8. Transport in Mammals

8.2 Transport of Oxygen and Carbon Dioxide

Paper 2

Marking Scheme

Q1.

(b)(i)	*any **two** from:* *details ;* pH approx. 7.4 and 37 °C **A** pH7 / neutral pH **A** 36 / 38 °C pH of, plasma / blood **or** body temperature **or** use conditions occurring in, body / plasma / blood / humans ; *idea that* oxygen uptake / haemoglobin activity / AW, affected by, temperature / pH ;	**2**
(b)(ii)	*any **three** from:* *in a person with malaria* **1** affinity of haemoglobin for oxygen, decreases / AW ; *context is infection so* **R** *in presence of carbon dioxide* **2** lower (percentage) saturation of haemoglobin with oxygen ; *allow ecf from mp1* **A** less oxygen binds to haemoglobin (in the lungs) **A** haemoglobin loads less oxygen AW **3** *idea that* more difficult to load oxygen in the lungs ; **I** slower **4** (as) higher partial pressure of oxygen needed to reach same percentage saturation of, haemoglobin ; **5** *idea that* oxygen released more readily in respiring tissues **or** in tissues, more oxygen released at any one partial pressure ; **I** carbon dioxide **but R** if stated that carbon dioxide causes oxygen to be released more readily	**3**

(c)	*any **four** from:* **1** (diameter / width) 6–8 μm so able to pass through (lumen of) capillaries ; **I** small size **2** small size / small diameter / just fits in a capillary / AW, so in a line / one by one / AW, which slows blood flow / maximises time to take up oxygen / reduces diffusion distance for uptake of oxygen ; **A** gas exchange for oxygen **3** no, nucleus / mitochondria ; **A** no organelles **4** so more space for haemoglobin ; AW *must be linked to mp3* **5** no mitochondria so oxygen is not used within cell (and can be transported) ; **6** flexible / can squeeze through / can deform / can change shape, to pass through capillary / AW ; *context of biconcave or property of cell surface membrane* **I** 'squeeze between' unless elsewhere there is ref. to rbc within a capillary **7** biconcave ; **8** (biconcave, so compared to spherical) increased, surface area / SA:V, for uptake of oxygen / gas exchange / AW ; **9** (biconcave, so) reduce distance for diffusion of oxygen to, haemoglobin / hb ;	**4**

Q2.

(c)(i)	line drawn to the left ; sigmoid shape of line and starting at 0, 0 ;	**2**

(c)(ii)	*any **three** from:* oxygen can be released (from haemoglobin to supply respiring tissues) ; increase in H^+ ions so more, hydrogen ions bind to haemoglobin / haemoglobinic acid forms ; haemoglobin affinity for oxygen reduces (when the pH decreases) ; aerobic respiration in muscle cells can continue for longer ; AVP ; e.g. *ref. to* Bohr shift / curve shifts to right providing ATP for muscle contraction	**3**

Q3.

(c)(i)	*mark to max 3 if no ref. to 'more' at least once in the response* *any **four** from:* **1** more carbon dioxide diffuses into red blood cells ; **2** more carbonic acid is formed by carbonic anhydrase ; **3** formation of more hydrogen ions ; **A** H^+ **4** haemoglobin has a high affinity for hydrogen ions ; **A** H^+ **5** haemoglobin binds more hydrogen ions to form, haemoglobinic acid (HHb) ; **A** H^+ **6** (formation of HHb) decreases affinity of haemoglobin for oxygen ; **7** haemoglobin releases more oxygen ; **8** carbon dioxide binds to $-NH_2$ / N terminal, of, globin / polypeptides / α chains and β chains ; **9** forms carbaminohaemoglobin ; **R** carboxyhaemoglobin *also lowers affinity* **10** allosteric effect / change in tertiary structure / AW, in (oxy)haemoglobin (causes, release / AW, more oxygen) ;	**4**

(c)(ii)	*any **two** from:* **1** hydrogencarbonate ions / HCO_3^- , pass out of red blood cells (into the plasma to increase concentration in deoxygenated blood) ; **2** chloride ions pass into red blood cells ; **3** to replace the, negatively-charged ions / anions / HCO_3^- ; **A** to achieve electroneutrality / balance the electrical charge **4** chloride shift ; **5** AVP ; chloride ions pass through, channel proteins / anion exchangers / transport proteins / by facilitated diffusion	**2**

Q4.

(a)	**R** if choice given and one is incorrect carbonic acid ; hydrogencarbonate (ions) ; **A** bicarbonate (ions)	**2**

Q5.

(d)	*allow Hb or hb or Hgb for haemoglobin* *two marks for points in left column* **or** *two marks for points in right column* cytoplasm / cytosol ; — (bound to) cell surface membrane ; close to haemoglobin (for H^+ uptake) **R** in / on / with, hb **or** *idea of* being dispersed within cell because haemoglobin is distributed throughout ; — close to, anion exchanger / transport protein, for (easy) exit of hydrogen carbonate (ions) ; quick for hydrogen carbonate (ions) to be transported out of cell / AW **or** H^+ (from dissociation) binds rapidly to haemoglobin **or** cytoplasm provides water for reaction to form carbonic acid ; — able to, hydrate / react with, carbon dioxide as it enters cell ; *if stated cytoplasm and cell surface membrane, one mark* *reason can be taken from either column if correctly linked, one mark*	**2**

Q6.

(c)(i)	*pH 7.7* = 72(%) *pH 7.4* = 60(%) ;	**1**
(c)(ii)	*allow Hb or hb for haemoglobin* decrease in supply of oxygen to tissues / AW ; (at lower pCO_2 / increase pH blood) affinity of, haemoglobin, for oxygen is higher **or** haemoglobin is more saturated ora **A** less oxygen, released / dissociates / AW, from haemoglobin (than normal) *must be in context of higher affinity in the tissues* **or** data quote for difference in saturation of haemoglobin in correct range of pO_2 (within 2–6 $kPaO_2$) ;	**2**

Q7.

(d)	globular ; intracellular ; **R** intercellular water and H_2O ; carbonic acid ; hydrogen and H^+ ;	**5**

Q8.

(a)(ii)	*any **two** from:* catalyses / AW, reaction between water and carbon dioxide ; (to form) carbonic acid ; catalyses formation of carbon dioxide and water from carbonic acid in lungs ;	**2**

Q9.

(c)	*any three from* *in respiring tissue* **1** (carbonic anhydrase) catalyses the reaction between water and carbon dioxide in, red (blood) cells / erythrocytes ; **2** to form carbonic acid, which dissociates to form HCO_3^- and H^+ ; **A** from equation **A** use of word ion(s) **3** HCO_3^-, moves / passes / diffuses (through membrane proteins from red blood cells) into plasma ; **4** (activity of enzyme) maintains (steep) concentration gradient for diffusion of carbon dioxide into red blood cells ; **5** *idea that* so helps to remove large quantities of carbon dioxide ; *in lungs* **6** (carbonic anhydrase) converts HCO_3^- back into carbon dioxide so can be, excreted / removed / exhaled ; *if described earlier* **A** catalyses reverse reaction so carbon dioxide can be, excreted / AW	**3**

Q10.

(d)	*any **three** from:* **A** Ψ for water potential **A** plasma for blood *mp1 and mp2 = consequence in blood of lower blood albumin than normal* **1** *idea that* low blood albumin means, less / AW, solute ; **2** (so) higher water potential (in blood); *must be in context of blood context can be anywhere along the capillary* **A** high water potential *if ref. to low albumin is made* **A** steeper water potential gradient (than normally, at arterial end) *mp3 and mp4 = return of water to blood from tissue fluid (capillary venous end)* **3** less steep water potential gradient (than normal) / little difference in water potentials ; **4** less / little, water returns to, blood / capillary (from tissue fluid) ; **A** (tissue) fluid *for water* **R** plasma *for water* *additional ideas* **5** *idea that* more, water / plasma / fluid, enters tissue fluid (than normal) **R** tissue fluid *for fluid* **A** more, water / fluid, enters tissue fluid than exits (to the capillary or lymph system) ; *(compared to normal)* **6** AVP ; e.g. water can enter tissue fluid for a longer time than normal less albumin than normal to act as an osmotic force for return of water / AW too much excess, water / fluid / tissue fluid, to be taken up into lymph, capillaries / vessels / system	**3**

Q11.

(a)	*any four from:* carbaminohaemoglobin ; **A** combined with haemoglobin hydrogencarbonate ions / HCO_3^- ; **R** HCO_3 CO_2 dissolved in the plasma ;	**2**
(b)	*any four from:* 1. correct direction of movement for oxygen and carbon dioxide ; e.g. oxygen, moves from, alveolus / **W**, to, capillary / blood / red blood cells, and carbon dioxide moves from, capillary/ blood /plasma to alveolus / blood to **W** ; 2. diffusion of, oxygen / carbon dioxide / respiratory gases ; **A** movement down, partial pressure / concentration, gradient **A** from high(er), partial pressure / concentration, to low(er), partial pressure / concentration **I** along a concentration gradient 3. use of data from Table 4.1 to support movement of oxygen or carbon dioxide ; *needs ref. to kPa once* *allow ecf from mp2* 4. (diffusion) through, alveolar wall / squamous epithelium ; 5. (diffusion) through, endothelium / capillary wall ; 6. AVP ; e.g. haemoglobin binding oxygen	**4**

(d)(ii)	*allow 'volume of blood' for 'mean volume of blood per kg body mass'* *any four from:* *description to max 3* 1. trend is / overall / AW, increase in volume of blood, over time / AW *or* increase in volume of blood over time except between 0 and 1–2 months ; 2. trend is / overall / AW, increase in red blood cell volume, over time / AW ; *or* increase in red cell volume over time except between 7–8 and 12 months ; 3. *ref. to* percentage of mean blood volume represented by red blood cells / haematocrit ; e.g. fluctuates / mainly increasing / decreases between 1–2 and 3–4months / decreases between 7–8 and 12 months ; 4. any comparative use of, figures / percentages ; *to support mp1, mp2 or mp3* *explanation to max 3* 5. lower partial pressure of oxygen at high altitude / less oxygen in inhaled air ; 6. lower oxygen saturation of haemoglobin / haemoglobin has lower oxygen affinity ; 7. compensation *or* *idea that* changes occur to make up for less, oxygen taken in / transported to tissues **R** *idea of* body getting more oxygen than at sea level 8. (over time) more red blood cells produced so more haemoglobin / AW ; 9. (over time) proportion of red cells / concentration of haemoglobin, increases so, take up / AW, greater volume of oxygen ; **A** more red blood cells per unit time passes through, lungs to take up oxygen / tissues to deliver oxygen 10. AVP ; e.g. *ref. to* erythropoietin / EPO	**4**

Q12.

(a)(i)	same shape and shift to the right ; *must start to rise within 2 small squares of 0 and end at or near to existing curve*	**1**
(a)(ii)	*max 2 if concept of more not mentioned in response* *any **three** from:* **1** actively respiring tissue means more carbon dioxide ; **2** increase in, formation of carbonic acid / dissociation of carbonic acid / hydrogen ions, (in the red blood cell) ; **A** from equation **3** more hydrogen ions, bind to haemoglobin / form haemoglobinic acid ; **A** HHb **4** (causes) more oxygen (to be), unloaded / dissociated / AW (from haemoglobin); **I** *ref. to* faster / quicker **I** incorrect *ref. to* affinity causing unloading, e.g. CO_2 **A** lower (percentage) saturation of haemoglobin with oxygen **A** oxygen released, more easily / readily from haemoglobin **5** haemoglobin affinity for oxygen decreases ; **6** more oxygen to meet demand for (aerobic / cellular) respiration ; AW **I** more oxygen for respiring tissues	**3**

6(b)	CO_2 = (passive / simple) diffusion ; HCO_3^- = facilitated diffusion ; **I** *ref. to* size CO_2 is, non-polar / not charged / not ionic and can cross, hydrophobic core / phospholipid bilayer ; HCO_3^- is, charged / ionic / hydrophilic and (needs to) cross, via, transport / carrier, protein ; **A** channel protein *if explanation mps not gained,* allow 1 mark for CO_2 is, non-polar / not charged / not ionic and HCO_3^- is, charged / ionic / hydrophilic	**4**

Q13.

(c)	*allow, Hb / hb, for haemoglobin and allow CO for carbon monoxide* *any four from:* **1** haemoglobin, has a higher affinity for / binds more readily with, carbon monoxide (than oxygen) **;** **A** carbon monoxide displaces oxygen from haemoglobin **A** carbon monoxide binds to Hb and decreases its affinity for oxygen **2** carboxyhaemoglobin formed **;** **3** binding is, (mainly) irreversible / permanent / (more) stable (than oxygen binding) / AW **;** **4** decreases saturation of haemoglobin with oxygen (in the lungs) / less haemoglobin available to bind oxygen **;** **A** less oxyhaemoglobin formed / less oxygen binds to haemoglobin *cigarette smoke:* **5** low concentration of oxygen in inhaled cigarette smoke **;** **6** *ref. to* (in airways), narrowed lumen / inflammation / increased mucus / accumulated, mucus **;** **A** bronchial constriction **7** (so) lower concentration of / less, oxygen, reaching alveolus / in alveolar air **or** (so) less oxygen, diffuses / AW, (from alveolus) into bloodstream / reaches red blood cells / reaches haemoglobin (in red blood cells) **;** **R** *ref. to* consequence of emphysema *must be in context of mp 5 or 6* **8** AVP **;** e.g. nicotine causes vasoconstriction and reduces blood supply (to extremities)	**4**

Q14.

(c)(ii)	carbonic anhydrase ; **R** carbon anhydrase / anhydrase	**1**

(d)	*assume spherocytosis type 2 unless stated otherwise* *any two from:* spherical means reduced surface area (to volume ratio) (so less oxygen diffuses in) ; **A** SA *for surface area* *idea of* further distance for oxygen to reach, (some) haemoglobin molecules / centre of red blood cell ; not enough time to reach, same level of / 98%, saturation of haemoglobin ; *idea of blood flowing through* *ref. to* spherical shape / larger / less flexible, so less able to pass through, (pulmonary capillary) network / AW ;	**2**

Q15.

(c)(ii)	*any three from:* less oxygen in inhaled air / AW ; **A** less oxygen taken up from alveoli low(er) saturation of haemoglobin (with oxygen) ; **A** Hb for haemoglobin **A** haemoglobin carries less oxygen *must be the context of oxygen* **R** saturation, with air / carbon dioxide haemoglobin has lower affinity for oxygen ; (so) more haemoglobin required (so more red blood cells) / (more red blood cells) so more haemoglobin ; AW compensation / compensates ; **A** so same, volume / quantity / amount, of oxygen reaches body cells (compared to lower altitude)	**3**

Q16.

(c)	*four from:* *assume from point of view of giving up smoking unless stated otherwise* *in lungs / at high partial pressures of oxygen* 1 (so) more oxygen taken up by haemoglobin / haemoglobin more saturated (with oxygen) / AW ; **A** haemoglobin has, increased / normal, affinity for oxygen 2 before and after data / calculated difference in data, to support, from 10 kPa ; 3 carbon monoxide no longer binding to haemoglobin / AW ; **A** carboxyhaemoglobin no longer forming / ora with ref. to smoking **A** haemoglobin has a higher affinity for CO than oxygen 4 more (sites on) haemoglobin available to take up oxygen ; *in respiring tissues* 5 more oxygen dissociates from (oxy)haemoglobin / AW, at, lower partial pressures / below 4 kPa / in (respiring) tissues (after stopping) ; **A** haemoglobin less saturated (with oxygen) **A** haemoglobin has, less / decreased, affinity for oxygen 6 before and after data / calculated difference in data, to support ; 7 ref. to increase in allosteric effect / regains ability for conformational change / AW ; *health benefits after stopping* 8 more / sufficient, oxygen to, transport / deliver to, tissues / body **or** more oxygen to reach (respiring) tissues ; **A** less, tired / fatigued **A** more able to, do work / carry out exercise / be mobile **R** more energy unless qualified with link to aerobic respiration	**4**

Q17.

(b)(i)	98 (%) ;	**1**
(b)(ii)	*four from:* 1 Bohr, shift / effect ; 2 (at any pO_2 on the left of graph) percentage saturation of haemoglobin decreases / haemoglobin releases more oxygen (to muscle tissue) / increases dissociation of oxyhaemoglobin ; **A** any comparative data quote for any one value of pO_2 between 1 and 5 kPa 3 (increase in carbon dioxide) increases production of carbonic acid ; 4 increase in hydrogen ions (in red blood cells) ; 5 haemoglobin accepts hydrogen ions / formation of haemoglobinic acid (HHb) ; **A** haemoglobin has an affinity for hydrogen ions 6 decreases the affinity between haemoglobin and oxygen ;	**4**

Q18.

(b)	**A** iron / Fe ; **I** oxidation status of Fe **A** iron atom / iron ion **R** iron molecule **B** carbaminohaemoglobin ; **C** haemoglobinic acid ;	**3**

Q19.

(b)(i)	llama = 90.5% human = 78.5% ;	**1**
(b)(ii)	*any two from* lower partial pressure of oxygen at high altitude ; at the same partial pressure the percentage saturation is (much) higher than for humans ; *ref.* to haemoglobin has a higher affinity for oxygen ; *idea that* sufficient oxygen delivered to tissues to satisfy demand ;	**2**