# FOURTH CHAPTER: Structure and physicochemical properties of Proteins (Part 2)

## II. Properties of amino acids

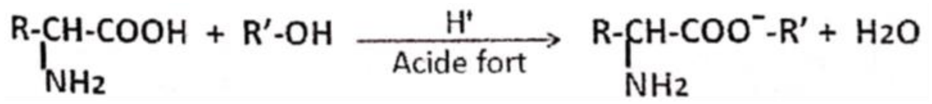
### a. Physical properties

- **Solubility:** amino acids form crystals. They are relatively soluble in water and in polar solvents due to their ionic nature and their ability to form hydrogen bonds with water molecules. This solubility is lower for hydrophobic amino acids.
- Absorption of light: Amino acids do not absorb visible light, they absorb ultraviolet.

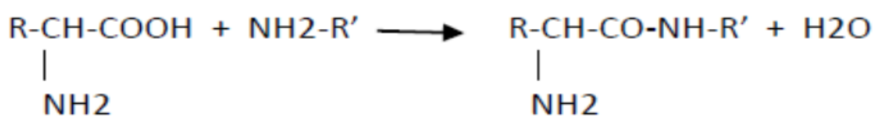
### b. Chemical properties

- **Amino acids are amphoteric:** AAs contain an acidic -COOH group and a basic $NH_2$ group. The ionization state varies depending on the pH:
  • In an acidic environment, the NH2 amine function is ionized by capturing a proton ($R\text{-}NH_3^+$).
  • In a basic medium, the acid function ionizes by releasing a proton ($R\text{-}COO^-$).
- **Properties due to the COOH carboxylic group:**

• **Esterification:** with an alcohol and in the presence of a strong acid.



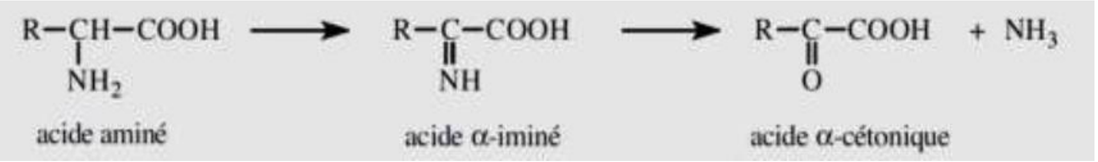

• **Amidification:** reaction with $NH_3^+$ leads to an amide.



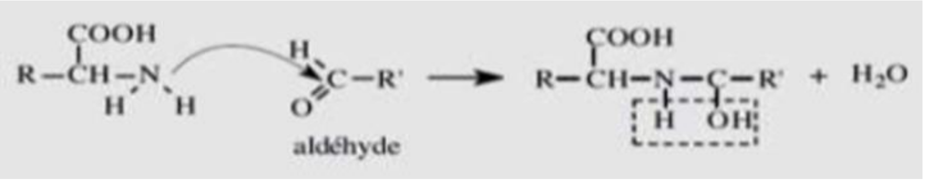

• **Formation of salts:** action of a base on a carboxylic group leads to the formation of salts.


- **Properties due to the NH2 grouping:**

• **Deamination:** To maintain the intracellular reserve of the 20 amino acids used for protein synthesis, the metabolism will go through deaminations with oxidation which will produce α ketone acids.




- **Addition of carbonyl:** The α amino functions of amino acids react reversibly with aldehydes to give a very fluorescent product. It is one of the very sensitive means of detecting amino acids.




## III. Peptides

A linear chain of amino acid residues is called a polypeptide. A protein contains at least one long polypeptide. Short polypeptides, containing less than 20–30 residues, are rarely considered to be proteins and are commonly called peptides.

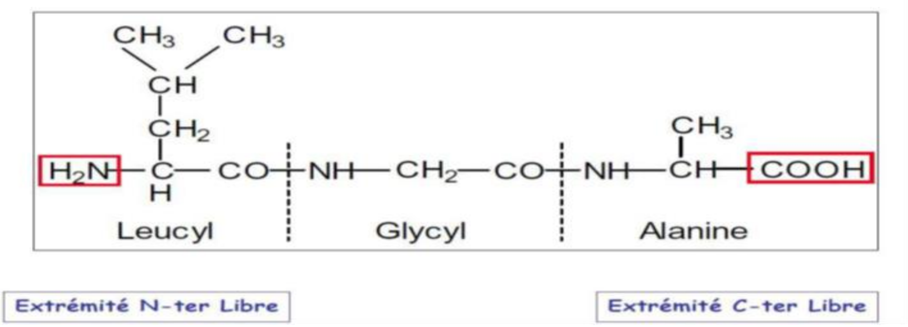
Peptides and proteins are synthesized in the cytoplasm and the endoplasmic reticulum by assembly of amino acids during the translation of messenger RNAs.

According to the number of constituent amino acids; we distinguish:

- **Dipeptides:** two amino acids connected via a peptide bond.
- **Tripeptides:** sequence of three amino acids.
- **Oligopeptides:** sequence of twenty amino acids.
- **Polypeptides:** between twenty and fifty amino acids.

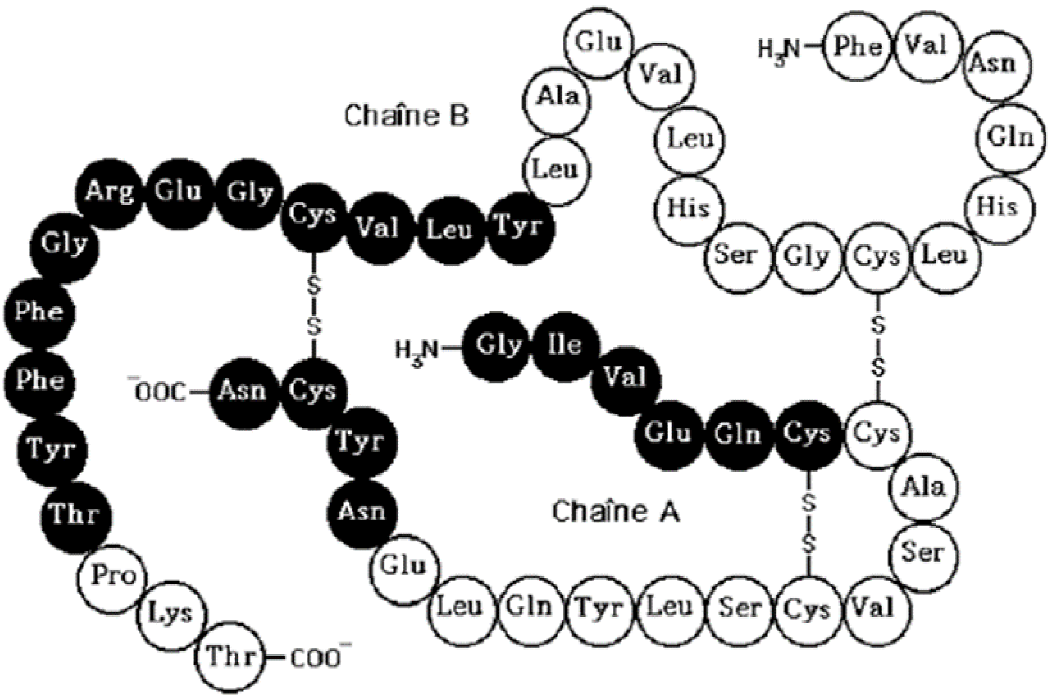
### III.1. Direction of the polypeptide chain

The amino acids involved in a peptide chain are called residues. Their name is that of the amino acid to which the suffix “yl” is added except for the last which keeps its full name. We number the amino acids by writing the sequence from left to right from the N-terminal end ($NH_2$) to the C-terminal end (COOH).




**III.2. Example of a peptide of biological interest**

**Insulin** is a peptide produced by the endocrine pancreas, at the level of the islets of Langerhans (β cell). Insulin is a hypoglycemic hormone, it is a polypeptide consisting of two chains, chain A (21 amino acids) and chain B (30 amino acids) with two interchain disulfide bridges and one intrachain bridge.



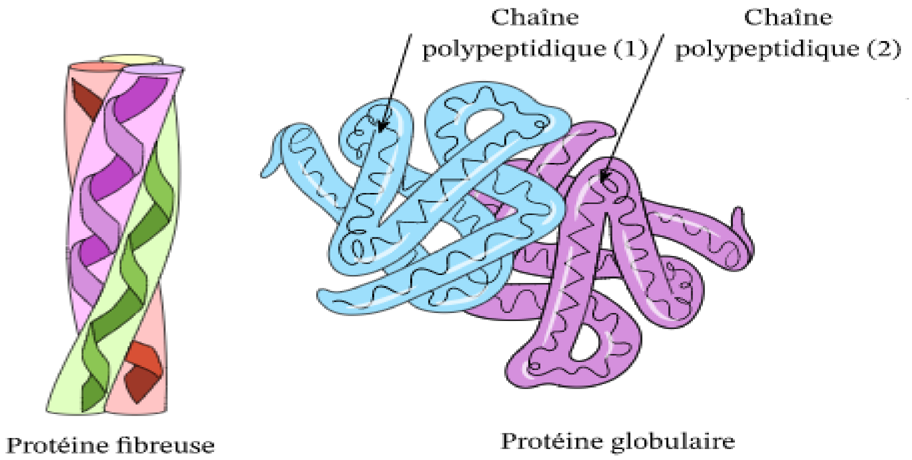

## IV. Proteins

Proteins can consist only of amino acids (holoproteins) or be associated with a non-protein mineral, metallic, carbohydrate, lipid or nucleic acid component (heteroproteins: glycoproteins, lipoproteins or nucleoproteins).

### IV.1. Classification of proteins according to their shape

Proteins can be divided into 2 main classes (Figure 12) according to their shape and certain physical characteristics:

- **Globular proteins:** The polypeptide chains forming globular proteins are tightly coiled into a spherical or globular structure. They are generally soluble in aqueous systems and diffuse rapidly. Most have a dynamic function (enzymes, antibodies, hormones, transport proteins and immunity proteins, etc.).
- **Fibrous proteins:** They are insoluble in water, elongated with polypeptide chains extended along an axis. They have a structural or protective role (keratin, collagen, fibroin, actin, myosin, etc.).




### IV.2. Three-dimensional structure of proteins

#### a. Primary Structure

The amino acid sequence is referred to as the primary structure and changes in it can affect every other level of structure as well as the properties of a protein. On a more immediate time scale, 3D protein structure arises as a result of a phenomenon called folding. Protein folding results from three different structural elements beyond primary structure. They are referred to as secondary, tertiary, and quaternary structures, each arising from interactions between progressively more distant amino acids in the primary structure.

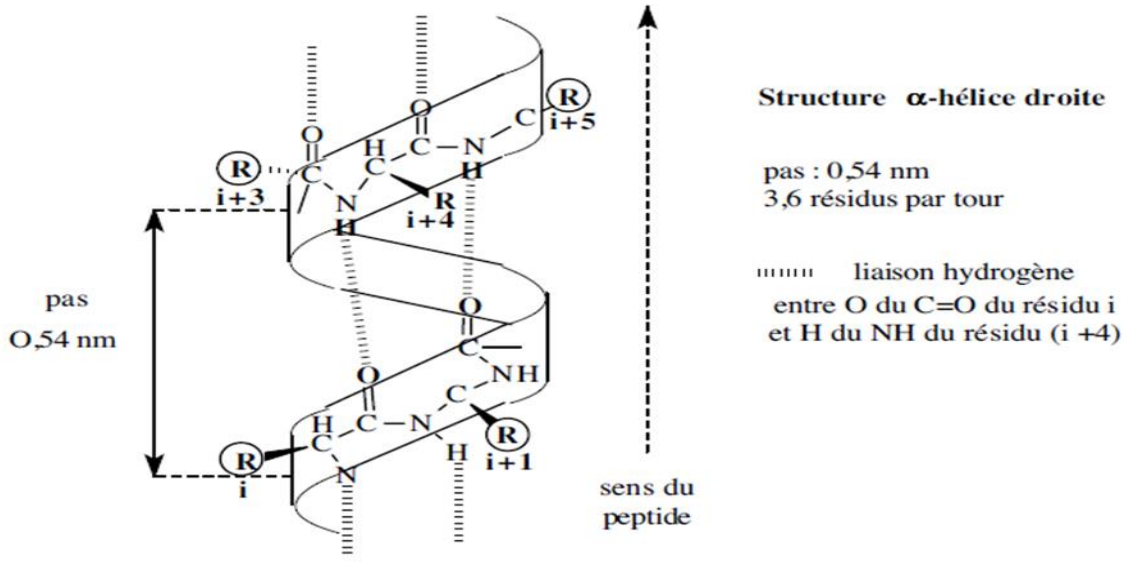
#### b. Secondary Structure

It designates the spatial arrangement of the peptide chain, it involves the hydrogen bonds between C=O and N-H of the peptide chain. 2 secondary structures are retained:

- **Alpha Helix**

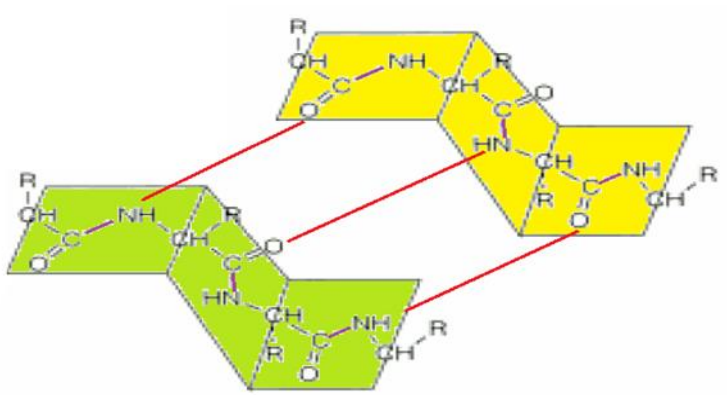
The alpha helix forms as a result of interactions between amino acids separated by four residues.

Hydrogen bonds occur between the C=O of one amino acid and the N-H of another amino acid four residues distant and these help to stabilize the structure. Some amino acids have high helix forming tendencies. They include methionine, alanine, leucine, uncharged glutamate, and lysine. Others, such as proline, glycine, and negatively charged aspartate, disfavor its formation.



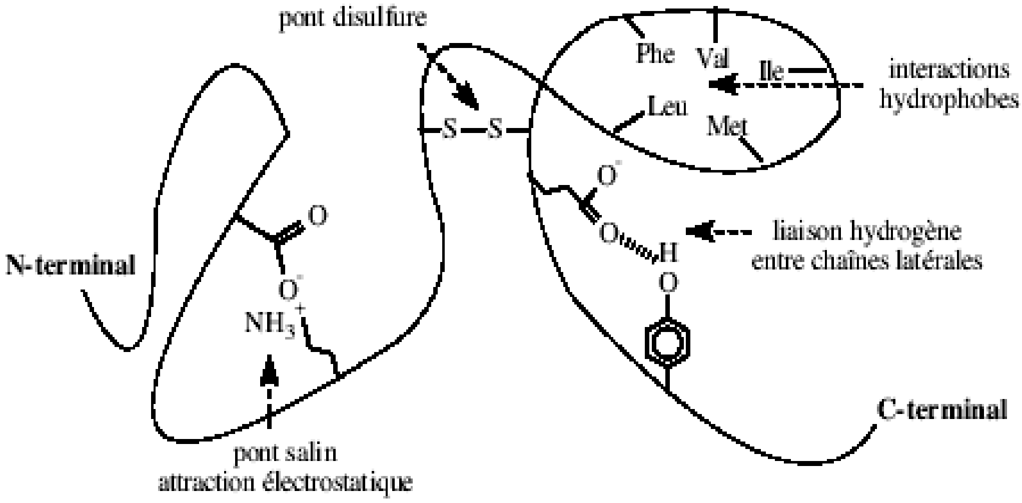

- **Beta Strands**

Beta strands are the most fundamental helix, having essentially a 2D backbone of 'folds' like those of the pleats of a curtain.



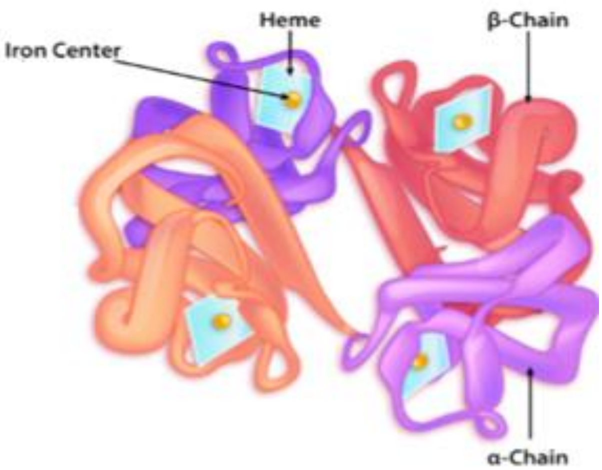
### c. Tertiary Structure

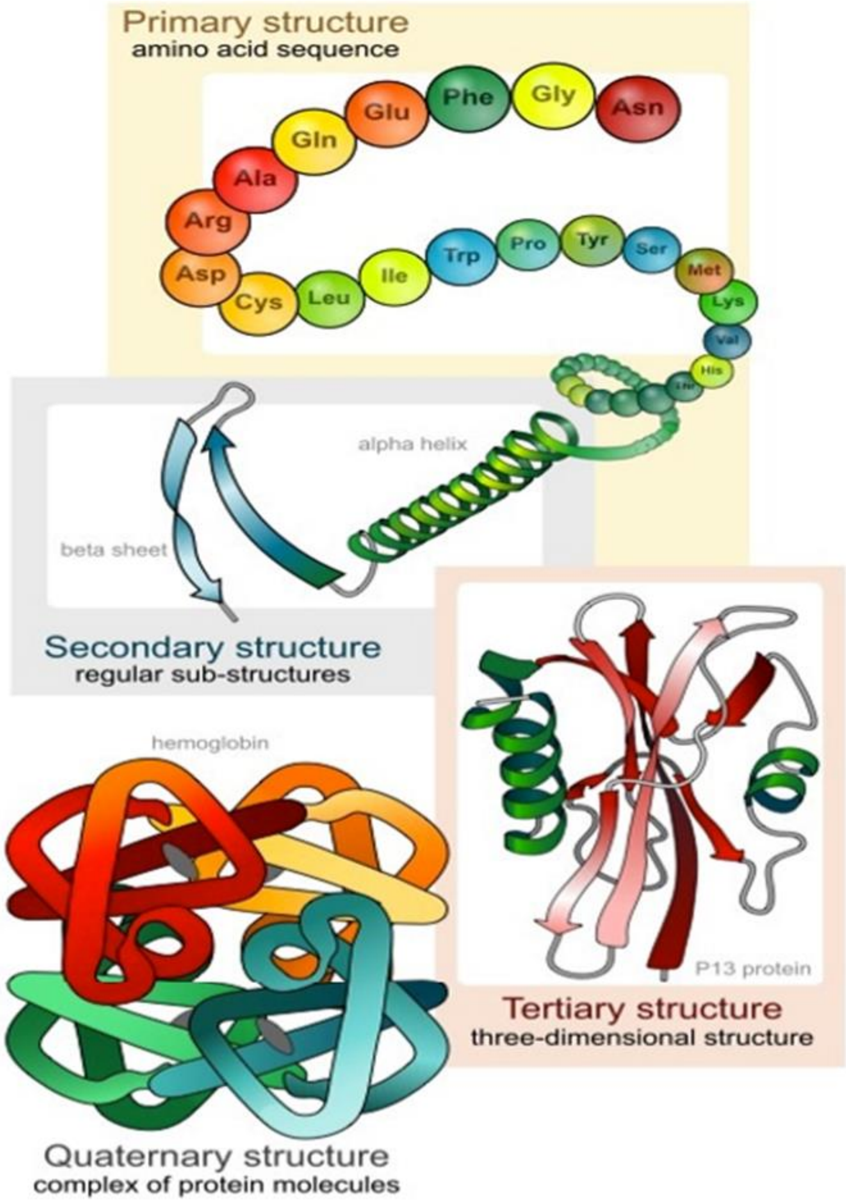
It is the result of the assembly of elementary forms of type α or β according to the three directions of space and by the folding of the chains. It is stabilized by non-covalent type interactions (ionic bonds, hydrogen bonds, Van der Waals bonds) and disulfide bridges.




### d. Quaternary Structure

The last level of protein structure we will consider is that of quaternary structure. In order to have quaternary structure, a protein must have multiple polypeptide subunits because the structure involves the arrangement of those subunits with respect to each other. The association of the different chains occurs via weak bonds and disulfide bridges.






**IV.3. Physicochemical properties of proteins:**

- **Molecular mass:** Proteins are characterized by molecular masses which vary from one protein to another.
- **Solubility:** It varies from one protein to another, it is influenced by:
  - **pH:** the solubility of a protein is minimal at isoelectric pH (the pH for which the net electric charge of the molecule is zero).
  - **Ionic strength:** when the salt concentration of the medium increases, the ionic strength increases and the solubility of proteins decreases which leads to the precipitation of proteins, this technique is used in the separation of proteins.

• **Temperature:** increasing temperature causes proteins to denature, making them insoluble.

- **The amphoteric character:** The net charge of the protein varies with the pH of the medium:

  • **In an acidic environment:** the basic groups capture the protons and the resulting charge of the protein is positive.

  • **In a basic medium:** the acidic groups lose protons and the resulting charge of the protein is negative.

  • **At suitable pH:** the net charge of the protein is zero, this is the isoelectric point.

- **Spectral properties:** Proteins can absorb ultraviolet light.
- **Protein hydrolysis:** Either chemical by the use of strong acid and hot, or enzymatic by endopeptidases which cut the peptide bonds inside the protein and exopeptidases which release the carboxy-terminal AA and the amino-terminal AA.