Proteins and Water (2.3 and 2.4): Cambridge (CIE) A Level Biology 9700 Exam Questions by Topic

22 questions · 55 marks · about 66 minutes. Answer in the spaces, then check the mark schemes at the end.

Question 1 · information from earlier in the question

(d) The polysaccharides and amino acids present in the mucilage are a source of nutrients for soil microorganisms that live in the area surrounding the root. Some of these microorganisms can break down soil compounds to release mineral ions.

Question 1 · Paper 2 · May/June 2023 (22) · Q2(d)(ii) · 2 marks

(ii) The soil microorganisms use amino acids to synthesise proteins. All of the twenty different amino acids that are present in proteins have the same general structure.

Draw the general structure of an amino acid in the space provided **and** use this drawing to explain how it is possible to have many different amino acids.

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Question 2 · Paper 2 · February/March 2023 (22) · Q2(a) · 1 mark

2 (a) Cysteine is an amino acid containing sulfur. Fig. 2.1 shows the structure of the molecule formed by joining two cysteine molecules together.

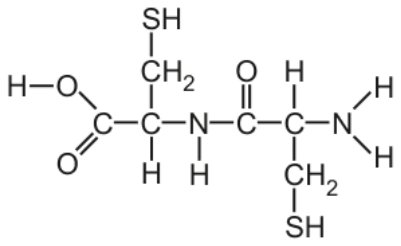


Fig. 2.1

Draw a circle around an R-group in the molecule shown in Fig. 2.1. [1]

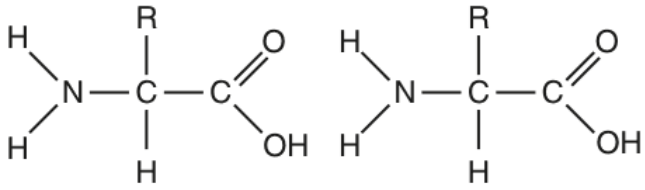
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Question 3 · Paper 2 · October/November 2016 (22) · Q2(c) · 2 marks

(c) Amino acids synthesised in the mesophyll cells of leaves are also transported in phloem sap to other locations where they are used to synthesise polypeptides.

Amino acids are joined by peptide bonds to form the polypeptides.

Two amino acids are shown below. Describe the formation of a peptide bond between these two amino acids. You may use the space below.



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(b) Fig. 2.2 shows part of a glycoprotein molecule.

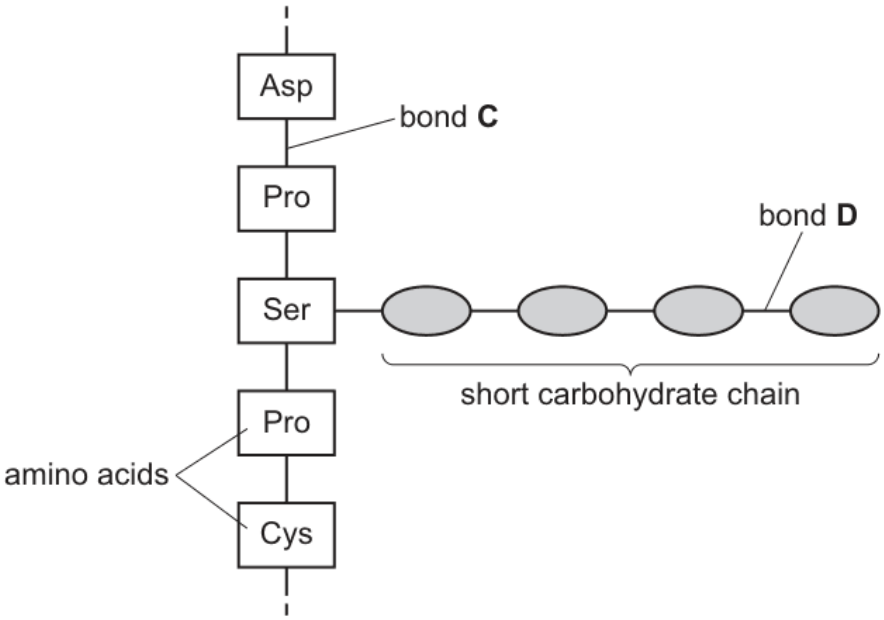


Fig. 2.2

(i) State the types of covalent bond labelled **C** and **D** in Fig. 2.2.

C .....

D .....

[2]

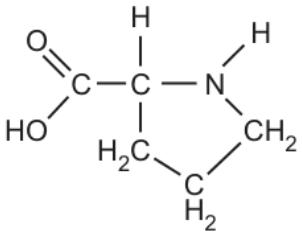
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(c) One of the proteins found in milk is β-casein.

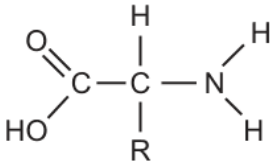
A molecule of β-casein consists of a single polypeptide of approximately 200 amino acids.

Molecules of β-casein have a **high** proportion of the amino acids proline and leucine. These amino acids have hydrophobic R-groups.

Fig. 2.3 compares the structure of proline (Pro) with the general structure of an amino acid. This shows that proline is an unusual amino acid because it has a cyclic R-group and the nitrogen atom is attached to only one hydrogen atom.



proline



general structure of an amino acid

Fig. 2.3

When a molecule of proline becomes part of a polypeptide, the hydrogen atom is lost from the nitrogen atom and is therefore **not** available for the formation of hydrogen bonds.

Molecules of β-casein have a relatively **low** proportion of the amino acids cysteine and serine. Table 2.1 shows the R-groups of cysteine and serine.

Table 2.1

amino acid	R-group	feature of R-group
cysteine (Cys)	$-CH_2SH$	can form a disulfide bond
serine (Ser)	$-CH_2OH$	hydroxyl group present

Compared to other protein molecules with a similar number of amino acids, β-casein molecules have:

- a much less organised secondary structure
- relatively little tertiary structure.

With reference to the four named amino acids, proline, leucine, serine and cysteine, suggest possible explanations for these **two** observations.

less organised secondary structure .....

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Question 6 · Paper 2 · October/November 2023 (22) · Q2(a) · 1 mark

2 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.

Question 7 · Paper 2 · May/June 2023 (23) · Q4(a)(i) · 3 marks

4 Food crops such as barley and wheat contain gluten. Gluten contains two proteins, glutenin and gliadin.

(a) (i) Table 4.1 contains descriptions of the structures of glutenin and gliadin.

Complete Table 4.1 by writing the level of protein structure that applies to each description.

Table 4.1

description	level of protein structure
a gliadin protein is a single polypeptide that forms a compact structure	
20% of the amino acids in a glutenin molecule are glycine	
gliadin and glutenin molecules contain regions of β-pleated sheets	

[3]

Question 8 · information from earlier in the question

3 Baculovirus is a virus that kills some of the insect pests of major crops. When the virus is released to the outside of the insect body, it is contained within stable, protective structures known as polyhedrons.

The main component of the polyhedron is a protein molecule, polyhedrin.

Polyhedrons can be sprayed onto plants as a bioinsecticide. They are ingested by feeding insect larvae and once inside the insect gut they break down to release the virus.

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Question 8 · Paper 2 · October/November 2021 (22) · Q3(c) · 4 marks

(c) A polyhedrin molecule is composed of three identical polypeptides. Each polypeptide is 245 amino acids long. The first 10 amino acids of the polypeptide are shown in Fig. 3.1.

1	2	3	4	5	6	7	8	9	10
met —	pro —	asp —	tyr —	ser —	tyr —	arg —	pro —	thr —	ile —

Fig. 3.1

Fig. 3.2 **A** is a ribbon diagram of a single polypeptide. Fig. 3.2 **B** shows a polyhedrin molecule composed of 3 polypeptides.

The two diagrams are not to the same scale.

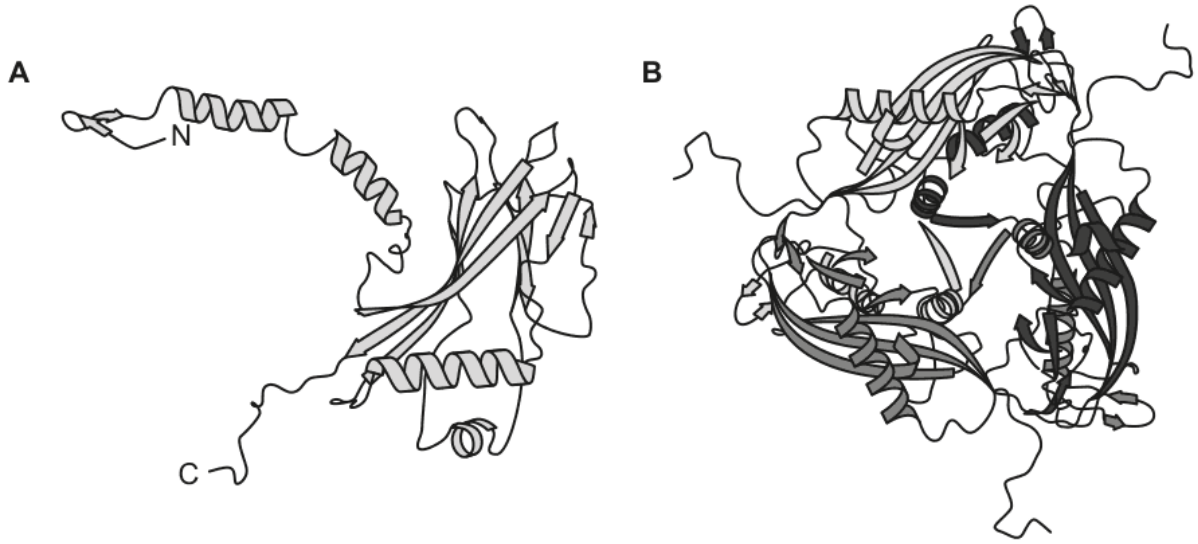


Fig. 3.2

With reference to Fig. 3.1 and Fig. 3.2, describe the structure of a polyhedrin molecule.

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Question 9 · information from earlier in the question

2 In mammalian red blood cells, carbonic anhydrase has an important role in the transport of carbon dioxide.

Carbonic anhydrase is an enzyme.

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(c) A ribbon structure of a molecule of carbonic anhydrase is shown in Fig. 2.2. The zinc ion is associated with the active site of the enzyme and is essential for the enzyme to function.

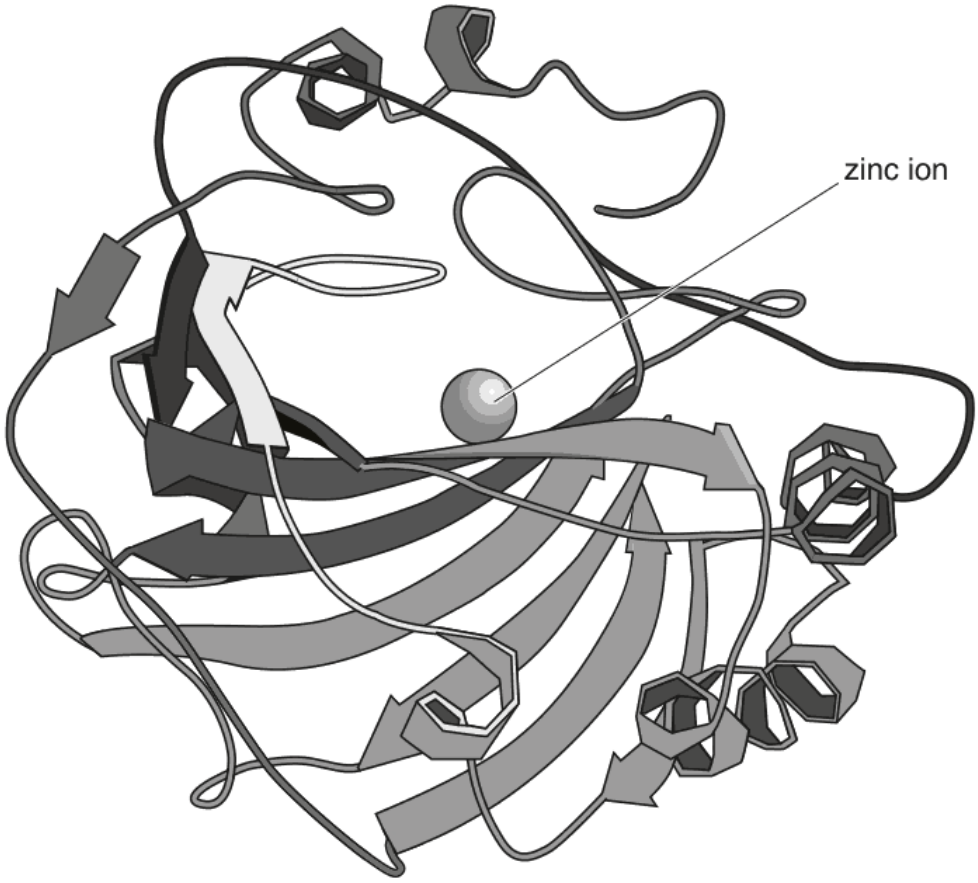


Fig. 2.2

The molecule of carbonic anhydrase has primary, secondary and tertiary structure.

Explain the extent to which Fig. 2.2 shows the primary, secondary and tertiary structure of carbonic anhydrase.

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Question 10 · Paper 2 · February/March 2023 (22) · Q2(b)(i) · 1 mark

(b) Goblet cells in the human gas exchange system produce proteins called mucins.

(i) The ends of mucin molecules contain many cysteine residues. Mucin strands are formed by joining the ends of mucin molecules together through covalent bonds between R-groups.

State the name of these covalent bonds.

Question 11 · Paper 4 (A level) · February/March 2018 (42) · Q4(a) · 2 marks

4 Ribulose 1,5-bisphosphate carboxylase/oxygenase (rubisco) is an important enzyme involved in the light independent stage (Calvin cycle) of photosynthesis. It fixes carbon by combining carbon dioxide with RuBP.

In certain situations, the active site of rubisco becomes occupied by a sugar phosphate, making the enzyme inactive. Rubisco can become active again in the presence of another enzyme, rubisco activase.

(a) Name all the bonds that are likely to hold a molecule of rubisco in shape.

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Question 12 · Paper 2 · May/June 2025 (22) · Q2(a) · 2 marks

2 The transport of respiratory gases involves blood plasma and red blood cells. Red blood cells contain the globular protein, haemoglobin.

(a) Describe features of a haemoglobin molecule that are typical of a globular protein, **other than** having an approximately spherical shape.

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Question 13 · information from earlier in the question

2 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.

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Question 13 · Paper 2 · October/November 2023 (22) · Q2(c) · 3 marks

(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.

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Question 14 · Paper 2 · October/November 2025 (22) · Q6(b)(i) · 2 marks

(b) Fig. 6.1 is a drawing of a haemoglobin molecule to show its globular structure.

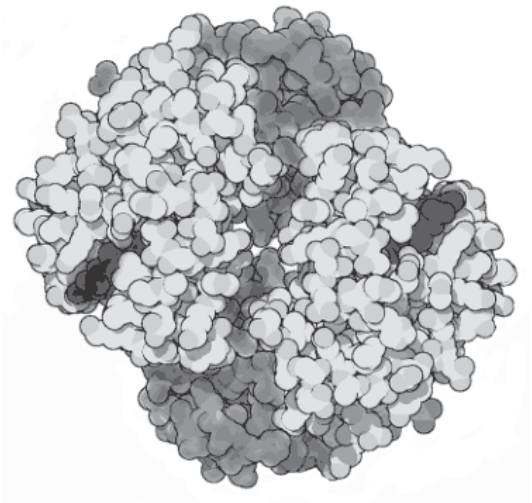


Fig. 6.1

(i) Describe the quaternary structure of a haemoglobin molecule.

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Question 15 · Paper 2 · October/November 2025 (22) · Q6(b)(ii) · 2 marks

(ii) Outline how a haemoglobin molecule can become fully saturated with oxygen to form oxyhaemoglobin.

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Question 16 · Paper 2 · October/November 2018 (22) · Q6(b) · 3 marks

(b) State the most appropriate term to match each of the descriptions **A** to **C**.

A The part of the haem group that binds oxygen in each haemoglobin polypeptide.

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B The compound formed when carbon dioxide binds to haemoglobin.

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C The compound formed when hydrogen ions (H^+) bind to haemoglobin.

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[3]

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Question 17 · Paper 2 · October/November 2022 (22) · Q5(a) · 3 marks

5 Fibroblasts are one of the cell types of connective tissue. The cells synthesise and secrete collagen, which forms part of the supporting external cellular environment, known as the extracellular matrix.

(a) Fig. 5.1 shows the primary structure of a section of a polypeptide chain of collagen.

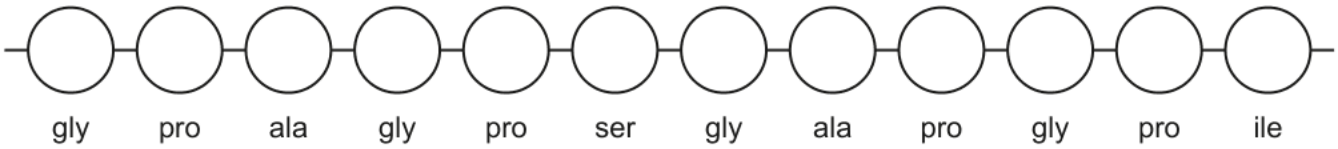


Fig. 5.1

Explain how the primary structure shown in Fig. 5.1 indicates that the structure of the polypeptide is suited to be a component of a collagen molecule.

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Question 18 · Paper 2 · May/June 2024 (23) · Q2(a) · 5 marks

2 Collagen is a fibrous protein that is found in many tissues in animals.

(a) Describe the structure of a collagen molecule **and** the structure of a collagen fibre.

collagen molecule .....

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collagen fibre .....

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[5]

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Question 19 · Paper 2 · February/March 2023 (22) · Q6(a) · 3 marks

6 **(a)** Collagen is the most common structural protein in vertebrates. Collagen provides the skin with flexibility and strength.

Explain how the structure of a collagen fibre provides the skin with strength.

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Question 20 · Paper 2 · October/November 2024 (22) · Q1(b) · 2 marks

(b) Glycerol is soluble in water. Triglycerides are insoluble in water.

Explain why water is a good solvent for some substances such as glycerol, but is a poor solvent for substances such as triglycerides.

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Question 21 · Paper 2 · February/March 2023 (22) · Q3(b)(i) · 2 marks

(b) Hydrogen bonding is important in the movement of water in xylem.

(i) Explain how hydrogen bonding occurs between two water molecules.

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Question 22 · Paper 2 · February/March 2023 (22) · Q3(b)(iii) · 2 marks

(iii) Hydrogen bonding between water molecules gives water a relatively high latent heat of vaporisation.

Suggest why it is important to plants that water has a high latent heat of vaporisation.

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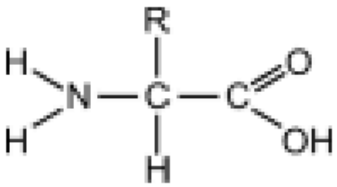
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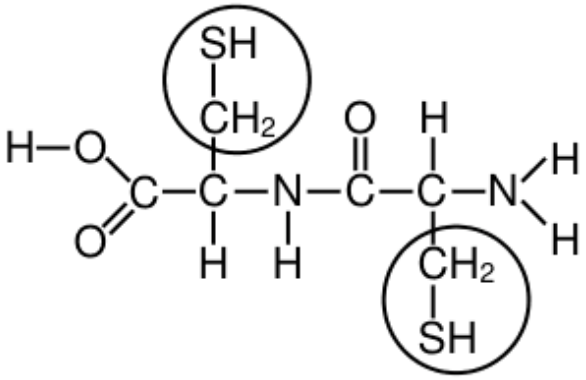
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Mark schemes

Question 1 · Paper 2 · May/June 2023 (22) · Q2(d)(ii) · 2 marks

2(d)(ii)	*all correct (NH_2 or COOH groups on left or right)* ; **A** H_2N  **A** COOH R-group / side chain, is variable **or** different amino acids have different, R-groups / side chains ; AW *this can be annotated on the diagram*	**2**

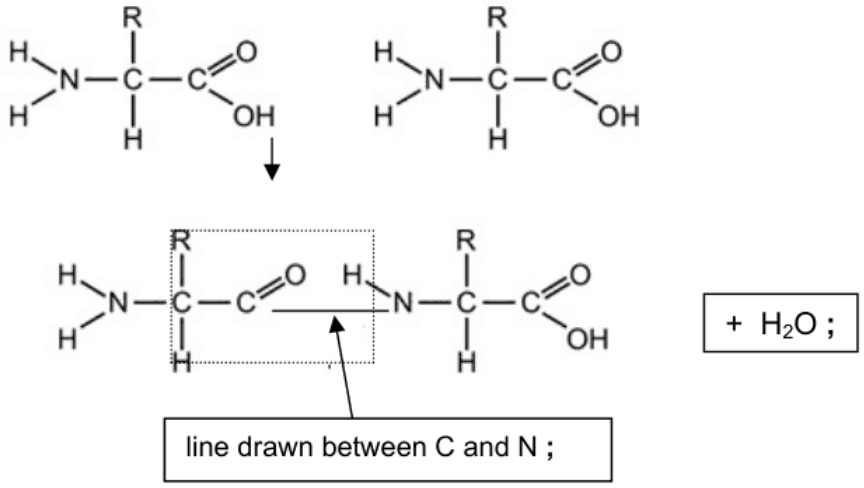
Question 2 · Paper 2 · February/March 2023 (22) · Q2(a) · 1 mark

2(a)	either **R** group circled ; 	**1**

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Question 3 · Paper 2 · October/November 2016 (22) · Q2(c) · 2 marks

(c) *can gain 2 marks if printed diagram is clearly modified to show correct bond and formation of water or/and if described as text*



dotted line area is minimum to gain mark
'peptide bond' label not required to gain mark

bond forms between the C of the carboxyl group and the N of the amino group ;
A amine *for amino*
water / H_2O, is formed ; **A** condensation (reaction) **R** hydrolysis [2]

Question 4 · Paper 2 · February/March 2025 (22) · Q2(b)(i) · 2 marks

2(b)(i)	**C** – peptide (bond) ; **D** – glycosidic (bond) ;	**2**

Question 5 · Paper 2 · February/March 2025 (22) · Q2(c) · 4 marks

2(c)	*any **four** from:* *less organised secondary structure (max **three**):* 1 high proportion of proline so less hydrogen bonding ; 2 so less, alpha helix / beta-pleated sheet, formation ; 3 less opportunity to form hydrogen bonds between –NH of one amino acid and –C=O of another amino acid (close by) ; 4 AVP ; e.g. greater proportion would have ~~a~~ random, coiling / structure ; *relatively little tertiary structure (max **three**):* 5 fewer amino acids will be forming ionic bonds between R-groups ; 6 little cysteine so, less / no, disulfide bonding (for tertiary structure) ; 7 (relatively little serine) so less hydrogen, bonding (in tertiary structure) ; 8 AVP ; e.g. high proportion of hydrophobic amino acids (proline and leucine) so tertiary structure will be more dependent on hydrophobic interactions	**4**

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Question 6 · Paper 2 · October/November 2023 (22) · Q2(a) · 1 mark

2(a)	secondary (structure) ;	1

Question 7 · Paper 2 · May/June 2023 (23) · Q4(a)(i) · 3 marks

4(a)(i) — 3

description	level of protein structure
a gliadin protein is a single polypeptide that forms a compact structure	tertiary
20% of the amino acids in a glutenin molecule are glycine	primary
gliadin and glutenin molecules contain regions of β-pleated sheets	secondary

1 mark per correct row ;;;

Question 8 · Paper 2 · October/November 2021 (22) · Q3(c) · 4 marks

3(c) — 4

if detail is linked to incorrect level of structure or levels of structure not named, **max 3**

1 primary structure detail ;
e.g. sequence of amino acids / ref. to sequence in Fig 3.1
(many) amino acids joined by peptide bonds

2 secondary structure detail ;
e.g. has, α / alpha, helices
has β / beta, pleated sheets **A** β / beta, pleats
has areas of random coils / AW

3 tertiary structure detail ;
e.g. interactions between, side chains / R groups
(R group interactions are) H bonds, ionic bonds, hydrophobic interactions, disulfide bridges *any two*
folding and coiling *in context of polypeptide chain*

4 quaternary structure detail;
e.g. three (identical) polypeptide chains
ref. to interaction of polypeptide chains
A polypeptides *for polypeptide chains*

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Question 9 · Paper 2 · February/March 2019 (22) · Q2(c) · 4 marks

2(c)	*any **four** from:* *primary:* sequence of amino acids not shown ; **A** cannot see primary structure of amino acids *secondary:* alpha / α, -helices shown ; beta / β, -pleated sheets shown ; (areas of) random arrangement shown ; *tertiary*: folding / coiling, (of polypeptide chain) shown / ref. to 3-D configuration ; globular shape shown ; interactions between, R-groups / side-chains, (of amino acids) not shown ; ref. to any two bond types not shown ; e.g. H bonds / disulfide bridges / ionic bonds / hydrophobic interactions folding allows presence of zinc / AW ;	**4**

Question 10 · Paper 2 · February/March 2023 (22) · Q2(b)(i) · 1 mark

2(b)(i)	disulfide (bonds) ;	**1**

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Question 11 · Paper 4 (A level) · February/March 2018 (42) · Q4(a) · 2 marks

4(a)	1 covalent / peptide ; 2 hydrogen ; 3 ionic / electrostatic ; 4 disulfide ; 5 hydrophobic interactions ; 6 Van der Waals ; *4 correct = 2 marks* *2 / 3 correct = 1 mark*	**2**

Question 12 · Paper 2 · May/June 2025 (22) · Q2(a) · 2 marks

2(a)	*any **two** from:* amino acids with hydrophilic R groups to, exterior / outside, (of molecule) **A** facing, watery / aqueous, environment / cytosol / cytoplasm **or** amino acids with hydrophobic R groups to, interior / centre / AW, (of molecule) **;** **A** hydrophilic / hydrophobic, amino acids *must see amino acids somewhere in text to allow hydrophobic / hydrophilic ideas* soluble (in water / cytoplasm / cytosol) **;** **A** forms colloidal suspension physiological / metabolic / dynamic, (role) **;** **I** functional unless qualified e.g. functional, for example haemoglobin carries oxygen has a functional role / functional, not structural AVP **;** e.g. non-repetitive / irregular, sequence(s) of amino acids *ref. to* two or more bond types holding (3D) shape / tertiary structure / quaternary structure in place, but **R** if peptide bonds listed	**2**

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Question 13 · Paper 2 · October/November 2023 (22) · Q2(c) · 3 marks

2(c)	*any **three** from:* fibrous ; **A** not globular **I** structural insoluble / does not dissolve / does not dissolve easily ; (high proportion of) disulfide bonds / disulfide bridges / covalent bonds (because of cysteines) ; high proportion of / many / AW, hydrogen bonds (between polypeptides) ; high proportion of / many, hydrophobic interactions ; **A** many, amino acids with hydrophobic R-groups / hydrophobic R-Groups tight / close, packing, of, chains / polypeptides / molecules ; **I** triple helix AVP ; e.g. arranged so peptide bonds are not accessible parts of molecule needing to bind to active site not accessible many amino acids with small R-groups / small amino acids **I** details specific to collagen e.g. gly every third amino acid amino acids	**3**

Question 14 · Paper 2 · October/November 2025 (22) · Q6(b)(i) · 2 marks

6(b)(i)	*if no marks gained allow one mark for four, polypeptides / polypeptide chains* two, (identical) alpha / α, chains / globins, and two, (identical) beta / β, chains / globins ; **A** subunits / polypeptides, for chains **R** beta-pleated sheets / globulin *plus **one** from;* each, chain / globin / polypeptide, incorporates / contains / AW, a haem (group) ; **A** four haem groups **A** molecule for polypeptide if mp1 gained **A** ferrous ion / Fe^{2+} / iron (ion / atom), within porphyrin (ring) for haem group **A** prosthetic group with, ferrous ion / Fe^{2+} / iron (ion / atom) hydrogen bonds / hydrophobic interactions / ionic bonds, between, chains / polypeptides / globins ; *context is interactions between chains* **R** if disulfide bond also stated	**2**

Question 15 · Paper 2 · October/November 2025 (22) · Q6(b)(ii) · 2 marks

6(b)(ii)	oxygen binds to, iron ion / ferrous ion / Fe^{2+} ; **A** oxygen bonds / oxygen forms a bond, *only if*, iron ion / ferrous ion / Fe^{2+} stated **A** oxygen binds to, iron / iron atom / haem (group) **R** if more than one oxygen molecule binds to one iron ion detail of saturated ; e.g. total of 4 oxygen molecules / 8 oxygen atoms (bind per haemoglobin molecule) each, chain / globin / polypeptide, binds one oxygen molecule **R** bonds *ref. to* cooperative binding / allostery **A** description *ref. to* (fully saturated molecule is) in, high partial pressures of oxygen / high concentration of oxygen ; *ref. to* T / tense, state to, R / relaxed, state	**2**

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Question 16 · Paper 2 · October/November 2018 (22) · Q6(b) · 3 marks

6(b)	**A** iron / Fe ; **I** oxidation status of Fe **A** iron atom / iron ion **R** iron molecule **B** carbaminohaemoglobin ; **C** haemoglobinic acid ;	**3**

Question 17 · Paper 2 · October/November 2022 (22) · Q5(a) · 3 marks

5(a)	*any **three** from: accept gly for glycine throughout* glycine every third amino acid ; glycine, is, small / smallest, amino acid ; **A** has H as R-group glycine allows tight coiling of polypeptides to form triple helix ; AW **A** glycine presence allows a, compact / AW, triple helix gly (-NH) can form hydrogen bonds with (C=O in pro of) other polypeptides of triple helix ; **A** *idea that* H bonds can form with other polypeptides in the triple helix AVP ; e.g. pro / ala, also small amino acids (for tight coiling) high proportion of smaller amino acids / amino acids with small side chains **A** high proportion of glycine *if mp1 <u>not</u> given and mp2 is* pro can form hydroxyproline for stability ref. insoluble and (some), amino acids with non-polar R-groups (e.g. ala)	**3**

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Question 18 · Paper 2 · May/June 2024 (23) · Q2(a) · 5 marks

2(a)	*max 1 in molecule section if mps from collagen fibre included as features of a molecule* *max 1 in fibre section if mps from molecule included as features of collagen fibre* ***or*** *if polypeptide described in molecule section and all features in fibre section are descriptive for a collagen molecule* *any* ***five*** *from*: *molecule (to max 4)* **1** three, helical / AW, polypeptides / chains **I** quaternary structure **or** triple helix ; **2** (helical chains) tightly wound ; **3** hydrogen bonds between, polypeptides / chains ; **4** (generally) every third amino acid (in each, polypeptide / chain) is glycine ; *fibre (to max 4)* **5** cross links / covalent bonds , between molecules ; **6** molecules arranged in parallel ; **7** molecules (in fibril / fibre) are, staggered / ends not aligned **/** AW ; **8** AVP ; e.g. detail of H bonds collagen fibre can be composed of collagen fibrils made of (parallel) collagen molecules glycosylated (amino acids in polypeptide) / hydroxylated	**5**

Question 19 · Paper 2 · February/March 2023 (22) · Q6(a) · 3 marks

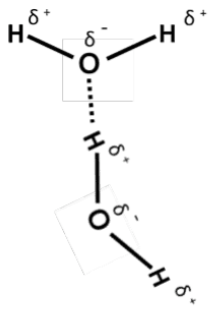
6(a)	*any* ***three*** *from:* covalent bonds between collagen molecules (between R groups / side-chains) ; covalent bonds are strong ; (molecules) staggered / overlapping molecules, so no weak areas **(**gives greater strength) ; (in skin) fibres line up in layers**,** not parallel / running in different directions ; provides tensile strength / strength in different directions ;	**3**

Question 20 · Paper 2 · October/November 2024 (22) · Q1(b) · 2 marks

1(b)	*any* ***two*** *from:* **1** water is, a polar molecule / polar / dipolar ; **A** water is a dipole **A** description e.g. the O atom (of water) has, a slightly negative / δ^-, charge, and the H atoms have a slightly positive / δ^+, charge **2** water can form, hydrogen bonds / H-bonds, with, glycerol / polar substances ; **ora** = water cannot form H-bonds with, triglycerides / non-polar substances **3** glycerol / polar molecules / ions, interact with water (molecules) / are attracted to water (molecules) / are hydrophilic ; **A** idea that water, attracts / collects around / AW, ions / charged substances **ora** = triglycerides / non-polar / uncharged, molecules, do not interact with water / repel water / are hydrophobic **I** 'tails'	**2**

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Question 21 · Paper 2 · February/March 2023 (22) · Q3(b)(i) · 2 marks

3(b)(i)	this could be answered diagrammatically or in text, e.g.  *any **two** from:* *idea that* oxygen has a small negative charge and hydrogen has a small positive charge **;** *idea that* a hydrogen bond forms between the oxygen of one water molecule and the hydrogen of a neighbouring water molecule **;** AVP **;** e.g. oxygen is more electronegative than hydrogen	**2**

Question 22 · Paper 2 · February/March 2023 (22) · Q3(b)(iii) · 2 marks

3(b)(iii)	*any **two** from:* ref. to plant leaves heat up, when light absorbed for photosynthesis / at high (ambient) temperatures **;** (high latent heat of vaporisation leads to large cooling effect / removal of (large quantities of) heat energy, by evaporation **;** reduces, protein / enzyme, denaturation **;** reduces rate of water loss by, transpiration / evaporation, at high temperatures **;** AVP **;**	**2**

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