S6 Biology Practice Paper (Set 1) | Dihybrid cross and chi-square, Hardy-Weinberg, restriction digest, glomerular filtration, water potential, mark-recapture

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

Section A: Dihybrid cross and chi-square test

Question 1 (17 marks)

1. In peas, round seed (R) is dominant to wrinkled (r) and yellow cotyledon (Y) is dominant to green (y). Two plants of genotype RrYy were crossed, giving 320 seeds: round yellow 178, round green 62, wrinkled yellow 58, wrinkled green 22. Assuming independent assortment, state the expected number of each phenotype. (4 marks)

> **Answer:** Phenotypic ratio is 9:3:3:1. Expected = 320 x 9/16 = 180 (round yellow), 320 x 3/16 = 60 (round green), 320 x 3/16 = 60 (wrinkled yellow), 320 x 1/16 = 20 (wrinkled green).

2. Use a chi-square test to compare the observed and expected numbers. Write the chi-square formula and calculate the chi-square value (to 3 decimal places). (4 marks)

> **Answer:** chi-square = sum of (O-E)^2/E = 4/180 + 4/60 + 4/60 + 4/20 = 0.022 + 0.067 + 0.067 + 0.200 = 0.356.

3. State the degrees of freedom. The critical value at p = 0.05 is 7.815. Decide whether to reject the hypothesis of independent assortment and state your conclusion. (4 marks)

> **Answer:** Degrees of freedom = 4 classes - 1 = 3. Since 0.356 < 7.815, do not reject the null hypothesis; the deviation from 9:3:3:1 can be explained by chance, so the data are consistent with independent assortment.

4. One of the RrYy plants is test-crossed with an rr yy plant, producing 200 seeds. State the expected phenotypic ratio and the expected number of each class. (5 marks)

> **Answer:** The test-cross progeny show a 1:1:1:1 ratio, i.e. 200 x 1/4 = 50 seeds in each class (round yellow 50, round green 50, wrinkled yellow 50, wrinkled green 50).

Section B: Hardy-Weinberg principle

Question 2 (17 marks)

5. Phenylketonuria, a recessive disorder, affects 1 in 10 000 people in a closed population. Assuming Hardy-Weinberg equilibrium, find the frequency of the recessive allele q. (4 marks)

> **Answer:** Affected individuals are qq, so q^2 = 1/10 000 = 0.0001 and q = square root of 0.0001 = 0.01.

6. Find the dominant allele frequency p and check that p + q = 1. (4 marks)

> **Answer:** p = 1 - q = 1 - 0.01 = 0.99; check 0.99 + 0.01 = 1.

7. Find the carrier (heterozygote) genotype frequency 2pq and express it as a percentage. (4 marks)

> **Answer:** 2pq = 2 x 0.99 x 0.01 = 0.0198, i.e. about 1.98 percent (roughly 198 carriers per 10 000 people).

8. If the population has 2 000 000 people, estimate the number of patients and carriers. Explain why the disease allele can persist in the population for a long time. (5 marks)

> **Answer:** Patients = 2 000 000 x 0.0001 = 200; carriers = 2 000 000 x 0.0198 = 39 600. Carriers are phenotypically normal and are not removed by selection, so the recessive allele is passed on through heterozygotes; only when two carriers mate can an affected child be produced.

Section C: Restriction digest and gel electrophoresis

Question 3 (17 marks)

9. A linear DNA molecule is 8 000 bp long. EcoRI recognises two sites, 2 300 bp and 6 500 bp from the left end. State the lengths of the three fragments produced. (4 marks)

> **Answer:** The fragments are 2 300 bp, 6 500 - 2 300 = 4 200 bp and 8 000 - 6 500 = 1 500 bp; total 8 000 bp.

10. A plasmid is circular, 5 000 bp long, with a single EcoRI site. How many fragments are produced and what is the length? How does this differ from the linear DNA case? (4 marks)

> **Answer:** Cutting circular DNA once opens the circle into one linear fragment of 5 000 bp (not two fragments). In linear DNA each additional site adds one more fragment.

11. A 1 200 bp insert is ligated into the 5 000 bp plasmid opened at its single site to form a recombinant plasmid. Calculate the total length of the recombinant plasmid. (4 marks)

> **Answer:** Length of the recombinant plasmid = 5 000 + 1 200 = 6 200 bp.

12. In agarose gel electrophoresis, which of the three linear fragments (2 300, 4 200 and 1 500 bp) travels furthest? Explain why. (5 marks)

> **Answer:** The 1 500 bp fragment travels furthest. The gel network hinders longer molecules more, so shorter fragments pass through the pores more easily and migrate faster, while longer fragments stay nearer the well.

Section D: Glomerular filtration and clearance

Question 4 (17 marks)

13. A person has a glomerular filtration rate (GFR) of 125 mL/min and a filtration fraction (GFR divided by renal plasma flow) of 0.20. Calculate the renal plasma flow. (4 marks)

> **Answer:** Renal plasma flow = GFR divided by filtration fraction = 125 / 0.20 = 625 mL/min.

14. Calculate the volume of filtrate produced each day (in litres). (4 marks)

> **Answer:** Daily filtrate = 125 mL/min x 60 x 24 = 180 000 mL = 180 L.

15. If 1.5 L of urine is excreted per day, find the volume reabsorbed by the renal tubules and the percentage reabsorbed (to 1 decimal place). (4 marks)

> **Answer:** Reabsorbed = 180 - 1.5 = 178.5 L; percentage = 178.5 / 180 x 100 = 99.2 percent.

16. The clearance of inulin equals the GFR. If the haematocrit is 0.45, calculate the renal blood flow. Explain why most of the filtrate must be reabsorbed. (5 marks)

> **Answer:** Renal blood flow = renal plasma flow / (1 - haematocrit) = 625 / 0.55 = about 1 136 mL/min. The filtrate contains much water, glucose, amino acids and salts; losing all of it would cause rapid dehydration and loss of nutrients, so it is reabsorbed to maintain a stable internal environment.

Section E: Water potential and plasmolysis

Question 5 (16 marks)

17. A plant cell has a solute potential of -800 kPa and a pressure potential (turgor) of 300 kPa. Calculate the water potential of the cell. (4 marks)

> **Answer:** Water potential = solute potential + pressure potential = -800 + 300 = -500 kPa.

18. The surrounding soil has a water potential of -200 kPa. In which direction does water move? Explain. (4 marks)

> **Answer:** Water moves from the higher water potential (-200 kPa, soil) to the lower one (-500 kPa, cell), so water enters the cell and the cell swells. The more negative the water potential, the lower the free energy of water.

19. When the cell is fully turgid its solute potential is -800 kPa and its pressure potential is 800 kPa. Calculate the water potential and state whether there is any net inflow of water when the cell is in pure water. (4 marks)

> **Answer:** Water potential = -800 + 800 = 0 kPa. Pure water also has a water potential of 0, so there is no net movement of water; the system is at equilibrium.

20. A plasmolysed cell has a pressure potential of 0 kPa and a solute potential of -900 kPa. Find its water potential. What happens if it is placed in pure water? (4 marks)

> **Answer:** Water potential = 0 + (-900) = -900 kPa. Pure water has a water potential of 0, which is higher, so water enters the cell, the cell regains turgor and deplasmolysis occurs.

Section F: Mark-recapture and energy transfer

Question 6 (16 marks)

21. Researchers caught and marked 80 snails in a pond. After release, a second random sample of 120 snails contained 15 marked individuals. Estimate the population size using the Lincoln index. (4 marks)

> **Answer:** N = (number marked in first sample x size of second sample) / number marked in second sample = (80 x 120) / 15 = 640 snails.

22. State two assumptions on which this estimate depends. (4 marks)

> **Answer:** First, marked and unmarked individuals mix randomly and have an equal chance of being caught. Second, marking does not affect survival and there is no birth, death, immigration or emigration during the study (a closed population).

23. Net production of the producers is 50 000 kJ m^-2 yr^-1. If the transfer efficiency between trophic levels is 10 percent, calculate the energy available to primary, secondary and tertiary consumers. (4 marks)

> **Answer:** Primary = 50 000 x 0.1 = 5 000; secondary = 5 000 x 0.1 = 500; tertiary = 500 x 0.1 = 50 kJ m^-2 yr^-1.

24. Explain where the other 90 percent of the energy goes, and why food chains usually have only four or five trophic levels. (4 marks)

> **Answer:** Most energy is lost as heat from respiration; some is not eaten (bones, roots) and some is not digested and is lost in faeces. Only about one tenth passes to the next level, so by the fourth or fifth level too little energy remains to support another population, which is why food chains are short.
