1. *Answers should be written in continuous prose. Credit will be given for biological accuracy, the organisation and presentation of information and the way in which an answer is expressed.*

Fick's law states that the rate of diffusion of a substance across a membrane is directly proportional to the surface area of the membrane and to the difference in concentration on either side. It is inversely proportional to the thickness of the membrane. Fick's law can be written in simple mathematical terms as:

$$\text{Rate of diffusion} \propto \frac{\text{Surface area} \times \text{Difference in concentration}}{\text{Thickness of membrane}}$$

(a) (i) Describe how a large difference in oxygen concentration is maintained between a fish gill and the surrounding water.

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(4)

(ii) Describe the adaptations of a mammalian lung which ensure a short diffusion pathway for respiratory gases.

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(3)

(b) Explain the link between the size of an organism and the way in which its cells are supplied with oxygen.

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(6)
(Total 13 marks)

2. The table shows the mean monthly temperatures recorded at a site in Finland.

Month	J	F	M	A	M	J	J	A	S	O	N	D
Mean monthly temperature/°C	–6	–6	–4	3	9	14	18	16	12	5	1	–3

(a) Many of the mammals found in this part of Finland have a larger size and body mass than related species found in warmer regions. Explain the importance of this to their survival.

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(4)

(b) Populations of consumers living in this part of Finland fluctuate considerably in number from year to year. Populations of consumers living in warmer areas are usually more stable. Explain this difference.

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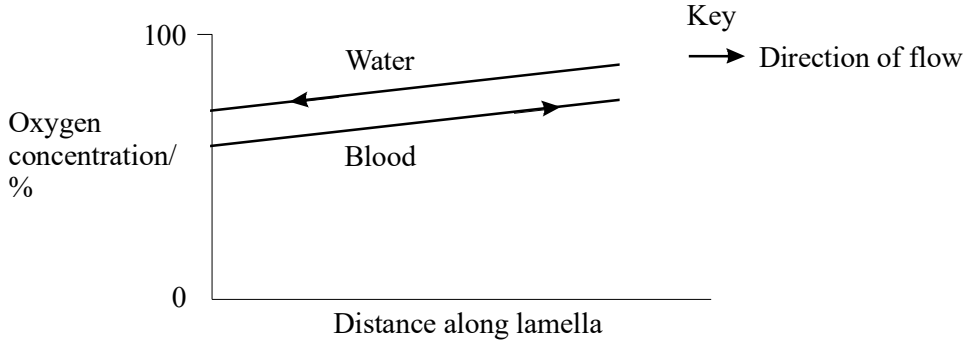
(4)
(Total 8 marks)

3. The graph shows the variation in the oxygen concentration of blood and water as they pass across a gill lamella of a fish.



(a) Use the graph to explain how the directions of flow of blood and of water increase the efficiency of the gill lamella as an exchange surface.

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(2)

(b) The table shows the thickness of the three layers between the water and the blood in the gill lamellae of three species of fish.

	Epithelial cells/ µm	Basement membrane/ µm	Endothelial lining of capillary/ µm
Dogfish	10.38	0.65	0.57
Skipjack	0.325	1.275	0.205
Mackerel	0.743	0.533	0.392

The mackerel is more active than the other two species. Explain how the figures in the table support this observation.

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(3)
(Total 5 marks)

4. The table shows the thickness of the three layers between the water and the blood in the gill lamellae of three species of fish.

	Epithelial cells/µm	Basement membrane/µm	Endothelial lining of capillary/µm
Dogfish	10.38	0.65	0.57
Skipjack	0.325	1.275	0.205
Mackerel	0.743	0.533	0.392

The mackerel is more active than the other two species. Explain how the figures in the table support this observation.

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(Total 3 marks)

5. The table shows the relative rate of diffusion of oxygen through three different media.

Medium	Relative rate of diffusion
Air	11.0
Water	3.4×10^{-5}
Muscle tissue	1.4×10^{-5}

(a) The measurements in the table were all made at the same temperature. Explain how an increase in temperature affects the rate of diffusion.

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(2)

(b) The lung alveoli have a moist surface.

(i) It is sometimes suggested that this moist surface makes gas exchange more efficient. Use the information in the table to explain why this suggestion is incorrect.

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(1)

(ii) Explain how diffusion results in the alveoli having a moist surface.

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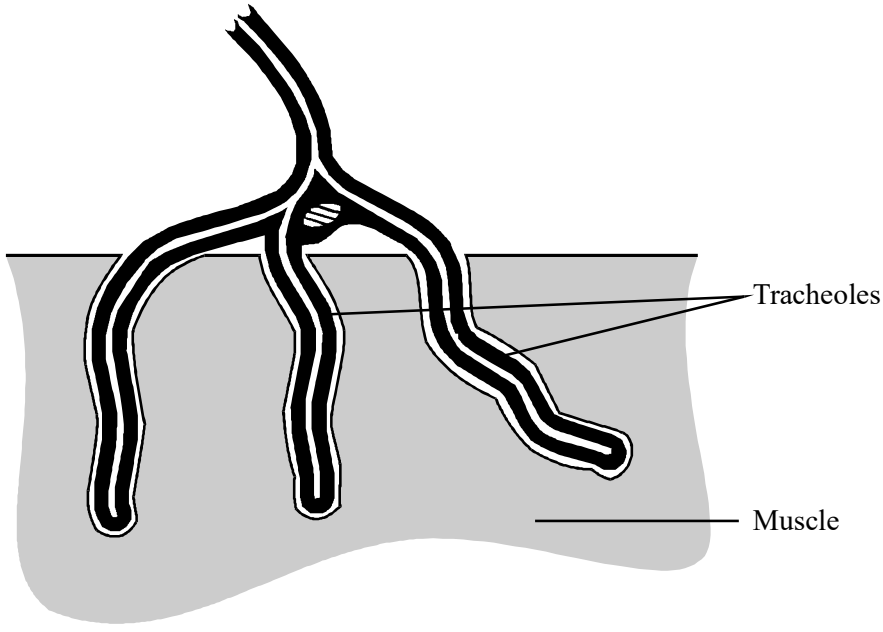
(2)

(c) The diagram shows the position of the tracheoles which supply oxygen to the muscles of an insect.



This insect has more than 1.5 million tracheoles. The distance between the ends of the tracheoles in the muscle is approximately 4 pm. Explain how these features allow efficient oxygen supply.

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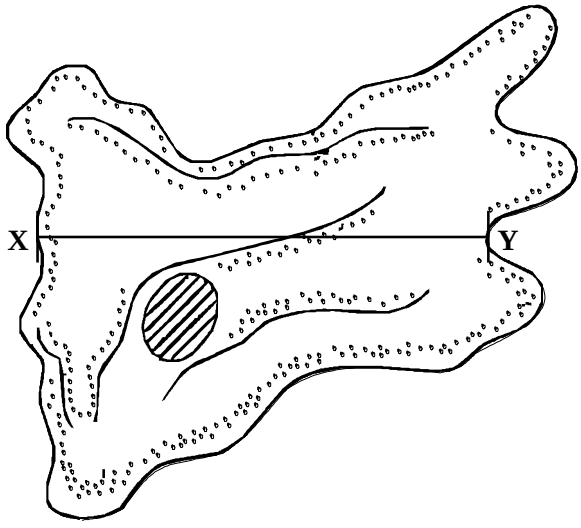
(3)
(Total 8 marks)

6. An amoeba is a single-celled organism. The drawing shows an amoeba.



(a) The magnification of the drawing is x 300. Calculate the actual length of this amoeba between points **X** and **Y.** Show your working and give your answer in micrometres.

Answer.....μm

(2)

(b) (i) Small organisms such as this amoeba can obtain sufficient oxygen for respiration without a specialised gas-exchange system. Explain why.

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(1)

(ii) Many large animals have blood systems. Explain why these animals need blood systems to supply their cells with oxygen.

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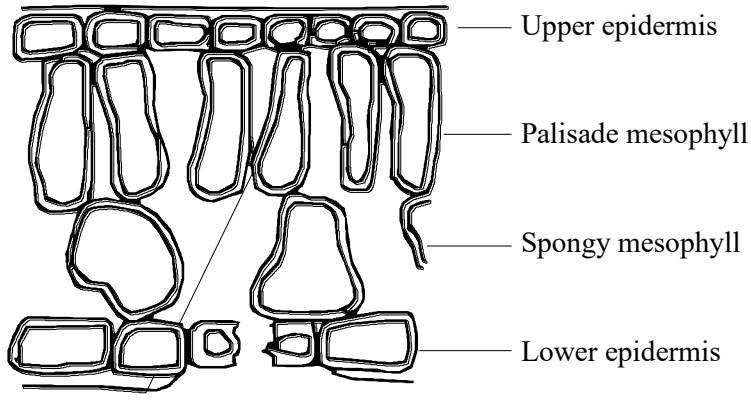
(2)
(Total 5 marks)

7. The diagram shows some of the tissues in a leaf.



(a) Name **two** organelles in a palisade mesophyll cell that could be seen with an electron microscope, but that could **not** be seen with a light microscope.

1 .....

2 .....

(2)

(b) Palisade mesophyll tissue is adapted for efficient photosynthesis.
Describe **two** ways in which the cells of the tissue are adapted for

(i) maximum light absorption;

1 .....

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2 .....

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(2)

(ii) efficient uptake of carbon dioxide.

1 .....

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2 .....

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(2)
(Total 6 marks)

8. (a) In the lungs oxygen passes from the alveoli to the blood.
Describe and explain the features that make this process rapid and efficient.

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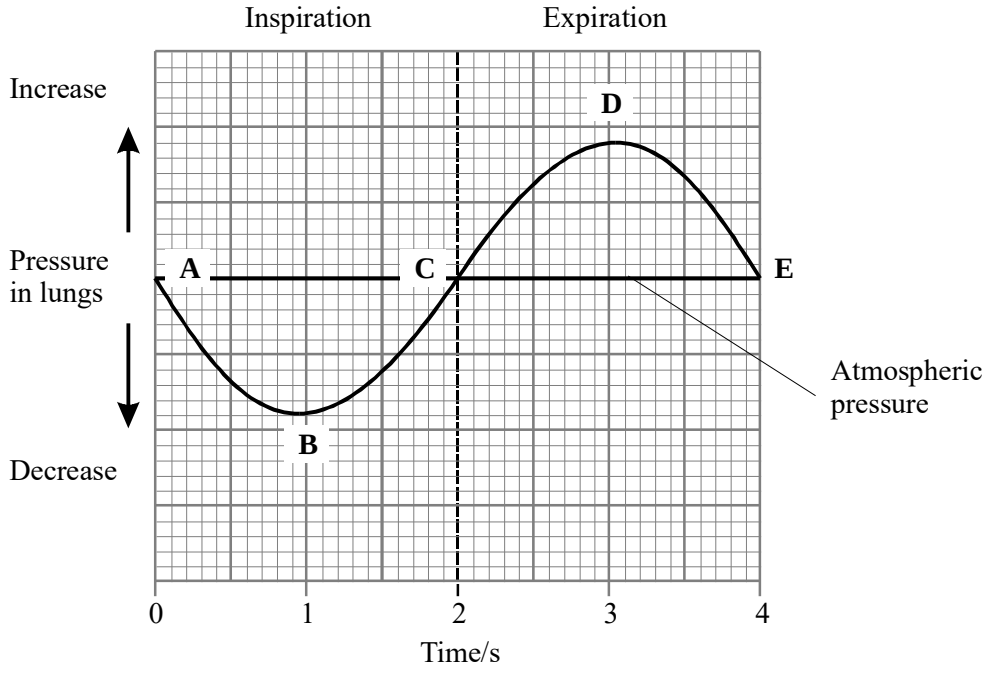
(4)

(b) The graph shows the pressure changes in the lungs during the period of one breath (inspiration + expiration) in a person at rest.



Use your knowledge of breathing to explain the changes in pressure during inspiration and expiration. The letters on the graph are to help you to refer to different parts of the curve.

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(6)

(c) Mammals such as whales and dolphins that are adapted to live in the sea have to come to the surface to take air into their lungs. Their lungs are not adapted to extract oxygen from the water.

Suggest **two** reasons why it would be very difficult to extract sufficient oxygen from water by moving water in and out of lungs.

1 .....

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2 .....

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(2)

(d) Explain how the countercurrent principle helps fish to extract oxygen from water.

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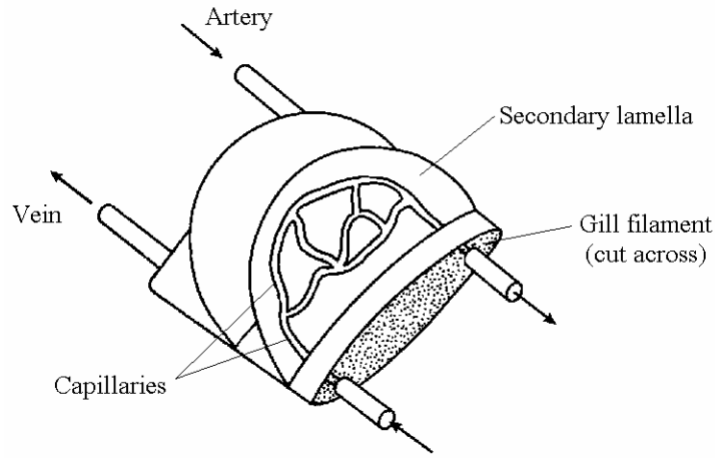
(3)
(Total 15 marks)

9. (a) The diagram shows part of a gill filament of a fish.



(i) Draw an arrow on the diagram to show the direction that water flows over the secondary lamella.

(1)

(ii) Explain the advantage of water flowing in this direction.

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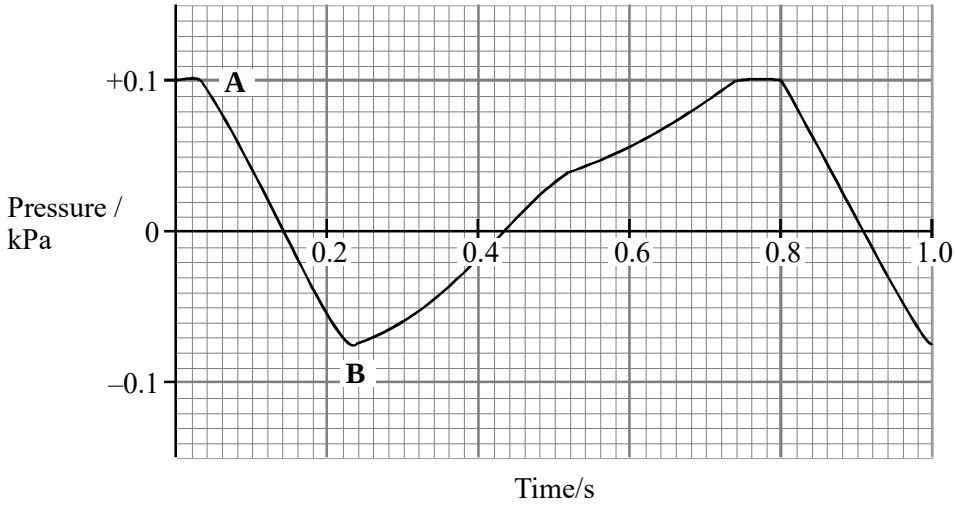
(2)

(b) The graph shows the change in pressure in the mouth (buccal) cavity of a fish during ventilation of the gills.



(i) Calculate the rate of ventilation per minute. Show your working.

Rate per minute .....

(2)

(ii) Explain what causes the fall in pressure between points **A** and **B.**

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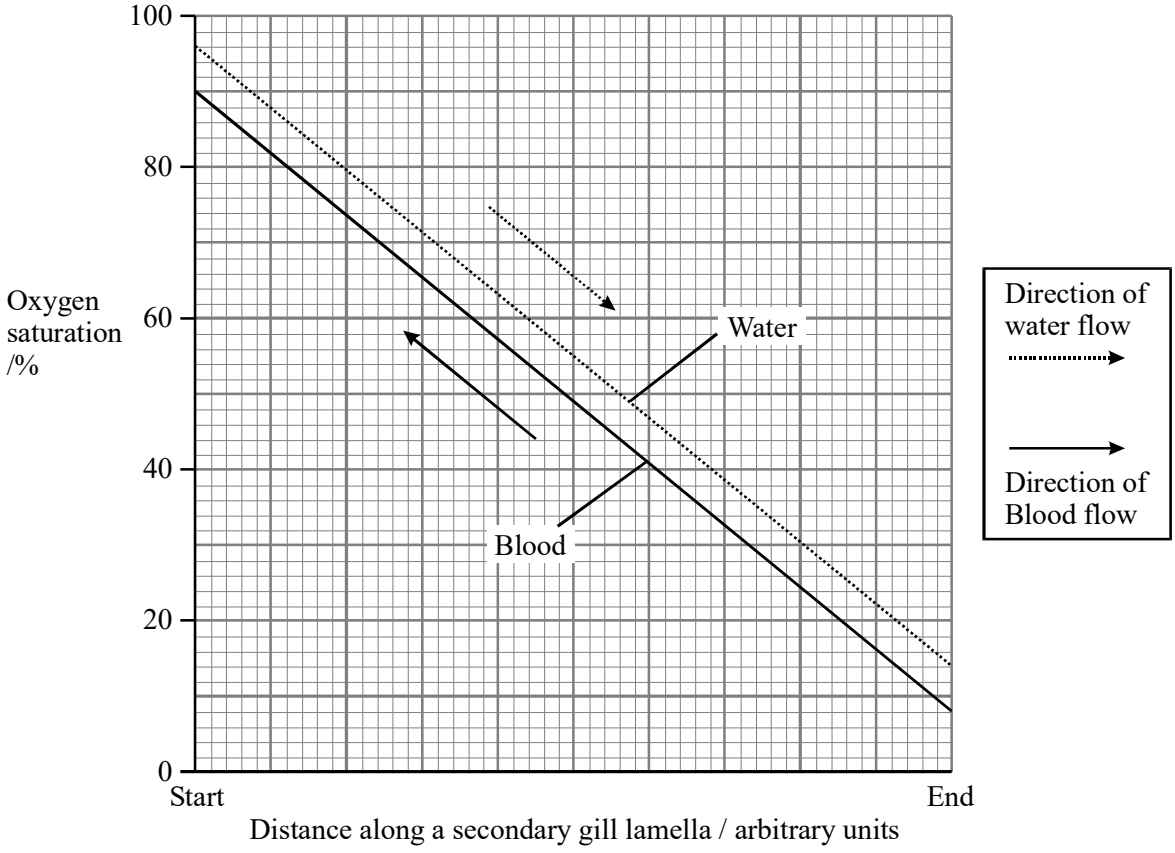
(1)
(Total 6 marks)

10. In fish, the flow of water over the gills and the flow of blood through the gills are in opposite directions (countercurrent flow) rather than in the same direction (parallel flow). The graph shows the effect of countercurrent flow on the oxygen saturation at different distances along a secondary gill lamella.



(a) What percentage of oxygen is removed from the water using this method of gas exchange?

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(1)

(b) Explain why countercurrent flow is more efficient for gas exchange than parallel flow.

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(2)

(c) Emphysema is a disease which affects the lungs. It causes a decrease in the number of alveoli. It may also cause the alveolar walls to become thickened.

Explain why people with emphysema may need to use oxygen masks to help with their breathing.

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(3)
(Total 6 marks)

11. (a) What is the relationship between the size of mammals and their surface area: volume ratio?

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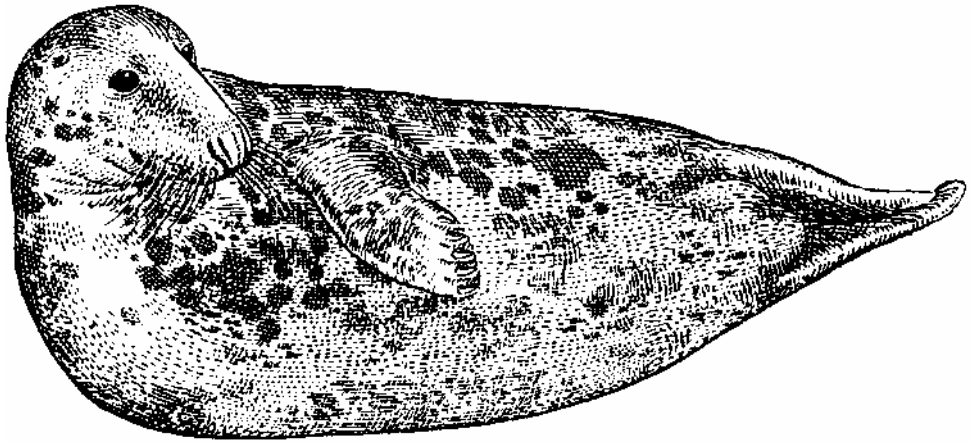
(1)

(b) The drawings show two species of seal, **X** and **Y.**



Seal **X**

Seal **Y**

Seal **X** is a mammal that lives in the very cold seas of the Arctic.

It grows to a length of 2.5 m and a mass of 400 kg.

Seal **Y** is much smaller than seal **X** and lives in warmer seas.

Use the drawings and the information above to explain **two** ways in which seal **X** is adapted for surviving in very cold conditions.

1 .....

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2 .....

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(4)
(Total 5 marks)

12. This question should be written in continuous prose, where appropriate.
Quality of Written Communication will be assessed in the answer.

(a) Explain how the ventilation mechanism of a fish and the structure of its gills result in the efficient uptake of oxygen from water.

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(6)

Table 1 compares some features of water and air.

Feature	Water	Air
Relative density	1000	1
Maximum concentration of oxygen / $cm^3\ dm^{-3}$	9	130

Table 1

Table 2 shows some features of gas exchange in a fish and in a mammal.

Feature	Fish	Mammal
Percentage of oxygen extracted from water or air	80	25
Oxygen consumption at rest / $cm^3\ kg^{-1}\ hour^{-1}$	100	200

Table 2

(b) (i) The fish has a body mass of 0.2 kg. Calculate the volume of water it will need to pass over its gills each hour to supply the oxygen required when resting. Show your working.

Answer ..... dm^3 / $hour^{-1}$

(2)

(ii) Ventilation in mammals involves movement of air to and from the gas exchange surface in a tidal pattern. Using information in the tables, explain why it is easier to move water over the gas exchange surface of a fish in one direction rather than in a tidal pattern.

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(2)

(c) A rise in the temperature of water decreases the amount of oxygen dissolved in the water. As the water temperature rises, the rate of ventilation in a fish also rises. Explain the advantage of this.

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(2)

(Total 12 marks)

13. (a) When first hatched, the young of some species of fish are less than 2 mm long. Explain how these young fish get enough oxygen to their cells without having gills.

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(2)

(b) Mackerel are fast swimming fish whereas toadfish only swim slowly. The table shows some features of the gills of these fish.

	Thickness of lamellae / µm	**Number of lamellae per mm of gill length**
Mackerel	5	32
Toadfish	35	8

Use evidence from the table to explain how mackerel are able to swim faster than toadfish.

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(3)
(Total 5 marks)

14. (a) Describe and explain how fish maintain a flow of water over their gills.

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(4)

(b) Describe and explain how the structure of the mammalian breathing system enables efficient uptake of oxygen into the blood.

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(6)
(Total 10 marks)

15. (a) The photograph shows part of the gill of a fish as seen through a light microscope. It is magnified

(i) Explain how the structure of the gill makes oxygen uptake efficient.

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(2)

(ii) Water containing dissolved oxygen flows over the gill in the opposite direction to the blood flow inside. Explain why this arrangement is important for efficient oxygen uptake.

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(2)

(b) Describe how the gills of a fish are ventilated **after** water has entered through its mouth.

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(3)

(c) There is a one-way flow of water over the gills of a fish whereas there is a two-way flow of air in the lungs of a mammal. Suggest **one** advantage to a fish of this one-way flow of water over its gills.

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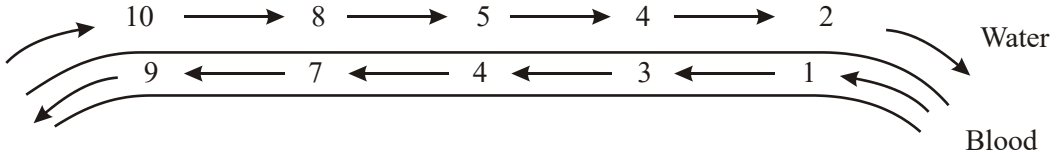
(1)

(Total 8 marks)

16. (a) The diagram represents the flow of water and blood through the gills of a fish. The figures give relative oxygen concentrations.



Use the information in diagram to explain the advantage of the countercurrent flow.

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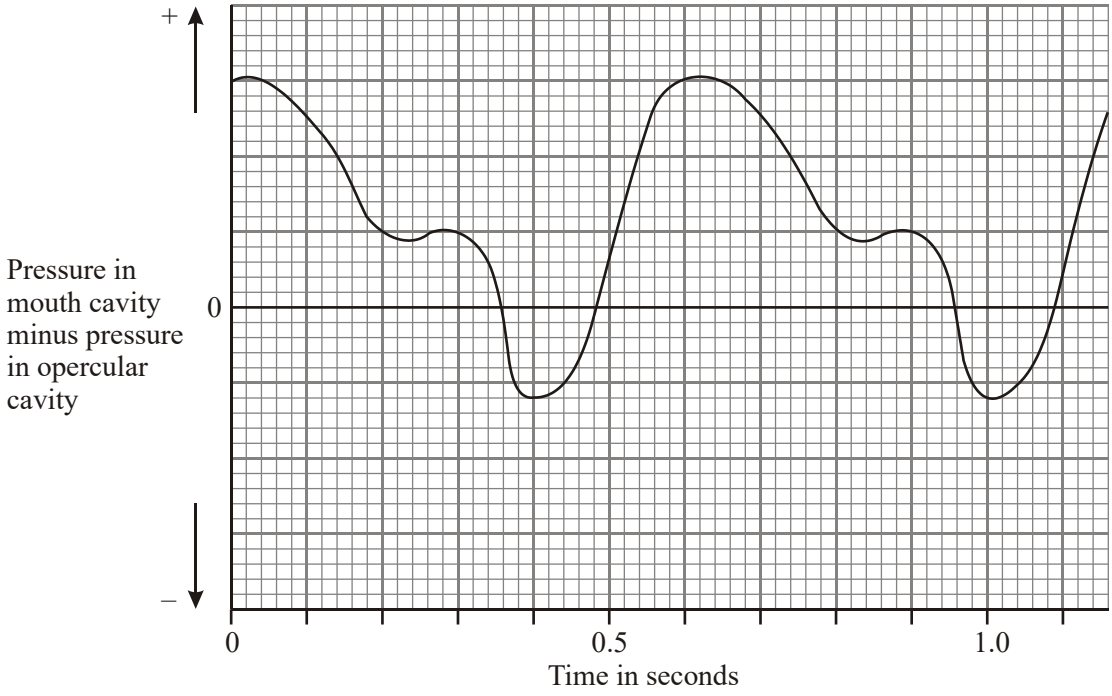
(2)

(b) In the ventilation cycle of a fish, water enters the mouth cavity and then passes through the gills into the opercular cavity. The graph shows the difference in pressure between the mouth cavity and the opercular cavity.



(i) Calculate the number of ventilation cycles per minute of the fish. Show your working.

Answer .....

(2)

(ii) Between 0 and 0.35 s the pressure in the mouth cavity is higher than the pressure in the opercular cavity. What causes this pressure difference?

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(2)

(iii) What causes the pressure difference to fall below zero?

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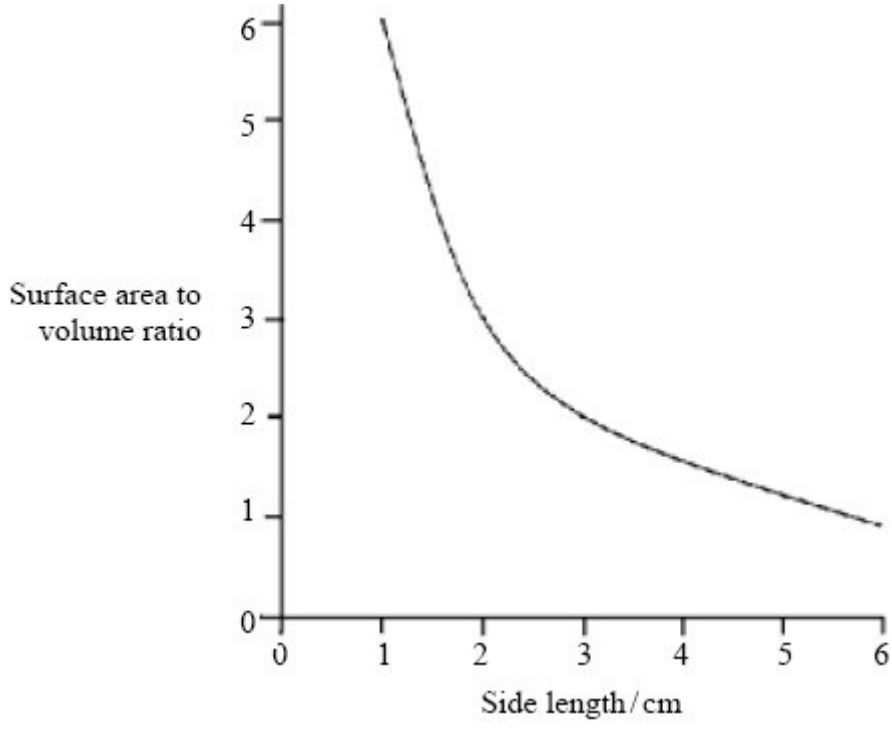
(2)
(Total 8 marks)

17. The graph shows the surface area to volume ratio of cubes of different size.



(a) Elephant seals are mammals that live in water that has a temperature of between 0°C and 4°C. Elephant seals are very large. Use the graph to explain the advantage of a large size to elephant seals.

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(2)

(b) (i) Describe how single-celled organisms exchange respiratory gases.

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(1)

(ii) This method of gas exchange is only possible in very small organisms. Explain why.

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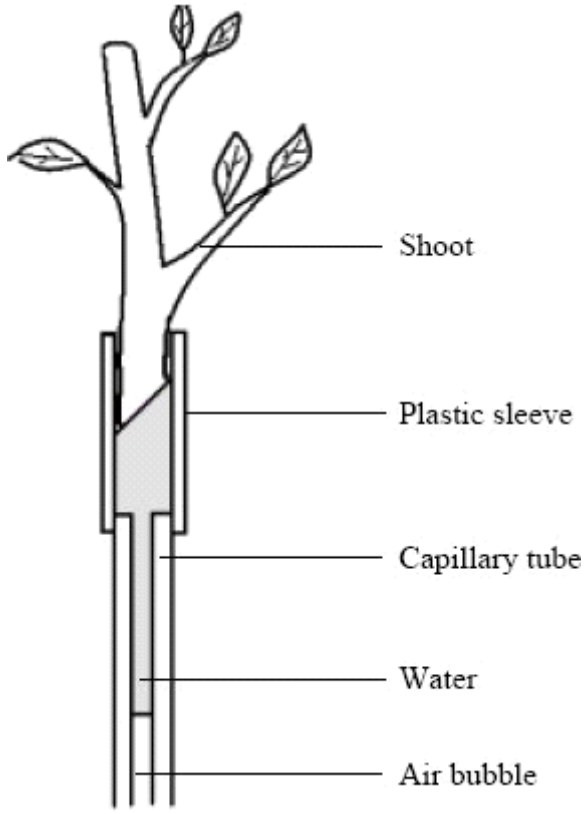
(2)

Students used the apparatus shown in the diagram to measure the rate at which a leafy shoot took up water.



(c) The students measure the distance moved by the air bubble every 30 seconds. What other measurement should they take if they wanted to compare water loss from different shoots? Explain your answer.

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(2)

(d) The students plotted the distance moved by the air bubble against time on a graph. Describe how they could use the graph to calculate the mean rate of water uptake.

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(2)

(e) An insect lives in air. Describe how the insect is able to obtain oxygen and limit water loss.

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(6)

(Total 15 marks)