BE/Bi 101: Order-of-Magnitude Biology
Homework 2
Due date: Friday, April 15, 2016

"Biology's atom is the cell, which is not only the basic structural unit of all living organisms, but is also the basic functional unit of life."

—Paul Nurse

1. Crick and morphogens.
In 1970, it was not known whether gradients in morphogens could play a role in embryogenesis. At the time, it was very difficult to measure gradients in living tissue. Therefore, in absence of experimental evidence for morphogen gradients, Francis Crick (Crick, Nature, 225, 420422, 1970) performed a thought experiment to see if gradients of morphogens could be set up by diffusion alone. He took two observations as given. First, that the most embryonic fields involve distances of less than 100 cells and often less than 50. Secondly, most embryologists estimated that if morphogen gradients were to be responsible for pattern formation, the gradients would need to be set up in an matter of hours. Cricks question, and the one we will address in this problem, is: what is the maximum distance over which a steady concentration gradient could be set up in times available to development (hours)? More specifically, how does the maximum distance over which a gradient could be set up scale with the diffusion coefficient and allotted time? You can look up typical diffusion coefficients on BioNumbers if you like.

2. Walking on water.
One of my favorite weekend activities is to hike in the Angeles Crest National Forest north of Pasadena. In a few of the streams along the way, there are more quiet pools, the surface of which are populated by water striders. These insects can walk on the surface of water; they do not sink. Use dimensional analysis to derive a relation showing how the practicality of walking on water scales with the size of the organism. By "practicality," we mean a dimensionless number which is large if walking on water is feasible and small if it is not. This dimensionless number depends on physical properties of the water and of the insect, and it has a name, the Jesus number, Je.

Given the analysis you just did, why do you suspect more animals do not walk on water?

3. Trascription factors and concentrations in bacteria.
In class we examined data on the abundance of transcription factors in bacteria and found that for many transcription factors, the typical number is between 10 and 100. Derive the rule of thumb relating concentration to number per cell in E. coli. Then, use that rule of thumb to work out the typical concentrations of transcription factors in bacteria.

4. Masses of the various macromolecules of the cell.
In class we carefully examined the number of proteins per bacterium as well as the number of mRNA and the number of ribosomes. Expand that discussion by working out the number of lipids per bacterial cell. What fraction of the dry mass are each of the following constituents: protein, mRNA, ribosomes, lipids? How many sugars (consider glucose) would be needed to make up all of these cellular constituents? Where do these sugars come from and how many needed to be transported into the cell each second? How does that happen?