

LIFE SCIENCES
PAPER II

1. a) Draw a graph that will represent the following equation:

$$\frac{dA}{dt} = kA \quad (5)$$

- b) Describe a method to determine surface area of a leaf without using any instrument. (5)

- c) Water is often contaminated by a variety of ionic impurities. What is the best method to determine purity of a sample of water? (5)

- d) You have to test if ponds A, B and C differ significantly in their primary productivity. What statistical test should be applied to your data? Justify your choice of the test. (5)

2. The extensive sequences (Gly-X-Pro)_n or (Gly-X-Hyp)_n stabilize the collagen triple-helix, in which X is any amino acid.

- (i) Why must Gly be present in every third residue? (5)

- (ii) What are the principal bonds which are responsible for holding three helical strands together in the superhelix? (4)

- (iii) How does each strand of the collagen helix differ from an α -helix in terms of structural characteristics? (3)

3. (a) An experiment was done to determine the effect of compound Y on the biochemical reaction $A + B \rightarrow C$. It was found that in the presence of Y, very little, if any, product C was formed. However, on increasing the concentration of A, C could be detected. Explain the effect of Y on the reaction. (2)

- (b) Describe an approach by which secondary structure of RNA molecules can be verified. (5)

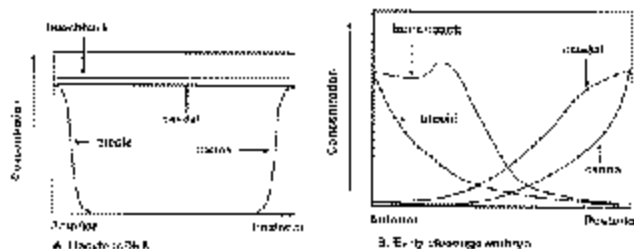
- (c) How would you determine the aggregation state and shape of a biomacromolecule in solution? (5)

4. a) What are the two tautomeric forms of cytosine? Show with the help of a diagram. (6)
- b) How could one determine the degree of polymerization of a sample of amylose? (6)
5. a) Draw diagrams to illustrate sequence-dependent variation between two adjacent base pairs, known as *tilt*, *roll* and *twist*. (6)
- b) What is the major difference between normal DNA double helix and RNA double helix? How does this influence the biological function of these two molecular forms? (6)
6. A liver cell has been pulse-labeled with [^3H] uridine and a thin section of it is obtained. The overall appearance of the autoradiograph (examined through electron microscope) shows regions of white patches interspersed with black dots (silver grains).
- 1) What are these sites? (2)
- 2) Which site is functionally inactive and why? (4)
- 3) One of these sites is thought to contain DNA that is never transcribed in any cell. Name the site and its physiological significance, if any. (6)
7. (a) The basic function of the cell cycle is to duplicate the DNA accurately and then distribute the copies precisely to daughter cells. So, why are there gaps between S phase and M phase? (4)
- (b) What are DNA damage checkpoints which block the cell cycle progression in G1 and G2 phases? (8)

8. (a) What is the role of cross-linking glycans, in plant cell wall synthesis? Name three cross-linking glycans, their structure and composition. (6)
- (b) "Cytoskeletal polymers have an intrinsic polarity". Comment on the statement. (6)
9. (a) What are the four major phospholipids present in the plasma membrane of mammalian cells? (4)
- (b) What is the distribution of these phospholipids in the outer and inner monolayer in human red cell membrane? (4)
- (c) The plasma membrane contains various phospholipases that are activated by extracellular signal to cleave specific phospholipids. What is the function of phospholipase C in response to extracellular signal? (4)
10. (a) Draw a diagram of a DNA molecule undergoing replication. Indicate the newly synthesized strands and identify the following. (5)
- Polarity of newly synthesized strands
 - Leading and lagging strands
 - Okazaki fragments
 - RNA primers
- (b) Cycloheximide and chloramphenicol both inhibit protein synthesis by blocking peptidyl transferase. How are these two inhibitors different? (4)
- (c) Name the three enzymes involved in the formation of 5'-cap in eukaryotic mRNA. (3)
11. (a) (i) What are the three components, which arise from the 45S rRNA precursor molecule? (6)
- (ii) If ^3H labeled uridine is fed to a cell transcribing rRNA genes, in which rRNA gene product would the label appear first?
- (iii) What is the major advantage of getting the three rRNA genes transcribed together? (6)
- (b) Show pictorially the organization of the *lac* operon of *E. coli*. (3)
- (c) Design an experiment to show that induction of host protein synthesis stops after T4-phage infection. (3)

12. (a) Mention two approaches used for deciphering the genetic code. (6)
- (b) Insertion of a base in a coding sequence leads to a shift in the reading frame, which in most cases produces a nonfunctional protein. What kind of mutation in a tRNA might suppress frame shifting? (2)
- (c) Bacteriophage T4 rapidly injects the total genome inside the host cell while T7 injects the genome slowly. Explain the reason. (4)
13. White blood cells (WBCs) lead a nomadic life, moving between the blood-stream and the tissues, necessitating the presence of special adhesive properties to bind to the endothelium in collaboration with integrin.
- (a) Name the various molecules responsible for these adhesive properties. (3)
- (b) With the help of some appropriate experiments prove the localization of these molecules on the cell surface and their carbohydrate-binding properties. (5)
- (c) What is the nature of collaboration of these molecules with "integrin"? Why is it crucial for WBC's life? (4)
14. (a) Giving one example each, describe the characteristics of autocrine and paracrine signaling. (4)
- (b) Explain how a single epinephrine molecule can generate numerous Ca^{+2} ions as second messenger. (4)
- (c) Describe how a cAMP mediated signal can be terminated? (4)
15. (a) What is the function of an adjuvant in immune response? (2)
- (b) When a virus is taken up by a dendritic cell, how is it processed and presented to the T cell? (5)
- (c) What are transgenic and knockout mice and how are they developed? (5)

16. Figure (A) below represents the distribution of mRNA of different genes involved in *Drosophila* development. Figure (B) represents the distribution of their proteins in early cleavage embryo.



- (a) Where are these mRNAs transcribed? (2)
- (b) How is the distribution of mRNA in oocytes (Fig. A) converted into protein gradient as shown in Fig. B. (8)
- (c) What are morphogens? (2)
17. (a) The following table shows the results obtained from a tissue transplantation experiment during early and late gastrula stages in newt. (2)

Donor region	Host region	Differentiation of donor tissue
EARLY GASTRULA Prospective neurons	Prospective epidermis	Epidermis
LATE GASTRULA Prospective neurons	Prospective epidermis	Neurons

Explain the results.

(your answer should include terms like determination/regulative/conditional/autonomous/mosaic/committed/fate)

- (6)
- (b) Distinguish between holoblastic and meroblastic cleavage, stating the kinds of eggs in which such cleavage takes place. (6)

18. (a) Three classes of organ identity genes A, B & C are involved in specifying the four whorls of a flower. Sepals (se) are determined by the action of A class of genes, petals (pe) are determined by both A & B, stamens (st) by B & C, while carpels (ca) are determined by C alone. Mutations in these genes lead to homeotic transformation. Given below is the phenotype of floral whorls observed in wild type and mutants of floral organ identity genes.

Whorl	1	2	3	4
Wild type	se	pe	st	ca
<i>apetala 2 (ap2)</i>	ca	st	st	ca
<i>pistillata (pi)</i>	se	se	ca	ca
<i>agamous (ag)</i>	se	pe	pe	se

To which class (A, B or C), do the genes *ap2*, *pi* and *ag* belong? Give reasons.

- (6)
- (b) Higher plants usually exhibit indeterminate growth during vegetative phase. This is achieved by the maintenance of an active shoot apical meristem (SAM) which generates precursors that develop into stem and lateral organs. Describe the cellular organization of SAM which enables a plant to achieve this growth pattern.
- (6)
19. (a) Diagrammatically show light response curve of photosynthesis in a C_3 plant highlighting light compensation point, light-limited and CO_2 -limited regions.
- (6)
- (b) How is the activity of pyruvate dehydrogenase (PDH), a key enzyme in citric acid cycle, regulated? Name one metabolite involved in activation and one in deactivation of PDH, and mention their respective targets.
- (6)
20. (a) A 3-day-old corn seedling grown in total darkness was irradiated with white light for 4 days. What phenotypic changes would you observe in such a seedling vis-à-vis a 7-day-old dark-grown seedling? Name the sensory photoreceptors involved in regulating these photomorphogenic changes.
- (6)
- (b) Explain the terms 'hypersensitive response' (HR) and 'systemic acquired resistance' (SAR) in relation to infection of a tobacco plant with tobacco mosaic virus.
- (6)
21. (a) Why is proline considered as a 'compatible solute' in plants? Mention the two molecules from which its biosynthetic pathways originate.
- (6)

- (b) Explain the process of loading of photoassimilates, tri- and tetra-saccharides, as proposed in "polymer trapping model". (6)
22. (a) Describe with examples open and closed circulatory systems. (7)
- (b) Differentiate between artery and vein. (5)
23. (a) Discuss the role of CO₂ in the blood in oxygenation of tissues. (6)
- (b) Describe briefly, the neural regulation of respiration in higher animals. (6)
24. (a) Name the neurohormone secreted by the suprarenal gland and explain briefly its cellular mechanism of action. (6)
- (b) What is the role of atrial natriuretic factor (ANF)? (2)
- (c) "Generally upon stimulation, a neuron is depolarized; however, in retina light stimulation hyperpolarizes rods for vision". Substantiate the statement. (4)
25. (a) A panel of cell lines was created from mouse-human somatic cell fusions. Each line was examined for the presence of human chromosomes and for the production of an enzyme. The following results were obtained:

Cell line	Enzyme	Human Chromosome											
		1	2	3	4	5	6	7	8	9	10	17	22
A	-	+	-	-	-	+	-	-	-	-	-	+	-
B	+	+	+	-	-	-	-	-	+	-	-	+	+
C	-	+	-	-	-	+	-	-	-	-	-	-	+
D	-	-	-	-	+	-	-	-	-	-	-	-	-
E	+	+	-	-	-	-	-	-	+	-	+	+	-

- On the basis of these results, decipher which chromosome has the gene that codes for the enzyme? Give reasons. (5)
- (b) Why a single crossover event between two linked genes will not result in more than fifty percent of recombinant gametes? (3)

- (c) Variegated corn kernels result from excision of DS elements (transposable elements) from genes controlling pigment production during development. The sizes of the spots vary from large to small as shown below:



- (i) Why are the spots of various sizes?
 (ii) Who discovered this phenomenon?

26. (a) In an interrupted mating experiment, an *E. coli* F⁻ strain was crossed with three different Hfr strains. The order of transfer of markers from Hfr to F⁻ in the three crosses was

- (1) thi thr pro lac pur gal F
 (2) lac pur gal his gly thi F
 (3) thr thi gly his gal pur F

- (i) From this result draw two main conclusions regarding the nature of F-mediated gene transfer.
 (ii) Diagrammatically represent the arrangement of these genes on *E. coli* chromosome, marking the position of F (▶) in each Hfr strain.

- (b) When a pure line of a squash plant that produces fruits of white color is crossed with a pure line that produces green fruits, the F₁ produces white fruits. When the F₁ plants are crossed with each other, they produce progenies bearing either white, yellow or green fruits in the ratio of 12:3:1. Explain the observation giving appropriate genotypes of the parents, F₁ and F₂ progenies.

27. In a large herd of cattle, three characters showing continuous distribution are measured and the variances are calculated as follows:

Variance	Characters		
	Shank length	Neck length	Fat content
Phenotypic	300	700	100
Environmental	250	300	50
Additive genetic	40	70	40
Dominance genetic	10	330	10

- (a) Calculate the broad and narrow-sense heritability of each character. (6)
- (b) In the population of animals studied which character would respond best to selection? Why? (2)
- (c) Two independent recessive mutations in *Drosophila* have been isolated which give the same phenotype. Design cross(es) to test if the two mutations are allelic or non-allelic. (4)
28. (a) *Nasikabatrachus*, a frog belonging to a primitive family of amphibians has recently been described from Western Ghats. Its closest relatives are found only in Madagascar. How do you interpret this distribution pattern? (4)
- (b) What type of vegetation is expected above 3500 m altitude in Eastern Himalayas? What are the two important floristic elements of this zone? (4)
- (c) Name the causative organisms for following diseases? (4)
- Red rot in sugarcane
 - Bacterial blight in rice
 - Kala azar
 - Typhoid
29. (a) How does a biosphere reserve accommodate both human activities and conservation efforts? (6)
- (b) What is the position of Nymphaeales in APG classification? What are the other groups that share similar positions? (6)
30. (a) Write any four major adaptations that helped vertebrates to invade land from water. (4)
- (b) The tangential section of a given wood shows uniseriate rays, with both parenchyma and tracheids. To which group of plants does the wood belong and why? (4)
- (c) List the characters that place Choanoflagellates closer to animals than to protists. (4)
31. (a) "Excess of ozone could be beneficial or detrimental for biological systems, depending on where it is found". Discuss this statement with supporting examples. (6)

- (b) Explain why litter C/N ratio is one of the most critical determinants of its decomposition rate. (6)

32. (a) In the terms 'r selection' and 'K selection', what do 'r' and 'K' signify? (4)

- (b) Consider the alternative reproductive strategies (i) producing a large number of small sized offspring or (ii) a small number of large sized offspring. List the conditions that will select for a switch from the former to the latter strategy. (8)

33. (a) Show which of the two communities X and Y is more diverse by calculating the *Simpson's Index of diversity*

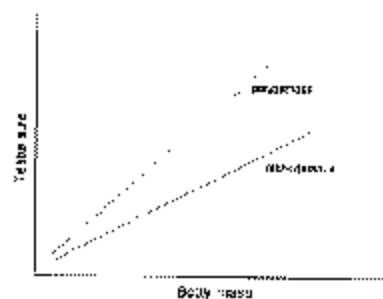
Species	Number of individuals	
	Community X	Community Y
A	10	10
B	15	11
C	25	12
D	20	15
E	10	54

- (b) How does species diversity change in relation to the area sampled? Show the relationship graphically and give the equation for it. (4)

34. (a) State Fisher's hypothesis for the evolution of secondary sexual characters. (3)

- (b) What are the problems faced by Fisher's hypothesis? (5)

- (c) The regression lines for body mass and testes size for monogamous and polygamous species of primates is given. What can you infer from the graph? (4)



35. (a) In most of the bird species with biparental care, sexes are morphologically alike. What hypothesis can you suggest to explain this finding? (4)

- (b) What are the possible advantages of extra-pair copulation (EPC) for males and females? (4)
- (c) In a flowering plant, 24% of flowers in an inflorescence do not contain nectar. Suggest at least two alternative hypotheses to explain the phenomenon of empty flowers. (4)
36. (a) Illustrate with a numerical example how heterozygote advantage leads to stable coexistence of alleles. (6)
- (b) If you are given the genotypic frequencies of AABB, AaBB, aaBB, AABb, AaBb, aaBb, AAbb and Aabb in a mating experiment. How will you test whether the loci A and B are linked? (6)
37. a) Define apomixis. In brief, list the significance of apomixis in crop improvement. (6)
- (b) List at least three possible reasons for the observed variation in the pattern and level of expression of the introduced gene in independent transgenic plants. (3)
- (c) Mention three mapping populations usually employed in crop breeding. (3)
38. (a) What are haploids? Distinguish between dihaploids and doubled haploids. (4)
- (b) What method would one use to transform chloroplast genome? Describe the role of Vir A and G in *Agrobacterium* mediated transformation of plants. (6)
- (c) What is the full form of AFLP. (2)
39. (a) On repeated cultures *in vitro*, one population of human liver cells appears to become immortalized but not transformed. Design an experiment to verify the observation. (6)
- (b) Using whole genome approach, how would you find out to what extent the cells mentioned above might differ from the normal liver cells? (6)
40. (a) State the basic equation that describes radioactive decay of a source. From this equation deduce the equation that can be used to determine half-life of any radionuclide. (6)
- (b) How will you determine the level of quenching in scintillation counting? (6)

- (c) What are the methods that are used to make autoradiographic signals quantitative? (3)
more (3)
41. (a) Describe a strategy to sequence a 4 kb fragment of DNA. (6)
(b) How can pET series of vectors be used in some eukaryotic cells? (6)
42. (a) Why shadowing is done to analyze fixed and dried specimens using scanning EM? (2)
(b) How does a spectrophotometer differ from a spectrofluorimeter? (4)
(c) An optical filter passes only red light with an average wavelength (λ) of 6500 Å. Calculate (i) the wavelength in nanometers and centimeters and (ii) frequency (given c =speed of light, 3×10^{10} cm/sec). (6)
43. (a) What is Type I error in statistical significance testing and what is its level set in most biological studies? (2)
(b) In a population of shrimp, the sex ratio is assumed to be 0.5♀: 0.5♂. How many male shrimp should turn up in a random sample of 80 so as to reject the hypothesis? (Note: $\chi^2 = 3.84$ for $df=1$, $\alpha = 0.05$) (4)
(c) Give a brief experimental protocol and statistical testing procedure for testing the hypotheses given below: (6)
(i) The newly introduced drug X for hypertension is not effective in reducing blood pressure.
(ii) The growth rate of the fish *Gambusia* increases with the amount of daily ration.