# S5 Biology Practice Paper (Set 2): Membrane Transport and Water Potential, Enzyme Kinetics, Photosynthesis and Respiration, Cell Cycle and Mitosis, Ecosystem Energy Flow and Population Estimation, Kidney and Osmoregulation (100 marks)

**Biology · S5**

S5 biology practice paper: 24 parts, 100 marks, 75 minutes on membrane transport, water potential, enzymes, photosynthesis, mitosis, energy flow and the kidney.

## Question 1 - Membrane Transport and Water Potential (16 marks)

*Plant cell A has a solute potential of -600 kPa and a pressure potential of +200 kPa. The surrounding solution B has a solute potential of -500 kPa and a pressure potential of 0 kPa. The temperature is 25 C.*

| # | Question | Answer and marking notes |
|---|---|---|
| 1 | Calculate the water potential of cell A. | Water potential = solute potential + pressure potential = (-600) + (+200) = -400 kPa. |
| 2 | Compare the water potentials of A and B, state the net direction of water movement and explain your answer. | A has a water potential of -400 kPa, which is higher than -500 kPa in B; water moves down a water potential gradient, so there is a net flow from cell A to solution B. |
| 3 | If the cell volume falls from 1.00 x 10^-13 m3 to 0.85 x 10^-13 m3 in 300 seconds, calculate the average rate of volume change. | (1.00 - 0.85) x 10^-13 / 300 = 5.0 x 10^-17 m3 per second. |
| 4 | The cell eventually becomes plasmolysed. Explain how it recovers and becomes turgid again when placed in pure water. | Pure water has a water potential of 0 kPa, higher than that inside the cell; water enters by osmosis, the vacuole swells and presses the cytoplasm against the cell wall, which exerts an opposing pressure, so the cell becomes turgid. |

## Question 2 - Enzymes and Metabolic Rate (16 marks)

*Enzyme X catalyses a reaction. The initial rate is 2.4 micromol per minute at 30 C and 6.0 micromol per minute at 50 C. After 5 minutes at 60 C the rate has fallen to 0.40 micromol per minute.*

| # | Question | Answer and marking notes |
|---|---|---|
| 5 | Calculate the temperature coefficient Q10 between 30 C and 50 C. | Q10 = (6.0 / 2.4) to the power (10 / 20) = 2.5^0.5 = 1.58. |
| 6 | Explain why the rate falls sharply at 60 C. | High temperature breaks hydrogen and ionic bonds, so the tertiary structure changes, the active site is no longer complementary to the substrate and no enzyme-substrate complexes form; this denaturation is usually irreversible. |
| 7 | If a competitive inhibitor is added, explain how Vmax and Km change. | Vmax is unchanged because a high substrate concentration outcompetes the inhibitor; Km increases, showing a lower apparent affinity for the substrate. |

| # | Question | Answer and marking notes |
|---|---|---|
| **8** | At 60 C the activity decays with first-order kinetics, k = 0.35 per minute. Calculate the percentage of activity remaining after 5 minutes. | Fraction remaining = exp(-0.35 x 5) = exp(-1.75) = 0.174, that is 17.4%. |

## Question 3 - Photosynthesis and Respiration (18 marks)

*A leaf in bright light shows a net uptake of 45 mg of carbon dioxide per hour. In darkness it releases 12 mg of carbon dioxide per hour through respiration. Molar masses: carbon dioxide 44 g/mol, glucose 180 g/mol.*

| # | Question | Answer and marking notes |
|---|---|---|
| **9** | Calculate the true rate of photosynthesis in the light in mg of CO2 per hour. | True photosynthesis = net uptake + respiration = 45 + 12 = 57 mg of CO2 per hour. |
| **10** | State the net rate of photosynthesis in the light and explain how it differs from the true rate. | The net rate is 45 mg of CO2 per hour; it equals the true rate minus the CO2 released by respiration over the same period, that is 57 - 12 = 45. |
| **11** | Using the true rate, calculate the mass of glucose produced per hour. | 264 g of CO2 (6 moles) gives 180 g of glucose; glucose = 57 / 264 x 180 = 38.9 mg. |
| **12** | A tissue uses 8.0 cm3 of oxygen and releases 6.8 cm3 of carbon dioxide per minute. Calculate the respiratory quotient and suggest the substrate used. | RQ = 6.8 / 8.0 = 0.85; this is close to the value for lipids (about 0.7 to 0.8) and below that of carbohydrates (1.0), so the substrate is mainly lipid. |

## Question 4 - Cell Cycle and Mitosis (16 marks)

*There are 20 synchronised dividing cells in an onion root tip meristem. The cell cycle lasts 20 hours: G1 8 hours, S 6 hours, G2 4 hours, M 2 hours.*

| # | Question | Answer and marking notes |
|---|---|---|
| **13** | If all the cells complete four mitotic divisions, calculate the final number of cells. | Each division doubles the number of cells: 20 x 2^4 = 320 cells. |
| **14** | Calculate the percentage of the cell cycle occupied by S phase. | S phase occupies 6 / 20 x 100% = 30% of the cycle. |
| **15** | A random sample of 500 cells is examined under the microscope. Estimate how many are in M phase. | M phase occupies 2 / 20 = 10% of the cycle; 500 x 10% = 50 cells. |
| **16** | Explain how mitosis keeps the chromosome number of the daughter cells the same as that of the parent cell. | DNA is replicated in S phase so each chromosome consists of two sister chromatids; in anaphase the centromeres divide and the sister chromatids are pulled to opposite poles, so each daughter cell receives one identical set of chromosomes (46 in humans). |

## Question 5 - Energy Flow and Population Estimation (18 marks)

*Energy in a grassland per square metre per year: producers 45 000 kJ, primary consumers 4 500 kJ, secondary consumers 450 kJ, tertiary consumers 45 kJ.*

| # | Question | Answer and marking notes |
|---|---|---|
| **17** | Calculate the efficiency of energy transfer from producers to primary consumers. | Efficiency = 4 500 / 45 000 x 100% = 10%. |
| **18** | State the energy available to tertiary consumers and calculate it as a percentage of the energy in producers. | Tertiary consumers receive 45 kJ per square metre per year, which is 45 / 45 000 x 100% = 0.1% of the producer energy. |
| **19** | If tertiary consumers need 900 kJ per square metre per year, calculate the producer energy required at the transfer efficiency found above. | Producer energy required = 900 / 0.001 = 900 000 kJ per square metre per year. |
| **20** | A researcher captures and marks 40 snails, releases them, then recaptures 50 snails of which 8 are marked. Estimate the population size using the Lincoln index. | N = (number marked first x number in second sample) / number marked in second sample = (40 x 50) / 8 = 250 snails. |

## Question 6 - Kidney and Osmoregulation (16 marks)

*A person has a glomerular filtration rate of 125 cm3 per minute, a plasma glucose concentration of 1.0 mg per cm3, a urine output of 1.0 cm3 per minute and no glucose in the urine.*

| # | Question | Answer and marking notes |
|---|---|---|
| **21** | Calculate the mass of glucose filtered into the Bowman capsules each minute. | Filtered load = 125 cm3 per minute x 1.0 mg per cm3 = 125 mg per minute. |
| **22** | Calculate the percentage of filtered glucose that is reabsorbed. | There is no glucose in the urine, so all 125 mg is reabsorbed in the proximal convoluted tubule; the percentage reabsorbed is 100%. |
| **23** | Calculate the percentage of filtered water that is reabsorbed. | Water reabsorbed = 125 - 1.0 = 124 cm3 per minute; percentage = 124 / 125 x 100% = 99.2%. |
| **24** | Explain how antidiuretic hormone (ADH) makes the urine more concentrated. | When the body is short of water, osmoreceptors in the hypothalamus are stimulated and the posterior pituitary releases more ADH; ADH increases the number of aquaporins in the collecting duct walls, so more water is reabsorbed into the blood, urine volume falls and the urine becomes more concentrated. |