The α Helix and the β Sheet Are Common Folding Patterns

Although the overall conformation each protein is unique, there are only two different folding patterns that are present in all proteins, which are α helix and β sheet. α helix was first discovered in α-keratin, which is abundant in skin and its derivative. β sheet was found in protein fibroin, the major constituent of silk.

These two folding patterns are particularly common because they result from hydrogen bonds forming between the N-H and C=O groups in the polypeptide backbone. Because amino acids side chains are not involved in forming these hydrogen bonds, α helices and β sheets can be generated by many different amino acid sequences.

Helices From Readily in Biological Structures

A helix is generated simply by placing many similar subunits next to each other, each in the same way strictly related repeated relationship to the one before. An α helix is generated when a single polypeptide chain turns around itself to form structurally rigid cylinder. A hydrogen bond is made between every fourth peptide bond, linking the C=O of one peptide bond to the N-H of another. This gives rise to a regular helix with a complete turn every 3.6 amino acids.

Short region of α helix are especially abundant in the proteins located in cell membranes, such as transport proteins and receptors.
Sometimes a pair of α helices will wrap around one another to form a particularly stable structure, known as a coiled-coil. This structure forms when two α helices have most of their nonpolar side chains on one side, so that they can twist around each other with these side chains facing inward.

β sheets are made when hydrogen bonds form between segments of polypeptide chains lying side by side.

When structure consists of neighboring polypeptide chains that run into same orientation, it is considered a parallel β sheet; when it form a polypeptide chain that folds back and forth upon itself, with each section of the chain running in the direction opposite to that of its immediate neighbors, the structure is an antiparallel β sheet. Both types of B sheets produce very rigid, pleated structure, and they form the core of many proteins.
β-sheets provide an ideal ice-binding surface in an antifreeze protein. The six parallel α strands, shown here in red, form a flat surface with 10 hydroxyl groups (blue) arranged at distances that correspond to water molecules in an ice lattice. The protein can therefore bind to ice crystals, preventing their growth.

Proteins Have Several Levels of Organization

A protein's structure doesn't end with α helices and β sheets; there are also higher levels of organization. A protein's structure begins with its amino acid sequence, which is also considered its primary structure.

The next level of organization includes the α helices and β sheets that form within certain segments of polypeptide chain; these folds are elements of the protein's secondary structure.

The full, three-dimensional conformation, formed by entire polypeptide chain-including α helices and β sheets, random coils, any other loops and folds that form within the N- and C-termini-is sometimes referred to as the tertiary structure.

Finally, if a particular protein molecule is formed as a complex of more than one polypeptide chain, then complete structure is designated its quaternary structure.

Proteins Can Be Classified into Families

Once protein had evolved a stable conformation with useful properties, its structure could be modified over time to enable it to perform new functions. Proteins can be grouped into families, in which each family member has an amino acid sequence and a three-dimensional conformation that closely resembles that of other family members. For example, the serine protease, which is a family of protein involved in cleavage of protein. Chymotrypsin and elastase are very similar and carry out similar reactions, but their substrates are different.

Large Protein Often Contain More Than One Polypeptide Chain

Some weak covalent bonds not only enable a polypeptide chain to fold into a specific conformation but also allow proteins bind each other to produce larger structure in the cell. Any region on protein's surface that interacts with another molecule through sets of noncovalent bond is termed a binding site. If a protein has more than one polypeptide, each polypeptide called a subunit.
Hemoglobin, a protein abundant in red blood cells, contains two copies of $\alpha$-globin and two copies of $\beta$-globin. Each of these four polypeptide chains contains a heme molecule (red rectangle), which is the site where oxygen (O2) is bound. Thus, each molecule of hemoglobin in the blood carries four molecules of oxygen.

Proteins Can Assemble into Filaments, Sheets, or Spheres

Proteins can form even larger assemblies. A chain of identical protein molecules can be formed if the binding site on the protein molecule is complementary to another region on the surface of another protein molecule of the same type.

(A) A protein with just one binding site can form a dimer with another identical protein. (B) Identical proteins with two different binding sites will often form a long helical filament. (C) If the two binding sites are disposed appropriately in relation to each other, the protein subunits will form a closed ring instead of a helix.

An actin filament is composed of identical protein subunits.

The helical array of actin molecules often extends for thousands of molecules and for micrometers in the cell.

Some Type of Proteins Have Elongated Fibrous Shapes

Fibrous proteins are relatively simple and elongated three-dimensional structures. $\alpha$-keratin, intermediate filaments, collagen, and elastin are the example of fibrous types proteins. Keratin filaments are extremely stable long-lived structures such as hair, horn, and nails are composed mainly of this protein. An $\alpha$-keratin molecule is a dimer of two identical subunits, with a long $\alpha$ helices of each subunit forming a coiled-coil.
Fibrous proteins are especially abundant outside the cell, where they form the gel-like extracellular matrix that helps cells bind together to form a tissue. These proteins are secreted by the cells into surroundings, where they often assemble into sheet or long fibrils. Collagen is the most abundant of these fibrous proteins in animal tissues. The collagen molecule consists of three long polypeptide chains each containing the nonpolar amino acid glycine at every third position. This regular structure allows the chains to wind around one another to generate long triple helices.

Extracellular Proteins Are Often Stabilized by Covalent Cross-Linkages

To maintain their structures outside the cell, proteins are often stabilized by covalent cross-linkages. These linkages can tie together two amino acids in the same protein, or connect different polypeptide chains into multisubunit protein. The most common cross-link in proteins are covalent sulfur-sulfur bonds. These disulfide bonds (also called S-S bonds) form as being exported from the cells.

How Proteins Work

Proteins are not inert lumps of material. Because of their different amino acid sequences, proteins come in an enormous variety of different shapes—each with unique surface topography of chemical groups.
All Proteins Bind to Other Molecules

The biological properties of a protein molecule depend on its physical interaction with other molecules.

Antibodies → virus or bacteria
Hexokinase → Glucose

All proteins stick, or bind, to other molecules. In some cases this binding is very tight; in others it is weak and short-lived. In all cases binding shows great specificity, in the sense that each protein molecule can bind to just a few molecules out of the many thousands of different molecules it encounters. Any substance that is bound by a protein is referred to as a ligand for that protein. The ability of a protein to bind selectively and with high affinity to a ligand is due to the formation of a set of weak, non covalent bonds plus hydrophobic interaction.

The region of a protein that associates with a ligand, known as its binding site, usually consists of a cavity in the protein surface formed by a particular arrangement of amino acids. These amino acids belong to widely separated regions of the polypeptide chain that are brought together when the proteins fold.

The Binding Sites of Antibodies Are Especially Versatile

Antibodies or immunoglobulins, are proteins produced by the immune system in response to foreign molecules. Each antibody binds to a particular target molecule extremely tightly, either activating the target directly or marking it for destruction. An antibody recognizes its target (called antigen) with a remarkable specificity.

Antibodies are Y-shaped molecules with two identical binding sites that are each complementary to a small portion of the surface of the antigen molecules.
**Antibodies Defend Us Against Infection**

Antibodies are made by a class of white blood cells, called B lymphocytes, in the bone marrow. Each B cell can carry a different membrane-bound antibody molecule on its surface that serves as a receptor for recognizing a specific antigen. When an antigen enters the body, it may be destroyed by antibodies that bind to it. This process, called agglutination, can cause the antigens to clump together, making them easier for phagocytic cells to remove.

**Antibodies Form Aggregates**

- **Foreign molecules**
- **Viruses**
- **Bacteria**

**Antibody and antigen forms**

Antibodies are produced by B lymphocytes and are found in the blood. They play a crucial role in the immune system by identifying and neutralizing foreign substances, such as bacteria and viruses.

**Antibody Specificity**

An individual animal can make billions of different antibody molecules, each with a distinct antigen-binding site. Each antibody recognizes its antigen with great specificity.

**Table 5-5 Some Common Types of Bacteria**

<table>
<thead>
<tr>
<th>Type of Bacteria</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Streptococcus</strong></td>
<td>Colonies form on the surface of the skin.</td>
</tr>
<tr>
<td><strong>Staphylococcus</strong></td>
<td>Colonies form in clusters.</td>
</tr>
<tr>
<td><strong>Escherichia coli</strong></td>
<td>Bacteria found in the intestines.</td>
</tr>
<tr>
<td><strong>Salmonella</strong></td>
<td>Causes food poisoning.</td>
</tr>
</tbody>
</table>

*Note: This table is a simplified representation and does not include all types of bacteria.*