BE/APh161: Physical Biology of the Cell
Homework 1
Due Date: Wednesday, January 23, 2013

"In Science, self satisfaction is death. Personal self satisfaction is the death of the scientist. Collective self satisfaction is the death of research. It is the restlessness, anxiety, dissatisfaction, agony of mind that nourish Science. - Jacques Monod

1. Who Are You?

It is said that you have more foreign cells in your body than those containing your own DNA. Make a simple estimate of the number of human cells you are made up of, the number of bacterial cells you harbor in your gut (assume there are 2 kg of bacteria in your gut), the number of human genes you carry and the number of genes associated with the more than 200 different species of bacteria you are carrying around.

2. RNA vs Protein

Using the kind of estimates we have talked about in class, give a simple characterization of the relative sizes of mRNAs and the proteins they code for. Specifically, first comment on the mean mass of amino acids and nucleotides as well as their typical physical sizes. Use both of these metrics as a way to provide a rough sense of the relative sizes of proteins and the mRNAs that code for them.

3. To Build a Cell.

(a) Make an estimate of the composition of carbon, hydrogen, oxygen and nitrogen in the dry mass of a bacterium. That is, using what you know about the size and mass of a bacterium, the fraction of that mass that is "dry mass" (i.e. $\approx 30\%$) and the chemical constituents of a cell, figure out the approximate small integers (< 10) for the composition $C_mH_nO_pN_q$, that is, find m, n, p and q. Note that roughly half of the dry mass of a cell is protein and that the ratio of protein to (RNA+DNA) is 3:1. This is an exercise in estimating. I am not interested in super precise characterizations. Your arguments should be of the style: "I think the majority of cell is proteins, the typical amino acid has 5 carbons, there are roughly 300 amino acids per protein, blah, blah, blah...". Most importantly, explain your logic. We are most interested in careful descriptions of your approximations and logic.

(b) Estimate the number of sugars to make an *E. coli* cell. Note that in class, we flirted with these kinds of estimates when we examined the construction of a bacterium. Now, it is your turn to exploit this kind of estimation to see what you come up with. Chap. 2 of PBoC should help you formulate your estimate. Remember to carefully state your assumptions. Also, for the moment, concentrate only on the building materials needed to make a cell and don't worry about the energy needed to assemble them.

(c) The estimate in the previous part of the problem was incomplete because we didn't consider the energetic cost of assembling all of the building blocks to make a cell. Begin by estimating how many ATPs it takes to make a cell. Given that it takes 4 ATPs for every polypeptide bond in a protein, what is a lower bound estimate on the number of ATPs to make a cell? How many sugars does it take to make those ATPs? How does this sugar consumption compare to that needed for the building materials themselves? How does your answer differ depending upon whether the growth is aerobic or not?

(d) LB media is one of the famed growth media for studying bacterial growth and physiology. However, for more controlled experiments, a growth medium with only a single carbon source is used (so-called minimal media) which has 0.5 g of glucose for every 100 mL of media. Look up the minimal media recipe by visiting *http://www.thelabrat.com/protocols/m9minimal.shtml* - note that different people use different glucose concentrations and our 0.5 g of glucose per 100 mL is slightly different from the recipe you will find on the website. A typical experiment involves 5 mL of minimal media which is inoculated with a small number of cells (let's assume one cell) which then grows and divides repeatedly until the culture saturates at roughly 10^9 cells per mL. Estimate the number of carbons in the 5 mL of growth media. Also, work out the fraction of these carbons that are used in the fully saturated culture. What about nitrogen? What is the source of nitrogen in our minimal media and how many nitrogens does it take to make a cell and hence, how many cells can the media support if nitrogen is limiting?

4. DNA replication rates.

Do problem 3.3 of PBoC2.

5. RNA Polymerase and Rate of Transcription.

Do problem 3.4 of PBoC2.