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.

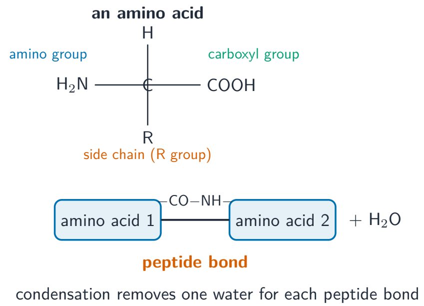
You must be able to:

- 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

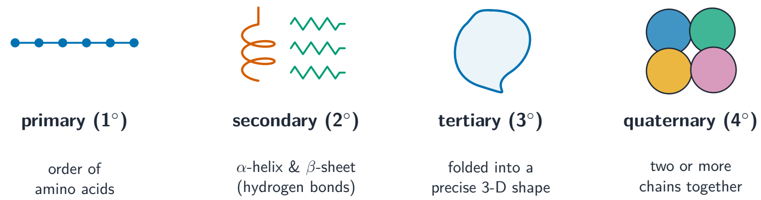
Every amino acid has a central carbon bonded to an **amino group** ($-NH_2$), a **carboxyl group** ($-COOH$), a hydrogen, and a variable **R group** 侧链. Two amino acids join by **condensation**: a peptide bond forms and **one water molecule is removed**. Many joined this way make a **polypeptide** 多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



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.