S4 Biology Practice Paper: Photosynthesis, Respiration, Enzymes, Membrane Transport, Microscopy and Inheritance

S4 Biology I Time allowed: 90 minutes I Total: 100 marks I 24 questions

A. Photosynthesis and Respiration (17 marks)

Take the molar volume as 24.0 dm³ mol⁻¹ at room temperature.

1. A leaf absorbs 200 cm³ of carbon dioxide in 10.0 minutes. Find the rate of carbon dioxide uptake and state the volume of oxygen produced in the same period. (5 marks)

> **Answer:** Rate = 200 / 10.0 = 20 cm³ min⁻¹; the molar ratio of carbon dioxide to oxygen in photosynthesis is 1 : 1, so 200 cm³ of oxygen is produced, giving the same rate of 20 cm³ min⁻¹.

2. Yeast ferments 1.0 mol of glucose anaerobically. Find the volume of carbon dioxide produced. (4 marks)

> **Answer:** Anaerobic equation: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$; 1.0 mol of glucose gives 2.0 mol of carbon dioxide; volume = 2.0 × 24.0 = 48 dm³.

3. A plant releases 30 cm³ of oxygen per hour in the light and takes up 10 cm³ of oxygen per hour in the dark. Find the gross rate of photosynthesis. (4 marks)

> **Answer:** Net photosynthesis = gross photosynthesis - respiration; gross photosynthesis = 30 + 10 = 40 cm³ h⁻¹.

4. Which two colours of light are absorbed most strongly by chlorophyll? Explain why leaves look green in natural light. (4 marks)

> **Answer:** Chlorophyll absorbs red light and blue-violet light most strongly and green light least; green light is reflected and transmitted, so leaves look green.

B. Enzymes (17 marks)

Assume a temperature coefficient Q_{10} of 2.

5. An enzyme works at 5.0 cm³ min⁻¹ at 20 °C. Assuming no denaturation before 40 °C, find the rate at 40 °C. (5 marks)

> **Answer:** The rate doubles for every 10 °C rise: 5.0 at 20 °C, 10.0 at 30 °C and 20 cm³ min⁻¹ at 40 °C.

6. At a certain pH the enzyme activity is 12 units, and at the optimum pH it is 15 units. Find the relative activity at that pH. (4 marks)

> **Answer:** Relative activity = 12 / 15 × 100 = 80 %.

7. Why does adding more substrate fail to raise the reaction rate once the substrate concentration is already high? (4 marks)

> **Answer:** All active sites are then occupied, so enzyme quantity becomes the limiting factor; the rate depends on enzyme concentration and only more enzyme can raise it further.

8. Compare the effects of competitive and non-competitive inhibitors on enzyme action. (4 marks)

> **Answer:** A competitive inhibitor resembles the substrate and occupies the active site, and its effect can be overcome by more substrate; a non-competitive inhibitor binds elsewhere, changing the enzyme shape, and more substrate cannot overcome it.

C. Membrane Transport and Osmosis (17 marks)

All percentage changes are based on the original mass.

9. A piece of potato tissue falls from 5.0 g to 4.4 g in a sugar solution. Find the percentage change in mass. (5 marks)

> **Answer:** Percentage change = (4.4 - 5.0) / 5.0 × 100 = -12 %; the negative value means water is lost.

10. Compare the surface area to volume ratio of cubes of side 1 cm and side 2 cm. (4 marks)

> **Answer:** 1 cm cube: surface area 6 cm^2, volume 1 cm^3, ratio 6 cm^{-1}; 2 cm cube: surface area 24 cm^2, volume 8 cm^3, ratio 3 cm^{-1}.

11. How does active transport differ from diffusion in the absorption of glucose by cells lining the small intestine? (4 marks)

> **Answer:** Active transport works against the concentration gradient, needs carrier proteins and ATP, and can absorb glucose completely; diffusion follows the gradient without energy and cannot absorb it fully.

12. Which has the stronger osmotic effect on red blood cells, 0.30 M sodium chloride solution or 0.30 M sucrose solution? Explain in terms of particle concentration. (4 marks)

> **Answer:** Sodium chloride dissociates fully, so its particle concentration is 0.30 × 2 = 0.6 mol dm^{-3}; sucrose does not dissociate and stays at 0.30 mol dm^{-3}; the ratio is 2 times, so the sodium chloride solution has the stronger osmotic effect.

D. Microscopy and Magnification (17 marks)

1 mm = 1 000 μm.

13. Under a microscope with a total magnification of 400 times, the image of a cell is 20 mm long. Find the actual length of the cell in μm. (5 marks)

> **Answer:** Actual length = 20 / 400 = 0.05 mm = 50 μm.

14. The eyepiece is 10 times and the objective is 40 times. Find the total magnification. (4 marks)

> **Answer:** Total magnification = eyepiece × objective = 10 × 40 = 400 times.

15. The field of view is 1.8 mm across with the 10 times objective. Find the field diameter with the 40 times objective. (4 marks)

> **Answer:** The field diameter is inversely proportional to magnification: 1.8 × 10 / 40 = 0.45 mm = 450 μm.

16. The object appears at the top right of the field. In which direction should the slide be moved, and why? (4 marks)

> **Answer:** Move the slide towards the top right; a compound microscope forms an inverted image, so the image moves opposite to the slide.

E. Inheritance and Mendel's Laws (16 marks)

Assume independent assortment and no lethal genotypes.

17. Two tall pea plants of genotype Tt are crossed and produce 1 000 offspring. Find the numbers of tall and dwarf plants. (4 marks)

> **Answer:** Tt × Tt gives TT : Tt : tt = 1 : 2 : 1, so tall : dwarf = 3 : 1; tall = 1 000 × 3 / 4 = 750 and dwarf = 250.

18. A Tt plant is crossed with a tt plant and 200 offspring are produced. Find the number of tall plants. (4 marks)

> **Answer:** The test cross Tt × tt gives 1 Tt : 1 tt, so half are tall; tall = 200 × 1 / 2 = 100.

19. Two double heterozygotes AaBb are crossed and produce 960 offspring. Find the numbers of the four phenotypes. (4 marks)

> **Answer:** The F_2 phenotypic ratio is 9 : 3 : 3 : 1, i.e. 16 parts; each part = 960 / 16 = 60; so the numbers are 540, 180, 180 and 60.

20. A carrier mother and an unaffected father have 400 sons. Find the number of colour-blind sons. (4 marks)

> **Answer:** The colour-blindness allele is on the X chromosome; each son takes his X chromosome from his mother and half of these carry the allele; colour-blind sons = 400 × 1 / 2 = 200.

F. Ecology and Energy Flow (16 marks)

Energy transfer follows the ten per cent rule in this question.

21. The tertiary consumers in a food chain hold 200 kJ of energy. Using the ten per cent rule, how much energy must the producers fix? (4 marks)

> **Answer:** Energy falls to one tenth at each level: secondary consumers 2 000 kJ, primary consumers 20 000 kJ, producers 200 000 kJ; that is 200000 kJ.

22. Forty snails are captured, marked and released; a second sample of 50 contains 8 marked snails. Estimate the population size. (4 marks)

> **Answer:** Lincoln index: population = marked in first sample × size of second sample / marked in second sample = 40 × 50 / 8 = 250.

23. State two ways in which carbon passes from the atmosphere into organisms and back to the atmosphere. (4 marks)

> **Answer:** Into organisms: producers fix carbon dioxide by photosynthesis; back to the atmosphere: respiration by organisms and decomposition of litter and dead bodies by decomposers both release carbon dioxide.

24. Explain why top predators carry the highest concentration of pollutants in a food chain. (4 marks)

Answer: The pollutant is not easily broken down or excreted, so it accumulates with each meal; as the trophic level rises, biomass falls but the pollutant taken in is still absorbed, so concentration increases at each level.
