breath do you breathe in with each breath you take?

Problem 1.4 (Estimations and questions from pictures, based on problems 2.09 and 2.10 of *PBoC2*, 12 pts)**.**
As we will see throughout the course, quantitative imaging techniques play a central role in physical cell biology. Sometimes, the pictures themselves are sources of inspiration. Bill Gelbart (who does really interesting work with viruses at UCLA) once told me that seeing an image is often the source of inspiration for him to start along a path of research. For each of the three images below, make the estimate asked of you and then pose a question that comes to your mind based on the image. The question need not be an unanswered one or one that will win you a big grant; just one that is sparked in your mind after looking at the images. Comment on why the question is particularly interesting to you.

a) Figure 1.16 from *PBoC2* shows an electron microscopy image of an escaped genome from a bacteriophage. As the caption in *PBoC2* suggests, later in the course we will investigate DNA conformations using principles from polymer physics. We can still estimate the total length of DNA in the capsid from the image alone. What is your estimate? Be sure to explain your reasoning. An example question for this image might be: How much energy does it take to pack all of that DNA into that tiny virus?

b) In Figure 2.18(C) from *PBoC2*, we see images of mitochondria of budding yeast. Estimate the volume and surface area of the mitochondria for yeast grown in glycerol. (You can see a similar image in 3D at this website: `http://p3d.in/oYoNV`, posted by Susanne Rafelski's lab at UC Irvine.) Approximately what fraction of the cell volume does the mitochondria occupy?

c) Figure 2.45 in *PBoC2* shows a fluorescent image of immunostained proteins, Bicoid, Even-skipped, and Caudal, in a developing fruit fly embryo. Sketch a plot of the concentration profiles along the long axis of the embryo for each of these three proteins. (Ignore the separation between cells.) Estimate the length scale of gradients in each along the long axis of the embryo. (The gradients are regions where the fluorescent intensity is changing from cell to cell.) Comment on the length scales of the respective gradients. It may help to look at the three channels separately in higher resolution. You can download images of these, taken from the FlyEx Database, from the course website at `http://beaph161.caltech.edu/2014/handouts/FlyExImages.tar.gz`.

Problem 1.5 (Concentrations and spacing, 10 pts)**.**
Use your skills of estimation to answer the following questions. Comment on the numbers you come up with.

a) Many biochemical studies in test tubes use nanomolar (nM) concentrations of purified proteins. If a protein species inside of an *E. coli* cell has concentration of 1 nM, how many total molecules of that species are there in the cell?

b) What is the typical intercell distance between *E. coli* cells in a saturated LB growth medium? *Hint*: According to BNID 104943, the saturation concentration in LB is about 10^9 cells/mL.

c) It is estimated that there are of order 10^{30} prokaryotic cells on Earth (BNID ID 104960, see also the beautiful paper by Whitman, et al.). Roughly 10% of these are in the open ocean. Give a rough estimate for the concentration of bacteria in sea water. What is the approximate intercell spacing? *For fun*: If all the bacteria in the sea were lined up end-to-end, how long would the line be?

d) There are approximately 2 to 3 kg of bacteria in your large intestine. What is their intercell spacing?

e) Approximately how many hydronium ions are in an *E. coli* cell?