S6 Biology Practice Paper (Set 1): Mendelian Inheritance and Chi-square Test, Population Growth and Carrying Capacity, Photosynthesis Rate and Limiting Factors, Enzyme Kinetics, Gas Exchange and Respiratory Quotient, Water Potential and Osmosis

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

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Section A: Mendelian Inheritance and Chi-square Test (16 marks)

Show working and genetic ratios; state the test conclusion at alpha = 0.05.

1. Two heterozygous tall pea plants (Tt x Tt) are crossed. Find the percentage of tall offspring.
Tt x Tt gives 1 TT : 2 Tt : 1 tt, so tall offspring = 3/4 = 75.0%.

2. Two double heterozygotes (AaBb x AaBb, genes assorting independently) produce 480 offspring. Find the expected number of double recessives (aabb).
P(aabb) = 1/4 x 1/4 = 1/16 = 6.25%, so expected = 480 x 1/16 = 30 plants.

3. The cross actually gave 470, 140, 145 and 45 plants (total 800) against the 9:3:3:1 expectation. Find the expected numbers and chi-square.
Expected = 450, 150, 150, 50; chi-square = 2.22.

4. With 3 degrees of freedom the critical value at alpha = 0.05 is 7.815. Draw a conclusion, then give the expected number of tall plants among 200 test-cross (Tt x tt) offspring and the probability that two randomly chosen are both tall.
chi-square = 2.22 < 7.815, so the null hypothesis is not rejected and the ratio fits 9:3:3:1; test-cross gives 1:1, i.e. 100 tall of 200; both tall = 0.5 x 0.5 = 0.25.

Section B: Population Growth and Carrying Capacity (18 marks)

Use N = N0*exp(rt) for exponential growth and dN/dt = rN(1 - N/K) for logistic growth.

5. A population starts at 200 individuals with intrinsic growth rate r = 0.35 per year. Find the population after 6 years (nearest whole number).
N = 200 x exp(0.35 x 6) = 200 x e^2.1 = 1,633.2, about 1,633 individuals.

6. Find the doubling time in years (3 significant figures) and state how it relates to r.
t_d = ln2 / r = 0.693 / 0.35 = 1.980, about 1.98 years; the larger r, the shorter the doubling time.

7. The carrying capacity is K = 5,000. At N = 1,000, find the unused fraction of environmental space and the population size giving maximum logistic growth.
Unused space = (K - N)/K = 0.80 (80%); maximum growth occurs at N = K/2 = 2,500.

8. Using the logistic equation, find dN/dt (individuals per year) when N = 1,000.

dN/dt = rN(1 - N/K) = 0.35 x 1,000 x 0.80 = 280 individuals per year.

Section C: Photosynthesis Rate and Limiting Factors (16 marks)

Oxygen volumes are in cm3 and rates in cm3 per hour.

9. A leaf releases 4.5 cm3 of oxygen net in 30 minutes at 20 kLux. Find the net photosynthetic rate (cm3 per hour).

Rate = 4.5 / 0.5 = 9.0 cm3 per hour.

10. In darkness the same leaf takes up 1.5 cm3 of oxygen in 30 minutes. Find the respiration rate and the gross photosynthetic rate at 20 kLux.

Respiration = 1.5 / 0.5 = 3.0 cm3 per hour; gross = 9.0 + 3.0 = 12.0 cm3 per hour.

11. Net oxygen release (kLux : cm3 per hour): 0 : -3.0, 5 : 0.0, 10 : 4.5, 20 : 9.0, 30 : 12.0, 35 : 12.0. Find the compensation point and saturation point and explain the plateau.

Compensation point = 5 kLux (zero net release); saturation point = 30 kLux; beyond 30 kLux other factors (CO2, temperature, enzyme amount) limit the rate.

12. If the 20 kLux result came from 10 cm2 of leaf, find the net rate per cm2 and the net release expected from 25 cm2 at the same light intensity.

Per cm2 = 9.0 / 10 = 0.90 cm3 per hour; for 25 cm2 = 0.90 x 25 = 22.5 cm3 per hour.

Section D: Enzyme Kinetics (18 marks)

Use v = Vmax*[S] / (Km + [S]); rate in micromol per minute, [S] in mM.

13. An enzyme has Vmax = 120 micromol per minute and Km = 5 mM. Find the rate at [S] = 5 mM.

v = 120 x 5 / (5 + 5) = 60 micromol per minute, half of Vmax.

14. Find the rate at [S] = 20 mM and explain the biological meaning of Km.

v = 120 x 20 / (5 + 20) = 96 micromol per minute; Km is the substrate concentration giving half Vmax and reflects affinity (lower Km, higher affinity).

15. Find the substrate concentration needed for v = 100 micromol per minute.

From 100 = 120[S]/(5+[S]), [S] = Km*v/(Vmax - v) = 5 x 100 / 20 = 25 mM.

16. With a competitive inhibitor Km rises to 15 mM while Vmax is unchanged. Find the rate at [S] = 15 mM and state how competitive inhibition can be relieved.

v = 120 x 15 / (15 + 15) = 60 micromol per minute; raising the substrate concentration relieves the inhibition and the rate approaches Vmax again.

Section E: Gas Exchange and Respiratory Quotient (16 marks)

RQ = volume of CO2 released / volume of O2 used; carbohydrate RQ = 1.0, fat RQ is about 0.7.

17. An organism uses 500 cm3 of oxygen and releases 500 cm3 of carbon dioxide. Find the RQ and identify the respiratory substrate.

RQ = 500 / 500 = 1.0, consistent with carbohydrate respired fully (RQ = 1.0).

18. If an animal respires fat (RQ = 0.7) and uses 600 cm3 of oxygen, find the volume of carbon dioxide released.

CO2 = 600 x 0.7 = 420 cm3; fat is more oxygen-rich, so RQ is below 1.

19. A tissue oxidises both substrates: 200 cm3 of O2 on carbohydrate and 400 cm3 on fat. Find the overall RQ.

CO2 = 200 + 400 x 0.7 = 480 cm3; O2 = 600 cm3; RQ = 480/600 = 0.8.

20. Carbohydrate yields 16 kJ per g and fat 38 kJ per g. Find the total energy from 5 g carbohydrate plus 2 g fat, and the mean energy per gram.

Total = 5 x 16 + 2 x 38 = 156 kJ; mean = 156/7 = 22.3 kJ per g.

Section F: Water Potential and Osmosis (16 marks)

Solute potential is -CRT with R = 8.31 kPa dm3 per mol per K and T = 300 K.

21. Find the solute potential (kPa) of a 0.2 mol dm-3 sucrose solution.

Solute potential = -0.2 x 8.31 x 300 = -498.6 kPa.

22. Find the solute potential of a 0.05 mol dm-3 sucrose solution and compare the water potentials of the two solutions.

Solute potential = -0.05 x 8.31 x 300 = -124.65 kPa; the more dilute solution has the higher water potential (-124.7 > -498.6 kPa).

23. A cell with solute potential -600 kPa (pressure potential zero) is placed in the 0.2 mol dm-3 solution. State the net water movement and explain.

Cell water potential = -600 kPa versus solution -498.6 kPa, so water moves into the cell through the partially permeable membrane and turgor rises.

24. Find the sucrose concentration (mol dm-3, 3 significant figures) that gives no net water movement for that cell.

Setting -CRT = -600 kPa gives C = 600/(8.31 x 300) = 0.241 mol dm-3, the isotonic concentration.

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