3.4 ORGANISMS AND SUBSTANCE EXCHANGE – MASS TRANSPORT IN ANIMALS (3) – QUESTIONS

Q1. (a) Explain how the shape of a red blood cell allows it to take up a large amount of oxygen in a short time.

_____

_____

_____

_____

(2)

Samples of blood were mixed with equal volumes of different liquids. A drop of each mixture was put on a slide and examined with an optical microscope. The table shows the appearance of each slide.

Slide	Liquid added	Appearance of slide
A	Distilled water	No cells seen. Slide appears a uniform pale red colour
B	Sucrose solution	Cells are smaller in diameter than in an untreated sample of blood
C	Detergent (dissolves lipids)	No cells seen. Slide appears a uniform pale red colour

(b) (i) What does the appearance of slide **B** tell you about the plasma membrane surrounding a red blood cell?

_____

_____

(1)

(ii) Explain the appearance of slide **C**.

_____

_____

_____

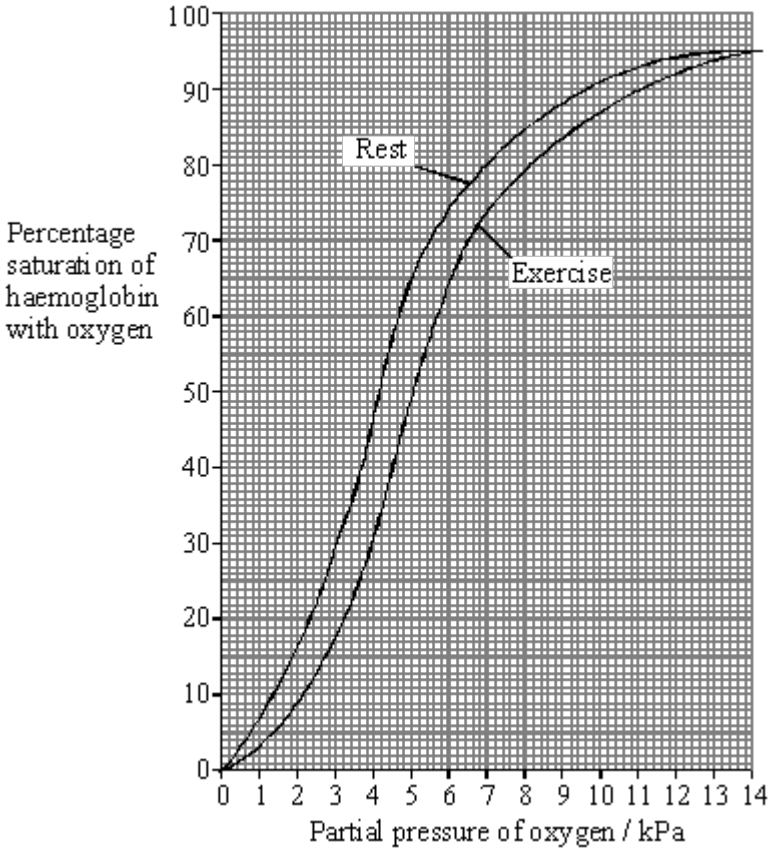
_____

(2)

(Total 5 marks)

Q2. 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*?

_____

_____ **(1)**

(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.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

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

_____

_____

_____

_____ **(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**.

_____

_____

_____

_____

_____

_____

(3)

(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. _____

_____

2. _____

_____

(2)

(Total 15 marks)

Q3. (a) Explain why both the heart and arteries are described as organs.

_____

_____

(1)

The table shows changes in the volume of blood in the left ventricle over a period of one second.

Time / s	Volume of blood as percentage of maximum
0	70

0.1	100
0.2	70
0.3	30
0.4	0
0.5	35
0.6	60
0.7	70
0.8	70
0.9	100
1.0	70

Use information in the table to answer the following questions.

(b) What is the approximate length of one cardiac cycle?

_____

(1)

(c) At what time is there least blood in the *right* ventricle? Explain your answer.

_____

_____

(1)

(d) (i) Between which times are the muscles in the wall of the left atrium contracting?

Give the reason for your answer.

Times _____

Reason _____

_____ **(1)**

(ii) Between which times are the semilunar valves in the arteries open? Give the reason for your answer.

Times _____

Reason _____

_____ **(1)**

(e) The maximum volume of blood in the left ventricle is 45 cm^3. Calculate the volume of blood in the left ventricle at 0.5 s. Show your working.

Volume of blood = _____ cm^3

(2)

(Total 7 marks)

Q4. (a) Explain how a rise in blood pressure results in a decrease in the rate of heartbeat.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(b) Some drugs inhibit the transmission of nerve impulses to the heart. Explain how these drugs reduce high blood pressure.

_____

_____

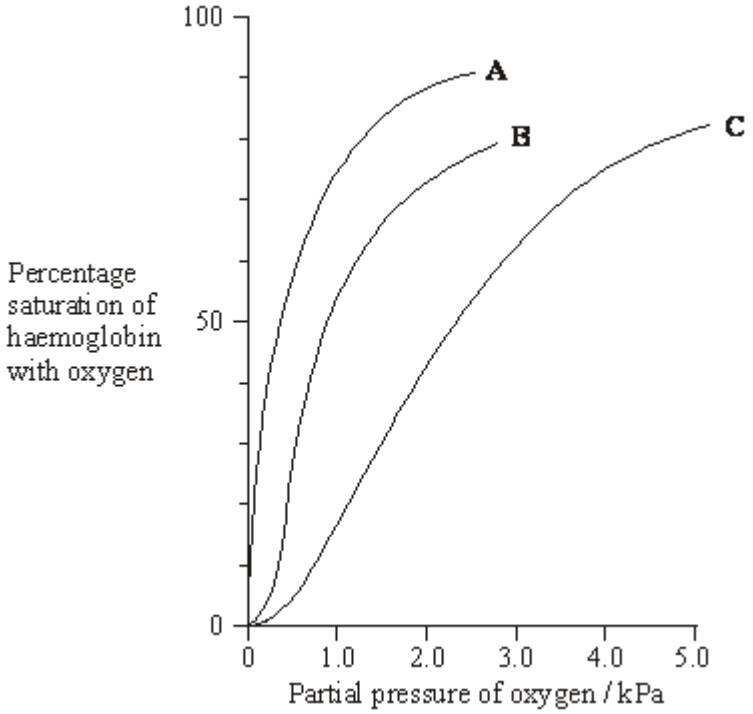
_____

_____

_____ **(2)**

(Total 8 marks)

Q5. The graph shows the oxygen haemoglobin dissociation curves for three species of fish.



(a) Species **A** lives in water containing a low partial pressure of oxygen. Species **C** lives in water with a high partial pressure of oxygen. The oxygen haemoglobin dissociation curve for species **A** is to the left of the curve for species **C**. Explain the advantage to species **A** of having haemoglobin with a curve in this position.

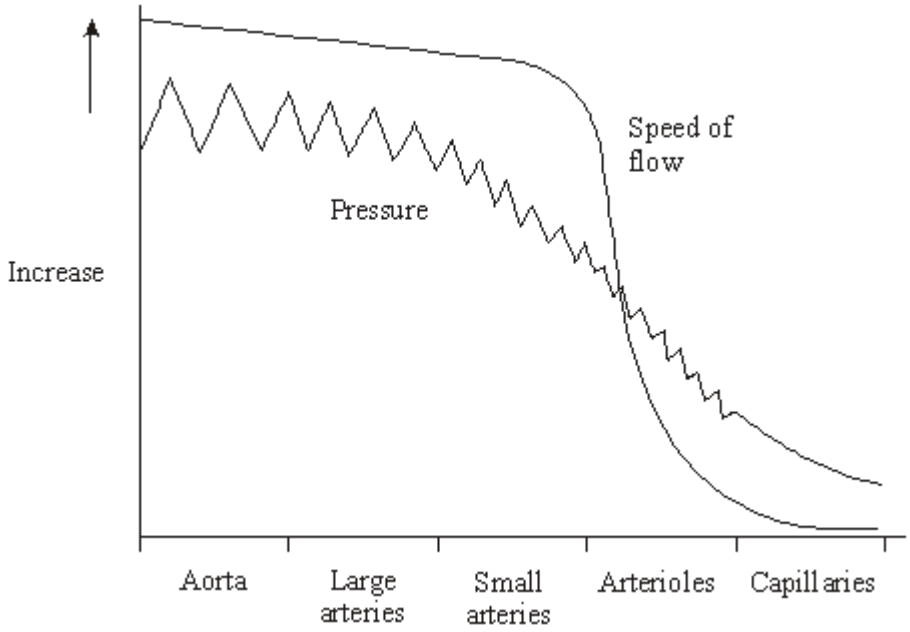
(3)

(b) Species **A** and **B** live in the same place but **B** is more active. Suggest an advantage to **B** of having an oxygen haemoglobin dissociation curve to the right of that for **A**.

(2)

(Total 5 marks)

Q6. The chart shows the change in the speed of flow and pressure of blood from the start of the aorta into the capillaries.



(a) Describe and explain the changes in the speed of flow of the blood shown in the chart.

_____

_____

_____

_____ **(2)**

(b) Explain how the structure of the arteries reduces fluctuations in pressure.

_____

_____

_____

_____ **(2)**

(c) Explain how the structure of capillaries is related to their function.

_____

_____

_____

_____ **(2)**

(d) In one cardiac cycle, the volume of blood flowing out of the heart along the pulmonary artery is the same as the volume of blood returning along the pulmonary vein. Explain why the volumes are the same although the speed of flow in the artery is greater than in the vein.

_____

_____ **(1)**

(Total 7 marks)

Q7. Lung cancer, chronic bronchitis and coronary heart disease (CHD) are associated with smoking. **Tables 1** and **2** give the total numbers of deaths from these diseases in the UK in 1974.

Table 1 Men

Age/years	**Number of deaths (in thousands)**		
	lung cancer	chronic bronchitis	coronary heart disease
35 - 64	11.5	4.2	31.7
65 - 74	12.6	8.5	33.3
75+	5.8	8.1	29.1
Total (35 - 75+)	29.9	20.8	94.1

Table 2 Women

Age/years	**Number of deaths (in thousands)**		
	lung cancer	chronic bronchitis	coronary heart disease
35 – 64	3.2	1.3	8.4
65 – 74	2.6	1.9	18.2
75+	1.8	3.5	42.3
Total (35 – 75+)	7.6	6.7	68.9

(i) Using an example from the tables, explain why it is useful to give data for men and women separately.

_____

_____

_____ **(2)**

(ii) Data like these are often given as percentages of people dying from each cause.

Explain the advantage of giving these data as percentages.

_____

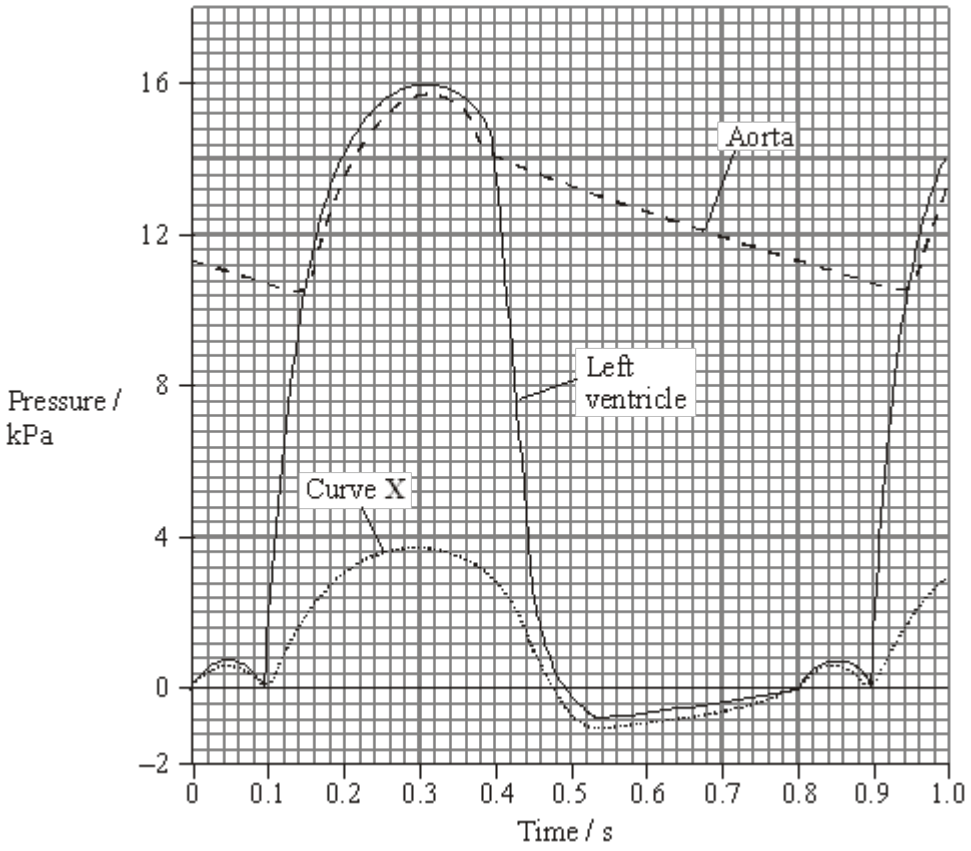
_____

_____

_____ **(2)**

(Total 4 marks)

Q8. The graph shows changes in pressure in different parts of the heart during a period of one second.



(a) (i) At what time do the semilunar valves close?

_____ **(1)**

(ii) Use the graph to calculate the heart rate in beats per minute.

Show your working.

Answer _____ beats per minute **(1)**

(iii) Use the graph to calculate the total time that blood flows out of the left side of the heart during one minute when beating at this rate. Show your working.

Answer _____ seconds **(1)**

(b) What does curve **X** represent? Explain your answer.

X = _____

Explanation _____

_____

(2)

(c) The volume of blood pumped out of the left ventricle during one cardiac cycle is called the stroke volume.

The volume of blood pumped out of the left ventricle in one minute is called the cardiac output. It is calculated using the equation

Cardiac output = stroke volume × heart rate

After several months of training, an athlete had the same cardiac output but a lower resting heart rate than before. Explain this change.

_____

_____

_____

_____

(2)

(Total 7 marks)

Q9. This question should be answered in continuous prose.

Quality of Written Communication will be assessed in these answers.

(a) Describe and explain **four** ways in which the structure of a capillary adapts it for the exchange of substances between blood and the surrounding tissue.

_____

_____

_____

_____

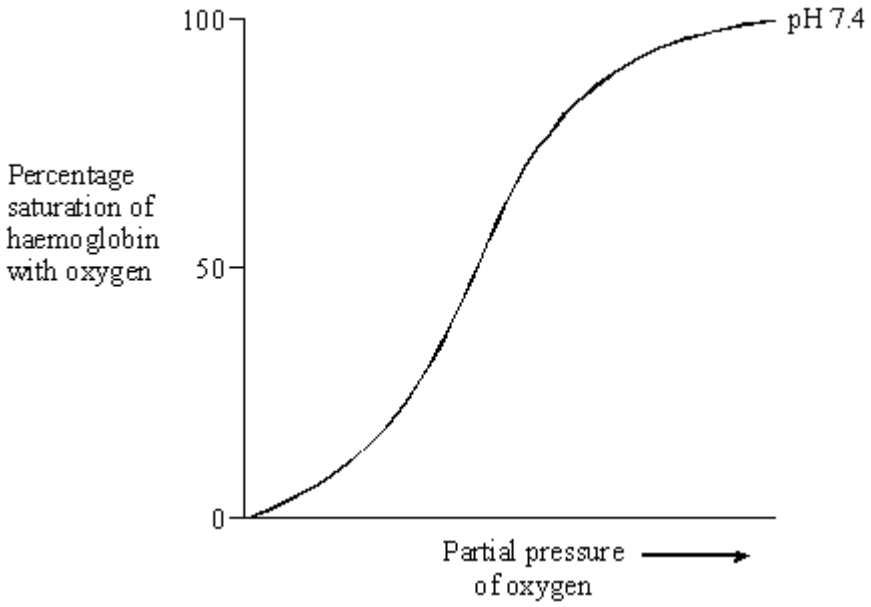
(4)

(b) Explain how tissue fluid is formed and how it may be returned to the circulatory system.

(6)

(Total 10 marks)

Q10. (a) The graph shows a dissociation curve for human haemoglobin at pH 7.4. The position of the curve is different at pH 7.2.



(i) Sketch a curve on the graph to show the likely position of the dissociation curve at pH 7.2.

(1)

(ii) Explain how a change in pH from 7.4 to 7.2 affects the supply of oxygen by haemoglobin to the tissues.

_____

_____

_____

_____

_____

_____

(2)

(b) Explain what causes the pH to be reduced from 7.4 to 7.2 in a tissue.

_____

_____

_____

_____

_____

_____

(3)

(Total 6 marks)

Q11. (a) Tissue fluid is formed from blood plasma. Complete the table to show substances present in tissue fluid and blood plasma. Use a tick if the substance is present and a cross if it is absent.

	Substance		
	Glucose	**Sodium ions**	**Haemoglobin**
Tissue fluid			
Blood plasma			

(2)

(b) The hydrostatic pressure of the blood at the arteriole end of the capillary helps to form tissue fluid. Explain how.

_____

_____

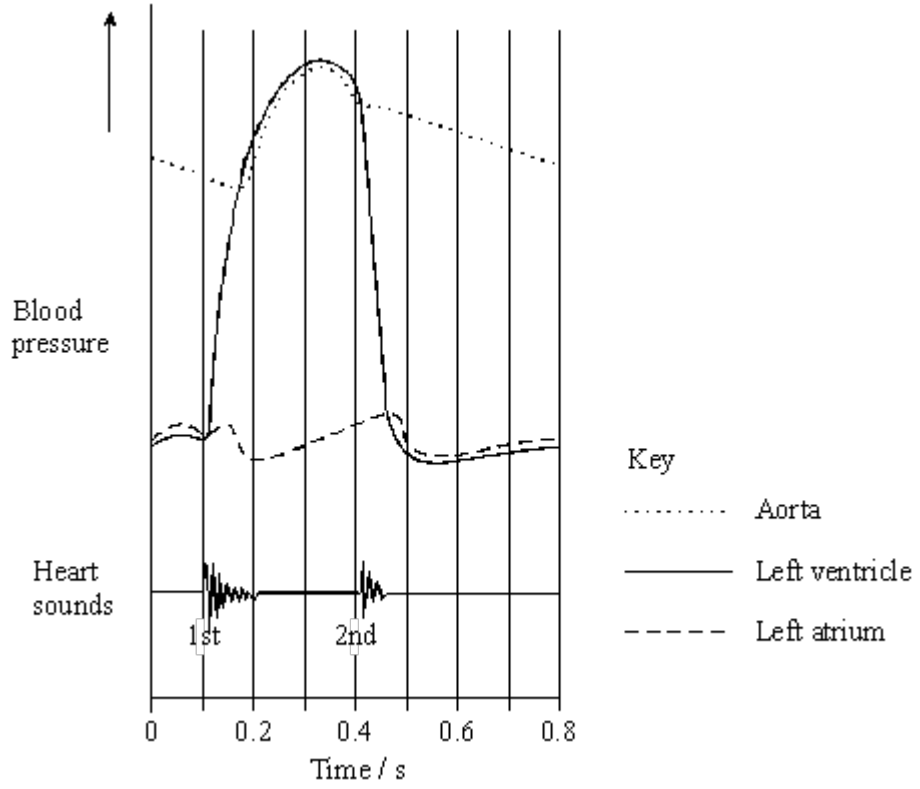
_____

_____

(2)

(Total 4 marks)

Q12. The graph shows changes in pressure in the aorta, left ventricle and left atrium during one heart beat.



(a) The maximum pressure in the left atrium is lower than the maximum pressure in the left ventricle. What causes this difference in maximum pressure?

_____

_____

(1)

(b) A stethoscope can be used to listen to the sounds made by the heart.

(i) What is the evidence from the graph that the first heart sound is caused by the atrioventricular valve closing?

_____

_____

(1)

(ii) What causes the second heart sound? Give the reason for your answer.

_____

_____

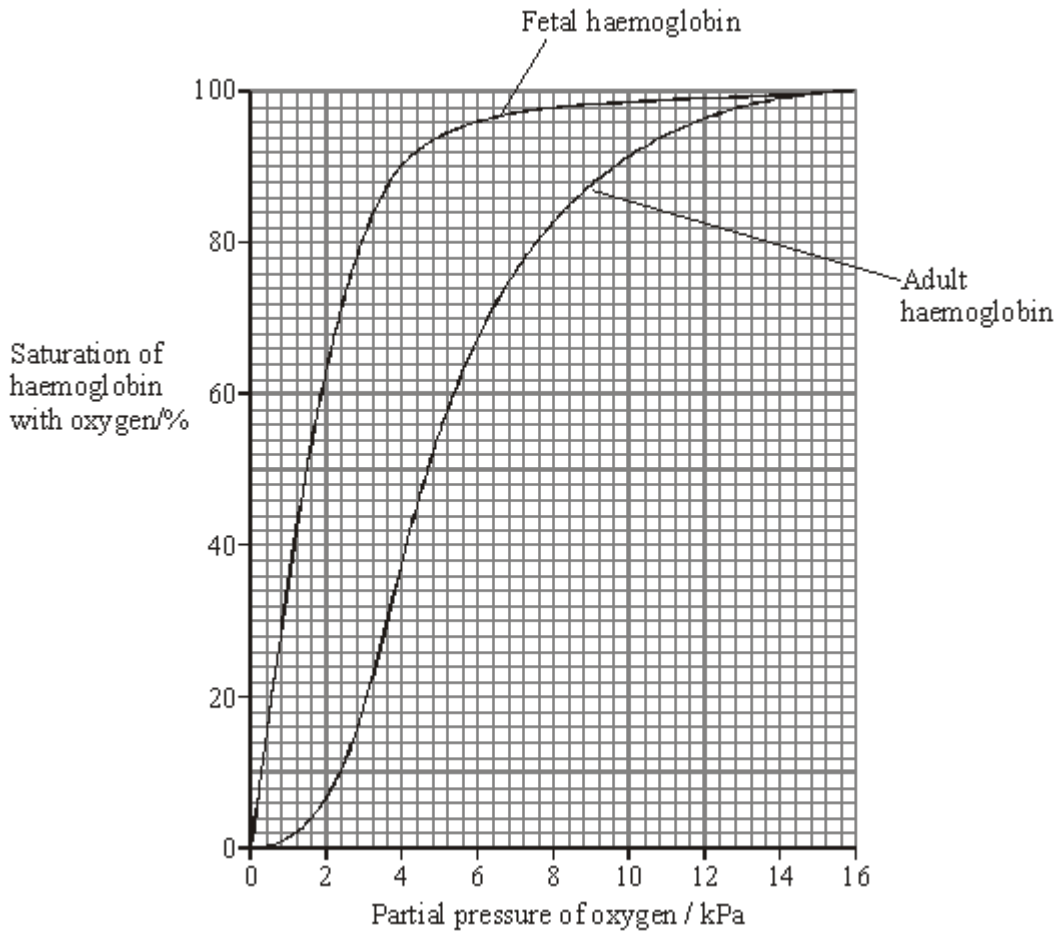
_____

_____

(2)

(Total 4 marks)

Q13. The graph shows dissociation curves for haemoglobin in a fetus and in an adult.



(a) (i) What is the difference in percentage saturation between fetal haemoglobin and adult haemoglobin at a partial pressure of 3 kPa?

_____

(1)

(ii) Explain the advantage of the curve for fetal haemoglobin being different from the curve for adult haemoglobin.

_____

_____

_____

_____

(2)

(b) The dissociation curve for adult haemoglobin changes during vigorous exercise.

(i) Sketch on the graph the position of the curve during vigorous exercise.

(1)

(ii) Explain the advantage of this change in position.

_____

_____

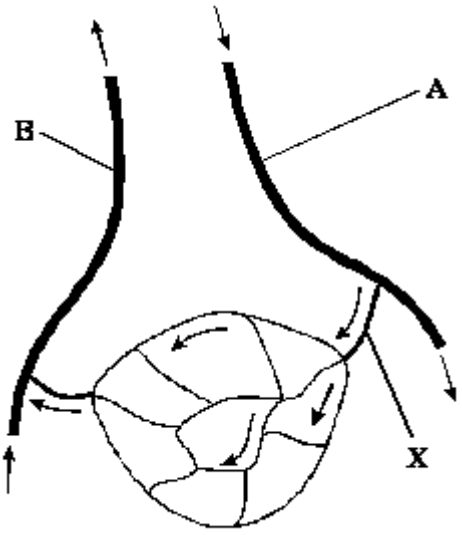
_____

_____

(2)

(Total 6 marks)

Q14. The diagram shows some blood vessels in muscle tissue.



Not drawn to scale

(a) (i) Which type of blood vessel is **X**?

_____

(1)

(ii) Name **two** substances which are at a higher concentration in the blood at **A** than in the blood at **B**.

1. _____

2. _____

(1)

(b) The table shows the mean diameter of the lumen and the rate of blood flow in some types of human blood vessel.

Type of blood vessel	Mean diameter of lumen / μm	Rate of blood flow / cm s^{-1}
Artery	400	10 – 40
Arteriole	30	0.1 – 10

Capillary	8	less than 0.1

Using information in the table, explain what causes the rate of blood flow to be slower in capillaries than in other vessels.

_____

_____

_____

_____

(2)

(c) (i) Which type of blood vessel has most elastic tissue in its wall?

_____

(1)

(ii) How does this elastic tissue help to smooth out the flow of blood in the blood vessel?

_____

_____

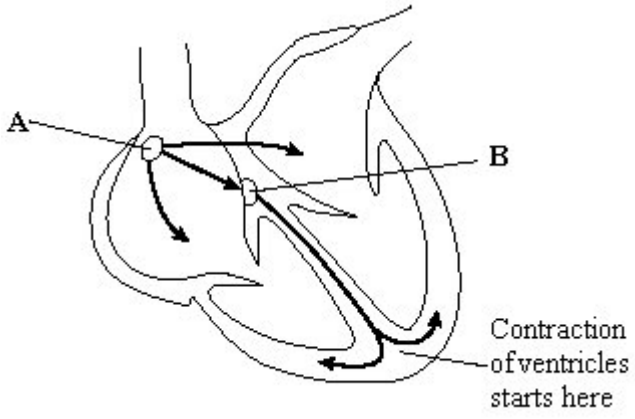
_____

_____

(2)

(Total 7 marks)

Q15. The diagram shows the pathways in the heart for the conduction of electrical impulses during the cardiac cycle.



(a) The table shows the blood pressure in the left atrium, the left ventricle and the aorta at different times during part of a cardiac cycle.

	Blood pressure / kPa

Time / s	Left atrium	Left ventricle	Aorta
0.0	0.5	0.4	10.6
0.1	1.2	0.7	10.6
0.2	0.3	6.7	10.6
0.3	0.4	17.3	16.0
0.4	0.8	8.0	12.0

(i) At which time is blood flowing into the aorta?

_____

(1)

(ii) Between which times are the atrioventricular valves closed?

_____

(1)

(b) The maximum pressure in the left ventricle is higher than the maximum pressure in the right ventricle. What causes this difference in pressure?

_____

_____

(1)

(c) The information below compares some features of different blood vessels.

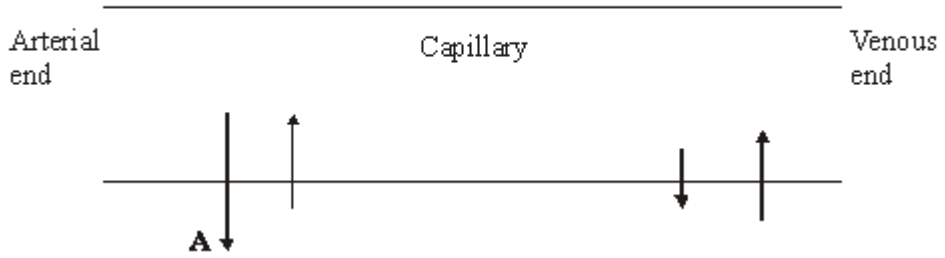
		Blood vessel		
		Artery	**Capillary**	**Vain**
Property	Mean diameter of vessel	4.0 mm	8.0 μm	5.0 mm
	Mean thickness of wall	1.0 mm	0.5 μm	0.5 mm
		Relative thickness (shown by length of bar)		
Tissues present in wall	Endothelium			
	Elastic tissue			
	Muscle			

Use the information to explain how the structures of the walls of arteries, veins and capillaries are related to their functions.

(6)

(Total 9 marks)

Q16. Tissue fluid is formed when water and small molecules pass out of capillaries at their arterial end. The diagram shows some pressures involved in tissue fluid formation. The relative lengths of the arrows indicate the size of the pressures.



(a) What causes the pressure represented by the arrow labelled **A**?

(1)

(b) Explain why there is a net loss of water from a capillary at the arterial end.

_____

(2)

(c) The total volume of fluid that passes from the capillaries to the surrounding tissue fluid is normally greater than the volume that is reabsorbed into them. Describe what happens to this extra fluid.

_____

_____

_____

_____

(2)

(d) Tissue fluid accumulates in the tissues of people who do not eat enough protein. Explain why.

_____

_____

_____

_____

(2)

(Total 7 marks)

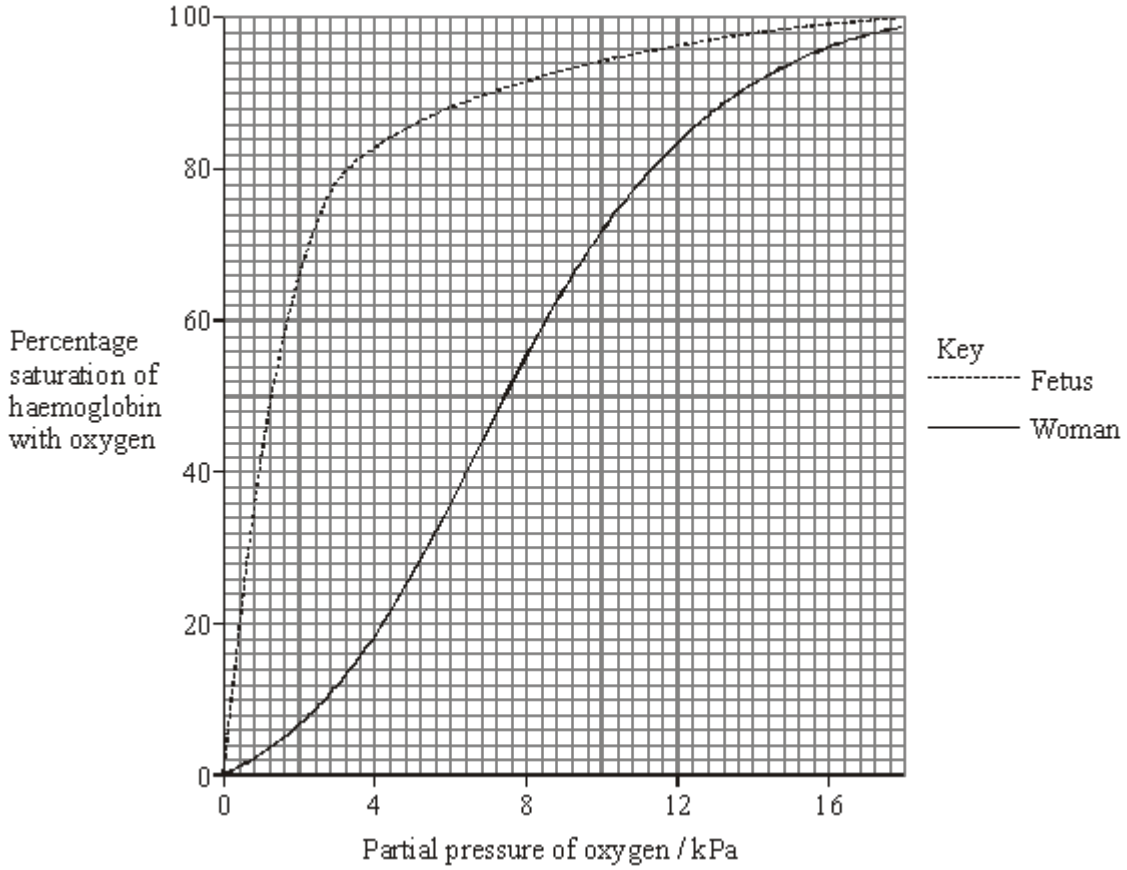
Q17. (a) Gas exchange in a fetus occurs across the placenta. Explain why it is important to maintain a supply of blood to the lungs of the fetus, even when they are not being used for gas exchange.

_____

_____

(1)

(b) The oxygen haemoglobin dissociation curves for a woman and her fetus are shown in the graph.



(i) Use the graph to find the difference between the percentage saturation of haemoglobin in the blood of the woman and the fetus when the partial pressure of oxygen in the placenta is 4 kPa.

Answer _____

(1)

(ii) Explain how efficient gas exchange is ensured by the dissociation curve for the fetus being to the left of the dissociation curve for the woman.

_____

_____

_____

_____

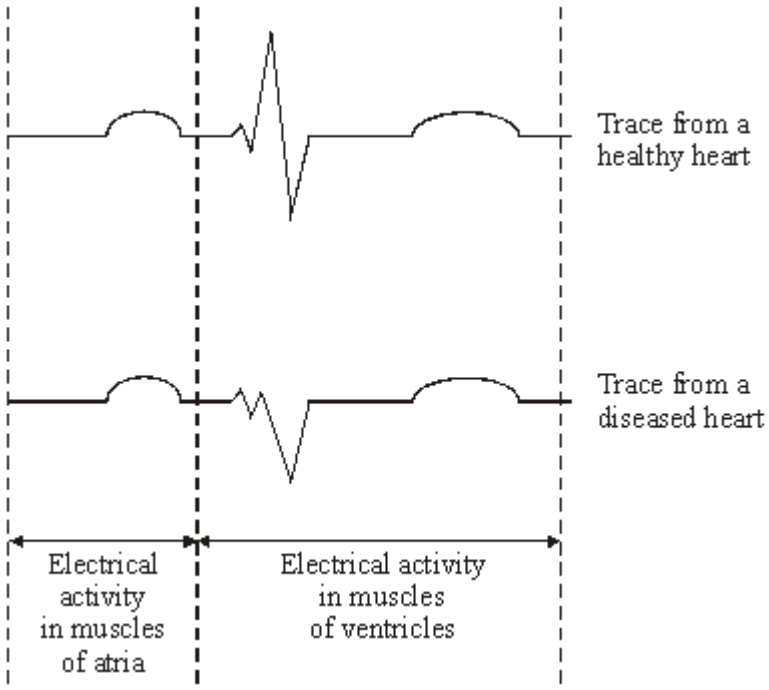
(2)

(Total 4 marks)

Q18. (a) A woman takes moderate exercise. Explain what causes her heart rate to increase while she exercises.

(6)

(b) An electrocardiogram (ECG) measures the electrical changes occurring in cardiac muscle as a heart is beating. An ECG trace for a healthy person and an ECG trace for a person suffering from heart disease are shown.



(i) Describe the route taken when electrical impulses are transmitted from the sinoatrial node to the muscles of the ventricles in a healthy heart.

_____

_____

_____

(2)

(ii) Explain how information from these ECG traces suggests that the damage caused to the diseased heart is unlikely to have affected the sinoatrial node.

_____

_____

_____

_____

(2)

(Total 10 marks)

Q19. In an investigation, the effects of caffeine on performance during exercise were measured. One group of athletes (**A**) was given a drink of decaffeinated coffee. Another group (**B**) was given a drink of decaffeinated coffee with caffeine added. One hour later the athletes started riding an exercise bike and continued until too exhausted to carry on. Three days later the same athletes repeated the experiment, with the drinks exchanged.

(a) (i) The researchers added caffeine to decaffeinated coffee. Explain why they did not just use normal coffee.

_____

_____

(1)

(ii) The performance of the athletes might have been influenced by how they expected the caffeine to affect them. How could the researchers avoid this possibility?

_____

_____

(1)

During the exercise the concentrations of glycerol and fatty acids in the blood plasma were measured. The results are shown in the table.

Drink	**Mean time to exhaustion /minutes**	**Mean concentration of blood glycerol/ mmol dm^{-3}**	**Mean concentration of blood fatty acids/ mmol dm^{-3}**
With caffeine	90.2	0.20	0.53

Without caffeine	75.5	0.09	0.31

(b) (i) Describe the effect of caffeine on exercise performance.

_____

_____

(1)

(ii) Suggest **one** explanation for the higher glycerol and fatty acid concentrations in the blood plasma of the athletes after they were given caffeine.

_____

_____

_____

_____

(2)

(c) The researchers measured the volumes of carbon dioxide exhaled and oxygen inhaled during the exercise. From the results they calculated the respiratory quotient (RQ), using the formula

$$RQ = \frac{\text{volume of carbon dioxide exhaled per minute}}{\text{volume of oxygen inhaled per minute}}$$

When a person is respiring carbohydrate only, RQ = 1.0

When a person is respiring fatty acids only, RQ = 0.7

(i) The basic equation for the respiration of glucose is

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Explain why the RQ for glucose is 1.0.

_____

_____

_____

_____

(2)

(ii) The researchers found that, when the athletes were given the drink containing caffeine, their mean RQ was 0.85. When given the drink without caffeine their mean RQ was 0.92.

The researchers concluded that when the athletes had caffeine they used glycogen more slowly than when they did not have caffeine, and that the store of glycogen in their muscles was used up less quickly during the exercise.

Explain the evidence from the information above and from the table which supports these conclusions.

_____

_____

_____

_____

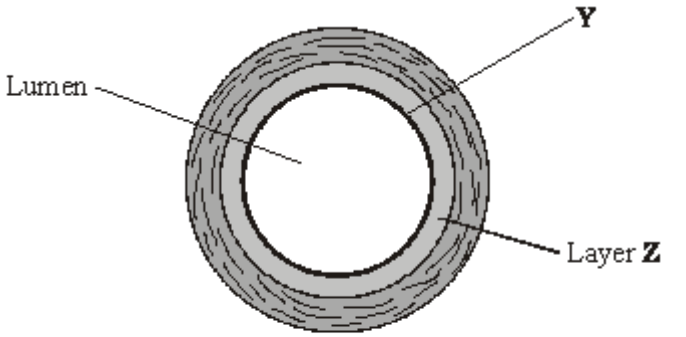
_____

_____

(3)

(Total 10 marks)

Q20. The diagram shows a cross-section of an artery.



Magnification × 10

(a) Name the layer labelled **Y**.

_____ **(1)**

(b) Layer **Z** contains a high proportion of elastic tissue.

Describe the advantage of having elastic tissue in the wall of an artery.

_____

_____

_____

_____ **(2)**

(c) Calculate the cross-sectional area of the lumen of the artery shown in the diagram. Show your working.

The area of a circle is given by πr^2, where r is the radius of a circle ($\pi = 3.14$).

Answer _____ mm^2 **(3)**

(Total 6 marks)

Q21. The pressure of the blood in an artery was measured during a cardiac cycle. The minimum pressure was 9.6 kPa and the maximum pressure was 13.4 kPa.

(a) Describe how the increase in pressure of the blood in the artery results from the events in the cardiac cycle.

_____

_____

_____

_____

(2)

(b) The elastin fibres in the wall of the artery help to smooth out the flow of blood. What happens to these fibres as the pressure of the blood in the artery changes?

_____

_____

_____

_____

(2)

(c) Give **one** way in which the structure of the wall of an artery is similar to the structure of the wall of a capillary.

_____

_____

(1)

(Total 5 marks)

Q22. A decrease in the pH of blood plasma reduces the affinity of haemoglobin for oxygen.

(a) (i) Explain how aerobic respiration in cells leads to a change in the pH of blood plasma.

_____

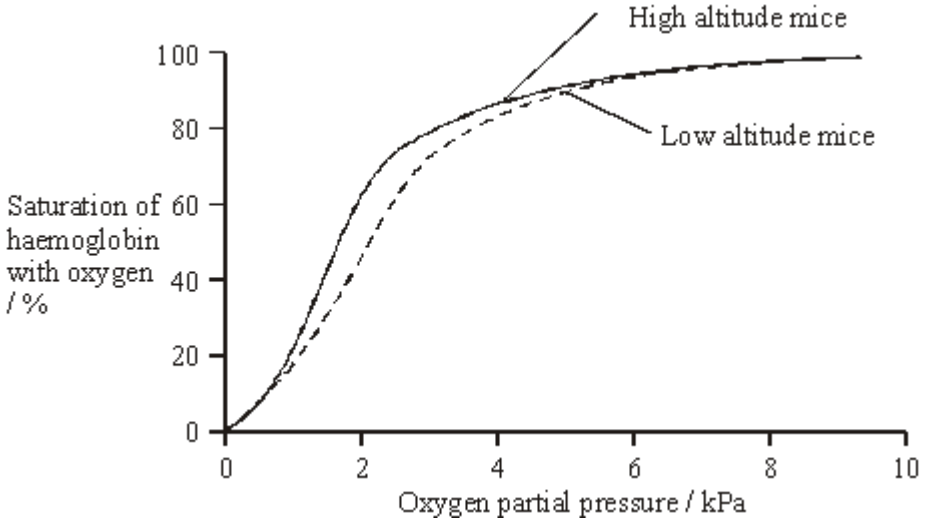
_____

(2)

(ii) What is the advantage to tissue cells of a reduction in the affinity of haemoglobin for oxygen when the plasma pH decreases?

(2)

(b) Deer mice are small mammals which live in North America. One population lives at high altitude and another at low altitude. Less oxygen is available at high altitude. The graph shows the oxygen haemoglobin dissociation curves for the two populations of deer mice.



(i) Explain the advantage for mice living at high altitude in having a dissociation curve which is to the left of the curve for mice living at low altitude.

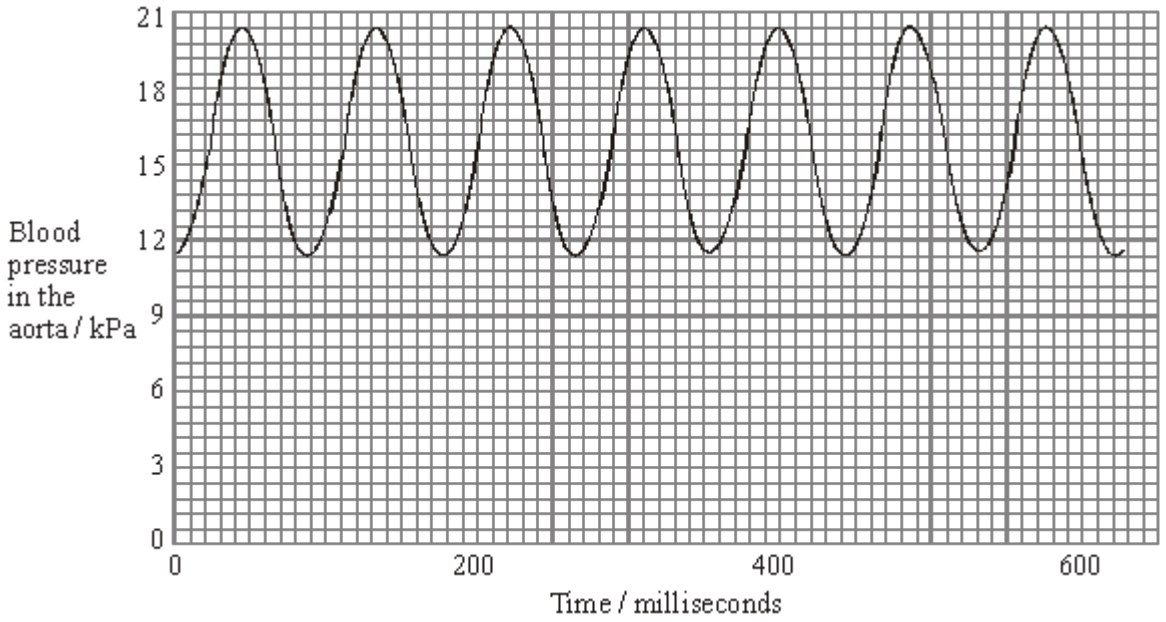
(2)

(ii) Suggest why it would be a disadvantage for the curve to be much further to the left.

(1)

(Total 7 marks)

Q23. The graph shows the changes in pressure which take place in the aorta of a mouse during several heartbeats.



(a) Which chamber of the heart produces the increase in pressure recorded in the aorta?

_____

(1)

(b) The pressure of blood in the aorta decreases during each heartbeat but does not fall below 10 kPa. Explain what causes the pressure of blood to

(i) decrease during each heartbeat;

_____

_____

(1)

(ii) stay above 10 kPa.

_____

_____

_____

_____

(2)

(c) The heart rate of a mouse is much higher than the heart rate of a human. Use the graph to calculate the heart rate of the mouse. Show your working.

Heart rate = _____ beats per minute

(2)

(d) The cardiac output is the volume of blood pumped by a heart in one minute. The stroke volume is the volume of blood pumped by a heart in a single heartbeat.

cardiac output = stroke volume × heart rate

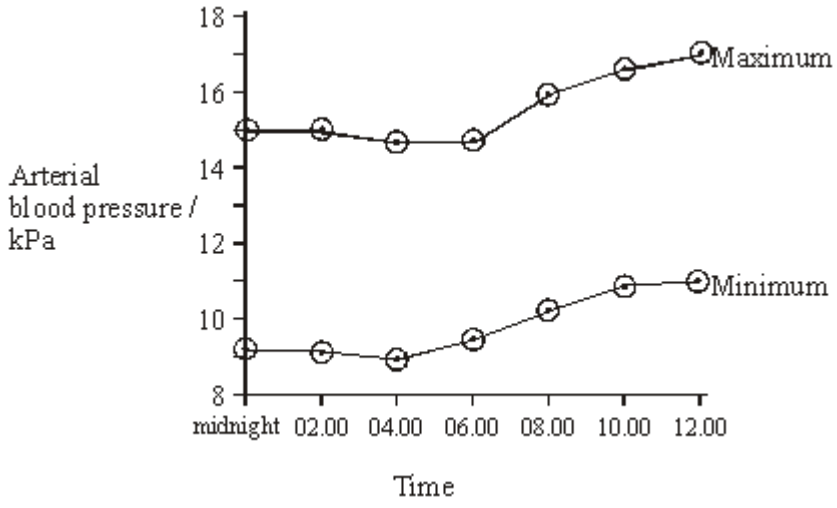
The cardiac output for a mouse with a heart rate of 550 beats per minute is 16.6 cm^3 per minute. Calculate the stroke volume for this mouse. Show your working.

Stroke volume = _____ cm^3

(2)

(Total 8 marks)

Q24. (a) The graph shows hourly blood pressure recordings from a group of 65 people.



(i) Describe how the mean maximum arterial blood pressure changes over the period shown in the graph.

_____

_____

(1)

(ii) In each cardiac cycle, the arterial pressure has a maximum value. Explain the link between this maximum value and the events of the cardiac cycle.

_____

_____

(1)

(iii) The recordings shown in this graph were taken from an artery. Describe **two** ways in which you would expect blood pressure in a vein to differ from that in an artery.

1 _____

_____

2 _____

_____ **(2)**

(b) Molecules of different substances differ in size. The relative molecular mass of a substance gives an indication of the size of its molecules. The table shows the relative permeability of the wall of a capillary to different molecules.

Substance	Relative molecular mass	Relative permeability of capillary wall
Water	18	1.00
Urea	60	0.96
Glucose	180	0.60
Haemoglobin	68 000	0.01
Albumin (plasma protein)	69 000	0
Globulin (plasma protein)	140 000	0

(i) Describe the relationship between molecule size and the permeability of the capillary wall.

_____

_____

_____

_____ **(2)**

(ii) The water potential of the plasma at the venule end of the capillary is more negative than the water potential at the arteriole end. Use the table to explain why.

_____

_____

_____

_____ **(2)**

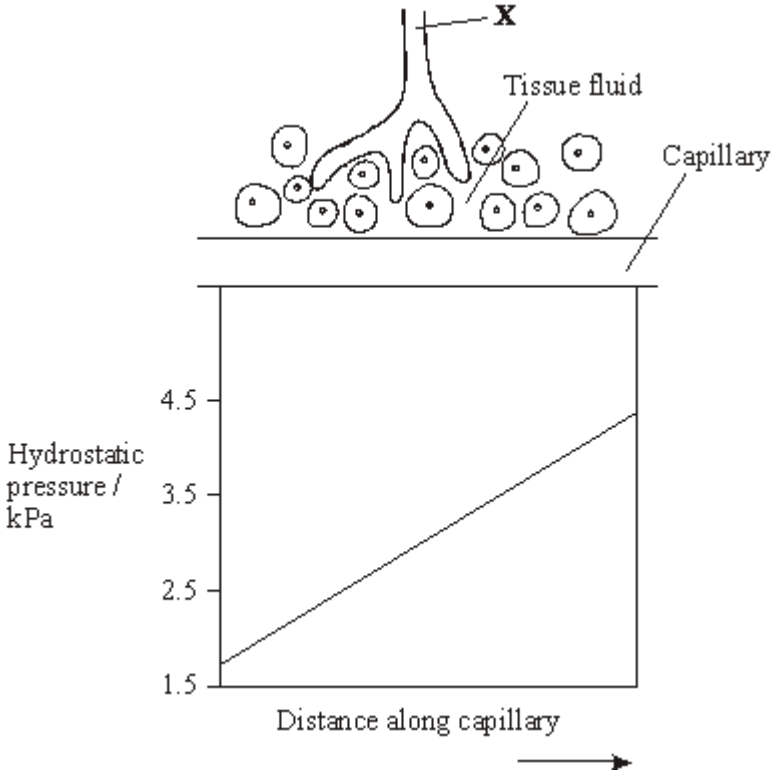
(iii) Although the capillary walls are slightly permeable to haemoglobin molecules, there is no haemoglobin in the tissue fluid. Explain what causes the absence of haemoglobin in tissue fluid.

_____

_____ **(1)**

(Total 9 marks)

Q25. The diagram shows vessels in a small piece of tissue from a mammal. The chart shows the hydrostatic pressure of the blood as it flows through the capillary.



(a) Name the fluid contained in vessel **X**. _____

(1)

(b) Draw an arrow on the capillary to show the direction of the flow of blood. Describe the evidence from the chart to support your answer.

_____

_____

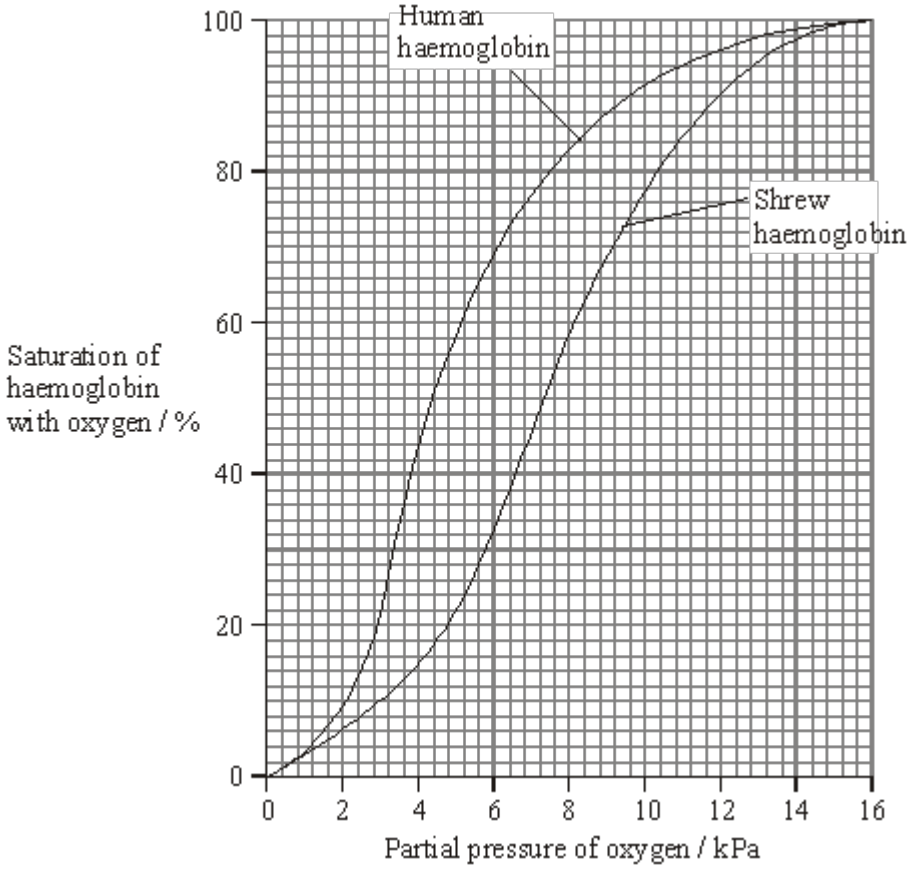
(1)

(c) Describe and explain how water is exchanged between the blood and tissue fluid as blood flows along the capillary.

_____

(4)

(d) Shrews are small mammals. Their tissues have a much higher respiration rate than human tissues. The graph shows the position of the oxygen haemoglobin dissociation curves for a shrew and a human.



Explain the advantage to the shrew of the position of the curve being different from that of a human.

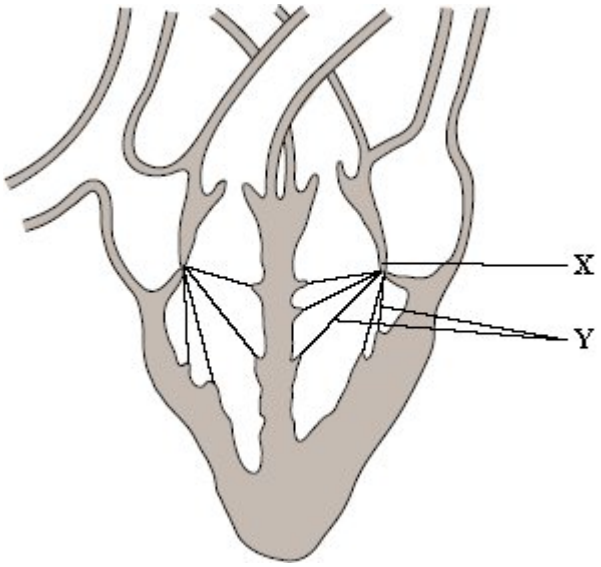
_____

_____

(3)

(Total 9 marks)

Q26. (a) The diagram shows a section through the heart at one stage of the cardiac cycle.



(i) Name the structure labelled **X**.

_____

(1)

(ii) Suggest how the structures labelled **Y** help to maintain the flow of blood in one direction through the heart.

_____

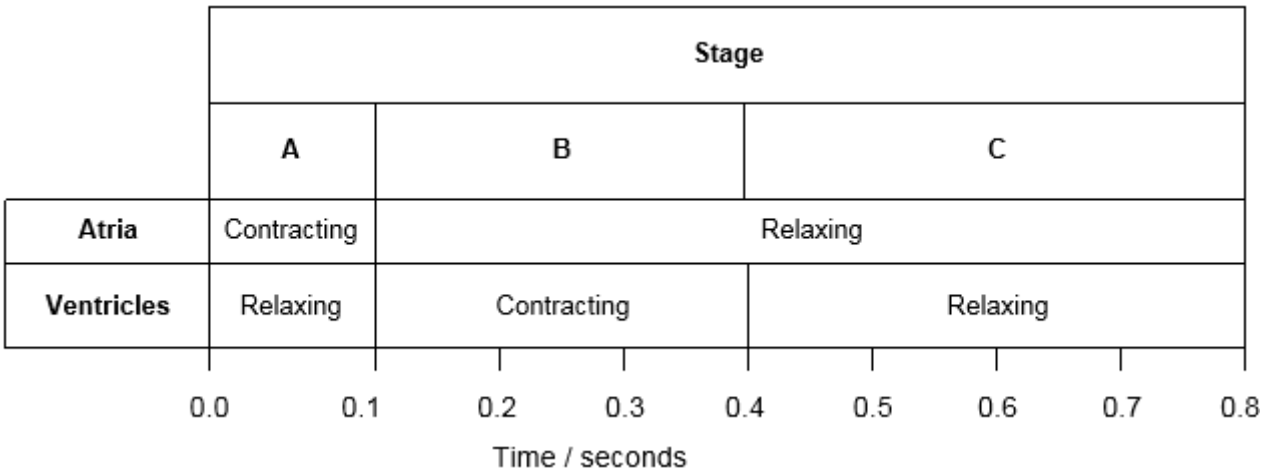
_____

_____

_____

(2)

(b) The chart shows the actions of the atria and the ventricles during a complete cardiac cycle. Different stages have been given letters and a time scale added.



(i) Give the letter of the stage which is shown in the diagram of the heart.

_____

(1)

(ii) The heart beats for one minute at the rate shown by the chart. Calculate the total time the ventricles are relaxed during one minute. Show your working.

Answer _____ seconds

(2)

(Total 6 marks)

Q27. (a) Haemoglobin is a protein with a quaternary structure. What is meant by a *quaternary* structure?

_____

_____

(1)

(b) Explain how oxygen in a red blood cell is made available for respiration in active tissues.

_____

_____

_____

_____

_____

_____

(3)

(c) Haemoglobin is broken down in the liver. One product of this breakdown is amino acids. Give **one** use in the body of these amino acids.

_____

(1)
(Total 5 marks)