Getting a feel for the numbers.[1]

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Instead of traditional lecture, here we will work through a series of order of magnitude problems in the form of a worksheet to try to understand typical numbers in biology and some weird units.

The numbers involved in biology and biophysics are often hard to understand. Here we will try to get a feel for order of magnitude calculations and numbers in biological physics. This draws heavily on Milo+Phillips wonderful book *Cell Biology by the numbers*.

[1] Readings: Lecture Notes 2 and papers below.

INSTRUCTIONS: Instead of a traditional lecture, this is structured as a worksheet to be done in small groups. Please form groups of 3 people. For most problems, there are two answer slots (individual and group). For the individual answer slot, please first make an honest attempt at solving the problem by yourself. After you are done/or stuck, compare/discuss your answer with the group and put answer in group slot. If you are satisfied as a group move on to the next question.

NEXT CLASS: We will do a Journal Club style discussion of wonderful papers from the Hwa group that can be found on website [2]

[2] Scot et al . Interdependence of Cell Growth and Gene Expression: Origins and Consequences. Science 2010; Scott and Hwa. Bacterial growth laws and their applications (2012)

Weird units that biologists use

Biologists use weird units. For example, to tell you the mass of a protein they often use the unit of “Dalton". Let us translate this to something sensible. A dalton is defined as the mass of a hydrogen atom (or more accurately as " defined precisely as 1/12 of the mass of an unbound neutral atom of carbon-12 in its nuclear and electronic ground state and at rest.") Convert this to grams. Recall that the molar mass (the mass of Avagrado’s number 6.02×10^{23} molecules) of hydrogen is 1g. of hydgrogen

- **Individual Answer:**

- **Group Answer:**

Another common unit for measuring concentrations is a “nanomolar" or nM. Recall a Molar is defined as “mol/L” . The typical volume of an *E. coli* bacteria cell is $1\mu m^3$.

- Estimate the number of molecules per *E. coli* cell for 1nM concentration.
  Group Answer:

- A eukaryotic cell (like a human) is typically $100\mu m^3$. What concentration corresponds to 10 molecules per eukaryotic cells?
  Group Answer:

Reproduction

Another interesting question is how many proteins are in a cell. In order to estimate this, we will make use of some interesting experimental observations. By comparing cells with out without water (dehydrated cells), we can estimate the protein’s mass per unit volume c_p. The units are (g proteins)/(mL cell volume). A typical number for this is $c_p \approx 0.2 g/mL$. As we discussed, proteins are composed of amino acids (aa). The typical mass of an amino acid is about $100 Da$ and a typical protein is 400 aa long.

- Estimate the number of proteins in *E. coli* .
  Individual Answer:

  Group Answer:

- An *E. coli* cell can reproduce every 30 minutes in good nutrient conditions. From this estimate the protein production rate.
  Individual Answer:

Group Answer:

- Estimate the number of protein in a eukaryotic cell. If proteins are made at the same rate, how long would we expect the Eukaryotic doubling time to be?
  Individual Answer:

  Group Answer: