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About AS LEVEL BIOLOGY

Paper 2

(TOPICAL)

About Learning Corner

This section reveals the extra/relevant information that are not required as part of the model answers but to expand the student's knowledge in the respective fields. At the same time, it induces eagerness and interest into their learning process.

period 2010 to 2025
contents June & November, P2, Worked Solutions
form Topic By Topic
compiled for AS Levels
special features Learning Corner

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☞ *AS LEVEL*

REVISION

June / November 2025 Paper 2

TOPIC III

Enzymes

Enzymes are essential for life to exist. The mode of action of enzymes and the factors that affect their activity are explored in this topic. Prior knowledge for this topic is an understanding that an enzyme is a biological catalyst that increases the rate of a reaction and remains unchanged when the reaction is complete.

There are many opportunities in this topic for candidates to gain experience of carrying out practical investigations and analysing, interpreting and evaluating their results.

CONTENT	CANDIDATES SHOULD BE ABLE TO:
3.1 Mode of action of enzymes	1 state that enzymes are globular proteins that catalyse reactions inside cells (intracellular enzymes) or are secreted to catalyse reactions outside cells (extracellular enzymes) 2 explain the mode of action of enzymes in terms of an active site, enzyme–substrate complex, lowering of activation energy and enzyme specificity, including the lock-and-key hypothesis and the induced-fit hypothesis 3 investigate the progress of enzyme-catalysed reactions by measuring rates of formation of products using catalase and rates of disappearance of substrate using amylase 4 outline the use of a colorimeter for measuring the progress of enzyme-catalysed reactions that involve colour changes
3.2 Factors that affect enzyme action	1 investigate and explain the effects of the following factors on the rate of enzyme-catalysed reactions: • temperature • pH (using buffer solutions) • enzyme concentration • substrate concentration • inhibitor concentration 2 explain that the maximum rate of reaction (V_{max}) is used to derive the Michaelis-Menten constant (K_m) which is used to compare the affinity of different enzymes for their substrates 3 explain the effects of reversible inhibitors, both competitive and non-competitive, on enzyme activity 4 investigate the difference in activity between an enzyme immobilised in alginate and the same enzyme free in solution, and state the advantages of using immobilised enzymes

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Question 1

Fig. 4.1 shows the primary structure of a lysozyme molecule, an enzyme found in tears, saliva and in lysosomes.

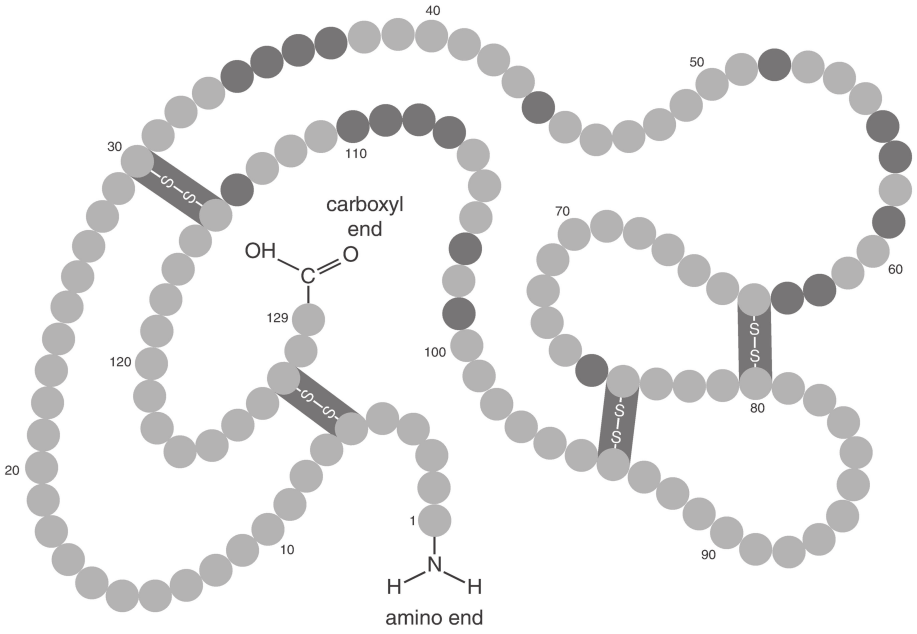
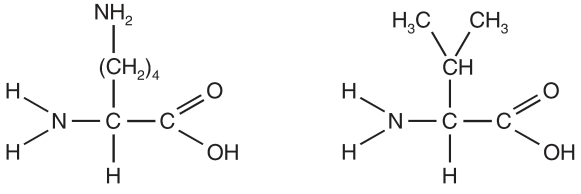


Fig. 4.1

(a) **(i)** Explain what is meant by the term *primary structure*. [1]

(ii) The molecular structure of the first two amino acids of lysozyme, lysine and valine, is shown below.

Use the space to show how these amino acids become linked in a condensation reaction.



lysine valine [3]

(b) Proteins, such as the enzyme lysozyme, have a secondary structure and a tertiary structure.

(i) Describe the secondary and tertiary structure of an enzymatic protein, such as lysozyme. [5]

(ii) State why it is important for enzymes, such as lysozyme, to possess a tertiary structure. [1]

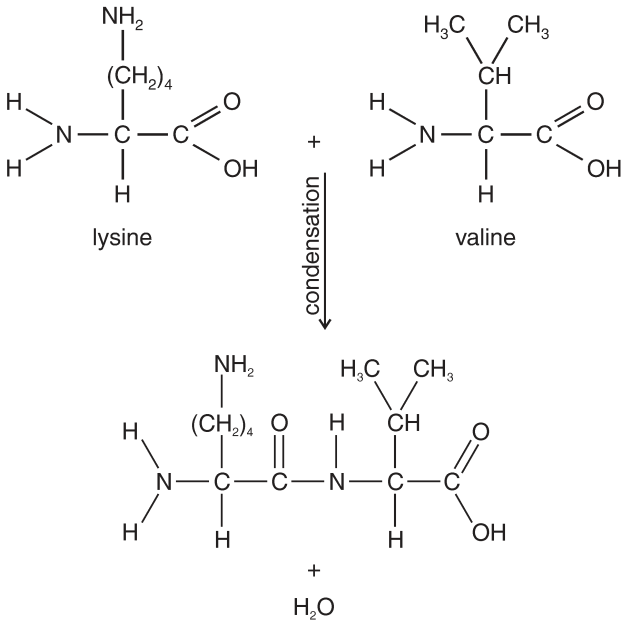
(c) Some people have a rare disease caused by a single change in the DNA nucleotide sequence of the gene coding for lysozyme. The change leads to the formation of an insoluble protein that has a different structure to the normal soluble lysozyme molecule. Suggest how a change in the gene can lead to the differences observed between the normal lysozyme and the changed lysozyme. [3]

[Total: 13] (J10/P2/Q4)

Solution

(a) (i) Primary structure shows the order or arrangement (or sequence) of amino acids in a polypeptide chain.

(ii)



(b) (i) *secondary:* Structure has a regular pattern/order developed by hydrogen/H-bonds. These bonds are made between co-group of one amino acid and NH-group of another amino acid. Alpha (α) helices and Beta (β)-pleated sheets are formed in secondary structure.

tertiary: Structure is formed by folding and coiling of secondary structure due to interactions between amino acids, i.e., hydrogen, ionic, disulphide bonds and nonpolar or hydrophobic interactions. Due to folding by different bonds, specific shape of specific/active sites is formed. Protein develops globular shape which is some what like a sphere. Amino acids with hydrophilic or polar groups form different type of bonds.

(ii) Tertiary structure enables protein to function because it provides active site.

(c) Due to mutation, a DNA triplet is changed and mRNA codon or triplet is altered. As a result a different amino acid is incorporated. If a stop condon is formed, then polypeptide chain may be shortened. A different primary structure formed shows different properties. Due to R groups of replaced amino acids an altered tertiary structure is formed. Active site may be changed. Such lysozyme may not function due to different properties.

Answer Tips

(a) (i) Sequence of amino acids in a polypeptide chain is encoded by sequence of nucleotides in DNA. Hence, primary structure is determined by DNA.

(ii) Peptide bond is form-ed between carboxyl (—COOH) group of lysine and amino group (—NH_2) of valine to make a dipeptide of lysine and valine. In condensation reaction water is also released.

(b) (i) Disulphide bonds are formed between S—H groups of cysteine residues. Ionic bonds are formed between ionised amino and carboxylic acid groups. Hydrogen bonds develop due to polar NH— and CO— groups. Hydrophobic or nonpolar interactions occur between nonpolar side chains.

(ii) Tertiary structure provides specificity and lysozyme functions as a biological catalyst and enables its antimicrobial action.

(c) Mutation in which a single nucleotide is changed in DNA is called point mutation. Due to point mutation, differences in transcription and translation may occur. Different R groups develop interactions which are not already formed. Even shape of a globular protein may change to fibrous protein.

Question 2

(a) Outline how an enzyme can be immobilised in alginate. [2]

(b) State two advantages, other than stability, of using an immobilised enzyme in an industrial process compared with the same enzyme that has not been immobilised. [2]

(c) Papain is a protease enzyme. Its activity at different temperatures, when immobilised onto an inert support, was compared with its activity in solution.

The results are shown in Fig. 2.1.

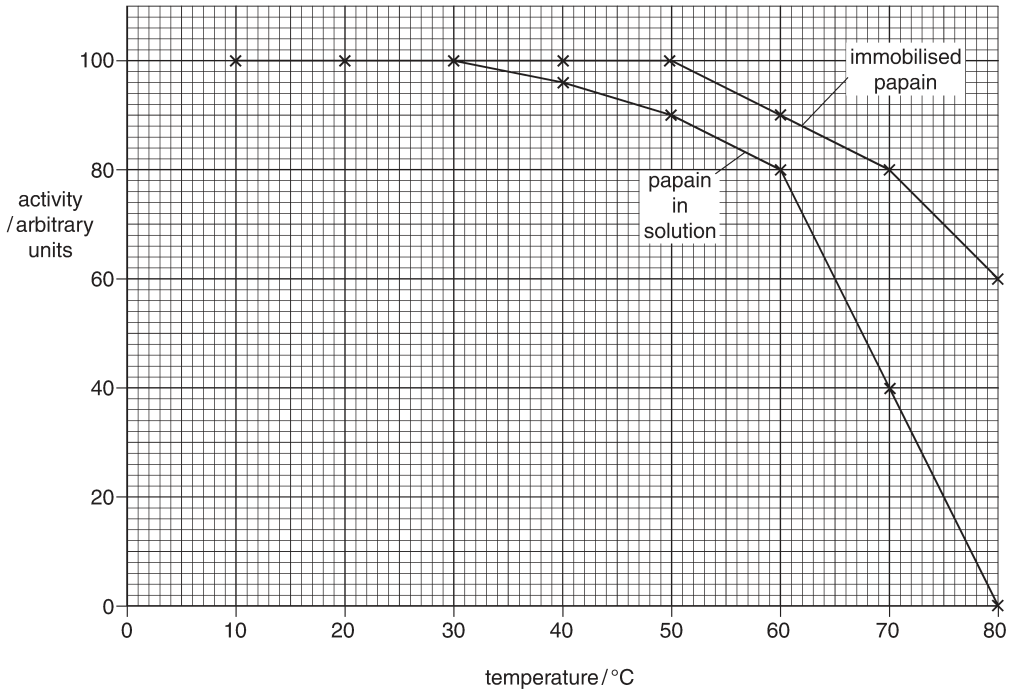


Fig. 2.1

With reference to Fig. 2.1, describe **and** explain the differences in activity of immobilised papain and papain in solution. [4]

[Total: 8] (J11/P4/Q2)

Solution

(a) A certain volume of enzyme solution is mixed with certain volume of sodium alginate solution and then the resultant mixture would be added drop-wise to a solution of calcium chloride using a syringe or a glass rod. It will make jelly-like beads containing the enzyme molecules.

(b) 1. Contamination of product by the enzyme would not occur and product can be easily purified.

2. Enzyme can be repeatedly used as it is not lost.

(c) At high temperature, i.e., above 30° C, immobilised papain is more active than papain in solution (which is comparatively less active). For example at 50° C, immobilised papain is 100% active while papain in solution is 90% active. Main reason for being more active is the inert support (like alginate beads) which protects the enzyme, so its tertiary structure and active site is stabilised. There are lesser chances of denaturation at high temperatures as its hydrogen bonds vibrate less and break less easily.

Question 3

Polysaccharides are synthesised by condensation reactions between monosaccharide or disaccharide subunits (monomers).

(a) Name the type of bond formed when polysaccharides are synthesised. [1]

(b) Disaccharides are formed following synthesis from monosaccharides or as a result of polysaccharide hydrolysis.
Cellobiose, maltose, sucrose and trehalose are four different disaccharides found in nature. Fig. 4.1 shows the molecular structure of these disaccharides.

Answer Tips

(a) Beads of sodium alginate containing enzyme fall in calcium chloride solution and soon sink to the bottom of the container.

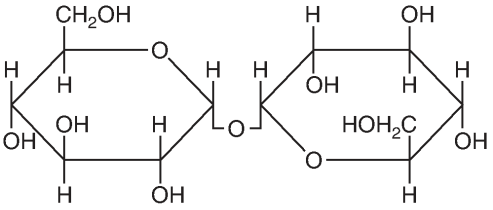
(b) Some other advantages include longer shelf life, use in continuous culture and more cost-effective as new enzymes would not need to be bought quite often.

(c) At 60 °C, papain in solution shows 80% activity while papain onto inert support shows 90% activity. At 70 °C, immobilised papain has 80% activity while papain in solution has 40% activity.

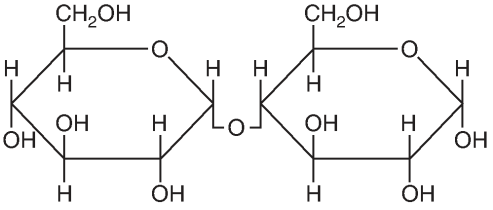
Identify the disaccharides, labelled **A** to **D**, using the information below.

- The disaccharide cellobiose is formed from the hydrolysis of the polysaccharide cellulose.
- When cellobiose is hydrolysed, two **β-glucose** molecules are produced.
- One of the disaccharides is sucrose.
- Trehalose is a disaccharide that is synthesised from two **α-glucose** molecules.
- The disaccharide maltose is formed from the hydrolysis of amylose, a component of starch.

Write the name of the disaccharides in the spaces provided on Fig. 4.1.



A .....



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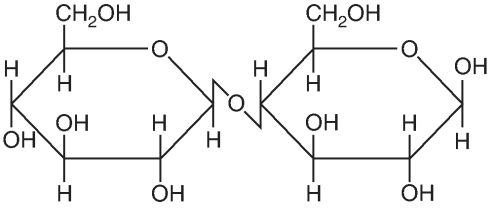
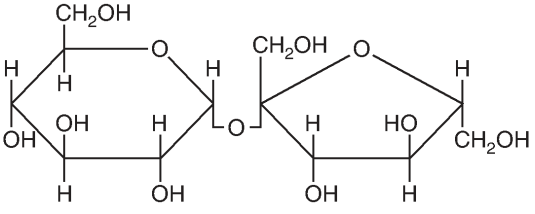


C .....



D .....

[3]

Fig. 4.1

In some organisms, trehalose is used as an energy store and gives protection against the harmful effects of very low temperatures. Trehalose is sometimes referred to as a cryoprotectant, allowing organisms to survive in freezing conditions.

Freezing temperatures can damage the cell surface membrane and membranes within the cell.

(c) Explain the importance of the cell surface membrane to cells. [3]

(d) Freezing temperatures can also completely stop enzyme activity by causing the molecules to undergo 'cold denaturation'. Enzyme activity is not recovered when temperatures are increased to a normal working temperature range.

(i) Explain the mode of action of enzymes. [3]

(ii) Suggest how the molecular structure of the enzyme changes during 'cold denaturation'. [2]

(e) Cryoprotectants, such as trehalose, are of particular interest in their application to preserving cells, tissues or organisms for future use.

An investigation was carried out to find the protective effect given by different concentrations of two cryoprotectants, trehalose and glycerol, on a respiratory enzyme.

The enzyme was subjected to a freezing temperature and then returned to its optimum temperature. The activity of the enzyme was measured at its optimum temperature.

Fig. 4.2 is a graph showing the results of the investigation.

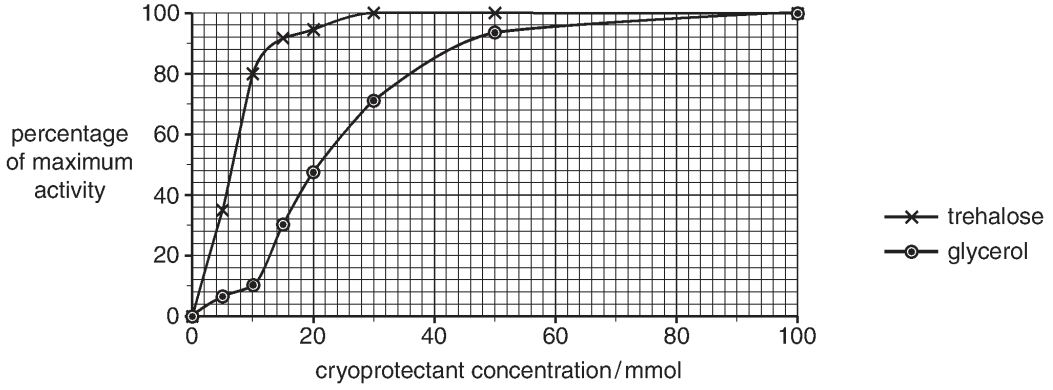


Fig. 4.2

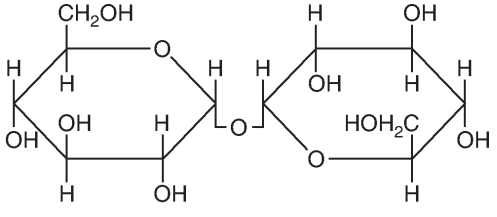
With reference to Fig. 4.2, **describe** the results of the investigation. [4]

[Total: 16] (J13/P2/Q4)

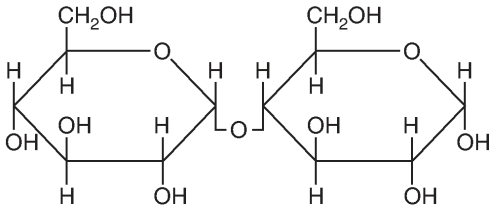
Solution

(a) Glycosidic or glucosidic.

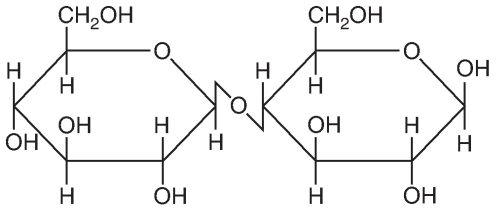
(b)



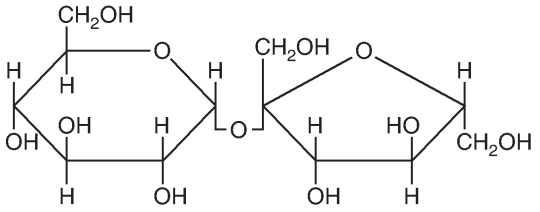
A trehalose



B maltose



C cellobiose



D sucrose

(c) Cell surface membrane separates the cell from surroundings or it acts as a barrier between cell contents and external environment. It regulates or controls the entry and exit of substances, e.g., polar or non-polar substances. Due to carbohydrate chains of glycoproteins and glycolipids, it enables recognition of self antigens or cell recognition. It allows binding of receptors for hormones, signal molecules, neurotransmitters and antigens. It also allows cell to cell adhesion, and provides location for enzyme, multi-enzyme systems or enzyme pathways.

(d) (i) Enzymes are specific having particular shape of their active site where substrate can bind. Active site is complementary to substrate so a substrate can fit into it. Sometimes enzymes bind with substrates by induced fit mechanism. When a substrate is held in the active site by hydrogen-bonding, enzyme-substrate complex is formed. Enzymes can lower the activation energy (Ea) of reaction, so rate of reaction increases and products are formed at a higher rate.

(ii) In severe cold, loss of tertiary or globular structure of enzyme occurs. Hydrogen bonds as well as ionic bonds are broken. Thus, 3-D shape of enzyme and its active site changes and substrate is unable to fit into it. Hydrophobic groups move to outside of molecule and hydrophilic groups no longer interact with water.

(e) Without any cryoprotectant, enzyme remains inactive, as it shows 0% activity at 0 mmol of cryoprotectant. For both cryoprotectants, by increasing concentration, enzyme activity increases or enzyme is recovered, as trehalose shows steeper curve upto 10 mmol concentration, while at all concentrations below 90 mmol, trehalose has higher percentage of maximum enzyme activity. As concentration of trehalose increases from 0 to 10 mmol, its percentage activity goes to 80% while for glycerol it goes to 10%. Both cryoprotectants can produce 100% or maximum enzyme activity. Trehalose produces 100% enzyme activity or full enzyme recovery at lower concentration than glycerol, i.e., at 30 mmol compared to 90-100 mmol of glycerol. So trehalose is more effective than glycerol, i.e., upto 90-95 mmol cryoprotectant. So trehalose is a better cryoprotectant than glycerol.

Answer Tips

(c) Carbohydrate chains on cell surface avoid cell destruction and act as antigens. Glycoproteins and glycolipids form hydrogen bonds with water for stability of membranes. For some cells, membranes provide flexibility.

(d) (i) Substrates are held closer together for bond formation at the active site, which facilitates transfer of electrons. It also places strain on bonds to be broken.

(ii) As enzyme changes its shape so does the active site alters its complementary shape to substrate.

(e) Trehalose and glycerol are cryoprotectants that have a protective effect for a respiratory enzyme which has been subjected to freezing temperature and then returned to optimum temperature. Trehalose allowed 100% of maximum activity to be restored.

Question 4

Keratin and chitin are two important biological molecules. Keratin is found in hair, fur and skin. Chitin is a modified polysaccharide found in a number of different organisms, for example in fungal cell walls and the hard outer skeletons of insects.

(a) Features of chitin and keratin are shown in the boxes in Fig. 2.1.

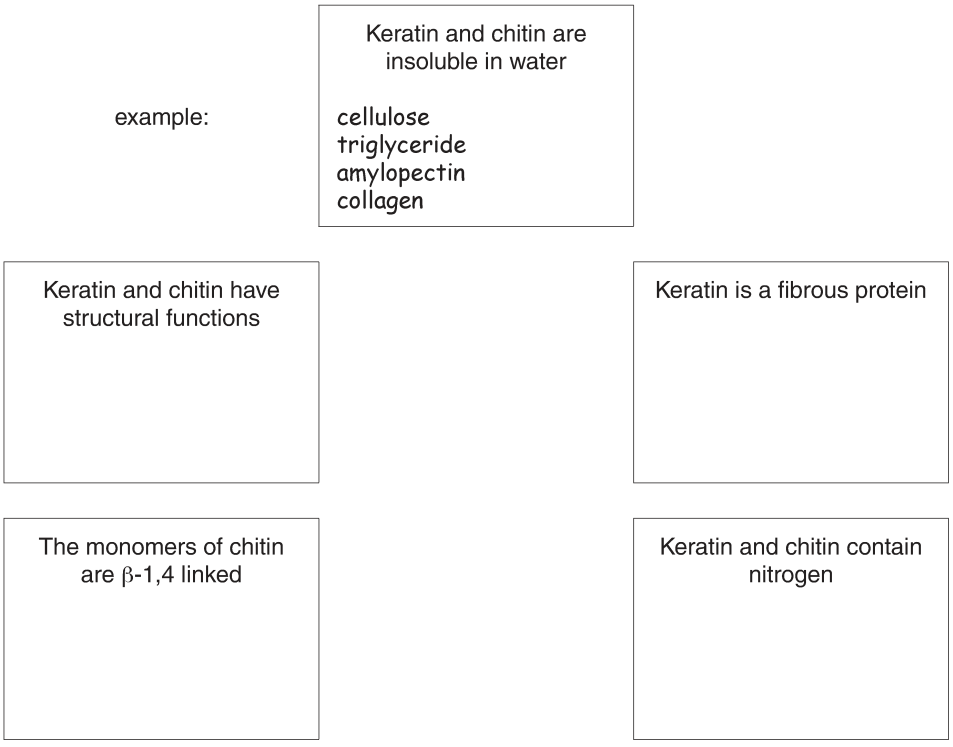


Fig. 2.1

Write, in each box, the biological molecules from the list below that have the same feature.

Each box may contain one, or more than one, biological molecule. The first box has been completed as an example.

amylopectin
cellulose
collagen
haemoglobin
mRNA
triglyceride

[5]

(b) Chitin and the products of chitin hydrolysis have many useful medical and environmental applications. Chitinase enzymes can be used commercially to hydrolyse chitin. Enzyme stability and activity are important considerations in technological applications of chitinase.

Fig. 2.2 is a graph showing the effects of temperature on chitinase extracted from a soil bacterium.

The relative activity of the enzyme was measured at different temperatures, with 100% representing maximum enzyme activity.

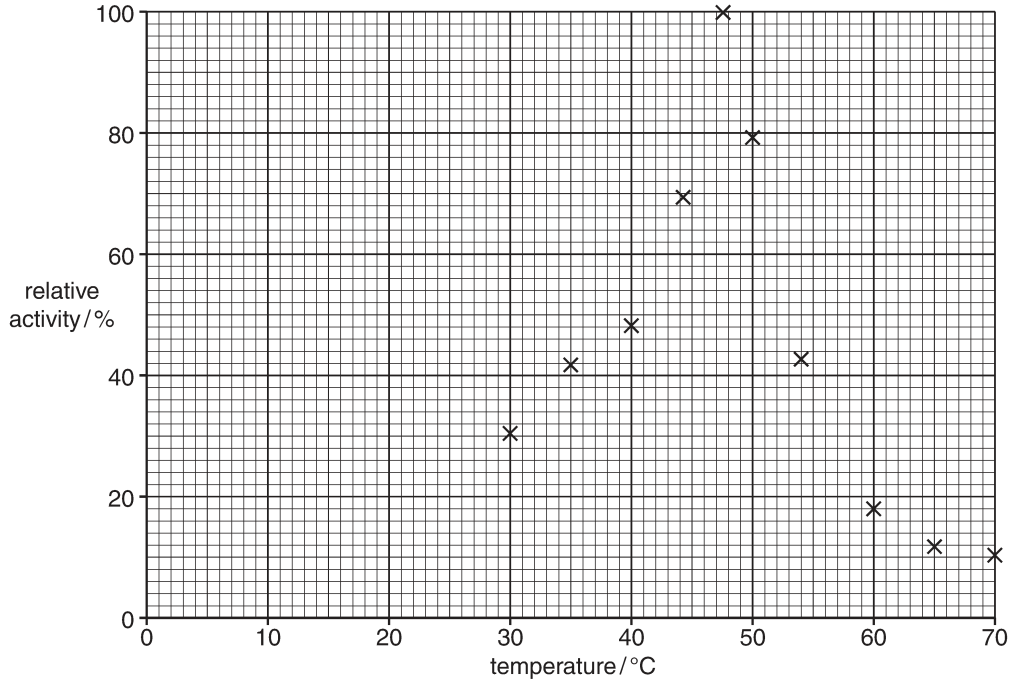


Fig. 2.2

(i) With reference to Fig. 2.2, state the optimum temperature for the chitinase enzyme. [1]

Fig. 2.3 is a graph showing how temperature affects the stability of chitinase. The activity of the enzyme was measured over a time period of 72 hours at each of five different temperatures.

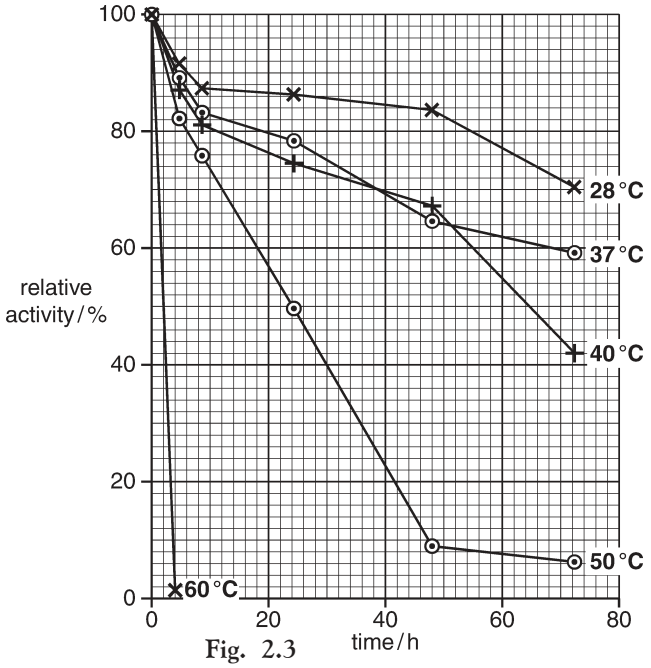


Fig. 2.3

(ii) With reference to Fig. 2.2 and Fig. 2.3, describe **and** discuss the effect of temperature on chitinase activity **and** stability. [5]

[Total: 11] (N13/P2/Q2)

Solution

(a)

Keratin and chitin have structural functions cellulose collagen	Keratin is a fibrous protein collagen
The monomers of chitin are β-1,4 linked cellulose	Keratin and chitin contain nitrogen collagen / haemoglobin mRNA

(b) (i) 47.5 °C

(ii) Relative activity of enzyme increases at different temperatures as temperature increases. Activity increases from 30 °C up to optimum, 47.5 °C and then decreases to 70 °C. At higher temperatures, enzyme is still active compared to most others. There is high optimum temperature compared to most other enzymes. Enzyme becomes less stable over time as activity decreases over time. Stability over time for enzyme is maintained at different temperatures For example, for 28 °C relative activity at 20 hours is 86% and 85% at 40 hours. However for 50 °C, relative activity decreases from 100% to 9% within 48 hours. Over the time period, at lower temperature, the enzyme is more stable. Enzyme has higher activity at lower temperatures, e.g., at 28 °C, enzyme has highest activity, so it is most stable. Due to increasing temperature, kinetic energy increases and there are more collisions up to optimum and at 60-70 °C, enzyme is denatured, so activity decreases. More molecules become denatured as time progresses. For hydrolysis to occur over long period of time, it is better to use lower temperature than optimum.

Answer Tips

(b) Activity decreases abruptly from 100% to 2% in 4 hours at 60 °C. Activity remains comparatively stable for first 50 hours at temperatures 28, 37 and 40 °C. At 28 °C, there is higher activity than 40 °C throughout the time period. Greater stability or higher activity is shown at 40 °C than 37 °C between 40-50 hours. Steep decrease in stability at 60 °C in short time is due to fast denaturation of enzyme.

Question 5

Many microorganisms can digest cellulose by using a group of enzymes collectively known as cellulases. Cellobiose is the disaccharide produced during cellulose digestion.

The cellulase known as β-glucosidase completes the digestion of cellulose by hydrolysing the cellobiose molecule to produce two β-glucose molecules.

(a) Draw the ring structure of one β-glucose molecule in the space provided. [2]

(b) β-glucosidase was extracted from two different bacteria, *Agrobacterium tumefaciens* and *Thermotoga maritima*.

Fig. 4.1 shows the results of an investigation into the effect of temperature between 0 °C and 100 °C, on the activity of each enzyme.

- **L** represents the lowest temperature at which activity of each enzyme was detected.
- **H** represents the highest temperature at which activity of each enzyme was detected.

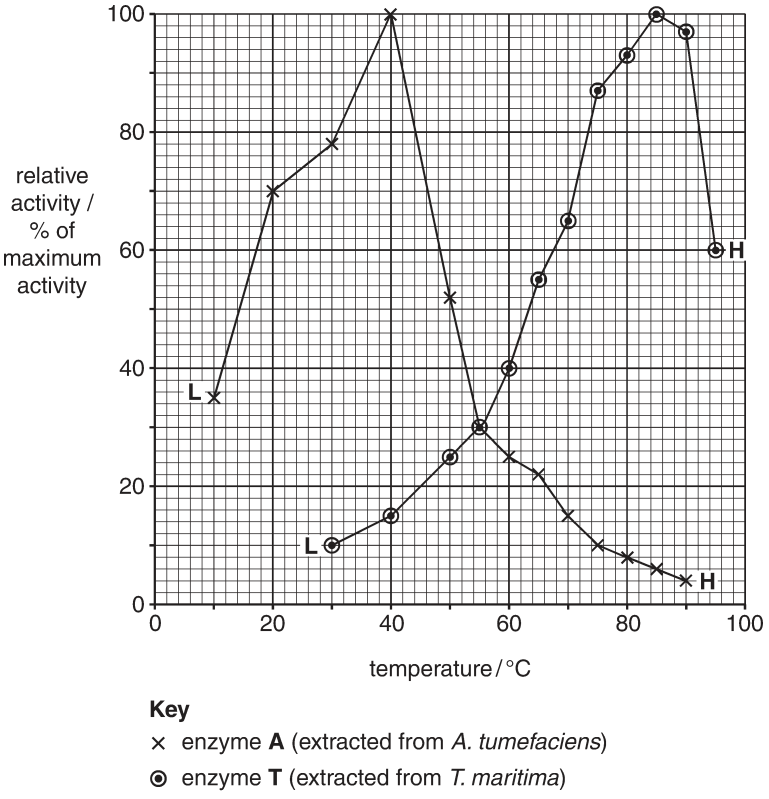


Fig. 4.1

(i) With reference to Fig. 4.1, describe the **differences** in the results for the two enzymes, **A** and **T**. [4]

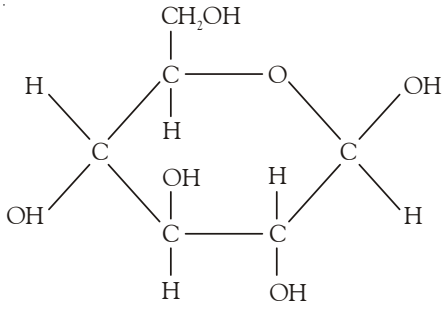
(ii) Both enzyme **A** and enzyme **T** act on cellobiose. They have a similar, but not identical, primary structure.

Suggest how similarities **and** differences in the primary structure of the two enzymes could help to explain the results obtained in the investigation. [4]

[Total: 10] (J15/P2/Q4)

Solution

(a)



(b) (i) Optimum temperature of A is lower than T, as maximum activity of A is at a lower temperature and of T at higher temperature, i.e., 40 °C for A and 85 °C for T is optimum temperature (A is lower by 45 °C). There is difference in shape of curve before or after optimum temperature, e.g. after optimum, T does not have the less steep decrease after the initial steep decrease (unlike A). Before optimum, steepest increase for A is at the lower temperature (unlike T). Below 55 °C, A has higher activity, while above it, A has lower activity than T, i.e. A has a higher activity at lower temperature and lower activity at higher temperature. Temperature range for activity is greater for A. A spans 80 °C while T spans 65 °C or temperature ranges 10 – 90 °C for A and 30 – 95 °C for T.

(ii) Primary structure dictates the folding of the polypepeptide chain in tertiary structure, i.e. differences in primary structure leads to differences in secondary as well as tertiary structures. Difference in folding leads to formation of active sites. Active sites of both enzymes are very similar in shape, as both act on substrate cellobiose, which has certainly complementary shape to their active sites, so Enzyme–Substrate (E–S) complexes are formed. However, there may be differences in side chains or interactions between R–groups, i.e. differences in numbers and types of bonds and differences in bonding gives different stabilities. Enzyme of T.maritima (or T) has more thermal stability which may be due to more bonds or more covalent (disulphide) bonds. Due to induced fit mechanism, active site may work in different ways. However, at lower temperatures, in T, induced fit mechanism may not work better and active site does not mould fully around substrate.

Answer Tips

(b) (i) A has lower, L, i.e. L is 20 °C lower for A than T. For A, L is 10 °C and 30 °C for T. At L, A has relative activity of 35% than T has 10%. T has higher H, i.e. H is 5 °C higher for T, as A has 90 °C and T has 95 °C. At H, relative activity is 4% and 60% for T.

(ii) Sequence of amino acids in primary structure is encoded in DNA. It has only peptide bonds between amino acids. However secondary structure develops H–bonds and tertiary structure also has ionic and disulphide bonds.

Question 6

(a) Describe how an enzyme can be immobilised in alginate **and** discuss the advantages of using an immobilised enzyme. [9]

[Total: 9] (J15/P4/Q10 a)

Solution

(a) Any enzyme to be immobilised is dissolved in water to make solution. Then some enzyme solution is mixed with sodium alginate solution. Mixture is placed / filled in a syringe. By pushing this mixture slowly with plunger, it is added drop by drop to solution of calcium chloride in a beaker. Beads with enzyme are formed. Beads are separated from calcium chloride solution and washed with water to remove surface $CaCl_2$.

Advantages: Such immobilised enzymes in alginate beads or in other support materials can be reused. Product (s) of reaction remain enzyme-free or uncontaminated, so purification to separate enzyme from product is not needed. It also reduces cost as it is re-used easily. Immobilised enzymes work at high temperatures and also can work in slightly changed pH. Enzyme-catalysed reaction can be faster so it gives higher yield.

Answer Tips

(a) There is less downstream processing done for separation of enzyme and product. Such enzymes are also thermostable to some extent and denature at relatively higher temperature than normal enzymes.

Question 7

Statements **A** to **E** are about the structure and functioning of enzymes.

State the correct term to match each of the statements **A** to **E**.

A The energy level, lowered by enzyme action, that needs to be overcome by reactants in order for products to be formed.

B The mechanism of enzyme action that relies on the active site being partially flexible and changing shape in order to bind the substrate.

C The term to describe a protein, such as an enzyme, with a tertiary or quaternary structure that results in an approximately spherical shape.

D The term for enzymes that function outside cells.

E The concentration of substrate that enables an enzyme to achieve half the maximum rate of reaction. [5]

[Total: 5] (J16/P2/Q1)

Solution

A Activation energy (Ea)

B Induced fit model or hypothesis

C Globular shape

D Extracellular enzymes

E Michaelis-Menten Constant (Km)

Question 8

High fructose corn syrup, made from maize, can be used as a replacement for sucrose to sweeten food and drink products.

Commercial production of high fructose corn syrup involves the enzyme glucose isomerase, extracted from bacteria.

(a) Fructose and sucrose are both sugars.
State two structural differences between fructose and sucrose. [2]

(b) The glucose isomerase used in the production of high fructose corn syrup is extracted from a strain of a bacterium, *Thermus thermophilus*, which is found in hot springs. The enzyme has an optimum temperature of 95 °C.
Suggest **and** explain the advantages of using glucose isomerase from *T. thermophilus* to produce high fructose corn syrup, rather than using glucose isomerase that has an optimum temperature of 37 °C. [3]

(c) The commercial production of high fructose corn syrup uses immobilised glucose isomerase.
Fig. 3.1 shows the effect of pH on the activity of immobilised glucose isomerase compared to glucose isomerase free in solution.

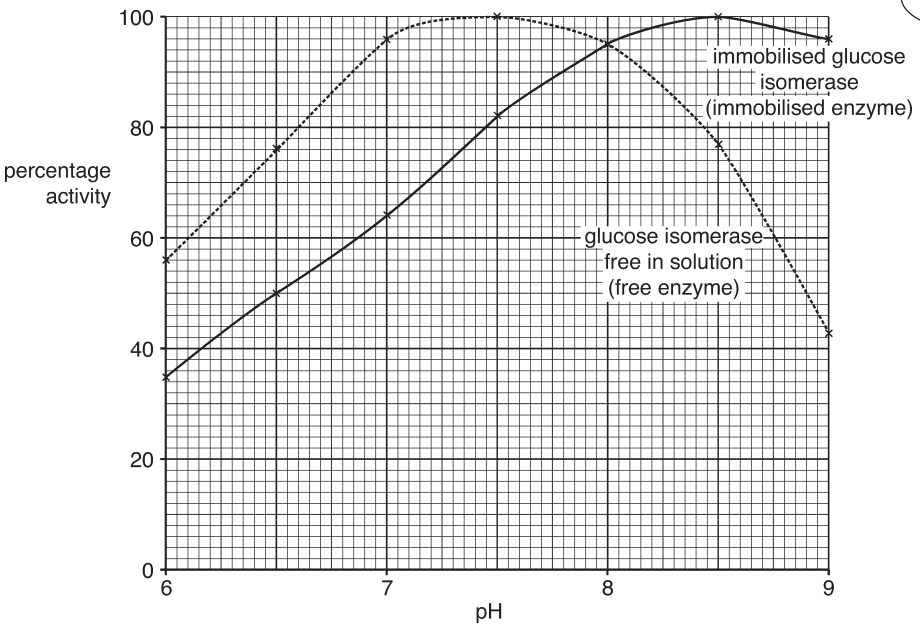


Fig. 3.1

With reference to Fig. 3.1, describe the differences shown between the immobilised enzyme and the free enzyme as pH changes. [3]

[Total: 8] (N16/P2/Q3 a,b,c)

Solution

(a) 1. Fructose is monosaccharide or one sugar unit while sucrose is disaccharide with two sugar units, which are fructose and glucose.

2. Fructose has no glycosidic bond while sucrose has glycosidic bond which joins fructose and glucose.

(b) Use of thermophilic enzyme can cause process to occur at very high temperature, i.e. 95 °C. Increasing temperature increases the number of collisions between enzyme and substrate, thus more E-S complexes are made, so due to higher rate of reaction , more products are formed. Lesser chances of loss of active sites and it is less prone to denaturation at higher temperature. Such enzyme is thermostable, so it is more stable and lasts longer. It can be reused over and over.

(c) Free enzyme has lower optimum pH, i.e, at pH 7.5, it shows peak or maximum activity. Immobilised has higher optimum pH, i.e. 8.5 upto pH 8, free enzyme shows higher activity and immobilised enzyme has lower activity. Till pH 7.5, activity of free enzyme increases from 56% to 100%, while immobilised enzyme activity increases from 34% to 82%. Free enzymes has lower activity from pH8 to pH9, while immobilized enzyme shows higher activity after pH8. For example, free enzyme has 77% activity at pH 8.5, while other enzyme has 100% activity.

Answer Tips

(a) Fructose is monomer while sucrose is dimer. Fructose is one ring while sucrose is two rings structure. Fructose has less C, H, O atoms, as its formula is $C_6H_{12}O_6$ while sucrose has more, i.e, $C_{12}H_{12}O_{11}$. Fructose is powder while sucrose is crystalline.

(c) Free enzyme has slightly steeper increase in activity as pH increases to 7, i.e. activity jumps from 56% at pH 6 to 96%, while immobilised enzyme activity increases from 34 to 64% till pH7.

Question 15

Amylase is an enzyme that catalyses the hydrolysis of starch into reducing sugars.

A student carried out an experiment to investigate the hydrolysis of starch using immobilised amylase. Fig. 6.1 is a diagram of the apparatus that was used in the investigation.

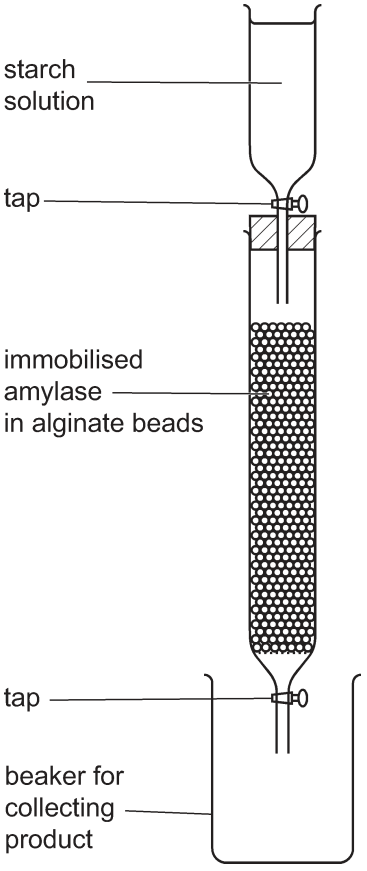


Fig. 6.1

The alginate beads were all the same size.

Both taps were opened to allow the starch solution to flow down the column and for the product to be collected.

The product was tested for the presence of reducing sugar and starch.

(a) The results of the investigation showed that the product collected in the beaker contained reducing sugar **and** starch.

With reference to Fig. 6.1, describe a method that would allow the student to use the immobilised amylase to collect a product that contains **only** reducing sugar. [3]

(b) One standardised variable in the investigation is the size of the alginate beads.

Suggest **one** reason why using larger or smaller alginate beads in the column would affect the results obtained. [1]

[Total: 4] (N21/P2/Q6)

Solution

(a) Open top tap and keep bottom tap closed for a longer time and then open bottom tap to collect product. May run starch solution through column, collect product and repeat a number of times. One may allow only a small quantity of starch solution through at a time. Experimental set-up may be modified by using smaller beads or using more beads or enzymes in beads, or using longer and narrower column.

(b) SA : V ratio decreases with increasing size or increases with decreasing size. Smaller beads means increased contact of substrate with enzyme in same conditions. Larger surface area is exposed by using smaller beads.

Answer Tips

(a) Visking tubing may be attached to end of column, so only reducing sugar passes out. Test sample of product with iodine solution to confirm no starch is present. If iodine in KI stays orange and does not change colour to blue-black, then it confirms that no starch is present. Optimum temperature, e.g, 35 °C may be used for amylase.

(b) In larger beads, rate of diffusion into beads is slow due to increased diffusion time to reach enzyme. Larger beads also increase rate of flow through column.

Question 16

Keratin is the structural protein in feathers of birds. Keratin polypeptides are composed of a high proportion of cysteine amino acids, which have sulfur-containing R groups.

Keratin polypeptides form filaments. The two main types of keratin in feathers are α-keratin, which consists of many α-helices, and β-keratin, consisting of many β-pleated sheets.

(a) Keratin can be classified as α-keratin or β-keratin based on a study of protein structure.

Suggest the level of protein structure used to classify a protein as α-keratin or β-keratin. [1]

(b) Protease enzymes hydrolyse proteins. Many proteases are able to hydrolyse more than one type of protein.

Suggest why it is possible for a protease to act on different types of protein. [1]

(c) Proteases known as keratinases vary in the extent to which they can hydrolyse keratin.

Feathers are not easily degraded (broken down) because keratin is a very stable protein.

Suggest features of keratin structure that contribute to its stability. [3]

Keratinases are used to degrade the large quantities of waste feathers from chickens and turkeys that are processed in the food industry. The products of feather degradation can be used in animal feed.

Scientists investigated whether three different keratinases, K12, A22 and P3, were suitable as industrial enzymes. These enzymes were extracted from three different soil bacteria.

The effects of temperature and pH on the activity of each keratinase were investigated.

The results are shown in Fig. 2.1 and Fig. 2.2.

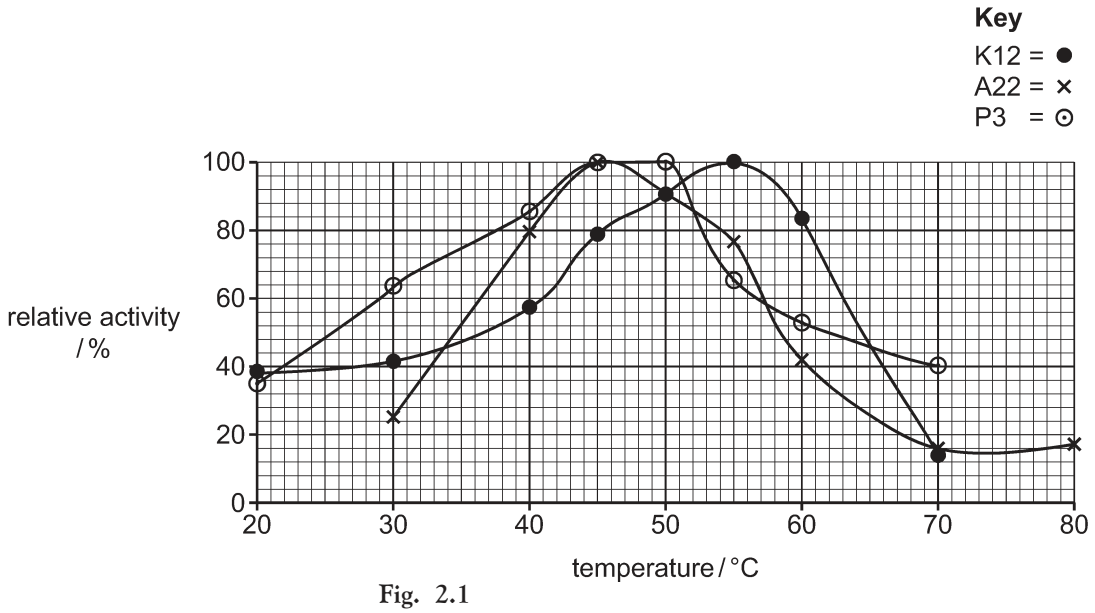


Fig. 2.1

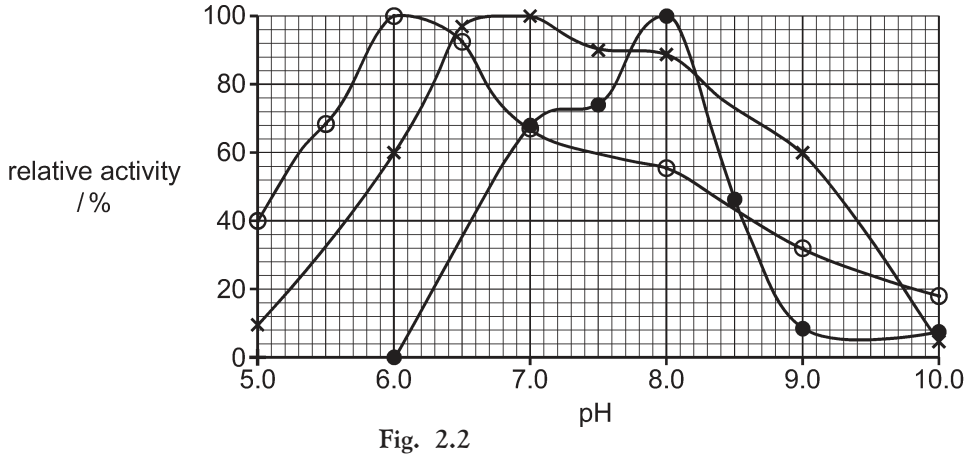


Fig. 2.2

(d) To degrade feather waste from industry, it is an advantage to use keratinases that show at least 60% relative activity in conditions where temperature and pH can vary widely.

Table 2.1 shows, for each keratinase, the working range of temperature and pH where at least 60% relative activity is obtained.

Use Fig. 2.1 and Fig. 2.2 to complete Table 2.1 **and** use the completed table to:

- name the keratinase that has the widest working range of temperature
- name the keratinase that has the widest working range of pH.

Table 2.1

keratinase	temperature range with at least 60% relative activity / °C	pH range with at least 60% relative activity
K12	41–63	
A22		6.0–9.0
P3	29–56	5.3–7.5

Keratinase with a relative activity of at least 60% that has:

- the widest working range of temperature .....
- the widest working range of pH .....

[4]

(e) Some detergents contain proteases to remove stains from clothes. These enzymes have a high relative activity in alkaline conditions.

The scientists reported that K12 and A22 could be suitable for use in the detergent industry.

With reference to Fig. 2.1 and Fig. 2.2, discuss the advantages **and** disadvantages of using K12 and A22 in the detergent industry. [3]

[Total: 12] (N23/P2/Q2)

Solution

(a) Secondary structure.

(b) So that it acts on peptide bonds to hydrolyse proteins between amino acids. Active site of protease is flexible for binding to similar substrates.

(c) Keratin is fibrous and insoluble protein which cannot dissolve easily. It is stronger protein due to high proportion of disulfide covalent bonds developed because of cysteines. It has high proportion of many hydrogen bonds between polypeptides. It also has high proportion of many hydrophobic interactions. Polypeptide chains are tight or closely packed. It has many amino acids with hydrophobic R-groups and many amino acids have small R-groups.

(d)

keratinase	temperature range with at least 60% relative activity / °C	pH range with at least 60% relative activity
K12	41–63	**6.8–8.4**
A22	**36–57**	6.0–9.0
P3	29–56	5.3–7.5

The widest working range of temperature: P3

The widest working range of pH: A22

(e) A22 and K12 are active and remove stains at a wide range of temperature, i.e., A22 is 20.5/21 °C and K12 is 22 °C. K12 is active at low temperature for washing. There is low activity or poor stain removal at 30 °C/70 °C for A22 and at 20/30 °C and 70 °C for K12. A22 has greatest activity at pH 7.5-8.0. It has, however, decrease in activity at high pH value.

Answer Tips

(b) Proteins are substrates having same shape, so can fit into active site. Shape of protein and active site of protease is still complementary. Protease may be a large enzyme complex with more than one active sites.

(c) Chains are arranged so that peptide bonds are not accessible. Parts of molecule needed to bind to active site are not accessible.

(e) A22 has at least 60% activity between pH 7.5-9.0. K12 is active between pH 7.5-8.0/8.5. So its optimum activity is at pH = 8.

Question 17

Lysozyme is an antibacterial enzyme that was discovered in 1921 by Alexander Fleming, the scientist who discovered penicillin.

Lysozyme catalyses the hydrolysis of glycosidic bonds present in peptidoglycan molecules to form smaller products, NAG (N-acetylglucosamine) and NAM (N-acetylmuramic acid).

(a) Before the induced fit hypothesis was proposed in 1958, scientists believed that the lock and key hypothesis explained how lysozyme catalyses the hydrolysis of peptidoglycan to its products.

Draw labelled **and** annotated diagrams in the space provided to show how the **lock and key hypothesis** was used to explain the mechanism of action of lysozyme on peptidoglycan. [3]

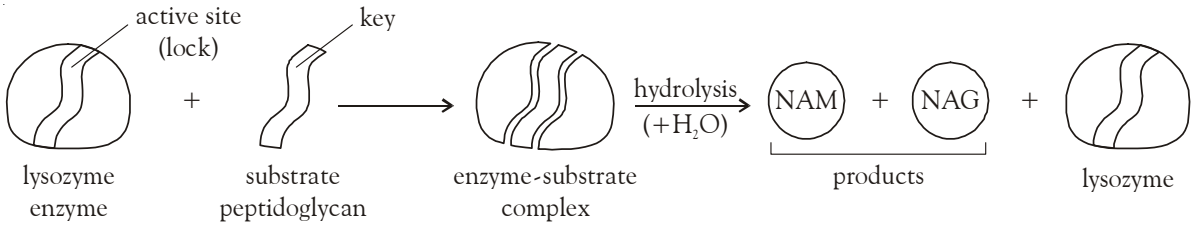
(b) Lysozyme and penicillin can be described as antibacterial agents.

Compare lysozyme **and** penicillin to show the similarities **and** differences between these two antibacterial agents. [3]

[Total: 6] (J24/P2/Q3)

Solution

(a)



(b) **Similarities:** Both cause cell lysis or bursting, killing bacteria. Cell wall is weakened as both act on peptidoglycan cell wall, so cell wall is unable to withstand turgor pressure.

Differences: Lysozyme is a protein acting as a catalyst or enzyme while penicillin is an antibiotic and an enzyme inhibitor. Lysozyme hydrolyses glycosidic bonds of peptidoglycan molecules but penicillin inhibits a transpeptidase enzyme. Penicillin is only effective when cell is growing and synthesising cell walls but lysozyme is effective at all stages.

Answer Tips

(b) Penicillin prevents formation of peptides or cross bridges. Lysozyme is much larger molecule and is denatured by high temperature but penicillin is less affected by heat.

TOPIC VIII

Transport in Mammals

As animals become larger, more complex and more active, transport systems become essential to supply nutrients to, and remove waste from, individual cells. Mammals are far more active than plants and require much greater supplies of oxygen. This is transported by haemoglobin inside red blood cells.

CONTENT	CANDIDATES SHOULD BE ABLE TO:
8.1 The circulatory system	1 state that the mammalian circulatory system is a closed double circulation consisting of a heart, blood and blood vessels including arteries, arterioles, capillaries, venules and veins 2 describe the functions of the main blood vessels of the pulmonary and systemic circulations, limited to pulmonary artery, pulmonary vein, aorta and vena cava 3 recognise arteries, veins and capillaries from microscope slides, photomicrographs and electron micrographs and make plan diagrams showing the structure of arteries and veins in transverse section (TS) and longitudinal section (LS) 4 explain how the structure of muscular arteries, elastic arteries, veins and capillaries are each related to their functions 5 recognise and draw red blood cells, monocytes, neutrophils and lymphocytes from microscope slides, photomicrographs and electron micrographs 6 state that water is the main component of blood and tissue fluid and relate the properties of water to its role in transport in mammals, limited to solvent action and high specific heat capacity 7 state the functions of tissue fluid and describe the formation of tissue fluid in a capillary network
8.2 Transport of oxygen and carbon dioxide	1 describe the role of red blood cells in transporting oxygen and carbon dioxide with reference to the roles of: • haemoglobin • carbonic anhydrase • the formation of haemoglobinic acid • the formation of carbaminohaemoglobin 2 describe the chloride shift and explain the importance of the chloride shift 3 describe the role of plasma in the transport of carbon dioxide 4 describe and explain the oxygen dissociation curve of adult haemoglobin 5 explain the importance of the oxygen dissociation curve at partial pressures of oxygen in the lungs and in respiring tissues 6 describe the Bohr shift and explain the importance of the Bohr shift

8.3 The heart	1 describe the external and internal structure of the mammalian heart 2 explain the differences in the thickness of the walls of the: • atria and ventricles • left ventricle and right ventricle 3 describe the cardiac cycle, with reference to the relationship between blood pressure changes during systole and diastole and the opening and closing of valves 4 explain the roles of the sinoatrial node, the atrioventricular node and the Purkyne tissue in the cardiac cycle (knowledge of nervous and hormonal control is not expected)

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Question 1

Fig. 1.1 is a diagram of a transverse section through a vein.

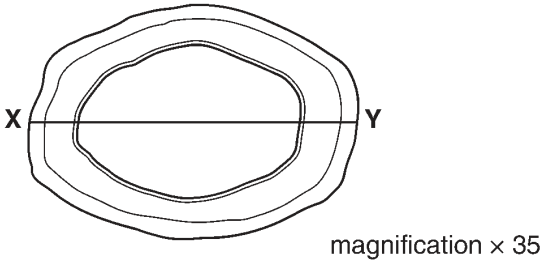


Fig. 1.1

(a) Calculate the actual diameter of the vein marked by the line **X–Y**.
Show your working and give your answer in millimetres (mm). [2]

(b) The presence of a valve would help to confirm that the blood vessel in Fig. 1.1 is a vein and not an artery.
Describe three structural features of the blood vessel shown in Fig. 1.1 that would help to identify it as a vein and **not** as an artery. [3]

(c) Explain how the following structural features of a capillary are related to its function.
(i) The capillary wall is composed of a single layer of squamous epithelial cells. [1]
(ii) The diameter of the capillary lumen is approximately 8 μm. [1]

(d) The inner lining of arteries and veins is composed of a layer of epithelial cells supported by a layer of elastic and connective tissue. The epithelial cells are capable of cell division by mitosis.
(i) State the role of mitosis in cell division of epithelial cells. [2]
(ii) Explain why the epithelial cells undergo mitosis and **not** meiosis. [2]

(e) Fig. 1.2 is a diagram of a cell in late prophase of mitosis.

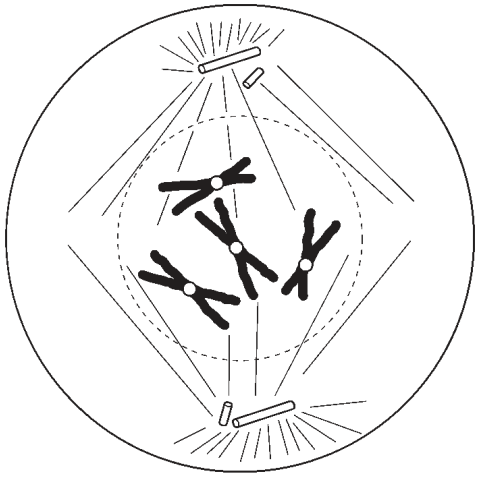


Fig. 1.2

Complete Fig. 1.3 to show the **same cell** in the **anaphase** stage of mitosis.

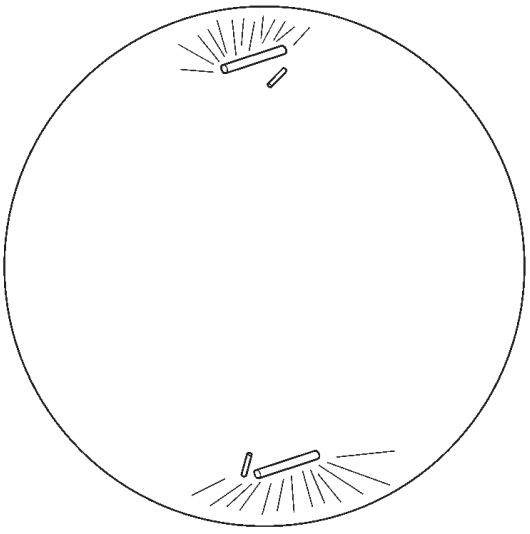


Fig. 1.3

[2]

[Total: 13] (N13/P2/Q1)

Solution

(a) $\text{Actual diameter} = \dfrac{\text{Length of line } \mathbf{XY}}{\text{magnification}} = \dfrac{42}{35} = 1.2 \text{ mm}$

(b) 1. It has large, wide lumen relative to thickness of wall while artery has narrow lumen compared with its wall thickness.

2. Shape is somewhat flattened and oval but not round. It is of irregular shape while artery is of regular, round shape. Vein is not spherical but artery is spherical.

3. Tunica media or middle layer has smooth muscles but proportionately less elastic smooth muscles. This layer is relatively thin compared to artery.

(c) (i) Thin capillary wall provides shorter diffusion distance for molecules, ions etc. Reduced distance causes short pathway.

(ii) Small size allows contact with many body cells as it can extend into small spaces. Red Blood Cells get close to body cells or tissue for efficient diffusion.

(d) (i) It produces genetically identical daughter epithelial cells for repair of tissue, as these cells replace dead, damaged or worn-out cells. Replacement of cells or repair gives protection to underlying tissue or muscles and elastic layer, i.e., tunica media.

(ii) Mitosis produces genetically identical cells and maintains genetic stability. It produces clones but meiosis produces genetically different cells. Mitosis ensures cells retain their function or cells function as a tissue. Mitosis maintains chromosomes number or diploid (2n) number while meiosis produces haploid cells or cells with n-chromosome number.

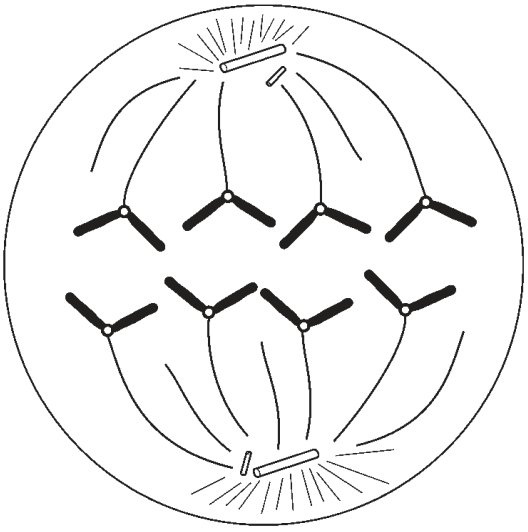
Answer Tips

(b) Its tunica externa or outer layer or tunica adventicia is relatively thin and is just a fibrous coat or layer. Tunica intima or tunica interna or inner layer or endothelim is smooth. It is not crinky or wavy like endothelim of artery.

(c) (i)&(ii) Short distance increases the rate of diffusion, so molecules or ions diffuse easily and faster, so diffusion is more efficient. Body cells are closer to capillary wall or endothelim. Flow of blood slows down, so more time is available for efficient diffusion. Cells obtain sufficient nutrients. Plasma containing glucose, oxygen and other nutrients is closer to body cells.

(d) (ii) Meiosis produces cell with half the number of chromosomes. So it is called reductional division while mitosis is called equational division. Meiosis is needed for gamete formation or formation of sex cells, i.e. sperms and ova.

(e)



(e) Four separate chromatids or daughter chromosomes to be shown in each half. All centromeres attached to spindle fibres and leading so that V shape of chromatids is visible.

Question 2

(a) Explain the need for transport systems in multicellular plants and animals. [3]

(b) In mammals, the role of the heart is to pump blood around the body. The events that occur during one heart beat are known as the cardiac cycle. The timing for one cardiac cycle is shown in Fig. 6.1.

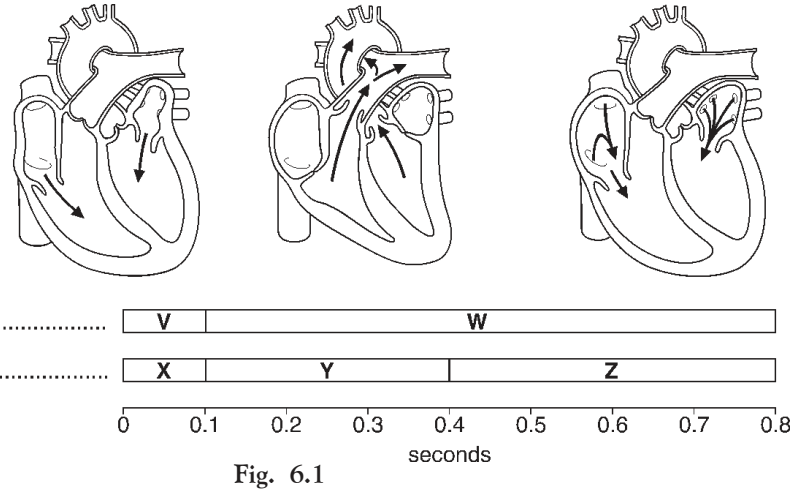


Fig. 6.1

P and **Q** represent the two types of heart chambers.

V, **W**, **X** , **Y** and **Z** represent the systolic (contracted) or diastolic (relaxed) state of the relevant heart chambers.

(i) In the spaces provided on Fig. 6.1, identify chambers **P** and **Q**. [1]

(ii) Complete the table by writing the letters **V**, **W**, **X**, **Y** and **Z** in the appropriate box to indicate the state of the heart chambers during the cardiac cycle as shown in Fig. 6.1.

systole	
diastole	

[2]

(c) In plants, assimilates are transported in phloem sieve tube elements by a process known as translocation.

Explain how assimilates that arrive in the phloem sieve tubes from mesophyll cells can be translocated to other parts of the plant. [4]

[Total: 10] (J14/P2/Q6)

Solution

(a) In small organisms, surface area to volume (SA : V) ratio is more due to large volume compared with surface area. As organism increases in size, its SA : V ratio decreases. Materials need to pass through longer distance to reach cells or tissues. So transport system is needed which reduces diffusion distance as it takes materials closer to cells. Diffusion alone is too slow or insufficient to satisfy needs of organism. So transport system decreases time to supply cells and there is efficient supply to cells of glucose, amino acids, dissolved food nutrients or hormones etc. Transport fluids have greater volume containing required materials, so concentration of materials is higher. Thus, more substances or materials reach to cells or tissues.

(b) (i) **P** : atria / auricle

Q : ventricles

(ii)

systole	**V, Y**
diastole	**W, X, Z**

(c) Assimilates like sucrose and amino acids lower water potential (Ψ), which becomes more negative. So water enters by osmosis and increases volume, thus, hydrostatic pressure also increases. Due to use of assimilates at sinks like roots, underground stems, seeds, fruits etc., hydrostatic pressure is lowered at sinks. Thus, there is a mass flow of cell sap from phloem sieve tubes in leaves to other parts or sinks, down pressure gradient, i.e., sucrose and other contents of cell sap move from high to low hydrostatic pressure regions.

Answer Tips

(a) In plants, xylem, phloem are part of transport system, while in animals, mostly arteries, veins are blood vessels of transport or circulatory system, which contain blood as transport fluid.

(b) (ii) **V** shows atrial systole, due to which atrial muscles contract and blood is pushed into ventricles. **Y**, shows ventricular systole, when blood is pushed into aorta and pulmonary artery by contraction of ventricle muscles. **W** shows atrial diastole, when atrial muscles are relaxed. After pushing blood ventricle muscles are relaxed, so **Z** represents ventricular diastole.

Question 3

In mammals, oxygen is transported by red blood cells in a system that is described as a closed double circulation. The majority of oxygen molecules are transported as oxyhaemoglobin. At the respiring tissues, oxygen dissociates from haemoglobin and diffuses to the surrounding cells.

(a) Explain what is meant by a *closed double circulation*. [2]

(b) Fig. 3.1 is a diagram that highlights the tertiary and quaternary structure of a haemoglobin molecule.

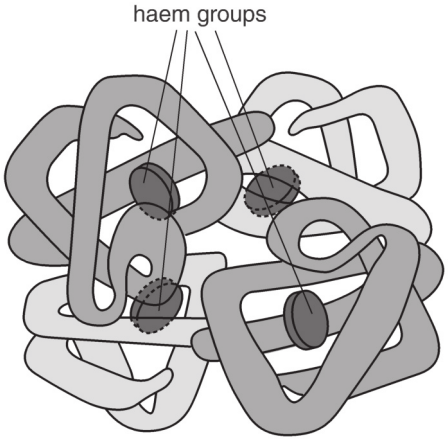


Fig. 3.1

Explain how the tertiary and quaternary levels of protein structure of the haemoglobin molecule contribute to its role in the transport of oxygen. [4]

(c) At high altitudes, the partial pressure of inspired oxygen is considerably lower than at sea level. This means that the partial pressure of oxygen in the blood is also much lower at high altitudes than at sea level.

Fig. 3.2 is an oxygen dissociation curve of adult oxyhaemoglobin.

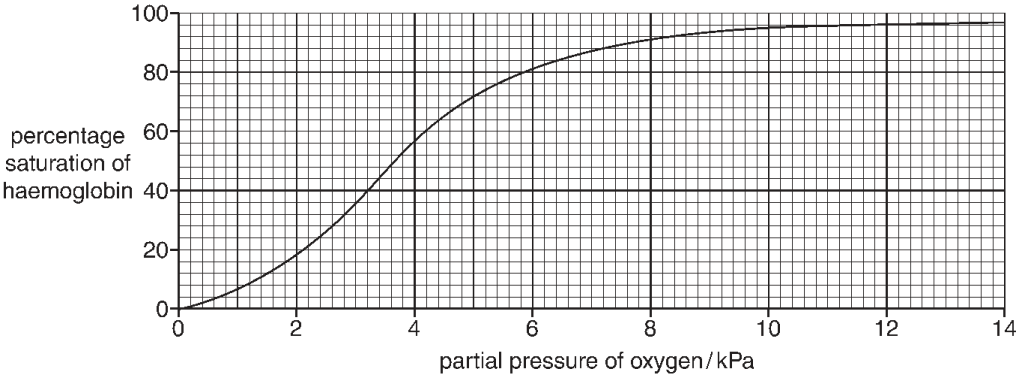


Fig. 3.2

With reference to Fig. 3.2, calculate the difference in percentage saturation of haemoglobin at sea level, where the partial pressure of oxygen is 13.0 kPa, and at a higher altitude, where the partial pressure of oxygen is 6.2 kPa.

Show your working. [2]

(d) After spending time at altitude, a person can become acclimatised. One feature of acclimatisation is an increase in the red blood cell count.

Explain the importance of the increase in the red blood cell count. [2]

(e) Before acclimatisation can occur, some people develop a condition known as acute mountain sickness when they travel to high altitude areas.
Acetazolamide is a non-competitive enzyme inhibitor that is used as a drug to prevent and treat acute mountain sickness.
Explain the effects of a non-competitive inhibitor on the rate of enzyme activity. [3]

(f) Tobacco smoking can have an effect on the transport of oxygen by haemoglobin.
Fig. 3.3 shows oxygen dissociation curves with and without the presence of carbon monoxide (CO).

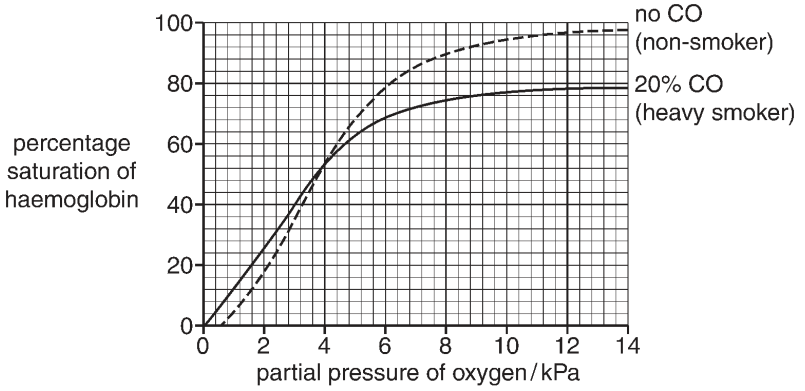


Fig. 3.3

With reference to Fig. 3.3, describe the effect of carbon monoxide on the cardiovascular system. [3]

[Total: 16] (N14/P2/Q3)

Solution

(a) Closed means blood move inside vessels as well as in heart. Vessels are arteries, veins and capillaries. Double circulation refers to passage of blood through heart twice for one circuit round the body. Blood moves by pulmonary and systemic circulation.

(b) Haemoglobin (Hb) is globular shape or round / spherical protein. Its hydrophilic amino acids or their R-groups face cytosol and hydrophobic amino acids or their R-groups face to the interior. So it is soluble and dissolved in cytoplasm. It has four polypeptide chains and each chain has a haem as prosthetic group which contains porphyrin ring with Fe^{2+} (iron ion). Ferrous ion (Fe^{2+}) binds to oxygen. Since four polypeptide chains have four haem groups, so 4 oxygen molecules (O_2) or 8 oxygen atoms bind with one Hb. Each polypeptide chain carries an O_2 (molecule). Interaction of O_2 with Hb is due to cooperative binding or of allosteric nature. Tertiary structure allows association of prosthetic group or haem containing Fe^{2+}, which, in turn, binds to O_2.

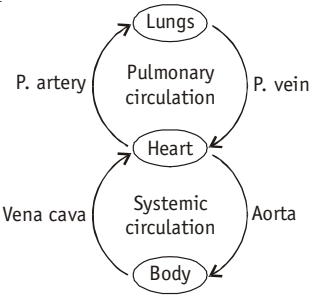
(c) % saturation of Hb with PO_2: 13.0 kPa = 96/97%
% saturation of Hb with PO_2: 6.2 kPa = 82/83%
Difference = 96 – 82 = 14
13 - 15 %

(d) Due to acclimatization, number of RBCs increases, thus, there is an increase in haemoglobin (Hb) content of blood. It compensates for decreased saturation of Hb as less oxygen (O_2) is available. So due to more RBCs, more O_2 can be taken up which is transported to tissues. Hence, tissues receive some or sufficient concentration of O_2.

(e) such inhibitor reduces the rate of enzyme activity. It binds at a site other than the active site of enzyme, and changes its tertiary structure. Due to its binding with enzyme, a change in shape, conformation or configuration of active site occurs. So substrate is not able to identify or bind at active site. Thus E-S complexes do not form and products are not made.

Answer Tips

(a) Pulmonary circulation means movement of blood from heart to lungs by pulmonary artery and from lungs to heart by pulmonary vein. Systemic circulation means passage of blood to all body parts via aorta and back to heart through vena cava.



(b) Hb has 2 α (alpha) and 2 β(beta) chains. Each α-chain contains 146 and each β-chain consists of 141 amino acids. So whole molecule of Hb has 574 amino acids-chains are folded to make a globular tertiary and quaternary structure.

(e) Due to non-competitive inhibitor, Vmax does not reach and increasing substrate concentration has no effect. Such type of inhibition is permanent or irreversible.

(f) Carbon monoxide binds to haemoglobin (Hb) as Hb as higher affinity for CO than O_2. In heavy smokers, carboxy haemoglobin is formed. With CO, Hb reaches lower % saturation, i.e., after 3.6 - 4.0 - 4.2 kPa. Less O_2 is taken up in lungs at higher partial pressures or volume of O_2 transported reduces. Below 3.6 - 4.2 kPa, with CO, curve shifts to left. It means Hb has relatively higher saturation. Less O_2 is unloaded at lower partial pressures in tissues, so heart rate increases to deliver sufficient O_2.

Answer Tips

(f) Due to CO, heart muscles receive insufficient O_2, which affects people with coronary heart disease (CHD).

Question 4

(a) Complete Table 5.1 by numbering each event to show the sequence occurring in the initiation and control of one heart beat.

Use **1** as the first event in the sequence.

Table 5.1

event	sequence
impulses pass down septum through conducting fibres known as the bundle of His	
atrioventricular node sends out impulses	
impulses travel across atrial walls	
impulses reach base of ventricles (apex of heart)	
impulses pass up through Purkyne fibres in ventricle walls	
sinoatrial node sends out impulses	

[3]

(b) Explain the circumstances that cause the closing of the semi-lunar valves during the cardiac cycle. [2]

(c) At the arterial end of a capillary bed in muscle tissue, the hydrostatic pressure is high enough to cause the formation of tissue fluid.

Explain the differences between the composition of blood and the composition of tissue fluid at the arterial end of a capillary bed. [2]

[Total: 7] (N14/P2/Q5)

Solution

(a)

event	sequence
impulses pass down septum through conducting fibres known as the bundle of His	4
atrioventricular node sends out impulses	3
impulses travel across atrial walls	2
impulses reach base of ventricles (apex of heart)	5
impulses pass up through Purkyne fibres in ventricle walls	6
sinoatrial node sends out impulses	1

(b) After ventricular systole or contraction of cardiac muscles, when ventricles are in diastole or their muscles relaxing, semi-lunar valves close. Pressure in arteries increases following ventricular systole.

(c) RBCs are too large to leave capillaries. Similarly some plasma proteins are too large to leave capillaries. Arterial end of capillaries have higher concentration of O_2 as it binds to Hb in RBCs from lungs. O_2 is not yet unloaded from Hb, so not yet diffused out of RBCs and not yet forced out of capillaries in plasma. Also there is higher concentration of glucose and other nutrients which are yet to be delivered to cells from absorption. Tissue fluid contains products excreted by cells and yet to enter blood. Some of the waste products in tissue fluid are lactate and more CO_2.

Answer Tips

(b) After ventricular systole, pressure in ventricles lowers than in arteries, i.e., aorta and pulmonary arteries. Then semi-lunar valves are closed.

(c) Some nutrients are amino acids, fructose, galactose and other products of digestion. Waste products are nitrogenous wastes like urea, in addition to CO_2.

Question 5

Each of statements **A to E** describe a structure associated with the mammalian heart. For each statement, identify the structure that is being described.

A The chamber that pumps blood into the pulmonary artery.

B A blood vessel that transports deoxygenated blood into the right atrium.

C The specialised tissue responsible for delaying the conduction of impulses from the atria to the ventricles.

D The blood vessels that supply cardiac muscle with oxygenated blood.

E The valve that prevents the backflow of blood from the ventricle that contains oxygenated blood. [5]

[Total: 5] (J15/P2/Q1)

Solution

A Right ventricle

B Vena cava (superior / inferior)

C Atrioventricular node (AVN)

D Coronary arteries / coronary capillaries

E Bicuspid valve / left atrioventricular / mitral valve

Question 6

Outside the body, red blood cells can be maintained in an intact state by keeping the cells in a 0.9% solution of sodium chloride. This is known as a normal saline solution.

Fig. 3.1 shows intact red blood cells.

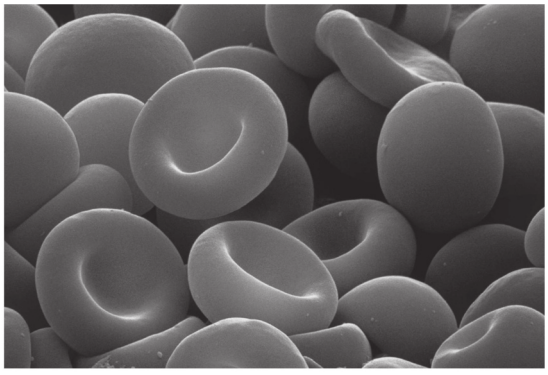


Fig. 3.1

(a) Explain why red blood cells can be maintained in an intact state by keeping them in a normal saline solution. [2]

(b) In the blood, red blood cells are suspended in plasma. The main component of blood plasma is water.

Suggest **one** other component of blood plasma that could enter red blood cells **and** describe how it would cross the cell surface membrane. [3]

Fig. 3.2 shows red blood cells within a capillary. The capillary shown in Fig. 3.2 allows the rapid exchange of substances between the blood, tissue fluid and body cells.

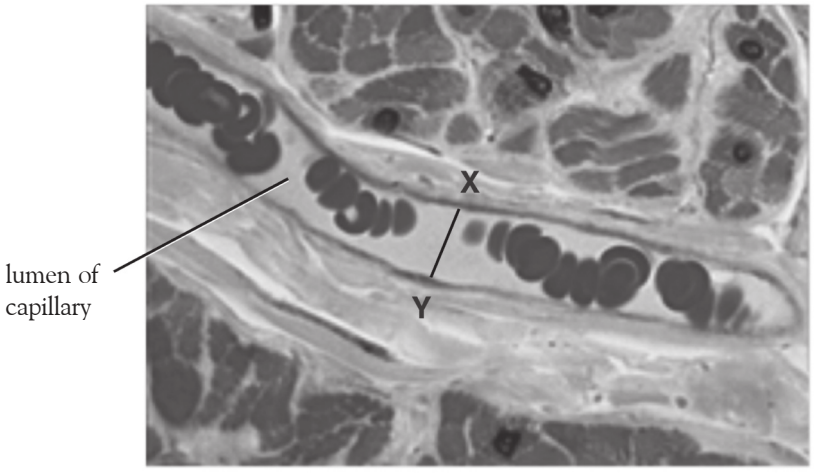


Fig. 3.2

(c) The actual diameter of the lumen of the capillary at the point **X–Y** in Fig. 3.2 is 9.5 μm.

Calculate the magnification of the image shown in Fig. 3.2. Show your working. [2]

(d) With reference to Fig. 3.2, explain **one** feature that enables the surrounding body cells to receive an adequate supply of oxygen from the blood supplied by the capillary. [2]

(e) Some areas of the brain, known as blood-brain barriers, have a type of capillary that is relatively impermeable to substances.

Suggest **one** way in which the structure of a capillary in the blood-brain barrier differs from the structure of the capillary shown in Fig. 3.2. [1]

[Total: 10] (J15/P2/Q3)

Solution

(a) In 0.9% NaCl solution, there is same water potential (Ψ) inside and outside of cell. Concentration of solution is isotonic to cell, so there is no water potential gradient. Hence osmosis does not occur significantly, as there is no net or overall movement of water molecules.

(b) *component* glucose

description it passes through cell surface membrane by passive transport, i.e. facilitated diffusion. Channel proteins are used for facilitated diffusion. Glucose is polar molecule and large in size, so channel is required for its passage through membrane. Glucose is also taken up by active transport and cotransport system. Certain carrier or transporter proteins are involved for active transport of glucose.

(c) $$\text{Magnification} = \frac{\text{image length}}{\text{actual length}}$$

$$= \frac{9.5\text{ mm}}{9.5\,\mu\text{m}} = \frac{9.5\times1000}{9.5} = \times1000$$

(d) Capillary endothelium or capillary wall is one cell thick, so due to thin epithelium / endothelium, haemoglobin in red blood cells is closer to body cells. So oxygen moves into cells through short diffusion distance.

(e) There are few or no pores, gaps or fenestrations in endothelium or capillary wall. Hence, there are tight junctions between epithelial / endothelial cells. Layer around capillary or basement membrane is impermeable.

Answer Tips

(b) O_2, Co_2 ,steroid hormones pass by diffusion through phospholipid bilayer or hydrophobic core of membrane. Amino acids, minerals, inorganic ions like Na^+, Mg^{+2}, Cl^-, H^+, HCo_3^-, Hpo_4^{-2}, K^+ etc either pass by facilitated diffusion or pumped by proteins or carriers for active transport. Many are also cotransported.

(c) One may measure the length between 9 to 10mm, so magnification between **X** 947 – **X** 1053 is correct.

(d) Diameter or size of RBC and lumen of capillary is very close. So it slows down flow of blood in capillary, thus sufficient O_2 moves out and passes into the cells.

(e) Cells wrap round, i.e., fewer cells make up capillary wall, so it reduces endothelial cell to cell contact.

Question 7

(a) The thickness of the different chambers of the mammalian heart is due to the amount of cardiac muscle present. The atria have less cardiac muscle than the ventricles, and hence thinner walls.

In terms of their functions, explain why the atria have thinner walls than the ventricles. [2]

(b) Name the dividing wall separating the right and left sides of the mammalian heart. [1]

(c) Transpiration and translocation are both processes occurring in plants.

(i) State **one** way in which transpiration differs from translocation. [1]

(ii) State **one** way in which transpiration and translocation are similar. [1]

[Total: 5] (N15/P2/Q6)

Solution

(a) Both chambers pump blood to different distances. Atria pump blood to shorter distance, i.e., to ventricles only, while ventricles pump blood to long distance, i.e., to lungs and other parts of body, especially left ventricle pumps blood to aorta which is carried to all body parts except lungs. Pulmonary artery carries blood to lungs. Resistance to overcome by atria is lower while ventricles need to overcome greater resistance. Atria generate lower pressure while ventricles generate higher pressure.

(b) Septum

(c) (i) Transpiration involves only water molecules. It occurs through evaporation and diffusion. Water moves out to external environment and lost from leaves. It occurs in one direction, from air spaces through stomata. Translocation involves assimilates like sucrose and amino acids making cell sap. It is done by hydrostatic pressure gradients, and mass flow. It occurs through phloem sieve tubes.

(ii) Both involve transport or movement of substances and water is involved in both cases. Both require energy, as heat energy helps evaporation during transpiration while ATP is needed for pumping H^+ out of companion cells during translocation.

Answer Tips

(c) (i) Transpiration from aerial parts is affected by external factors like humidity, light, wind speed, temperature etc. ATP is not required for it. In translocation cell sap flows from source to sink. ATP is used for loading of sucrose into phloem sieve tubes.

Question 8

Fig. 4.1 is a simplified diagram of the circulatory system of a mammal. Some of the lymph system is also shown.

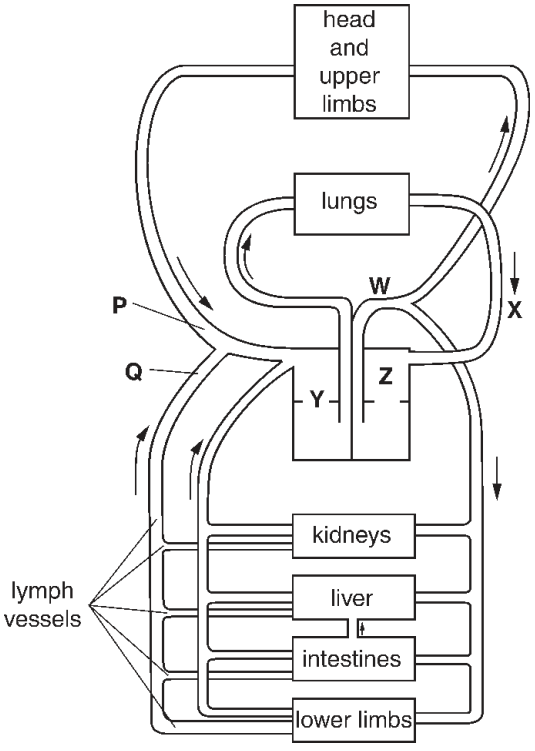


Fig. 4.1

(a) The type of circulatory system shown in Fig. 4.1 is a closed double circulation.

Explain what is meant by a *closed double circulation*. [2]

(b) With reference to Fig. 4.1, name:

blood vessel **W,** blood vessel **X,** valve **Y,** heart chamber **Z** [4]

(c) State the component present in the blood at location **P** that is **not** present in the lymph at location **Q** in Fig. 4.1. [1]

(d) As blood passes through the capillary network in the lungs, gas exchange occurs.

Describe the process of gas exchange between the alveolus and the blood. [4]

(e) As blood passes through the small intestine, small soluble products of digestion such as glucose are absorbed into the capillaries to be transported to the liver.

Fig. 4.2 is a transmission electron micrograph of intestinal epithelial cells.

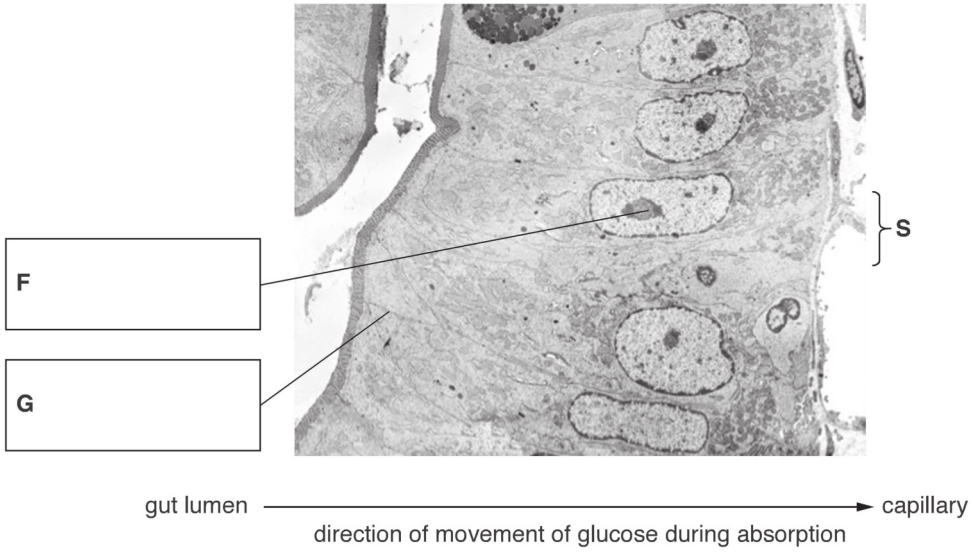


Fig 4.2

(i) Write the name of cell structures **F** and **G** in the boxes provided on Fig. 4.2. [2]

(ii) At the surface labelled **S**, movement of glucose molecules out of the intestinal epithelial cell occurs by facilitated diffusion.

Outline the features of facilitated diffusion of glucose molecules. [3]

[Total: 16] (J16/P2/Q4)

Solution

(a) In closed system blood is contained in blood vessels, i.e. in heart, arteries, veins and capillaries. Double circulation refers to systemic and pulmonary circulation. For each complete circuit round the body, blood passes twice through heart, i.e. from heart to lungs and back, then to rest of the body and back.

(b) blood vessel **W**: Aorta / aortic arch
Blood vessel **X**: Pulmonary vein
Valve **Y**: Right atrioventricular or tricuspid valve
Heart chamber **Z**: Left atrium or auricle

(c) Red blood cells (or platelets).

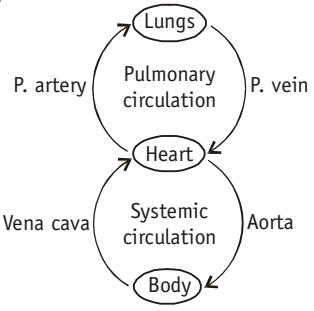
(d) Carbon dioxide diffuses out of blood to alveolus and oxygen diffuses in to alveolus. Movement of both carbon dioxide and oxygen occurs from higher concentration to lower concentration (down a concentration gradient) across squamous epithelial cells or pavement cells of alveolar walls and endothelial cells of capillary wall. Capillary wall is also made up of squamous cells. Oxygen then enters into red blood cells. Steep gradient is maintained by ventilation and uptake of oxygen by haemoglobin as blood carries oxygen away. Steep gradient is also maintained by blood arriving with carbon dioxide or deoxygenated blood arriving low in oxygen.

(e) (i) **F:** Nucleolus (in the nucleus)
G: Cell surface, membrane.

(ii) Epithelial cell surface membrane has transporter or carrier proteins, which are specific proteins with glucose binding site. Binding of glucose causes conformational change, i.e., change in shape. Glucose moves by passive transport, so no extra energy or ATP is required. Passive transport occurs down the concentration gradient, i.e., from high to low concentration through the membrane protein.

Answer Tips

(a)



(c) Plasma proteins like albumin, fibrinogen etc are also present at **P**.

(d) Blood in capillaries around alveoli contains 16-17% oxygen while air in alveoli contains 21% O_2. CO_2 in air is 0.03% while in blood at alveoli it is 4.5%.

Question 9

Fig. 4.1 is a cross-section of a human renal artery, a vessel that supplies blood to the kidney.

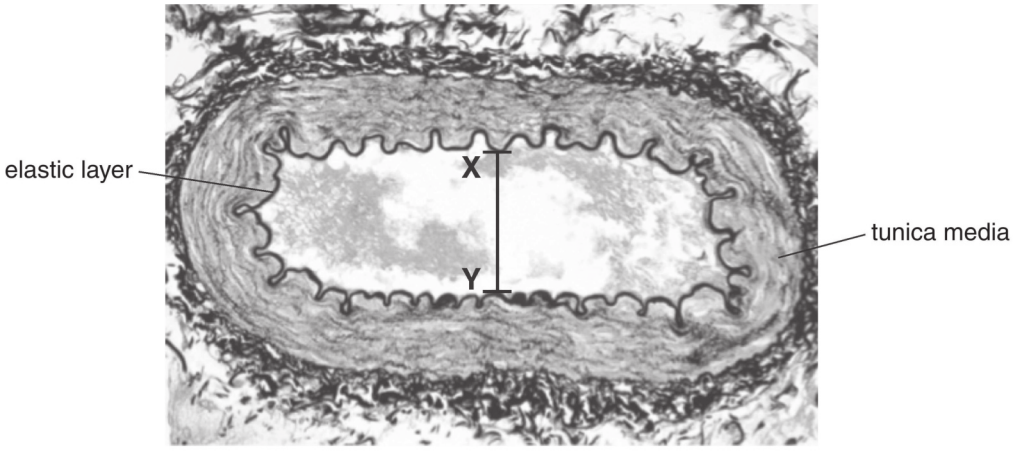


Fig. 4.1

(a) The elastic layer shown in Fig. 4.1, located between the endothelium and the tunica media, is one feature that suggests that the blood vessel is the renal artery and not the renal vein, which may be of a similar size.

Complete the sentence to state **one** additional structural feature, **visible in Fig. 4.1**, that would identify the blood vessel as an artery.

This is an artery because it has [1]

(b) Explain the relationship between the structure of the tunica media and the function of an artery, such as the renal artery. [2]

(c) The actual diameter of the lumen of the renal artery at the point **X–Y** in Fig. 4.1 is 5.2 mm.

Calculate the magnification of the image shown in Fig. 4.1. Write down the formula you will use to make your calculation and show your working.

formula

[3]

(d) Blood plasma contains approximately 90% water. Many of the properties of water are due to its ability to form hydrogen bonds.

Outline how the properties of water make it ideal as the largest component of plasma. [3]

[Total: 9] (N16/P2/Q4)

Solution

(a) *This is an artery because:* it has a thick tunica media than tunica externa. It also has a thick layer of smooth muscles and elastic tissue or thick muscular wall. Thickness is due to many layers of smooth muscle cells.

(b) Elastic tissue has smooth muscles which maintain or increase blood pressure, because thick tunica media with elastic tissue and collagen fibres withstands high blood pressure so it prevents rupture of artery wall. It has elastic tissue to smooth out pulsatile flow, as muscles or elastic tissue helps to maintain blood flow and keep blood moving forwards. Due to contraction and relaxation of smooth muscles altering volume of blood is delivered and blood flow is diverted to regulate it.

(c) $$\text{Magnification} = \frac{\text{image diameter}}{\text{actual diameter}}$$

$$= \frac{18\ \text{mm}}{5.2\ \text{mm}} = 3.46$$

Magnification = x 3.5

(d) Water is good solvent as polar molecules (ions) dissolve in water. Ions also dissociate in water and many substances dissolve in it as water is attracted to many different substances. There is cohesion between water molecules, so water molecules are sticky. Due to cohesive water, there is continuous, uninterrupted blood flow. Water has high specific heat capacity so plasma helps stabilise body to regulate and maintain constant blood temperature. Water resists changes to temperature. Due to high latent heat of vaporization, plasma stays liquid at body temperature as water does not evaporate.

Answer Tips

(a) Artery has well defined, firm, oval, regular shape. It has narrow lumen in relation to thickness of wall. Its endothelium or tunica intima is convoluted or folded.

(d) Water or plasma is the transport medium for substances and presence of solutes maintains constant water potential. Water has low compressibility. It maintains efficient blood flow as it helps to push the blood through vessels. It allows efficient circulation of blood due to its low viscosity. It has neutral pH which keeps proteins stable and prevents denaturation.

Question 10

Fig. 6.1 is a diagram of a vertical section through the mammalian heart. The labels **Q** to **X** represent valves and blood vessels of the heart.

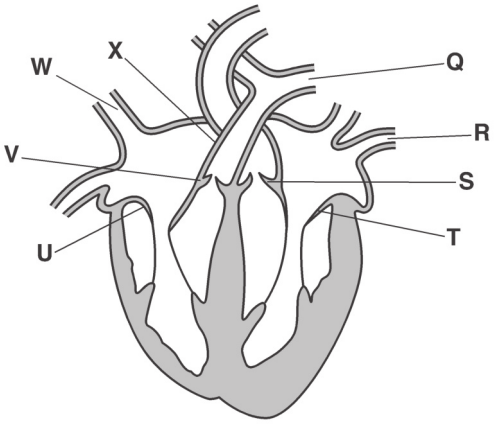


Fig. 6.1

(a) (i) State which label represents the valve that prevents the backflow of blood from the aorta into the ventricle. [1]

(ii) Name the blood vessel that carries oxygenated blood from the lungs to the heart **and** state which label represents this blood vessel. [2]

(b) State **precisely** where the sinoatrial node is located. [1]

(c) Explain the role of the atrioventricular node in the coordination of heart action. [2]

[Total: 6] (N17/P2/Q6)

Solution

(a) (i) S

(ii) *name:* Pulmonary vein
label: **R**

(b) Wall or muscle of right atrium.

(c) AVN passes the wave of excitation or impulses to the Purkyne fibres (or Bundle of His) down the septum, so it allows a short delay, as atria contract before ventricles. It allows ventricles to be filled, so atria have emptied due to contraction before ventricular contraction begins. Hence atria and ventricles do not contract at the same time.

Answer Tips

(a) (i) **S** is semilunar or pocket valve. It is also found in Pulmonary artery.

(c) SAN generates impulses which first spread over atrial muscles causing atrial systole. Then impulses reach to AVN and from there move to ventricles.

Question 11

Woolly foxglove, *Digitalis lanata*, shown in Fig. 2.1**A**, and common oleander, *Nerium oleander*, shown in Fig. 2.1**B**, are plants grown for the attractive flowers that they produce.

Both plants are poisonous, as their leaves produce toxic organic compounds known as cardiac glycosides. Cardiac glycosides have a powerful effect on the action of cardiac muscle.

A

B

Fig. 2.1

(a) *N. oleander* is able to grow in very dry conditions. The leaves have adaptations to reduce water loss by transpiration.

State the term used to describe a plant, such as *N. oleander*, that has adaptations to allow it to grow in conditions where water is in short supply. [1]

(b) Aphids are small insects that feed on plant fluids using piercing and sucking mouthparts. When aphids feed on the sap present in vascular tissue of leaves and stems, a sugary liquid called honeydew is passed out of the gut. The honeydew can be analysed to find out what is present in the sap.

(i) State the name of the vascular tissue from which the aphids feed. [1]

(ii) An investigation found that aphids feeding on *D. lanata* produced honeydew containing cardiac glycosides.

Suggest why cardiac glycosides were present in the sap from the vascular tissue. [2]

Cardiac glycosides have an effect on the movement of ions into and out of cardiac muscle cells. The outcome is an increased ability for the cells to contract.

(c) Investigations into the action of the cardiac glycoside oleandrin, extracted from *N. oleander*, have shown that it acts to prevent the correct functioning of Na/K-ATPase, a membrane transport protein.

Na / K-ATPase has a role as an enzyme **and** as a transport molecule.

- ATPase is an enzyme that catalyses the hydrolysis of ATP to ADP and inorganic phosphate.
- Energy released from this hydrolysis is used to transport sodium ions (Na^+) out of cardiac muscle cells and potassium ions (K^+) into the cells.

(i) Explain what is meant by the *hydrolysis of ATP*. [2]

(ii) Name the type of transport mechanism involved in the transport of Na^+ and K^+ across the cell surface membrane of cardiac muscle cells. [1]

(iii) Oleandrin is a non competitive reversible inhibitor of ATPase.

Describe the mode of action of oleandrin **and** explain how this will affect ion movement through Na/K-ATPase transport proteins of the cell surface membranes of cardiac muscle cells. [4]

(d) Digoxin, a cardiac glycoside extracted from *D. lanata* leaves, can be purified and used as a drug to treat some heart disorders.

Examples of these heart disorders are:

- atrial fibrillation, where the normal rhythmic cardiac cycle is disrupted
- heart failure, where cardiac muscle is contracting weakly.

(i) Describe the **sequence** of events occurring in the left side of the heart during one **normal** cardiac cycle. Include reference to blood pressure changes.

The first event in the sequence is described for you.

The left atrium fills with blood during relaxation of the left atrium and left ventricle ..... [4]

(ii) Suggest how the health of a person with heart failure can be improved by treatment with the drug digoxin. [3]

[Total: 18] (N18/P2/Q2)

Solution

(a) Xerophyte

(b) (i) Phloem or sieve tubes.

(ii) Translocation occurs from source to sinks. Source is a place of synthesis and sink is area where food is not manufactured or where food is stored or used. Assimilates or products of metabolism are transported or move through phloem, like sucrose and amino acids. Cardiac glycosides are found as defense mechanism against sap feeders like aphids.

(c) (i) Hydrolysis of ATP means to break bonds between phosphate groups of adenosine triphosphate (ATP) by using water, i.e., $ATP + H_2O \rightarrow ADP + Pi$

(ii) Active Transport

(iii) It binds reversibly to allosteric site or site other than the active site of enzyme. Due to binding of Oleandrin, 3-D structure or tertiary structure of active site or enzyme changes shape. Hence its substrate or ATP cannot enter or fit into active site as active site is no longer complementary to substrate. There is no or less hydrolysis of ATP and less or no energy is released . As a result, Na^+ do not move out and K^+ do not move in, as Na / K ATPase cannot work.

(d) (i) *The left atrium fills with blood during relaxation of the left atrium and left ventricle.* Atrioventricular valves opens following atrial contraction and blood trickles into ventricle. Following blood flow to ventricles, left ventricle fills with blood. Now follows the ventricular contraction, when bicuspid valve closes and semi-lunar valve opens. So blood flows into aorta from left ventricle. During ventricular contraction, atrium is in relaxation. Atrial contraction increases its pressure. Similarly blood pressure increases in ventricle when its muscles contract. When pressure in atrium is greater than in ventricle, then atrioventricular valve opens. When pressure in ventricle is greater than aorta then semilunar valve opens.

(ii) Due to fibrillation, normal rhythmic cardiac cycle is disrupted. More powerful contraction of cardiac muscles increases ability of cardiac muscle to contract. Blood is pumped at higher pressure and there is more force to overcome resistance in blood vessels. More blood reaches lungs to obtain oxygen per unit time. So more oxygen reaches rest of body tissues through blood. More oxygenated blood can be delivered to heart muscles.

Answer Tips

(c) (iii) Mostly non-competitive inhibitors are irreversible, but few like Oleandrin are reversible. However they bind to a different site than active site and distort the shape of active site. Due to no substrate entering active sites, no enzyme substrate complexes (E-S complexes) are made and products are not formed.

(d) (i) When pressure in ventricle is greater than atrium, then bicuspid valve closes. Differences in blood pressure cause opening or closing of valves.

(ii) Stronger contraction of cardiac muscles increases contractility. Due to receiving more oxygen, energy is increased causing less fatigue and increased mobility.

Question 20

The sinoatrial node (SAN) and the atrioventricular node (AVN) have an important role in the control of the cardiac cycle. The timing of atrial and ventricular systole and diastole must be controlled so that blood passes through the heart efficiently.

(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**.

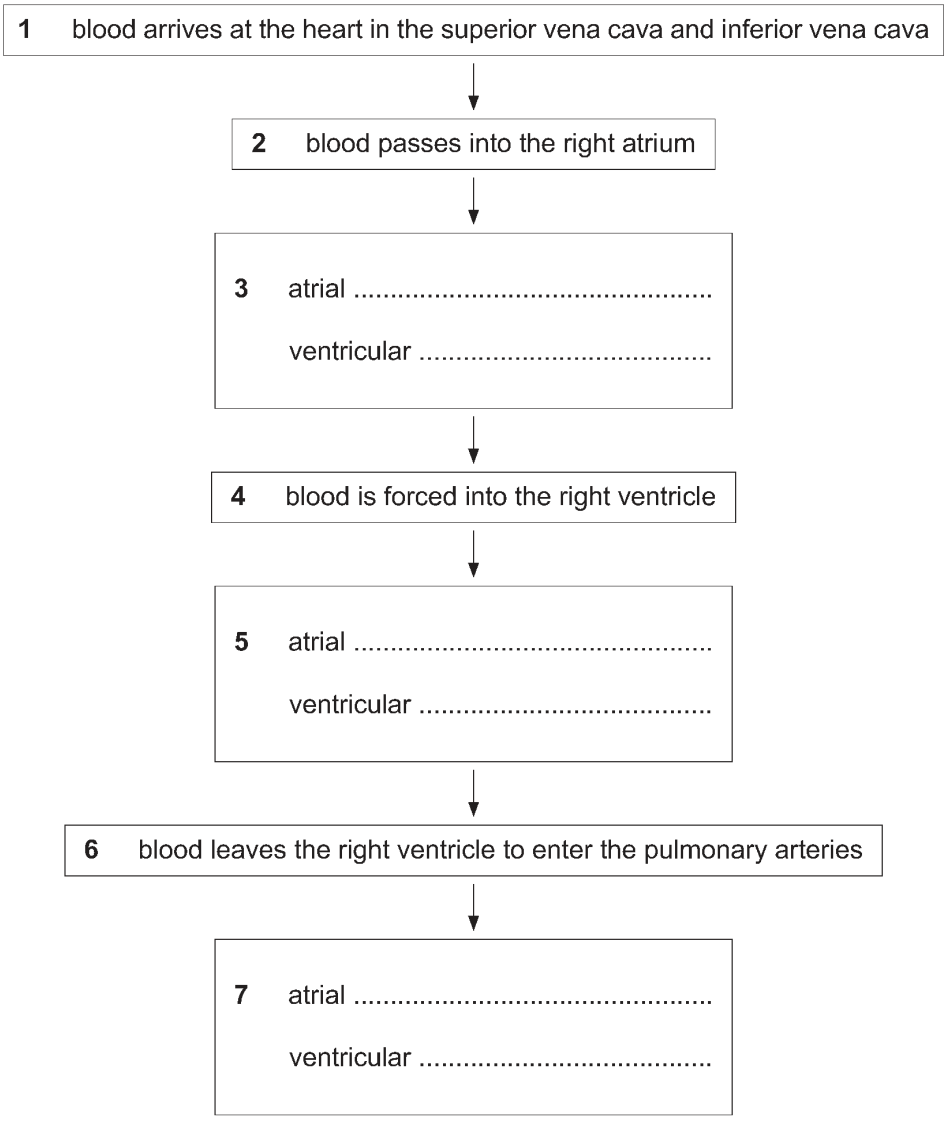


Fig. 1.1

[2]

(b) Impulses sent out by the SAN pass to the AVN, where there is a short delay.

With reference to Fig. 1.1, 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. [2]

(c) 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:

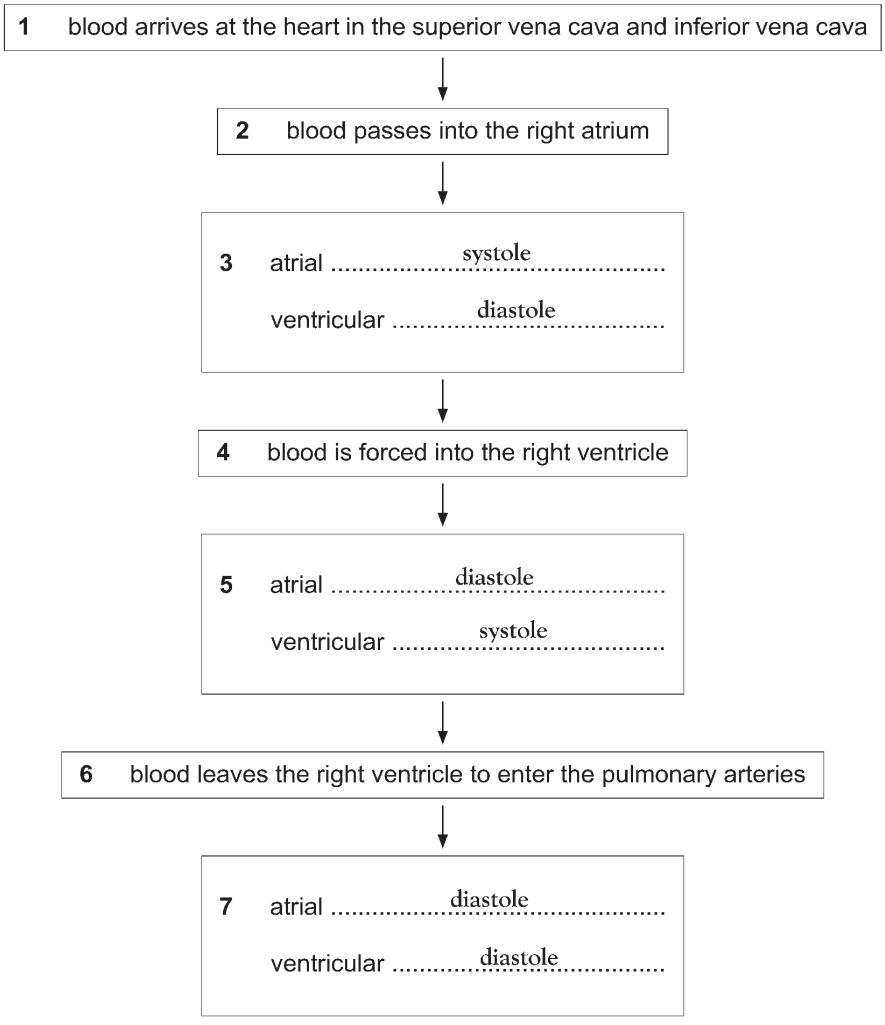
- cause the **opening** of the **tricuspid** valve
- cause the **opening** of the **pulmonary** valve
- help the flow of blood through the heart.

[3]

[Total: 7] (J23/P2/Q1)

Solution

(a)



(b) Atria and ventricles do not contract or not in systole, at the same time. Ventricles contract or are in systole after atria. It allows atria to empty completely and allows ventricles to be filled.

(c) Due to lower pressure in right ventricle than right atrium, **tricuspid** valve opens. When pressure in right ventricle becomes higher than pressure in **pulmonary** artery, then semilunar valve of **pulmonary** artery opens. In the heart, blood flows from area of higher pressure to area of lower pressure, i.e., it flows from atrium to ventricle, then into **pulmonary** artery to lungs. So blood flows in one direction and backflow of blood is prevented.

Answer Tips

(b) All blood from atria is pushed into ventricles and then ventricles are ready for systole.

(c) Changes in blood pressure aid in coordination for blood flow. Semilunar valve opens about same time when **tricuspid** valve is shut.

Question 21

The liver receives blood from the hepatic artery and from the hepatic portal vein. The hepatic portal vein transports blood from the digestive system.

Hepatocytes are the main cell type of the liver. They have a wide range of functions, including:

- the synthesis of triglycerides and plasma proteins
- detoxifying waste
- energy storage.

(a) The hepatic artery branches from the main artery that transports blood from the heart.

Name the main artery that transports blood to the hepatic artery. [1]

(b) Blood arriving at the liver enters specialised blood vessels known as sinusoids.

Fig. 3.1 is a diagram of part of a sinusoid and surrounding hepatocytes. A second type of cell found in the liver, a Kupffer cell, is also shown.

Kupffer cells are phagocytic cells of the immune system.

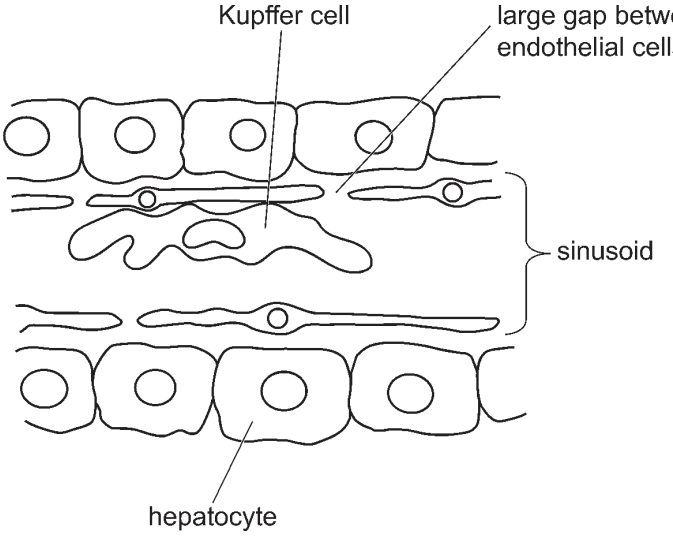


Fig. 3.1

(i) Suggest **one** advantage of having large gaps between the endothelial cells of the sinusoid, as shown in Fig. 3.1. [1]

(ii) In addition to removing bacteria present in the blood inside the sinusoid, Kupffer cells are also able to remove old or damaged red blood cells.

Describe the mode of action of a Kupffer cell in removing and breaking down a damaged red blood cell. [4]

[Total: 6] (N23/P2/Q3 a,b)

Solution

(a) Aorta / dorsal aorta.

(b) (i) It facilitates exchange of substances or nutrients which are exchanged at higher rate because substances do not have to cross, a cell layer into and out of endothelial cells.

Answer Tips

(b) (i) Large molecules or plasma proteins can also pass through these gaps. Kupffer cells and other phagocytes can pass through, into tissue fluid.

(ii) Kupffer cells undergo phagocytosis, in which by endocytosis red blood cells (RBCs) are engulfed. A phagocytic vacuole or vesicle (phagosome) carrying RBC develops in the cytoplasm. A lysosome then fuses with phagosome to make phagolysosome. Hydrolytic enzymes or hydrolases in lysosome digest RBCs to produce products of haemoglobin, which are haem and globin. Globin is further digested to produce amino acids.

Answer Tips

(b) (ii) In endocytosis, Kupffer cells envelop its pseudopodia around RBC, to make an endocytic vesicle. Primary lysosome from Golgi body is pinched off and merges or joins with phagocytic vesicle.

Question 22

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.

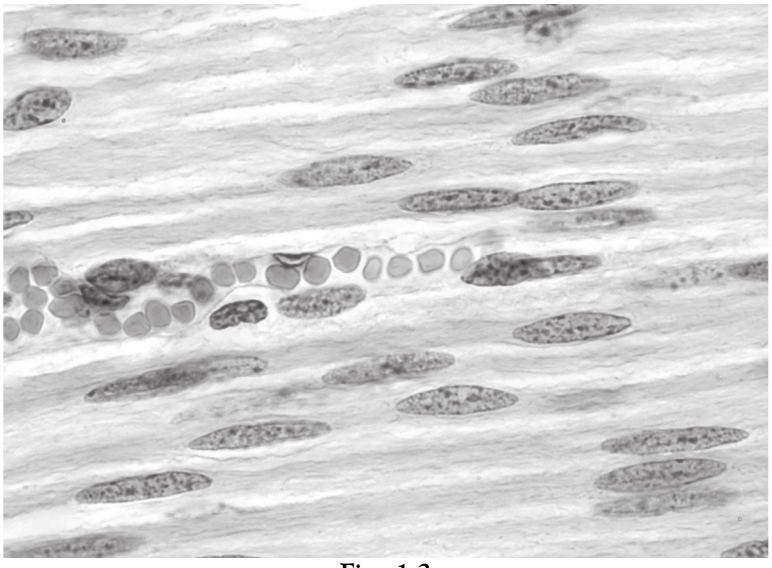


Fig. 1.2

(i) Outline the features that help to identify the blood vessel in Fig. 1.2 as a capillary. [2]

(ii) Explain how the structure of a capillary is related to its function in smooth muscle. [3]

[Total: 5] (J24/P2/Q1 c)

Answer Tips

(i) Capillary has thin wall of endothelium containing a single layer of cells. Diameter of capillary is narrower than the smooth muscle cell. Capillary has no muscle or elastic layer.

(ii) Exchange of respiratory gases between capillary and cells is facilitated. Due to small size or narrow diameter all cells are close and rate of blood flow slows down, which helps in uptake of oxygen and release of CO_2.

Solution

(i) Capillary contains wall which is one-cell thick. Red blood cells are transported in single file or in a queue. RBC, diameter is $7\ \mu m$, which is same as capillary diameter.

(ii) It supplies oxygen and nutrients such as glucose and amino acids to smooth muscle cells and removes CO_2 and lactic acid as waste from muscle cells. It has thin wall so substances can diffuse through short distance. Fenestrations or gaps between endothelial cells of capillary wall increase the rate of supply of substances. Endothelial pores help leakage of plasma for formation of tissue fluid around cells. Through these pores, WBCs like phagocytes, macrophages, monocytes can pass out.

Question 23

Studies suggest that people who are infected with HIV may be at a higher risk of heart disease. One cause of heart disease is the narrowing of the lumen of one or both of the main coronary arteries.

A coronary artery bypass graft (bypass graft) is a surgical operation that uses healthy blood vessels to divert blood around diseased sections of coronary arteries. The main choice of blood vessel to use for a bypass graft is known as the internal thoracic artery.

Fig. 6.1 is a diagram of an external view of the heart to show a **double** bypass graft.

The blood vessels used in the bypass graft shown in Fig. 6.1 are the great saphenous vein from the leg and the internal thoracic artery.

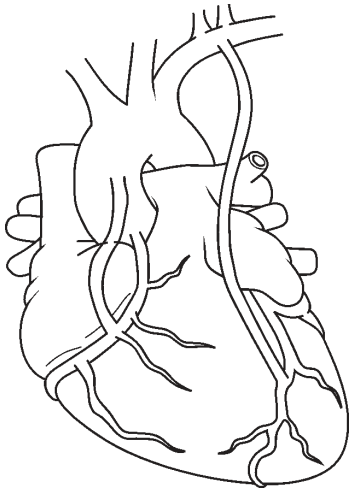


Fig. 6.1

(i) Draw a cross (**X**) on Fig. 6.1 to show an area of the **right** coronary artery that has been bypassed. [1]

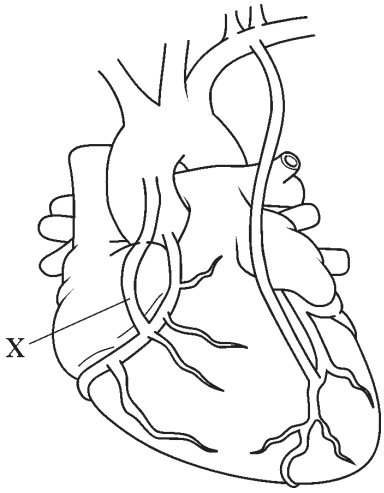
(ii) After surgery, the wall of the great saphenous vein becomes thicker.

Suggest **and** explain why it is important for the wall of the vein to become thicker after surgery. [2]

[Total: 3] (J24/P2/Q6 c)

Solution

(i)



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(ii) It thickens to withstand higher blood pressure and is less likely to burst. Thickness causes blood vessel to last longer. In tunica media of artery, there are more smooth muscle fibres having more elastic fibres, which help faster onward movement of blood.

Answer Tips

(ii) Thicker tunica externa or adventitia contains more collagen fibres which give it strength.

Question 24

Malaria is an infectious disease caused by the protoctist, *Plasmodium*.

As part of its lifecycle, *Plasmodium* infects human red blood cells. Researchers can compare haemoglobin from the red blood cells of a healthy person with haemoglobin from a person with malaria.

(a) Throughout the world, most deaths from malaria are caused by *P. vivax* and *P. falciparum*.

Name **one** other species of *Plasmodium* that causes malaria. [1]

(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**.

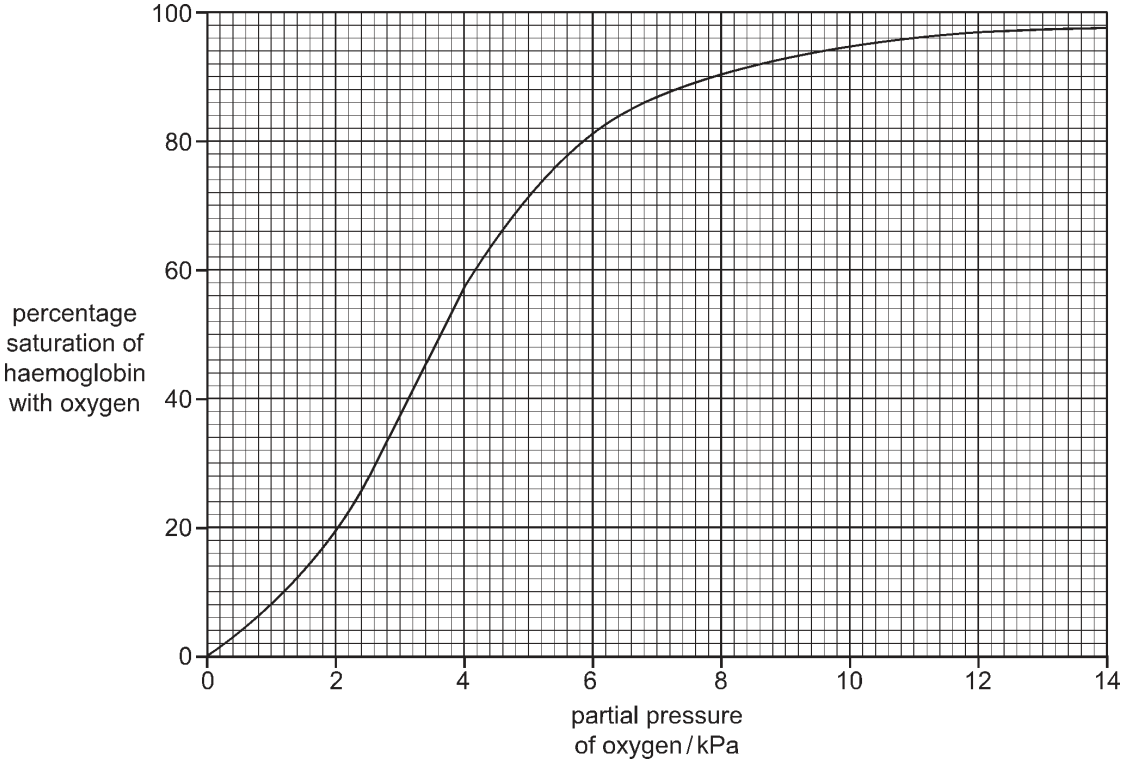

Fig. 5.1

(i) In the experiment used to obtain the results shown in Fig. 5.1, the temperature and pH were standardised.

Explain what the researchers would consider when deciding which temperature and pH to use in the experiment. [2]

(ii) 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. [3]

(c) A red blood cell that is infected with *Plasmodium* cannot carry out its function as effectively as a normal red blood cell.

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. [4]

[Total: 10] (N24/P2/Q5)

Solution

(a) ***Plasmodium:*** Ovale / malariae.

(b) (i) pH should be neutral, i.e., 7 or approximately 7.4 as blood pH fluctuates between 7 to 7.4. Body temperature is 37 °C to any value between 36 to 38 is acceptable. Uptake of oxygen and activity of Hb is affected by pH and temperature.

(ii) It will cause decreasing affinity of Hb for O_2. Lower percentage saturation of Hb with O_2 occurs, so lesser oxygen binds to Hb in the lungs. It becomes more difficult to load oxygen in the lungs. Oxygen is more readily released in respiring tissues. At any one partial pressure more oxygen is released in tissues.

(c) Diameter of RBC is $6-8\,\mu$m, so it is able to pass through lumen of capillary. Due to small size, it just fits into capillary and RBCs move in a line, one by one. Due to movement in single file, blood flow slows down which maximises time to take up O_2. It reduces diffusion distance for uptake of O_2. RBC has no nucleus and other organelles so more space is available for packing of Hb. No mitochondria, so oxygen is not used within the cell and can be only transported. It has biconcave shape, so compared to spherical, surface area for uptake of O_2 or gas exchange increases.

Answer Tips

(b) (ii) Higher partial pressure of oxygen is needed to reach same percentage saturation of Hb as due to infection, more RBCs are bursting.

(c) RBC has elastic CSM, so it can deform and squeeze through to change shape for passing through capillary. Due to biconcave shape, diffusion distance for O_2 to Hb is also decreased.