

## **CORE COURSE 12: FOOD CHEMISTRY**

### **UNIT 4: PROTEINS (part 1)**

#### **Topic: Structure & Classification of proteins**

**Objectives:** The aim of the present study module is to learn about structure, classification & nature of proteins.

**Introduction:** Proteins, amino acids & peptides are important constituents of food. They supply the required building blocks for protein biosynthesis.

In addition, they directly contribute to the flavor of food and are precursors for aroma compounds and colors formed during thermal or enzymatic reactions in production, processing and storage of food.

Proteins play a central role in biological systems & their synthesis occurs in ribosomes. At the elemental level, proteins contain 50–55% carbon, 6–7% hydrogen, 20–23% oxygen, 12–19% nitrogen, and 0.2–3.0% sulfur. They are highly complex polymers, made up of 20 different amino acids.

With this introduction we shall study proteins structure & their classification in details under the following subtopics:

- 1) Structure of proteins
  - ✓ Primary, secondary, tertiary & quaternary structures
  - ✓ Stability of proteins & denaturation
- 2) Classification of proteins
  - Based on chemical composition & conformation
  - Based on structure of amino acids
  - Based on quality
  - Based on nutrition
  - Based on function
- 3) Nature of food proteins
- 4) Protein recommendations
- 5) Conclusion

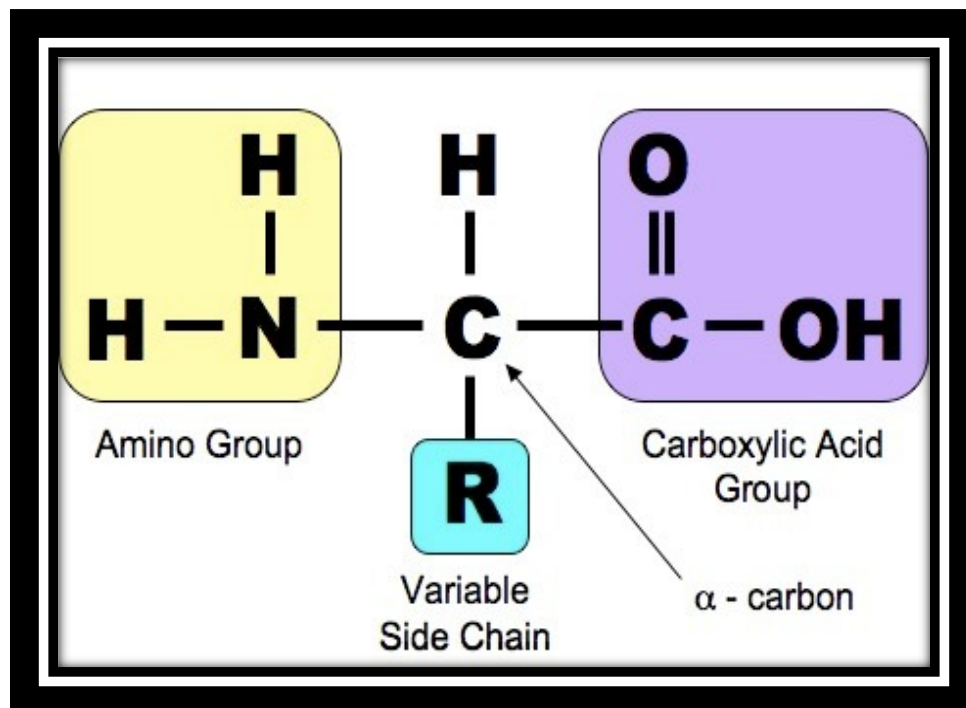
## 1) STRUCTURE OF PROTEINS

Proteins are complex macromolecules, made up of 20 different amino acids. They are hydrolyzed to form simpler substances and ultimately amino acids. These amino acids are the basic structural units of proteins.

The hydrolytic process takes place during digestion by proteolytic enzymes.

Protein ~~Polypeptide~~ ~~Peptide~~ ~~Amino~~ acids

The general structure of amino acid is as shown on the screen



(They consist of an  $\alpha$ -carbon atom covalently attached to a Hydrogen atom, an amino group (NH<sub>2</sub>), a Carboxyl group (COOH), and a side-chain R group).

**Primary structure:** Amino acids, as the name itself indicates, contain both a basic amino group ( $\text{NH}_2$ ) & an acidic carboxyl group ( $\text{COOH}$ ).

The di-functionality of these two groups allows the individual amino acids to join together in long chains by forming peptide bonds.

It is the bond which is formed between amino groups ( $\text{NH}_2$ ) of one amino acid to carboxyl group ( $\text{COOH}$ ) of another amino acid.

A dipeptide bond is two amino acids joined by a peptide bond, likewise; oligopeptide refers to a chain of 4-10 amino acids. The sequence formed with more than 10 amino acids is referred to as proteins or polypeptides.

The end of the peptide or protein sequence with a free carboxyl group is called the *carboxy-terminus* or *C-terminus* & the end of free amino group is called *amino-terminus* or *N-terminus*.

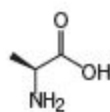
The amino acids differ in structure by the side chains. These side chains confer different chemical, physical and structural properties to the final proteins.

The structures of the 20 amino acids commonly found in proteins are shown on the screen

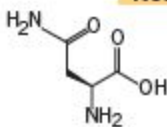
Figure 1

## AMINO ACID STRUCTURES AND ABBREVIATIONS

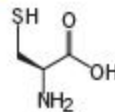
### Neutral



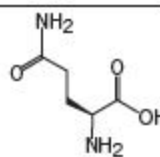
**L-Alanine**  
Ala  
A



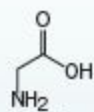
**L-Asparagine**  
Asn  
N



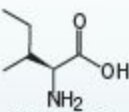
**L-Cysteine**  
Cys  
C



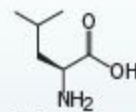
**L-Glutamine**  
Gln  
Q



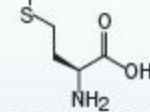
**Glycine**  
Gly  
G



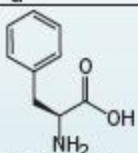
**L-Isoleucine**  
Ile  
I



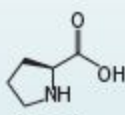
**L-Leucine**  
Leu  
L



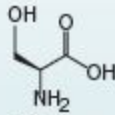
**L-Methionine**  
Met  
M



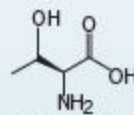
**L-Phenylalanine**  
Phe  
F



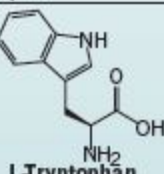
**L-Proline**  
Pro  
P



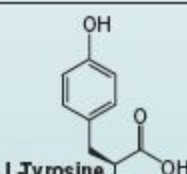
**L-Serine**  
Ser  
S



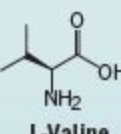
**L-Threonine**  
Thr  
T



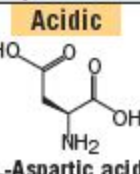
**L-Tryptophan**  
Trp  
W



**L-Tyrosine**  
Tyr  
Y

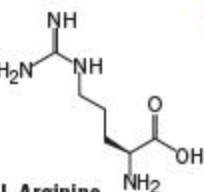


**L-Valine**  
Val  
V

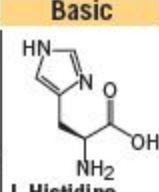


**L-Aspartic acid**  
Asp  
D

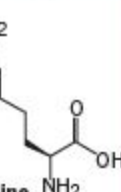
### Acidic



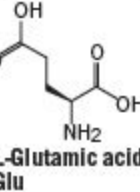
**L-Arginine**  
Arg  
R



**L-Histidine**  
His  
H



**L-Lysine**  
Lys  
K



**L-Glutamic acid**  
Glu  
E

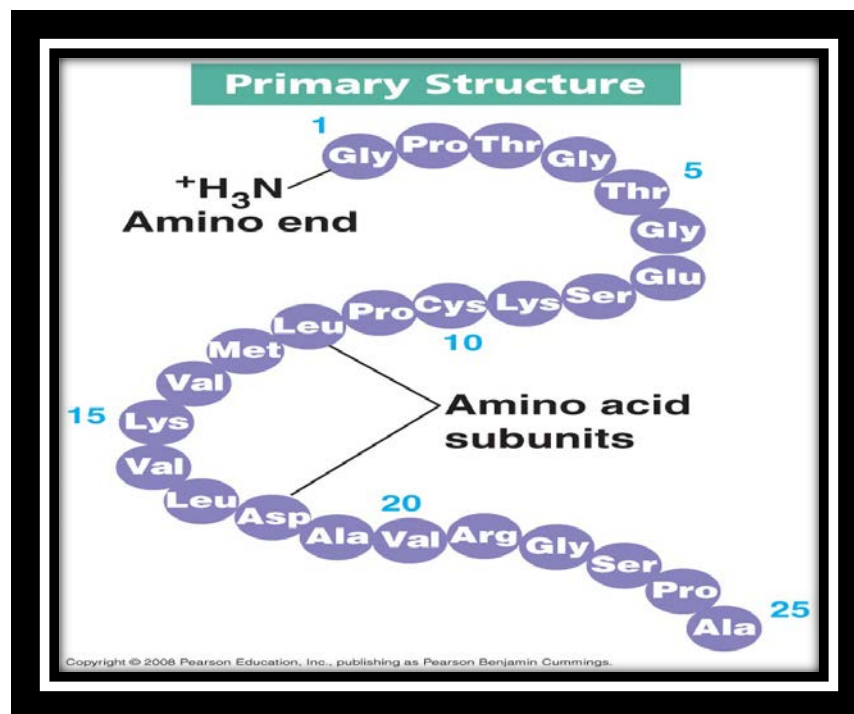
Particle Sciences

Source reference: Protein Structure *Particle Sciences - Technical Brief* 2009:  
Volume 8

Each amino acid has both a one-letter and three-letter abbreviation. These abbreviations are commonly used to simplify the written sequence of a peptide or protein.

The amino acid sequence of a protein is encoded in DNA. Proteins are synthesized by a series of steps called transcription (the use of a DNA strand to make a complimentary messenger RNA strand - mRNA) and translation (the mRNA sequence is used as a template to guide the synthesis of the chain of amino acids which make up the protein).

While the amino acid sequence makes up the *primary structure* of the protein, the chemical/biological properties of the protein are dependent on the three-dimensional or tertiary structure.



**Source reference:** Biochemanics – protein structure level, 2013

**Secondary structure:** Strands of proteins or peptides have distinct characteristic local structural conformations or *secondary structure*, dependent on hydrogen bonding.

The two main types of secondary structure are the  $\alpha$ -helix and the  $\beta$ -sheet.

**$\alpha$ -helix:** is a right-handed coiled strand. The side-chain substituents of the amino acid groups in  $\alpha$ -helix extend to the outside.

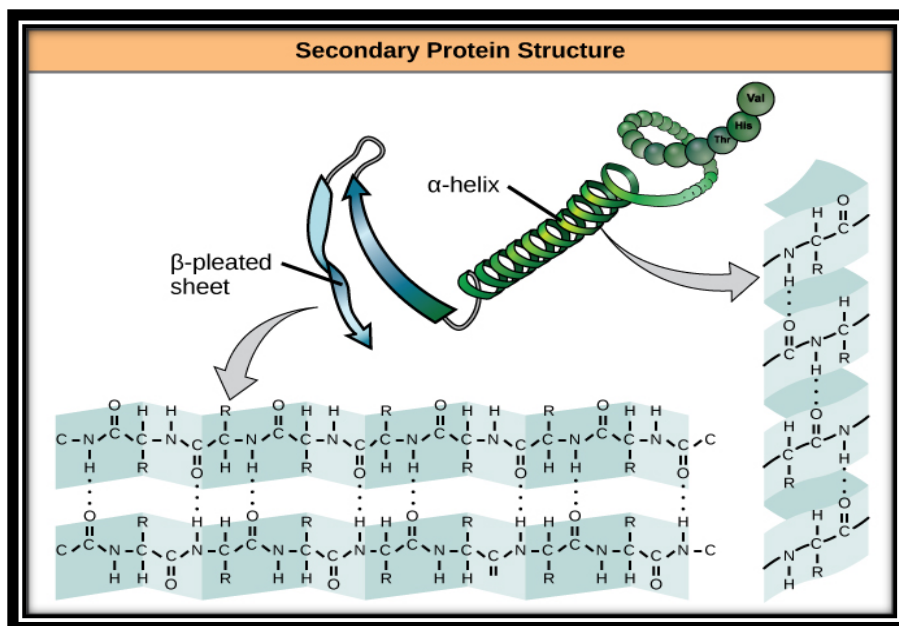
Hydrogen bonds form between the oxygen of the C=O of each peptide bond in the strand and the hydrogen of the N-H group of the peptide bond four amino acids below it in the helix.

The hydrogen bonds make this structure especially stable. The side-chain substituents of the amino acids fit in beside the N-H groups.

**$\beta$ -sheet:** The hydrogen bonding in a  $\beta$ -sheet is between strands (inter-strand) rather than within strands (intra-strand).

The sheet conformation consists of pairs of strands lying side-by-side. The carbonyl oxygens in one strand hydrogen bond with the amino hydrogens of the adjacent strand.

The two strands can be either parallel or anti-parallel depending on whether the strand directions (N-terminus to C-terminus) are the same or opposite. The anti-parallel  $\beta$ -sheet is more stable due to the more well-aligned hydrogen bonds.



Source reference: (boundless.com) protein structure

Several weak interactions are very important in determining the secondary & tertiary structure of proteins. All these weak bonds are non-covalent, the main types are:

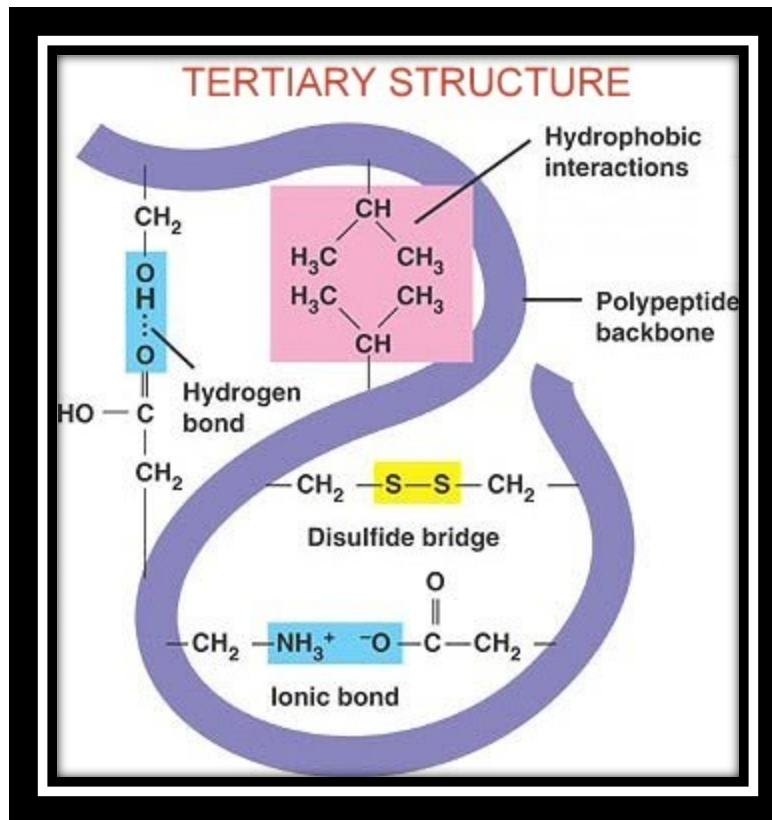
- 1) **Ionic or electrostatic bonds:** These results from the attractive force between ionized groups of opposite charge.
- 2) **Hydrogen bonds:** These results from a H<sup>+</sup> (proton) that is shared between two neighboring electro-negative atom. The H<sup>+</sup> can be shared between nitrogen or oxygen atoms which are close to each other.
- 3) **Hydrophobic interactions:** In these water is excluded by non-polar groups. These associate with each other so that they are not in contact with water. In globular proteins the side chains of the most hydrophobic amino acids(non-polar)aggregate inside the molecule, & the polar (charged) groups protrude from the surface of the tertiary structure. The hydrophobic residues repel the water molecules that surround the protein, thereby causing the globular structure to be more compact.
- 4) **Vander Waals interactions:** They occur only when two atoms come very close together. The closeness of two molecules can induce charge fluctuations which may produce dipoles & mutual attraction at very short range.

**Tertiary structure:**The overall three-dimensional shape of an entire protein molecule is the *tertiary structure*.

The protein molecule will bend and twist in such a way as to achieve maximum stability or lowest energy state. Although the three-dimensional shape of a protein may seem irregular and random, it is fashioned by many stabilizing forces due to bonding interactions between the side-chain groups of the amino acids.

Tertiary structures are stabilized by various weak molecular forces as well as by covalent linkages in the form of disulphide bonds or occasional iso-peptide bonds. These are peptide linkages formed between a side chain amino group & a side chain carboxyl group.

Some of the forces which determine tertiary structure are ionic bond, hydrogen bond, iso-peptide bond, hydrophobic interactions & disulphide bonds.



Source reference: [biochemiazunited.com](http://biochemiazunited.com) (catalyst authors)

**Quaternary Structure:** Many proteins are made up of multiple polypeptide chains, often referred to as *protein subunits*. These subunits may be the same or different & has its own tertiary structure.

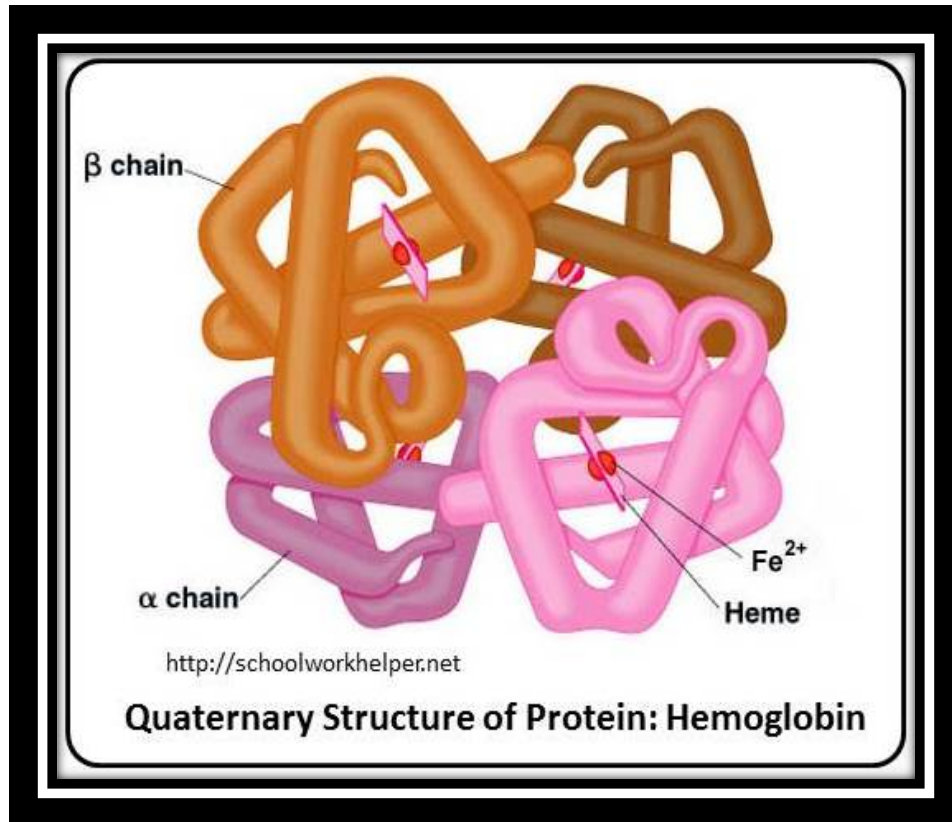
The *quaternary structure* refers to how these protein subunits interact with each other and arrange themselves to form a larger aggregate protein complex.

The final shape of the protein complex is once again stabilized by various interactions, including hydrogen-bonding, disulfide-bridges and salt bridges.

A protein is referred to have quaternary structure if it is composed of several polypeptide chains & are not covalently linked to one another. These chains may or may not be identical but in both cases they are linked by weak bonds.

Hemoglobin was the first protein for which a complete quaternary structure was determined.





**Source reference: biomolecules of cell proteins**

### **Stability of proteins & denaturation**

Due to the nature of the weak interactions controlling the three-dimensional structure, proteins are very sensitive molecules. The term native state is used to describe the protein in its most stable natural conformation.

This native state can be disrupted by a number of external stress factors including high temperature, pH, removal of water, alcohol, oxidation, agitation, presence of hydrophobic surfaces, presence of metal ions etc.

The loss of secondary, tertiary or quaternary structure due to exposure to a stress factor is called denaturation. Denaturation causes a protein to unfold & lose its shape.

Protein functions are mainly dependent on its shape; hence denatured proteins lose their ability to function properly. In addition to becoming denatured, proteins can also form aggregates under certain stress conditions.

In addition to the physical forms of protein degradation, it is also important to be aware of the possible pathways of protein chemical degradation. These include oxidation, deamidation, peptide-bond hydrolysis, disulfide-bond reshuffling and cross linking.

## 2) CLASSIFICATION OF PROTEINS

There are a number of ways of classifying protein.

### 1) Based on chemical composition& conformation

Proteins	Characteristics	Example or occurrence
<b>Globular</b>		
Albumins	Soluble in water, dilute salt solutions, dilute acids, & bases. Coagulated by heat	Lactalbumin, egg albumin, serum albumin
Globulins	Soluble in salt solutions, insoluble in water	Serum globulin, arachin&conarchin of peanuts, myosin.
Histones	Basic proteins. Soluble in most common solvents	Nucleoproteins
<b>Fibrous (Scleroproteins)</b>		
Collagens	Resistant to digestive enzymes; insoluble	Skin, tendons, bones
Elastins	Partially resistant to digestive enzymes	Arteries, tendons, elastic tissues
Keratin	Highly insoluble & resistant to digestive enzymes; high cysteine content	Skin, hair, nails

## Proteins are also classified as

(i) **Simple proteins:** which yield only amino acid on hydrolysis.

e.g., Protamine, Albumin, Globulins, etc.

(ii) **Conjugated proteins:** These are made up of simple proteins (apoprotein) & non protein substance known as prosthetic group. They yield not only amino acids but also other organic or inorganic compounds.

e.g., Nucleoproteins, Chromo protein, Glycoproteins, Phosphoproteins, Lipoproteins, and Metalloproteins, and

(iii) **Derived proteins:** These are formed from simple & conjugated proteins & are the degradation products obtained by the action of acids, alkalis or enzymes on proteins.

e.g., Denatured proteins, Metaproteins, Secondary proteoses, peptones, polypeptides, simple peptides and amino acids are the derived proteins.

## 2) Based on structure of amino acids

Proteins can be classified depending on the structure of amino acids. The side chains are the deciding factors for intra- and intermolecular interactions in proteins, and hence, for protein properties, amino acids can be classified as:

- Amino acids with nonpolar, uncharged side chains: e. g., glycine, alanine, valine, leucine, isoleucine, proline, phenylalanine, tryptophan and methionine.
- Amino acids with uncharged, polar side chains: e. g., serine, threonine, cysteine, tyrosine, asparagine and glutamine.
- Amino acids with positively charged (basic) side chains: e. g. histidine, lysine and arginine.
- Amino acids with negatively charged (acidic) side chains: aspartic acid, glutamic acid.

Amino acids can also be classified based on their **R** group or side group

- 1) Acidic amino acids – contains more carboxyl group than amino group  
(Aspartic acid, Glutamic acid)
- 2) Basic amino acids – contains more amino group than carboxyl group (Lysine, Glutamine, Histidine)
- 3) Neutral amino acids- equal number of amino & carboxyl group  
(Glycine, Alanine, Serine)
- 4) Aromatic amino acids-contains aromatic group (ring form)  
(Phenylalanine, Tyrosine, Tryptophan)
- 5) Sulphur containing amino acids- contains sulphur  
(Methionine, Cysteine)

### 3) Based on quality

Although both plant & animal foods contain protein, the quality of protein in these foods differs.

Proteins can be divided into 3 types depending on their quality as;

- **Complete proteins** – Foods that supply all the essential amino acids in the proportions the body needs are called complete proteins or high quality proteins.
- **Partially complete proteins-** Foods that partially lack in one or more essential amino acids are referred to as partially complete proteins
- **Incomplete proteins**–Foods that completely lack in one or more essential amino acids are called low quality proteins or incomplete proteins.

Higher quality protein produces a faster growth rate. Pattern & abundance of essential amino acids, relative amounts of non-essential amino acids, digestibility & presence of trypsin inhibitors affect the quality of proteins & in turn affect the growth rate.

### **Nutritional classification of proteins depending on the quality**

<b>Group</b>	<b>Limiting essential amino acids</b>	<b>Example</b>
Complete proteins	Nil	Animal foods- red meats, eggs, poultry, fish, milk & milk products
Partially complete proteins	Partially lack in one more essential amino acid	Wheat proteins
Incomplete proteins	Completely lack in or more essential amino acids	Plant foods – grains, legumes

### **Determination of protein quality**

Food proteins are composed of both essential & nonessential amino acids.

Quality of protein is affected by the amino acid content, amino acid imbalance, interference of non-available carbohydrates & trypsin inhibitors & influence of heating & processing.

There are different methods for evaluating quality of proteins such as chemical assays, biological assays, etc.

One of the methods of evaluating the quality of proteins is by experimentally determining the biological value (BV).

The BV measures the ability of a protein to support 'growth & maintenance'. The BV of a protein is defined as the percentage of the absorbed nitrogen ( $N \times 6.25 = \text{protein}$ ) retained in the body.

$$BV = \frac{N \text{ retained in the body}}{N \text{ absorbed}} \times 100$$

N absorbed

Protein quality is directly related to BV; higher the BV better will be protein nutritionally.

#### **4) Based on nutrition**

Based on their nutritional/physiological roles, amino acids can be differentiated as:

- **Essential amino acids:** They are the amino acids that cannot be synthesized in the body & therefore has to be supplied by foods.
- **Nonessential amino acids:** They are the amino acids that the body can synthesize if adequate amounts of nitrogen are available in the diet.
- **Conditionally essential amino acids:** Some of the nonessential amino acids may become conditionally essential if the body cannot make them because of illness or in certain circumstances where the body lacks the necessary precursors or enzymes to make them.

**Classified list of amino acids is as shown on the screen**

<b>Essential amino acids</b>	<b>Conditionally essential amino acids</b>	<b>Nonessential amino acids</b>
Histidine Isoleucine Leucine Methionine Lysine Phenylalanine Threonine Tryptophan Valine	Arginine Cysteine Glycine Glutamine Proline Tyrosine	Alanine Arginine Asparagine Aspartic acid Cysteine Glutamic acid Glutamine Serine Glycine Proline Tyrosine

## **5) Based on function**

On the functional basis, proteins can be classified according to their biological role as:

**Enzymes-** Hexokinase, Lactate dehydrogenase, DNA polymerase

**Contractile proteins-** myosin, actin, flagellar proteins.

**Storage proteins-** casein, ovalbumin, ferritin, zein

**Transport proteins**- Hemoglobin, myoglobin, serum albumin

**Protective proteins** – antibodies, thrombin, complement fibrinogen, ricin,

**Hormones**– insulin, growth hormone

**Structural proteins** – glycoproteins, collagen, elastin, fibroin

**Genetic proteins** – nucleoproteins, histones

### 3. Nature of food proteins

The formation of body tissue in a growing organism requires a never ending supply of amino acids, for building new tissues as well as for repairing the old worn out of the existing body tissues.

The protein obtained naturally in our diet includes both plant & animal sources. Proteins contribute to the structure, texture & taste of food. They are often added to foods to enhance these properties.

Example: Milk protein-casein is added to frozen dessert toppings. Gelatin is added to yogurt & fillings. Protein hydro lysates are added to many foods as thickeners, stabilizers, or flavor enhancers.

**Animal proteins:**Animal-derived proteins are easily digested and generally contain a mix of amino acids that is very similar to proteins found in human body (complete protein source).

They are used up more rapidly than plant proteins in our body &are considered to be more complete because they contain all essential amino acids which are needed by the body to function effectively.

Animal sources of protein include meat, milk, fish, eggs,poultry and dairy products.

**Plant proteins:**Plant sources of protein are not as easily digested and more than one source of plant protein is required in order to create an optimum amino acid profile or complete protein.

The storage proteins of cereals & pulses are the major sources of food protein. They are divided into 2 groups – the reserve proteins of seeds & the functional proteins of the vegetative parts of the plants (leaves, stalks & roots).

Plant protein foods include soy products such as soybeans, tofu, soy bean curd that are sources of high quality protein. Others foods are cereal grains, nuts, oilseeds, oats, millets, legumes (dried beans & peas).

One of the advantages of taking in plant protein is preventing the amount of unhealthy fatty acids often found in animal protein food source.

**4. Protein recommendations:** It's recommended that 10–35% of our daily calories should come from protein.

Recommended Dietary Allowances (RDA),2010 for different age groups is shown on the screen

<b>Recommended Dietary Allowances (RDA)</b>	
<b>Age group</b>	<b>Grams of proteins needed/day</b>
Children (1-3years)	17
Children (4-8years)	20
Children (9-13years)	40
Girls (14-18years)	50
Boys (14-18years)	54
Women (18+years)	55
Men (18+years)	60

## **5. Conclusion**

Proteins are complex organic compounds. The basic structure of protein is a chain of amino acids. They provide energy for the body.

Proteins are important component of every cell in the body. Hair and nails are mostly made of protein. Our body uses protein to build and repair tissues, to make enzymes, hormones, and other body chemicals.

They are made up of one or more polypeptide chains folded into a characteristic 3 dimensional configuration. The specific configuration of a protein is required for its biological activity.

Protein configuration is described in terms of four levels of organization; primary, secondary, tertiary & quaternary.



It is important to consider the amount, quality and balance of essential amino acids in the proteins that we ingest. The amount of protein required in the diet is inversely proportional to the amount of complete or complementary proteins that are ingested.