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AS Level Biology

Topic 5: Exchange Surfaces and Mass Transport

AQA Biology (7401) | Mark Scheme | 100 marks

Instructions

- Answer **all** questions.
- In calculations show your working and give your answer to an appropriate number of significant figures.
- In extended-response questions you should write in clear, well-organised continuous prose.
- There are 17 questions in this paper. The total mark is **100**.

1. This question is about surface area to volume ratio and exchange.

(a) Explain why small organisms, such as single-celled organisms, do not need specialised exchange surfaces. **(2)**

✓ they have a large surface area to volume ratio (1)
✓ so substances can be exchanged across the body surface fast enough (the diffusion distance is short) (1)

(b) Explain why large, multicellular organisms need specialised exchange surfaces and transport systems. **(3)**

✓ they have a small surface area to volume ratio (1)
✓ diffusion across the outer surface would be too slow to meet their needs (the diffusion distance is too great) (1)
✓ they have a high metabolic rate so a high demand for oxygen/nutrients (1)

(c) A cube has sides of 2 cm. Calculate its surface area to volume ratio. Show your working. **(3)**

✓ surface area = $6 \times (2 \times 2) = 24$ cm^2 (1)
✓ volume = $2 \times 2 \times 2 = 8$ cm^3 (1)
✓ ratio = 24:8 = 3:1 (1)

2. This question is about the features of efficient exchange surfaces.

(a) State three features that an efficient gas exchange surface should have. **(3)**

✓ a large surface area (1)
✓ a thin surface / short diffusion distance (1)
✓ a steep concentration gradient (maintained by blood flow / ventilation) (1)

(b) Explain how a steep concentration gradient is maintained across the gas exchange surface in the lungs. **(2)**

✓ ventilation (breathing) brings in fresh air with a high oxygen concentration / removes carbon dioxide (1)
✓ the blood flow constantly removes oxygen / brings in carbon dioxide (1)

3. This question is about gas exchange in single-celled organisms and insects.

(a) Explain how gases are exchanged in a single-celled organism such as an amoeba. **(2)**

✓ gases diffuse directly across the cell-surface membrane (1)
✓ the diffusion distance is short / surface area to volume ratio is large (1)

(b) Describe how oxygen reaches the respiring tissues in an insect. **(3)**

✓ air enters through spiracles (in the body surface) (1)
✓ oxygen travels along the tracheae and then the tracheoles (1)
✓ oxygen diffuses from the tracheoles into the (respiring) cells/tissues (1)

(c) Explain how an insect reduces water loss through its spiracles. **(2)**

✓ the spiracles can be closed (by valves/muscles) when gas exchange is not needed (1)
✓ this reduces water loss by evaporation (1)

4. This question is about gas exchange in fish.

(a) Name the organs used for gas exchange in a fish. **(1)**

✓ gills (1)

(b) Explain how the structure of the gills provides a large surface area for gas exchange. **(2)**

✓ each gill is made of many gill filaments (1)
✓ each filament is covered in many gill lamellae (plates) (1)

(c) In the counter-current system, water and blood flow in opposite directions across the gill lamellae. Explain how this maximises the diffusion of oxygen into the blood. **(3)**

✓ the blood and water flow in opposite directions (1)
✓ so a concentration gradient (of oxygen) is maintained along the whole length of the lamella (1)
✓ so oxygen always diffuses from water (higher) into blood (lower) along the whole gill / more oxygen is absorbed (1)

5. This question is about gas exchange in plants.

(a) Name the structures in a leaf through which gases enter and leave. **(1)**

✓ stomata (1)

(b) Name the cells that control the opening and closing of a stoma. **(1)**

✓ guard cells (1)

(c) Explain how the structure of a leaf is adapted for efficient gas exchange. **(3)**

✓ many stomata allow gases to diffuse in and out (1)
✓ air spaces (in the spongy mesophyll) allow gases to move and give a large surface area (1)
✓ the leaf is thin so the diffusion distance to the cells is short (1)

(d) A plant adapted to dry conditions is called a xerophyte. State two features that help a xerophyte to reduce water loss. **(2)**

✓ sunken stomata / stomata in pits (trapping water vapour) (1)
✓ a thick waxy cuticle / hairs on the leaf / rolled leaves / fewer stomata (any one) (1)

6. This question is about the human gas exchange system.

(a) Name the tiny air sacs in the lungs where gas exchange occurs. **(1)**

✓ alveoli (1)

(b) Describe three ways in which an alveolus is adapted for efficient gas exchange. **(3)**

✓ there are many alveoli, giving a large surface area (1)
✓ the alveolar (and capillary) walls are one cell thick, giving a short diffusion distance (1)
✓ a good blood supply (capillary network) maintains a steep concentration gradient (1)

(c) Describe the path taken by a molecule of oxygen from an alveolus into the blood. **(2)**

✓ oxygen diffuses across the alveolar epithelium (1)
✓ then across the capillary endothelium / wall into the blood (plasma/red blood cell) (1)

7. This question is about ventilation in humans.

(a) Describe the changes that bring about inspiration (breathing in). **(4)**

✓ the diaphragm contracts and flattens (moves down) (1)
✓ the external intercostal muscles contract, moving the ribs up and out (1)
✓ the volume of the thorax increases (1)
✓ the pressure in the thorax decreases (below atmospheric), so air moves into the lungs (1)

(b) Explain why expiration is described as a passive process during normal quiet breathing. **(2)**

✓ the diaphragm and external intercostal muscles relax (1)
✓ the elastic recoil of the lungs forces air out (no muscle contraction needed) (1)

8. Tidal volume is the volume of air breathed in or out in one normal breath. Pulmonary ventilation rate is calculated using tidal volume and breathing rate.

(a) State the equation used to calculate pulmonary ventilation rate. **(1)**

✓ pulmonary ventilation rate = tidal volume × breathing rate (ventilation rate) (1)

(b) A person has a tidal volume of 0.5 dm^3 and a breathing rate of 15 breaths per minute. Calculate their pulmonary ventilation rate. State the units. **(2)**

✓ 0.5 × 15 = 7.5 (1)
✓ $dm^3\ min^{-1}$ (1)

(c) During exercise, the pulmonary ventilation rate increases. Explain why. **(2)**

✓ the muscles respire faster, so more oxygen is needed / more carbon dioxide is produced (1)
✓ so both tidal volume and breathing rate increase (to supply more oxygen and remove carbon dioxide) (1)

9. This question is about lung disease and risk factors.

(a) In a disease such as fibrosis, the alveolar walls become thickened with scar tissue. Explain how this reduces the efficiency of gas exchange. **(2)**

✓ the diffusion distance for gases increases (1)
✓ so oxygen diffuses into the blood more slowly / less efficiently (1)

(b) In emphysema, the walls between alveoli break down. Explain how this reduces gas exchange. **(2)**

✓ the total surface area of the alveoli decreases (1)
✓ so the rate of gas exchange (oxygen uptake) is reduced (1)

(c) Scientists found a positive correlation between smoking and the risk of lung disease. Explain why a correlation does not prove that smoking causes lung disease. **(2)**

✓ a correlation only shows the two factors are linked, not that one causes the other (1)
✓ another (third) factor may be responsible / further (controlled) experiments are needed to establish cause (1)

10. This question is about digestion and absorption in mammals.

(a) Explain why large biological molecules in food must be digested (hydrolysed) before they can be absorbed. **(2)**

✓ large molecules are too big / insoluble to be absorbed across the gut wall (1)
✓ they are hydrolysed into smaller, soluble molecules that can be absorbed (1)

(b) Name the enzyme that digests starch and name the products. **(2)**

✓ amylase (1)
✓ maltose (then glucose) (1)

(c) Name the products formed when a triglyceride (lipid) is fully digested by lipase. **(2)**

✓ fatty acids (1)
✓ (and) glycerol / monoglycerides (1)

11. This question is about the absorption of the products of digestion in the ileum.

(a) Explain how the ileum is adapted to provide a large surface area for absorption. **(2)**

✓ it is folded / has many villi (1)
✓ each villus is covered in microvilli, increasing the surface area further (1)

(b) Amino acids are absorbed into the epithelial cells of the ileum by co-transport with sodium ions. Outline how this occurs. **(3)**

✓ sodium ions are actively transported out of the epithelial cell, setting up a concentration gradient (1)
✓ sodium ions diffuse back into the cell from the lumen through a co-transport protein (1)
✓ amino acids are carried in with the sodium ions (against their concentration gradient) (1)

12. This question is about the structure of haemoglobin and the transport of oxygen.

(a) State the role of haemoglobin in the blood. **(1)**

✓ it transports oxygen (around the body) (1)

(b) Haemoglobin has a quaternary structure. Explain what this means. **(2)**

✓ it is made of more than one polypeptide chain (four chains) (1)
✓ each (with an iron-containing haem group) able to bind one oxygen molecule (1)

(c) Name the reaction that occurs when haemoglobin binds to oxygen, and name the product. **(2)**

✓ association (loading) / oxygen binds (1)
✓ forming oxyhaemoglobin (1)

13. The graph of percentage saturation of haemoglobin against partial pressure of oxygen produces an S-shaped (sigmoid) oxygen dissociation curve.

(a) Explain why haemoglobin becomes loaded (saturated) with oxygen in the lungs. **(2)**

✓ there is a high partial pressure of oxygen in the lungs (1)
✓ so haemoglobin has a high affinity for oxygen and oxygen binds / loads (1)

(b) Explain why haemoglobin releases (unloads) oxygen at the respiring tissues. **(2)**

✓ there is a low partial pressure of oxygen at the tissues (1)
✓ so haemoglobin has a lower affinity for oxygen and oxygen is released (1)

(c) The Bohr effect describes how an increase in carbon dioxide concentration shifts the dissociation curve to the right. Explain how this is an advantage during exercise. **(3)**

✓ respiring/exercising tissues produce more carbon dioxide (1)
✓ the curve shifts right, so haemoglobin has a lower affinity for oxygen and releases more oxygen (at a given partial pressure) (1)
✓ so more oxygen is supplied to the (respiring) muscle cells (when it is most needed) (1)

14. Different organisms have haemoglobins with different oxygen affinities, adapted to their environments.

(a) An animal living in an environment with a low oxygen concentration has haemoglobin with a high affinity for oxygen. Explain why this is an advantage. **(2)**

✓ haemoglobin loads/binds oxygen even at a low partial pressure of oxygen (1)
✓ so the animal can still absorb enough oxygen in its low-oxygen environment (1)

(b) A very active animal with a high metabolic rate has haemoglobin with a lower affinity for oxygen. Explain why this is an advantage. **(2)**

✓ haemoglobin unloads/releases oxygen more readily (at the tissues) (1)
✓ supplying more oxygen to the respiring tissues for its high rate of respiration (1)

15. This question is about the mammalian circulatory system and the heart.

(a) The mammalian circulatory system is described as a double circulatory system. Explain what this means. **(2)**

✓ the blood passes through the heart twice for each complete circuit of the body (1)
✓ one circuit goes to the lungs (pulmonary), the other to the rest of the body (systemic) (1)

(b) Explain the advantage of a double circulatory system over a single one. **(2)**

✓ the blood pressure is not greatly reduced after passing through the lungs / can be raised again before going to the body (1)
✓ so blood flows faster to the tissues, delivering oxygen/nutrients more quickly (maintaining a high metabolic rate) (1)

(c) Explain why the muscle wall of the left ventricle is thicker than that of the right ventricle. **(2)**

✓ the left ventricle pumps blood to the whole body (a long distance), the right only to the lungs (1)
✓ so the left ventricle must generate a higher pressure / contract more strongly (1)

16. This question is about the structure of blood vessels.

(a) Explain how the structure of an artery is adapted to withstand and maintain high blood pressure. **(2)**

✓ it has a thick wall with a lot of elastic tissue (and smooth muscle) (1)
✓ the elastic tissue stretches and recoils to maintain/smooth out the pressure (1)

(b) Explain how the structure of a capillary is adapted for efficient exchange of substances. **(2)**

✓ the wall is one cell thick, giving a short diffusion distance (1)
✓ there are many capillaries (a large surface area) / a narrow lumen slows blood flow for exchange (1)

(c) Explain why veins contain valves. **(1)**

✓ to prevent the backflow of blood (keeping it moving towards the heart, as the pressure is low) (1)

17. This question is about mass transport of water in plants.

(a) Name the tissue that transports water and mineral ions from the roots to the leaves in a plant. **(1)**

✓ xylem (1)

(b) Define the term *transpiration*. **(1)**

✓ the evaporation/loss of water (vapour) from the leaves/surface of a plant (1)

(c) Explain how the cohesion-tension theory accounts for the movement of water up the xylem. **(3)**

✓ water evaporates from the leaves (transpiration), lowering the water potential, so water is pulled up (tension) (1)
✓ water molecules are attracted to each other by hydrogen bonds (cohesion), forming a continuous column (1)
✓ so as water leaves the top, water is pulled up the xylem (the whole column moves up) (1)

(d) State one factor that would increase the rate of transpiration from a plant. **(1)**

✓ increased temperature / increased air movement (wind) / decreased humidity / increased light intensity (any one) (1)