A-Level Biology

Haemoglobin

Mark Scheme

Time available: 85 minutes
Marks available: 69 marks

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1.

(a) 1. Increases/more oxygen dissociation/unloading
OR
Deceases haemoglobin's affinity for O_2;
Accept more readily
Accept releases more O_2

2. (By) decreasing (blood) pH/increasing acidity;
Reject if reference made to active site

2

(b) 1. High(er) affinity for O_2 (than haemoglobin)
OR
Dissociates oxygen less readily
OR
Associates more readily;
Accept holds O_2 at lower ppO_2

2. Allows (aerobic) respiration when diving/at low(er) pO_2
OR
Provides oxygen when haemoglobin unloaded
OR
Delays anaerobic respiration/lactate production;
Accept acts as an oxygen store

2

(c) Correct answer for 2 marks

10.8 to 11 (mins)
OR
10 minutes and 48 seconds = 2 marks;;

Accept for 1 mark, 10.48 minutes
OR
Reference to 2057.7 to 2058 (10 700 ÷ 5.2, time oxygen would last if its mass was 1 kg)
OR
Reference to 56 to 56.3 (10700 ÷ 190, oxygen in 1 kg of seal)
OR
Reference to 988 (5.2 × 190, oxygen used min^{-1} by the seal)
OR
Incorrect answer with correct answer shown in working

2

[6]

2.

(a) 1. y axis 0 – 100 in linear scale **and** x axis minimum 1 to 8 in linear scale **and** both axes use at least half size of grid;

If tick marks are used on the axis, they must be accurate to within ± half a small square.

2. Correct plots for 50% and 25% for both animals;

25% - 1.9, 3.3 and 50% - 3.2 and 6.5

Accept plot ± half a small square.

3. Both curves levelling off (at higher partial pressures and at percentage saturations ≤100%);

3

(b) Correct answer of 15 (times faster) **= 2marks** ;;

If ≥3sf given, accept answers in the range 15.0 to 15.4 (times faster) **= 2marks**;;

Incorrect answer 1 mark for evidence of:

$23^{-0.27}$ divided by $550\ 000^{-0.27}$
OR
0.42888777
OR
0.02819045
OR
Between 27 and 27.1
OR
Between 1.77599861 and 1.8
OR
0.06

Accept any number of significant figures ≤2, if rounding correct.

2

(c) 1. Mouse haemoglobin/Hb has a lower affinity for oxygen
OR
For the same pO_2 the mouse haemoglobin/Hb is less saturated
OR
At oxygen concentrations found in tissue mouse haemoglobin/Hb is less saturated;

For 'Hb is less saturated' accept 'less oxygen will be bound to Hb'.

2. **More** oxygen can be dissociated/released/unloaded (for metabolic reactions/respiration);

*Accept 'oxygen dissociated/released/unloaded **more** readily/easily /quickly'*

Reject 'oxygen loaded more readily/easily/quickly' or 'more oxygen loaded'

2

(d)

Accept converse answers in relation to the horse.

Mouse

1. (Smaller so) larger surface area to volume ratio;
   Accept larger SA:V.
   Must be comparative.

2. More/faster heat loss (per gram/in relation to body size);
   Ignore heat lost more easily/readily.
   Must be comparative.

3. (Faster rate of) respiration/metabolism releases heat;
   Accept respiration/metabolism replaces heat.
   Reject produce/generate heat/energy.

3

[10]

3. (a) 1. Binding of first oxygen changes tertiary / quaternary (structure) of haemoglobin;
   Ignore ref. to 'positive cooperativity' unqualified
   Ignore ref. to named bonds
   Accept conformational shift caused

2. Creates / leads to / uncovers second / another binding site
   OR
   Uncovers another iron / Fe / haem group to bind to;
   Reject ref. to active site

2

(b) 5.6×10^6 (red blood cells per mm^3);;

Award 1 max for **one of**

2.8×10^4 (standard form but ignoring dilution)

OR

5 600 000 (correct but not standard form)

OR

5.6×10^5 (failure to use depth of liquid on slide);

2

(c) 1. To avoid dealing with parts of cells;

2. To avoid counting same cells twice / more than once;

3. To be consistent / get comparable results;

Accept more accuracy

Ignore reliability / repeatability / reproducibility / precision / validity

2 max

(d) There are fewer white cells, **so** no need to dilute (further to see enough);

Accept converse of too few to see if greater dilution / at 200 times

Do not accept ref. to numbers of red and white cells unqualified

Ignore ref. to white cells larger

1

(e) White cells have a nucleus (that stains but red cells do not);

Accept converse for red cells

1

[8]

4.

(a) First oxygen binds (to Hb) causing change in shape;
(Shape change of Hb) allows more O_2 to bind (easily) / greater saturation with O_2
OR
Cooperative binding;

2

(b) 1. (HbA has) lower affinity for O_2 at low partial pressures;
OR
(HbA has) lower affinity for oxygen at pp found in tissues;
2. Easier unloading of O_2 for (aerobic) respiration;

2

(c) 1. A large/significant increase in HbF;
2. (HbF has) higher affinity for O_2 (than faulty HbA);
3. Higher proportion of HbF in blood so more oxygen carried;
OR
More oxygen carried after treatment;

3

[7]

5.

(a) (Molecule contains) more than one polypeptide (chain).

Accept: has four polypeptides

1

(b) $\frac{\text{oxygenated haemoglobin}}{\text{maximum saturation}} \times 100$

1

(c) 1. At low partial pressure of oxygen, little increase in saturation as oxygen increases;

2. (then) rapid rise as it gets easier for oxygen to bind.

Accept use of appropriate numbers from graph

2

(d) Ensures rapid / more intake of oxygen in lungs / release of oxygen in tissues.

1

(e) Volume of blood leaving heart = (0.6 × 0.6) dm^3 $minute^{-1}$ = 3.6 dm^3 $minute^{-1}$

Mass of haemoglobin in this volume of blood = (3.6 × 150) g = 540g

Volume of oxygen at 100% saturation of this haemoglobin = (540 × 1.35) = 729 cm^3

The graph shows 60% of this volume of oxygen has been released to the tissues, so final answer is (729 × 0.6) = 437.4 cm^3 $minute^{-1}$

3

[8]

6.

(a) Quaternary (structure);

Accept phonetic spelling eg quarternary/quarternery /4°

Award no mark for quaternary as part of a list

1

(b) 423;

1

(c) 1. Oxyhaemoglobin formed/ haemoglobin is loaded/ uptakes/associates/binds with oxygen in area of higher ppO_2 / in gas exchange surface/lungs/gills;

Reference to "react with" = max 1

Accept: reversible interaction with oxygen

Ignore: haemoglobin is carried / contained in red blood cells

2. (oxygen) unloaded/dissociates from/released (in area of lower ppO_2 / in capillaries/to cells/tissues);

2

(d) (i) 56(%);

Accept responses in the range 54-58(%)

1

(ii) 1. (Anaemia curve shifted to right) haemoglobin has lower affinity for oxygen / binds less tightly;

Assume reference is to haemoglobin of anaemia unless stated

2. releases more oxygen / oxygen is released quicker / oxygen dissociates/ unloads more readily to muscles/tissues/cells;

3. (For) respiration;

Accept: even with a lower haemoglobin concentration / meet demand for ATP/energy;

3

[8]

7.

(a) High(er) affinity for oxygen / absorbs / loads more oxygen;

At lower partial pressure (of oxygen) / lower pO_2;

Accept: Loads oxygen 'quicker', 'more readily', 'higher saturation', use of figures from graph for first point.

Neutral: References to unloading.

2

(b) 1. (Hydrostatic) pressure lower in capillary / blood / higher in tissues / tissue fluid;

2. Water (returns);

3. By osmosis;

4. Water potential lower / more negative in blood / capillary / higher / less negative water potential in tissues / via water potential gradient;

5. Due to protein (in blood);

6. (Returns) via lymph (system / vessels);

First marking point must be in context of between blood and tissue fluid.

Neutral: References to hydrostatic pressure and water potential at arteriole end of capillary.

3 max

[5]

8.

(a)

Statement	Haemo-globin	Cellulose	Starch
Has a quaternary structure	✓		
Formed by condensation reactions	✓	✓	✓
Contains nitrogen	✓		

One mark for each correct row

3

(b) 16;

1

(c) 1. Higher affinity / loads more oxygen at low / same / high partial pressure / pO_2;

2. (Therefore) oxygen moves from mother / to fetus;

2

(d) 1. Low affinity / oxygen dissociates;

Assume 'it' is adult haemoglobin

1. Accept: converse if 'fetal haemoglobin' is clearly stated

2. (Oxygen) to respiring tissues / muscles / cells;

*2. **Q**: Neutral 'respirate'*

2

(e) Enough adult Hb produced / enough oxygen released / idea that curves / affinities / Hb are similar / more red blood cells produced;

Neutral: 'adult Hb is also produced' as in the question stem

Reject: curves / affinities / Hb are the same

1

[9]

9. (a) More that one polypeptide / chain;

Ignore references to haem / other groups

1

(b) (i) 141;

1

(ii) 1. Stop / start sequences;

2. Non coding DNA (in the gene) / introns / multiple repeats / junk DNA;

Do not credit "some bases repeated"

3 Two chains / a non-coding strand / complementary base pairs;

4. Addition of base by mutation;

2 max

(c) Different primary structure / amino acids / different number of polypeptide chains;

Question is about haemoglobin so do not credit differences in DNA

1

(d) 1. Low partial pressure of oxygen in lungs;

2. (Llama) haemoglobin able to load more oxygen / (llama) haemoglobin saturated (at low / particular partial pressure of oxygen);

3. Higher affinity for oxygen;

The terms used in the graph (or near approximations) should be used in this answer.

Ignore references to unloading

The answer must relate to llamas

3

[8]