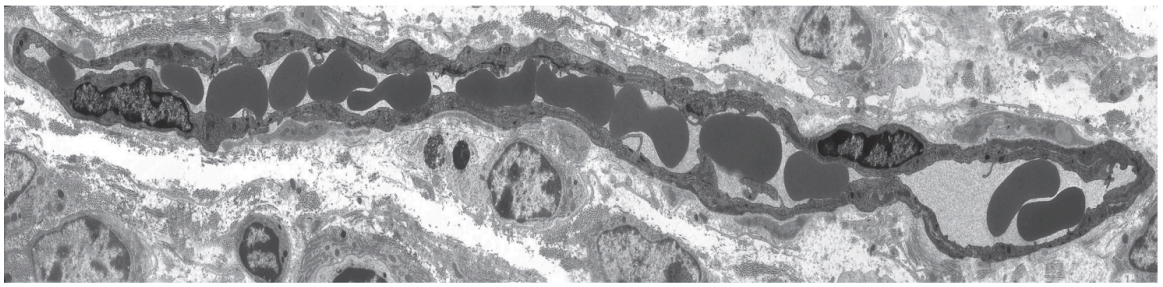
8. Transport in mammals

1.

Fig. 5.1 is a longitudinal section of a capillary in muscle tissue as viewed with a transmission electron microscope.



magnification ×2000

State the evidence, visible in Fig. 5.1, that identifies the cells inside the capillary as red blood cells.

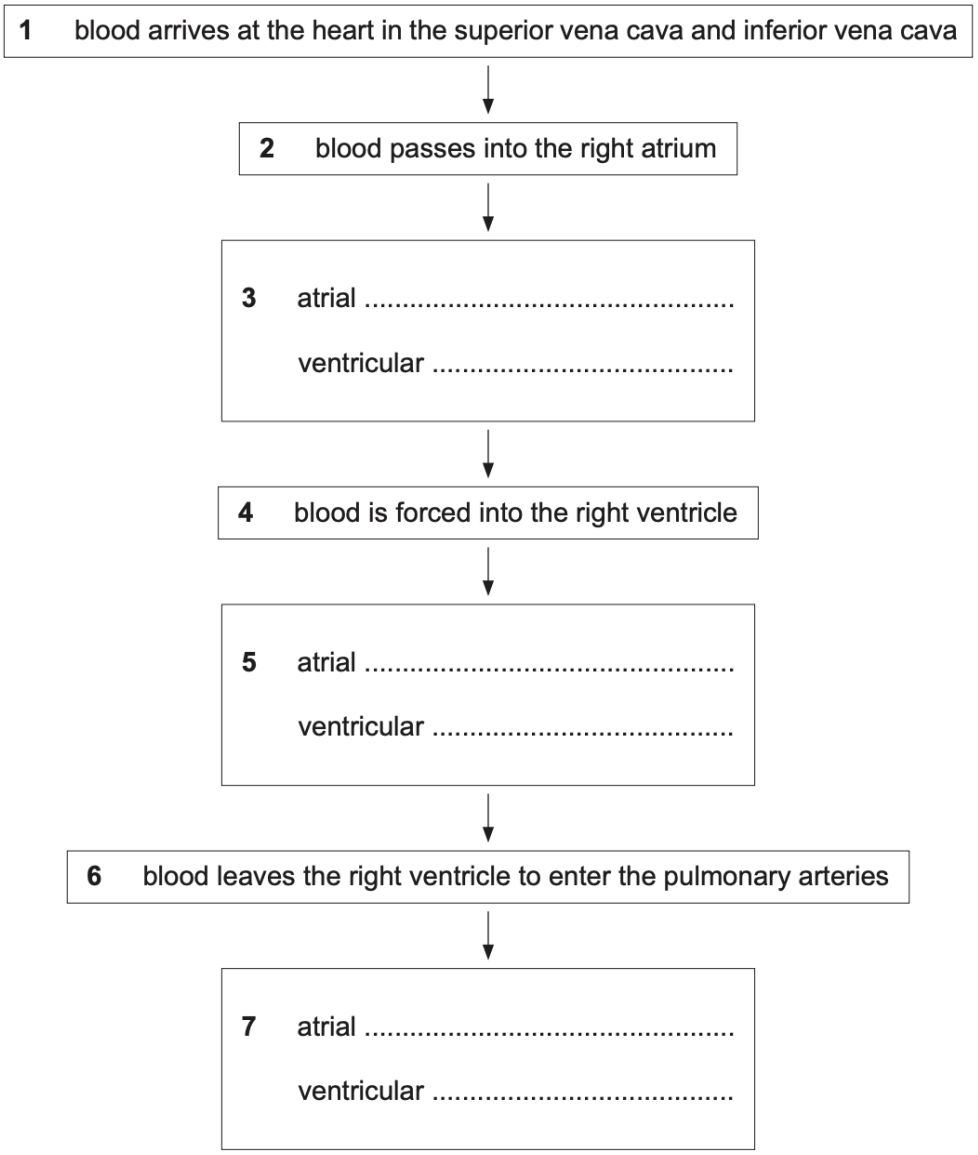
- no nucleus
- no organelles / uniform appearance / homogeneous cytoplasm
- (some are) biconcave shape
- same width / size as the lumen of the capillary

2. Explain how the structure of the capillary wall is related to its functions.
   - (wall is) thin / one cell thick / 1–2 μm in thickness
   - ref to endothelial cells / endothelium
   - short distance for diffusion
   - endothelial pores / fenestrations OR pores / gaps between endothelial cells of the wall
   - for passage of small molecules from / to plasma / blood / tissue fluid

3.

(a) Fig. 1.1 is a summary of blood flow through the **right** side of the heart during one cardiac cycle. Three boxes in Fig. 1.1 are **not** complete.

Complete boxes **3**, **5** and **7** in Fig. 1.1 using **only** the terms **systole** and **diastole**.



3 = (atrial) systole
(ventricular) diastole
5 = (atrial) diastole
(ventricular) systole ;

7 = (atrial) diastole
(ventricular) diastole ;

4. Impulses sent out by the SAN pass to the AVN, where there is a short delay. Explain why it is important for the control of the cardiac cycle that there is a short delay at the AVN after impulses have been sent out by the SAN.

- so atria and ventricles do not contract / are not in systole at the same time
- ventricles contract / are in systole after the atria
- this allows atria to empty completely / allows ventricles to fill

5. Changes in blood pressure occur in the heart during the cardiac cycle. These changes cause the opening and closing of the bicuspid and tricuspid (atrioventricular) valves and the aortic and pulmonary (semilunar) valves. Explain how blood pressure changes:
   • cause the opening of the tricuspid valve
   • cause the opening of the pulmonary valve
   • help the flow of blood through the heart.

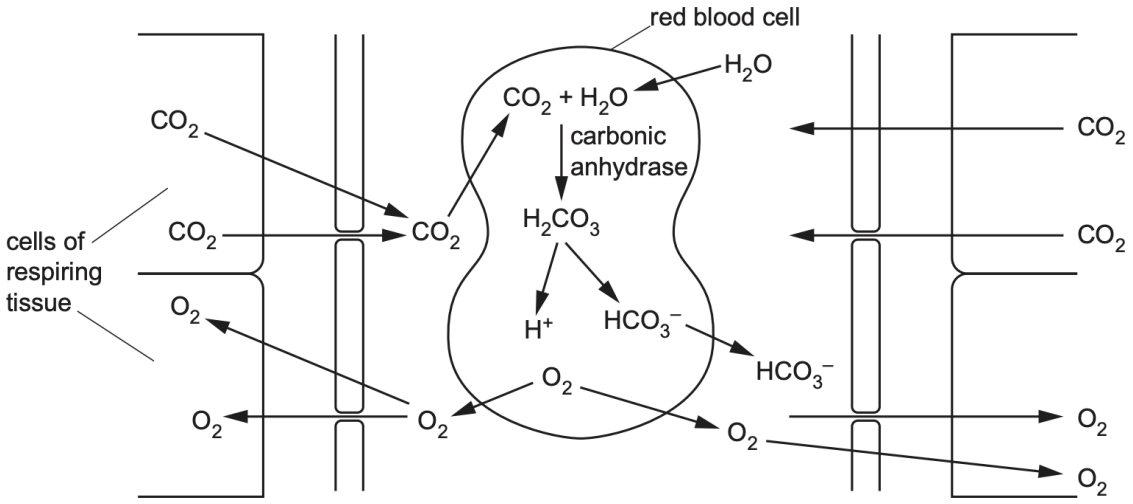
   <u>opening of tricuspid valve</u>
   - pressure in right atrium becomes higher than pressure in right ventricle

   <u>opening of pulmonary (semilunar) valve</u>
   - pressure in right ventricle becomes higher than pressure in pulmonary artery

   <u>help flow of blood through the heart</u>
   - one-way flow of blood / prevents backflow of blood: blood flows from atrium to ventricle to pulmonary artery / lungs
   - blood flows from area of higher pressure to area of lower pressure
   - blood pressure changes aid coordination: semilunar valve is open (about same time) when tricuspid valve is shut

6.

(c) Fig. 5.2 is a diagram showing some of the events that occur as blood flows through a capillary in a respiring tissue.



An increase in respiration results in an increase in the carbon dioxide

concentration in the blood and the release of more oxygen from red blood cells to tissues. Explain how an increase in carbon dioxide in the blood leads to the release of more oxygen from red blood cells.

- more CO_2 diffuses into red blood cells
- carbonic anhydrase catalyses the reaction between CO_2 and H_2O
- to form carbonic acid / H_2CO_3; more H_2CO_3 is formed by carbonic anhydrase
- formation of H^+ ions (together with HCO_3^- from dissociation of H_2CO_3)
- haemoglobin has a high affinity for H^+ ions; H^+ binds to haemoglobin to form haemoglobinic acid (HHb)
- formation of HHb decreases affinity of haemoglobin for oxygen; oxygen is displaced/ released from haemoglobin
- carbon dioxide binds to $-NH_2$ / N terminal of globin / polypeptides / α chains and β chains to form carbaminohemoglobin, which also lowers affinity
- allosteric effect / change in tertiary structure of oxyhaemoglobin causes, release of more oxygen

Chloride ions are a constituent of blood plasma. The concentration of chloride ions in the plasma of deoxygenated blood is between 2–4 mmol dm^{-3} lower than in the plasma of oxygenated blood. Explain why the concentration of chloride ions in the blood plasma of deoxygenated blood is lower than in the plasma of oxygenated blood.

- hydrogencarbonate ions / HCO_3^- pass out of red blood cells into the plasma to increase concentration in deoxygenated blood
- chloride ions pass into red blood cells
- to replace the negatively-charged ions / anions / HCO_3^- / to achieve electroneutrality / balance the electrical charge
- chloride shift
- AVP: chloride ions pass through channel proteins / transport proteins by facilitated diffusion

7. Chloride ions move across the membrane of human red blood cells in a process called the chloride shift. Explain why the chloride shift is important in the transport of carbon dioxide from respiring tissues.
   - hydrogen carbonate ions move out of red blood cells to be transported in plasma, and chloride ions move in
   - to maintain electrical neutrality inside cytoplasm / cell OR to balance the charges either side of membrane OR to prevent build-up of negative charge in cytoplasm
   - AVP: maintain equilibrium to increase reaction between carbon dioxide and water

8.

A person infected with HIV may develop a heart condition called cardiac tamponade.

The pericardium is a thin sac surrounding the heart, as shown in the healthy heart in Fig. 4.2. When a person develops cardiac tamponade, the pericardium starts to fill with blood. This prevents the ventricles functioning efficiently.

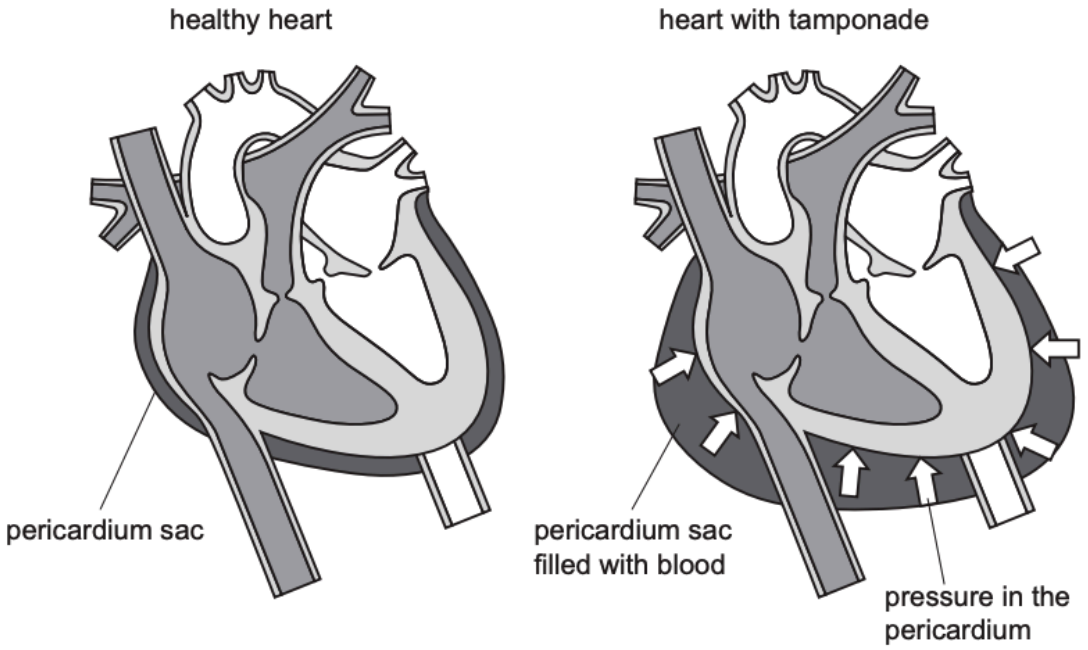


Fig. 4.2

People with cardiac tamponade experience a variety of symptoms including low blood pressure and an increased breathing rate.

Suggest why a person with cardiac tamponade would experience symptoms of low blood pressure and an increased breathing rate.

- compression on ventricles
- so volume of the ventricles reduces / ventricles cannot fully increase in size
- less blood filling / leaving ventricles each cardiac cycle
- ventricular contraction / systole less powerful / weaker / less forceful
- less blood pumped to the pulmonary / systemic circulation per contraction / cardiac cycle / unit time
- faster breathing rate to compensate for less oxygen diffusing into the blood // less carbon dioxide diffusing out of the blood // less oxygen delivered to the tissues
- faster breathing rate to try and increase quantity of oxygen absorbed in the lungs // increase quantity of carbon dioxide excreted
- AVP: heart / cardiac muscle does not receive enough glucose / oxygen

9. M. tuberculosis can spread in the blood and lymph to other organs in the body. In very rare cases, a disease known as mycotic aneurysm can be caused by

infection of the arterial wall, particularly in elastic arteries. The damage caused by the pathogen can lead to a rupture (bursting) of the artery. With reference to the structure of the wall of elastic arteries, suggest how damage caused by M. tuberculosis infection can lead to the rupture of the artery. You may draw a diagram if you wish.

- loss of / damage to elastic fibres and smooth muscle from tunica media OR scar tissue replaces elastic fibres / smooth muscle in tunica media
- loss of / damage to collagen fibres in tunica externa / adventitia ;
- cannot withstand high pressure / increase in pressure / pressure of blood
- overstretching / over-expansion
- impaired / poor / no recoil due to loss of elastic fibres

10.

Dromedary camels are classified in the family Camelidae and live in desert habitats of North Africa and Asia. In these hot, dry environments, dromedary camels can lose up to 30% of their body mass from dehydration, causing their blood to become more viscous (thicker).

Fig. 2.1 shows a drawing of red blood cells of a dromedary camel. Fig. 2.2 is a drawing of human red blood cells.

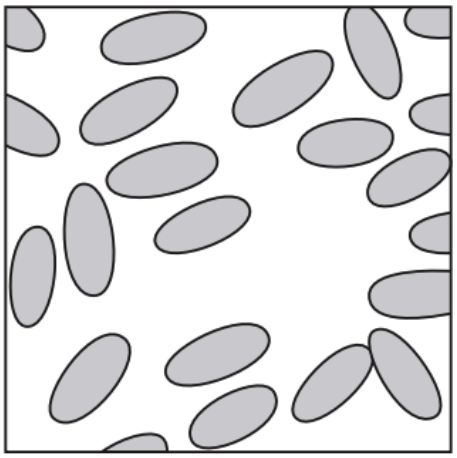


Fig. 2.1

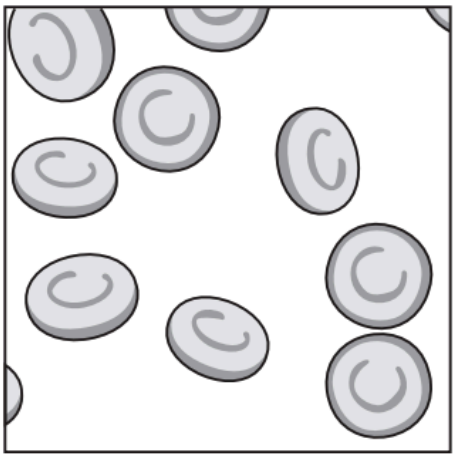


Fig. 2.2

Fig. 2.1 and Fig. 2.2 show differences between the red blood cells of dromedary camels and the red blood cells of humans. Suggest how these differences adapt dromedary camels for living in hot, dry environments.

- allows easier / quicker flow / movement of blood compared to human red blood cells

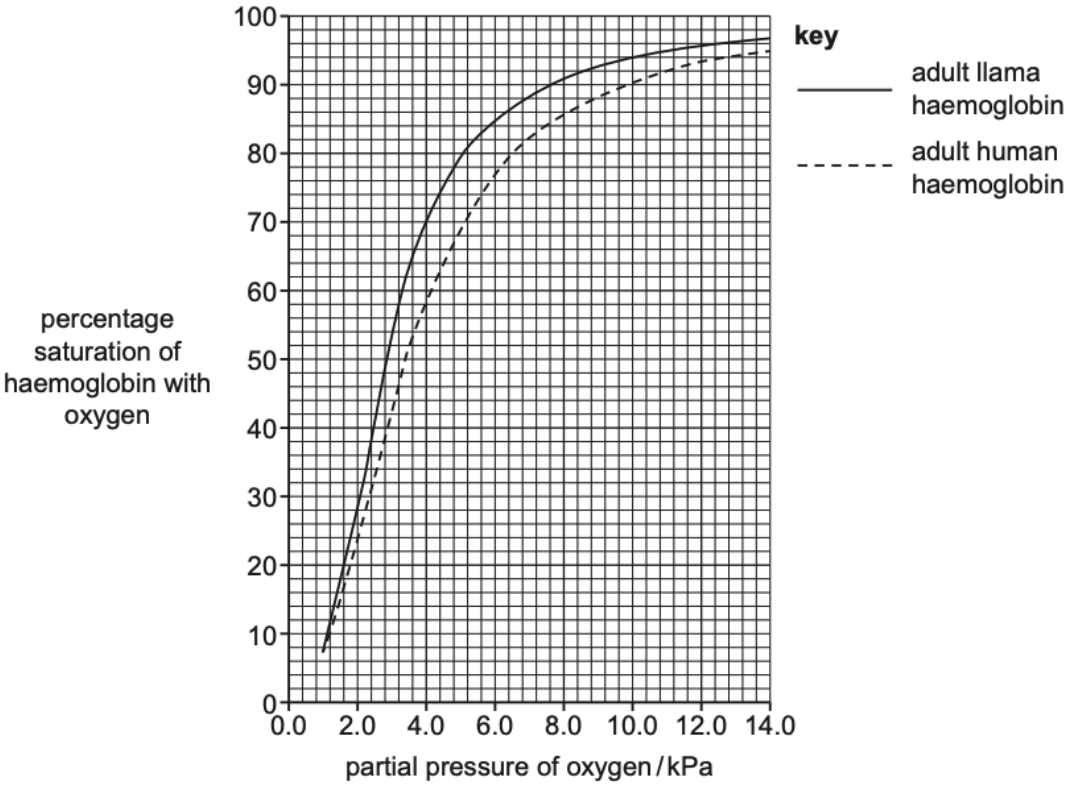
  plus any two explanations from :
- lozenge / torpedo / elliptical shape of camel red blood cells vs biconcave disc of human red blood cells
- camel red blood cells are smaller than human red blood cells
- larger number of camel red blood cells per unit volume

11.

(c) The llama is also classified in the family Camelidae. Llamas live in mountainous areas of South America, often at altitudes of 3500 m or higher. As the altitude above sea level increases, the air pressure decreases.

The partial pressure of oxygen in the lungs of mammals at 3500 m is 6.4 kPa.

Fig. 2.3 shows the oxygen dissociation curve of adult human haemoglobin and adult llama haemoglobin.



a. With reference to Fig. 2.3, explain how the differences between the oxygen dissociation curves for humans and llamas show that llamas are better adapted for living at high altitudes than humans.

- at high altitude haemoglobin of llama more highly saturated with oxygen than haemoglobin of human
- at 6.4 kPa / 3500 m, oxygen saturation is 86% for llama and 80% for human; 6 / 7% higher oxygen saturation for llama
- llama haemoglobin has a higher affinity for oxygen than human haemoglobin
- more oxygen transported / delivered to tissues
- so sufficient oxygen unloaded in tissues to satisfy demand

b. Sketch a curve on Fig. 2.3 to show the effect of an increased carbon dioxide concentration on the percentage saturation of adult human haemoglobin with oxygen.

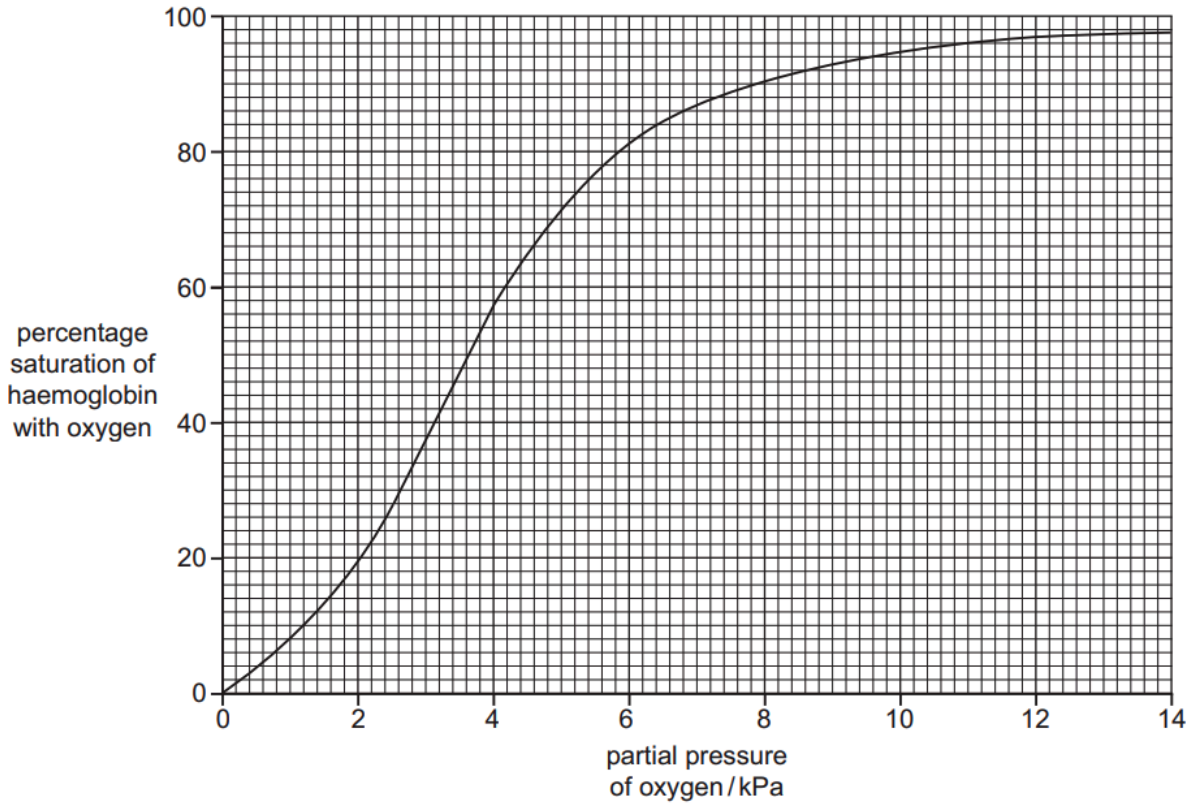
- curve drawn to the right of the human dissociation curve

12. Explain the importance of the Bohr shift in metabolically active organs, such as the liver.
    - metabolically active organs release more carbon dioxide / partial pressure of carbon dioxide is higher
    - decreased affinity of haemoglobin for oxygen / explained ; e.g. ref to haemoglobinic acid
    - more oxygen released
    - for more aerobic respiration / more ATP production

13.

(b) In the laboratory, oxygen at different partial pressures can be bubbled through a solution of haemoglobin to determine the percentage saturation of haemoglobin at each partial pressure. A graph constructed from the results is known as an oxygen dissociation curve.

Fig. 5.1 is an oxygen dissociation curve for **normal** adult haemoglobin in **humans**.



Using a different, more rapid technique, researchers compared the haemoglobin contained in red blood cells of a healthy person with the haemoglobin of a person with malaria who had been infected with P. vivax.
By analysing the results, the researchers concluded that the oxygen dissociation curve of a person with malaria would be shifted to the right.
With reference to Fig. 5.1, explain how a shift to the right of the oxygen dissociation curve would affect oxygen loading in the lungs, and unloading in respiring tissues, in a person with malaria.

- in a person with malaria affinity of haemoglobin for oxygen decreases

- lower (percentage) saturation of haemoglobin with oxygen
- more difficult to load oxygen in the lungs
- as higher partial pressure of oxygen needed to reach same percentage saturation of haemoglobin
- oxygen released more readily in respiring tissues // in tissues, more oxygen released at any one partial pressure

14. Describe how the size and structure of a red blood cell is related to its function, other than the fact that it contains a very large number of haemoglobin molecules.
    - diameter / width = 6–8 μm so able to pass through lumen of capillaries
    - small size / small diameter / just fits in a capillary, so in a line / one by one / which slows blood flow / maximises time to take up oxygen / reduces diffusion distance for uptake of oxygen
    - no nucleus / mitochondria // no organelles
    - so more space for haemoglobin
    - no mitochondria so oxygen is not used within cell (and can be transported)
    - flexible / can squeeze through / can deform / can change shape, to pass through capillary
    - biconcave
    - biconcave, so compared to spherical increased surface area for uptake of oxygen / gas exchange
    - biconcave, so reduce distance for diffusion of oxygen to haemoglobin

15. Describe the role of carbonic anhydrase in the transport of carbon dioxide

    <u>In respiring tissue:</u>
    - carbonic anhydrase catalyses the reaction between water and carbon dioxide in red (blood) cells / erythrocytes
    - to form carbonic acid, which dissociates to form HCO_3^- and H^+
    - HCO_3^- moves / passes / diffuses through membrane proteins from red blood cells into plasma
    - activity of enzyme maintains steep concentration gradient for diffusion of carbon dioxide into red blood cells
    - so helps to remove large quantities of carbon dioxide ;

    <u>in lungs</u>
    - carbonic anhydrase converts HCO_3^- back into carbon dioxide so can be excreted / removed / exhaled

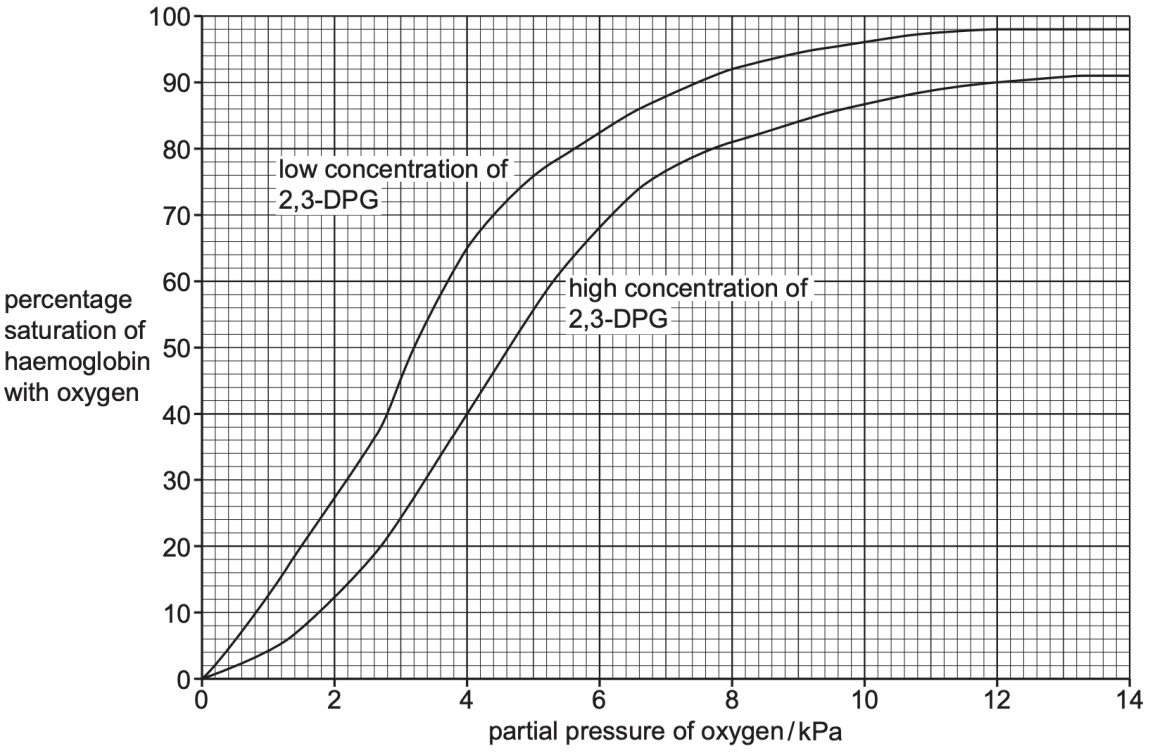
16. Explain how haemoglobin is involved in the transport of carbon dioxide molecules that are not converted to carbonic acid.
    - haemoglobin combines with / binds to / reacts with carbon dioxide

- carbon dioxide reacts with terminal amine groups / –NH2 of each chain / globin / polypeptide
- to form carbaminohemoglobin
- carbon dioxide is bound to Hb until in region of low pCO2 or high pO2 / pulmonary circulation / lungs / alveoli OR carbaminohaemoglobin dissociates / unbinds in the lungs

17.

(d) The compound 2,3-diphosphoglycerate (2,3-DPG) is produced in red blood cells. 2,3-DPG binds to haemoglobin and stabilises it.

Fig. 3.2 shows oxygen dissociation curves when red blood cells have high and low concentrations of 2,3-DPG.



a. P50 is the partial pressure of oxygen when haemoglobin is 50% saturated. The P50 is used to compare the affinity of haemoglobin for oxygen under different conditions. Use the information in Fig. 3.2 to describe the effect of an increase in the concentration of 2,3-DPG on the oxygen dissociation curve.

- curve shifts to the right and curve is lower
- haemoglobin is less saturated at every pO2 / higher pO2 required to reach same % saturation as low [DPG]

b. Blood is stored in blood banks for use in hospitals during operations. The concentration of 2,3-DPG in red blood cells decreases when blood is stored in a blood bank. State and explain the effect that the use of blood taken from a

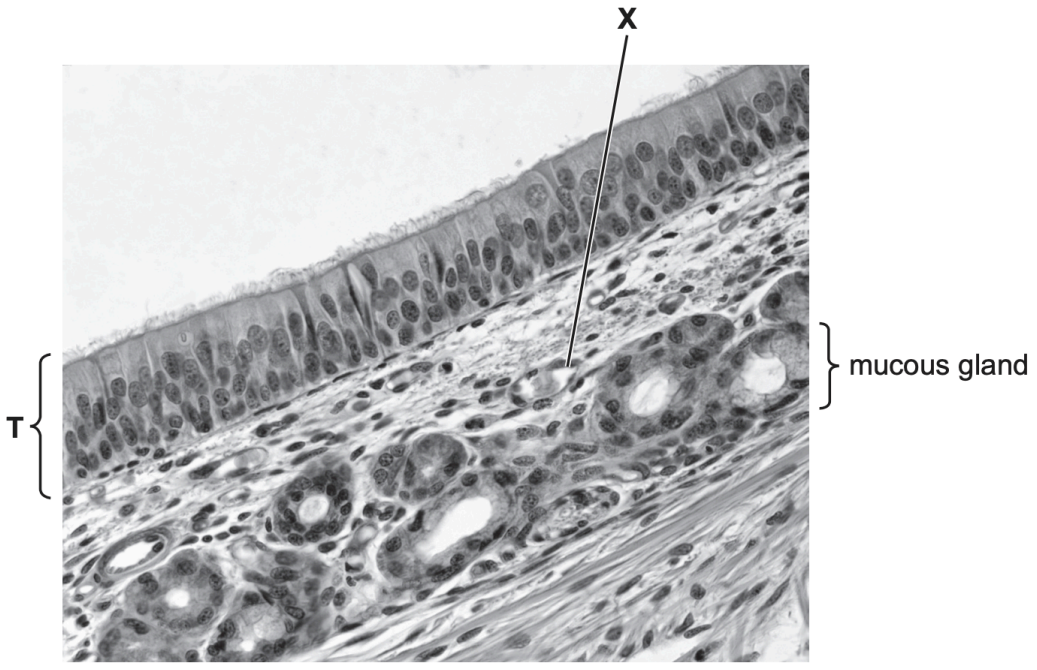
blood bank has on the supply of oxygen to the tissues of a person during an operation.

- less oxygen is available for tissues
- haemoglobin has a higher affinity for oxygen

18. The lower part of the trachea receives blood from arteries that branch from the aorta. Different arteries carry blood from the heart to the alveoli of the lungs. State the differences between the arteries supplying the lower part of the trachea and the arteries that supply blood to the alveoli of the lungs.

Arteries supplying blood to lower part of trachea	**Arteries supplying blood to alveoli of lungs**
carries oxygenated blood // blood with more oxygen	carries deoxygenated blood // blood with less oxygen
lower concentration of carbon dioxide	higher concentration of carbon dioxide
blood at higher pressure	blood at lower pressure
part of systemic circulation or branch from the aorta / originates from left ventricle	part of pulmonary circulation or pulmonary artery or from right ventricle of heart

19.



magnification ×360

20. Describe the structural features of tissue T.

- ciliated epithelium / ciliated epithelial cells / ciliated cells / cells with cilia
- detail (of ciliated epithelial cells):
    - e.g. columnar / description
    - cilia only facing the lumen / on apical lumen / lining the lumen
- goblet cells ;
- AVP:
    - basement membrane
    - pseudostratified (epithelium)
    - large nuclei
    - basal nuclei (in goblet cells)
    - nucleoli visible within nuclei

21. Identify structure X in Fig. 1.1 and outline the features that helped your identification.
    - blood vessel / capillary / venule
    - plus two from:
        - endothelium / endothelial cells
        - very thin / one cell thick walls
        - presence of red blood cells (in the lumen)
        - ref. to small size: e.g. narrow lumen / comparison to other tissues

22. State the precise location in the heart of the sinoatrial node.
    - wall / muscle of right atrium

23. State the part of the cardiac cycle that is directly initiated by the wave of excitation sent out by the sinoatrial node.
    - atrial systole / contraction

24. Part of the control of the cardiac cycle involves the contraction of the ventricle walls after the walls of the atria have finished contracting. Outline how this control is achieved.
    - AVN delays impulse / excitation wave from sinoatrial node
    - ring of non-conducting fibrous tissue prevents impulse from sinoatrial node directly passing to ventricles
    - impulse must pass through atrioventricular node / AVN
    - then passes to Purkyne tissue to ventricles for contraction

25. Explain why the ventricles have thicker walls than the atria
    - ventricles pump blood a greater distance / into the pulmonary and systemic circulations / to the lungs and to the body
    - ventricles have more cardiac muscle to pump blood at higher pressure / with more force than atria

- ventricles pump blood to overcome a higher resistance

26.

(b) Complete Table 6.1 to identify the structure in the heart responsible for each function listed.

Table 6.1

function	structure in the heart
initiates the heartbeat	
delays the wave of depolarisation between the atria and the ventricles	
transmits the wave of depolarisation through muscles of the ventricle	
closes when the left ventricle contracts	

function	structure in the heart
initiates the heartbeat	sinoatrial node ;
delays the wave of depolarisation between the atria and the ventricles	atrioventricular node and non-conducting tissue / AW (between atria and ventricles) ; **I** atrioventricular septum
transmits the wave of depolarisation through muscles of the ventricles	Purkyne / Purkinje, fibres / tissue ;
closes when the left ventricle contracts	left atrioventricular / bicuspid / mitral, valve ; **R** right atrioventricular valve **I** AV valves

27. Explain how the properties of water make it suitable as the main component of blood.
    - water is a good / universal solvent // dissolves many substances // dissolves (named) ions and (named) polar molecules
    - transport of one named substance for a correct reason: e.g. urea for excretion
    - high specific heat capacity: the amount of heat that must be added to one unit of mass of the substance / 1 gram or 1 cm3 of water to increase the temperature by one unit / 1 C
    - so temperature of blood remains (fairly) constant / heat is dispersed throughout the body
    - AVP: water is dipolar

28. Explain why the mammalian circulation is described as a closed, double circulation.
    - Closed = blood is contained within vessels

- Double = blood flows twice through the heart in one complete circuit/circulation of the body

29. Explain why it is important that the pressure of blood decreases as it passes through arterioles.
    - blood at high pressure will burst / damage capillaries
    - capillaries have thin walls / capillary walls are composed of one thin layer of endothelial cells // capillary walls are one cell thick
    - low pressure blood flows slowly to allow exchange / diffusion of substances (in capillaries)

30. Compare the structure of a muscular artery with the structure of an arteriole

    <u>Similarities</u>
    - both have endothelium / tunica intima / tunica interna
    - both have tunica media / smooth muscle

    <u>Differences</u>
    - muscular artery has smaller lumen to wall thickness / ratio of wall thickness to lumen width is smaller
    - muscular artery has wider lumen
    - muscular artery has more smooth muscle layers / thick layer of smooth muscle / thicker tunica media
    - more / presence of elastic fibres / tissue
    - more / presence of collagen fibres

31.

Fig. 1.2 is a photomicrograph of smooth muscle tissue in the wall of the intestines. A capillary is visible in addition to smooth muscle cells.

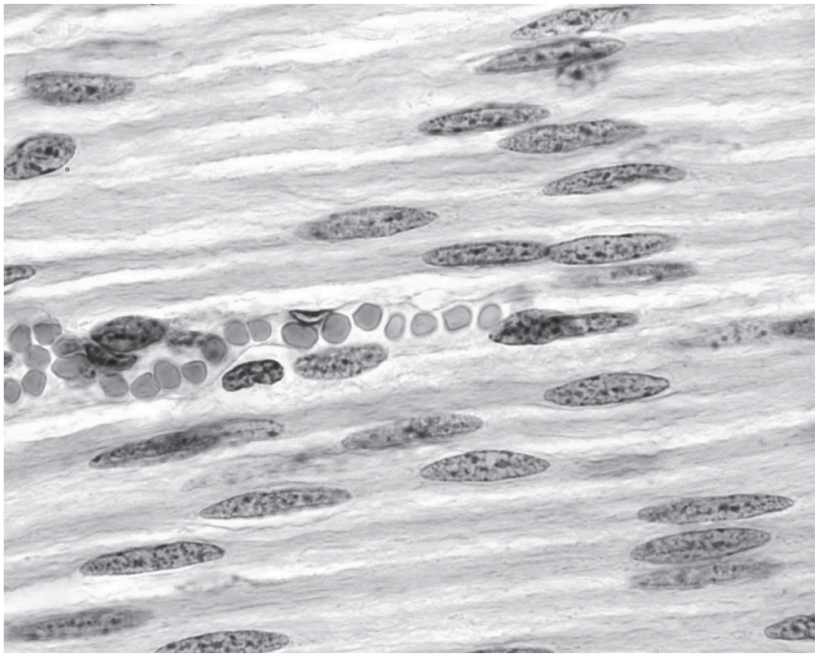


Fig. 1.2

Outline the features that help to identify the blood vessel in Fig. 1.2 as a capillary.

- wall is one cell thick // thin wall // endothelium is a single layer of cells
- red blood cells transported in single file
- red blood cells diameter approximately same as capillary lumen
- diameter of capillary narrower than smooth muscle cell
- AVP: no muscle and elastic layer // muscle fibres / elastic fibres / collagen not present

Explain how the structure of a capillary is related to its function in smooth muscle.

- capillary function: supply oxygen / nutrients / glucose / amino acids / cell-signalling molecule and removes carbon dioxide / lactic acid / waste OR exchange of respiratory gases between capillary and cells
- thin wall so short diffusion distance
- endothelial pores / fenestrations / gaps between endothelial cells of capillary wall for more efficient passage / to increase quantity / rate of supply of substances / for formation of tissue fluid around cells
- endothelial pores for passage of phagocytes / monocytes / macrophages / neutrophils
- small / narrow diameter to reach cells / so all cells are close
- narrow lumen slows red blood cell movement for uptake of oxygen // to increase time for exchange of gases

- only one red blood cell fits (at a time) so short diffusion distance

32. Describe the differences between the blood arriving at the arterial end of the capillary network and the tissue fluid surrounding the body cells.

any three from

blood	**tissue fluid**	
has red blood cells	has no red blood cells	;
more, white blood cells / leucocytes / named e.g. neutrophils, lymphocytes, monocytes **or** fewer macrophages	fewer white blood cells / leucocytes / named e.g. neutrophils, lymphocytes, monocytes **or** more macrophages	;
has platelets	has no platelets	;
has, more protein / large proteins **or** has, plasma proteins / named example e.g albumin / fibrinogen / globulin *these are large proteins*	has, fewer / no large, proteins **or** has no, plasma proteins / named example e.g. albumin / fibrinogen / globulin *only allow <u>fewer</u> plasma proteins if clear the proteins present are small enough to leave blood*	;
higher, concentration / AW, oxygen **A** more oxygenated	lower, concentration / AW, oxygen **A** less oxygenated	;
higher, concentration / AW, glucose / amino acids / fatty acids	lower, concentration / AW, glucose / amino acids / fatty acids	;
lower, concentration / AW, carbon dioxide **A** urea, in liver / muscles **I** waste	higher, concentration / AW, carbon dioxide **A** urea, in liver / muscles **I** waste	;
higher pressure	lower pressure	;