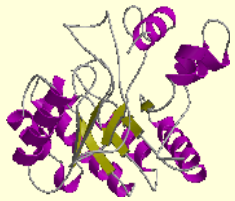

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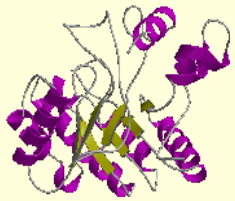
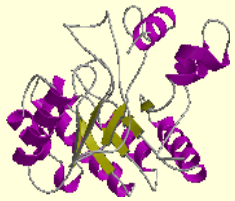


1. Introduction

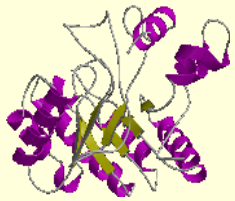
- Proteins (1839)
  - Protos or proteios (Greek)
  - First or primary
- Biologica functions
  - Enzyme catalysts
  - Structural proteins
  - Contractile proteins (actin, myosin)
  - Hormones (insulin, growth hormone)
  - Transfer proteins (serum albumin, transferrin, hemoglobin)
  - Antibiotics (immunoglobins)
  - Storage proteins as sources of N and amino acids for germinating seed s and embryos (egg albumin, seed proteins)
  - Protective proteins as a part of defense mechanism for the survival of certain microorganisms and animals (toxins, allergens)



1. Introduction

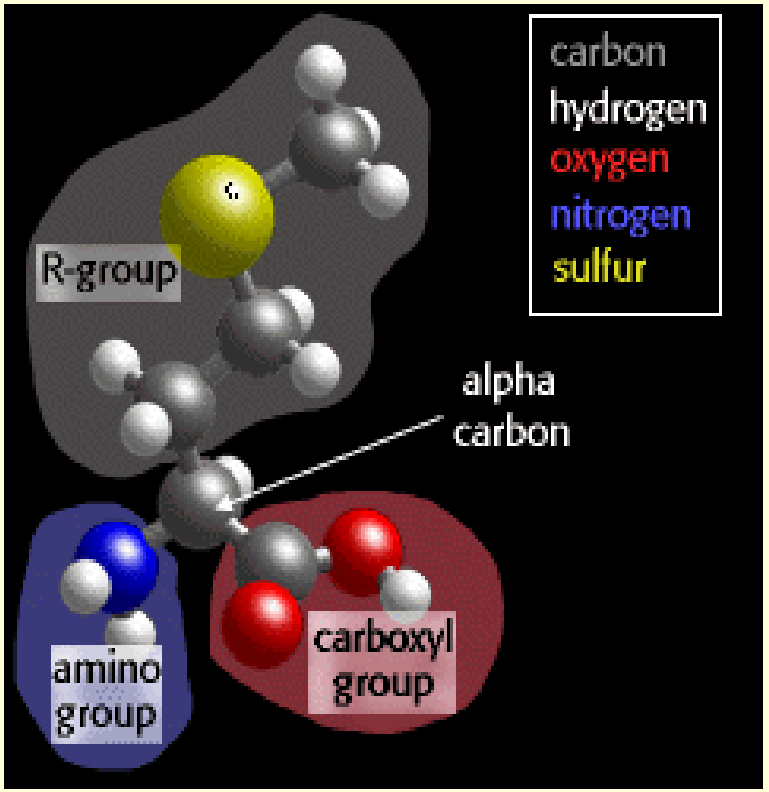
Food Proteins

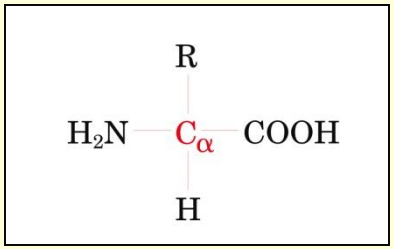
Product	Protein (g/100 g)
Meat: beef pork	16.5 10.2
Chicken (light meat)	23.4
Fish: haddock cod	18.3 17.6
Milk	3.6
Egg	12.9
Wheat	13.3
Bread	8.7
Soybean: dry, raw cooked	34.1 11.0
Peas	6.3
Beans: dry, raw cooked	22.3 7.8
Rice: white, raw cooked	6.7 2.0
Cassava	1.6
Potato	2.0
Corn	10.0

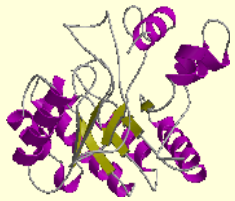


2. Physicochemical Properties of Amino Acids

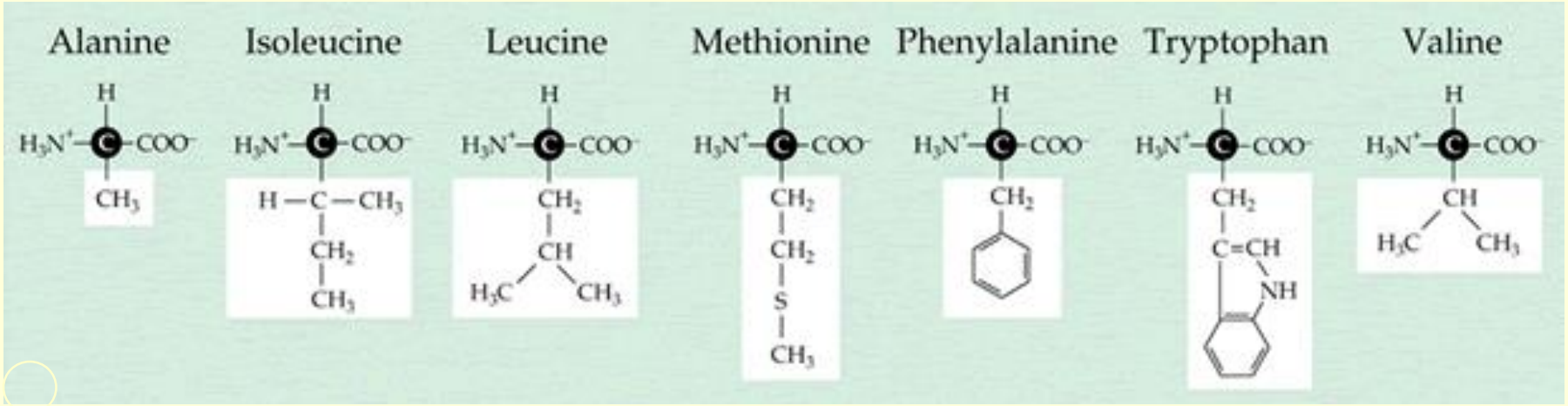
- 20 amino acids
- 1 – 10 : oligopeptide
  - or peptides
  - di, tri, …peptide
- 10 – 50 : polypeptide
- > 50 : protein (> 5000 D)
- On the basis of the degree of interaction of the side chains with water :
  - Non-polar (hydrophobic) residues
  - Polar (hydrophilic) residues
    - Charged
      - Positive or basic
      - Negative or acidic
    - Uncharged (neutral)

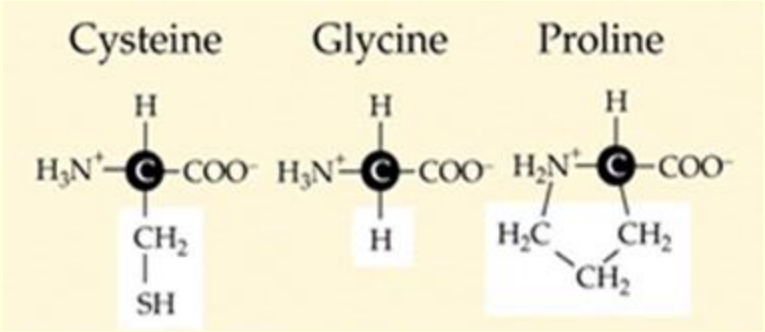




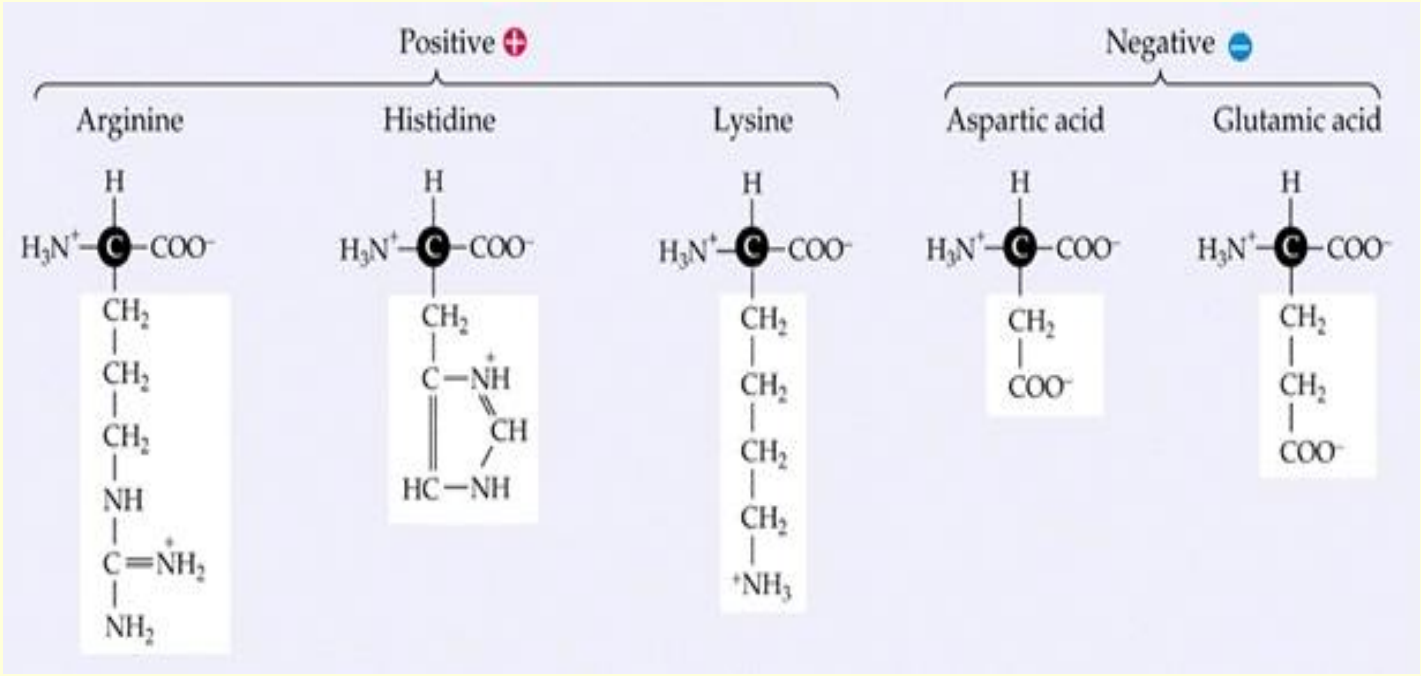


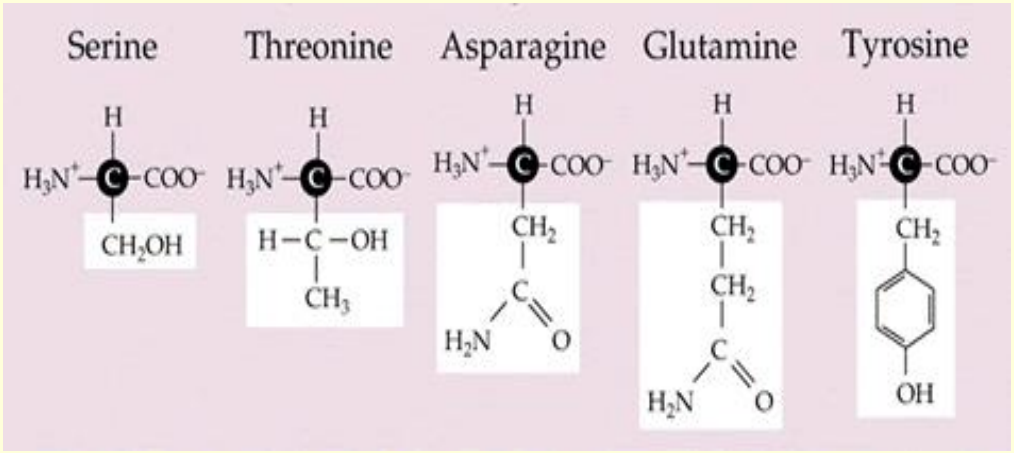
2. Physicochemical Properties of Amino Acids



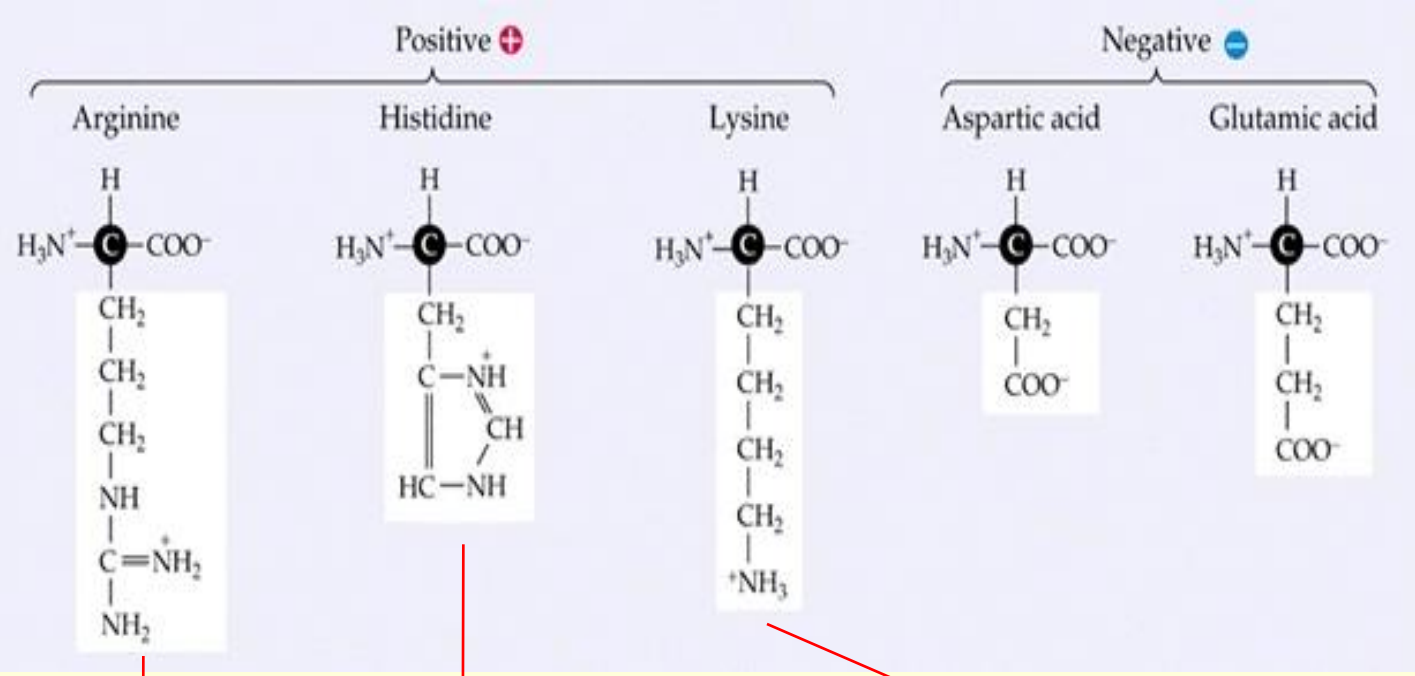


2. Physicochemical Properties of Amino Acids





2. Physicochemical Properties of Amino Acids



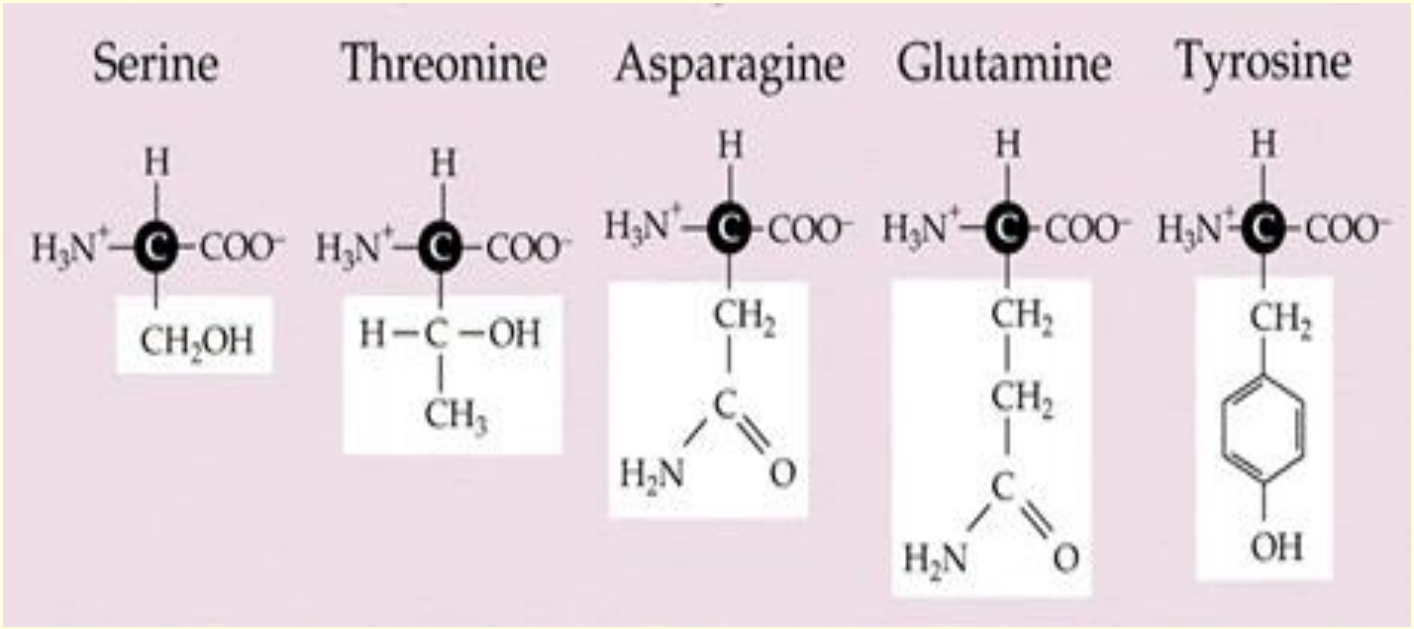
Guanidino group
Guanidinium ion

Imidazole ring (Im)
Imidazolium on (ImH+)

ε-amino group
Ammonium ion

Albumin and globulin
Gliadin and glutenin

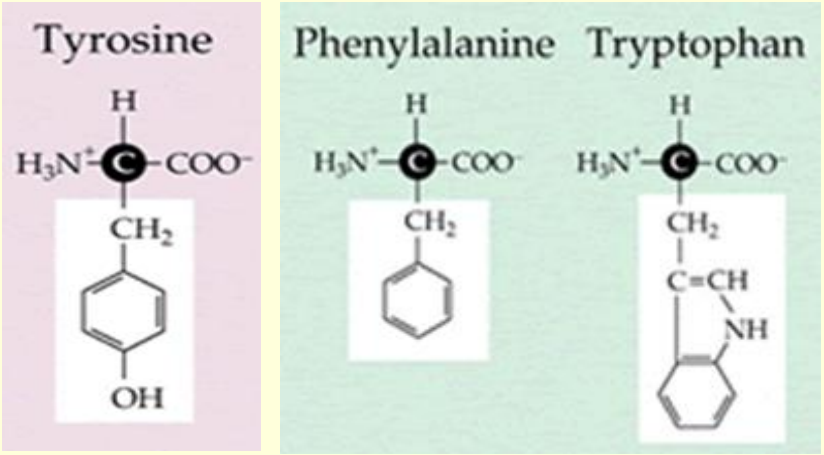
2. Physicochemical Properties of Amino Acids



Hydroxylated amino acids

Nontitratable amide group
β-amide aspartic acid
γ-amide glutamic acid

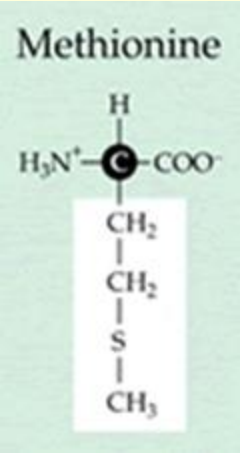
p-hydroxy phenylalanine

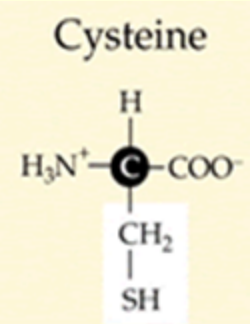


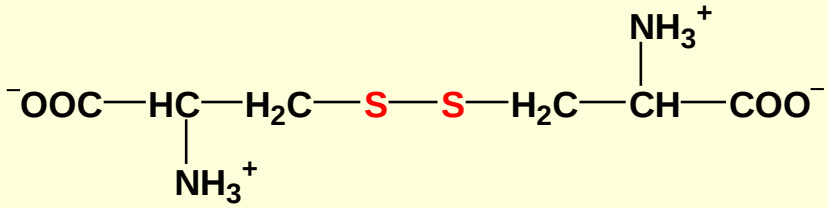
Aromatic amino acids :

Trp & Tyr : λ_m = 275 – 280 nm
Phe : λ_m = 260 nm

2. Physicochemical Properties of Amino Acids



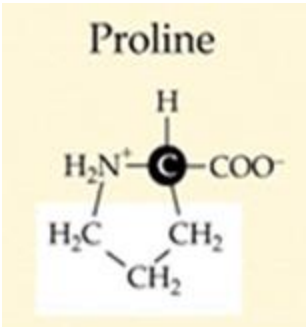




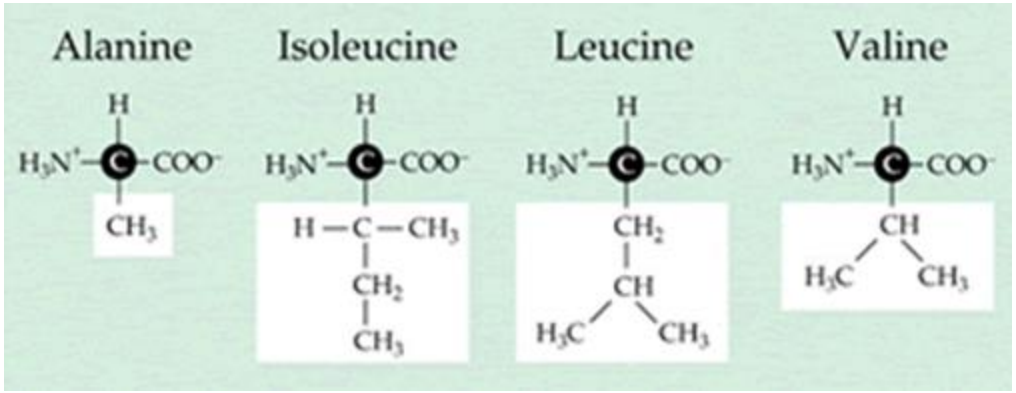
Sulfur-containing amino acids :

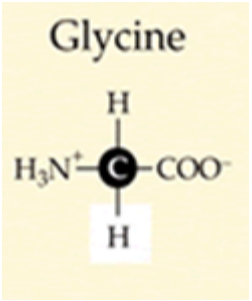
Met : methyl thioester group
Sys : Cystine (disulfide bond)

2. Physicochemical Properties of Amino Acids



Imino acid
Pyrrolidine ring





Gly : Glycocol

TABLE 1 Primary α-Amino Acids That Occur in Proteins

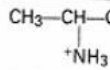
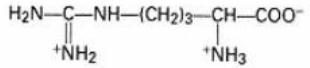
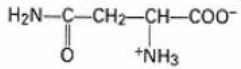
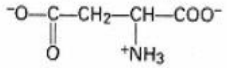
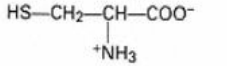
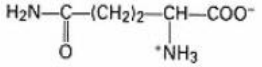
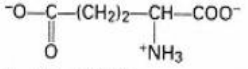
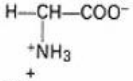
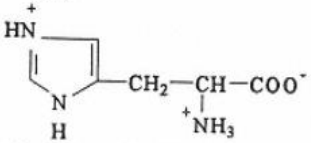
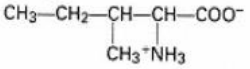
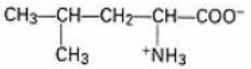
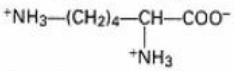
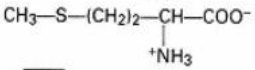
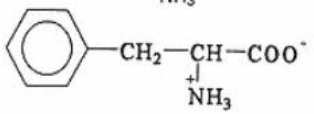
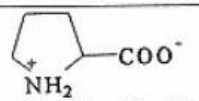
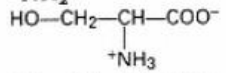
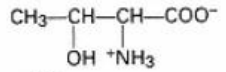
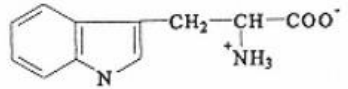
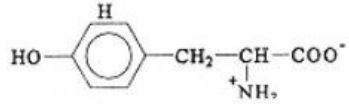
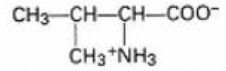
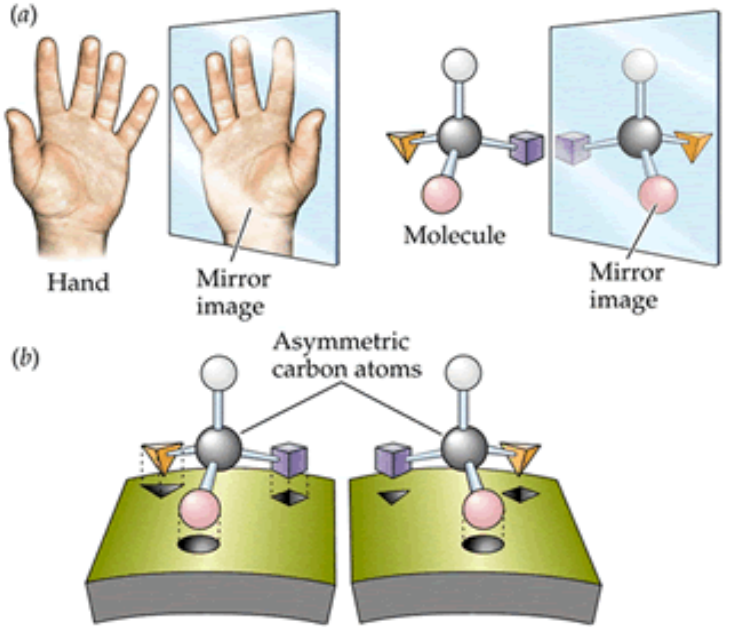
Amino acid					
	Symbol				
Name	Three letters	One letter	Molecular weight	Genetic code	Structure at neutral pH
Alanine	Ala	A	89.1	GC(N)	
Arginine	Arg	R	174.2	AGA AGG CG(N)	
Asparagine	Asn	N	132.1	AAU AAC	
Aspartic acid	Asp	D	133.1	GAU GAC	
Cysteine	Cys	C	121.1	UGU UGC	
Glutamine	Glu	Q	146.1	CAA CAG	
Glutamic acid	Glu	E	147.1	GAA GAG	
Glycine	Gly	G	75.1	GG(N)	
Histidine	His	H	155.2	CAU CAC	
Isoleucine	Ile	I	131.2	AUU AUC AUA	
Leucine	Leu	L	131.2	UUA UUG CU(N)	
Lysine	Lys	K	146.2	AAA AAG	
Methionine	Met	M	149.2	AUG	
Phenylalanine	Phe	F	165.2	UUU UUC	

TABLE 1 Continued

Amino acid					
Name	Symbol				
	Three letters	One letter	Molecular weight	Genetic code	Structure at neutral pH
Proline	Pro	P	115.1	CC(N)	
Serine	Ser	S	105.1	AGU AGC	
Threonine	Thr	T	119.1	AC(N)	
Trytophan	Trp	W	204.2	UGG	
Tyrosine	Tyr	Y	181.2	AUA UAC	
Valine	Val	V	117.1	GU(N)	

2. Physicochemical Properties of Amino Acids

- Gly
- Thr, Ile (D, D-allo, L, L-allo)
- Essential (8)
- Nonessential (8) : Val, Leu, Ile, Thr, Met, lys, Phe, Trp
- Semiessential
- Perfect protein
- Imperfect protein (limiting amino acid)
- Active site : His, Ser, Thr, Tyr, Cys
- Acid-base properties



Dipolar ion or zwitterion

Glycine

Isoelectric point

pI = (pK$_{a1}$ + pK$_{a2}$) / 2

Acidic amino acids

pI = (pK$_{a1}$ + pK$_{a2}$) / 2

Basic amino acids

pI = (pK$_{a2}$ + pK$_{a3}$) / 2

Henderson-Hasselbach equation

$$pH = pK_a + \log \frac{[\text{conjugated base or proton acceptor}]}{[\text{conjugared acid or proton donor}]}$$

$pK_1 = 2.34$

$pK_2 = 9.60$

$pI = 5.97$

[NH$_3^+$] > [NH$_2$] **[NH$_3^+$] < [NH$_2$]**

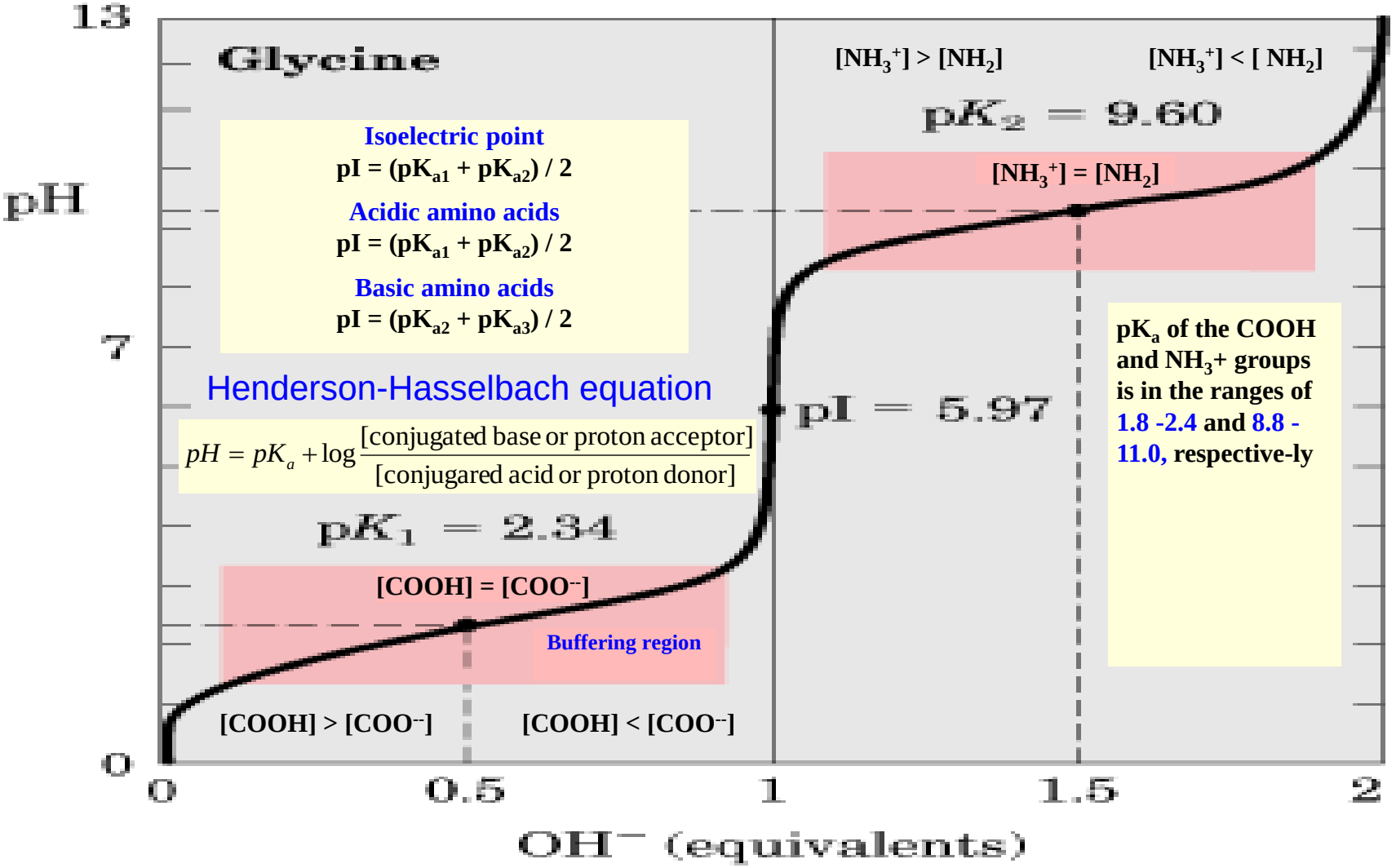
[NH$_3^+$] = [NH$_2$]

[COOH] = [COO$^-$]

Buffering region

[COOH] > [COO$^-$] **[COOH] < [COO$^-$]**

pK$_a$ of the COOH and NH$_3$+ groups is in the ranges of 1.8 -2.4 and 8.8 - 11.0, respective-ly

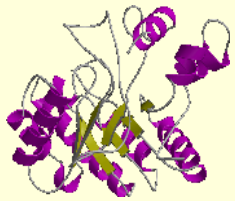


pK_a and pI values of ionizable groups in free amino acids and proteins at 25°C

Amino acid	pK_{a1} (α-COOH)	pK_{a2} α-NH_3^+	pK_{aR} AA	pK_{aR} Residue (different chemical environment)	pI
Ala	2.34	9.69	-		6.00
Arg	2.17	9.04	12.48	➢12.00	10.76
Asn	2.02	8.80	-		5.41
Asp	1.88	9.60	3.65	4.60	2.77
Cys	1.96	10.28	8.18	8.80	5.07
Gln	2.17	9.13	-		5.65
Glu	2.19	9.67	4.25	4.60	3.22
Gly	2.34	9.60			5.98
His	1.82	9.17	6.00	7.00	7.59
Ile	2.36	9.68	-		6.02
Leu	2.30	9.60	-		5.98
Lys	2.18	8.95	10.53	10.20	9.74
Met	2.28	9.21	-		5.74
Phe	1.83	9.13	-		5.48
Pro	1.94	10.60	-		6.30
Ser	2.20	9.15	-		5.68
Thr	2.21	9.15	-		5.68
Trp	2.38	9.39	-		5.89
Tyr	2.20	9.11	10.07	9.60	5.66
Val	2.32	9.62	-		5.96

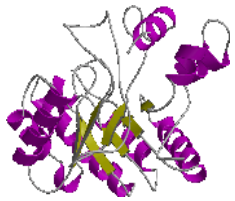
TABLE 2 Solubilities of Amino Acids in Water at 25°C

Amino acid	Solubility (g/L)	Amino acid	Solubility (g/L)
Alanine	167.2	Leucine	21.7
Arginine	855.6	Lysine	739.0
Asparagine	28.5	Methionine	56.2
Aspartic acid	5.0	Phenylalanine	27.6
Cysteine	—	Proline	1620.0
Glutamine	7.2 (37°C)	Serine	422.0
Glutamic acid	8.5	Threonine	13.2
Glycine	249.9	Tryptophan	13.6
Histidine	—	Tyrosine	0.4
Isoleucine	34.5	Valine	58.1



3. Protein Structure

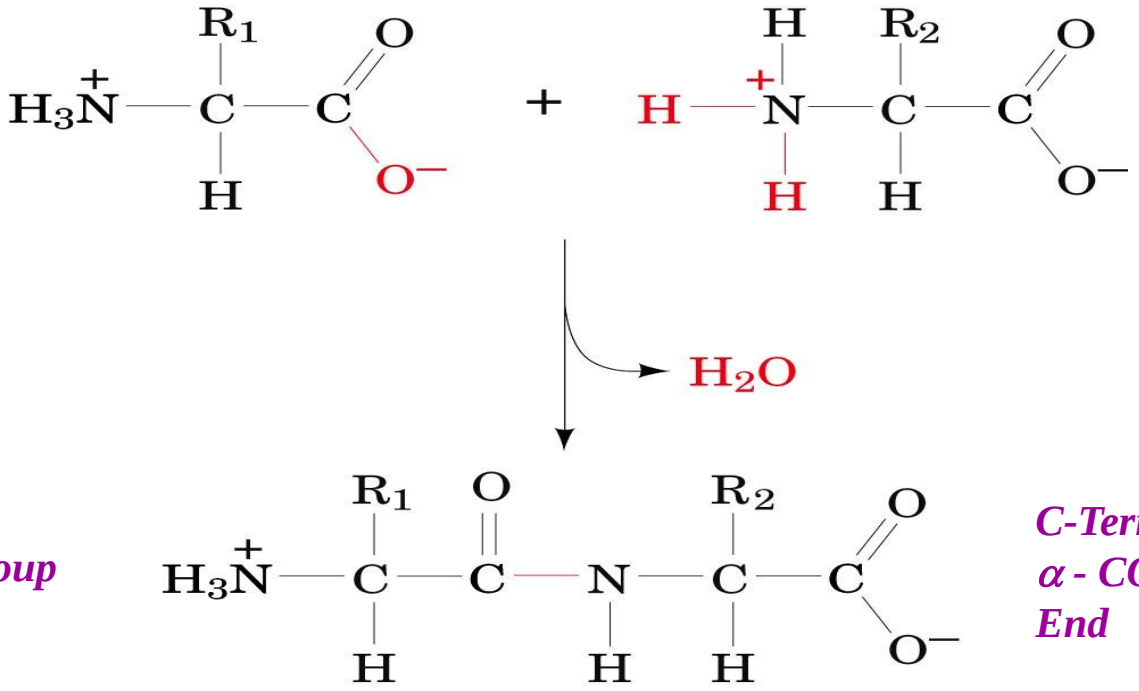
- Structural Hierarchy (Structure Levels) in Proteins
  - Primary
  - Secondary
  - Tertiary
  - Quaternary



3. Protein Structure

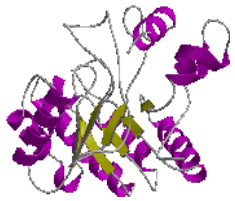
Primary structure

- The linear sequence in which the constituent amino acids are covalently linked through amide or peptide bonds.

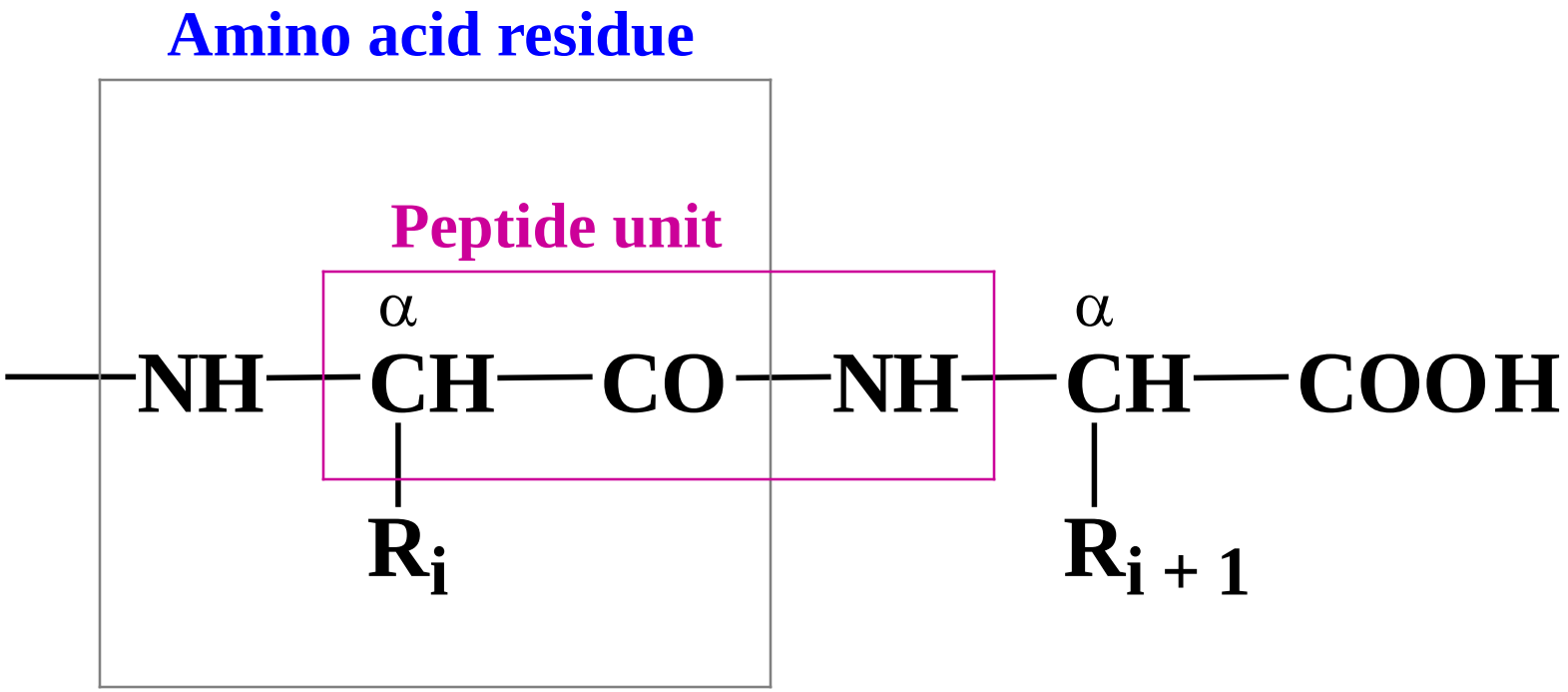


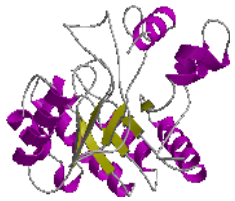
N-Terminal
α -Amino group
Beginning

C-Terminal
α - COOH group
End

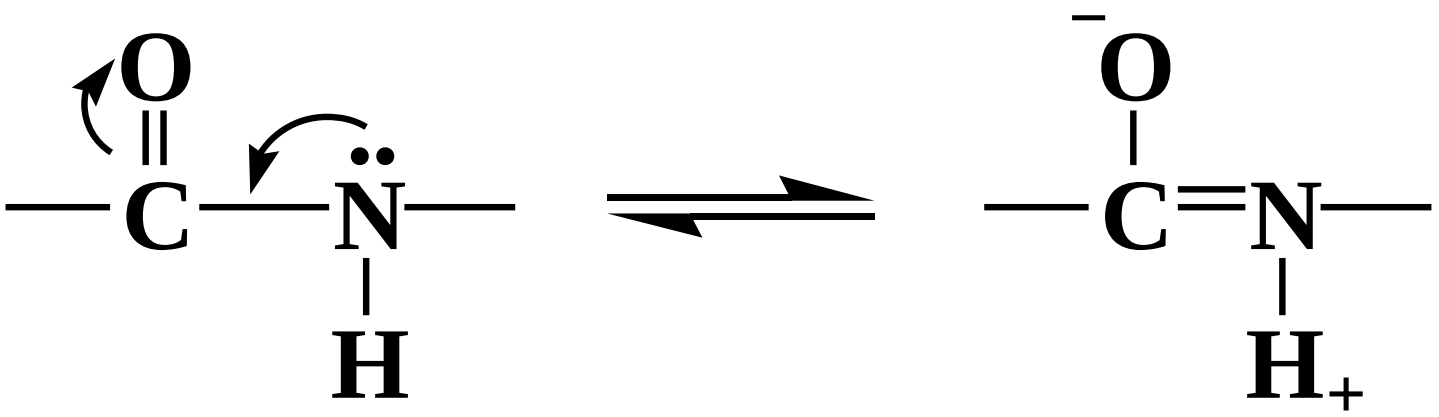


3. Protein Structure

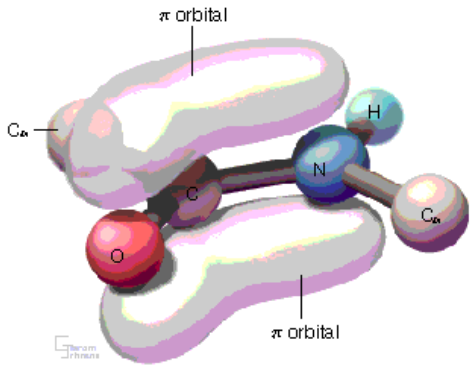




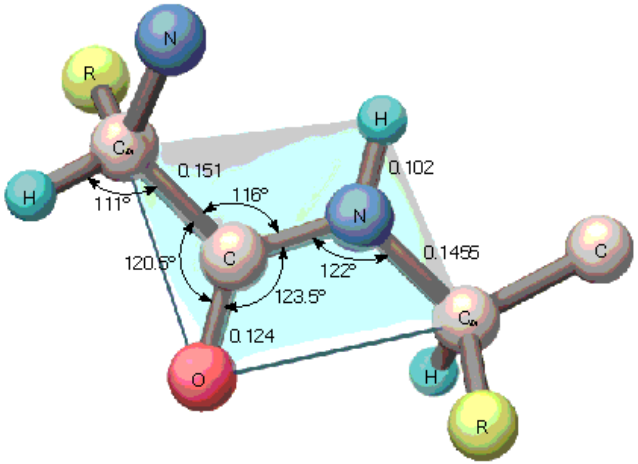
3. Protein Structure



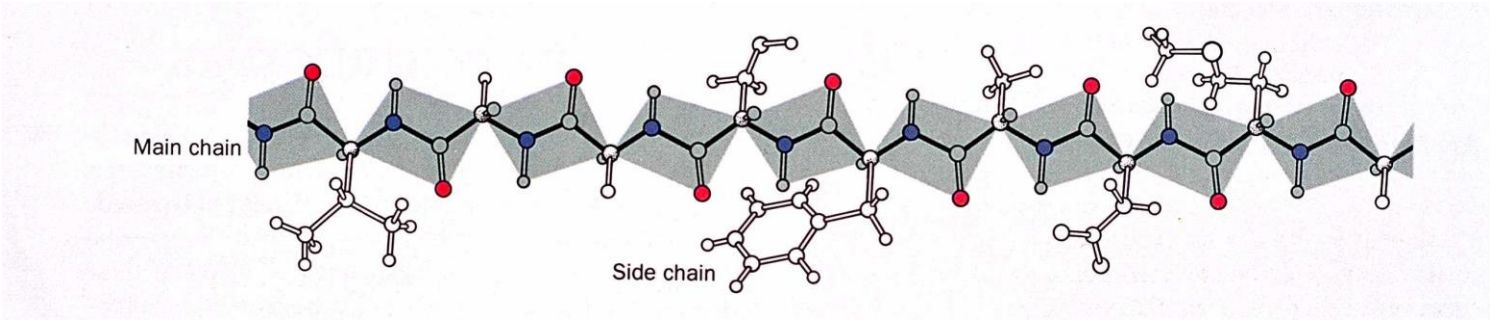
Structure of the peptide bond



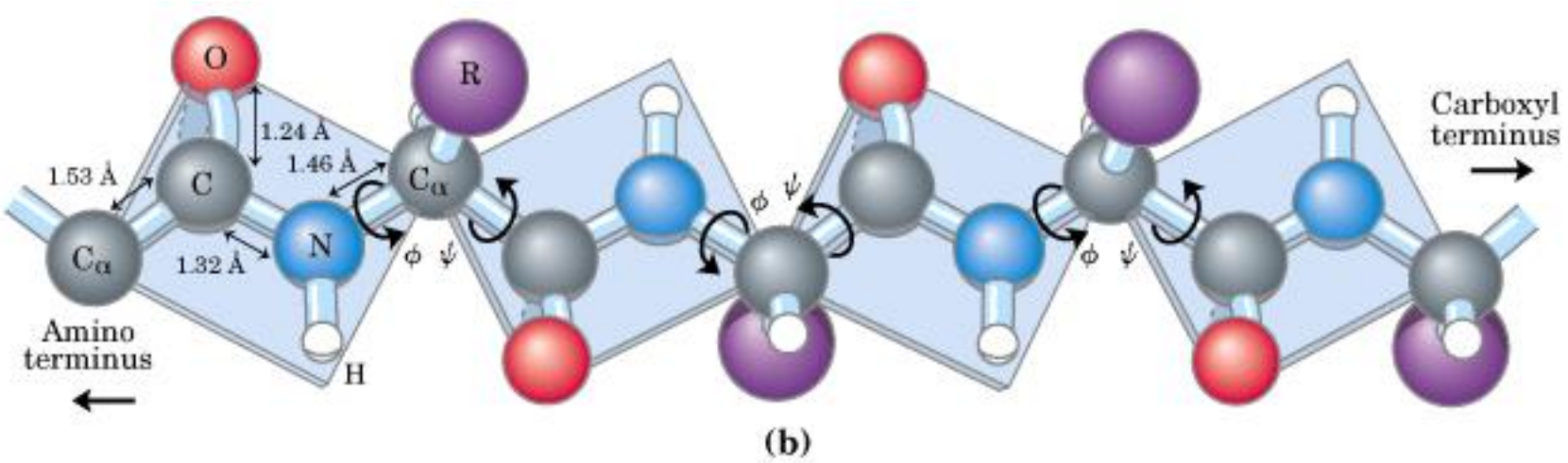
(a) Partial double-bond character of peptide bond



(b) Bond angles and lengths

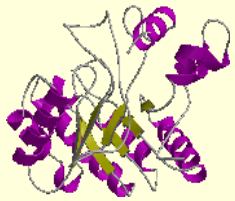


Angles of fully extended peptide



phi (ϕ) : *dihedral angle about the N-C_α bond*
psi (Ψ) : *dihedral angle about the C_α-C bond*
omega (ω) : *dihedral angle about the C-N (peptide) bond*

Main-chain torsion angles : ϕ and Ψ
Rotation is allowed only on both sided of the α-carbons.



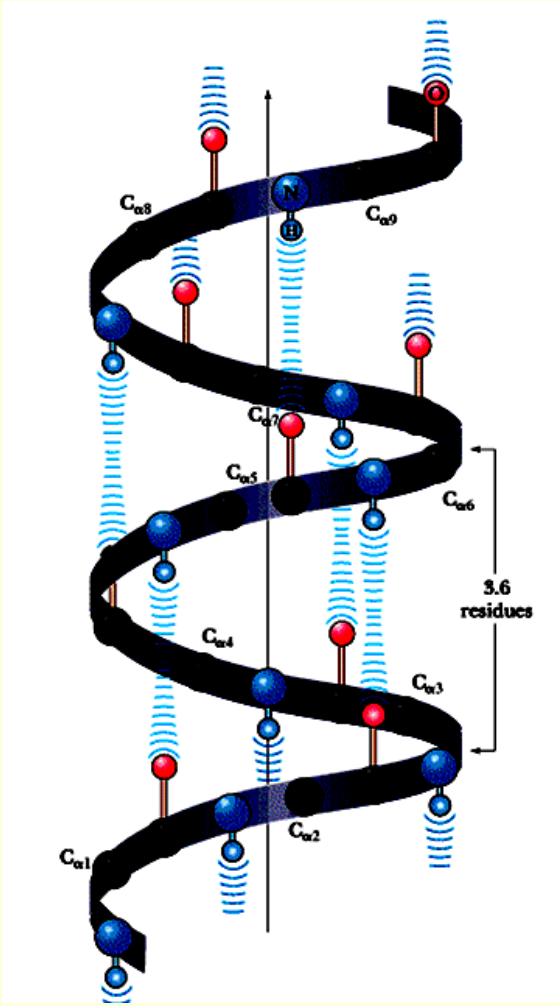
3. Protein Structure

Secondary structure

- The periodic spatial arrangement of amino acid residues at certain segments of the polypeptide chain.
- In general, two forms of periodic (regular) secondary structures are found in proteins :
  - α-helix structure (3.6_{13}-helix)
  - β-pleated sheet structure

α - Helix

- Carbonyl oxygen of the i^{th} residue forms H-bond with amide proton of the $(i+4)^{th}$ residue.
- 13 backbone atoms are in this hydrogen-bonded loop (3.6_{13}-helix, 3.6: residues per turn or pitch).



α - Helix

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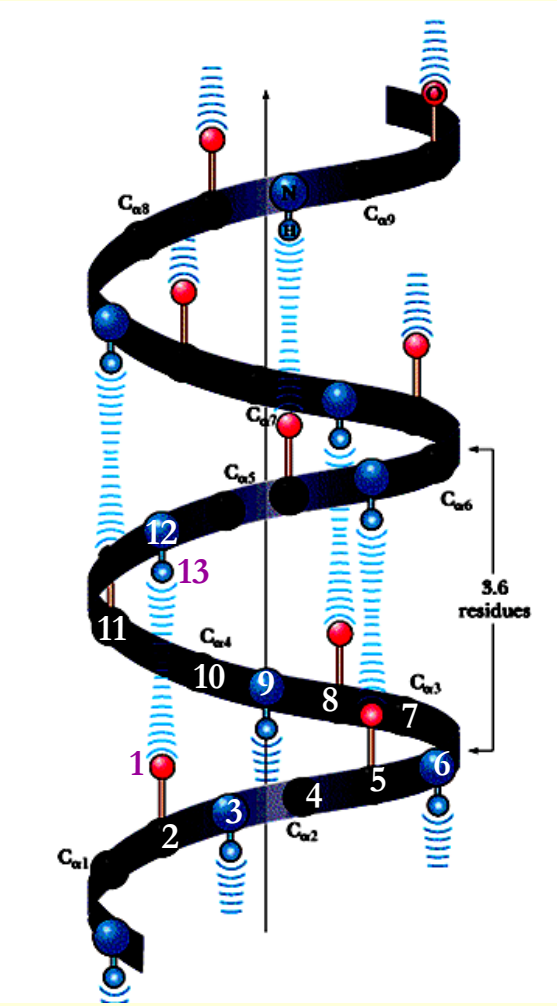
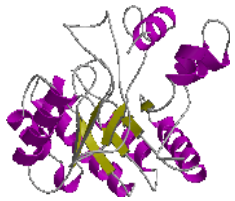
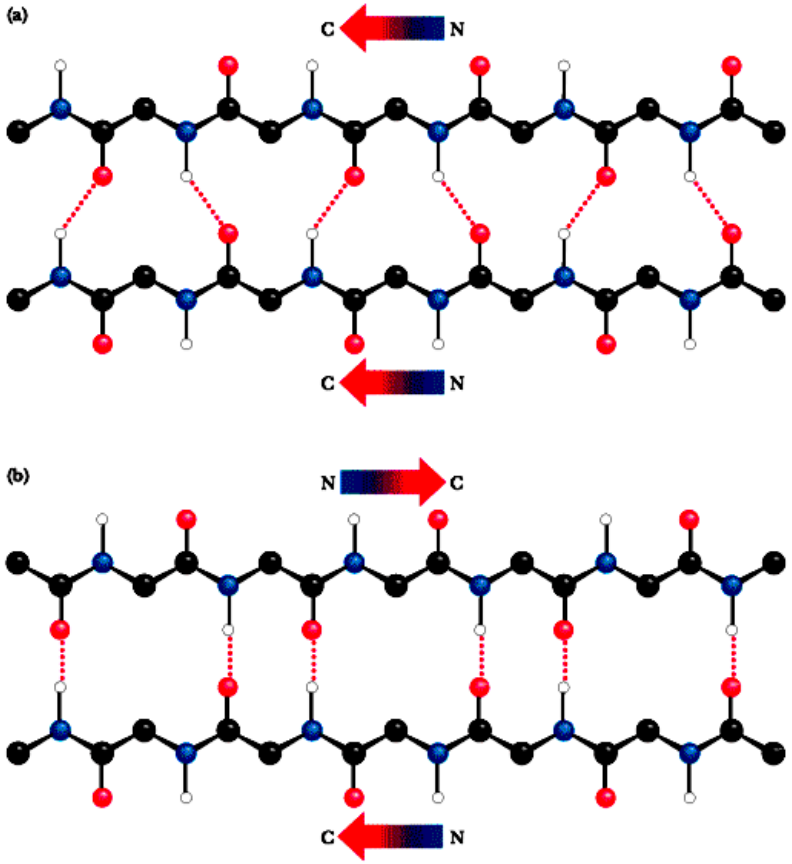


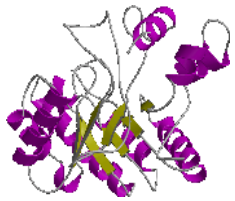


3. Protein Structure

β - Pleated Sheet

- An extended structure comprising β-strands.
- Depending on the N→C directional orientations of the strands:
  - Parallel β-strands (0.325 nm between two residues)
  - Antiparallel β-strands (0.347 nm between two residues)





3. Protein Structure

β - Pleated Sheet

- Because of the tetrahedral nature of the alpha carbon and the planarity of the peptide bond, the extended structure appears pleated (β-pleated sheet).
- R groups are perpendicular to the peptide backbone plane (sheet), and alternate from face to face.

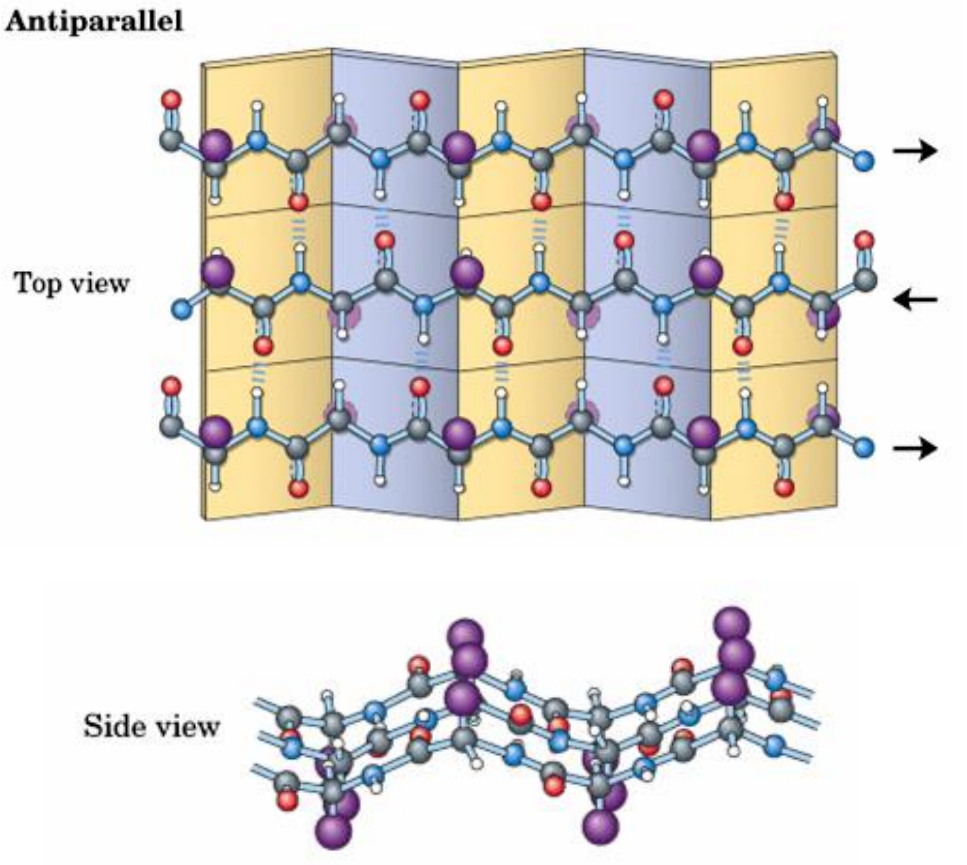
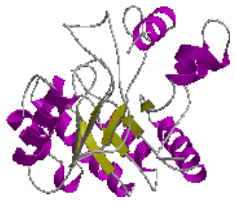


Table 8 Secondary Structure Content of Selected Proteins

Protein	α-Helix (%)	β-Sheet (%)	β-Turns (%)	Aperiodic (%)
Deoxyhemoglobin	85.7	0	8.8	5.5
Bovine serum albumin	67.0	0	0	33.0
Chymotrypsinogen	11.0	49.4	21.2	18.4
Immunoglobulin G	2.5	67.2	17.8	12.5
Insulin (dimer)	60.8	14.7	10.8	15.7
Bovine trypsin inhibitor	25.9	44.8	8.8	20.5
Ribonuclease A	22.6	46.0	18.5	12.9
Lysozyme	45.7	19.4	22.5	12.4
Papain	27.8	29.2	24.5	18.5
α-Lactalbumin	26.0	14.0	—	60.0
β-Lactoglobulin	6.8	51.2	10.5	31.5
Soy 11S	8.5	64.5	0	27.0
Soy 7S	6.0	62.5	2.0	29.5
Phaseolin	10.5	50.5	11.5	27.5

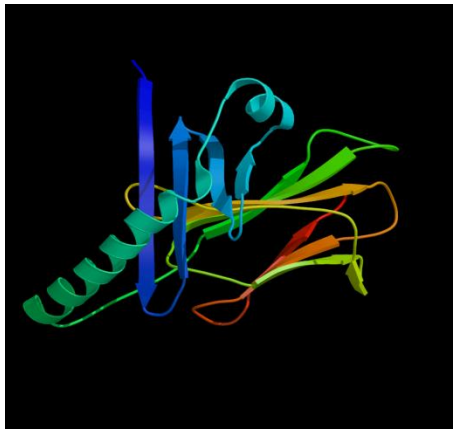
*Note:*Compiled from various sources. The values represent percent of total number of amino acid residues.

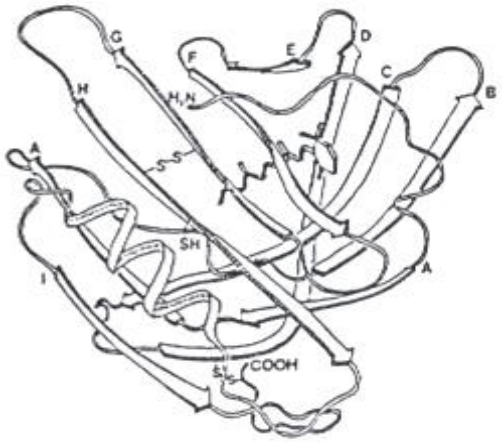


3. Protein Structure

Tertiary structure

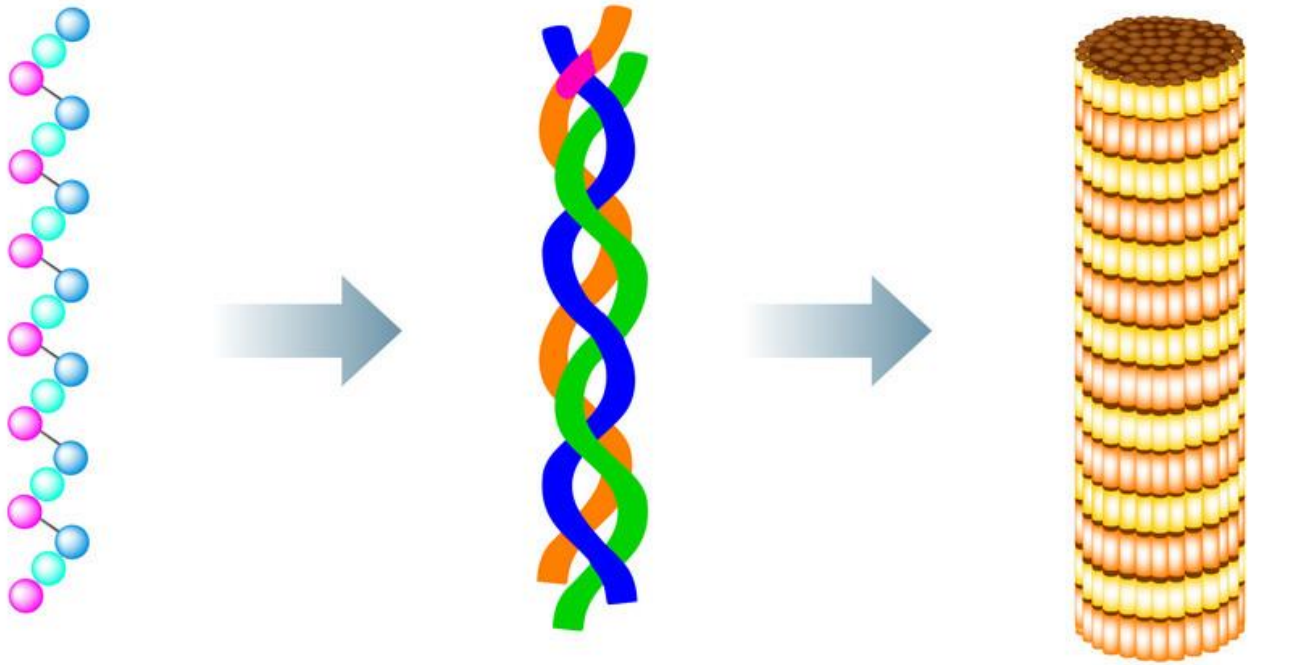
- The spatial arrangement attained when a linear protein chain with secondary structure segments folds further into a compact three-dimensional form.
- This level of structure defines the location of each amino acid of the protein in three-dimensional space.
- In fact, once secondary structures have formed the molecules fold into relatively compact structures.
- Collagen, Elastin, Keratin
- Enzyme, Albumin





β-lactoglobulin

Collagen Structure



Amino Acid

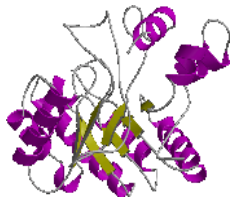
Collagen Molecule

Collagen Fiber

Albumin

SERUM ALBUMIN

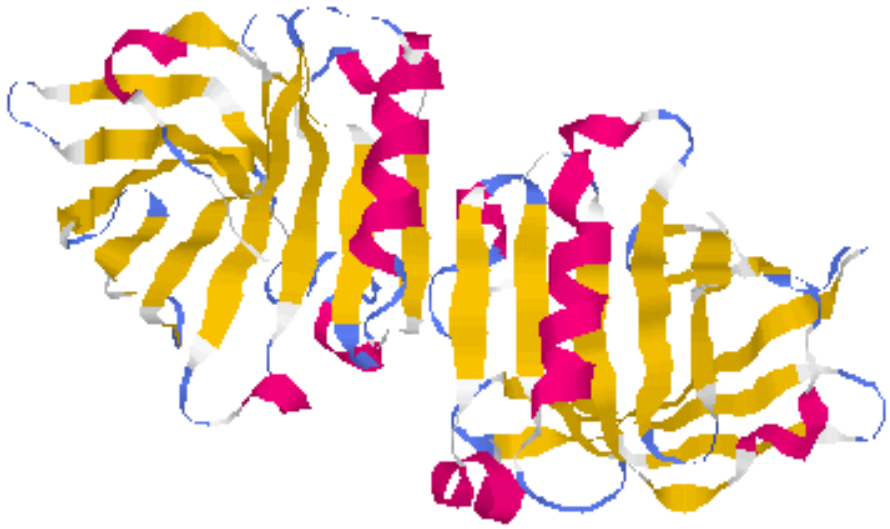
Albumin is a protein that keeps intravascular fluids inside vessels and prevents their leakage. It is synthesized in the liver.



3. Protein Structure

Quaternary structure

- Oligomer
  - Monomer (subunit or protomer)
  - Dimer, trimer, tetramer
  - Homogenous or heterogenous
  - Hemoglobin (tetramer)
  - Beta-lactoglobolin
    - Dimer at p 5-8
    - Octomer at pH 3-5
    - Monomer at pH > 8
- Folding process



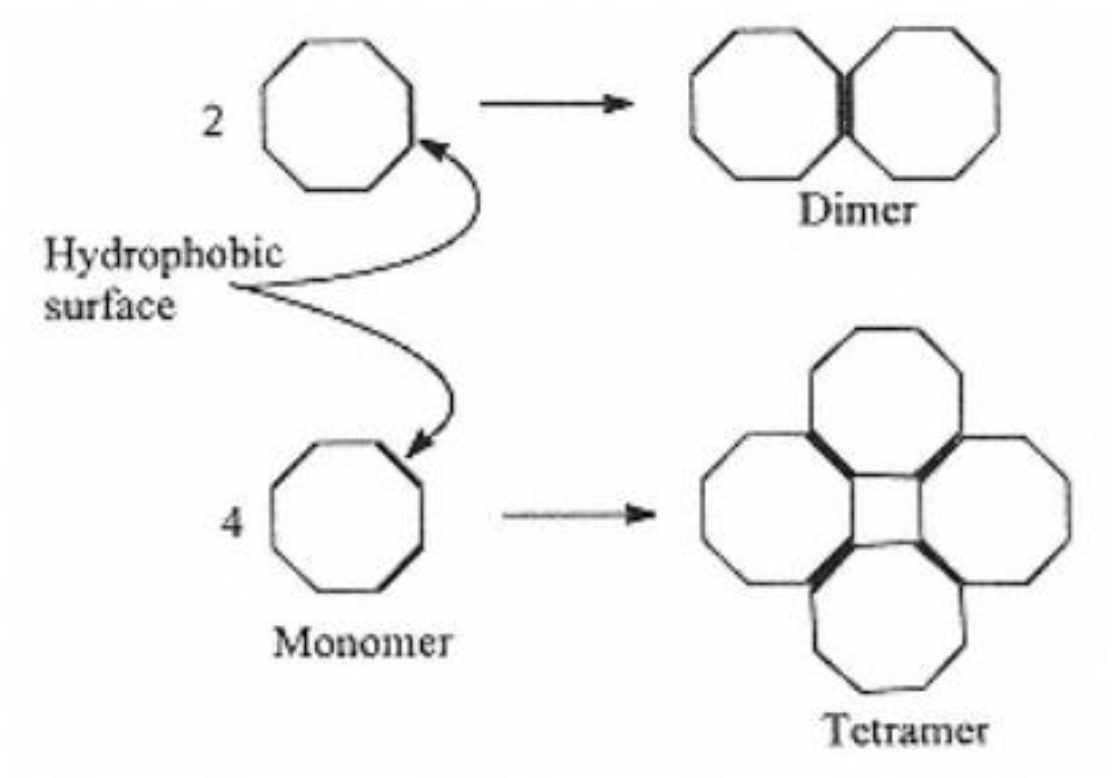
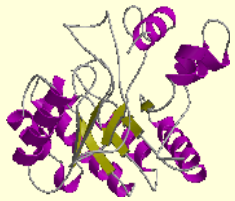
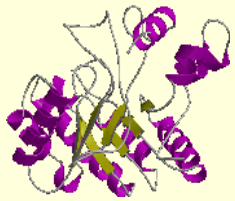


FIGURE 8
Schematic representation of formation of dimers and oligomers in proteins.



4. Protein Classification

- Categories of proteins base on individual chemical constituents
- Categories of proteins based on solubility
- Categories of proteins based on shape

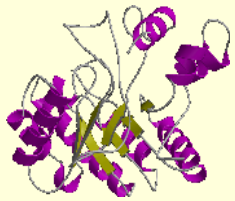


4. Protein Classification

Categories of proteins base on individual chemical constituents

(1) Simple proteins (only amino acids)
(2) Conjugated proteins [amino acid + minerals and/or organic compounds (prosthetic group)]

a. Nucleoproteins (in nucleus of cells)
b. Phosphoproteins (casein in milk, in egg yolk)
c. Lipoproteins (in milk and egg yolk)
d. Glyco- and mucoproteins or mucoids (ovomucin in egg white)
e. Chromoproteins (hemoglobin, myoglobin, flavoproteins)



4. Protein Classification

Categories of proteins based on solubility

(1) Albumins (ovalbumin, lactalbumin and serum albumin in whey, leucosin in cereals, legumelin in legumes)
(2) Globulins (serum globulin and β-lactoglobulin in milk, actin and myosin in meat, glycinin in soybean)
(3) Glutelins (glutenin in wheat, oryzenin in rice)
(4) Prolamins (zein in corn, gliadin in wheat, hordein in barley)
(5) Protamins (clupein in herring, scombrin in mackerel)
(6) Histones
(7) Scleroproteins (collagen in muscle tissue, elastin in tendons, keratin in hair and hoofs)

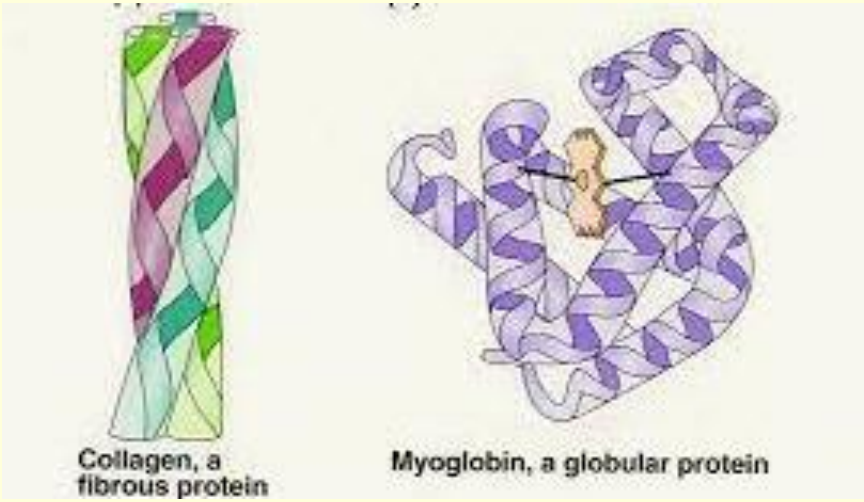
4. Protein Classification

Categories of proteins based on shape

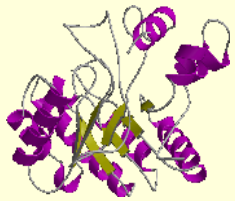
(1) Fibrous

a. Collagens
b. Elastins
c. Keratins

(1) Globular



Properties	Fibrous proteins	Globular proteins
Shape	long and narrow	rounded/spherical
Role	structural (strength and support)	functional (catalysts and transport)
Solubility in water	mostly insoluble	mostly soluble
Sequence of amino acids	repetitive amino acid sequence	irregular amino acid sequence
Stability	less sensitive to changes in heat and pH	more sensitive to changes in heat and pH
Examples	collagen, keratin	hemoglobin, insulin, catalase



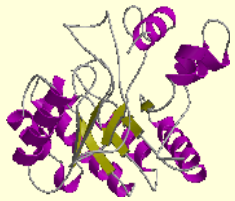
4. Protein Classification

Derived Proteins

(1) Primary derivatives

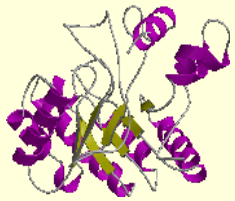
(2) Secondary derivatives

Proteoses → Peptones → Peptides



5. Protein Denaturation

- Unfolding
- Connotations
  - Solubility
  - Biological activity
  - Functional properties
  - Proteases
  - Viscosity
  - WBC
- Reversible or irreversible
- Denaturants
  - Physical agents
    - Temperature, hydrostatic pressure, mechanical treatments (stirring, whipping, kneading, shaking)
  - Chemical agents
    - pH, organic solvents, salts



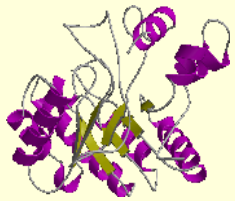
Functionality

Those physical and chemical properties which affect the behavior of proteins in food systems during processing, storage, and preparation

Hydration properties
Solubility
Gelation
Interfacial properties (enulsification, foaming)
Flavor binding
Fat binding
Viscosity
Adhesion
Cohesion

TABLE 12 Functional Roles of Food Proteins in Food Systems

Function	Mechanism	Food	Protein type
Solubility	Hydrophilicity	Beverages	Whey proteins
Viscosity	Water binding, hydrodynamic size and shape	Soups, gravies, and salad dressings, desserts	Gelatin
Water binding	Hydrogen bonding, ionic hydration	Meat sausages, cakes, and breads	Muscle proteins, egg proteins
Gelation	Water entrapment and immobilization, network formation	Meats, gels, cakes, bakeries, cheese	Muscle proteins, egg and milk proteins
Cohesion-adhesion	Hydrophobic, ionic, and hydrogen bonding	Meats, sausages, pasta, baked goods	Muscle proteins, egg proteins, whey proteins
Elasticity	Hydrophobic bonding, disulfide cross-links	Meats, bakery	Muscle proteins, cereal proteins
Emulsification	Adsorption and film formation at interfaces	Sausages, bologna, soup, cakes, dressings	Muscle proteins, egg proteins, milk proteins
Foaming	Interfacial adsorption and film formation	Whipped toppings, ice cream, cakes, desserts	Egg proteins, milk proteins
Fat and flavor binding	Hydrophobic bonding, entrapment	Low-fat bakery products, doughnuts	Milk proteins, egg proteins, cereal proteins



6. Functional Properties

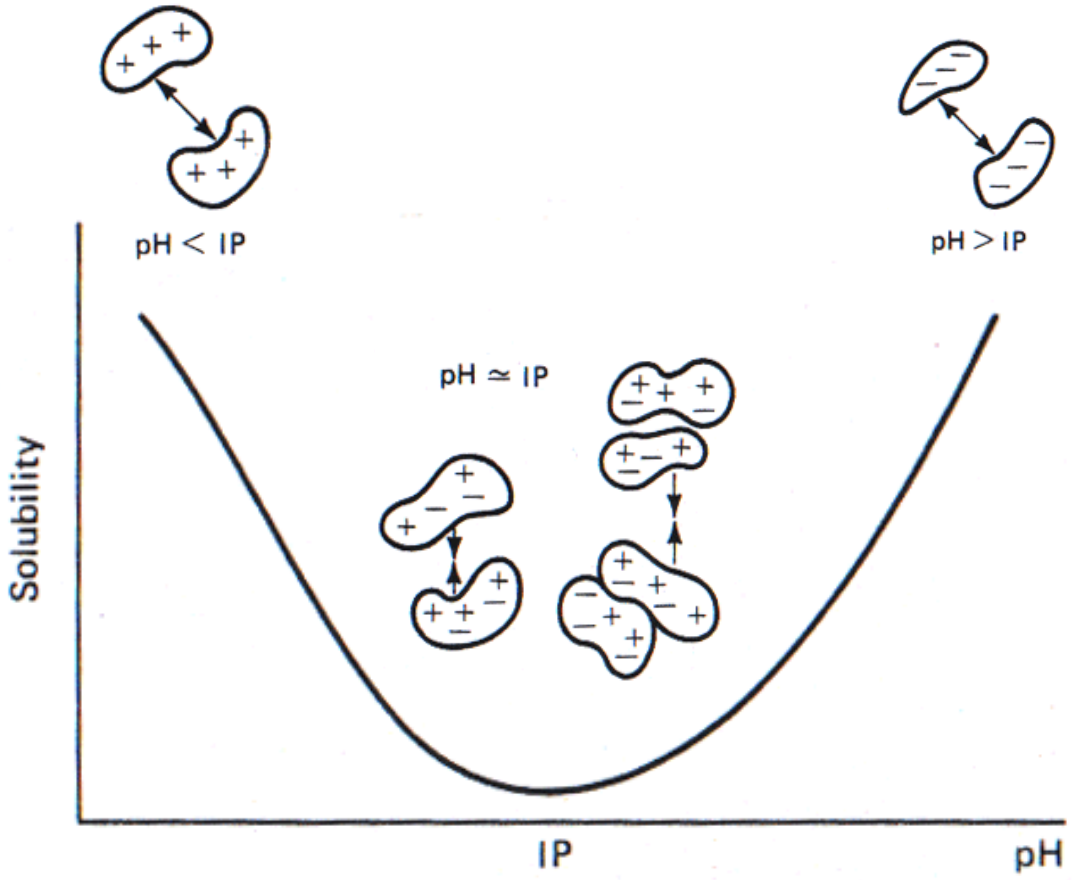
Hydration

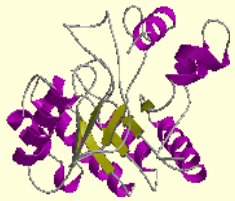
- Water absorption, water uptake, water affinity, water binding
- WBC or hydration capacity
- WHC
- pH
- Temperature
  - Aggregation
- Salts

6. Functional Properties

Solubility

- PDI (protein dispersability index)
- NSI (nitrogen solubility index)
- pH
- Temperature
- Salts
  - Salting-in effect
  - Salting-out effect





6. Functional Properties

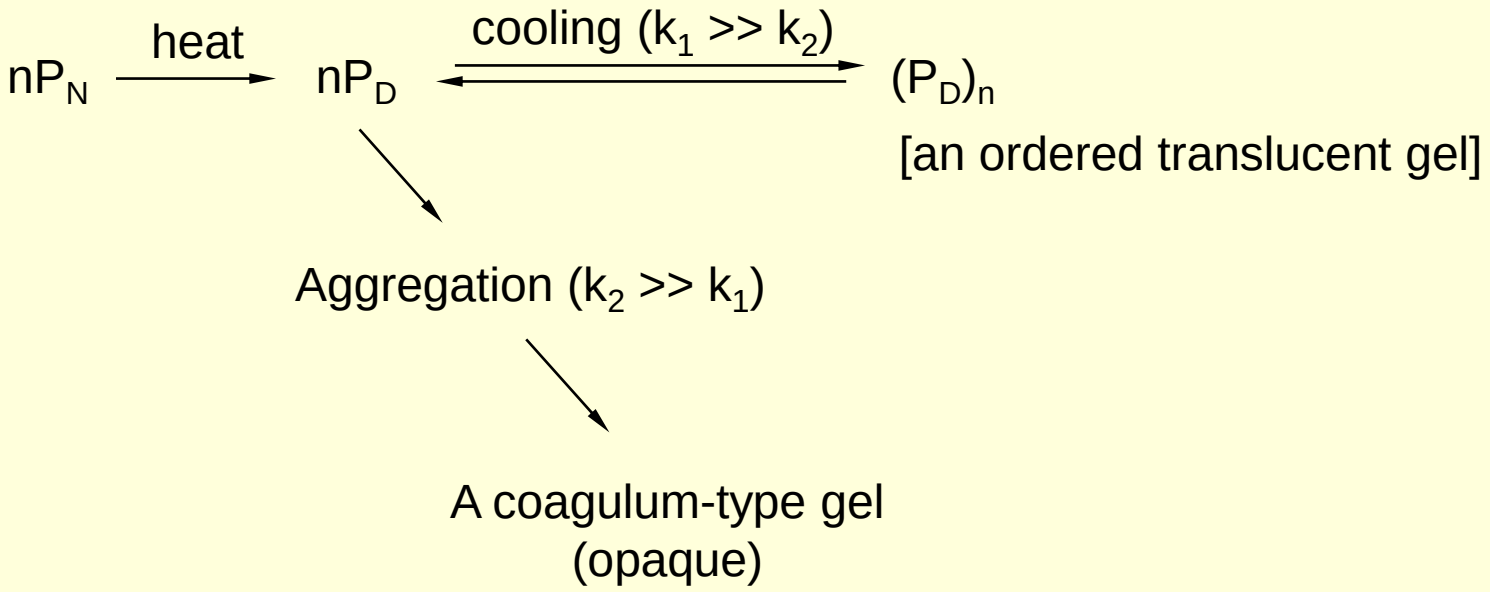
Gelation

- Association
- Aggregation or polymerization
- Precipitation
- Flocculation
- Coagulation (coagulum)
- Gelation
- Mechanism
  - Thermoset or reversible (Gelatin)
  - Thermoplastic or irreversible (egg white gel)

$$\text{Sol state} \xrightarrow[\text{Often heat}]{\text{Denaturation, } k_1} \text{Progel state} \xrightarrow{k_2} \text{Gel state (Protein network)}$$

Gelation

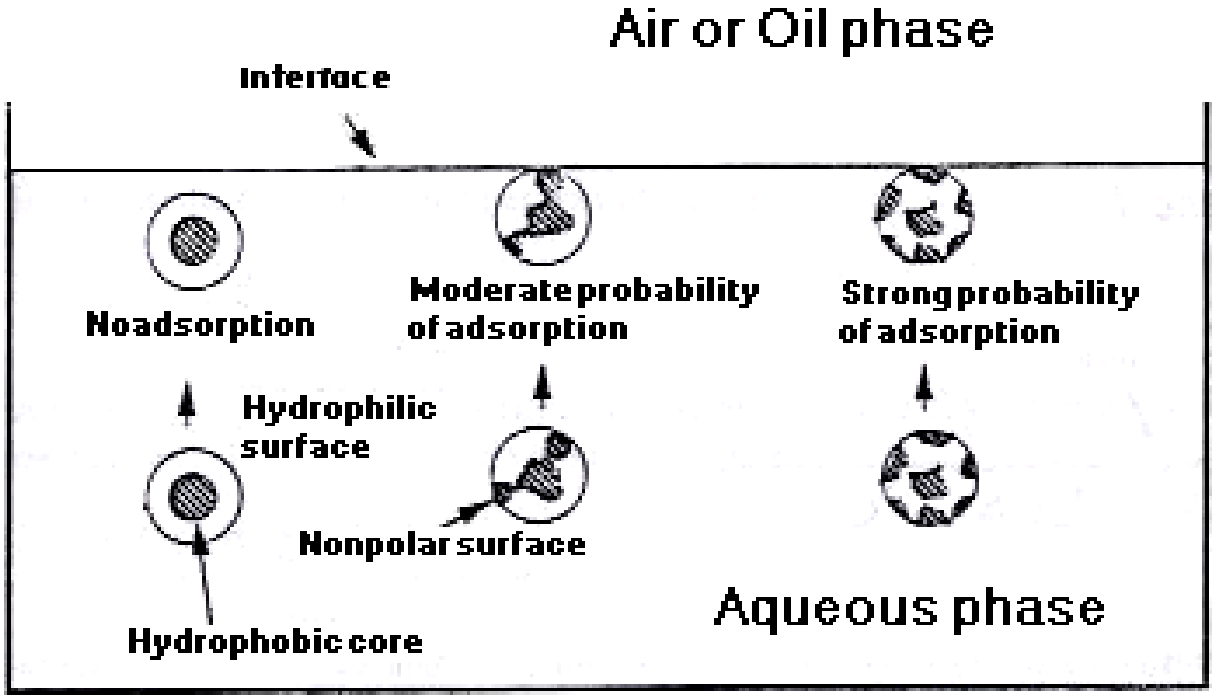
- Gel types:



6. Functional Properties

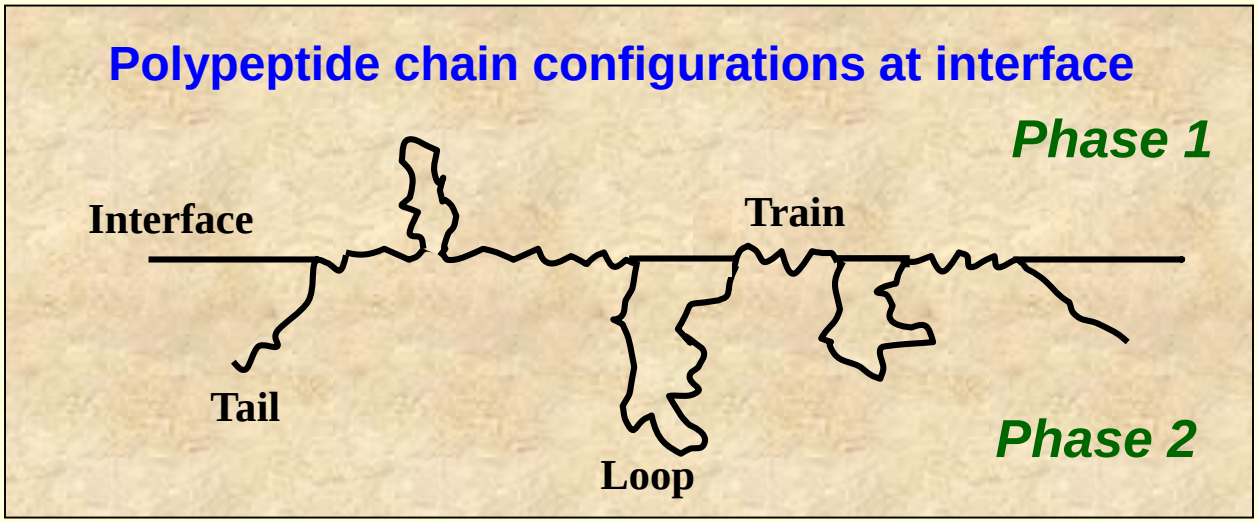
Interfacial properties

- Basic requirements for effectively foaming or emulsifying :
  (1) Ability to rapidly adsorb to interface

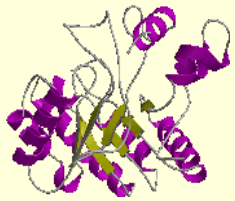


Interfacial properties

- Basic requirements for effectively foaming or emulsifying :
  (2) Ability to rapidly unfold and reorient (or rearrange) at the interface



Train : the segments of the polypeptide chain that are in direct contact with the interface
Loop : the segments that are suspended in two phases
Tail : the N- and C-terminal segments that are usually located in the aqueous phase



6. Functional Properties

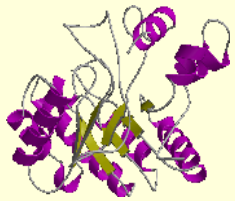
Interfacial properties

- Basic requirements for effectively foaming or emulsifying :

  (3) Once at the interface,

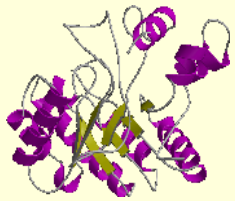
  ♣ability to interact with the neighboring molecules

  ♣ form a strong cohesive, viscoelastic film that can withstand thermal and mechanical motions.



7. Organized Protein Systems

- Milk proteins
- Egg proteins
- Meat proteins
- Wheat proteins

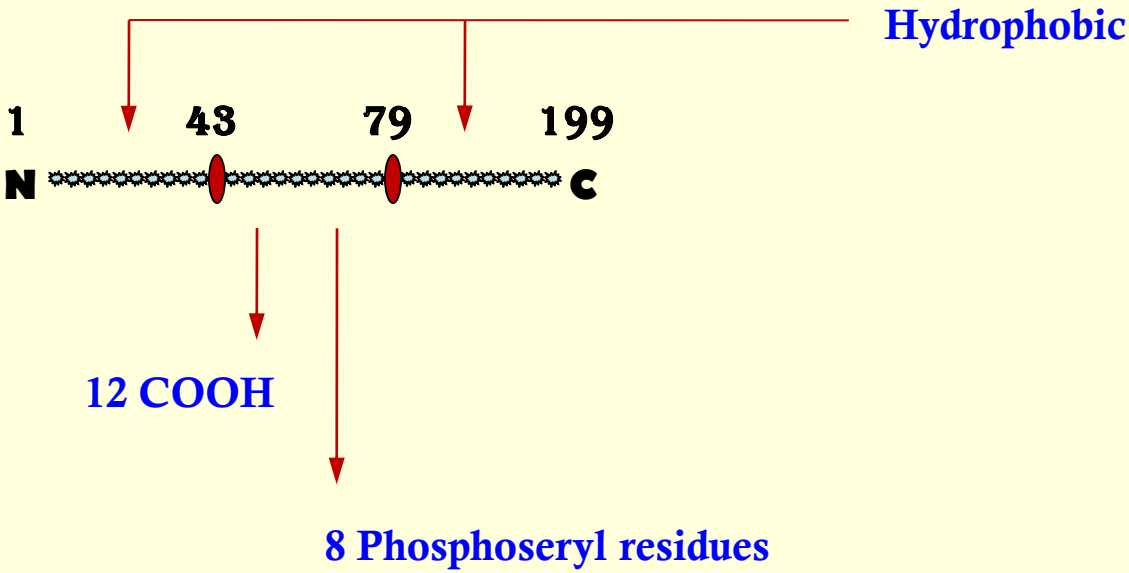


Milk proteins

- Bos taurus
- Skimmed milk
- Skimmed milk at pH = 4.6 and T = 20 °C
  - Precipitate (Casein proteins) (phosphoprotein), 80% (27 g/L milk)
    - α_S-caseins, 40% ($\alpha_{S0} - \alpha_{S5}$)
    - β-casein, 24%
    - κ-casein, 12%
    - γ-casein, 4%
      - The mains: α_{S1}-casein, β-casein, κ-casein
  - Serum or whey, 20% (7 g/L milk)
    - Lactose
    - Whey proteins
      - Lactalbumin, 12%
      - Lactoglobulin, 5%
      - Immunoglobulin, 2%
      - Others, 1%

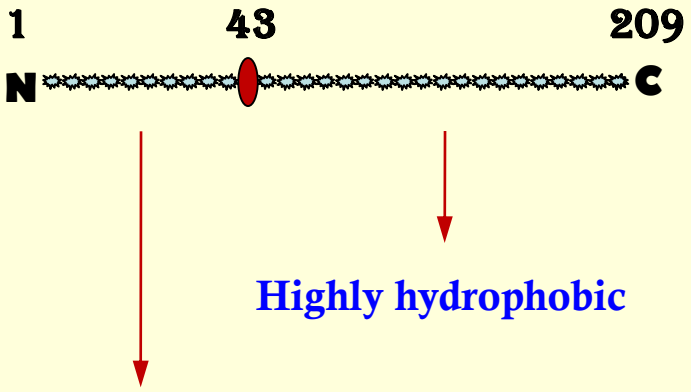
Milk proteins

- α_{S1}-casein, MW = 23600



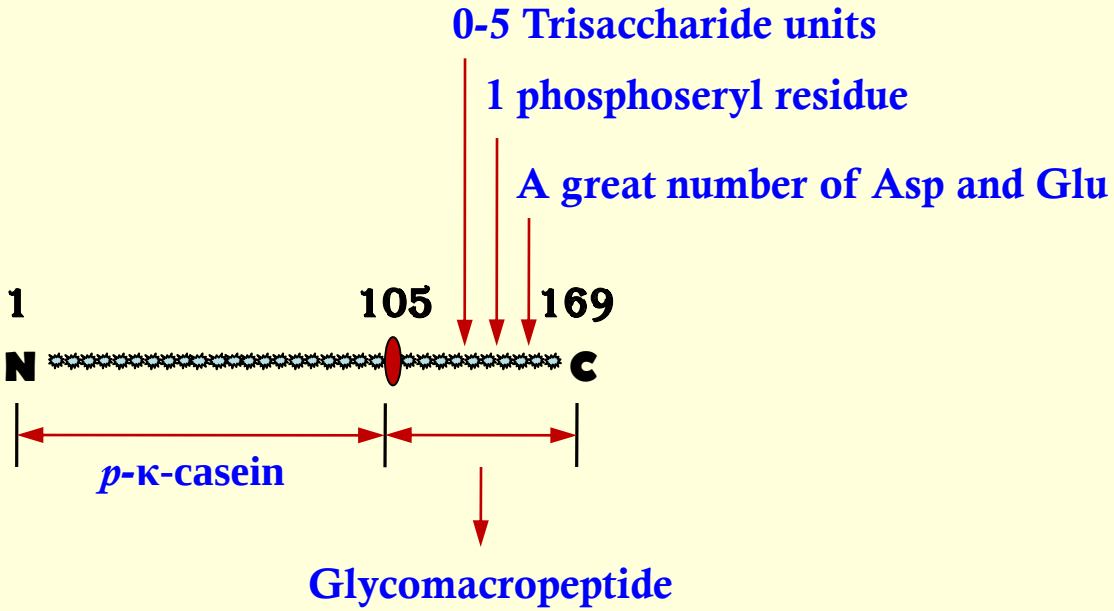
Milk proteins

- β-casein, MW = 24000



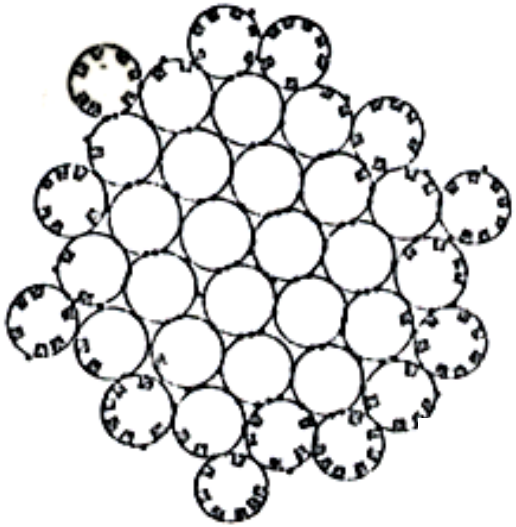
Milk proteins

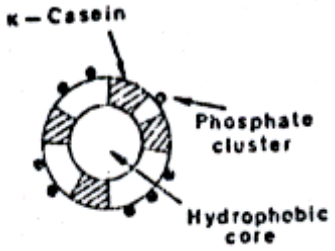
- κ-casein, MW = 19000

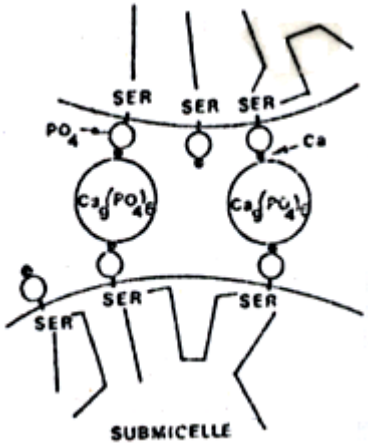


Milk proteins

- Casein micelle
  - d = 50-300 nm
  - MW = 10^7 – 3 × 10^{10}
  - 10^{15} micelles / dm^3 milk
  - Composition
    - 93% casein
    - 7% : Ca (3%), phosphate (3%), Mg, Na, K, Citrate (1%)
    - Colloid calcium phosphate
  - Structure
    - Submicelles
      - MW = 3-6 × 10^5
      - d = 10 – 20 nm
      - 25 – 30 submicelle / micelle

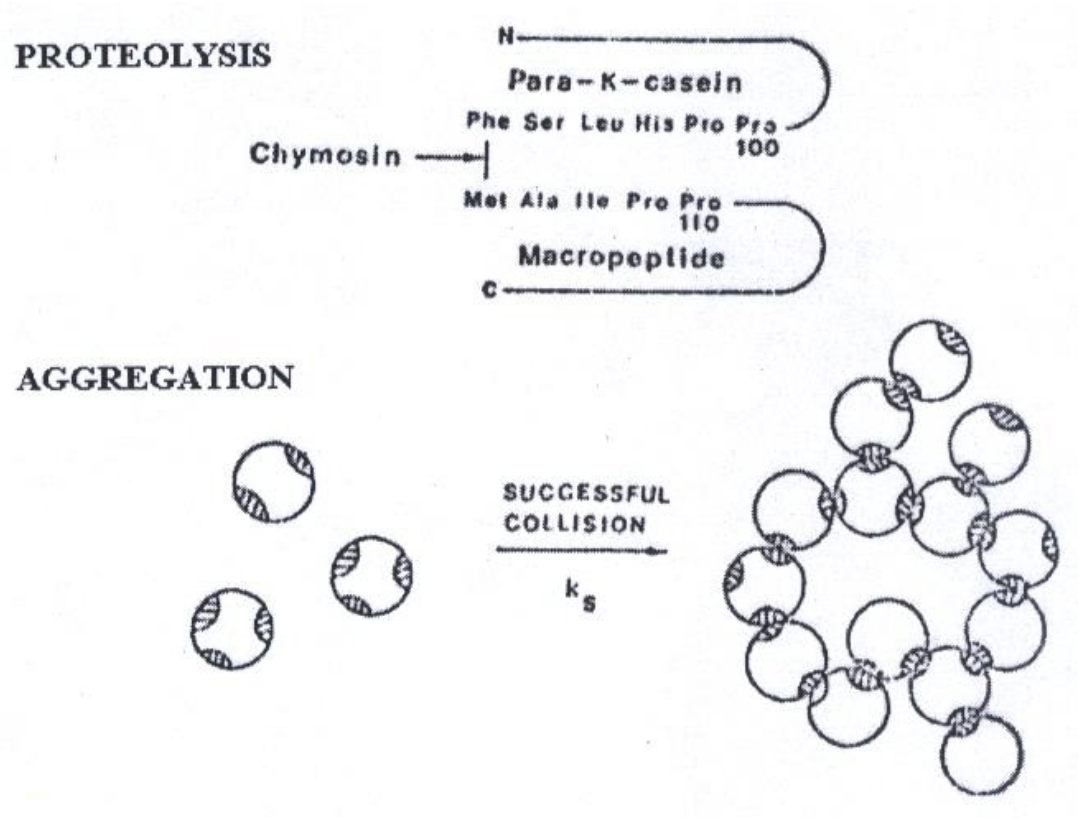






Milk proteins

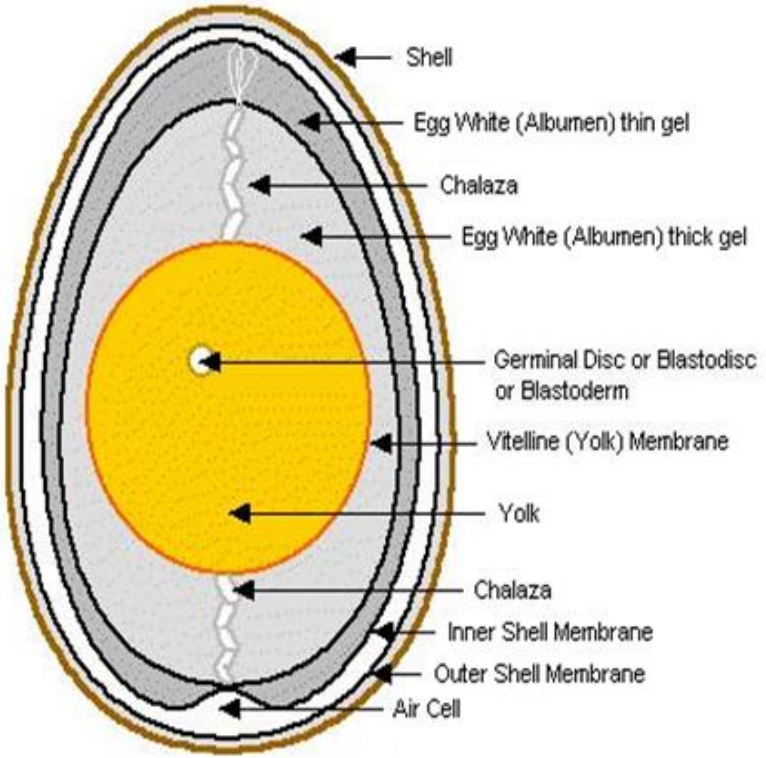
- Milk coagulation



Egg proteins

- Gallus domesticus
- Chicken or hen's egg
- Yolk and white

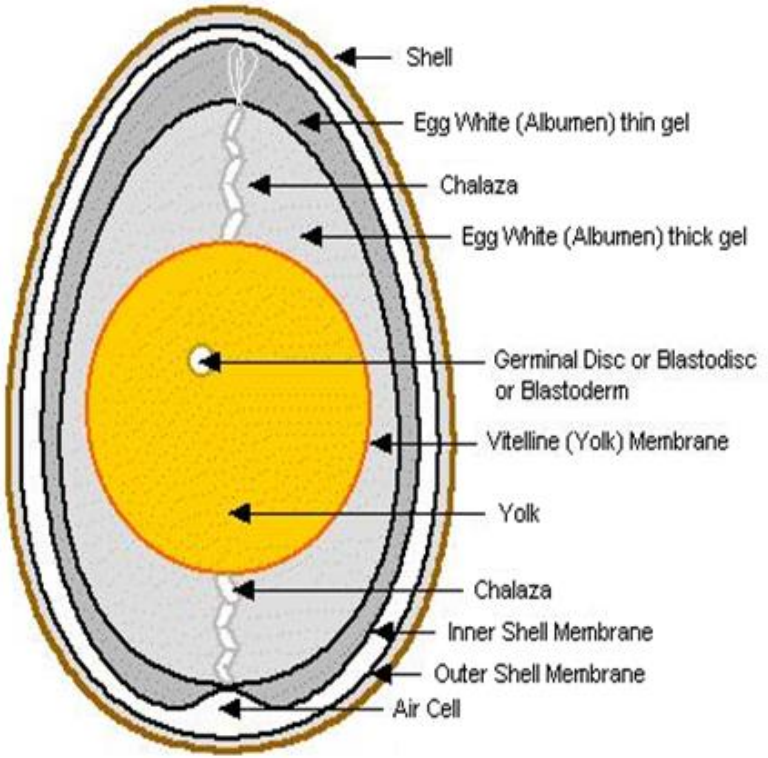
- **Yolk**
  - O/W (with 50% dry solid)
  - 1/3 : protein
  - 2/3 : lipid
    - 67% TAG
    - 28% phospholipid
      - Mainly lecithin (73%), cephalin (15%)
      - Others (lysophosphatides & sphingomyelins)
  - Two important lipoprotein:
    - Lipovitellin (17-18% lipid, 1% P)
    - Lipovitellenin (36-41% lipid, 29% P)
  - Two major protein:
    - Livetin, phosvitin (10% P)

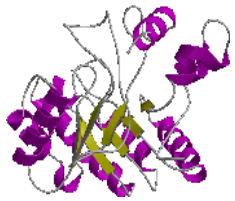


Egg proteins

- Gallus domesticus
- Chicken or hen's egg
- Yolk and white

- **White (albumen)**
  - An protein solution with 11-13% protein
  - Thick layer (Chalaziferous layer)
    - Chalazae
  - Thin layer
  - Thick layer
  - Thin layer
  - Similar protein composition but ovomucin more in the thick layer





7. Organized Protein Systems

Egg proteins

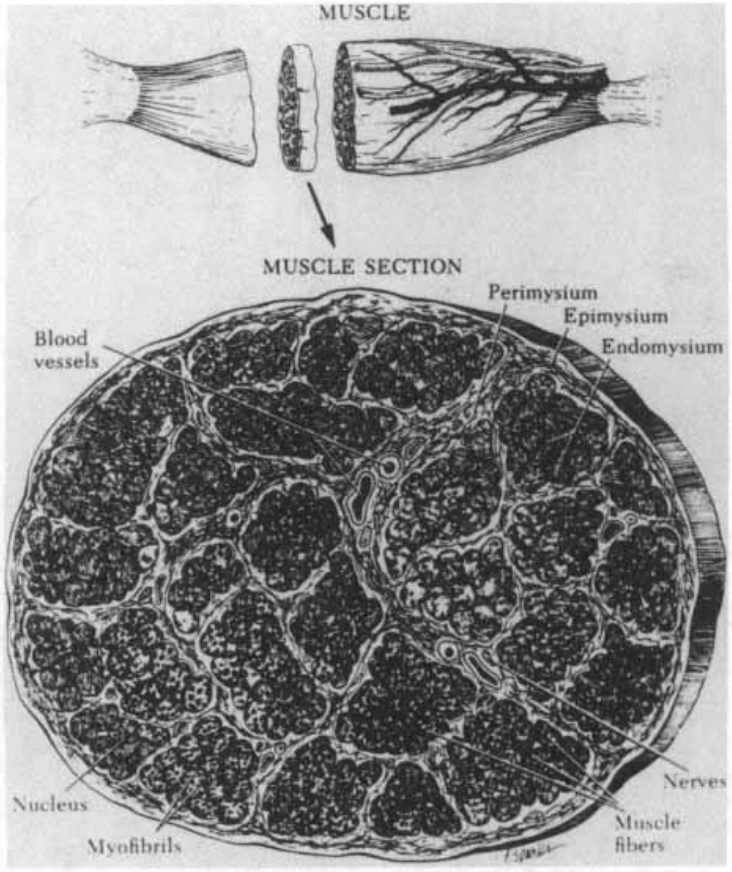
Constituent	*Approximate Amount (%)*	*Approximate Isoelectric Point (pH)*	*Unique Properties*
Ovalbumin	54	4.6	Denatures easily, has sulfhydryls
Conalbumin	13	6.0	Complexes iron, anti-microbial
Ovomucoid	11	4.3	Inhibits enzyme trypsin
Lysozyme	3.5	10.7	Enzyme for polysaccha-rides antimicrobial
Ovomucin	1.5	?	Viscous, high sialic acid, reacts with viruses
Flavoprotein	0.8	4.1	Binds riboflavin
Proteinase inhibitor	0.1	5.2	Inhibits enzyme (bacterial proteinase)
Avidin	0.05	9.5	Binds biotin, antimicrobial
Unidentified proteins	8	5.5, 7.5 8.0, 9.0	Mainly globulins
Nonprotein	8		Primarily glucose and salts (poorly characterized)

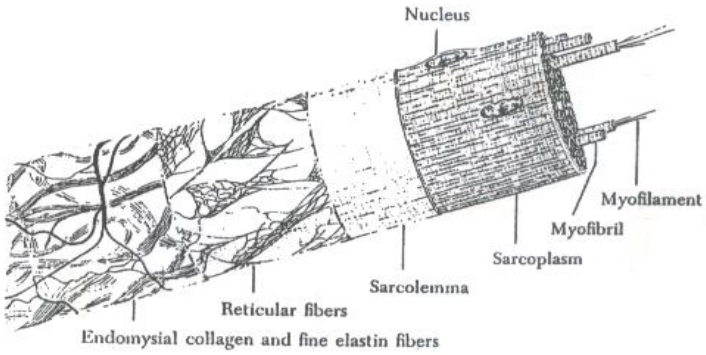
7. Organized Protein Systems

Meat proteins

- Soluble proteins, 30%
  - Myogens & myoalbumins
- Contractile proteins, 64%
  - Actin & myosin
- Stroma (connective tissue) proteins, 6%

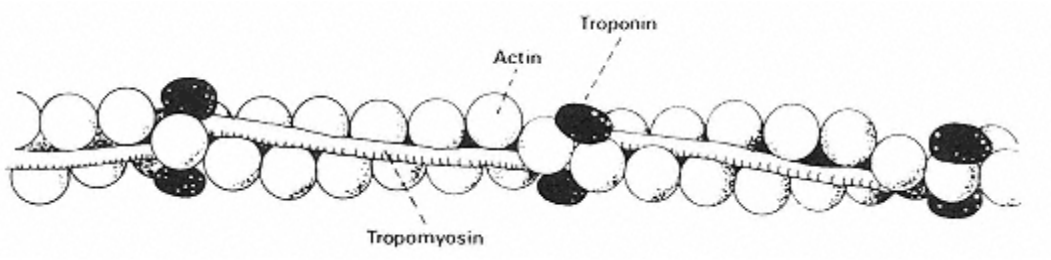
- **Muscle fibers**
  - Sarcolema
  - A great number of nucleous
  - Sarcoplasm
  - Mitocondry
  - Ribosome
  - Lizozyme
  - Glycogen granules
  - Sarcoplasmic reticulum
  - Myofibrils



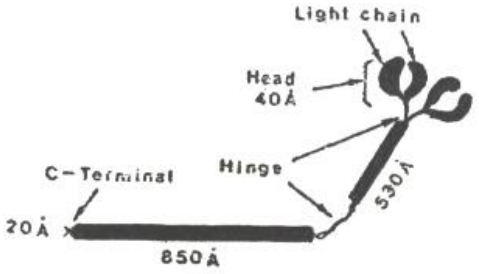


Meat proteins

- Thin myofilaments
  - Actin
    - G-actin
    - F-actin
  - Tropomyosin
  - Troponin



- Thick myofilaments
  - Myosin
    - 2 heavy meromyosin
    - 4 light meromyosin
  - Myomesin or M-line protein
  - C-protein



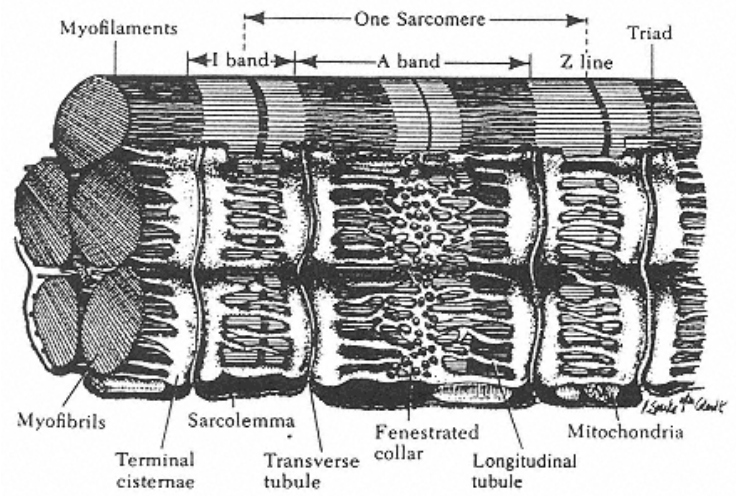
MYOSIN

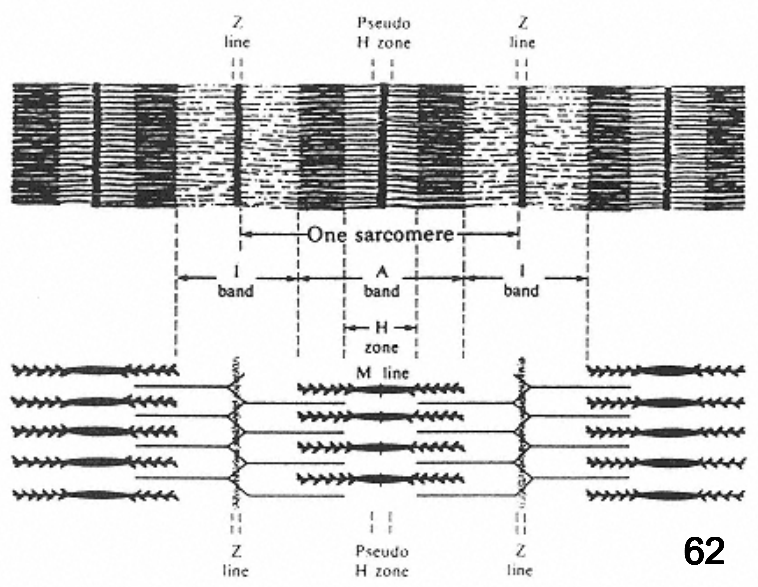
THICK FILAMENT

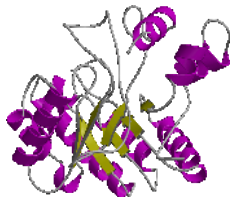
Meat proteins

- Thin filaments
  - Actin
    - G-actin
    - F-actin
  - Tropomyosin
  - Troponin

- Thick filaments
  - Myosin
    - 2 heavy meromyosin
    - 4 light meromyosin
  - Myomesin or M-line protein
  - C-protein



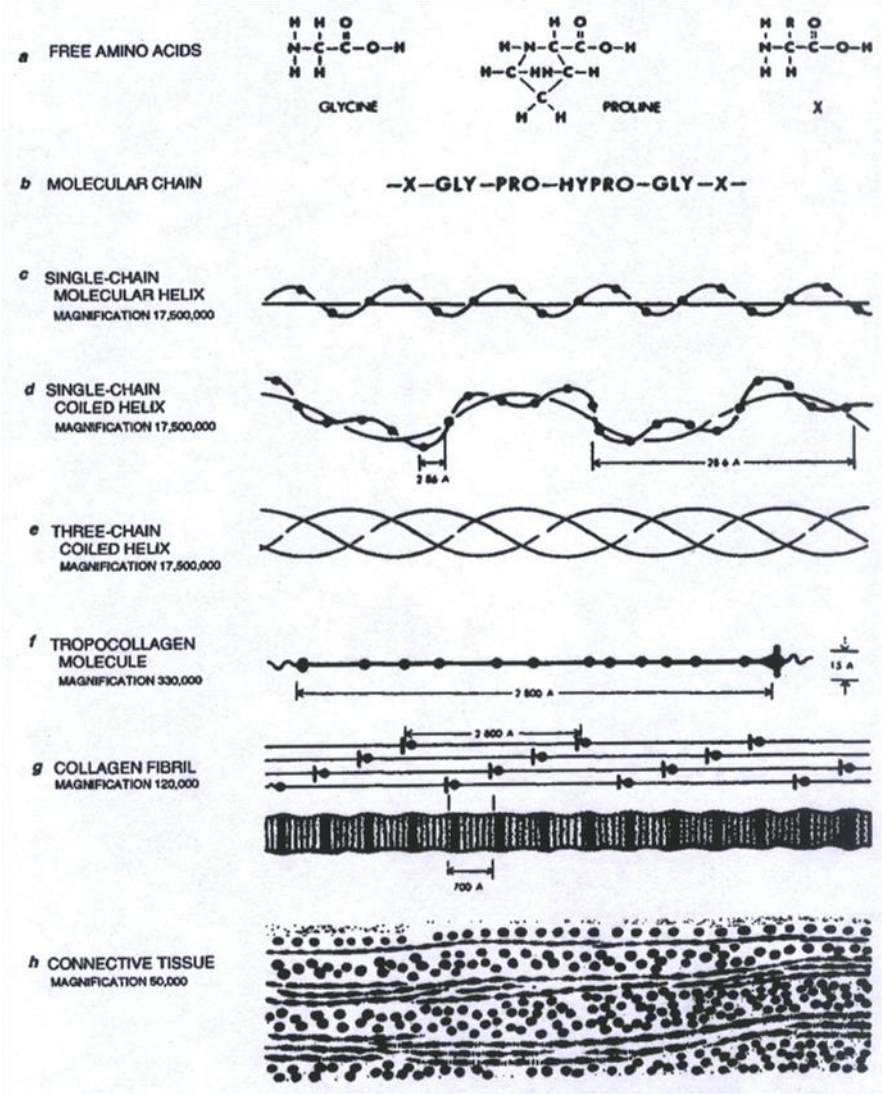


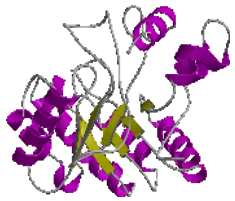


7. Organized Protein Systems

Meat proteins

- Collagen
- Gelatin





7. Organized Protein Systems

Wheat proteins

- Crumb and crust
- Seed
  - Embryo or germ
  - Endosperm
  - Seed coats (bran)
- Wheats
  - Hard
  - Soft