S6 Biology Practice Paper (Paper 2)

S6 | Biology | Time: 75 minutes | Total: 100 marks | 24 questions

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Part A Mendelian Genetics and the Chi-square Test (18 marks)

Assume independent assortment, no linkage and no lethal alleles. Give probabilities to 3 significant figures.

1. A cross Aa x Aa produces 800 offspring. Find the expected number showing (a) the dominant phenotype, (b) the recessive phenotype. (6 marks)

Answer: Segregation ratio 3:1. (a) dominant = 800 x 3/4 = 600; (b) recessive = 800 x 1/4 = 200.

2. A test cross Aa x aa produces 400 offspring. Find the expected number of each phenotype. (4 marks)

Answer: Test cross gives 1:1, so each phenotype = 400 / 2 = 200 (dominant 200, recessive 200).

3. A dihybrid cross AaBb x AaBb produces 1600 offspring. Using 9:3:3:1, find the expected number in each phenotypic class. (4 marks)

Answer: 1600 x 9/16 = 900; 1600 x 3/16 = 300; 1600 x 3/16 = 300; 1600 x 1/16 = 100.

4. The observed numbers are 890, 310, 290 and 110. Calculate chi-square using chi2 = sum of (O-E)^2/E (3 significant figures) and decide whether the data fit 9:3:3:1 (critical value 7.815 at alpha = 0.05). (4 marks)

Answer: chi2 = 100/900 + 100/300 + 100/300 + 100/100 = 1.778; since 1.778 < 7.815 we do not reject the null hypothesis, so the data are consistent with 9:3:3:1.

Part B Hardy-Weinberg Equilibrium (18 marks)

The population is in Hardy-Weinberg equilibrium, where q is the recessive allele frequency, p + q = 1 and the carrier frequency is 2pq.

5. The incidence of a recessive disorder is 1 in 10000. Find q, p and the carrier (heterozygote) frequency (3 significant figures). (6 marks)

Answer: q^2 = 1/10000 so q = 0.01; p = 1 - q = 0.99; carriers 2pq = 2 x 0.99 x 0.01 = 0.0198.

6. If the carrier frequency is 1/25 (0.04), solve 2q(1 - q) = 0.04 for q (3 significant figures). (4 marks)

Answer: q^2 - q + 0.02 = 0, so q = (1 - sqrt(0.92))/2 = 0.02042 (the other root 0.98 is p), hence p = 0.9796.

7. The population is 50,000. Find the number of affected individuals and carriers (nearest whole number). (4 marks)

Answer: affected = q^2 x 50000 = 20.84, about 21; carriers = 0.04 x 50000 = 2000.

8. If no affected individual reproduces, will q increase, decrease or stay the same after one generation? Explain. (4 marks)

Answer: q decreases. Affected individuals are qq homozygotes and each carries two q alleles; removing them from the breeding population directly removes q alleles from the gene pool, so q falls and p rises.

Part C DNA, Gene Expression and Mutation (16 marks)

Each codon consists of 3 bases and codes for one amino acid; a stop codon codes for no amino acid.

9. The coding region of a gene is 3000 base pairs long and ends with one stop codon. Find (a) the number of codons in the mRNA, (b) the number of amino acids in the protein. (4 marks)

Answer: (a) 3000 / 3 = 1000 codons; (b) 1000 - 1 = 999 amino acids after removing the stop codon.

10. If the average amino acid has a mass of 110 Da, estimate the mass of the protein. (4 marks)

Answer: 999 x 110 = 109,890 Da, about 1.10 x 10^5 Da.

11. In a double-stranded DNA molecule, adenine (A) makes up 30% of all bases. Find the percentage of guanine (G). (4 marks)

Answer: A = T = 30%, so G + C = 100% - 60% = 40% and G = C = 20%.

12. A double-stranded DNA molecule has 1200 base pairs and A makes up 22%. Find the total number of G bases. (4 marks)

Answer: Total bases = 1200 x 2 = 2400; G = (100 - 44)/2 = 28%, so G count = 0.28 x 2400 = 672.

Part D Enzyme Kinetics (16 marks)

Use the Michaelis-Menten equation v = Vmax[S] / (Km + [S]); rates are in umol min^-1.

13. An enzyme has Vmax = 120 umol min^-1 and Km = 5 mM. Find the initial rate when [S] = 15 mM. (4 marks)

Answer: v = 120 x 15 / (5 + 15) = 90 umol min^-1.

14. Find the rate when [S] = Km and state its kinetic significance. (4 marks)

Answer: v = 120 x 5 / (5 + 5) = 60 umol min^-1, half of Vmax; Km is the substrate concentration giving half maximal velocity and reflects the affinity of the enzyme for its substrate.

15. Find the initial rate when [S] = 2 mM (3 significant figures). (4 marks)

Answer: v = 120 x 2 / (5 + 2) = 34.29 umol min^-1.

16. A Lineweaver-Burk plot of 1/v against 1/[S] has slope 0.0417 min umol^-1 mM and y-intercept 0.00833 min umol^-1. Find Vmax and Km. (4 marks)

Answer: y-intercept = 1/Vmax so Vmax = 1/0.00833 = 120 umol min^-1; slope = Km/Vmax so Km = 0.0417 x 120 = 5.01 mM.

Part E Immunity and Vaccination (16 marks)

Herd immunity threshold = 1 - 1/R0; vaccine efficacy = (attack rate in unvaccinated - attack rate in vaccinated) / attack rate in unvaccinated x 100%.

17. A disease has R0 = 12. Find the percentage of the population that must be immune for herd immunity (one decimal place). (4 marks)

Answer: 1 - 1/12 = 91.67%, so about 91.7% of the population must be immune.

18. In a vaccine trial the attack rate was 8% in the unvaccinated group and 1% in the vaccinated group. Find the vaccine efficacy. (4 marks)

Answer: (8% - 1%) / 8% x 100% = 87.5%.

19. After vaccination a person has an antibody titre of 1:40. After 4 rounds of doubling, what is the final titre? (4 marks)

Answer: 40 x 2^4 = 640, i.e. a titre of 1:640.

20. Give two reasons why the secondary immune response is faster and stronger than the primary response. (4 marks)

Answer: (1) There are far more memory B cells than naive B cells, so antigen binding and clonal expansion start much sooner. (2) Memory B cells have already undergone class switching and affinity maturation, so they produce high affinity IgG quickly, while memory helper T cells give rapid help, giving a faster rise and a higher antibody peak.

Part F Energy Flow in Ecosystems (16 marks)

Productivity is in kJ m^-2 yr^-1; ecological efficiency is the percentage of energy transferred between successive trophic levels.

21. An ecosystem has a gross primary production (GPP) of 45,000 kJ m^-2 yr^-1 and respiration of 20,000 kJ m^-2 yr^-1. Find the net primary production (NPP). (4 marks)

Answer: NPP = GPP - respiration = 45,000 - 20,000 = 25,000 kJ m^-2 yr^-1.

22. Primary consumers take in 10% of NPP. Find the energy assimilated by primary consumers. (4 marks)

Answer: 25,000 x 10% = 2,500 kJ m^-2 yr^-1.

23. In a food chain the net production of the tertiary consumer is 25 kJ m^-2 yr^-1 and each ecological efficiency is 10%. Find the net production of the primary consumer. (4 marks)

Answer: 25 / 0.1 / 0.1 = 2,500 kJ m^-2 yr^-1, the same as in the previous question, showing that about nine tenths of the energy is lost at each transfer.

24. Give two reasons why food chains rarely have more than 5 trophic levels. (4 marks)

Answer: (1) Much energy is lost at each transfer (respiration, excretion, uneaten parts) with an ecological efficiency of only about 10%, so the energy left at high trophic levels cannot support a viable breeding population. (2) Energy and biomass decrease up the chain, so too little energy reaches apex predators to support one more level.