BB 101: Module II

TUTORIAL 2

1. Consider a microscopic swimmer trying to make progress by cycling between the forward and backward strokes of its paddles as shown in Figure A. (a) On the first stroke, the paddle move downward at relative speed v, propelling the body through the fluid upward at speed u. (b) On the second stroke, the paddle move upward at relative speed v', propelling the body downward at speed u' (c) Then the cycle repeats. Assume this is low Reynolds number motion where moving the body through the fluid requires a force determined by drag coefficient γ_1 and moving the paddles through the fluid requires a force determined by a different constant γ_2. Show that reciprocal motion like this cannot give net progress in low Reynolds number environment.

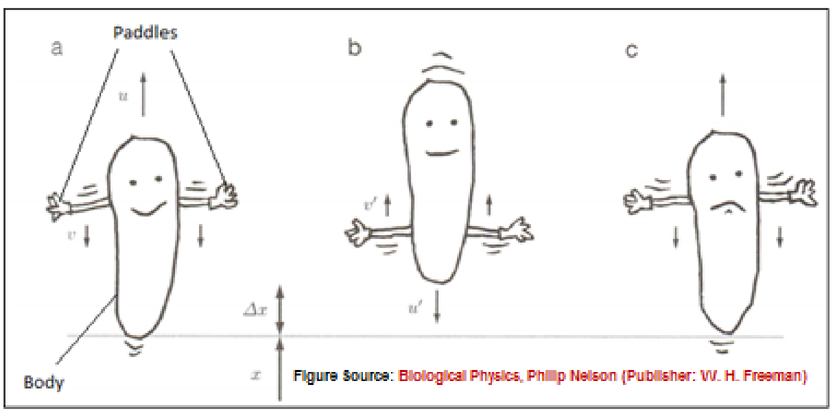


Figure A

2. Bacterial use flagella motor to rotate the helical flagellum to generate the propulsive force. Provide a qualitative explanation (using the result from Problem 6 of Tutorial 1) that if a thin, rigid helical rod as shown in Figure B is cranked about its helix axis at a certain angular speed then it can generate a net force propulsive force.

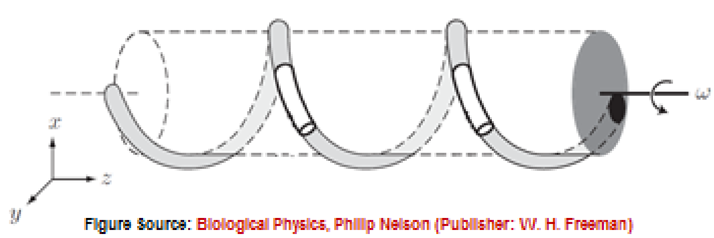


Figure B

3. In most cases, the energy budget of cells is ultimately mediated by adenosine triphosphate (ATP). Assume that daily human dietary intake of energy is 2016 kcal, and half of the energy input in the form of our diet is turned into ATP, which is hydrolyzed to obtain the energy required for various processes in body. Suppose that energy liberated by the hydrolysis of ATP is 12 kcal/mole and molecular weight of ATP is roughly 0.5 kg/mole

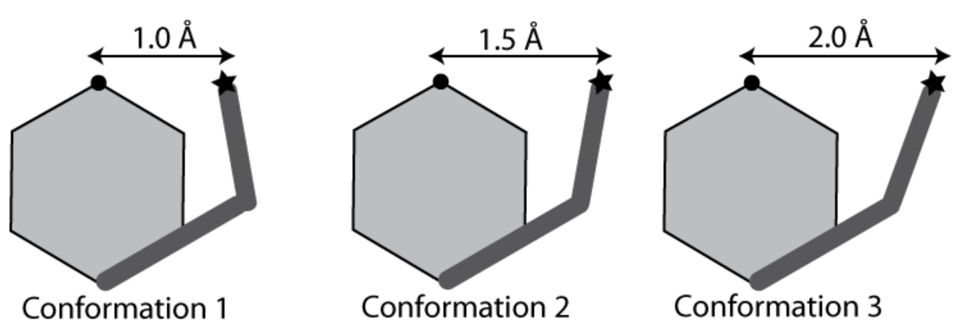
i) Calculate the number of ATP synthesized each day in moles?
ii) Calculate the daily turnover i.e. amount of ATP produced daily in Kg?

4. Suppose a biomolecule can be found in two states A and B. The energy of biomolecule in state A is 12.20×10^{-21} J and in state B is 16.34×10^{-21} J respectively. It is given that probability of find finding the biomolecule in State A and State B is given by following relation where k_B Boltzmann constant is and $k_B T$ is the thermal energy available to biomolecule from surrounding at temperature T.

$$\frac{P_B}{P_A} = e^{-(E_B - E_A)/k_B T}$$

i) Find out the ratio $\frac{P_B}{P_A}$ at T = 300 K?
ii) Now assume that energy of the biomolecule in State A and B is 12.200×10^{-21} J and in state B is 12.614×10^{-21} J respectively. Find out the ratio $\frac{P_B}{P_A}$ at T = 300 K?
iii) Find out the probability of finding the system in State A at $T=\infty$. What is the interpretation of this result?

5. A peptide loop on a protein molecule was probed using fluorescence spectroscopy to measure the separation l from a point on the loop to a point on the protein as shown in figure below. After experiment you decide to model the loop as having following three different conformations:



(1) In first conformation, the loop sticks to the side of the loop with separation l=1.0 Å; and you define this as the ground state, with energy ϵ=0 pN nm

(2) In second conformation, the loop is more distant from the protein with separation l=1.5 Å; you define this as first excited state with energy ϵ=4.14 pN nm

(3) In third conformation, the loop is far away from the protein with separation l=2.0 Å; and you define this as second excited state with energy ϵ=8.28 pN nm

Using above model, calculate following at T=300 K:

(a) Partition function for the loop **(b)** Average separation i.e. ⟨l⟩ **(c)** Average energy of the loop ⟨ϵ⟩

6. The aim of this problem is to show that a random walk leads to diffusive behavior. Suppose there is a drunkard person, as shown in Figure C, walking along a line such that he takes steps of L, either to the left or right, with equal probability. So that his position x_N after taking N such random steps is given by $< (x_N)^2 >= NL^2$, where $<>$ denotes average over number of all possible way in which drunkard person can take Nsteps.

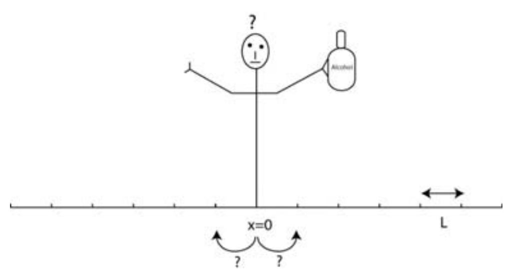


Figure C