Problem 1. Howard, Problem 2.3. During mitosis, the chromosomes move several micrometers over the course of about 30 minutes. Calculate the average speed. If the viscosity of the cytoplasm is 1000 times that of water, estimate the required force.

Problem 2. Howard, Problem 2.4. The probes used in atomic force microscopes (AFMs) typically have stiffnesses of \( \sim 1 \text{ N/m} \). Given that the mass is \( \sim 100 \text{ ng} \) what is the resonance frequency in vacuum (without damping)? The damping coefficient of a probe in water is \( \sim 1 \mu \text{m s/m} \). Is the motion in water overdamped or underdamped?

Bacteria use swimming to seek out food. Imagine that the bacterium is in a region of low food concentration. For the bacterium to profit from swimming to a region with more food, it has to reach there before diffusion of food molecules makes the concentrations in the two regions the same. Here we find the smallest distance that a bacterium needs to swim so it can outrun diffusion.
(a) Make a plot in which you sketch the distance traveled by a bacterium swimming at a constant velocity \( v \) as a function of time \( t \), and the distance over which a food molecule will diffuse in that same time. Indicate on the plot the smallest time and the smallest distance that the bacterium needs to swim to outrun diffusion.
(b) Make a numerical estimate for these minimum times and distances for an E. coli swimming at a speed of \( 30 \mu \text{m/s} \). The diffusion constant of a typical food molecule is roughly \( 500 \mu \text{m}^2/\text{s} \).
(c) Estimate the number of ATP molecules the bacterium must consume (hydrolyze) per second in order to travel at this speed, assuming that all of the energy usage goes into overcoming fluid drag. The amount of energy released from one ATP molecule is approximately \( 20kT \). Note that the bacterial flagellar motor is actually powered by a proton gradient and this estimate focuses on the ATP equivalents associated with overcoming fluid drag.

Problem 4. To get feeling of how much information is available in biological databases, you are asked to find your favorite protein. Select a gene in the genome of a fully sequenced organism and find:
(a) Its nucleotide sequence.
(b) The aminoacid sequence of the protein it encodes.
(c) The crystal structure of the protein (print the 3D structure with a PDB viewer).
(d) A list of known interaction partners of the protein.
(e) An image showing the localization of the protein within the cell.