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S.Y. B.Sc. (Sem. III) (CBCS)

BIOCHEMISTRY

BIOCHEMISTRY-301

Unit - 3

AMINO ACID AND PROTEIN

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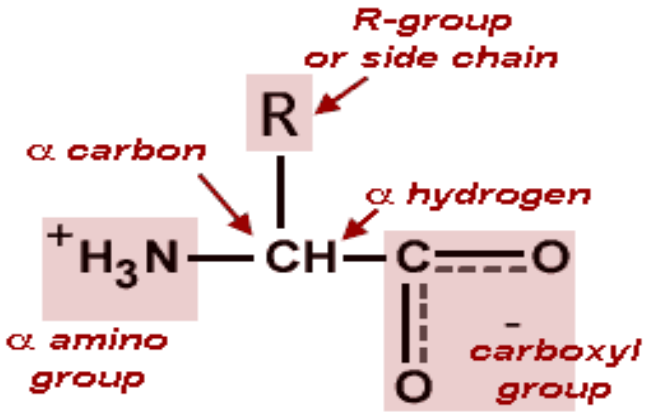
CONTENT

AMINO ACID: STRUCTURE AND CLASSIFICATION.

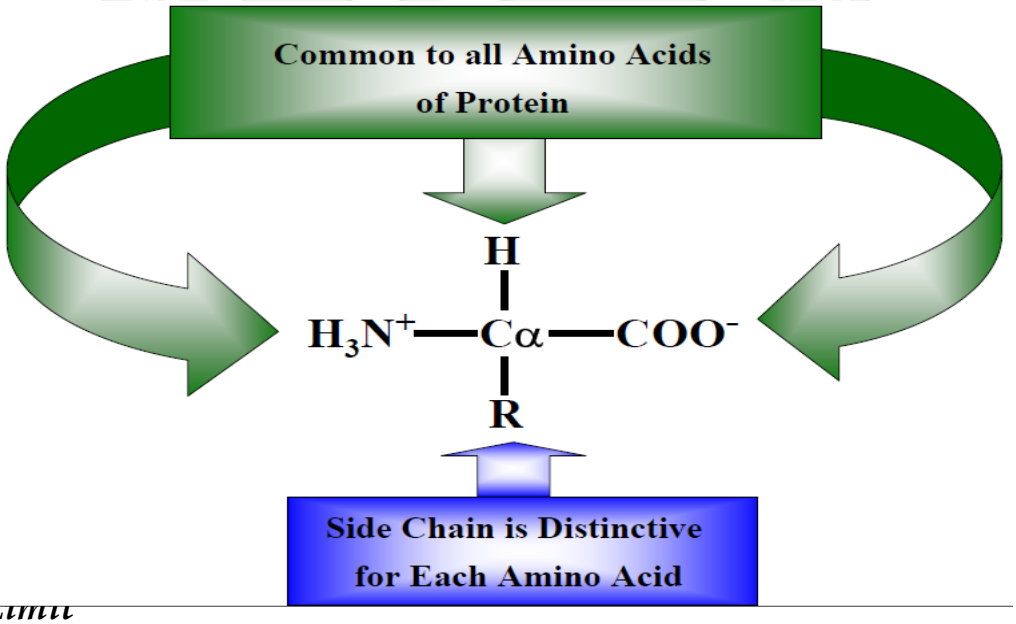
Amino Acids are the building units of proteins. There are about 300 amino acids occur in nature. Only 20 of them enter in proteins synthesis.

Structure of amino acids:

Each amino acid has 4 different groups attached to α- carbon (which is C-atom next to COOH). These 4 groups are: amino group, COOH group, Hydrogen atom and side Chain (R). At physiological pH (7.4), -COOH group is dissociated forming a negatively charged carboxylate ion (COO-) and amino group is protonated forming positively charged ion (NH3 +) forming Zwitter ion .



- Proline is an imino acid not amino acid .



Classification of Amino Acids:

I. Classification by R group
II. Chemical Classification
III. Nutritional Classification
IV. Metabolic Classification

Classification according to polarity of side chain (R):

A- Polar amino acids: in which R contains polar hydrophilic group so can forms hydrogen bond with H2O. In those amino acids, R may contain:

1- OH group : as in serine, threonine and tyrosine

2- - SH group : as in cysteine

3- amide group: as in glutamine and aspargine

4- NH2 group or nitrogen act as a base (basic amino acids): as lysine, arginine and histidine

5- COOH group (acidic amino acids): as aspartic and glutamic.

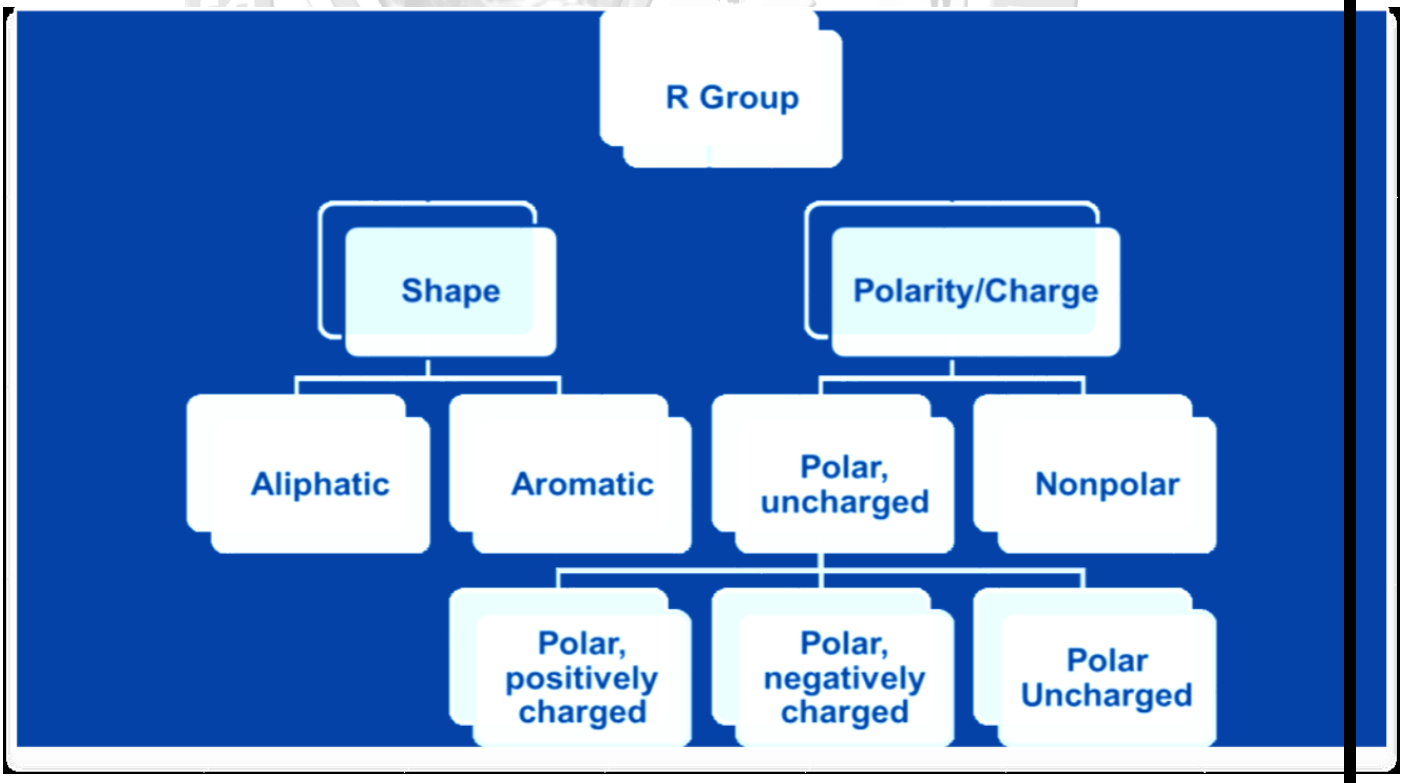


Figure: Classification by R group

B- Non polar amino acids: R is alkyl hydrophobic group which can't enter in hydrogen bond formation. 9 amino acids are non-polar (glycine, alanine, valine, leucine, isoleucine, phenyl alanine, tryptophan, proline and methionine).

The ***twenty common amino acids*** are often referred to using three-letter abbreviations. The structures, names, and abbreviations for the twenty common amino acids are shown below. Note that they are all ***α*-amino acids**

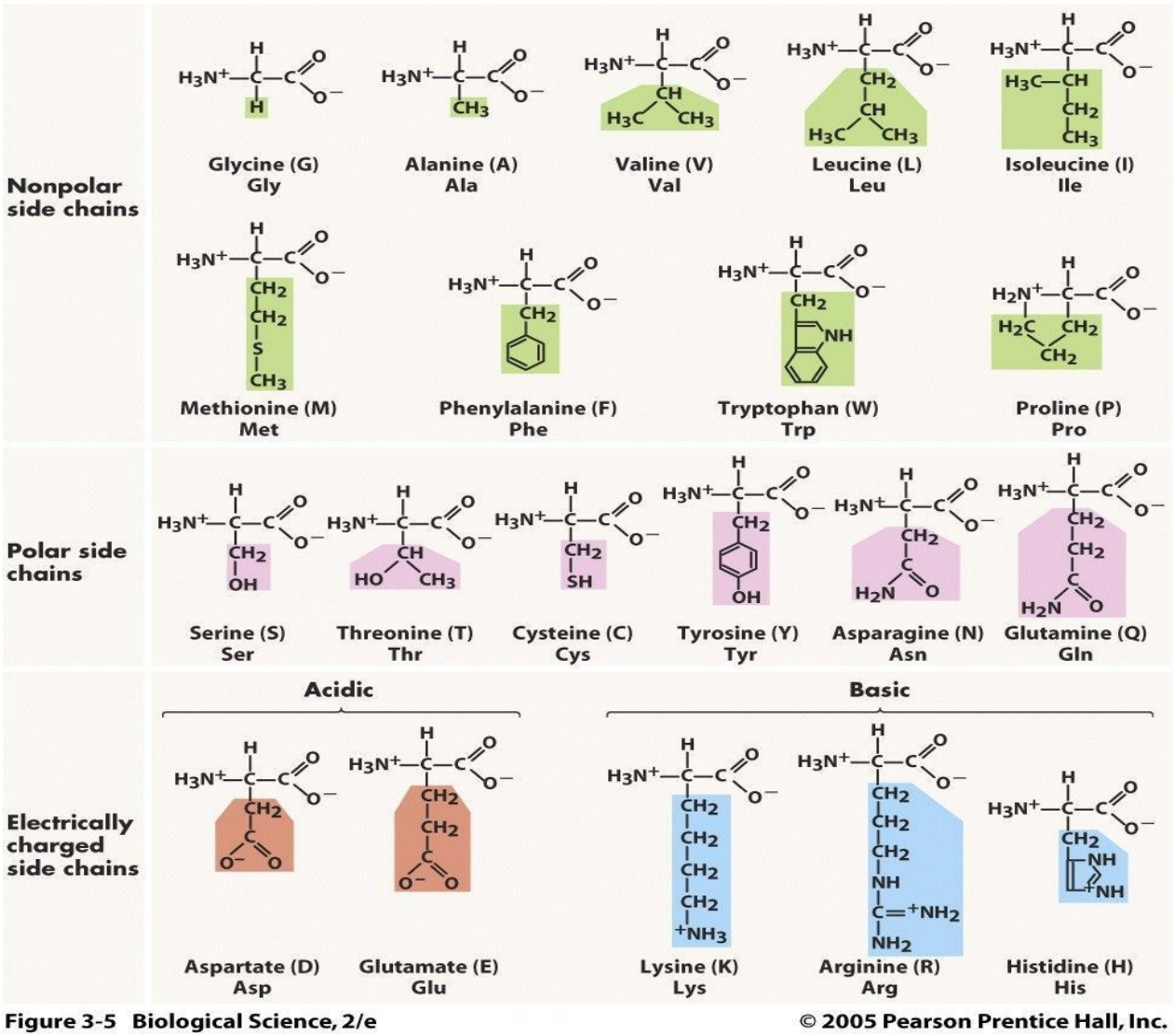


Figure 3-5 Biological Science, 2/e

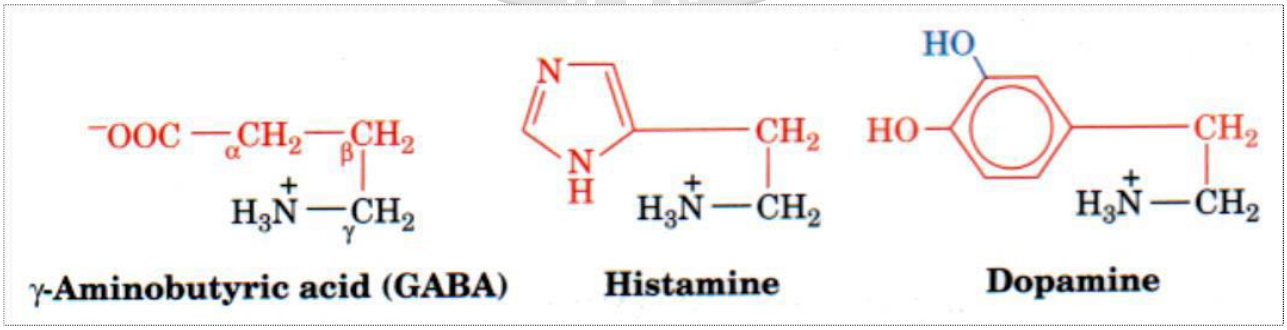
Each amino acid, aside from its name, has a three letter abbreviation and a one letter code.

Nomenclature

Amino Acid	3 letter code	1 letter code	Amino Acid	3 letter code	1 letter code
Glycine	Gly	G	Threonine	Thr	T
Alanine	Ala	A	Cysteine	Cys	C
Valine	Val	V	Tyrosine	Tyr	Y
Leucine	Leu	L	Asparagine	Asn	N
Isoleucine	Ile	I	Glutamine	Gln	Q
Methionine	Met	M	Aspartic Acid	Asp	D
Proline	Pro	P	Glutamic Acid	Glu	E
Phenyl alanine	Phe	F	Lysine	Lys	K
Tryptophan	Trp	W	Arginine	Arg	R
Serine	Ser	S	Histidine	His	H

Nutritional Classification

1- Essential Amino Acids 10 in number can't be synthesized in the body, essential to be taken in diet. Their deficiency affects growth, health and protein synthesis.



2- Semi-essential formed in the body but not in sufficient amount for body requirements especially in children. Arginine and histidine are semi-essential
3- Non-essential can be synthesized in the body.

Non Standard Amino Acids

A nonstandard amino acid is an amino acid that occurs naturally in cells but do not participate in peptide synthesis. Many are metabolic intermediates *eg.* ornithine and citrulline are intermediates in urea biosynthesis

Amino Acid Derivatives

Chemical derivatives of amino acids also have important biological functions, eg. Catecholamines (below) lack the carboxylate of amino acids
GABA & Dopamine are neurotransmitters. Histamine mediates parts of the immune response.

Functions of Amino Acids

Apart from being the monomeric constituents of proteins and peptides, amino acids serve variety of functions.
Some amino acids are converted to carbohydrates and are called as **glucogenic amino acids**. Specific amino acids give rise to specialized products, e.g **Tyrosine** forms hormones such as **thyroid hormones**, (T3, T4), **epinephrine** and **norepinephrine** and a pigment called **melanin**.

- **Tryptophan** can synthesize a vitamin called **niacin**.
- Glycine, arginine and methionine synthesis **creatine**.
- Glycine and cysteine help in **synthesize of Bile salts**.
- Glutamate, cysteine and glycine synthesis **glutathione**.

Histidine changes to **histamine** on decarboxylation.

- **Serotonin** is formed from tryptophan.
- Glycine is used for the synthesis of **haem**.
- Pyrimidines and purines use several amino acids for their synthesis such as aspartate and glutamine for pyrimidines and glycine, aspartic acid, Glutamine and serine for purine synthesis

- Some amino acids such as glycine and cysteine are used as detoxicants of specific substances.
- Methionine acts as “active” methionine (S-adenosylmethionine) and transfers methyl group to various substances by transmethylation.
- Cystine and methionine are sources of sulphur

PROTEINS

- Proteins are large biomolecules, or macromolecules, consisting of one or more long chains of amino acid residues.
- Proteins are known as building blocks of life.
- Proteins are the most abundant intracellular macro-molecules.
- They provide structure, protection to the body of multicellular organism in the form of skin, hair, callus, cartilage, ligaments, muscles, tendons.
- Proteins regulate and catalyze the body chemistry in the form of hormones, enzymes, immunoglobulin's etc.

General Characteristics of Proteins

- Proteins are organic substances; they are made up of nitrogen and also, oxygen, carbon and hydrogen.
- Proteins are the most important biomolecules; they are the fundamental constituent of the cytoplasm of the cell.
- Proteins are the structural elements of body tissues.
- Proteins are made up of amino acids.
- Proteins give heat and energy to the body and also aid in building and repair.
- Only small amounts of proteins are stored in the body as they can be used up quickly on demand.
- Proteins are considered as the bricks, they make up bones, muscles, hair and other parts of the body.
- Proteins like enzymes are functional elements that take part in metabolic reactions.
- Antibodies, blood hemoglobin are also made of proteins.
- Proteins have a molecular weight of 5 to 300 kilo-Daltons.

Physical Properties of Proteins

- Proteins are colorless and tasteless.
- They are homogeneous and crystalline.
- Proteins vary in shape; they may be simple crystalloid structure to long fibrillar structures.
- Protein structures are of two distinct patterns - Globular proteins and fibrillar proteins.

- Globular proteins are spherical in shape and occur in plants. Fibrillar proteins are thread-like, they occur generally in animals.
- In general proteins have large molecular weights ranging between 5 X 103 and 1 X 106 .
- Due to the huge size, proteins exhibit many colloidal properties.
- The diffusion rates of proteins are extremely slow.
- Proteins exhibit Tyndall effect.
- Proteins tend to change their properties like denaturation. Many a times the process of denaturation is followed by coagulation.
- Denaturation may be a result of either physical or chemical agents. The physical agents include, shaking, freezing, heating etc. Chemical agents are like X-rays, radioactive and ultrasonic radiations.
- Proteins like the amino acids exhibit amphoteric property i.e., they can act as Acids and Alkaline.
- As the proteins are amphoteric in nature, they can form salts with both cations and anions based on the net charge.
- The solubility of proteins depends upon the pH. Lowest solubility is seen at isoelectric point, the solubility increases with increase in acidity or alkalinity.
- All the proteins show the plane of polarized light to the left, i.e., levorotatory.

Chemical Properties of Proteins

- Proteins when hydrolyzed by acidic agents, like conc. HCl yield amino acids in the form of their hydrochlorides.
- Proteins when are hydrolyzed with alkaline agents leads to hydrolysis of certain amino acids like arginine, cysteine, serine, etc., also the optical activity of the amino acids is lost.
- Proteins with reaction with alcohols give its corresponding esters. This process is known as esterification.
- Amino acid reacts with amines to form amides.
- When free amino acids or proteins are said to react with mineral acids like HCl, the acid salts are formed.
- When amino acid in alkaline medium reacts with many acid chlorides, acylation reaction takes place.

- **Xanthoproteic test** - On boiling proteins with conc. HNO3, yellow color develops due to presence of benzene ring.
- **Folin's test** - This is a specific test for tyrosine amino acid, where blue color develops with phosphor molybdian tungstic acid in alkaline solution due to presence of phenol group.

Structure of Proteins

•• Proteins are constructed by polymerization of only 20 different amino acids into linear chains.

•• Proteins are the polymers of L-a-amino acids. The structure of proteins is rather complex which can be divided into 4 levels of organization.

1. Primary structure:

•• The linear sequence of amino acids forming the backbone of proteins (polypeptides).

•• Examples of protein with a primary structure are ***Hexosaminidase, Dystrophin.***

2. Secondary structure:

•• The special arrangement of protein by twisting of the polypeptide chain.

•• Example of protein with a secondary structure is ***Myoglobin.***

3. Tertiary structure:

• The three-dimensional structure of a functional protein.

• Number of forces act to hold the polypeptide chain in this final configuration:

Polar/Nonpolar Interactions

➢ Hydrogen Bonds

➢ Van der Waals Forces

➢ Ionic Interactions

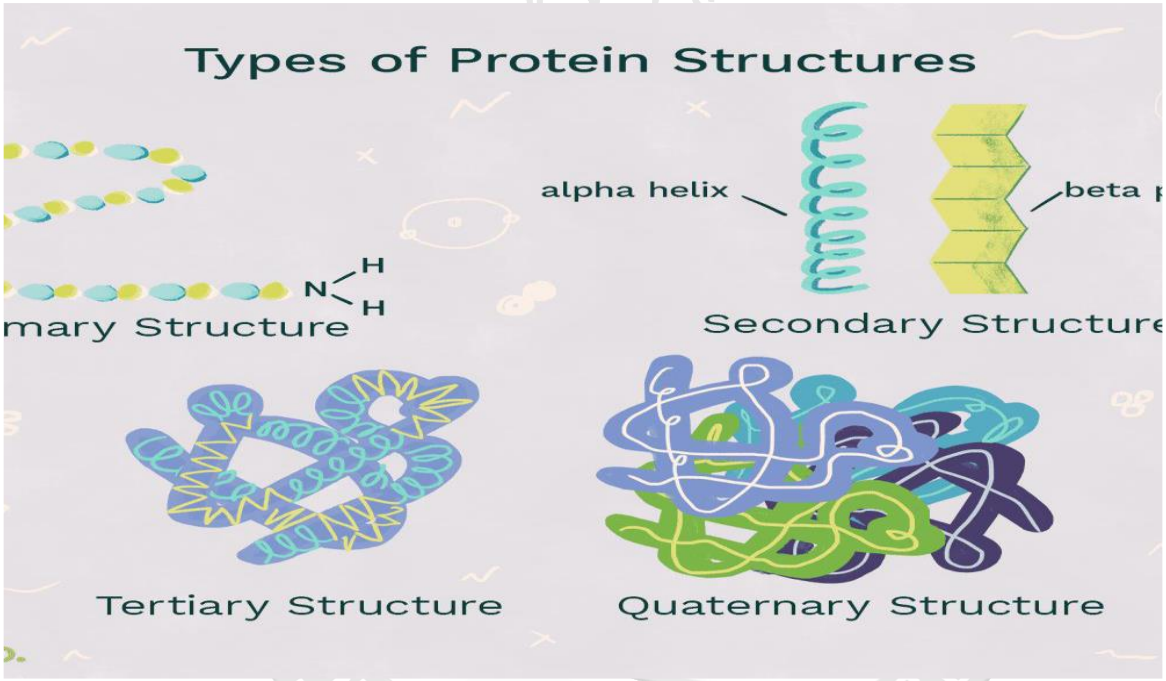
➢ Disulfide Bonds

Examples of protein with a Tertiary structure are ***Globular Proteins*** (Enzymes) and ***Fibrous Proteins***.

4. Quaternary structure:

•• Some of the proteins are composed of two or more polypeptide chains referred to as subunits. The special arrangement of these subunits is known as quaternary structure.

•• Examples of protein with a Quaternary structure are ***DNA polymerase***, and ***ion channels***.



Secondary Structure of Proteins

•• Shape

•➢ ***Alpha Helix:*** Alpha Helix is a right-handed coiled rod-like structure.

•➢ ***Beta Pleated Sheet:*** Beta sheet is a sheet-like structure.

•• Formation

•➢ ***Alpha Helix:*** Hydrogen bonds form within the polypeptide chain in order to create a helical structure.

• ➢ ***Beta Pleated Sheet:*** Beta sheets are formed by linking two or more beta strands by H bonds.

• • Bonds

• ➢ ***Alpha Helix:*** Alpha helix has n + 4 H-bonding scheme. i.e. Hydrogen bonds form between N-H group of one amino residue with C=O group of another amino acid, which is placed in 4 residues earlier.

• ➢ ***Beta Pleated Sheet:*** Hydrogen bonds are formed in between the neighboring N-H and C=O groups of adjacent peptide chain

• • R group

• ➢ ***Alpha Helix:*** -R groups of the amino acids are oriented outside of the helix.

• ➢ ***Beta Pleated Sheet:*** -R groups are directed to both inside and outside of the sheet.

• • Number

• ➢ ***Alpha Helix:*** This can be a single chain.

• ➢ ***Beta Pleated Sheet:*** This cannot exist as a single beta strand; there are must be two or more.

• • Type

• ➢ ***Alpha Helix:*** This has only one type.

• ➢ ***Beta Pleated Sheet:*** This can be parallel, anti-parallel or mixed.

• Qualities

• ➢ ***Alpha Helix:*** 100o rotation, 3.6 residues per turn and 1.5 Ao rise from one alpha carbon to the second

• ➢ ***Beta Pleated Sheet:*** 3.5 Ao rise between residues Amino Acid

• ➢ ***Alpha Helix:*** Alpha helix prefers the amino acid side chains, which can cover and protect the backbone H- bonds in the core of the helix.

•➢ ***Beta Pleated Sheet:*** The extended structure leaves the maximum space free for the amino acid side chains. Therefore, amino acids with large bulky side chains prefer beta sheet structure.

•• Preference

•➢ ***Alpha Helix:*** Alpha helix prefers Ala, Leu, Met, Phe, Glu, Gln, His, Lys, Arg amino acids.

•➢ ***Beta Pleated Sheet:*** Beta sheet prefers Tyr, Trp, (Phe, Met), Ile, Val, Thr, Cys.

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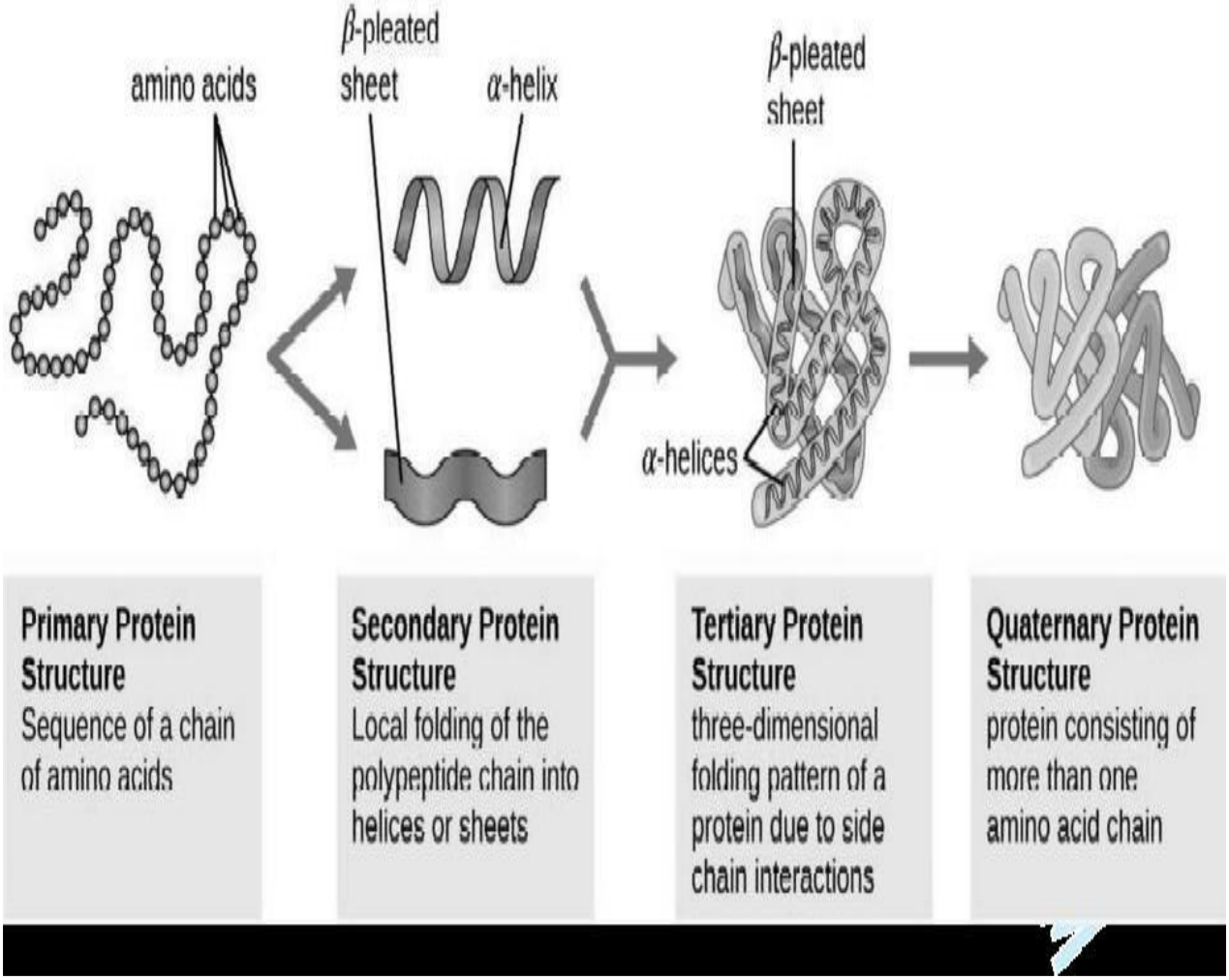

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Protein Classification

Classification of Proteins Based on Shape

• • Globular or Corpuscular Proteins

• ➢ Globular proteins have axial ratio less than 10 but not below 3 or 4.

• ➢ They are compactly folded and coiled and possess a relatively spherical or ovoid shape.

• ➢ They are usually soluble in water and in aqueous media.

• ➢ **Example**: Insulin, plasma albumin, globulin enzymes.

Axial ratio, for any structure or shape with two or more axes, is the ratio of the length (or magnitude) of those axes to each other - the longer axis divided by the shorter.
In chemistry or materials science, the axial ratio (symbol P) is used to describe rigid rod-like molecules. It is defined as the length of the rod divided by the rod diameter.

• • Fibrous or Fibrillar Proteins

• ➢ These proteins have axial ratio more than 10, hence, they resemble long ribbons or fibers in shape.

• ➢ They are mostly found in animals, and are not soluble in water or in solution of dilute acids.

• ➢ Fibrous proteins aid in protection and structural support.

• ➢ **Example:** Collagen, Keratin, Elastin, Fibroin

Classification of Proteins Based on Composition and Solubility

➢ Simple Proteins or Holoproteins:

➢ These proteins are made of only one type of amino acid, as structural component, on decomposition with acids, they liberate constituent amino acids. They are mostly globular type of proteins except for scleroproteins, which are fibrous in nature.

➢ Simple proteins are further classified based on their solubility.

1. Protamine and histones

➢ These proteins occur only in animals and are basic proteins.

➢ They possess simple structure and low molecular, are water soluble and are not coagulated by heat.

➢ They are strongly basic in character due to the high content of lysine, arginine.

Example: Protamine - salmine, clupine, cyprinine; Histones - nucleoshistones, globin.

2. Albumins

➢ They are widely distributed in nature, mostly seen in seeds.

➢ They are soluble in water and dilute solutions of acids, bases and salts.

➢ **Example:** Leucosin, legumeline, serum albumin.

3. Globulins

➢ They are of two types, pseudo globulins which are soluble in water,

➢ Other is euglobulin which are insoluble in water.

➢ They are coagulated by heat.

➢ **Example:** Pseudo globulin, serum globulin, glycinin. etc.

4. Scleroproteins or Albuminoids

➢ These occur mostly in animals and are commonly known as animal skeleton proteins.

➢ They are insoluble in water, and in dilute solution of acids, based and salts.

➢ Conjugated or Complex Proteins or Heteroproteins:

➢ These are proteins that are made of amino acids and other organic compounds. The non-amino acid group is termed as prosthetic group.

➢ Complex proteins are further classified based on the type of prosthetic group present.

Metalloproteins:

➢ These are proteins linked with various metals.

➢ Example: casein, collagen, ceruloplasmin, etc.

Chromoproteins

➢ These are proteins that are coupled with a colored pigment.

➢ Example: Myoglobin, hemocyanin, cytochromes, flavoproteins, etc.

Glycoproteins and Mucoproteins

➢ These proteins contain carbohydrates as the prosthetic group.

➢ Example: Glycoproteins - egg albumin, serum globulins, serum albumins; Mucoproteins - Ovomucoid, mucin etc.

Phosphoproteins

➢ These proteins are linked with phosphoric acid.

➢ Example: casein.

Lipoproteins

➢ Proteins forming complexes with lipids are lipoproteins.

➢ Example: lipovitellin, lipoproteins of blood.

Nucleoproteins

➢ These are compounds containing nucleic acids and proteins.

➢ Example: Nucleoproteins, nucleohistones, nuclein.

Derived Proteins

➢ These are proteins that are derived from the action of heat, enzyme or chemical reagents.

➢ Derived proteins are of two types, primarily derived proteins and secondary derived proteins.

▪ Primary derived proteins

➢ Derivatives of proteins, in which the size of the protein molecule is not altered materially.,.

➢ Primary derived proteins are classified into three types - **Proteans**, **Infraproteins** and **Coagulated proteins**.

➢ **Example:** edestan, coagulated egg-white.

▪ Secondary derived proteins.

➢ While in secondary derived proteins, hydrolysis occurs, as a result the molecules are smaller than the original proteins.

➢ They are further classified into 3 types - Proteoses, Peptones and Polypeptides

Classification of Proteins on Biological Function

• • Enzymic Proteins ➢ They are the most varied and highly specialized proteins with catalytic activity. Enzymes catalyze a variety of reactions.

• ➢ **Example:** Urease, catalase, cytochrome C, etc.

• Structural Proteins

• ➢ These proteins aid in strengthening or protecting biological structures.

• ➢ **Example:** Collagen, elastin, keratin, etc.

• Transport or Carrier Proteins

• ➢ These proteins help in transport of ions or molecules in the body.

• ➢ **Example:** Myoglobin, hemoglobin, etc.

• Nutrient and Storage Proteins

• ➢ These proteins provide nutrition to growing embryos and store ions.

• Contractile or Motile Proteins

• ➢ These proteins function in the contractile system.

• ➢ **Example:** Actin, myosin, tubulin, etc.

• • Defense Proteins

•➢ These proteins defend against other organisms.

•➢ **Example:** Antibodies, Fibrinogen, thrombin.

•• Regulatory Proteins

•➢ They regulate cellular or metabolic activities.

•➢ **Example:** Insulin, G proteins, etc.

•• Toxic Proteins

•➢ These proteins hydrolyze or degrade enzymes.

•➢ **Example:** snake venom, ricin.

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Function of Proteins

•• Proteins are seen in muscles, hair, skin and other tissues; they constitute the bulk of body's non-skeletal structure. *Example:* The protein keratin is present in nails and hair.

•• Some proteins are hormones and regulate many body functions. *Example:* Insulin hormone is a protein and it regulated the blood sugar level.

•• Some proteins act enzymes, they catalyze or help in biochemical reactions. *Example:* Pepsin and Trypsin.

•• Some proteins act as antibodies; they protect the body from the effect of invading species or substances.

•• Proteins transports different substances in blood of different tissues. *Example:* Hemoglobin is an oxygen transport protein.

•• Contractile proteins help in contraction of muscle and cells of our body. *Example:* Myosin is contractile protein.

•• Fibrinogen a glycoprotein helps in healing of wounds. It prevents blood loss and inhibits passage of germs.