Group A

1. For three pairs of values of x and y, the values of $x + y$ are -1, 0, 1. x and y have equal variances $\frac{2}{3}$.

   (a) Calculate the correlation coefficient between x and y.

   (b) If $\bar{x} = 2$, find the regression equation of y on x.

   (c) Can you predict x using the above regression equation?

   $[8 + 6 + 4 = 18]$

2. A biologist conducting experiments wishes to investigate whether the average blood sugar fasting levels differ between working and non-working males. Meanwhile, another biologist is interested in determining if there is a significant difference in the average blood sugar fasting levels of non-working males before and two hours after taking a specific medicine.

   (a) Would you recommend employing the same statistical test for these distinct scenarios?-Justify your answer.

   (b) State clearly the test statistics and critical region of the test(s).

   (c) Assume that the level of significance is 0.05. What conclusion can you draw if the calculated p-value is 0.67 and 0.0003 for the two tests?

   $[5 + 8 + 5 = 18]$

Group B

1. A man who has color blindness and type O blood has children with a woman who has normal color vision and type AB blood. The woman's father had color blindness. Color blindness is determined by an X-linked gene and blood type is determined by an autosomal gene.

   (a) What are the genotypes of the man and the woman?

   (b) What proportion of their children will have color blindness and type B blood?

   (c) What proportion of their children will have color blindness and type A blood?

   (d) What proportion of their children will have color blindness and type AB blood?

   $[2 + 2 + 2 + 2 = 8]$

2. (a) Would a human with two X chromosomes and a Y chromosome be male or female? Explain your answer.

   (b) Although XYY men are phenotypically normal, would they be expected to produce more children with sex chromosome abnormalities than XY men? Explain your answer.

   (c) A phenotypically normal boy has 45 chromosomes, but his sister, who has Down syndrome, has 46. Suggest an explanation for this paradox.

   $[2 + 3 + 3 = 8]$

3. (a) If the haploid human genome contains 3×10^9 nucleotide pairs and the average molecular weight of a nucleotide pair is 650, how many copies of the human genome are present, on average, in 1 mg of human DNA?

   (b) What is the weight of one copy of the human genome?

(c) The nucleic acids from various viruses were extracted and examined to determine their base composition. Given the following results, what can you hypothesize about the physical nature of the nucleic acids from these viruses?
(i) 30% A, 30% T, 20% G, and 20% C
(ii) 30% A, 20% T, 30% G, and 20% C

$[3 + 2 + 3 = 8]$

4. (a) In what ways does chromosomal DNA replication in eukaryotes differ from DNA replication in prokaryotes?

(b) The chromosomal DNA of eukaryotes is packaged into nucleosomes during the S phase of the cell cycle. What obstacles do the size and complexity of both the replisome and the nucleosome present during the semi-conservative replication of eukaryotic DNA? How might these obstacles be overcome?

$[4 + 4 = 8]$

5. (a) Identify three different types of RNA that are involved in translation and list the characteristics and functions of each.

(b) How do the reverse genetic approaches used to dissect biological processes differ from classical genetic approaches?

$[4 + 4 = 8]$

6. (a) How would you distinguish between an enhancer and a promoter?

(b) Why do steroid hormones interact with receptors inside the cell, whereas peptide hormones interact with receptors on the cell surface?

$[4 + 4 = 8]$

7. (a) Human beings carrying the dominant allele T can taste the substance phenylthiocarbamide (PTC). In a population in which the frequency of this allele is 0.4, what is the probability that a particular taster is homozygous?

   (b) A gene has three alleles, A_1, A_2, and A_3, with frequencies 0.6, 0.3, and 0.1, respectively. If mating is random, predict the combined frequency of all the heterozygotes in the population.

$[4 + 4 = 8]$

8. (a) Cancer cells frequently are homozygous for loss-of-function mutations in the TP53 gene, and many of these mutations map in the portion of TP53 that encodes the DNA-binding domain of p53. Explain how these mutations contribute to the cancerous phenotype of the cells.

   (b) Inherited cancers like retinoblastoma show a dominant pattern of inheritance. However, the underlying genetic defect is a recessive loss-of-function mutation, often the result of a deletion. How can the dominant pattern of inheritance be reconciled with the recessive nature of the mutation?

$[4 + 4 = 8]$

9. Consider an uncatalyzed reaction, A $\rightleftharpoons$ B. The rate constant for the forward and reverse reactions are $K_f = 10^{-4}\ sec^{-1}$ and $K_r = 10^{-7}\ sec^{-1}$. The overall reaction rate is $v = v_f - v_r = K_f[A] - K_r[A]$, where, $v_f = K_f[A]$ and $v_r = K_r[B]$, the rates or velocities (v) of the forward and reverse reactions respectively.

   (a) What is the overall reaction rate at equilibrium?

   (b) What is the value of the equilibrium constant, K?

(c) You now add an enzyme that increases K_f by a factor of 10^9. What will the value of the equilibrium constant be with the enzyme present? What will the value of K_r be?

$[2 + 3 + 3 = 8]$

10. (a) What is the function of the introns in eukaryotic genes?

(b) Why is RNA needed as an intermediary in protein synthesis?

$[4 + 4 = 8]$