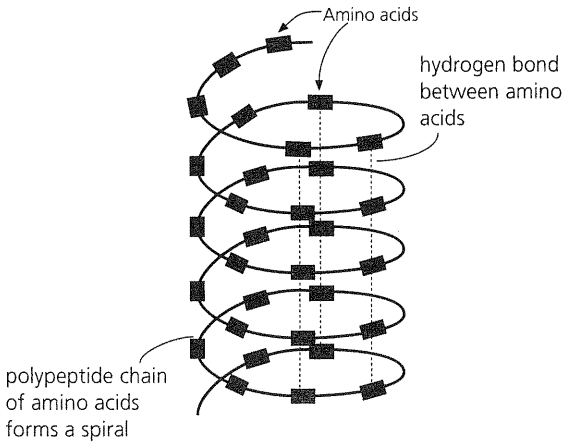
T 2 Shapes of protein molecules

Look up the structure of amino acids and formation of peptide bonds (see CAMS *Biology Core* book page 10, Fig. 7). In different amino acids, the R-group is different, for example in alanine it is CH_3. Some amino acids contain the element sulphur. A protein molecule is made up of a long chain of amino acids joined together by peptide bonds. The chain is called a polypeptide. The sequence of amino acids is called the **primary structure** of the protein. The genetic information carried in DNA determines the primary structure.

But proteins are three-dimensional structures, not flat chains. They form complicated shapes due to the linking together of different amino acids, each with its own shape. The amino acid chains produce spirals, with hydrogen bonds forming between twists in the spiral. This helical structure of a protein is called the **secondary structure** (Fig. 1).

Fig. 1 Secondary structure of a protein



Different spirals of amino acids link together in different ways, to give a range of polypeptides with different functions. **Fibrous** proteins form when these spirals join together to form long threads, such as keratin, a protein found in hair. Most proteins, however, form irregular-shaped structures, called **globular** proteins. Enzymes and proteins found in cell membranes are globular proteins. The way that the amino acids twist and turn to form the globular shape is caused by the way in which the amino acids in the chain attract or repel each other. The overall shape of a protein molecule is called its **tertiary structure** (Fig. 2). Where the chain twists and folds around itself, chemical bonds form between amino acids that come close to each other. Three types of bond can form (Fig. 3).

Fig. 2 Tertiary structure of a globular protein

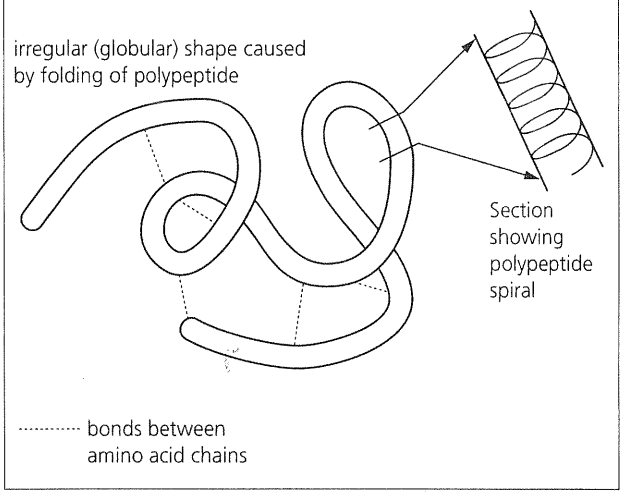
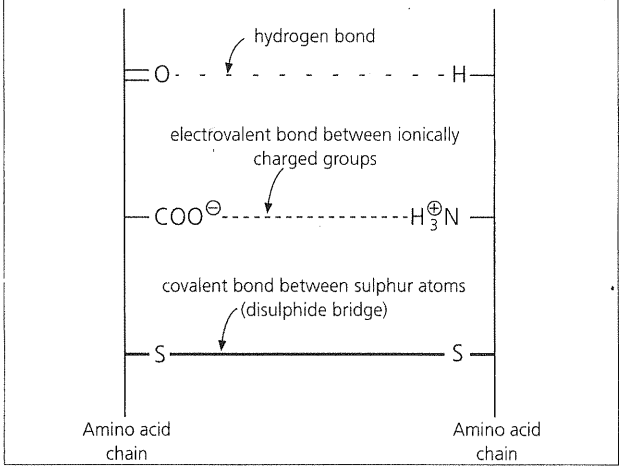


Fig. 3 Chemical bonding in a protein molecule



The main group of globular proteins are enzymes. Enzyme molecules need to have a particular shape, so that they can link with the right substrate molecules for the reactions they catalyse. A mistake during protein synthesis could mean that the wrong amino acid is inserted into the protein molecule. This would produce an enzyme with a different shape. The new shape may mean that the enzyme and substrate do not fit together, and the reaction is not catalysed.

Some proteins consist of several polypeptide chains linked together, such as haemoglobin, which is made up of four separate polypeptide chains. The linking of polypeptides in a protein produces a **quaternary structure**.

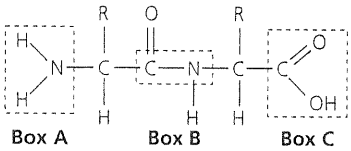
Questions

1 Match the following aspects of the structure of a protein molecule with the correct description:

a Primary structure.
b Secondary structure.
c Tertiary structure.
d Quaternary structure.

A The coiling of an amino acid chain into a spiral structure.
B The association of several polypeptide chains.
C The sequence of amino acids in a polypeptide chain.
D The irregular folding of a polypeptide chain into a globular shape.

2 The diagram shows a dipeptide.



a Show, by means of a similar drawing, one of the two amino acids produced by hydrolysis of this dipeptide.
b What is the name of the chemical group represented by Box A?
c What is the chemical group represented by Box C?
d What is the name of the chemical bond shown in Box B?

3 The tertiary structure of a protein is held in place with chemical bonds.

a Give the name of one chemical bond that is present in the tertiary structure of a protein, but not in the secondary structure.
b Name a chemical bond present in both the tertiary structure and the secondary structure.

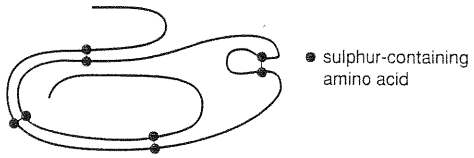
The tertiary structure is important in determining the shape of a protein molecule.

c Explain why a mistake leading to the insertion of the wrong amino acid during protein synthesis could produce an enzyme that does not function.
d Why do enzymes no longer function if heated to a temperature of 80 °C?
e Glucose, and no other sugar, is transported into cells by protein carrier molecules in the cell-surface membrane. How do the carrier molecules specifically recognise glucose?

4 The enzyme RNAase is a protein containing 124 amino acids.

a Assuming that there are 20 different amino acids involved in protein structure, how many different sorts of protein molecule could be made containing 124 amino acids?
b Explain what causes the sequence of amino acids in molecules of RNAase to be the same each time they are made.

The diagram shows the tertiary structure of a molecule of RNAase.



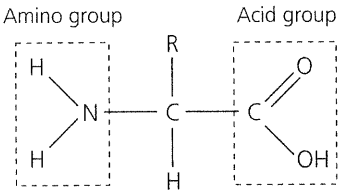
c Apart from involving different amino acids, in what way do the two ends of the RNAase molecule differ from each other?
d Explain why all molecules of RNAase have the same tertiary structure.
e Urea breaks hydrogen bonds and the substance mercaptoethanol breaks disulphide bridges. If a molecule of RNAase were treated with a mixture of urea and mercaptoethanol, explain what would happen to:
- the structure of the RNAase;
- its enzyme activity.

Answers

1 a Primary structure.
C The sequence of amino acids in a polypeptide chain.
b Secondary structure.
A The coiling of an amino acid chain into a spiral structure.
c Tertiary structure.
D The irregular folding of a polypeptide into a globular shape.
d Quaternary structure.
B The association of several polypeptide chains.

2 a Hydrolysis will produce two amino acids like this.

A molecule of amino acid can be represented like this



Make sure that you have split the dipeptide at the correct point.
b Amino group.
c (Carboxylic) acid group.
d Peptide bond.

3 a Electrovalent bond or disulphide bridge.
b Hydrogen bond.
c Inserting a different amino acid will give a different shape to the protein molecule (enzyme) and to its active site. The substrate may no longer fit, so the enzyme will not function.
d Heating proteins causes the bonds holding their tertiary structure in place to break. This again will alter the shape of the active site of the enzyme.
e Protein carrier molecules have different shaped carrier sites. These are specific and match the shape of the molecule that they transport – glucose in this case.

4 a 20 x 20 x 20 ... or 20^{124}
b DNA codes for the sequence.
c One has a free $-NH_2$ group, the other a free –COOH group.
d They all have the same sequence of amino acids, which always folds in the same way.
e This would break the bonds that hold the tertiary structure, changing its shape and, in particular, that of its active site. Changing the shape of the active site would mean that the substrate would no longer fit and the enzyme would cease to function.

Points to note

- You don't need to learn any more detail in terms of chemical structure than that shown in Question 2. You should be able to show how two amino acids are joined to give a dipeptide, and how a dipeptide can be hydrolysed to give two amino acids. You certainly don't need to learn what the R-group represents in all amino acids.
- You will come across proteins many times in your course. The key to almost everything that a protein does is shape; the shape produced by the tertiary structure of the molecule. It is this that determines why proteins on cell membranes only recognise certain molecules, how enzymes function and why antibodies are specific.