InkBiology

ANSWER BOOK

Haemoglobin: an S-shaped curve and everything it explains

Animal transport and cardiovascular biology · Unit B09

AQA 3.3.4.1 · OCR A 3.1.2 (l)-(o) · Edexcel A Topic 1.6, 7.10 · CAIE 8.2

7 questions · 23 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 **A1** the haem group, each holding one iron(II) ion. **A1** four molecules of oxygen in total. [2]

SECTION B · Standard, 3 to 5 marks

B1 **B1** the first oxygen molecule binds with difficulty, because the folded molecule presents its binding sites awkwardly, so the curve is shallow at low partial pressures. **B1** binding changes the quaternary structure so the remaining sites are easier to reach, and the second and third oxygens bind more readily, which is cooperative binding and makes the curve steep. **B1** the curve flattens at the top because only one site is left to find and there is almost no spare capacity above about 90 per cent saturation. **A1** at the alveoli haemoglobin sits on the plateau and loads reliably to about 97 per cent, while in respiring tissue it sits on the steep part where a small fall in partial pressure releases a great deal of oxygen. [4]

B2 **B1** the muscle produces more carbon dioxide, which forms carbonic acid in the blood and releases hydrogen ions, lowering the pH. **B1** hydrogen ions bind to haemoglobin and alter its tertiary and quaternary structure, so it holds oxygen less tightly and the curve shifts to the right. **B1** at the partial pressure found in respiring tissue the curve is steep, so a sideways shift drops the saturation a long way and much more oxygen is unloaded. **A1** at the lungs the partial pressure is around 12 kPa, where the shifted curve has already flattened off and is still over 90 per cent saturated, and blowing off carbon dioxide raises the pH and moves the curve back anyway. [4]

B3 **B1** carbon dioxide diffuses into the plasma and on into the red blood cells, with about 5 per cent staying dissolved and about 10 per cent binding to haemoglobin as carbaminohaemoglobin. **B1** carbonic anhydrase catalyses its reaction with water to form carbonic acid, which dissociates into hydrogen ions and hydrogencarbonate ions. **B1** hydrogencarbonate ions diffuse out into the plasma, where about 85 per cent of the carbon dioxide is carried, while the hydrogen ions are taken up by haemoglobin as haemoglobinic acid, which buffers them. **A1** chloride ions move into the red blood cell from the plasma to replace the negative charge lost, keeping the cell electrically neutral, which is the chloride shift. [4]

B4 **M1** the fall in saturation is 97 − 17 = 80 per cent of full capacity. **M1** multiply that fraction by the volume carried at full saturation: 0.80 × 20. **A1** 16 cm³ of oxygen per 100 cm³ of blood, keeping the percentage and the volume distinct. [3]

B5 **B1** the foetal curve lies to the left of the adult curve, so at any given partial pressure foetal haemoglobin is more highly saturated than adult haemoglobin. **B1** foetal haemoglobin therefore has the higher affinity for oxygen and adult haemoglobin the lower. **A1** at the low partial pressure available at the placenta the foetal blood can take oxygen from the maternal blood, whereas adult haemoglobin is adapted to load at the lungs and unload readily in respiring tissue. [3]

B6 **B1** its curve lies to the left of the human adult curve. **B1** a curve further to the left means a higher affinity for oxygen, so the pigment is more highly saturated at any given partial pressure. **A1** the only oxygen available in the burrow is at a low partial pressure, so a higher affinity is needed if the pigment is to load properly there. [3]