11.1 Proteins

Name: _____ Class: _____ Date: _____ **Total: 24 marks**

KEY WORDS amino acid • peptide bond • polypeptide • denaturation • R group R • essential amino acid

Objective

Build the skills to answer exam questions on **proteins** : amino acids, peptide bonds, the variety of proteins and denaturation.

You must be able to:

- draw the general structure of an amino acid and show how a peptide bond forms
- explain how the sequence of amino acids gives proteins their great variety
- explain how heat and pH denature proteins
- explain why some amino acids are essential in the diet
- describe the primary, secondary, tertiary and quaternary structure of proteins, and compare globular and fibrous proteins

1 Key knowledge and worked examples

Proteins

Amino acid: a central carbon with an **amine group** ($-NH_2$), a **carboxyl group** ($-COOH$), a hydrogen and an **R group**. There are **20** amino acids in proteins; they differ only in the R group. **Essential** amino acids cannot be made by the body, so they must come from the diet.

Peptide bond: a condensation reaction joins the carboxyl group of one amino acid to the amine group of the next, releasing water. A chain is a **polypeptide**.

Variety: a chain of n amino acids can have 20^n sequences, so the number of possible proteins is huge. The sequence decides how the chain folds, and the shape decides the function.

Denaturation: high temperature or extreme pH breaks the bonds that hold the shape (hydrogen bonds, ionic bonds), so the protein loses its shape and function. It is usually **permanent**.

HL: primary structure = the sequence; **secondary** = α-helix and β-pleated sheet, held by hydrogen bonds between backbone groups; **tertiary** = the 3-D fold of one chain, held by R-group bonds (hydrogen, ionic, disulfide bridges, hydrophobic interactions); **quaternary** = two or more chains (haemoglobin has four, plus haem groups: a **conjugated** protein). **Globular** proteins are round and soluble (enzymes); **fibrous** are long and insoluble (collagen).

Worked example. A dipeptide forms from two amino acids: **one** peptide bond, **one** water released. A chain of 3: $20^3 = \mathbf{8000}$ possible sequences.

Answer shapes: heat → bonds break → shape changes → active site / function lost.

2 Practice

2.1 Draw the general structure of an amino acid and label the R group. [2]

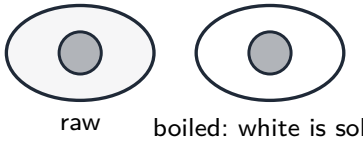
2.2 Explain how two amino acids join to form a dipeptide. [3]

$$H_2N{-}CHR_1{-}COOH \quad H_2N{-}CHR_2{-}COOH$$

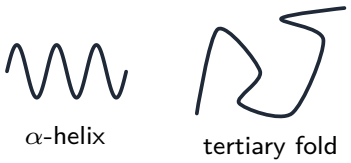
these groups react

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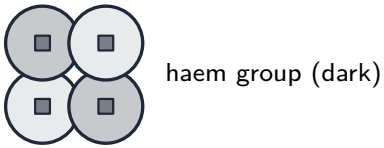
2.3 Explain why boiling an egg changes the egg-white protein permanently. [3]



2.4 Distinguish between the secondary and tertiary structure of a protein. [2]



2.5 Haemoglobin is a conjugated protein with quaternary structure. Explain both terms. [2]



3 Exam-style questions

3.1 A student counted the possible sequences of short polypeptides.



$20^2 = 400$



$20^3 = 8000$

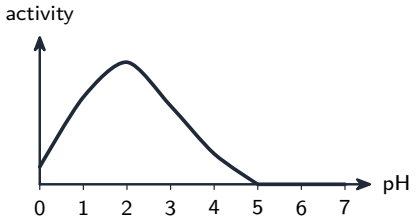
(a) Calculate the number of possible sequences for a chain of 4 amino acids. [1]

(b) Explain why the sequence of amino acids decides the function of a protein. [2]

(c) State what is meant by an essential amino acid. [1]

(d) Suggest why a vegan diet should include a mix of plant proteins. [2]

3.2 The graph shows the activity of a protein-digesting enzyme at different pH values.



(a) State the optimum pH of this enzyme. [1]

(b) Suggest where in the body this enzyme works. [1]

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(c) Explain why the activity is zero at pH 6. [2]

(d) State two types of bond that hold the shape of a protein. [2]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

central C with H, NH_2 and COOH; R group labelled on the central carbon

2.2

a condensation reaction; between the carboxyl group of one and the amine group of the other; forming a peptide bond and releasing water

2.3

heat makes the molecules vibrate; bonds that hold the folded shape break, e.g. hydrogen bonds; the protein is denatured: it unfolds and cannot refold, so the change is permanent

2.4

secondary: α-helix / β-sheet held by hydrogen bonds between backbone groups; tertiary: the overall 3-D folding of the chain, held by bonds between R groups

2.5

quaternary: made of more than one polypeptide chain (four in haemoglobin); conjugated: contains a non-protein part, the haem group

3.1

(a) $20^4 = \mathbf{160\,000}$

(b) the sequence decides where the chain bonds and folds; the folded shape decides function, e.g. the shape of an active site

(c) an amino acid the body cannot make, so it must come from food

(d) some plant proteins are low in certain essential amino acids; a mix (e.g. beans and grains) supplies all of them

3.2

(a) pH 2

(b) the stomach

(c) the pH changes the charges on R groups, breaking ionic / hydrogen bonds; the enzyme is denatured, so the active site changes shape and the substrate no longer fits

(d) any two: hydrogen bonds; ionic bonds; disulfide bridges; hydrophobic interactions

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