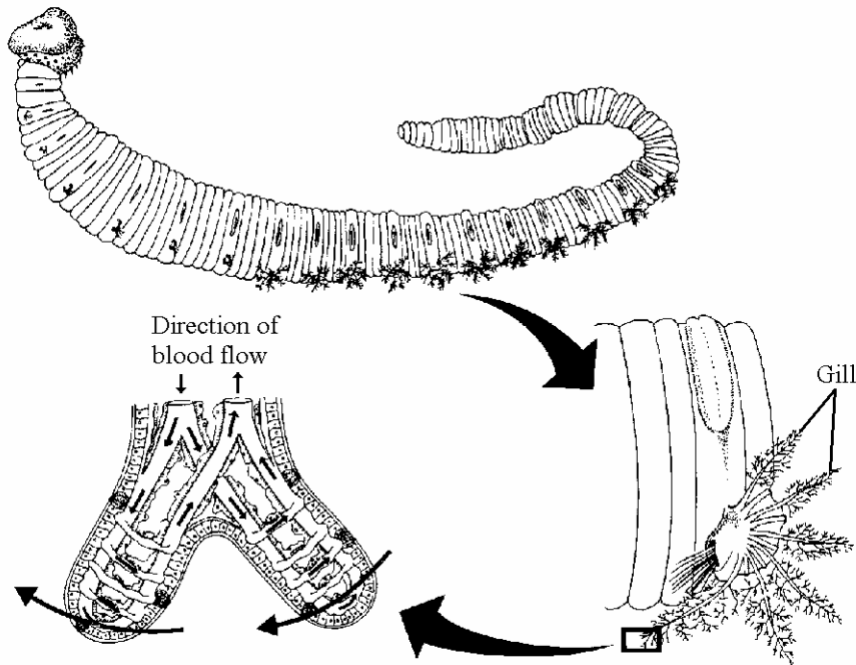


1. There are many different species of annelid worm. Some are very small, only a few millimetres in length. Others, such as lugworms, are much larger. The drawing shows a lugworm and part of one of its gills.



- (a) Smaller species of annelid do not have gills. Explain why these small worms do not need gills to obtain sufficient oxygen.

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(2)

- (b) In many of the lugworm gills, the blood flows in the opposite direction to the current of water passing over them. Explain the advantage of this arrangement.

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(2)

(c) Explain **two** ways, other than that described in part (b), in which the structure of a lugworm gill is adapted for efficient gas exchange.

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(2)

(d) Explain why water is always lost from the gas exchange surfaces of terrestrial organisms.

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(2)

The table shows the ratio of the amount of water lost to the amount of oxygen gained for two terrestrial animals, an annelid worm and an insect.

Organism	Ratio $\frac{\text{Mass of water lost}/\text{mg g}^{-1} \text{ minute}^{-1}}{\text{Volume of oxygen taken up}/\text{cm}^3 \text{ g}^{-1} \text{ minute}^{-1}}$
Annelid worm	2.61
Insect	0.11

(e) Both the annelid and the insect take up oxygen at a rate of $2.5 \text{ cm}^3 \text{ g}^{-1} \text{ minute}^{-1}$ Calculate the rate at which water would be lost in meeting these requirements in:

(i) the annelid;

Answer..... $\text{mg g}^{-1} \text{ minute}^{-1}$

(ii) the insect.

Answer.....mg g⁻¹ minute⁻¹

(2)

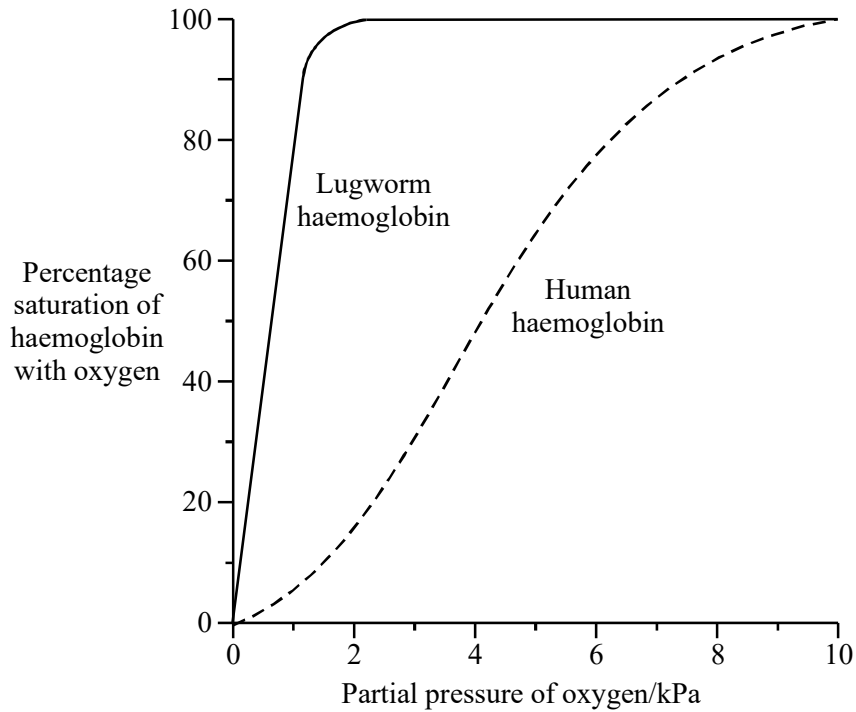
(f) Give **two** explanations as to why the rate of water loss during gas exchange is very low in most insects.

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2.....
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(4)

- (g) Annelids like the lugworm have blood which contains haemoglobin. The graph shows the oxygen dissociation curves for lugworm haemoglobin and for human haemoglobin.



- (i) During exercise, the rate of respiration of muscle cells increases. Explain what causes human haemoglobin to unload more oxygen to these cells.

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(4)

- (ii) The lugworm lives in a burrow in the sand on the seashore. When the tide is out, water bringing a fresh supply of oxygen no longer flows through the burrow. Suggest how the lugworm's haemoglobin allows it to survive in these conditions.

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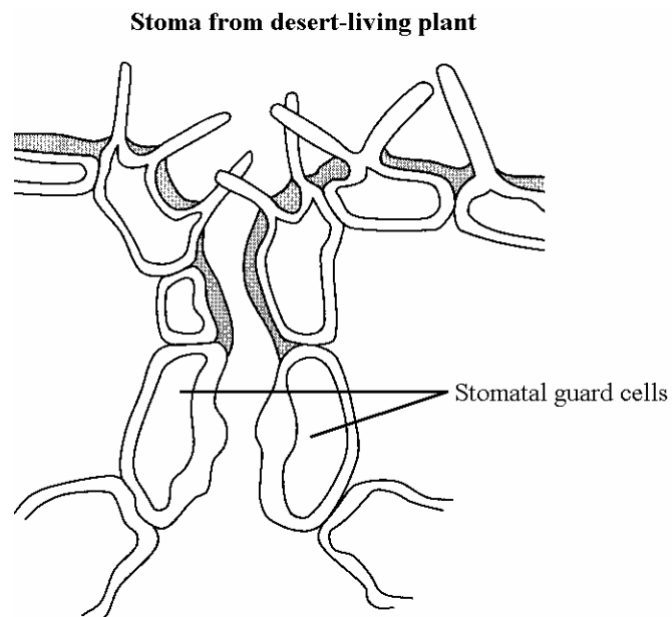
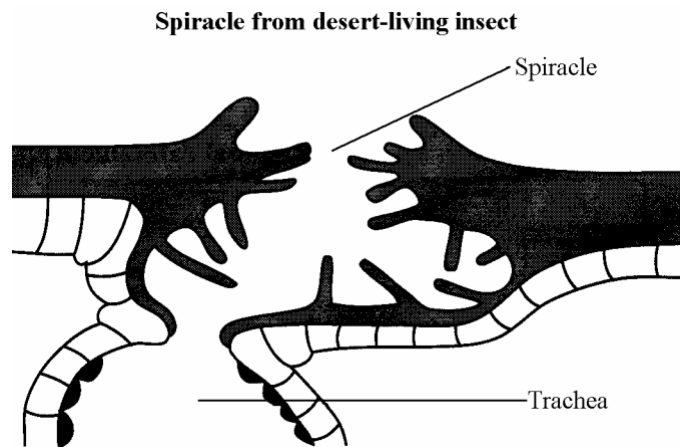
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(2)
(Total 20 marks)

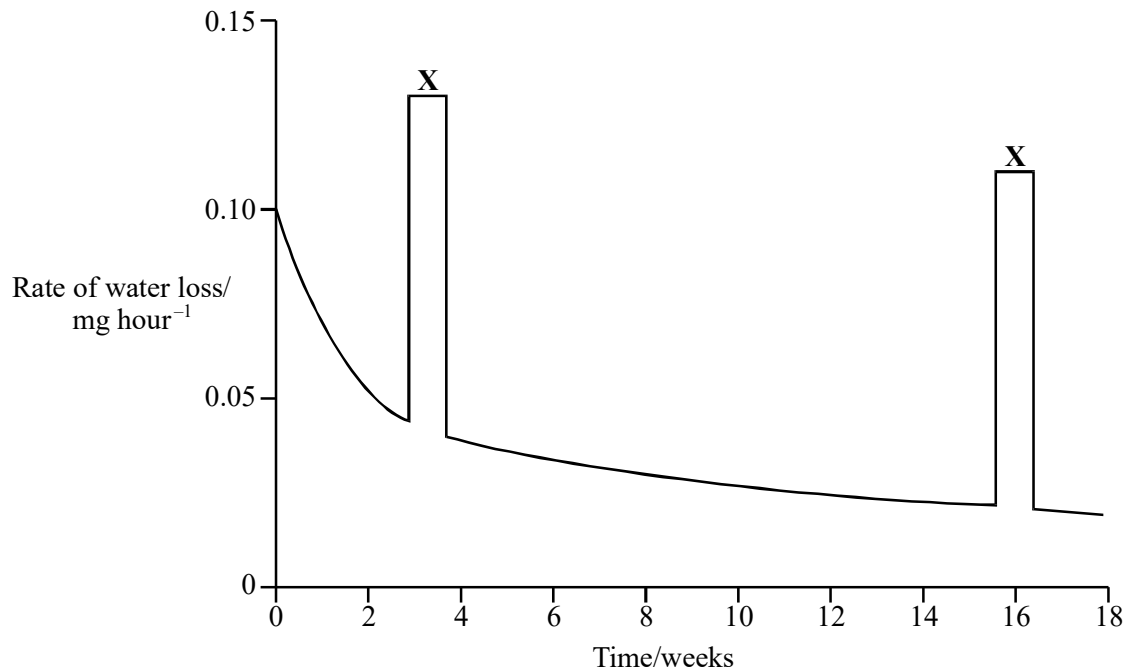
2. (a) Plants and insects which live in desert conditions have adaptations which reduce water loss. The diagrams show sections through an insect spiracle and a plant stoma.



Describe and explain **two** similarities in the way in which the structures shown in these diagrams limit water loss from these organisms.

(4)

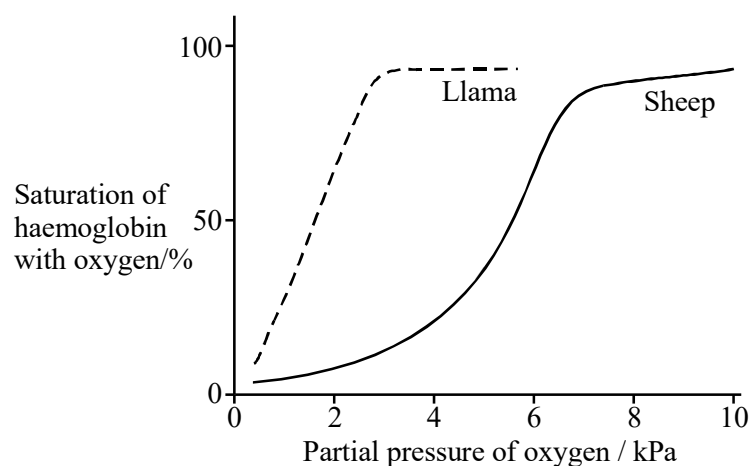
- (b) The graph shows the rate of water loss from a desert-living insect. Over the periods of time marked X the concentration of carbon dioxide in the air was increased from approximately 0.03% to 5%.



Suggest an explanation for the change in rate of water loss when the carbon dioxide concentration was increased.

(3)
(Total 7 marks)

3. The llama is a mammal which lives at high altitude. Sheep live at low altitude. The graph shows dissociation curves for llama and sheep haemoglobin.



Explain the advantage of the shape and position of the llama's dissociation curve.

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(Total 2 marks)

4. (a) A diffusion gradient is essential for gas exchange. Describe **two** ways in which a diffusion gradient for oxygen is maintained at the gas exchange surface of a fish.

1

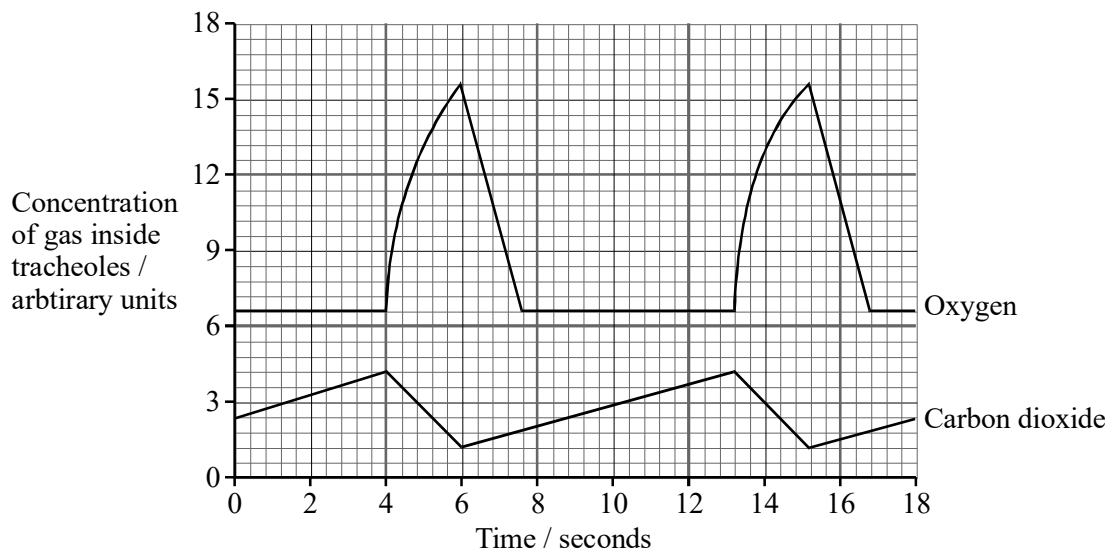
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2

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(2)

The graph shows the concentration of gases inside the tracheoles of an insect.



- (b) For how long were the insect's spiracles open during the period shown in the graph?
Explain how you arrived at your answer.

Length of time:

Explanation:

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(2)
(Total 4 marks)

5. Read the following passage.

All mammals can dive. They are able to hold their breath and swim below the surface. For most of them, this is a very limited facility involving brief dives to depths of no more than a few metres. Seals, however, have many adaptations which allow them to spend far longer under water and to dive to much greater depths.

- 5 A diving human breathes in deeply and enters the water with the lungs fully inflated. Seals do not do this. They exhale before they dive. Full lungs would make it energetically expensive to swim down through the water. As they cannot take down an oxygen supply in the lungs, they must take it in other ways. Their main oxygen store is the blood.
- 10 Seals have greater blood volumes than terrestrial mammals. A Weddell seal, for example, has about 150 cm³ of blood per kg of body mass, twice the corresponding value for humans. In addition, the seal's blood contains more haemoglobin. The combined result is that the seal's oxygen store is over three times that of a human of comparable mass. Not only do seals have more haemoglobin in their blood, they also
- 15 have a higher concentration of another oxygen-binding pigment, myoglobin. Myoglobin is what makes meat red. The darker the meat, the greater the concentration of myoglobin. Weddell seal muscles are almost black, so great is the concentration of myoglobin. Crabeater seals forage for krill near the surface and their muscles are no darker than uncooked beef.
- 20 The combined store of oxygen in a 450 kg Weddell seal is about 30 litres. The average rate of oxygen consumption in tissue is about 250 cm³ kg⁻¹ hour⁻¹, so we can estimate how long the oxygen store should allow this seal to remain under water. We know, however, that Weddell seals can remain submerged for much longer than this. How do they do this?

25 When a seal dives, changes occur in its blood system. The brain is very sensitive to oxygen deprivation so its oxygen supply must be maintained. On the other hand, most other systems, such as the gut and muscles, are able to function without oxygen. When a seal dives, the heart rate slows right down. At the same time, a ring of muscle, the caval sphincter, contracts round the main vein bringing blood back to the heart from the abdomen. This prevents any more blood returning from the liver, gut and muscles of the back. Blood flow to the brain is unimpeded although that to the rest of the body is reduced by about 90%.

35 Once their oxygen stores are exhausted, the organs outside the heart-brain-lung system continue to derive energy anaerobically from glycolysis and to accumulate lactate. It is the accumulation of lactate in the muscles which gives rise to fatigue. During rest and recovery, this lactate is processed in the liver. Blood samples from Weddell seals have shown that there is no significant increase in blood lactate concentrations until the dive time exceeds 25 minutes. After this, lactate accumulates and reaches a concentration of about 230 mg per 100 cm³ in dives of 60 minutes duration.

Source: adapted from BONNER, *Seals and sea lions of the world* (Blandford) 1994

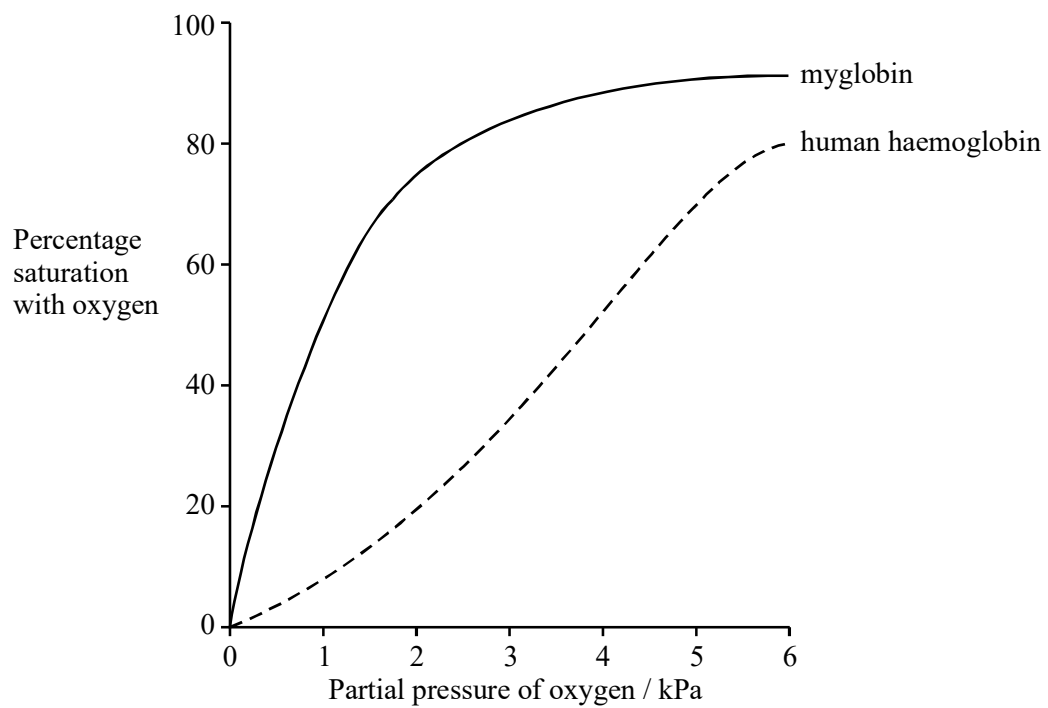
Use information from the passage and your own knowledge to answer the following questions.

(a) Explain why full lungs would make it 'energetically expensive to swim down through the water' (lines 6-7).

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(2)

- (b) (i) The graph shows the dissociation curve for myoglobin.



Use this graph to explain how the presence of myoglobin in its muscles can be of benefit to a seal.

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(2)

- (ii) Weddell seals get their food by diving to great depths. Explain the link between the colour of a Weddell seal's muscles and the animal's diving habits.

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(3)

- (c) (i) Use the figures in paragraph 4 to calculate the time you would expect a 450 kg Weddell seal to be able to remain under water, respiring aerobically. Explain your working.

Answer

(2)

- (ii) Weddell seals can remain under water for longer than this. Describe **two** adaptations of the blood system which allow them to remain under water longer.

1

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2

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(2)

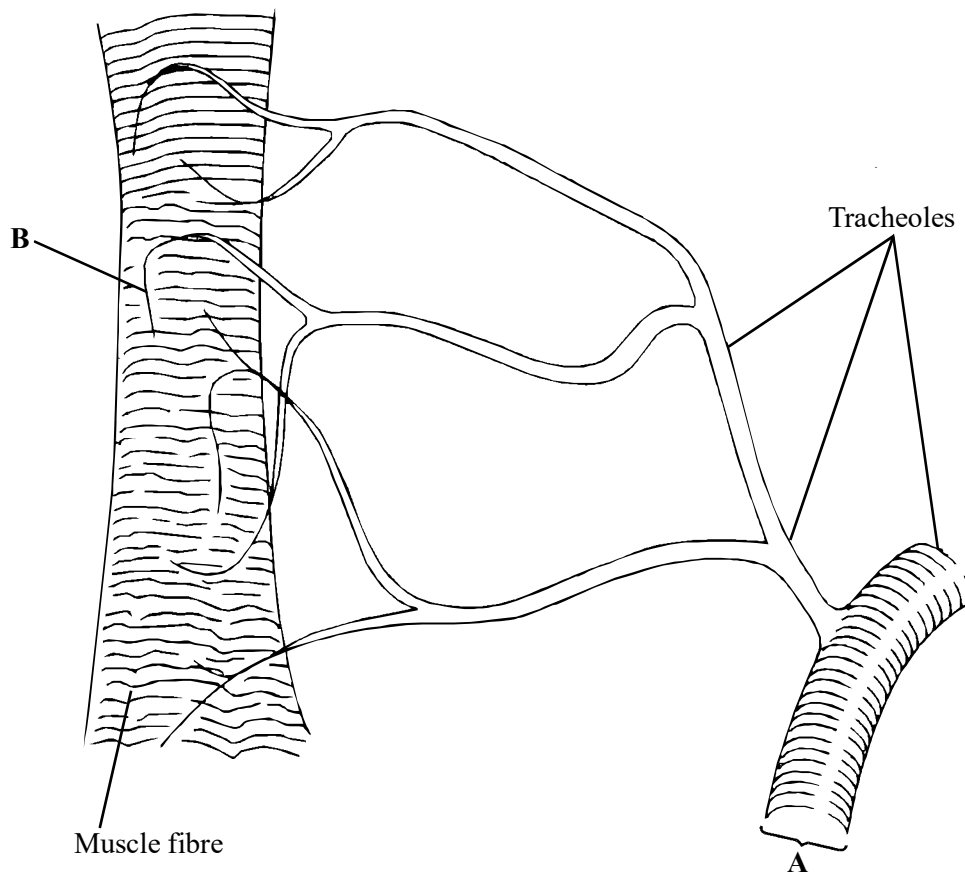
- (d) Describe **one** way in which the change in blood flow to the organs of the body of a diving seal differs from that in a human undergoing moderate exercise.

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(1)
(Total 12 marks)

6. The drawing shows some tracheoles that carry air to a muscle fibre in an insect.



- (a) (i) Explain how the structure of the gas exchange system of an insect ensures that there is a large surface area for gas exchange.

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(1)

(ii) Describe **one** way in which the transport of oxygen to a muscle in an insect is different from that in a fish.

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(1)

S (b) The diameter of the tracheole at point **A** is 20 μm . Calculate the magnification of the drawing. Show your working.

Answer: magnification =

(2)

S (c) Breathing movements can bring about the mass flow of air as far as point **B**. What causes the diffusion of oxygen molecules from **B** into a muscle fibre?

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(1)

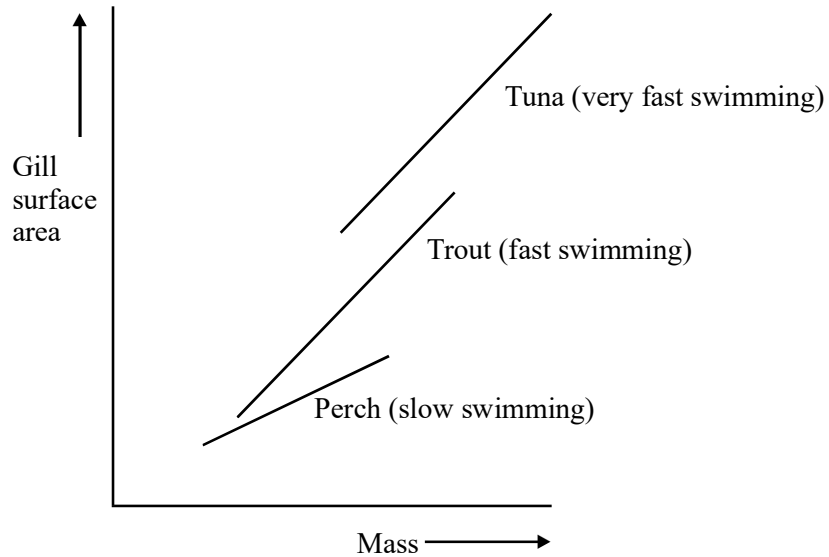
(Total 5 marks)

7. (a) Describe the features of fish gills that give them a large surface area.

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(2)

The graph shows the relationship between gill surface area and body mass for three species of fish.



- (b) (i) Describe the relationships between gill surface area, mass and swimming speed shown in the diagram.

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(1)

- (ii) Explain the relationship between gill surface area and swimming speed.

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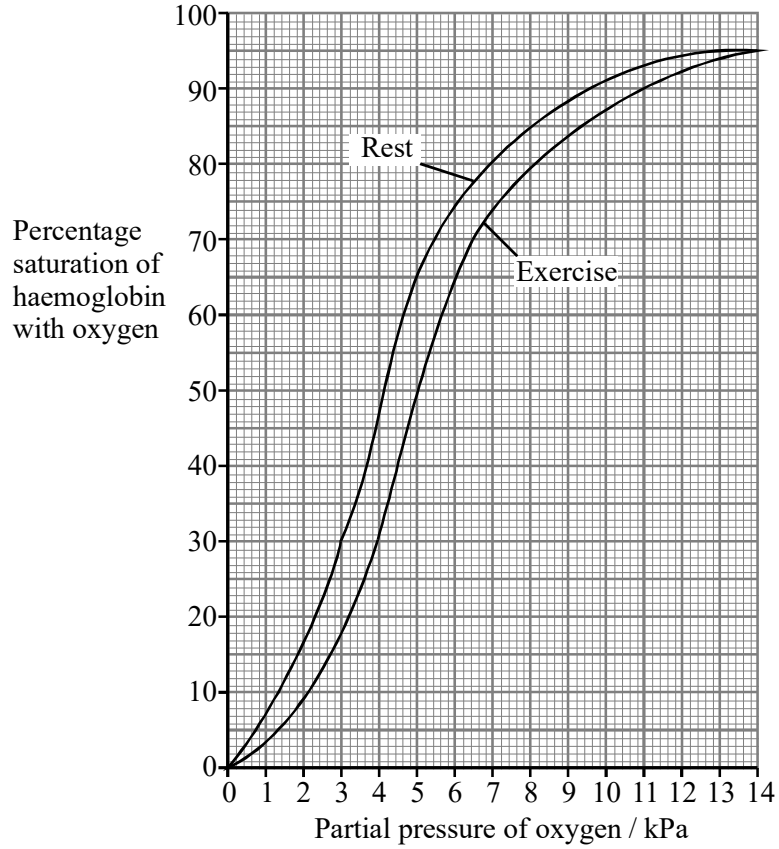
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(2)

(Total 5 marks)

8. The graph shows dissociation curves for human oxyhaemoglobin at rest and during exercise. **Table 1** gives information about conditions in the body at rest and during exercise.



	Rest	Exercise
Plasma pH	7.4	7.2
Blood temperature / °C	37.0	39.0
Alveolar partial pressure of oxygen / kPa	13.3	13.3
Tissue partial pressure of oxygen / kPa	5.0	4.0

Table 1

- (a) What is meant by the term *partial pressure*?

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- (b) Use **Table 1** and the graph to calculate the difference in the percentage saturation of haemoglobin in the tissues between rest and exercise.

Answer %

(1)

- (c) Explain the differences between the figures shown in **Table 1** for rest and exercise.

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(4)

- (d) Explain the advantage of the difference in position of the dissociation curve during exercise.

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(2)

Table 2 shows how the oxygen concentration in the blood going to and from a muscle changes from rest to heavy exercise.

		Oxygen concentration / cm ³ per 100 cm ³ blood	
		Blood in arteries	Blood in veins
At rest	In solution	0.3	0.2
	As oxyhaemoglobin	19.5	15.0
	Total oxygen	19.8	15.2
During heavy exercise	In solution	0.3	0.1
	As oxyhaemoglobin	20.9	5.3
	Total oxygen	21.2	5.4

Table 2

- (e) By how many times is the volume of oxygen removed from the blood by the muscle in **Table 2** during heavy exercise greater than the volume removed at rest?
Show your working.

Answer times

(2)

- (f) Does enriching inspired air with oxygen have any effect on the amount of oxygen reaching the tissues? Support your answer with evidence from the graph and **Table 2**.

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(3)

- S** (g) The change to the dissociation curve is one of a number of ways in which the total oxygen supplied to muscles is increased during exercise. Give **two** other ways in which the total oxygen supplied to muscles during exercise is increased.

1

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2



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(2)

(Total 15 marks)

9. The electron micrograph shows a section through a fish gill. The directions of flow of water and of blood are indicated by arrows.



Key	
	Direction of flow of water
	Direction of flow of blood

10 μm

Source: www.ucdavis.edu/mjguinan

- (a) Calculate the minimum distance that a molecule of oxygen would have to travel from the water to a red blood cell. Give your answer in micrometres and show your working.

Answer μm .

(2)

- (b) Explain how the relationship between the direction of flow of water and of blood shown in the micrograph is useful to a fish.

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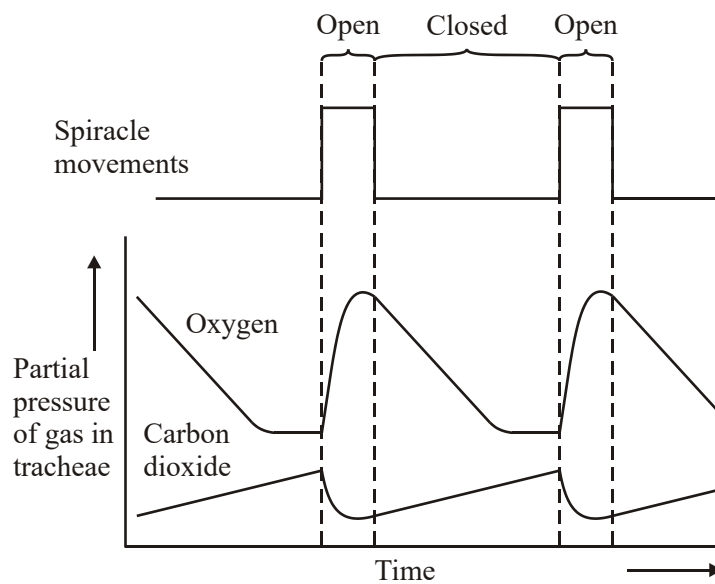
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(3)
(Total 5 marks)

10. Many insects release carbon dioxide in short bursts even though they produce it at a constant rate. The diagram shows how this is achieved in one particular insect.



- (a) Using information from the diagram, suggest what stimulates the spiracles to open.

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(1)

- (b) Explain what causes the oxygen concentration in the tracheae to fall when the spiracles are closed.

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(2)

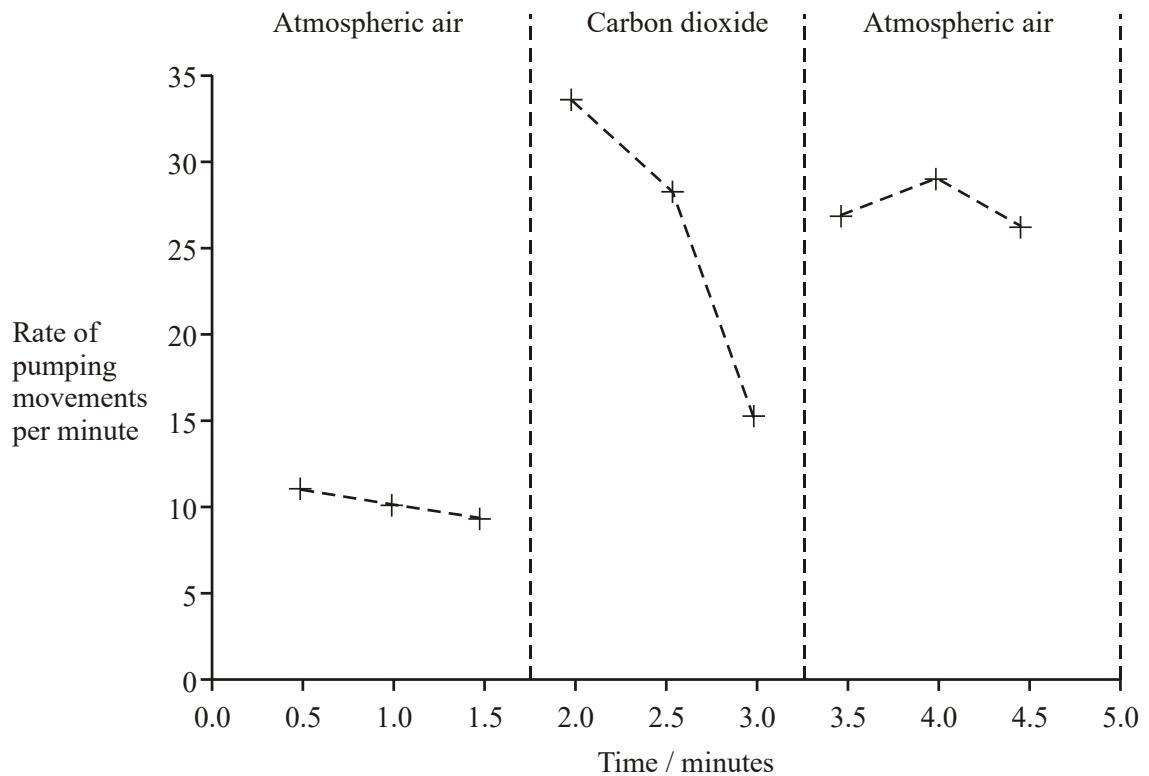
- (c) The insect lives in dry conditions. Suggest an advantage of the pattern of spiracle movements shown in the diagram.

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(2)

(Total 5 marks)

11. In an investigation, a locust was given alternating supplies of atmospheric air and pure carbon dioxide. The rate of pumping movements of the insect's abdomen was measured. The graph shows the results.



(a) Explain what caused

- (i) the rise in the rate of abdominal pumping movements between 1.5 and 2.0 minutes,

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(1)

- (ii) the fall in the rate of abdominal pumping movements between 2.0 and 3.0 minutes.

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(2)

- (b) The rate of abdominal pumping movements increases between 3.0 and 3.5 minutes. Suggest the advantage of this change to the locust.

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(1)
(Total 4 marks)

- 12. (a) Changing the carbon dioxide concentration had a greater effect on the rate of transpiration when the plants were watered than when they were kept in dry conditions. Explain why.

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(2)

- S (b) (i) Giving a reason for your choice, suggest **one** factor which should be kept constant during this investigation.

Factor

Reason

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(1)

- (ii) The figures in the table are the mean values \pm standard deviation. Suggest what the values of standard deviation given in the table indicate about the effects of carbon dioxide concentration and of watering on the variability of the results.

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(1)
(Total 4 marks)

13. Gas exchange in frogs takes place through both the skin and the lungs.

(a) **Figure 1** shows the rate of oxygen uptake through the skin and lungs of a frog during one year.

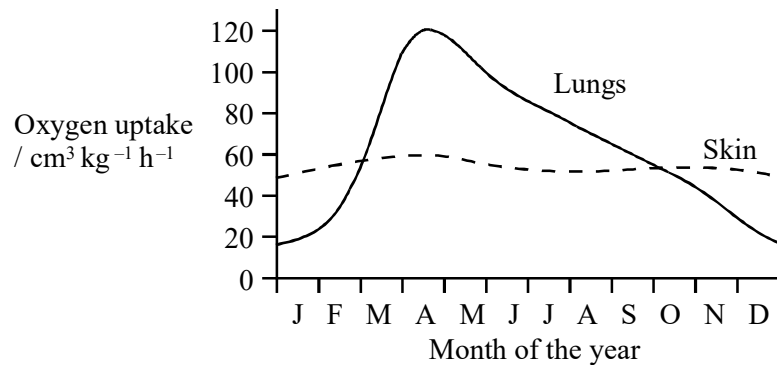


Figure 1

(i) Suggest why the rate of oxygen uptake through the skin remains nearly constant during the year.

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(1)

(ii) Compare the relative importance of the skin and lungs in the uptake of oxygen in winter and summer.

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(1)

(b) **Figure 2** shows the rates of gas exchange through the skin and lungs of a frog at different temperatures.

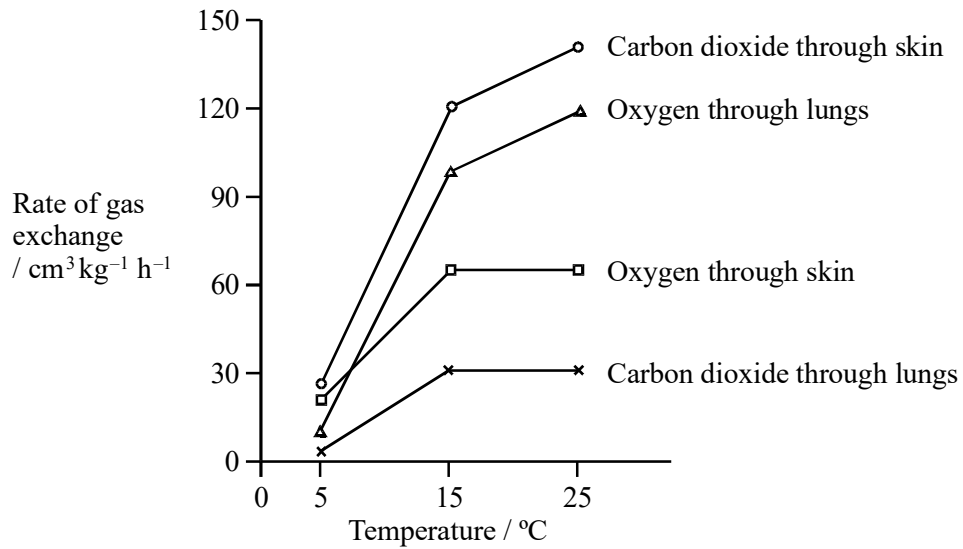


Figure 2

(i) Explain how information provided in **Figure 2** supports your answer to part (a)(ii).

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(2)

(ii) Using information provided in **Figure 2** describe the relative importance of the skin and lungs in the removal of carbon dioxide in winter and summer.

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(1)

(c) Frogs are amphibians. A number of amphibians have developed ways to increase gas exchange through their skin. Explain how each of the following adaptations increases gas exchange by this pathway.

(i) The hairy frog has numerous thin, hair-like tufts of tissue along its legs and the sides of its body.

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(2)

(ii) The hellbender salamander often displays rocking and swaying movements of its body when underwater.

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(1)

(Total 8 marks)

14. (a) A fish uses its gills to absorb oxygen from water. Explain how the gills of a fish are adapted for efficient gas exchange.

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(6)

Mackerel live in the surface waters of the sea. Toadfish live on the seabed in deep water.

- (b) The concentration of oxygen is higher in the surface waters than it is in water close to the seabed. Suggest why.

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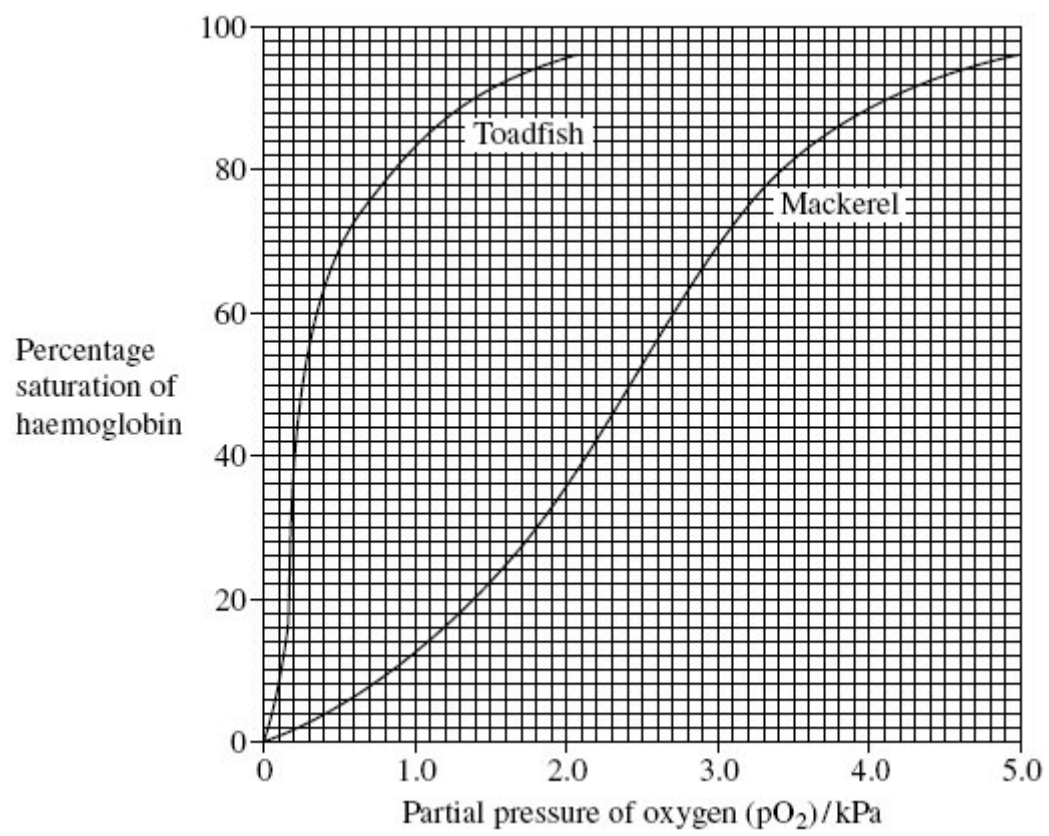
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(2)

- (c) The graph shows oxygen dissociation curves for toadfish haemoglobin and for mackerel haemoglobin.



Explain how the shape of the curve for toadfish haemoglobin is related to where the toadfish is normally found.

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- (d) Scientists analysed the sequence of amino acids in one polypeptide chain in the haemoglobin of four different species of ape. The only difference they found affected the amino acids at three positions in the polypeptide chain. Their results are shown in the table. The letters are abbreviations for particular amino acids.

Species	Position 87	Position 104	Position 125
Chimpanzee	T	R	P
Bonobo	T	R	P
Gorilla	T	K	P
Orang utan	K	R	Q

- (i) What information do the data in the table suggest about the relationships between the chimpanzee, the bonobo and the gorilla? Explain your answer.

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(2)

- (ii) Hybrid DNA was made from the gene for chimpanzee haemoglobin and the genes for the haemoglobin of the other three species of ape. Which of the three samples of hybrid DNA would separate into two strands at the lowest temperature? Explain your answer.

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(3)

(Total 15 marks)