Week 5

A-Level Biology

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

A-Level Biology Name: ______________ Score: ______

1. A sample is heated with Benedict's solution and turns brick-red. This shows the presence of:
   - ☐ a reducing sugar
   - ☐ starch
   - ☐ a lipid
   - ☐ a protein
2. Which is a monosaccharide?
   - ☐ glucose
   - ☐ starch
   - ☐ sucrose
   - ☐ glycogen
3. A triglyceride is made from:
   - ☐ one glycerol and three fatty acids joined by ester bonds
   - ☐ three glycerols and one fatty acid
   - ☐ amino acids joined by peptide bonds
   - ☐ glucose units joined by glycosidic bonds
4. The bond that joins two amino acids is a:
   - ☐ peptide bond, formed by condensation (water removed)
   - ☐ glycosidic bond
   - ☐ ester bond
   - ☐ hydrogen bond
5. Water is a polar molecule that forms hydrogen bonds.

   ☐ True ☐ False
6. Orange-brown iodine solution turns blue-black. This detects:
   - ☐ starch
   - ☐ a reducing sugar
   - ☐ a lipid
   - ☐ a protein

7. Sucrose is a non-reducing sugar, so it gives a negative Benedict's test unless it is first hydrolysed.

   ☐ True ☐ False

8. Glycerol joins each fatty acid by an _________ bond, formed by condensation.

   ____

9. A protein made of two or more polypeptide chains joined together has a _________ structure.

   ____

10. In the biuret test, a positive result for protein turns the solution from blue to _________.

   ____

A-Level Biology

1. **a reducing sugar**

   Benedict's test (with heat) detects reducing sugars; a positive result goes blue → green → orange → brick-red.

2. **glucose**

   Glucose is a single sugar unit (monosaccharide); sucrose is a disaccharide; starch and glycogen are polysaccharides.

3. **one glycerol and three fatty acids joined by ester bonds**

   A triglyceride = 1 glycerol + 3 fatty acids, joined by ester bonds (each forms by condensation).

4. **peptide bond, formed by condensation (water removed)**

   Amino acids join by peptide bonds, formed by condensation with the loss of one water molecule.

5. **True**

   Polarity (a slightly negative oxygen and slightly positive hydrogens) lets neighbouring molecules form hydrogen bonds, which explain water's properties.

6. **starch**

   The iodine test detects starch — the orange-brown solution turns blue-black.

7. **True**

   Glucose and maltose are reducing sugars (positive Benedict's); sucrose is non-reducing, so you must hydrolyse it (acid + heat) first.

8. **ester**

   Three ester bonds form, removing three water molecules in total.

9. **quaternary**

   Quaternary structure is two or more chains in one protein — e.g. haemoglobin (four chains).

10. **purple**

    Biuret solution turns blue → purple when protein is present (no heating needed).

2.1 Testing for biological molecules

Name: ____________ Class: ________ Date: __________ **Total: 17 marks**

KEY WORDS reducing sugar 还原糖 • iodine 碘 • hydrochloric acid 盐酸 • protein 蛋白质 • starch 淀粉

Objective

Build the skills to answer exam questions on **testing for biological molecules** — carrying out and interpreting the food tests, the **semi-quantitative** 半定量 Benedict's test, and the test for **non-reducing sugars** 非还原糖.

You must be able to:

- name the reagent, method and positive result for the reducing-sugar, starch, lipid and protein tests
- make the Benedict's test semi-quantitative and use it to estimate a concentration
- describe the acid-hydrolysis test for a non-reducing sugar

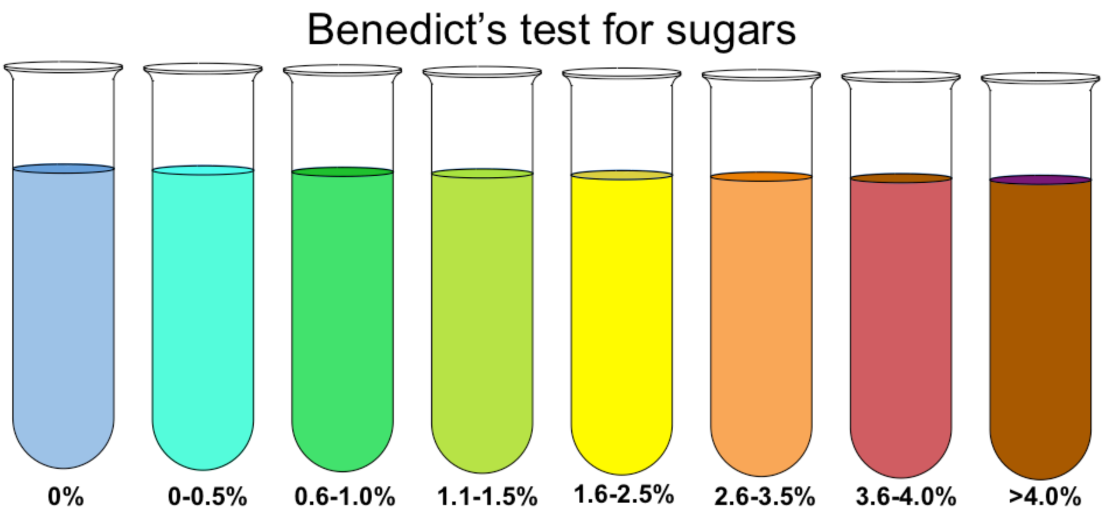
1 Worked examples

Study these first. Each one shows the **method** 方法 for a question type used later.

The four food tests

Learn the reagent and the colour change for each test.

test	finds	method	positive result
Benedict's	**reducing sugar** 还原糖	add Benedict's solution, heat in a water bath	blue → green → yellow → orange → brick-red **precipitate** 沉淀
iodine	**starch** 淀粉	add orange-brown iodine solution	turns blue-black
emulsion	**lipid** 脂质	mix with ethanol, then pour into water	white cloudy **emulsion** 乳浊液
biuret 双缩脲	**protein** 蛋白质	add biuret solution (no heating)	blue → purple



Benedict's test: more reducing sugar gives a colour further along, from blue to brick-red

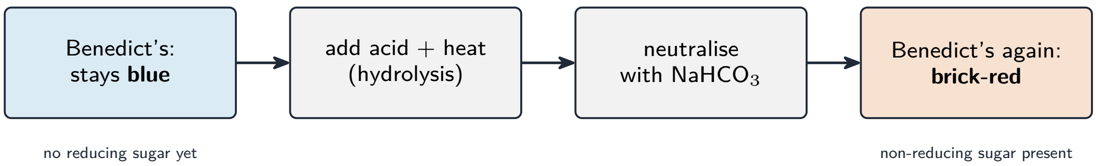
■ Making Benedict's semi-quantitative

The normal test only says "yes/no". To estimate **how much** sugar is present, first **standardise** 标准化 the test on solutions of known **concentration** 浓度. Then estimate an unknown by either the **time to the first colour change** (more sugar → faster change) or by matching the final colour to your set of standards.

■ Testing for a non-reducing sugar

Sucrose gives a *negative* Benedict's test. To detect it:

1. Do a normal Benedict's test — it stays blue (no reducing sugar).
2. With a fresh sample, add dilute hydrochloric acid and heat — this **hydrolyses** 水解 the sugar into reducing sugars.
3. **Neutralise** 中和 the acid with sodium hydrogencarbonate.
4. Repeat the Benedict's test — a brick-red colour now shows a non-reducing sugar was present.



Hydrolyse the sugar with acid first, then the second Benedict's test turns red

2 Practice

2.1 State the reagent and the positive result for each test. [4]

test	reagent	positive result
starch		
protein		

2.2 A student wants to compare the reducing-sugar concentration of three drinks. Describe how the Benedict's test can be made **semi-quantitative** to do this. [3]

3 Exam-style questions

3.1 Which test and result correctly identifies a protein? [1]

- **A** biuret solution, stays blue
- **B** biuret solution, turns purple
- **C** Benedict's solution, turns brick-red
- **D** iodine solution, turns blue-black

3.2 A solution gives a negative Benedict's test. After boiling it with hydrochloric acid, neutralising, and re-testing, it turns brick-red. The solution contained: [1]

- **A** a lipid
- **B** a non-reducing sugar
- **C** a protein
- **D** starch

3.3 A student is given an unknown solution X and asked to find out whether it contains reducing sugar, starch and protein.

(a) Describe the tests the student should carry out and the result that would show each substance is present. [4]

(b) The student finds that X contains a non-reducing sugar but no reducing sugar. Describe how the student could have shown this. [3]

(c) State **one** variable the student should keep the same when comparing the colour from different samples. [1]

Solutions

2.1 starch — iodine (solution); turns blue-black. protein — biuret solution; turns purple/lilac.

2.2 standardise the test using solutions of **known concentration**; record the time to first colour change *or* the final colour for each; estimate the unknown by comparing its time/colour to these standards.

3.1 B. Biuret turns from blue to purple with protein; no heating is needed.

3.2 B. A non-reducing sugar (e.g. sucrose) is negative until acid hydrolysis breaks it into reducing sugars.

3.3 (a) Benedict's solution + heat → brick-red shows reducing sugar; iodine solution → blue-black shows starch; biuret solution → purple shows protein.
(b) do a Benedict's test (stays blue); then boil a fresh sample with hydrochloric acid and neutralise; Benedict's now gives brick-red → non-reducing sugar present.
(c) e.g. volume of sample / volume of Benedict's / temperature / time of heating.

6 Solution X was tested for the presence of non-reducing sugars. It did **not** contain reducing sugars.

Some steps that can be used to test for the presence of biological molecules are listed.

1 Add Benedict's solution to the test-tube.

2 Add dilute hydrochloric acid to the test-tube.

3 Add sodium hydrogencarbonate to the test-tube.

4 Heat the test-tube in a water-bath.

Which order of steps to identify the presence of non-reducing sugars in solution X is correct?

A $1 \rightarrow 4$

B $2 \rightarrow 3 \rightarrow 1 \rightarrow 4$

C $2 \rightarrow 4 \rightarrow 3 \rightarrow 1 \rightarrow 4$

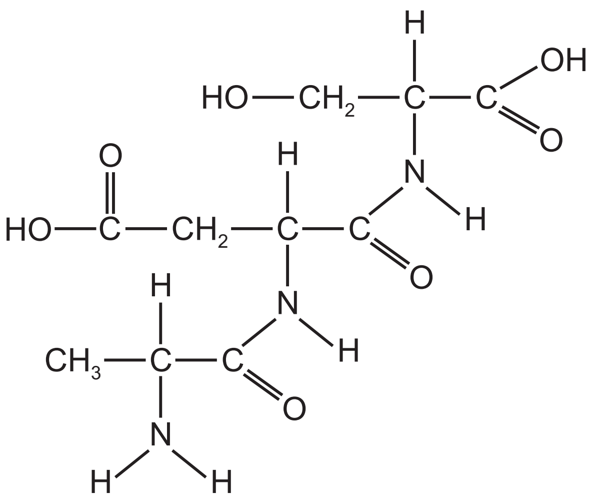
D $3 \rightarrow 2 \rightarrow 4 \rightarrow 1$

6 A student carried out four tests for biological molecules. The observations are shown in the table.

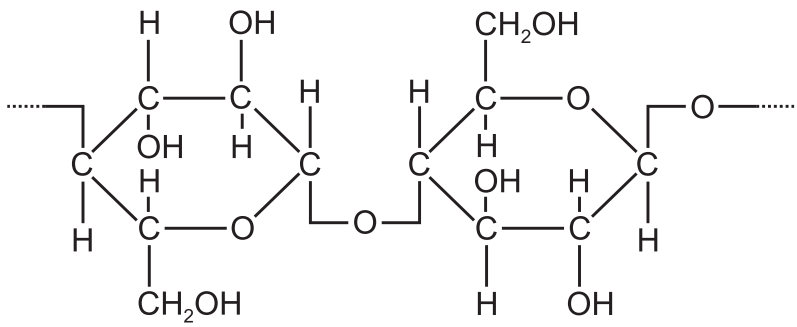
test	observations
iodine	orange
biuret	purple
Benedict's	orange
emulsion	clear

The diagrams show molecules or parts of molecules.

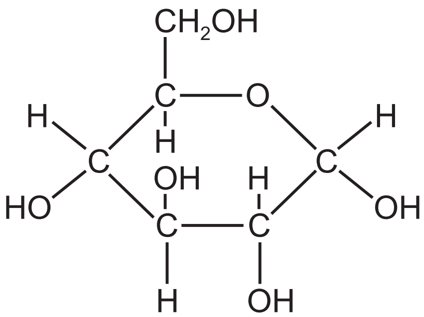
Which pair is present in the solution?



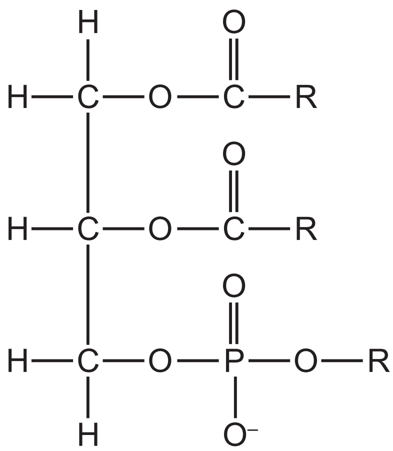
1



2



3



4

A 1 and 2 **B** 1 and 3 **C** 2 and 3 **D** 3 and 4

8 The diagram shows some steps in a laboratory method used to identify the presence of non-reducing sugars in a food sample.

Some terms are missing.

step X → step Y → end colour Z

Which terms are correct for the expected result for a very low concentration of non-reducing sugar?

	X	Y	Z
A	acid hydrolysis	Benedict's test	orange
B	Benedict's test	acid hydrolysis	orange
C	acid hydrolysis	Benedict's test	green
D	Benedict's test	acid hydrolysis	green

A-Level Biology: **w25 14**

6 Trehalose is a non-reducing disaccharide.

Separate samples of a mixture of fructose and trehalose were tested with Benedict's solution before and after acid hydrolysis.

What will be the results of these Benedict's tests?

	before acid hydrolysis	after acid hydrolysis
A	✓	✓
B	✓	✗
C	✗	✓
D	✗	✗

key

✓ = positive result with Benedict's test

✗ = negative result with Benedict's test

1 Dialysis tubing is a partially permeable membrane. Glucose molecules can diffuse through the dialysis tubing.

You are required to investigate the diffusion of glucose across dialysis tubing.

You are provided with the materials shown in Table 1.1.

Table 1.1

labelled	contents	hazard	volume / cm^3
G	20.0% glucose solution	low	50
W	distilled water	low	200
Benedict's	Benedict's solution	harmful irritant	40
D	length of dialysis tubing in distilled water	low	–

If any solution comes into contact with your skin, wash off immediately with cold water. It is recommended that you wear suitable eye protection.

You will need to:

- put glucose solution into dialysis tubing surrounded by water
- take samples of the water surrounding the dialysis tubing
- test for the presence of glucose in each sample of water.

Carry out step 1 to step 11.

step 1 Draw a mark 8 cm from the top of a large test-tube, as shown in Fig. 1.1.

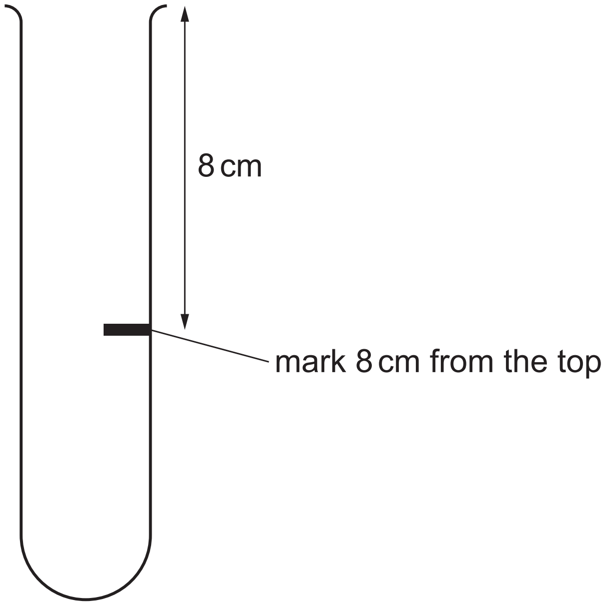


Fig. 1.1

step 2 Remove the dialysis tubing from beaker **D**. Tie a knot in the dialysis tubing as close as possible to one end, so that the end is sealed.

step 3 The whole length of the dialysis tubing needs to be separated to allow the tubing to be filled with solution. To do this, rub the whole length gently between your finger and thumb.

step 4 Put 10 cm^3 of 20.0% glucose solution, **G**, into the open end of the dialysis tubing.

step 5 Rinse the outside of the dialysis tubing by dipping it in the water in beaker **D**.

step 6 Put the dialysis tubing containing **G** into the large test-tube and keep it in position using an elastic band as shown in Fig. 1.2.

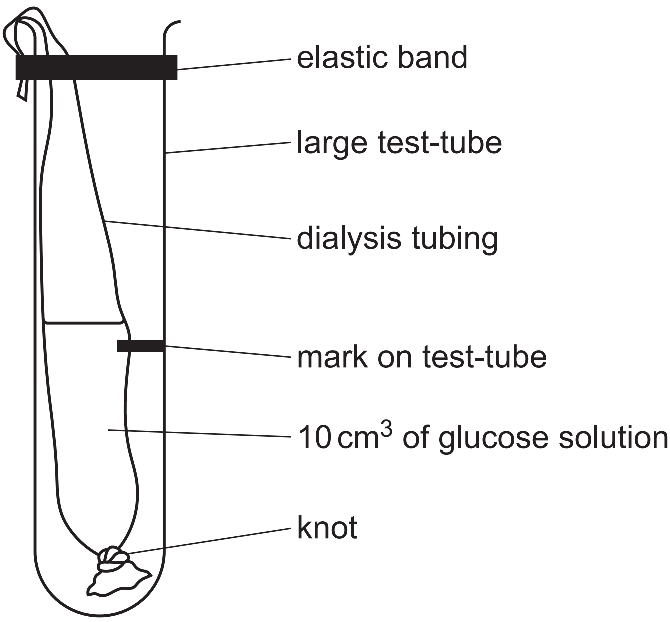


Fig. 1.2

step 7 Put distilled water into the large test-tube so that the top of the water is above the level of the glucose solution in the dialysis tubing.

step 8 Start timing.

You are required to take samples of the water surrounding the dialysis tubing every 5 minutes for 15 minutes. You will collect three samples.

step 9 Label three test-tubes with the times the samples of water will be taken (**5**, **10** and **15**).

step 10 After 5 minutes (step 8), put a 1 cm^3 syringe into the water surrounding the dialysis tubing so that the end of the syringe is level with the mark on the test-tube. Remove 1 cm^3 from the water surrounding the dialysis tubing and put this into the test-tube labelled **5**. Repeat this action to remove another 1 cm^3 from the water surrounding the dialysis tubing and put this into the test-tube labelled **5**. The test-tube labelled **5** will now contain a 2 cm^3 sample. Do **not** stop timing.

step 11 Repeat step 10 at 10 minutes and at 15 minutes using the appropriately labelled test-tubes.

You need to carry out a dilution of the 20.0% glucose solution, **G**, to make a 1.0% glucose solution. You will need 20 cm^3 of this 1.0% glucose solution.

(a) **(i)** Complete Table 1.2 to show the volume of distilled water, **W**, you will use to make 20 cm^3 of a 1.0% glucose solution.

Table 1.2

volume of 20.0% glucose solution, G / cm^3	**volume of distilled water, W / cm^3**
1	....

[1]

step 12 Prepare the 1.0% glucose solution as shown in Table 1.2.

You will need to carry out a **serial** dilution of the 1.0% glucose solution you have prepared in step 12 as shown in Fig. 1.3. You must reduce the concentration by **half** between each successive dilution.

You will need to prepare **four** concentrations of glucose solution in addition to the 1.0% glucose solution from step 12.

After the serial dilution is completed, you will need to have 10 cm^3 of each concentration available to use.

(ii) Complete Fig. 1.3 to show how you will prepare your serial dilution.

Each beaker should have:

- a labelled arrow to show the volume of glucose solution transferred
- a labelled arrow to show the volume of distilled water, **W**, added.

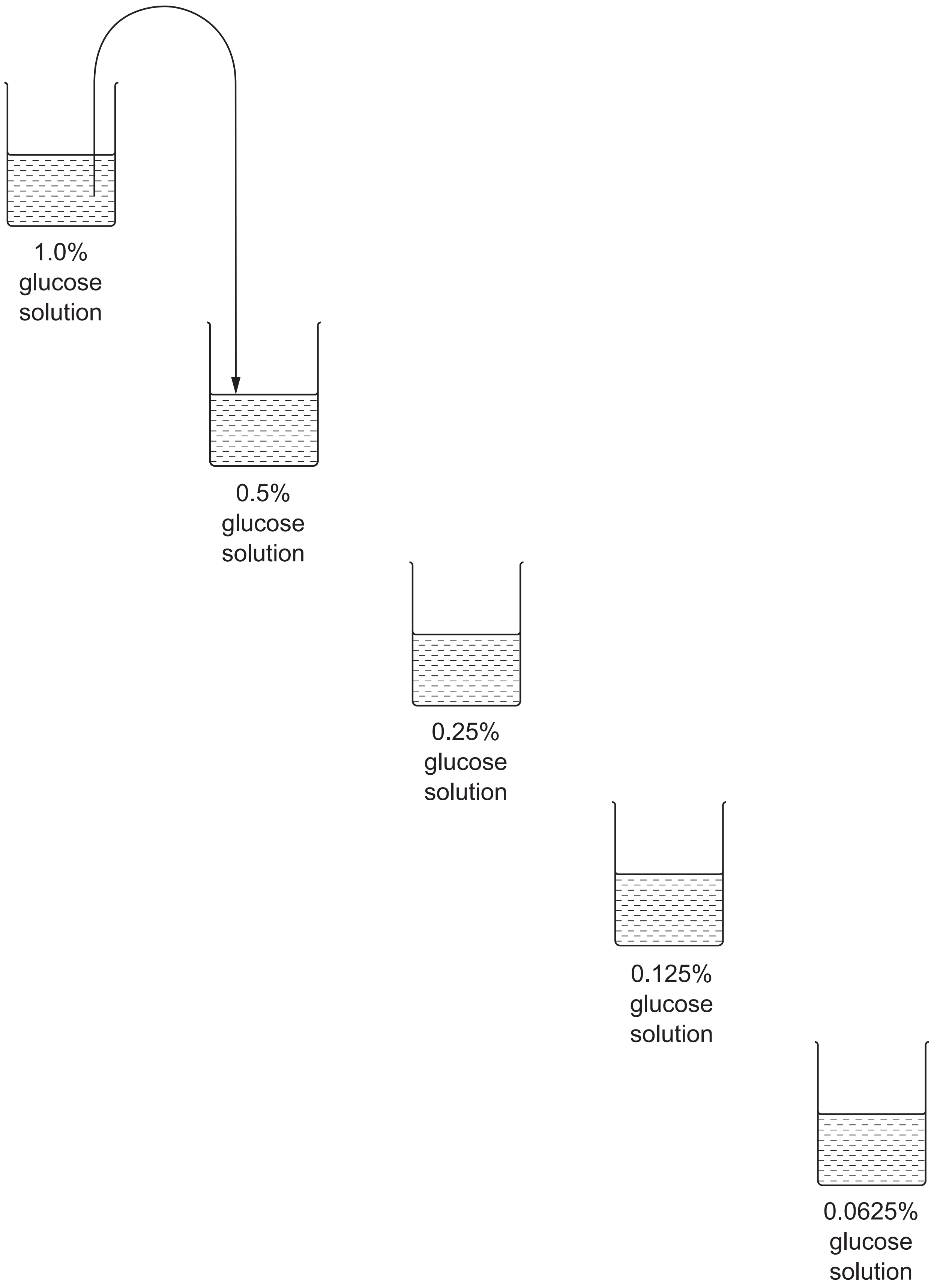


Fig. 1.3

[2]

step 13 Set up a boiling water-bath ready for step 18 and step 22.

step 14 Prepare the concentrations of glucose solution as shown in Fig. 1.3.

step 15 Label 5 test-tubes with the concentrations of glucose solution shown in Fig. 1.3.

step 16 Put 2 cm^3 of the 1.0% glucose solution into the appropriately labelled test-tube.

(iii) You are required to carry out the Benedict's test on the glucose solutions that you have prepared in step 14.

State the volume of Benedict's solution you will use for each reducing sugar test. Explain why you have selected this volume.

volume of Benedict's solution .... cm^3

explanation ....

....
[1]

step 17 Put the volume of Benedict's solution stated in **(a)(iii)** into the test-tube labelled 1.0%. Shake gently to mix.

step 18 Put this test-tube into the boiling water-bath and record in Table 1.3 the time to the first colour change.

If there is no colour change after 120 seconds, stop timing and record the time as 'more than 120'.

step 19 Remove the test-tube from the boiling water-bath.

step 20 Repeat step 16 to step 19 using 2 cm^3 of each of the other concentrations of glucose solution.

(iv) Complete Table 1.3 to record your results.

Table 1.3

percentage concentration of glucose	
1.0	
0.5	
0.25	
0.125	
0.0625	

[1]

You are required to carry out the Benedict’s test on the three samples collected from the water surrounding the dialysis tubing (**5**, **10** and **15**).

step 21 Put the volume of Benedict’s solution stated in **(a)(iii)** into the test-tube labelled **5**. Shake gently to mix.

step 22 Put this test-tube into the boiling water-bath and record in **(a)(v)** the time to the first colour change.

If there is no colour change after 120 seconds, stop timing and record the time as ‘more than 120’.

step 23 Remove the test-tube from the boiling water-bath.

step 24 Repeat step 21 to step 23 for the other samples (**10** and **15**).

(v) Record your results in an appropriate table.

[4]

(vi) State **one** source of error when carrying out the Benedict’s test.

....

.... [1]

(vii) Use your results in **(a)(iv)** and **(a)(v)** to estimate the percentage concentration of glucose in the samples taken at **5**, **10** and **15** minutes.

percentage concentration of glucose in sample **5** = ...

percentage concentration of glucose in sample **10** = ...

percentage concentration of glucose in sample **15** = ...

[1]

(viii) Suggest a reason for the percentage concentrations of glucose estimated in **(a)(vii)**.

....

....

....

.... [1]

Question 1 continues on page 10.

(b) A dialysis membrane, similar to dialysis tubing, is used in the treatment of kidney disease.

During this treatment, the blood of a person with kidney disease is passed through a dialysis machine to remove unwanted waste products from the blood.

The machine contains dialysate which is a solution of glucose and ions. Blood flows through the dialysis machine and is separated from the dialysate by a membrane. Some molecules diffuse from the blood into the dialysate. This is shown in Fig. 1.4.

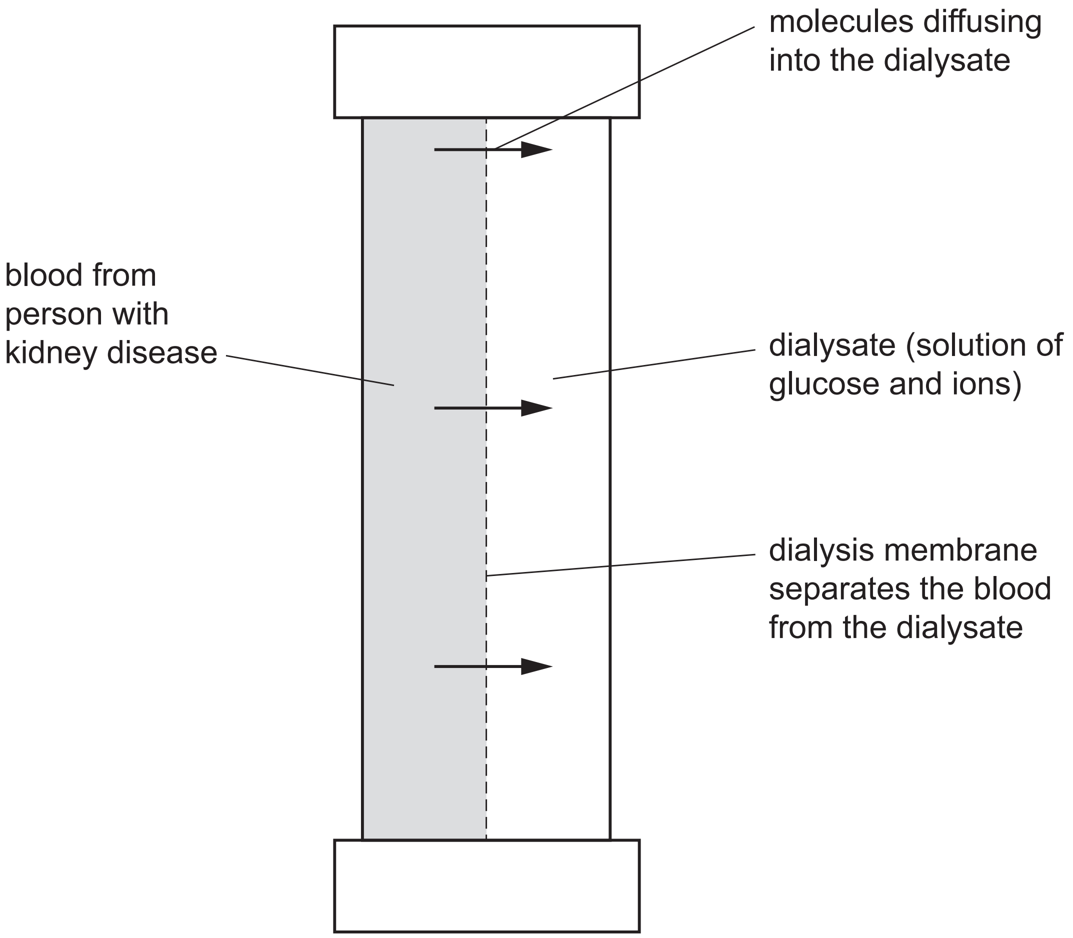


Fig. 1.4

Scientists studied the movement of two molecules, **P** and **Q**, found in the blood of a person with kidney disease. They wanted to see if these two molecules would remain in the blood or move out of the blood across the dialysis membrane into the dialysate.

The scientists took samples of blood from a person using a dialysis machine every 5 minutes for 20 minutes and recorded the concentration of **P** and **Q** in these samples. The results are shown in Table 1.4.

Table 1.4

time sample was taken from the blood / min	concentration of P in the blood / arbitrary units	concentration of Q in the blood / arbitrary units
0	200	400
5	205	280
10	200	150
15	195	90
20	200	75

(i) Plot a line graph of the data in Table 1.4 on the grid in Fig. 1.5.

Use a sharp pencil.

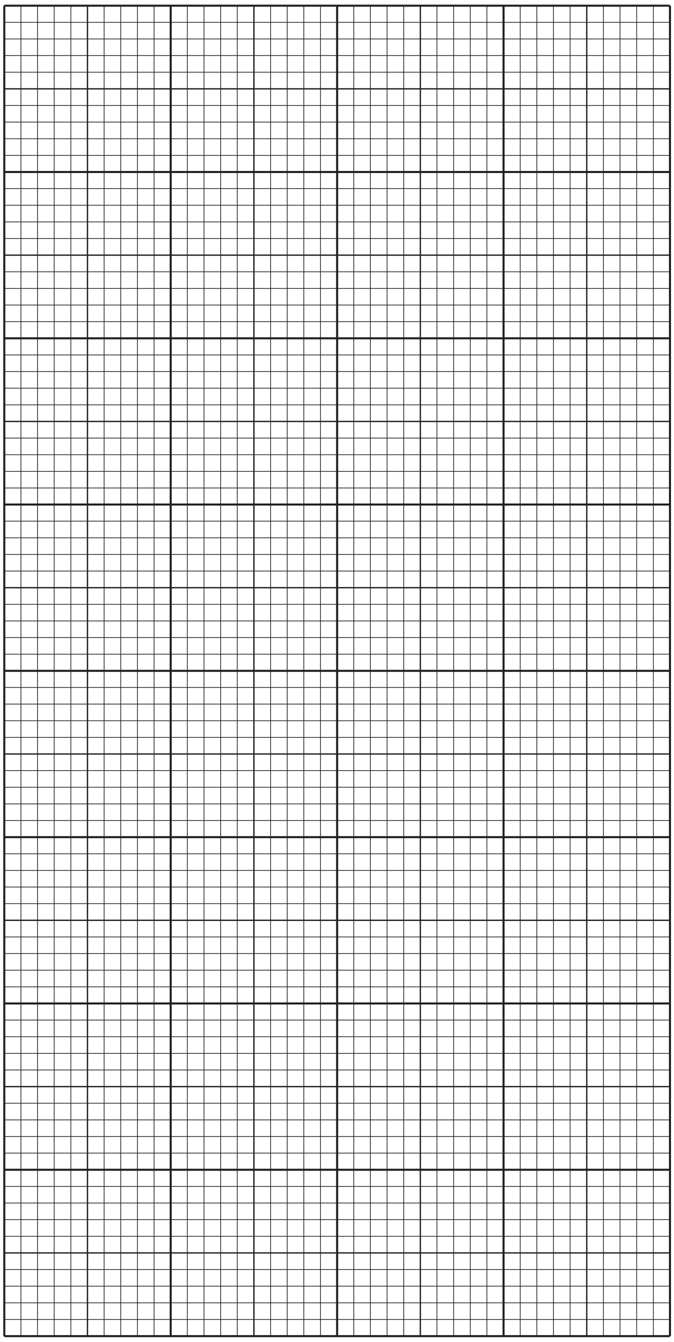


Fig. 1.5

[4]

(ii) Calculate the percentage decrease in concentration of **Q** between 5 minutes and 20 minutes.

Show your working and give your answer to **two** significant figures.

.... %
[2]

(iii) Suggest a reason for the rate of decrease in the concentration of **Q** from 0 to 10 minutes and from 10 to 20 minutes.

0 to 10 minutes ....

....

....

10 to 20 minutes ....

....

....
[2]

[Total: 20]

Question 2 starts on page 14.

A-LEVEL BIOLOGY • EXERCISE SHEET

2.2 Carbohydrates and lipids

Name: ______________ Class: __________ Date: ____________ **Total: 18 marks**

KEY WORDS polysaccharide 多糖 • glucose 葡萄糖 • triglyceride 甘油三酯 • monomer 单体 • polymer 聚合物

Objective

Build the skills to answer exam questions on **carbohydrates and lipids** — the structure of sugars and **polysaccharides 多糖**, the bonds that join them, and how **triglycerides 甘油三酯** and **phospholipids 磷脂** are built and used.

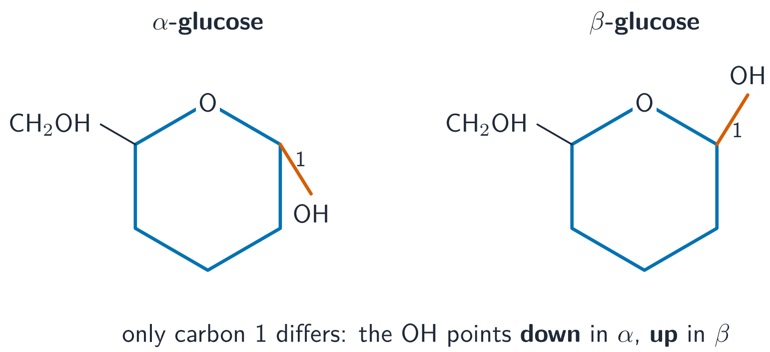
You must be able to:

- describe α-glucose and β-glucose and the **glycosidic bond 糖苷键** formed by condensation
- relate the structures of starch, glycogen and **cellulose 纤维素** to their functions
- describe a triglyceride (glycerol + three fatty acids, **ester bonds 酯键**) and relate it to its function
- describe a phospholipid and its hydrophilic head and hydrophobic tails

1 Worked examples

■ Glucose and the glycosidic bond

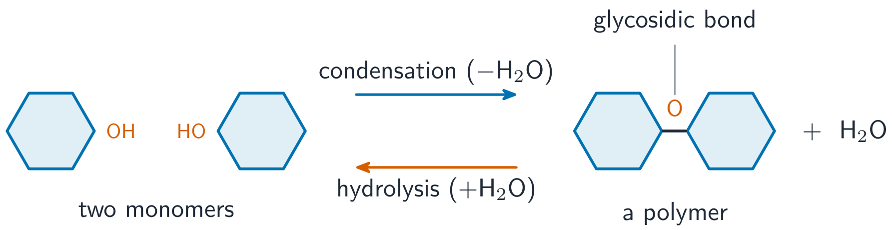
Glucose forms a ring with six carbons. The two ring forms differ only at carbon 1: in **α-glucose** the –OH points **down**; in **β-glucose** it points **up**. This small difference decides which polysaccharide can be built.



The two ring forms differ only at carbon 1

Two sugars join by **condensation 缩合** — a glycosidic bond forms and **one water**

molecule is removed. The reverse, **hydrolysis** 水解, adds water to break the bond.

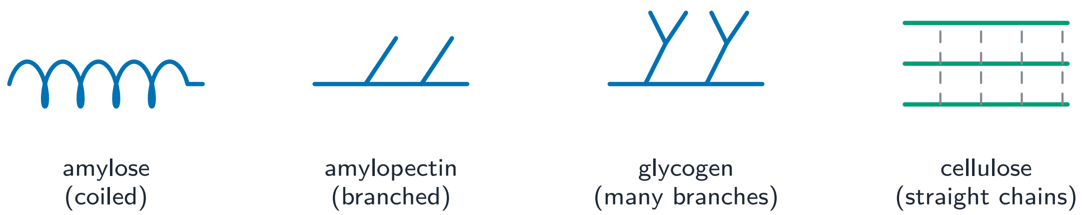


Condensation removes water to join monomers; hydrolysis adds water to split them

■ Polysaccharides: shape fits function

- **starch** 淀粉 (plant store) = **amylose** (unbranched, coils) + **amylopectin** (branched).
- **glycogen** 糖原 (animal store) = like amylopectin but more branched → broken down fast.
- **cellulose** = β-glucose, so chains are straight and pack into strong fibres for the cell wall.

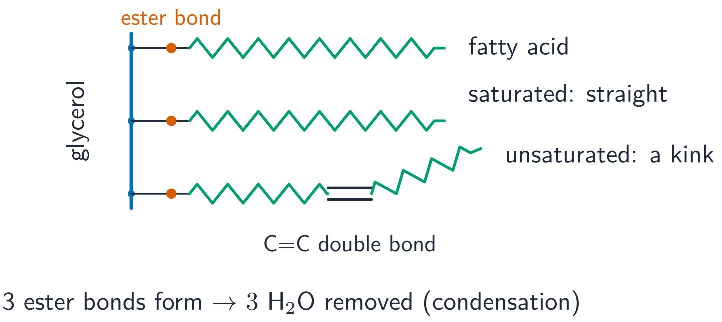
Storage polysaccharides are compact, **insoluble** 不溶 (stay in the cell) and do not change the **water potential** 水势.



Branched, coiled stores (starch, glycogen) vs straight, strong cellulose fibres

■ Triglycerides and phospholipids

A **triglyceride** is one **glycerol** 甘油 + three **fatty acids** 脂肪酸, joined by three ester bonds (three water molecules removed). **Saturated** 饱和 fatty acids have no C=C double bonds; **unsaturated** 不饱和 have one or more. Triglycerides are a good energy store: they release about twice the energy per gram of carbohydrate, and are insoluble.



One glycerol plus three fatty-acid tails, joined by ester bonds

A **phospholipid** has one fatty acid replaced by a **phosphate** 磷酸 group, giving a **hydrophilic** 亲水 head and two **hydrophobic** 疏水 tails — why phospholipids form membranes.

2 Practice

2.1 Name the bond formed when (a) two monosaccharides join, and (b) a fatty acid joins glycerol. [2]

2.2 State **two** ways the structure of starch suits its function as an energy store. [2]

2.3 Explain why cellulose is strong enough to support a plant cell wall. [3]

3 Exam-style questions

3.1 Which statement about α-glucose and β-glucose is correct? [1]

- **A** they are different elements
- **B** they differ in the position of an –OH group on carbon 1
- **C** β-glucose cannot form a ring
- **D** only α-glucose is a reducing sugar

3.2 How many water molecules are released when one glycerol joins three fatty acids to form a triglyceride? [1]

- **A** 1
- **B** 2
- **C** 3
- **D** 6

3.3 Which polysaccharide is made of β-glucose and forms straight chains? [1]

- **A** amylopectin
- **B** amylose
- **C** cellulose
- **D** glycogen

3.4 (a) Describe how a glycosidic bond is formed between two glucose molecules. [2]

(b) Glycogen and cellulose are both polymers of glucose, but have very different functions. Explain how their structures relate to their functions. [4]

3.5 Explain why a triglyceride is a good long-term energy store. [2]

Solutions

2.1 (a) glycosidic bond; (b) ester bond.

2.2 Any two: compact / insoluble (does not leave the cell or affect water potential) / branched so many ends for fast hydrolysis / large molecule.

2.3 β-glucose means every other glucose is flipped, so chains are long and straight; many straight chains lie side by side, held by hydrogen bonds into strong microfibrils.

3.1 B. They differ only in the position of the –OH on carbon 1.

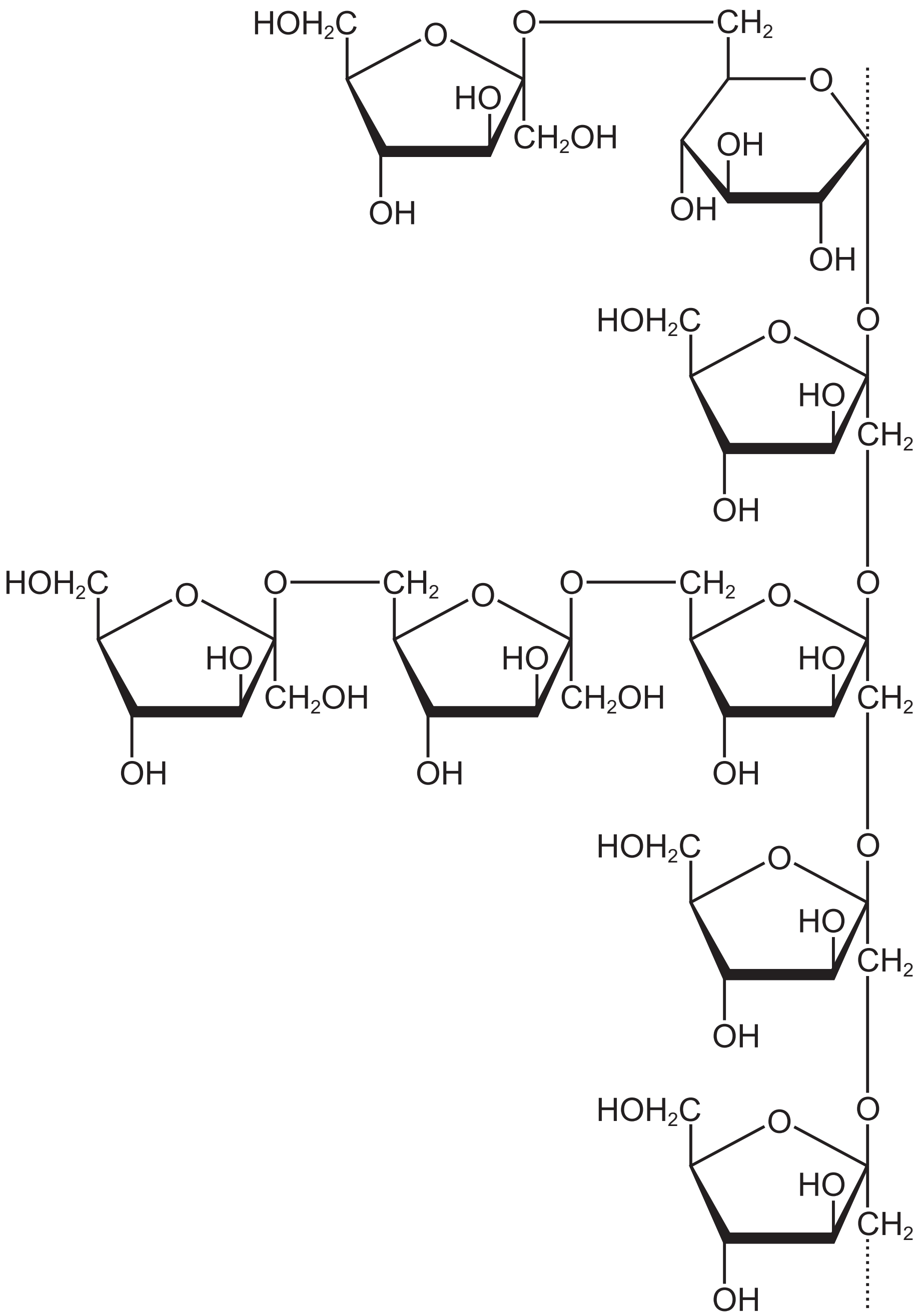
3.2 C. Three ester bonds form, so three water molecules are released.

3.3 C. Cellulose is made of β-glucose and forms straight chains.

3.4 (a) a glycosidic bond forms by condensation, removing one water molecule.
(b) glycogen is highly branched, giving many ends for fast hydrolysis to release glucose for respiration; cellulose is straight β-glucose chains held side by side by hydrogen bonds into strong fibres that support the cell wall.

3.5 insoluble / does not affect water potential; releases about twice the energy per gram of carbohydrate.

7 The diagram shows the structure of part of a biological molecule.



Which statements about this biological molecule are correct?

1 It has monomers joined by ester bonds.

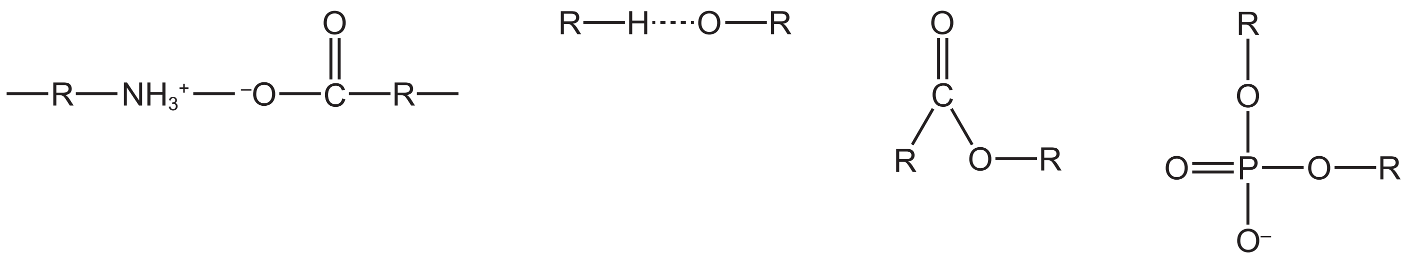
2 It is a macromolecule.

3 It is a polysaccharide.

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

8 Which diagram has a covalent bond that joins monomers together to form a biological polymer in eukaryotes?

A **B** **C** **D**



9 Which feature of storage polysaccharides means they do **not** change the water potential of cells?

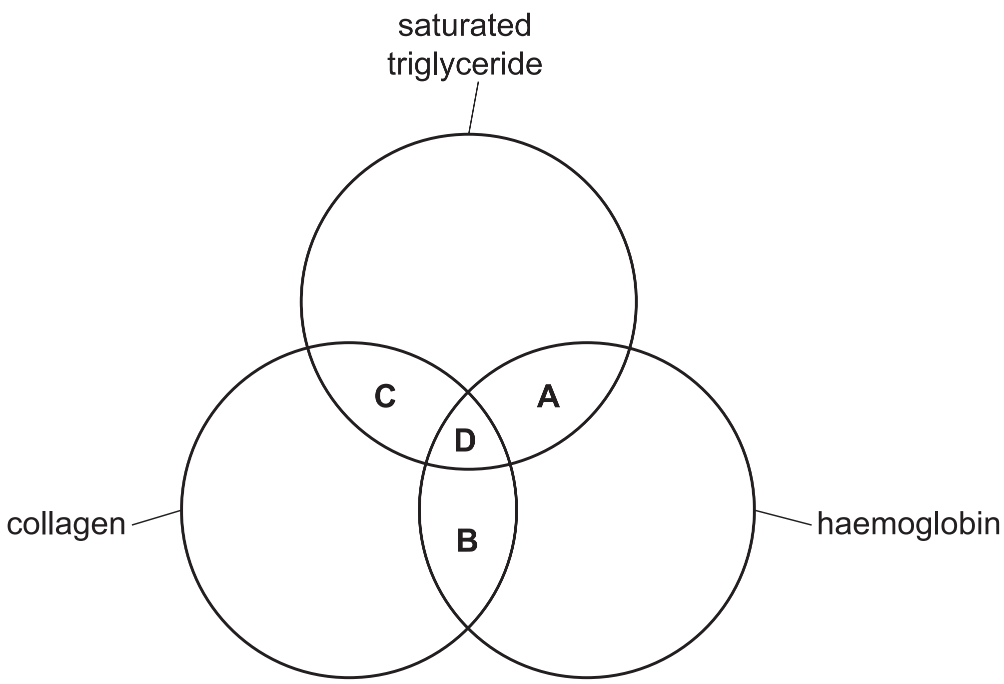
A They are easily hydrolysed.

B They are compact.

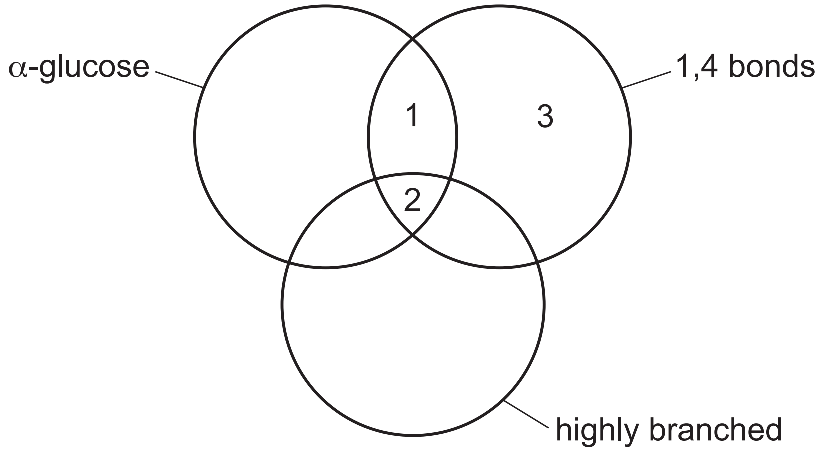
C They are insoluble.

D They are branched molecules.

10 Which molecules contain at least four double bonds?



7 The diagram shows some relationships between features of carbohydrates.



Which row correctly matches the carbohydrate with some of its features?

	1	2	3
A	amylopectin	glycogen	amylose
B	amylose	amylopectin	cellulose
C	cellulose	glycogen	sucrose
D	glycogen	amylose	amylopectin

A-Level Biology: **w25 13**

9 Many biological molecules exist as polymers made up of monomer subunits.

Which row correctly identifies the monomer in each of the biological molecules?

	collagen	glycogen	cellulose
A	amino acid	α-glucose	β-glucose
B	α-glucose	β-glucose	amino acid
C	β-glucose	amino acid	α-glucose
D	amino acid	β-glucose	α-glucose

11 Which row describes amylopectin?

	α-1,4 glycosidic bonds	α-1,6 glycosidic bonds	shape of molecule	function of molecule
A	✓	✓	branched	storage
B	✓	✗	helical	storage
C	✓	✓	branched	structural
D	✗	✓	helic[illegible]	structural

key

✓ = present

✗ = **not** present

13 An unsaturated fatty acid molecule has 17 carbon atoms in the tail which is attached to its carboxyl group. The tail contains three double bonds.

How many hydrogen atoms does the tail contain?

A 29 **B** 31 **C** 33 **D** 35

7 Which molecules have a structural formula that contains C=O bonds?

1 glucose

2 glycerol

3 protein

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

9 Which row is correct for glycogen?

	glycogen is hydrolysed rapidly due to its branched structure	glycogen is insoluble so the water potential of cells is unaffected	glycogen is a compact molecule because it contains many β-glucose molecules
A	✓	✓	✓
B	✓	✓	✗
C	✗	✗	✓
D	✗	✓	✗

key

✓ = correct for glycogen

✗ = incorrect for glycogen

A-LEVEL BIOLOGY • EXERCISE SHEET

2.3 Proteins

Name: ____________ Class: ________ Date: __________ **Total: 31 marks**

KEY WORDS amino acid 氨基酸 • collagen 胶原蛋白 • primary 一级 • primary structure 一级结构 • fibrous 纤维状

Objective

Build the skills to answer exam questions on **proteins** — the structure of **amino acids** 氨基酸 and the **peptide bond** 肽键, the four levels of protein structure, and how the structures of **haemoglobin** 血红蛋白 and **collagen** 胶原蛋白 fit their functions.

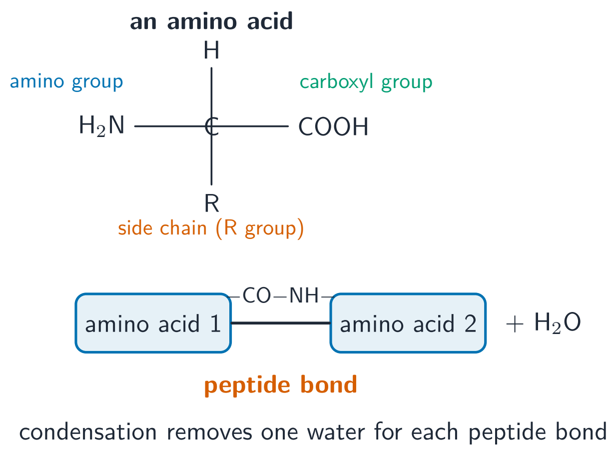
You must be able to:

- draw the general structure of an amino acid and the formation of a peptide bond
- explain primary, secondary, tertiary and quaternary structure and the bonds that hold them
- relate the structure of haemoglobin (globular) and collagen (fibrous) to their functions

1 Worked examples

■ Amino acids and the peptide bond

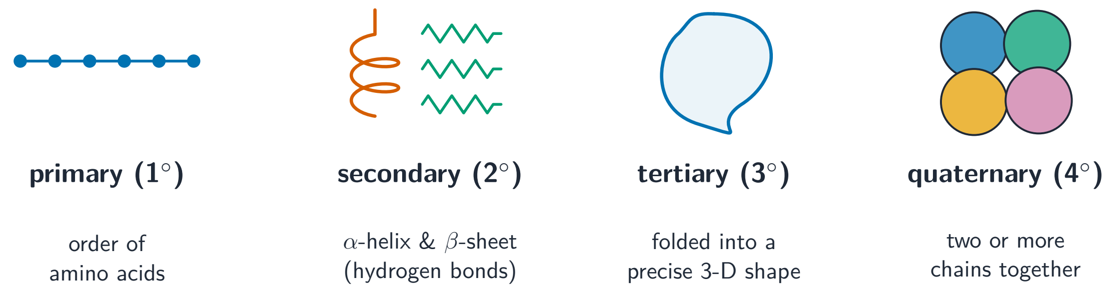
Every amino acid has a central carbon bonded to an **amino group** (–NH_2), a **carboxyl group** (–COOH), a hydrogen, and a variable **R group** 侧链. Two amino acids join by **condensation**: a peptide bond forms and **one water molecule is removed**. Many joined this way make a **polypeptide** 多肽.



Two amino acids join by a peptide bond, releasing water

■ **The four levels of structure**

level	meaning
primary 一级	the order of amino acids
secondary 二级	local shapes (α-helix, β-pleated sheet) held by hydrogen bonds
tertiary 三级	the whole chain folded into a precise 3-D shape
quaternary 四级	two or more chains joined into one protein



Primary → secondary → tertiary → quaternary structure

The folded shape is held by interactions between R groups: **hydrophobic interactions**, hydrogen bonds, **ionic bonds** 离子键, and strong **disulfide bonds** 二硫键.

■ **Globular vs fibrous**

Globular 球状 proteins fold into rounded, usually **soluble** shapes with jobs in the body — e.g. **haemoglobin**, four chains (two α, two β), each with a **haem group** 血红素 holding an iron atom that binds one O_2 (so one molecule carries four O_2). **Fibrous** 纤维状 proteins form long, insoluble strands for support — e.g. **collagen**, three chains wound into a triple helix, cross-linked into strong fibres.

2 Practice

2.1 Name the bond that forms between two amino acids, and state what small molecule is removed. [2]

2.2 State the level of protein structure described by each: [3]

(a) two or more polypeptide chains joined together

(b) the sequence of amino acids

(c) folding into a precise 3-D shape

3 Exam-style questions

3.1 Which bond is **not** involved in holding the tertiary structure of a protein? [1]

- **A** disulfide bond
- **B** glycosidic bond
- **C** hydrogen bond
- **D** ionic bond

3.2 A polypeptide is made from 120 amino acids. How many water molecules were released in forming it? [1]

- **A** 60
- **B** 119
- **C** 120
- **D** 240

3.3 Haemoglobin has a quaternary structure.

(a) Describe what is meant by quaternary structure, using haemoglobin as an example. [3]

(b) Explain the importance of the iron in each haem group. [2]

3.4 Collagen is a fibrous protein.

(a) Describe the structure of a collagen molecule and how collagen molecules form a fibre. [3]

(b) Explain how this structure makes collagen suitable for its function. [2]

3.5 Haemoglobin and collagen are both proteins, but they differ completely in structure and function.

(a) Draw the general structure of an amino acid, and describe how a peptide bond forms between two of them. [4]

(b) Explain what is meant by the primary, secondary, tertiary and quaternary structure of a protein. [4]

(c) Compare haemoglobin and collagen under **three** headings: shape, the level of structure that determines their function, and their solubility in water. [3]

(d) A mutation changes one amino acid in the haemoglobin β chain from glutamate (charged) to valine (non-polar). Explain how a single change can alter the whole molecule's behaviour. [3]

Solutions

2.1 peptide bond; a water molecule is removed.

2.2 (a) quaternary; (b) primary; (c) tertiary.

3.1 B. A glycosidic bond joins sugars, not amino acids.

3.2 B. Joining 120 amino acids needs 119 peptide bonds, so 119 water molecules are released.

3.3 (a) two or more polypeptide chains joined into one protein; haemoglobin has four chains — two α and two β — each with a haem group.
(b) the iron atom is where one oxygen molecule binds; four haem groups let one haemoglobin carry four O_2 molecules.

3.4 (a) three polypeptide chains wound into a triple helix held by hydrogen bonds; many molecules lie side by side, staggered and cross-linked into fibres.
(b) the triple helix and cross-links make it very strong when pulled, suiting it to support skin, tendons and bone.

3.5 (a) A central carbon bonded to an amino group $-NH_2$, a carboxyl group $-COOH$, a hydrogen and an R group. A peptide bond forms by **condensation**: the $-OH$ of one carboxyl group and an $-H$ of the next amino group leave as water, giving a $-CO-NH-$ link.
(b) Primary — the sequence of amino acids. Secondary — regular folding into an α helix or β pleated sheet, held by hydrogen bonds. Tertiary — the overall three-dimensional fold, held by hydrogen, ionic and disulfide bonds and hydrophobic interactions. Quaternary — two or more polypeptide chains, plus any prosthetic group, assembled into one functional molecule.
(c) Haemoglobin is **globular**, collagen **fibrous**; haemoglobin's function depends on tertiary and quaternary structure — the haem pockets — while collagen's depends on its primary structure, the glycine at every third residue that lets three chains wind together; haemoglobin is soluble because its hydrophilic R groups face outwards, collagen is insoluble.
(d) The R group is part of the tertiary structure, so exchanging a charged R group for a non-polar one changes which bonds can form; a hydrophobic patch now sits on the outside of the molecule; molecules stick to one another and the haemoglobin polymerises, distorting the whole cell — so one substitution changes the quaternary behaviour.

11 In some people a mutation can affect the beta chains in their haemoglobin molecules. As a result polar amino acids on the outer surfaces of the chains are replaced by non-polar amino acids.

What will be the effect on haemoglobin?

A Haemoglobin will become less soluble.

B Haemoglobin will become more soluble.

C Hydrophobic interactions between amino acids will decrease.

D More hydrogen bonds will form in the molecule.

A-Level Biology: **w25 12**

10 Which bonds between amino acids hold the shape of the secondary structure and also the tertiary structure of proteins?

A peptide bonds

B disulfide bonds

C hydrogen bonds

D ionic bonds

11 Resilin is a protein found in the wings of insects. It is an elastic, fibrous protein and scientists have suggested that it may have an important role in allowing the wings of an insect to fold and unfold without damage.

Peptidyl transferase is an enzyme which catalyses the condensation of amino acids during translation to form resilin.

Which statements are correct?

1 Peptidyl transferase and resilin have structural roles in the insect.

2 Peptidyl transferase is a globular protein.

3 Peptidyl transferase is soluble in water.

A 1 and 2 **B** 1 and 3 **C** 1 only **D** 2 and 3

12 Collagen is a protein that helps to strengthen and increase the elasticity and hydration of the skin. Aging can lead to dry skin and the formation of wrinkles, due to the body producing less collagen.

Which row is correct for the structure of collagen in the skin?

	every fourth amino acid is glycine	fibrous protein
A	✗	✗
B	✓	✓
C	✗	✓
D	✓	✗

key

✓ = correct

✗ = **not** correct

A-Level Biology: **w25 14**

11 Thermostable enzymes can maintain their tertiary structure at high temperatures.

Scientists studying the primary structure of a thermostable enzyme found that the enzyme contained:

- more charged amino acids
- fewer polar amino acids that are **not** charged
- more hydrophobic amino acids

than enzymes that are **not** thermostable.

Which row shows a correct comparison between this thermostable enzyme and an enzyme that is **not** thermostable?

	number of amino acids forming interactions at the centre of a thermostable enzyme compared to an enzyme that is **not** thermostable	number of ionic bonds in a thermostable enzyme compared to the number in an enzyme that is **not** thermostable
A	less than	more than
B	less than	less than
C	more than	less than
D	more than	more than

12 Collagen is a strong, elastic molecule that is often found in the connective tissues of animals. Glycine is an amino acid found at regular positions in the primary structure of a collagen polypeptide.

Which row shows features of collagen that contribute to its strength and elasticity?

	glycine is found on the outside of the helical polypeptides to allow them to lie closer together	disulfide bonds form between glycine amino acids to join the polypeptides together
A	✓	✓
B	✓	✗
C	✗	✓
D	✗	✗

key

✓ = contributes to the strength and elasticity of collagen

✗ = does **not** contribute to the strength and elasticity of collagen

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

Fig. 2.1 shows the composition of a collagen fibre.

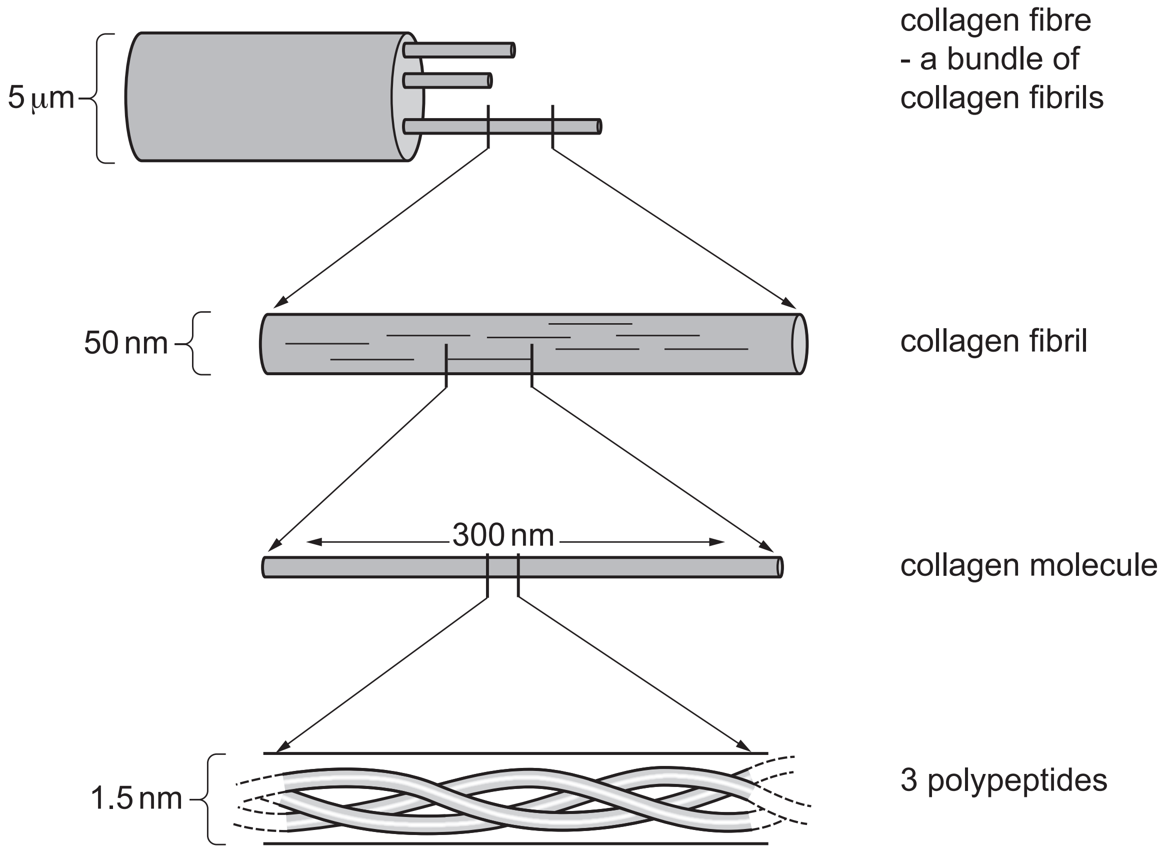


Fig. 2.1

(a) **(i)** Describe the arrangement of the 3 polypeptides in each molecule of collagen.

....

....

....

....

....

.... [2]

(ii) With reference to Fig. 2.1, explain how the molecules of collagen are arranged **and** held together in a collagen fibril.

....

....

....

....

....

....

[3]

(b) Collagen fibres and elastic fibres are found in the structures of the gas exchange system of mammals.

(i) Suggest **two** properties of collagen that contribute to the function of cartilage in the trachea in the gas exchange system.

....

....

....

....

.... [2]

(ii) State the function of elastic fibres in the alveoli in the lungs.

.... [1]

(c) Table 2.1 shows the DNA triplets in the two strands of DNA in part of a gene that codes for one of the polypeptides in collagen.

Table 2.1

non-transcribed strand	GGT	CCA	ATG	GGT	CCC	CGA	GGT	CCC	CCA	GGT
template strand	CCA	GGT	TAC	CCA	GGG	GCT	CCA	GGG	GGT	CCA
amino acid	gly									

Table 2.2 shows the triplets of bases in **DNA** and the amino acids for which they code.

The table can be used to determine the sequence of the amino acids in a polypeptide.

Table 2.2

first base	second base: **T**		second base: **C**		second base: **A**		second base: **G**		third base
T	TTT	phe	TCT	ser	TAT	tyr	TGT	cys	**T**
	TTC		TCC		TAC		TGC		**C**
	TTA	leu	TCA		TAA	stop	TGA	stop	**A**
	TTG		TCG		TAG		TGG	trp	**G**
C	CTT	leu	CCT	pro	CAT	his	CGT	arg	**T**
	CTC		CCC		CAC		CGC		**C**
	CTA		CCA		CAA	gln	CGA		**A**
	CTG		CCG		CAG		CGG		**G**
A	ATT	ile	ACT	thr	AAT	asn	AGT	ser	**T**
	ATC		ACC		AAC		AGC		**C**
	ATA		ACA		AAA	lys	AGA	arg	**A**
	ATG	met	ACG		AAG		AGG		**G**
G	GTT	val	GCT	ala	GAT	asp	GGT	gly	**T**
	GTC		GCC		GAC		GGC		**C**
	GTA		GCA		GAA	glu	GGA		**A**
	GTG		GCG		GAG		GGG		**G**

(i) Complete Table 2.1 to show the amino acids coded by the DNA nucleotide sequence in Table 2.1. [1]

(ii) The sequence of amino acids that you have worked out is representative of the whole of the collagen polypeptide.

Explain how the sequence of amino acids makes the polypeptide suitable as a component of a collagen molecule.

....

....

....

....

....

....

.... [3]

(iii) Two mutations, **P** and **Q**, can have an effect on the primary structure of the polypeptide.

- Mutation **P** is a deletion of the first nucleotide pair in the DNA nucleotide sequence shown in Table 2.1.
- Mutation **Q** is a substitution of G with T as the first base in the DNA nucleotide sequence shown in Table 2.1.

State the effects of the mutations, **P** and **Q**, on the primary structure of the polypeptide.

mutation **P** ....

....

....

mutation **Q** ....

....

....

[2]

[Total: 14]

2.4 Water

Name: ______________ Class: __________ Date: ____________ **Total: 11 marks**

KEY WORDS solvent 溶剂 • latent heat of vaporisation 汽化潜热 • specific heat capacity 比热容 • hydrogen bonding 氢键 • polar 极性

Objective

Build the skills to answer exam questions on **water** — how **hydrogen bonding 氢键** arises, and how it explains water's roles as a **solvent** 溶剂, its high **specific heat capacity** 比热容, and its **latent heat of vaporisation** 汽化潜热.

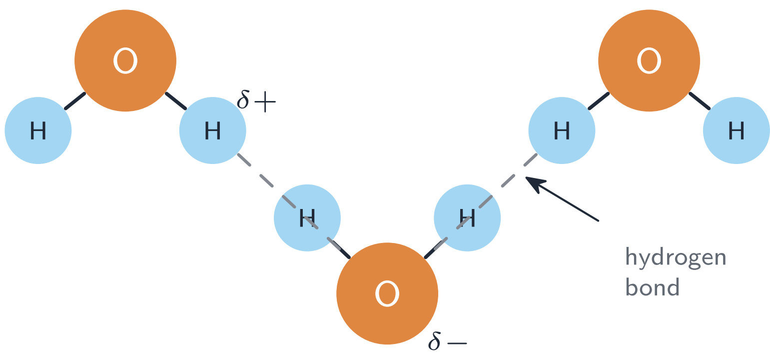
You must be able to:

- explain how hydrogen bonds form between water molecules
- relate hydrogen bonding to solvent action, high specific heat capacity and latent heat of vaporisation

1 Worked examples

■ Why water is polar and forms hydrogen bonds

Water's O–H bonds are **polar** 极性: the oxygen is slightly negative ($\delta-$) and the hydrogens slightly positive ($\delta+$). So the $\delta+$ hydrogen of one molecule attracts the $\delta-$ oxygen of its neighbour — a weak **hydrogen bond**. Each molecule can bond to several others.



Water is polar ($\delta-$ oxygen, $\delta+$ hydrogens), so its molecules attract each other by hydrogen bonds

■ **Relating the property to the role**

Always link the property back to **hydrogen bonding** and then to a use in living things:

- **solvent action** — polar water surrounds and dissolves other polar/charged molecules, so reactions can happen and substances can be transported (e.g. in blood).
- **high specific heat capacity** — many hydrogen bonds must gain energy before the temperature rises, so water (and organisms) stays at a steady temperature.
- **latent heat of vaporisation** — much energy is needed to break enough hydrogen bonds to evaporate water, so sweating/transpiration removes a lot of heat and cools the organism.

2 Practice

2.1 State which atom in a water molecule is slightly negative, and which is slightly positive. [2]

2.2 Name the property of water that allows it to act as a transport medium in blood. [1]

3 Exam-style questions

3.1 Explain how a hydrogen bond forms between two water molecules. [2]

3.2 Water has a high specific heat capacity.

(a) Explain, in terms of hydrogen bonds, why water's temperature changes only slowly. [2]

(b) Explain why this property is useful to living organisms. [1]

3.3 When an animal sweats, water evaporates from its skin and the animal cools down. Use the idea of **latent heat of vaporisation** and hydrogen bonds to explain why evaporation has a strong cooling effect. [3]

Solutions

2.1 oxygen is slightly negative ($\delta-$); the hydrogens are slightly positive ($\delta+$).

2.2 solvent action / it is a (good) solvent.

3.1 the $\delta+$ hydrogen of one water molecule is attracted to the $\delta-$ oxygen of another; this attraction is the hydrogen bond.

3.2 (a) energy must be absorbed to break/loosen many hydrogen bonds before the molecules move faster, so the temperature rises only slowly.
(b) it keeps the temperature of cells/organisms or aquatic habitats stable.

3.3 evaporation needs much energy to break the hydrogen bonds holding water molecules together; this energy (latent heat) is taken from the skin/body, so the body loses heat and cools.