Tutorial 29 Aug Biophysics 2nd year

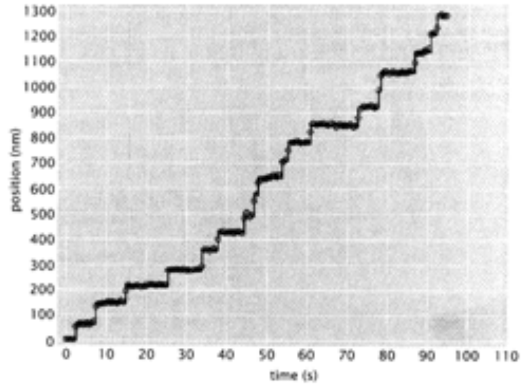
1) A spherical polystyrene bead in water, trapped (deep in the water) in an optical trap can be thought of as trapped in a 3D spring with a **spring constant k (0.22 pN/μm)**. The trap pulls it back to the centre (x=0) if the bead moves away in any direction. Even in the absence of any constant force applied on it, it always feels random kicks from the thermal agitation of the medium around it.
   a) Draw a diagram of the bead and plot underneath a probability distribution of its x position. What kind of distribution do you expect? What would be the mean and variance of the distribution?
   b) Using Boltzmann distribution find out the ratio of probability of finding it at x=0 vs. x=0.5 μm.

2) Assume an ion channel to have a pore size 1/10th its length. Length of the channel may be approximated to that of thickness of the lipid bilayer. It sits on the plasma membrane that separates the cell's inside from the outside. The concentration difference between inside and outside for sodium ions is ~100mM.
   a) Find the diffusion constant for small ions (eg. Sodium) assuming the medium viscosity to be close to that of water (0.001 SI units)
   b) Find the flux of ions through a single channel.
   c) Find the number of ions traversing through the channel per second.

3) If introducing a apolar molecule at one vertex of a water molecule requires 0.7 $k_B T$, and an area of $1 nm^2$ affects 10 water molecules, write the expression for the energy cost ($\Delta E(r)$) associated with introducing a hole in the membrane of radius r nm in terms of $k_B T$.

4) A protein (dia 5nm) synthesized in the cell body of a neuron is needed at the end of the axon.
   a) For an axon of length 10cm, estimate the time taken for the protein to traverse the length of the axon and reach the end by pure diffusion.
   b) If the protein is transported by molecular motors whose single molecule trajectory is given below, estimate the time taken to reach the axon end.
   c) For bacteria, estimate the time taken by the same protein to explore the entire bacteria.

d) Comment on the use of diffusion as a mechanism of transport.



5) Estimate the packing fraction of the yeast genomic DNA. The packing fraction is defined as the ratio of the volume taken up by the genome to the volume of the nucleus. It is given that the yeast genome is 1.2×10^7 bp in length, and the nucleus has a volume $\approx 4\ \mu m^3$.

6)

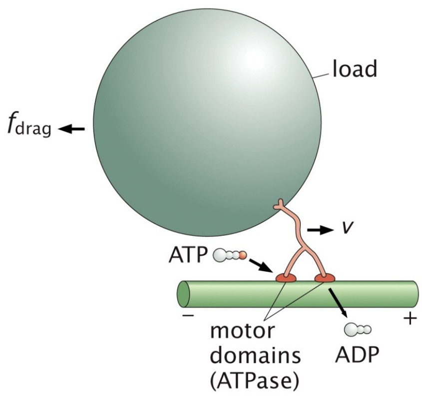


Figure 12.13 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

Estimate the drag force experienced by a molecular motor (step size 8 nm) carrying a vesicle of radius 1 μm at a speed of 1 μm/sec (assume cell to have water's viscosity (0.001 SI units)). How does the energy consumed to drag a vesicle through one step compare with the 1 ATP hydrolysis that is used by the molecular motor of a single step. Predict what would be the maximum force it could apply if it were use the energy of ATP hydrolysis (assume ATP hydrolysis releases $15k_BT$ of energy).