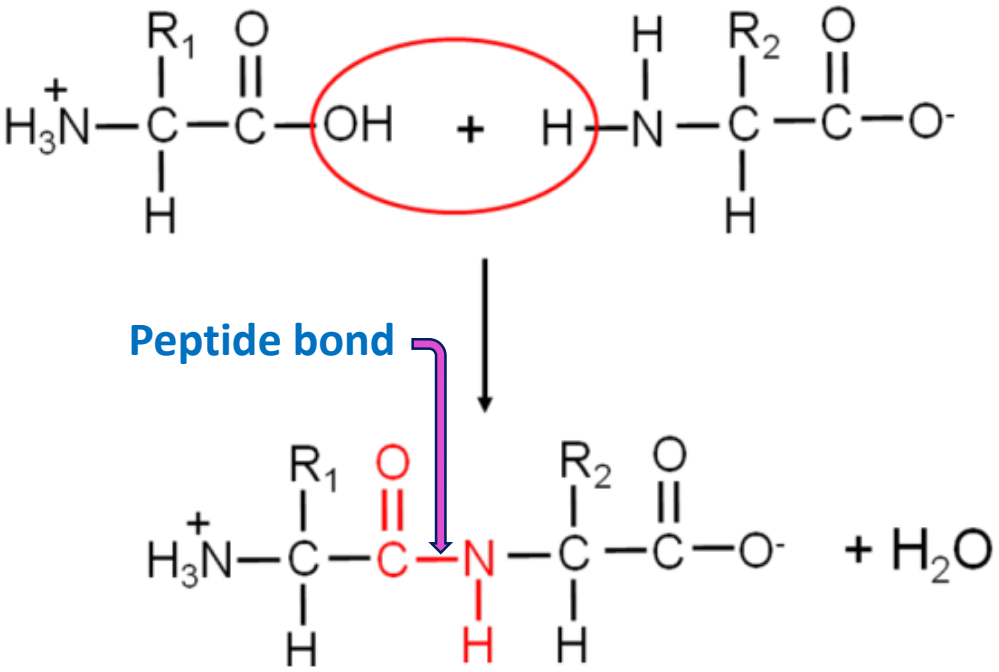
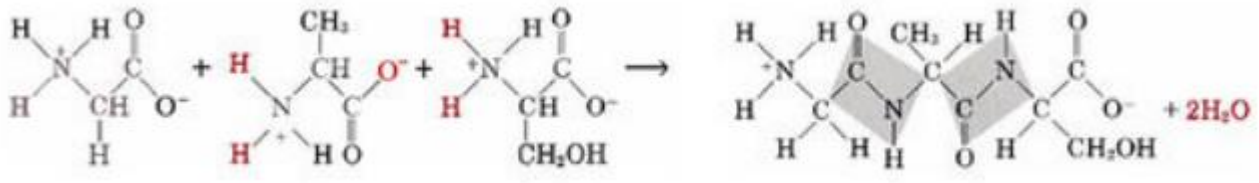
Proteins are made up of chains of these amino acids that are linked together by peptide bonds to form a polypeptide chain.

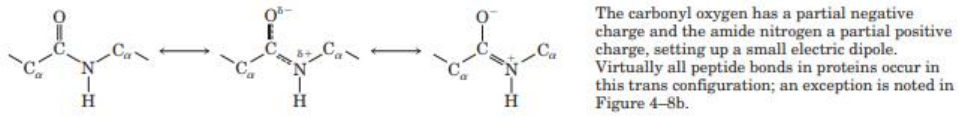
What is a peptide bond?

- The connection between two amino acids occurs through a peptide bond.
- The peptide bond is formed by the **condensation** of amino acids with the elimination of water.
- Proteins are called polypeptides because they contain many such peptide bonds.

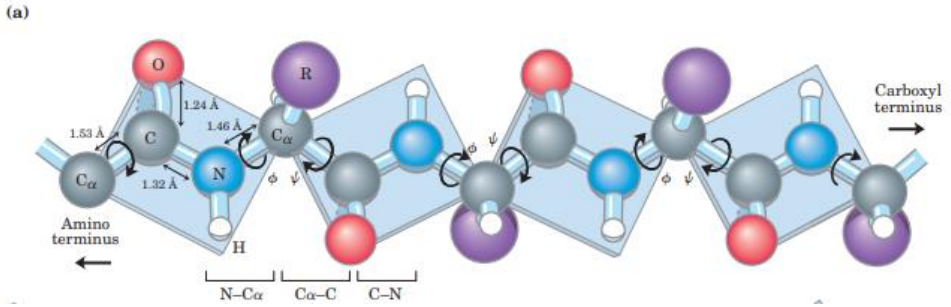


- The peptide bond has a partial double bond character because of the lone pair present on the Nitrogen atom of the peptide bond.

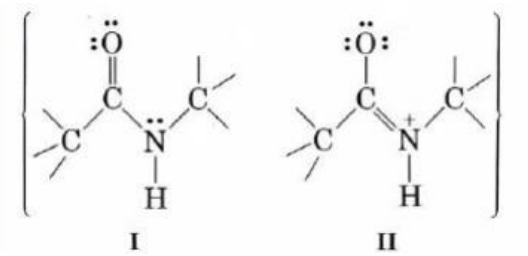




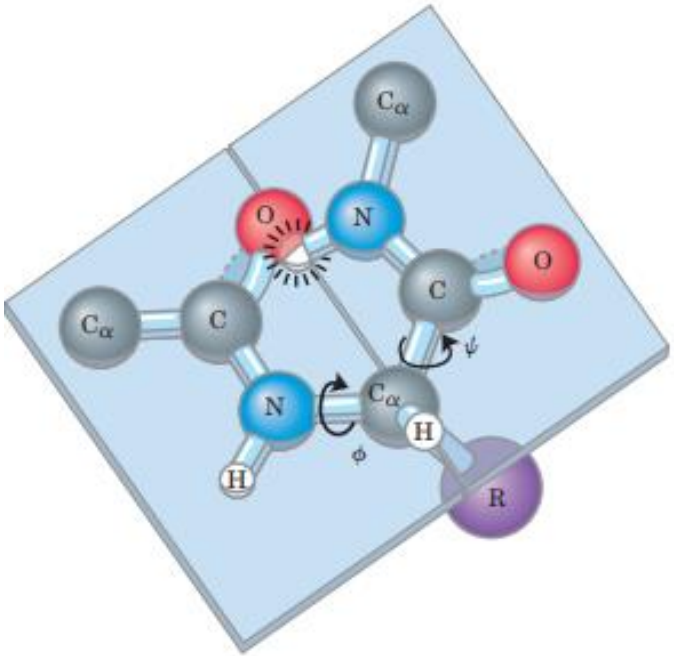
The carbonyl oxygen has a partial negative charge and the amide nitrogen a partial positive charge, setting up a small electric dipole. Virtually all peptide bonds in proteins occur in this trans configuration; an exception is noted in Figure 4–8b.



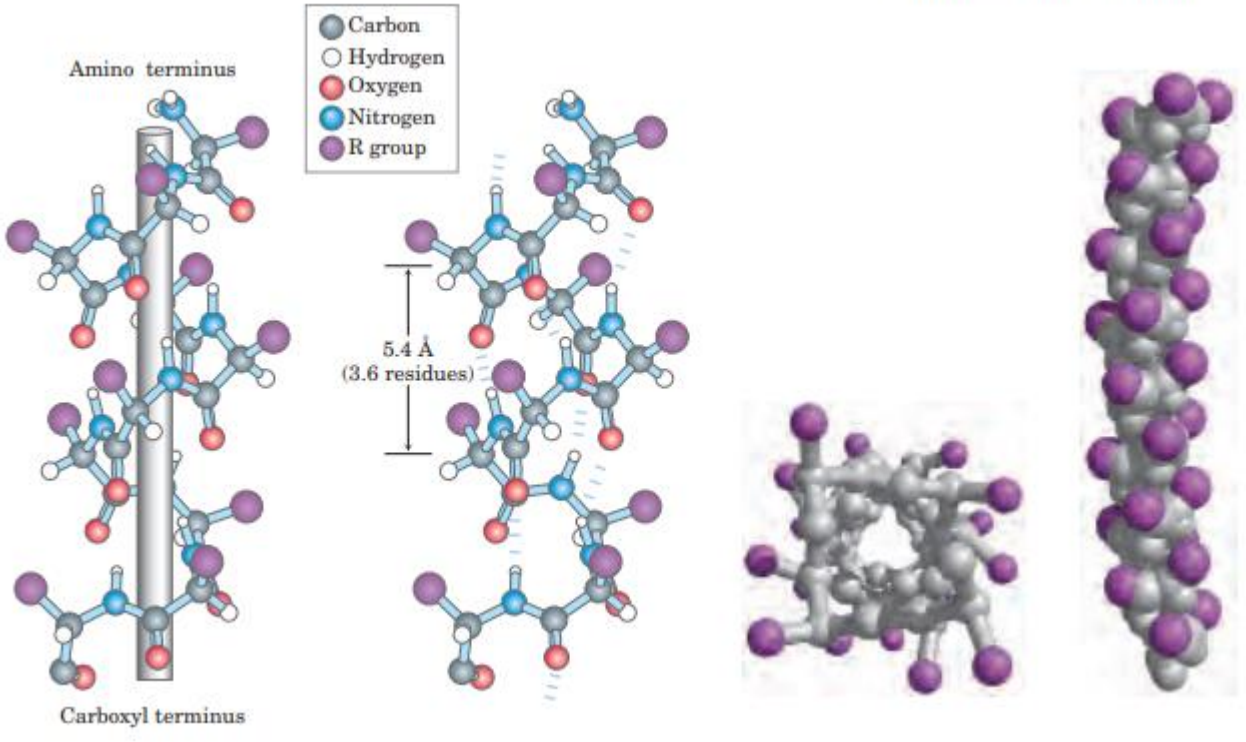
- In structure II there is a double bond between the carbon and the nitrogen atoms. This imparts a rigidity to this bond thus restricting its rotation because the bonds involving the C and N atoms must lie in the same plane. This renders a planar structure often referred to as the peptide plane



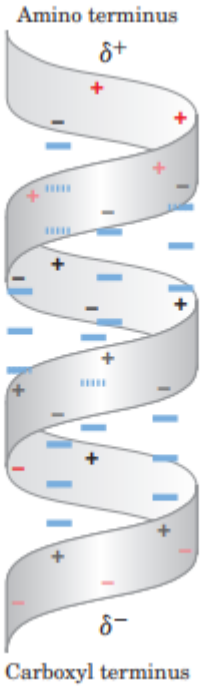
- There is a possibility of hydrogen bonding between the oxygen on the carbonyl group and the hydrogen on an NH_2 group that could be close to one another or even further along the chain



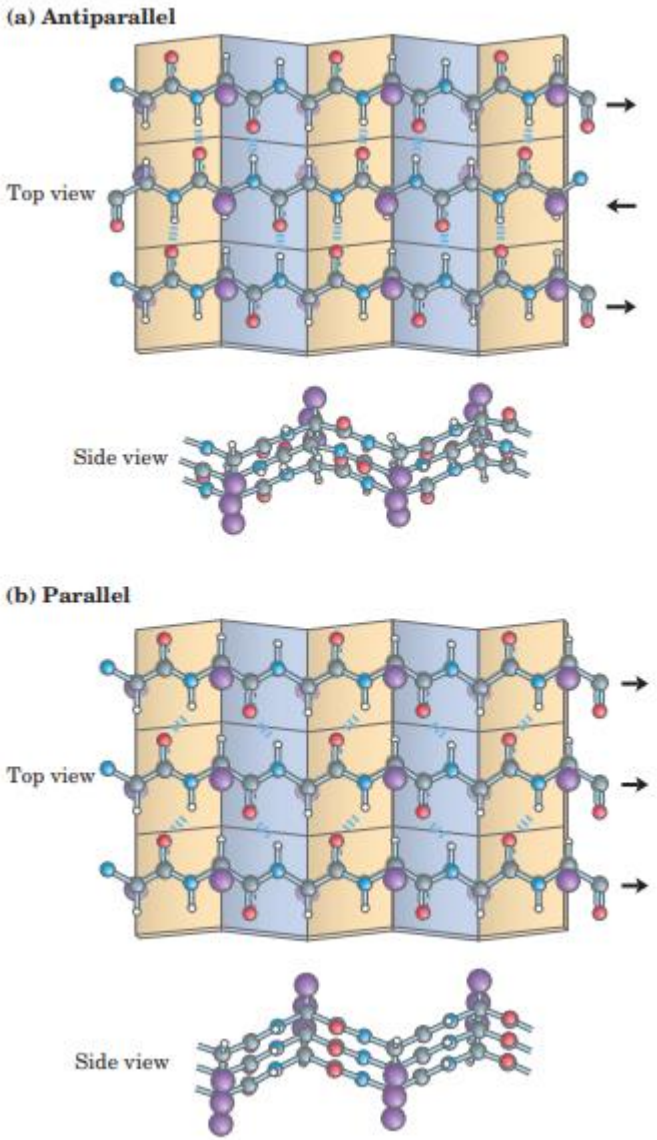
Thus the structure of the peptide bond exhibits a double bond character that leads to a coplanar nature.
rotation about the single bonds is feasible resulting in different conformational possibilities.
These are called the torsion angles and have definitions corresponding to the atoms considered in the formation of the dihedral angle.
These are:
phi (φ) torsion angle around N-C_α bond
psi (ψ) torsion angle around C_α-C bond



Four models of the helix, showing different aspects of its structure. (a) Formation of a right-handed α helix. The planes of the rigid peptide bonds are parallel to the long axis of the helix, depicted here as a vertical rod. (b) Ball-and-stick model of a right handed α helix, showing the intrachain hydrogen bonds. The repeat unit is a single turn of the helix, 3.6 residues. (c) The α helix as viewed from one end, looking down the longitudinal axis (derived from PDB ID 4TNC). Note the positions of the R groups, represented by purple spheres. This ball-and-stick model, used to emphasize the helical arrangement, gives the false impression that the helix is hollow, because the balls do not represent the van der Waals radii of the individual atoms. As the space-filling model (d) shows, the atoms in the center of the helix are in very close contact



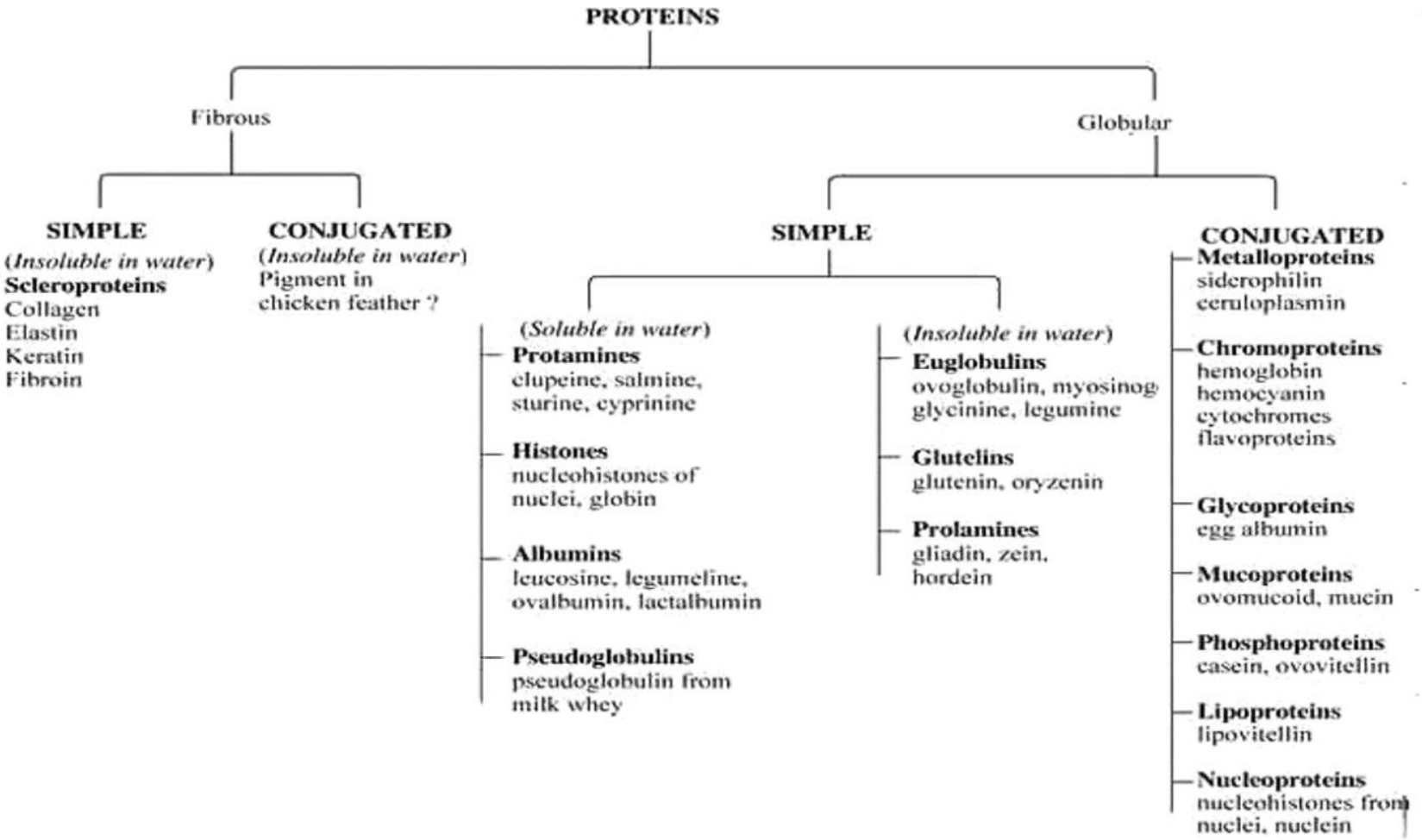
Helix dipole.



The β conformation of polypeptide chains

Classification based on biological function

Class of protein	*Function*	*Examples*
Enzyme proteins	Biological catalysts	Alcohol dehydrogenase. Cytochrome C, Urease, Amylase, Catalase,
Structural proteins	Strengthening or protecting biological structures	Collagen, Elastin, Keratin, Fibroin
Transport or carrier proteins	Transport of ions or molecules	Hemoglobin, Myoglobin
Nutrient and storage proteins	Provide nutrition to growing embryos and store ions	Ovalbumin, Casein, Ferritin
Contractile or motile proteins	Function in the contractile system	Actin, Myosin, Tubulin system
Defense proteins	Defend against other organisms	Antibodies, Fibrinogen, Thrombin
Regulatory proteins	Regulate cellular or metabolic activities	Insulin, G proteins, Growth hormone
Toxic proteins	Hydrolyze (or degrade) enzymes	Snake venom, Ricin.


PROTEINS
Fibrous
Globular
SIMPLE
(Insoluble in water)
Scleroproteins
Collagen
Elastin
Keratin
Fibroin
CONJUGATED
(Insoluble in water)
Pigment in
chicken feather ?
SIMPLE
(Soluble in water)
Protamines
clupeine, salmine,
sturine, cyprinine
Histones
nucleohistones of
nuclei, globin
Albumins
leucosine, legumeline,
ovalbumin, lactalbumin
Pseudoglobulins
pseudoglobulin from
milk whey
(Insoluble in water)
Euglobulins
ovoglobulin, myosinog
glycinine, legumine
Glutelins
glutenin, oryzenin
Prolamines
gliadin, zein,
hordein
CONJUGATED
Metalloproteins
siderophilin
ceruloplasmin
Chromoproteins
hemoglobin
hemocyanin
cytochromes
flavoproteins
Glycoproteins
egg albumin
Mucoproteins
ovomucoid, mucin
Phosphoproteins
casein, ovovitellin
Lipoproteins
lipovitellin
Nucleoproteins
nucleohistones from
nuclei, nuclein

Proteins

Proteins are macromolecules composed of amino acids linked together with peptide bonds

Classification based on the source of proteins

Animal proteins

- Derived from animal sources such as eggs, milk, meat and fish.
- Usually called ***higher-quality proteins*** because they contain adequate amounts of all the essential amino acids.

Plant proteins

- ***Lower-quality proteins*** since they have a low content (limiting amount) of one or more of the essential amino acids.
- The ***four most common limiting amino acids are methionine, lysine, threonine and tryptophan.***

Globular proteins

Conn and Stumpf (1976) have classified globular proteins into 9 groups

- Cytochrome C
- Blood proteins
- Serum albumin
- Glycoproteins
- Antibodies (= Immunoglobulins)
- Hemoglobin
- Hormones
- Enzymes
- Nutrient proteins

Fibrous or Fibrillar Proteins

- Axial ratios greater than 10 and, resemble long ribbons or fibres in shape.
- **Mainly of animal origin and are insoluble in all common solvents** (water, dilute acids, alkalis and salts and also in organic solvents).
- Mostly serve structural or protective role.
- It is a heterogeneous group and includes the proteins of connective tissues, bones, blood vessels, skin, hair, nails, horns, hoofs, wool and silk.
- Extremely strong and possess two important properties which are: (*a*) ***stretchable and later recoil to their original length.*** **(*b*) *They have a tendency to creep, i.e., if stretched for a long time, their basic length increases and equals the stretched length but, if the tension on the two ends of the fibril is relaxed, they creep to their shorter and shorter length.***
- A large scar, for example, creeps to a smaller size if there is no tension on the scar. On the contrary, if the scar is in a region of high tension, the scar becomes larger and larger as happens in the skin of a person gradually becoming obese.

Fibrous or Fibrillar Proteins

- **Collagens**
  - Mesenchymal origin
  - Major proteins of white connective tissues (tendons, cartilage) and bone.
  - More than half the total protein in mammalian body is collagen
  - Produce soluble gelatins upon by boiling in water, dilute acids or alkalis.
  - Contains high contents (12%) of hydroxyproline.
  - Poor in sulfur due to lack of cysteine and cystine.
- **Elastins**
  - Mesenchymal origin.
  - Major constituents of yellow elastic tissues (ligaments, blood vessels).
  - Differ from collagens in not being converted to soluble gelatins.
- **Keratins**
  - Ectodermal origin
  - Major constituents of epithelial tissues (skin, hair, feathers, horns, hoofs, nails)
  - Contain large amounts of sulfur in the form of cysteine– human hair has about 14% cysteine.
- **Fibroin**
  - Principal constituent of the fibres of silk
  - Composed mainly of glycine, alanine and serine units
  - Insoluble in water and organic solvent

Classification based on composition and solubility

The most accepted system of classification is based on the recommendations made by the committees of *British Physiological Society* (1907) and the *American Physiological Society* (1908). The system divides the proteins into 3 major groups based on their composition

- Simple Proteins or Holoproteins
- Conjugated or Complex Proteins or Heteroproteins.
- Derived Proteins.

Simple Proteins or Holoproteins

- Mostly globular (except scleroproteins is fibrous in nature).
- Only consist of amino acids as structural components.
- These are further classified mainly on their solubility basis as follows
  - **Protamines and Histones**
    - **Low molecular weight,** strongly basic (high contents of lysine, arginine) in nature, soluble in water, not coagulated by heat
    - Protamines are mainly found in sperm cells.
    - Histones are nucleoproteins found in chromosomes of all the eukaryotes

- **Albumins**
  - Widely distributed in nature specifically in seeds.
  - Soluble in water and dilute solutions of acids, bases and salts.
  - Coagulated by heat.
  - e.g., leucosine in cereals, legumeline in legumes, ovalbumin from white of egg, serum albumin from blood plasma, myosin of muscles and lactalbumin of milk whey.
- **Globulins**
  - Mainly of two types pseudoglobulins (water soluble) and euglobulins (water insoluble)
  - Euglobulins are widely distributed in nature
  - Include serum globulin from blood plasma, *ovoglobulin* from egg white; *myosinogen* from muscle; globulins of various plant seeds like hemp (*edestin*), soybeans (*glycinine*), peas (*legumine*), peach (*amandine*), oranges (*pomeline*); also potato (*tuberin*).
  - Lesser abundant in nature e.g., than the pseudoglobulins (water soluble); *e.g.,* pseudoglobulins of milk whey..

- **Glutelins**
  - Present in plant seeds.
  - Insoluble in water, dilute salt solutions and alcohol solutions but soluble in dilute acids and alkalis
  - Coagulated by heat *e.g., glutenin* from wheat, *glutelin* from corn, *oryzenin* from rice, etc.
- **Prolamins**
  - Only present in plant seeds
  - Insoluble in water and dilute salt solutions but soluble in dilute acids and alkalis and also in 60 – 80% alcohol solutions;
  - Not coagulated by heat *e.g.*, *gliadin* from wheat, *zein* from corn, *hordein* from oat etc.
- **Scleroproteins or Albuminoids**
  - Present only in animals and commonly known as the '*animal skeleton proteins*'.
  - Insoluble in water
  - *e.g.*, collagen of bones, *elastin* in ligaments, *keratin* in hair and *fibroin* of silk.

Conjugated or Complex Proteins or Heteroproteins

- Proteins linked with a separable non-protein portion called ***prosthetic group.***
- Prosthetic group may be either a metal or a organic compound.
- ***On decomposition with acids, these liberate the constituent amino acids as well as the prosthetic group.***
- Mostly of globular type except for the pigment in chicken feathers which is probably of fibrous nature.
- Conjugated proteins can be further classified on the basis of the type of prosthetic group present.
  - Metalloproteins,
  - Chromoproteins
  - Glycoproteins
  - Phosphoproteins
  - Lipoproteins
  - Nucleoproteins

(Instead of metalloproteins, chromoproteins etc., the terms metalloproteids, chromoproteids etc., are sometimes used.)

Conjugated Proteins

- **Metalloproteins**
  - Proteins linked with various metals such as iron, zinc, copper, calcium, selenium, magnesium and nickel.
  - Metal may bind weakly (cofactor) or tightly (prosthetic group) to the proteins
    - Iron containing protein (Hemoglobin, Myoglobin, cytochromes, ferritin etc)
    - Copper containing proteins (Ceruloplasmin, Oxidase enzymes)
    - Zn containing proteins (Carbonic anhydrase)
    - Mg containing proteins (Kinases and phosphatases)
- **Chromoproteins**
  - Proteins coupled with a colored pigment.
  - Such pigments have also been found in the enzymes like catalase, peroxidase and flavoenzymes.
  - Chlorophyll in the form of chloroplastin in leaf cells.
  - Other examples are *myoglobin, hemoglobin, hemocyanin, hemoerythrin, cytochromes, flavoproteins, catalase, etc.*

Conjugated Proteins

- **Glycoproteins and Mucoproteins**
  - Proteins containing carbohydrate as prosthetic group
  - Glycoproteins contain small amounts of carbohydrates (less than 4%)
  - Whereas mucoproteins contain comparatively higher amounts (more than 4%)
  - Glycoproteins— *egg albumin*, elastase, certain *serum globulins* and also certain *serum albumins*. Mucoproteins— *ovomucoid* from eggwhite, *mucin* from saliva and *Dioscorea* tubers, *osseomucoid* from bone and *tendomucoid* from tendon.
- **Phosphoproteins**
  - Proteins linked with phosphoric acid
  - Mostly acidic in nature. *e.g., casein* from milk and *ovovitellin* from egg yolk.
- **Lipoproteins**
  - Proteins forming complexes with lipids (cephalin, lecithin, cholesterol)
  - soluble in water but insoluble in organic solvents.
  - *Examples are lipovitellin* and *lipovitellenin* from egg yolk; lipoproteins of blood such as VLDL, IDL, LDL, HDL etc.
- **Nucleoproteins**
  - Proteins associated with nucleic acid, i.e., protamines and histones.

Derived Proteins

- Derivatives of proteins resulting from the action of heat, enzymes or chemical reagents.
- This group also includes the artificially-produced polypeptides.

Primary derived proteins.

- Protein derivatives in which the size of protein molecules is not altered materially.
- **Proteans**
  - Insoluble in water
  - Appear as the first product produced by the action of acids, enzymes or water on proteins. *e.g., edestan* derived from edestin and *myosan* derived from myosin.
- **Metaproteins or Infraproteins**
  - Insoluble in water but soluble in dilute acids or alkalis.
  - Produced by further action of acid or alkali on proteins at about 30–60°C. *e.g., acid* and *alkali metaproteins.*
- **Coagulated Proteins**
  - Insoluble in water produced by the action of heat or alcohol on proteins. e.g., *coagulated egg white.*

Derived Proteins

Secondary derived proteins.

- Hydrolytic products of proteins.
- Smaller than the original proteins.
- **Proteoses**
  - Soluble in water
  - Coagulable by heat
  - Produced when hydrolysis proceeds beyond the level of metaproteins *e.g.*, *albumose* from albumin; *globulose* from globulin.
- **Peptones**
  - Soluble in water
  - Noncoagulable by heat
  - Produced by the action of dilute acids or enzymes when hydrolysis proceeds beyond proteoses.
- **Peptides**
  - These are the combinations of two or more amino acid units.