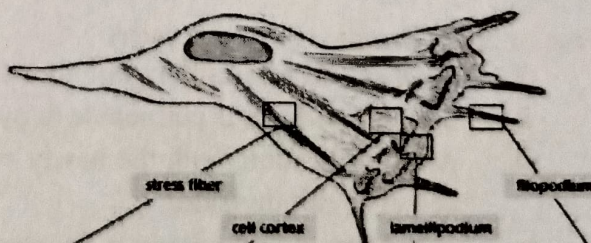Indian Association for the Cultivation of Science
(Deemed to be University under *de novo* Category)
Integrated Bachelor's-Master's Program
End-Semester (Sem-I) Examination-Autumn 2022

Subject: Molecules of life and cells
Full Marks: 50

Subject Code(s): BIS 1101
Time Allotted: 3 h

Use separate pages for Part A and Part B
(Keep all subparts of a question together)

Part A: Answer all questions (25 marks)

1. i.   Name a processive and a non-processive motors that interact with microtubules.   1

    ii. Write down Fick's 2nd equation for a protein concentration diffusing uniformly from all directions   1
         into a spherical cell.

    iii. Choose the correct options: Microtubules are present in which of the following structures?   1
         (A) Cilia (B) Flagella (C) Microvilli (D) DNA

    iv. Which cellular component does form the protective cage for DNA in the nucleus?   1
         (A) Actin filaments (B) Ribosomes (C) Microtubules (D) Intermediate filaments

    v.   True or false: In most animal cells, minus end-directed microtubule motors deliver their cargo to   1
         the periphery of the cell, whereas plus end-directed microtubule motors deliver their cargo to the
         interior of the cell

    vi. Actin dynamics can be regulated by   1
         (A) Latrunculin (B) Cytochalasin B (C) Phalloidin (D) all of these

    vii. Average time taken by a potassium ion with diffusion constant $2000\,\mu m^2/s$ to diffuse across a   1
         $1\,\mu m$ bacterium is
             (A) 0.15 ms (B) 1.5 s (C) 0.25 ms (D) 2.5 s

2. i.   Draw the structures of the actin arrays within   2
         the boxes with appropriate polarity

stress fiber

cell cortex   lamellipodium   filopodium

    ii. Draw the appropriate figure for the time course of actin polymerization (in vitro) and show   2
         various regimes.

    iii. Consider a reaction-limited actin polymerization drive the movement of Listeria through   3
         cytoplasm at a maximum speed $1\,\mu m/s$ at $30^{\circ}C$. Gvien that polymeric actin has two

proptofilaments and monomeric actin is ~ 5.5 nm wide, estimate the effective number of actin monomers added per sec.
Is the maximum speed consistent with the actin polymerization? What is the maximum equilibrium force generate by a single actin filament? Consider for actin, $k_{on} = 12\ \mu M^{-1}.s^{-1}$, $k_{off} = 1.2\ s^{-1}$ critical concentration $K_c = 0.12\ \mu M$ and an usable ATP-actin (monomer) concentration $30\ \mu M$.

3. i. Sketch the rotating crossbridge model of a myosin motor (single head) and label each step clearly showing ATP hydrolysis and working distance. 2

ii. Define the duty ratio related to (i) with an appropriate diagram. 2

iii. Estimate the force exerted during a single step by kinesin. The kinesin motor moves 8 nm per ATP hydrolysis event. Given, that the thermal energy scale $k_B T \sim 4\ pN.nm$ and the free energy of ATP hydrolysis $20\ k_B\ T$. 2

4. i. Imagine two similar bacteria confined in a narrow channel (1-dimension) step at $1\mu m.s^{-1}$: one deposits slime to avoids its traced-trail, while the other lacks the feature. What would be the mean separation between them after 1.5 days, if they start at the same position? 2

ii. Evidence shows that chemoreceptors in *E. coli* tend to cluster near the poles (see Figure). One hypothesis about the role of such clustering is that it might increase the ability of a bacterium to better detect molecules in its environment. Determine the efficiency of this strategy for counting (absorbing) molecules of chemoattractant as follows. Approximate *E. coli* as a sphere $a = 1\ \mu m$ in radius, and neglect its motion. Then compare the diffusive current to $N = 1000$ receptors (disk-like absorbing patches of radius $s = 1\ nm$) scattered over the surface of the cell with the diffusive current to the same receptors incorporated into 2 circular patches on opposite surfaces with the same total area of all the patches. 3

Part B: Answer all questions (25 marks)

5. True of false Explain (0.5 + 0.5.each) 10
    i. By mass, oxygen is the most abundant element in the human body. If so, explain why?
    ii. The lipid bilayer is permeable to hydrophobic molecules. If so, explain why?
    iii. After replication, both the newly synthesized DNA strands are passed to the same daughter cell after cell division.
    iv. In proline, the side group is attached to the Carbon atom of the carboxyl group
    v. Helmholtz Free energy and Gibbs free energy are different for reactions in incompressible liquid.

vi. ATP hydrolysis Free energy is larger than the C-C covalent energy. If not, explain its consequence for cells.

vii. In hydrophobic interactions, two hydrophobic molecules attract each other strongly. If so, explain the nature of the interaction.

viii. When a spherical wavefront enters a high refractive index glass slab from the air, the curvature of the wavefront remains unchanged. Explain through the diagram.

ix. Two spherical droplets, A ($r=5\times10^{-9}$ m) and B (5×10^{-9} m) of pure water with different radii are invisible on optical microscopes due to high transparency. To make droplets A and B visible, same-sized droplets of water mixed with ink are prepared. Mixing ink makes B visible but not A. true or false? Explain why?

x. In TIRF, the XY resolution of the system improves over conventional fluorescence microscopy. Explain

6. Describe the factors that lead to the self-assembly of lipids in water. Depict different probable structures that lipid molecules can self-assemble into when they are dispersed in a) Water and b) oil   3

7. Describe the difference between the primary, secondary, tertiary, and quaternary structures of protein and discuss the role of different interactions in these structures   2

8. Discuss why a lipid bilayer in XY plane has 2D fluid-like properties in the XY direction and has an elastic modulus in the z-direction   5

9. (A) Describe lateral and axial resolution. How do they impact the quality of the image? (2.5+2.5)   5

     OR

   (B) Describe the schematic and working of the phase contrast microscopy