S4 Biology Practice Paper (Set 2): Cell Cycle and Mitosis, Enzyme Kinetics, Cell Membrane and Osmosis, Nutrition and Digestion, Gas Exchange and Respiration, Plant Transport and Transpiration

S4 | Biology | Time: 75 minutes | Total: 100 marks | 24 questions

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Part 1 Cell Cycle and Mitosis

Study the data and show all working.

1. Source 1: the cell cycle of an animal cell lasts 20 hours, with 19 hours of interphase and 1 hour of mitosis. Find the percentage of the cycle spent in interphase and in mitosis (1 d.p. each), and state the main activities of interphase. [5]

Answer: Interphase = 19 / 20 x 100% = 95.0%; mitosis = 1 / 20 x 100% = 5.0%, totalling 100.0%. In interphase the cell replicates DNA, synthesises proteins and duplicates organelles to prepare for division.

2. Source 2: a culture starts with 12 cells that all undergo mitosis synchronously for 5 rounds. Find the multiplication factor per round, the total number of cells after 5 rounds and the net increase. [4]

Answer: Factor per round = 2; after 5 rounds the total is 12 x 2^5 = 12 x 32 = 384 cells; net increase = 384 - 12 = 372 cells.

3. Source 3: a human body cell has 46 chromosomes. State the chromosome number of each daughter cell after mitosis, and compare the DNA content of a G1 cell with that of a G2 cell (as a multiple). [4]

Answer: Each daughter cell has 46 chromosomes, identical to the parent cell, because the chromosomes are replicated before mitosis and shared equally. DNA replicates in S phase, so a G2 cell holds twice the DNA content of a G1 cell.

4. Source 4: among 500 root tip cells under a microscope, 30 are in mitosis. Find the mitotic index (percentage, 1 d.p.); if another slide has 800 cells in the same proportion, estimate how many are in mitosis. [4]

Answer: Mitotic index = 30 / 500 x 100% = 6.0%; estimated count = 800 x 6.0% = 48 cells. A low index is expected because mitosis occupies only a small part of the cell cycle.

Part 2 Enzyme Kinetics

Study the experimental data and show all working.

5. Source 1: enzyme X breaks down 25 g of substrate in 10 minutes, with 10 g broken down in the first 2 minutes. Find the average rate in the first 2 minutes and over the whole experiment (g/min), the ratio between them, and explain why the rate falls. [5]

Answer: First 2 minutes: 10 / 2 = 5.0 g/min; overall: 25 / 10 = 2.5 g/min, a factor of 2.0. Later the substrate concentration falls, fewer active sites are occupied and the rate of reaction slows down.

6. Source 2: enzyme Y shows activities of 12, 24, 24 and 6 units/min at 20, 30, 40 and 50 C. Find the Q10 between 20 C and 30 C, and explain the sharp fall at 50 C. [4]

Answer: Q10 = 24 / 12 = 2.0; between 40 C and 50 C activity drops from 24 to 6. High temperature breaks the bonds holding the enzyme shape, the active site is denatured and the substrate can no longer bind, so activity collapses.

7. Source 3: the same enzyme shows activities of 18, 72 and 45 units/min at pH 2, 7 and 9. State the optimum pH and the activity at pH 9 as a percentage of the maximum (1 d.p.). [4]

Answer: Optimum pH = 7 (highest activity 72 units/min); at pH 9 the activity is 45 / 72 x 100% = 62.5%. Moving away from the optimum pH alters the charges around the active site and weakens substrate binding.

8. Source 4: an enzyme solution is heated to 80 C for 5 minutes and then cooled to 37 C; its activity is 0. Explain this result and contrast it with storage at 4 C. [4]

Answer: At 80 C the enzyme is denatured: hydrogen bonds and other interactions holding the tertiary structure break, the active site is permanently distorted and cooling cannot restore it, so activity stays at 0. At 4 C only the kinetic energy of the molecules falls and the rate drops; the structure is intact, so activity returns at 37 C.

Part 3 Cell Membrane and Osmosis

Study the experimental data and show all working.

9. Source 1: three potato strips each start at 2.50 g. After immersion the strip in 0.0 M sucrose weighs 2.80 g and the strip in 0.4 M sucrose weighs 2.20 g. Find the percentage change in mass (1 d.p.) and estimate the concentration of the isotonic solution. [5]

Answer: 0.0 M: (2.80 - 2.50) / 2.50 x 100% = +12.0%; 0.4 M: (2.20 - 2.50) / 2.50 x 100% = -12.0%. The changes are equal and opposite, so the isotonic concentration is about 0.2 M, where the change in mass would be close to zero.

10. Source 2: a cell has a solute potential of -0.6 MPa and a pressure potential of 0.2 MPa. Find its water potential and decide whether water enters the cell from a solution of water potential -0.2 MPa. [4]

Answer: Water potential = solute potential + pressure potential = (-0.6) + 0.2 = -0.4 MPa. The external solution at -0.2 MPa has a higher water potential than the cell, so water moves down the water potential gradient into the cell.

11. Source 3: two cube models have sides of 2 cm and 4 cm. Find the surface area, volume and surface area to volume ratio (per cm) of each, and state which model diffuses more efficiently. [4]

Answer: Side 2 cm: surface area = 6 x 2^2 = 24 cm2, volume = 8 cm3, ratio = 3.0 per cm. Side 4 cm: surface area = 96 cm2, volume = 64 cm3, ratio = 1.5 per cm. The 2 cm cube has the larger ratio, more surface per unit volume and a shorter diffusion path, so it exchanges materials more efficiently.

12. Source 4: red blood cells burst in distilled water but keep their normal shape in 0.9% sodium chloride solution. Explain both results in terms of water potential and osmosis. [4]

Answer: Distilled water has a water potential near zero, higher than the cytoplasm, so water enters the red blood cell by osmosis until the membrane bursts (haemolysis) as there is no cell wall. The 0.9% sodium chloride solution is isotonic with plasma, so there is no net movement of water and the cell keeps its shape.

Part 4 Nutrition and Digestion

Study the data and show all working.

13. Source 1: 100 g of a food contains 12 g protein, 60 g carbohydrate and 8 g fat. Using 17 kJ per gram for protein and carbohydrate and 37 kJ per gram for fat, find the total energy (kJ) and the percentage of energy supplied by fat (1 d.p.). [5]

Answer: Protein = 12 x 17 = 204 kJ; carbohydrate = 60 x 17 = 1020 kJ; fat = 8 x 37 = 296 kJ; total = 1520 kJ. Fat supplies 296 / 1520 x 100% = 19.5% of the energy.

14. Source 2: villi increase the absorbing surface of the small intestine about 8 times and the microvilli on them add a further 20 times. Find the total amplification and the actual absorbing surface if the inner wall itself has an area of 0.35 m2. [4]

Answer: Total amplification = 8 x 20 = 160 times; actual surface = 0.35 x 160 = 56 m2. The very large surface, together with a rich blood supply, lets digested products diffuse rapidly into the blood.

15. Source 3: salivary amylase works best near pH 6.8, pepsin near pH 2 and trypsin near pH 8. The three enzymes are placed in tubes at pH 2, pH 7 and pH 8. Identify the most active enzyme in each tube and explain why pepsin is almost inactive at pH 7. [4]

Answer: pH 2 tube: pepsin is most active; pH 7 tube: salivary amylase is most active; pH 8 tube: trypsin is most active. At pH 7 the charges around the pepsin active site change and its tertiary structure is unstable, so it cannot bind protein substrate effectively and activity is very low.

16. Source 4: bile salts emulsify fat into small droplets, greatly increasing the surface area available to lipase. If poor bile secretion cuts the available fat surface area by 60%, estimate the fall in the rate of fat hydrolysis and explain why. [4]

Answer: The rate falls by about 60%. Lipase acts only at the water-fat interface, so the rate is roughly proportional to the exposed surface area; with 60% less area there are proportionally fewer sites for the enzyme and fat digestion slows by a similar amount.

Part 5 Gas Exchange and Respiration

Study the data and show all working.

17. Source 1: at rest the breathing rate is 18 breaths per minute with a tidal volume of 0.5 L; during exercise it is 30 breaths per minute with 0.9 L. Find the minute ventilation (L/min) in both cases and the percentage increase during exercise. [4]

Answer: Rest = 18 x 0.5 = 9.0 L/min; exercise = 30 x 0.9 = 27.0 L/min. Increase = (27.0 - 9.0) / 9.0 x 100% = 200%, which keeps alveolar oxygen partial pressure high and speeds diffusion into the blood.

18. Source 2: aerobic respiration yields 30 ATP per glucose molecule. A muscle cell uses 0.02 mol of glucose in 10 minutes. Find the amount of ATP produced in moles. [4]

Answer: ATP = 0.02 x 30 = 0.6 mol. Most of it comes from oxidative phosphorylation, so aerobic respiration yields far more energy than fermentation.

19. Source 3: lactate fermentation yields only 2 ATP per glucose molecule while aerobic respiration yields 30. Find the ratio of ATP yield and explain why muscles still ferment lactate during vigorous exercise. [4]

Answer: Ratio = 30 / 2 = 15 times. In vigorous exercise oxygen supply cannot keep up with demand, so muscles rely on lactate fermentation to make ATP quickly without oxygen, producing lactate and an oxygen debt.

20. Source 4: an adult has about 70 m2 of alveolar surface and about 1.8 m2 of body surface. Find how many times larger the alveolar surface is (1 d.p.) and explain its importance for gas exchange. [4]

Answer: Ratio = 70 / 1.8 = 38.9 times. The huge surface, together with very thin alveolar walls and a dense capillary network, allows large amounts of oxygen and carbon dioxide to diffuse in a short time and keeps blood gas tensions stable.

Part 6 Plant Transport and Transpiration

Study the experimental data and show all working.

21. Source 1: the bubble of a potometer moves 12 mm in 4 minutes and the leaf area is 6 cm2. Find the transpiration rate in mm per minute and the rate per cm2 of leaf per minute. [4]

Answer: Rate = 12 / 4 = 3.0 mm/min; per cm2 = 3.0 / 6 = 0.5 mm/min/cm2. Dividing by leaf area allows fair comparison between plants of different sizes.

22. Source 2: a field of view of 0.5 mm2 on the lower epidermis contains 40 stomata. Find the stomatal density (per mm2) and estimate the total number on a lower epidermis of 1200 mm2. [4]

Answer: Density = 40 / 0.5 = 80 per mm2; estimated total = 80 x 1200 = 96,000 stomata. Stomata are concentrated on the lower epidermis, which limits water loss under direct sun.

23. Source 3: about 95% of the water absorbed by a plant is lost by transpiration, the rest being used in photosynthesis and to maintain turgor. Find the percentage used otherwise and explain how the transpiration pull lifts water from root to leaf. [4]

Answer: The rest = 100% - 95% = 5%. Transpiration from the stomata lowers the water potential of mesophyll cells, creating a tension that runs down the xylem as a continuous water column; cohesion between water molecules lets the column withstand the tension and be pulled up to the leaves, with the root taking up replacement water.

24. Source 4: a ring of bark including the phloem is removed from a tree trunk; weeks later the bark above the cut swells while the region below withers. Explain the observation and state what the girdling experiment proves. [4]

Answer: Sucrose made in the leaves is transported downwards in the phloem; girdling cuts that route, so sugars accumulate above the cut and water follows by osmosis, swelling the bark, while tissues below starve and wither. This shows the phloem is the channel for organic nutrients, moving mainly from leaves towards roots.