Indian Institute of Technology Guwahati
Department of Biosciences and Bioengineering
Physical Cell Biology: BT 630
End Semester Examination (1 May 2024)

[Duration: 3 hrs] **Answer All the Questions** **[Total marks: 55]**

Note:

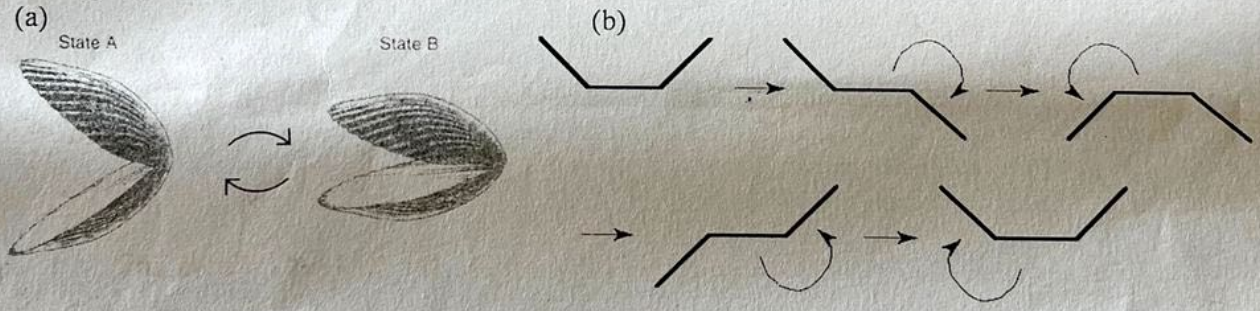
- **All problems should be worked out in a systematic manner explaining the steps involved.**
- **Answers should be short and up to the point. Ambiguous and circuitous answers will attract penalty.**
- **The question paper has to be returned along with the answer scripts.**

PART-A

1. Show that the binding probability of RNA polymerase to its promoter is a simple function of the number of polymerase molecules and the binding energy. [4 marks]

2. (i) Mention the different kinds of deformations the cell membrane is subjected to. [2 Marks]
(ii) In the membrane, which of the following is a very slow process: (a) lateral diffusion, (b) rotation, and (c) flip-flop of lipid molecule. Why? [2 Marks]
(iii) Consider the function $h(x_1, x_2) = x_1^2 + x_1x_2 - 2x_2^2$, which we assume describes the shape of a deformed lipid bilayer membrane. Compute the principal radii of curvature as functions of x_1 and x_2. [3 Marks]

3. (i) Comment on the peculiar features of living in a low Reynolds number world. [2 Marks]
(ii) Which of the following animals can propel itself in the low Reynolds number world? Why? [3 marks]



4. (i) Diffusion of a molecule in aqueous solution is countered by frictional forces. Derive and show how diffusion and friction are related. [5 marks]
(ii) Explain the significance of this relationship and discuss how it is "Universal". [2 marks]

5. Explain how the strategy employed by cilia and flagella counters the reciprocal motion and generates a net forward thrust. [2 marks]

6. A gold fish (2 cm) and *E. coli* (2 μm) are swimming in water with a velocity of 2 cm s^{-1} and 2 $\mu m\, s^{-1}$, respectively. Which of these will find high resistance to swimming in water and why? Kinematic viscosity of water = $10^{-2} cm^2 s^{-1}$ [3 marks]

7. During cell division, the partition of the molecules between daughter cells, which follows a binomial distribution, can be tracked based on the intensity of the fluorescently-labeled molecules. Show that $< (I_1 - I_2)^2 > = \alpha\, I_{tot}$, where I_1 and I_2 are the intensities of daughter cells 1 and 2, respectively and I_{tot} is the total fluorescence intensity of the mother cell. Assume that there is a linear relation between intensity (I) and number of fluorophores (N) such that $I = \alpha N$ [5 marks]

8. *E. coli* swims in search of food. Assume that a 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. The bacterium swims at 30 μm s^{-1} and the diffusion constant of the food molecules is roughly 500 $\mu m^2 s^{-1}$.
   (i) Estimate the minimum distance (and the corresponding time) the bacterium has to swim in order to outrun diffusion. [2 marks]
   (ii) Calculate the number of ATP molecules the *E. coli* (2 μm in diameter) must consume 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 by one ATP molecule is approximately 20 k_BT. Viscosity of water – 10^{-2} g cm^{-1} s^{-1} [2 marks]
   (iii) *E. coli* spends about 10^7 ATP s^{-1} for metabolic activities. Estimate the energy required for *E. coli* to swim in water when traveling at a speed of 10 μm s^{-1}. Comment whether is it worth spending that amount of energy on locomotion. Viscosity of water – 10^{-2} g cm^{-1} s^{-1} [2 marks]
   (iv) When *E. coli* has to escape from its predator at low Reynolds number world, comment on the challenge it faces to evade the capture and how it overcomes it. [2 marks]

9. (a) Estimate the time of diffusion for moving a protein (diffusion constant ~ 100 $\mu m^2 s^{-1}$) across (i) E. *coli* having a diameter of 1 μm and (ii) giant squid axon having a length of about 10 cm. Based on the estimate above, comment on the apparent paradox in transporting biomolecules across longer distances purely by passive diffusive transport. [2 marks]
   (b) Any apparent deterministic process inside a cell has to counter diffusive limit set by K_BT where K_B is the Boltzmann constant and T represents absolute temperature in *kelvin* (K). How cells seem to cope up with this disadvantage? [2 marks]

PART-B

Note: ***To address the following questions, the circulated research paper may be referred to. Don't write answers directly picking from the paper verbatim. You are expected to convey through your own words. Each question carries 2 marks.***

10.
   a. Garner et al. used FRET to characterize ParM polymerization. How do you think FRET will discriminate the ParM monomer and polymer?
   b. What led to the conclusion that ATP hydrolysis and not ATP binding promotes disassembly?
   c. While actin requires accessory factors to promote assembly/disassembly, ParM doesn't seem to have this requirement. Based on the paper, reason this out.
   d. How Garner et al. proved that both ParM ends have ATP cap and that it guards against the depolymerization?
   e. In what way, the dynamic instability of ParM facilitates the plasmid segregation?

→ THE END ←