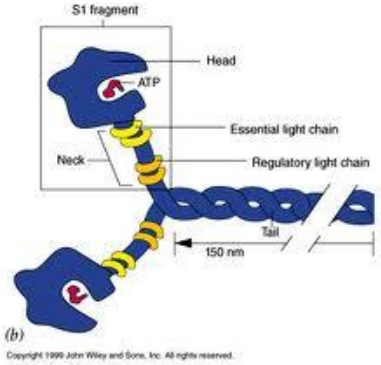
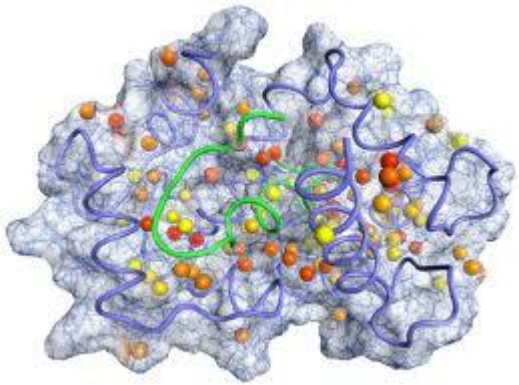
دانشگاه علوم کشاورزی
و منابع طبیعی گرگان
دانشکده صنایع غذایی

بیوشیمی عمومی

Protein





- The name protein (proteios G = pre-eminent or first) was first suggested, in 1838, by a Swedish chemist Berzelius to a Dutch chemist Mulder, who referred it to the complex organic nitrogenous substances found in the cells of the living beings.

• در گیاهان و جانوران ماده ای وجود دارد که بدون شک مهمترین ماده شناخته شده در موجودات زنده است، بطوریکه بدون این ماده در سیاره ما حیات غیر ممکن خواهد بود. این ماده پروتئین نام دارد.

- They are most abundant intracellular macro-molecules and constitute over half the dry weight of most organisms. “Proteins occupy a central position in the architecture and functioning of living matter.

- They are intimately connected with all phases of chemical and physical activity, that constitute the life of the cell.
- Some proteins serve as important structural elements of the body, for example, as hair, wool and collagen, an important constituent of connective tissue ; other proteins may be enzymes, hormones or oxygen- carriers. Still other proteins participate in muscular contraction, and some are associated with the genes, the hereditary factors.

وظایف بیولوژیک پروتئین ها	مثال
فعالیت آنزیمی	الکل دهیدروژناز در تخمیر الکلی و..
انتقال دهنده ها	• هموگلوبین (انتقال دهنده اکسیژن در خون) •کرلوپ لاسمین (انتقال دهنده مس در خون)
ذخیره کننده ها	▪فریتین (ذخیره آهن در طحال ▪کازیین (ذخیره اسید آمینه در شیر)
ساختمانی	کلاژن - رشته ارتباط دهنده بافت
منقبض کننده	•میوزین (لایه ضخیم در اسکلت ماهیچه) •اکتین (لایه باریک در اسکلت ماهیچه)
محافظ	آنتی بادی ها– موثر با پروتئین خارجی فیبرینوژن– پروتئین لازم برای لخته شدن خون
فعالیت هورمونی	انسولین– تنظیم گلوکز در متابولیسم هورمون رشد– لازم برای رشد استخوان
توکسین (سم)	سم مار– آنزیم هیدرولیتیکی سم کلستریدیدم بوتولینوم (سم مرگ آور باکتریهای غذایی)

Role of proteins

1. Nutrition
   - Energy and essential amino acids
   - May cause allergies and be toxic/carcinogenic
2. Structure
   - Provide structure in living organisms and also foods
3. Catalysts
   - Enzymes catalyze chemical reactions in living tissue and foods

Role of proteins….

4. Functional properties
   - Gelation
   - Emulsifiers
   - Water bonding
   - Increase viscosity
   - Texture

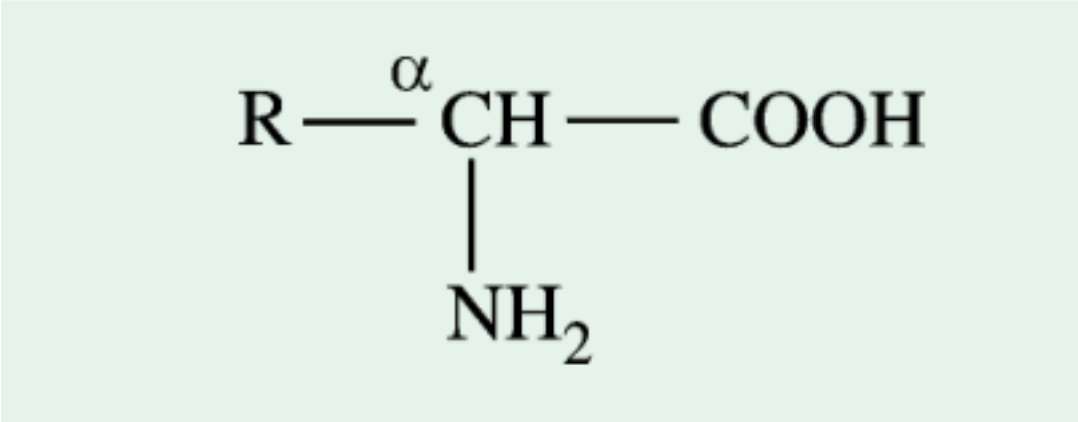
Role of proteins….

5. Browning
   - Have amino acids that can react with reducing sugars
   - Some enzymes can also cause browning

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

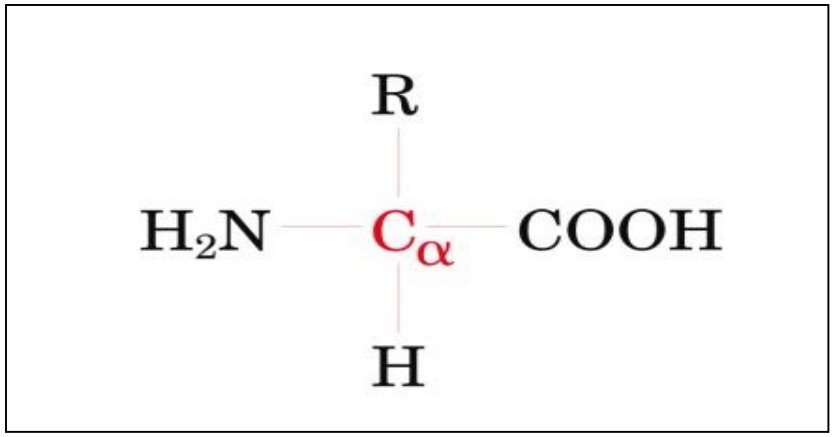
Amino Acids

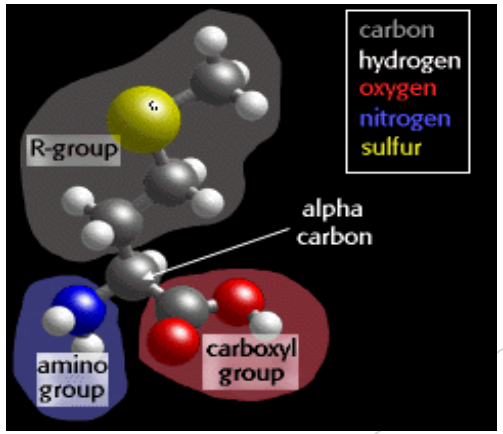
- All proteins are macromolecules because of their very high molecular weights.
- These are the polymers, i.e., chain-like molecules produced by joining a number of small units of amino acids called monomers.
- The amino acids are, therefore, regarded as ‘building blocks of proteins’.



Amino Acids

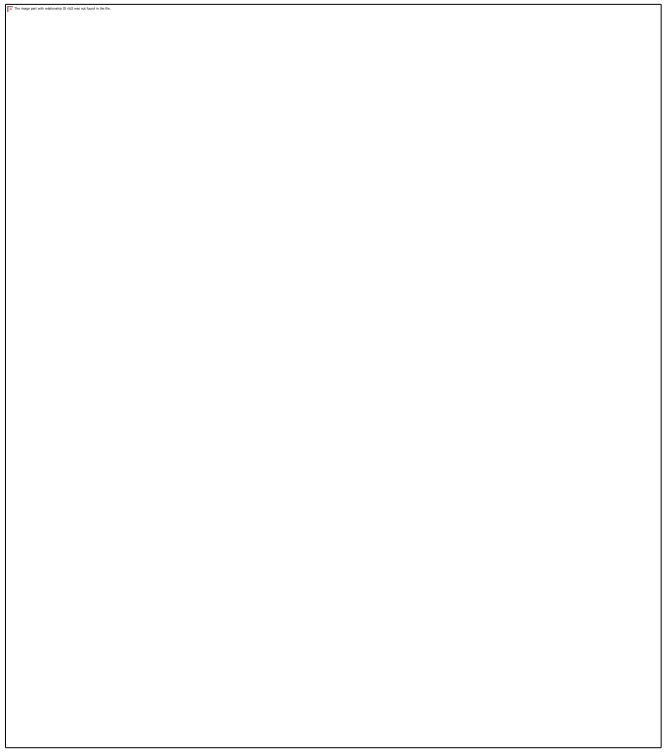
- Each amino acid is a nitrogenous compound having both an acidic carboxyl (— COOH) and a basic amino (— NH 2) group.
- At pH 7.0, both the carboxyl and amino groups are ionized. An amino acid in its dipolar state is called a zwitterion.
- R stands for the side chains that are different for each amino acid.





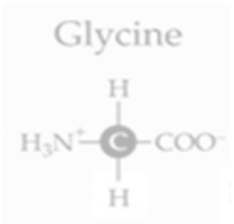
Gly : Glycocol

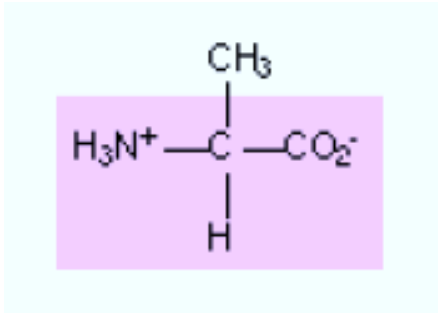
گلایسین



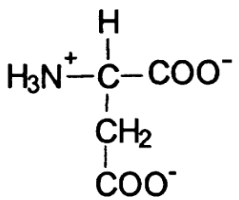
- اولین و ساده ترین اسیدآمینه، مزه شیرین
- فروانترین اسیدآمینه بعد از آلانین
- فاقد کربن نامتقارن
- فاقد ایزومرفضایی و فعالیت نوری

- R can be as simple as a hydrogen atom (H) or a methyl group (— CH_3) or a more complex structure.

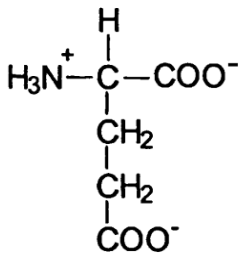




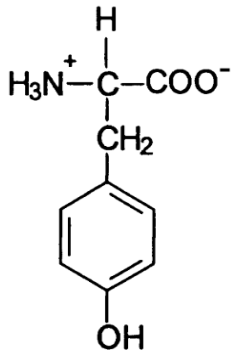
Aspartic Acid (Asp)
Hydrophilic, acidic



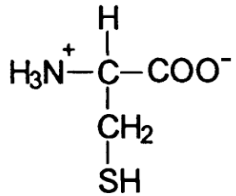
Glutamic Acid (Glu)
Hydrophilic, acidic



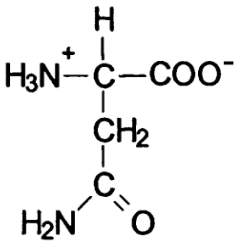
Tyrosine (Tyr)
Hydrophilic, neutral



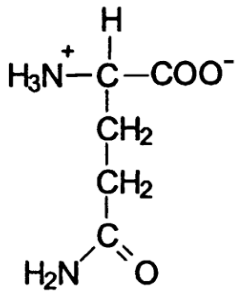
Cysteine (Cys)
Hydrophilic, neutral



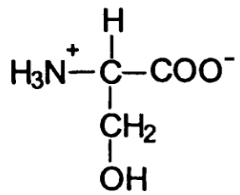
Asparagine (Asn)
Hydrophilic, neutral



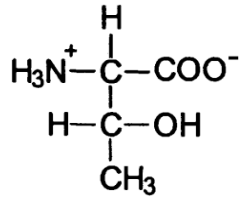
Glutamine (Gln)
Hydrophilic, neutral



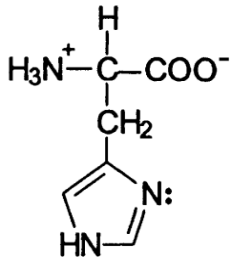
Serine (Ser)
Hydrophilic, neutral



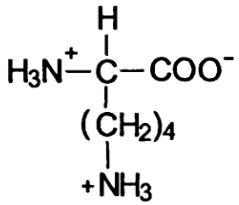
Threonine (Thr)
Hydrophilic, neutral

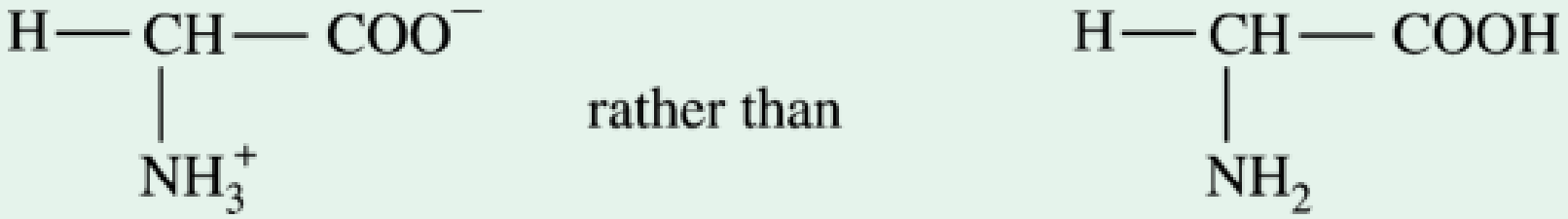


Histidine (His)
Hydrophilic



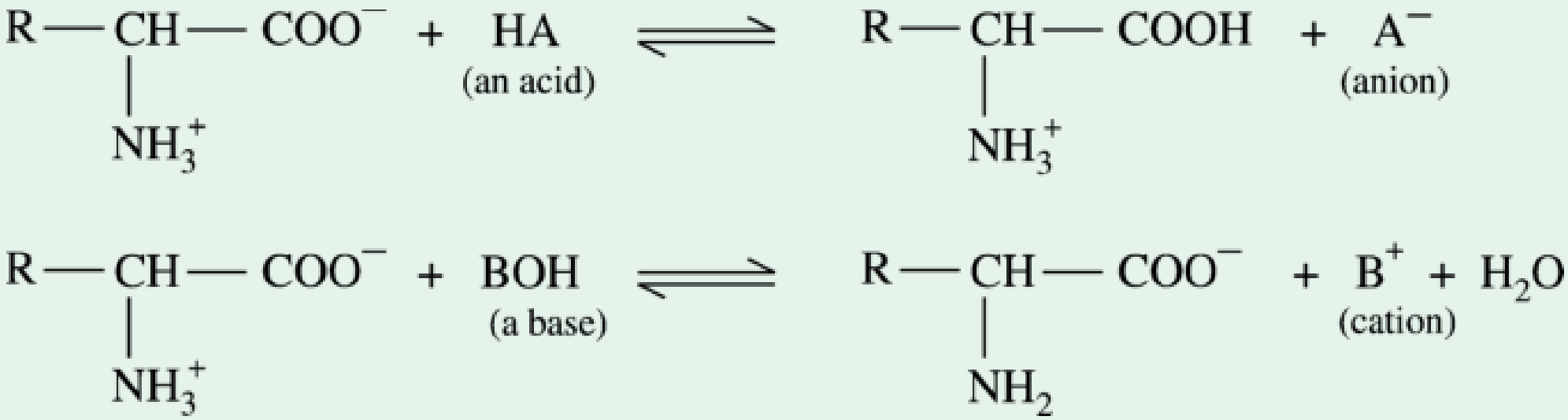
Lysine (Lys)
Hydrophilic, basic





In the ionic form, the proton migrates from the carboxyl to amino group, thus producing carboxylate (COO^-) and ammonium (NH_3^+) ions.

Amino acids react with both acids and bases. Hence, they are **amphoteric** in nature.



These reactions are of reversible nature and depend on the pH of the medium. Henceforth, amino acids serve as buffers and tend to prevent pH change when an acid or a base is added.

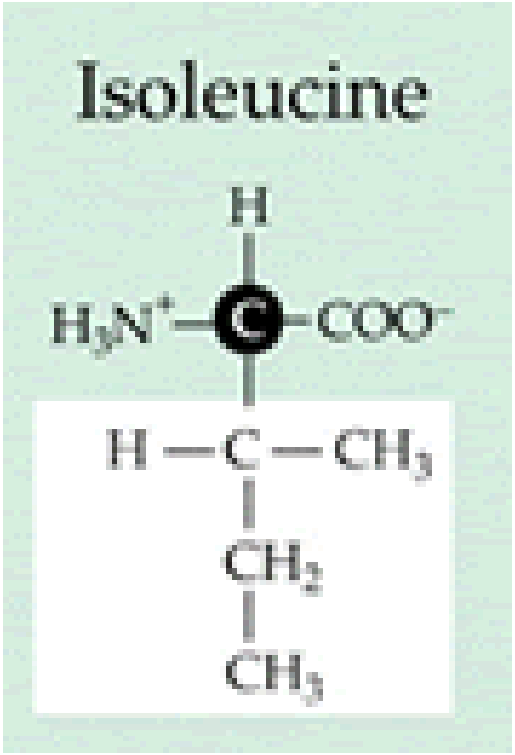
- The α-carbon of most amino acids is joined by covalent bonds to 4 different groups.

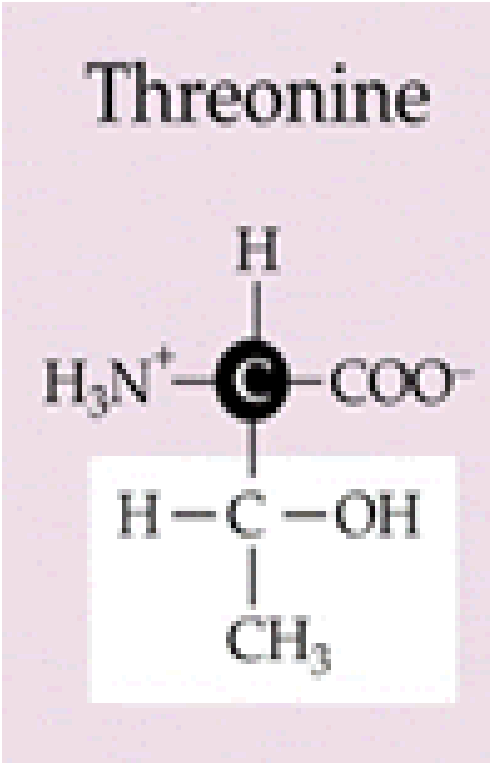
- Thus, the α-carbon in all the amino acids is asymmetric except in glycine where the α-carbon is symmetric.

Because of this asymmetry, the amino acids (of course, except glycine) exist in two optically active forms :

- Those having — NH_2 group to the right as D -forms
- Those having — NH_2 group to the left as L-forms

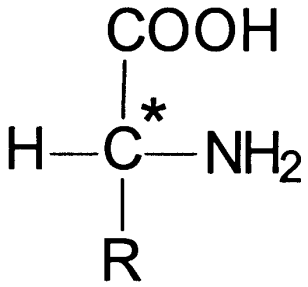
- However, the two amino acids, threonine and isoleucine have two asymmetric carbon atoms each and thus have 4 optical isomers.



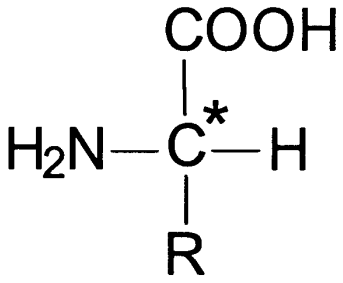


Specific Rotation

- It is interesting to note that the amino acids found in the proteins belong to the L-series.
- Many of the naturally occurring L-amino acids rotate the plane of polarized light to the left (i.e., they are levorotatory) while others rotate the plane of polarized light to the right (i.e., they are dextrorotatory).



D-Amino acid



L-Amino acid

DL nomenclature

Specific rotation of some amino acids isolated from proteins

Amino acid	*Specific rotation,* $[\alpha]_D^{25^\circ}$
L-alanine	– 86.2
L-histidine	– 38.5
L-phenylalanine	– 34.5
L-threonine	– 28.5
L-serine	– 7.5
L-alanine	+ 1.8
L-glutamic acid	+ 12.0
L-isoleucine	+ 12.4
L-arginine	+ 12.5
L-lysine	+ 13.5

Thus, it is evident that the symbols D and L do not identify the property of light rotation, i.e., D -isomers can be either dextrorotatory (d) or levorotatory (l); similarly, L-isomers can be either (d) or (l).

- However, to minimize confusion, the symbols d and l are usually not used nowadays.
- Moreover, the DL nomenclature has limitations because it describes the asymmetry of only one carbon atom in a compound and many biomolecules contain two or more asymmetric carbon atoms.

The R and S classification or RS notation of isomers ???

- Although over 100 amino acids have been shown to be present in various plants and aminals, only 20 of them (L -isomers) are found as constituent of most proteins.

- These 20 amino acids of proteins are often referred to as standard, primary or normal amino acids, to distinguish them from others.

- The distribution of the 20 amino acids is not uniform in all proteins.

1 Unique first letter:

Cysteine	=	Cys	=	**C**
Histidine	=	His	=	**H**
Isoleucine	=	Ile	=	**I**
Methionine	=	Met	=	**M**
Serine	=	Ser	=	**S**
Valine	=	Val	=	**V**

2 Most commonly occurring amino acids have priority:

Alanine	=	Ala	=	**A**
Glycine	=	Gly	=	**G**
Leucine	=	Leu	=	**L**
Proline	=	Pro	=	**P**
Threonine	=	Thr	=	**T**

3 Similar sounding names:

Arginine	= Arg	= **R**	("a**R**ginine")
Asparagine	= Asn	= **N**	(contains N)
Aspartate	= Asp	= **D**	("aspar**D**ic")
Glutamate	= Glu	= **E**	("glut**E**mate")
Glutamine	= Gln	= **Q**	("**Q**-tamine")
Phenylalanine	= Phe	= **F**	("**F**enylalanine")
Tyrosine	= Tyr	= **Y**	("t**Y**rosine")
Tryptophan	= Trp	= **W**	(double ring in the molecule)

4 Letter close to initial letter:

Aspartate or asparagine	=	Asx	=	**B** (near **A**)
Glutamate or glutamine	=	Glx	=	**Z**
Lysine	=	Lys	=	**K** (near **L**)
Undetermined amino acid	=			**X**

Amino Acids Classification

Based on the degree of interaction of the side chains with water :

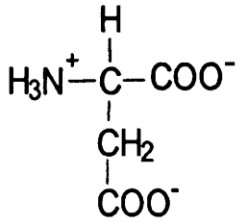
- Non-polar (hydrophobic) residues

in the interiors of proteins where there is little or no access to water

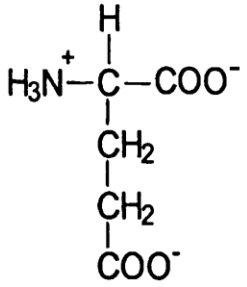
- Polar (hydrophilic) residues (on the surfaces of proteins)
  - Charged
    - Positive or basic
    - Negative or acidic
  - Uncharged (neutral)

Polar Amino Acids - Hydrophilic

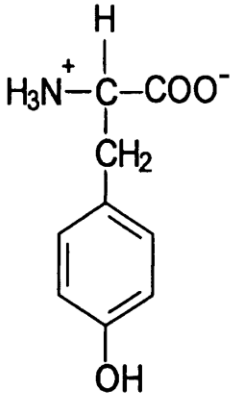
Aspartic Acid (Asp)
Hydrophilic, acidic



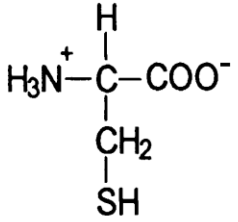
Glutamic Acid (Glu)
Hydrophilic, acidic



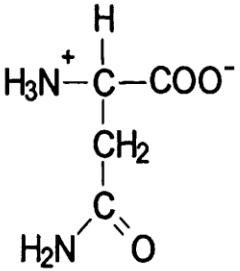
Tyrosine (Tyr)
Hydrophilic, neutral



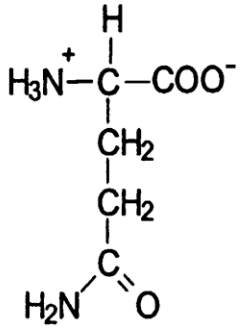
Cysteine (Cys)
Hydrophilic, neutral



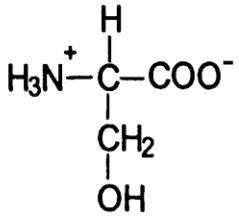
Asparagine (Asn)
Hydrophilic, neutral



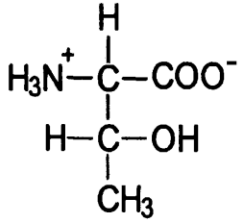
Glutamine (Gln)
Hydrophilic, neutral



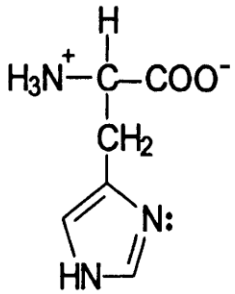
Serine (Ser)
Hydrophilic, neutral



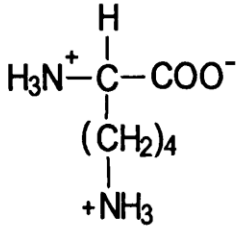
Threonine (Thr)
Hydrophilic, neutral



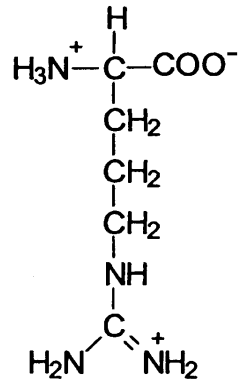
Histidine (His)
Hydrophilic



Lysine (Lys)
Hydrophilic, basic



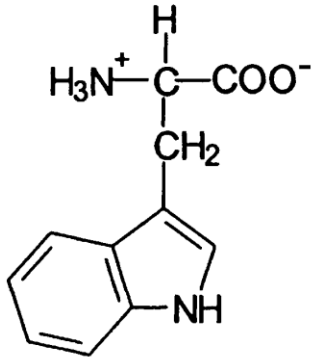
Arginine (Arg)
Hydrophilic, basic



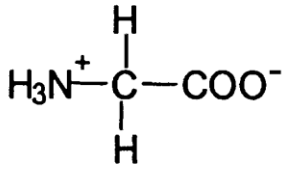
Non-polar Amino Acids – Hydrophobic/Amphophilic

polar water-soluble group attached to a water-insoluble hydrocarbon cha

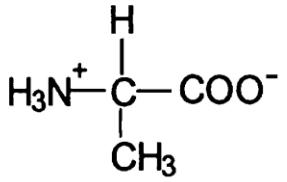
Tryptophan (Trp)
Amphiphilic



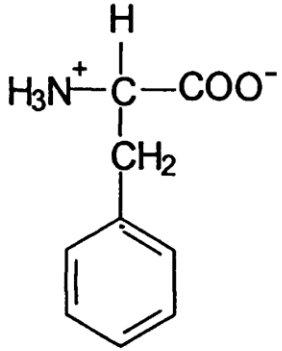
Glycine (Gly)
Amphiphilic



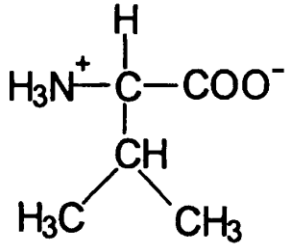
Alanine (Ala)
Amphiphilic



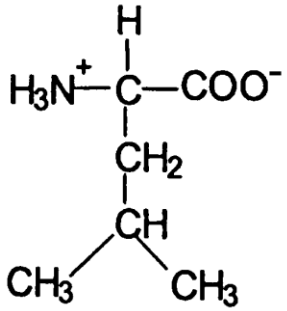
Phenylalanine (Phe)
Hydrophobic



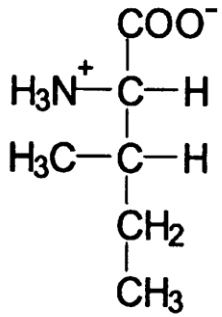
Valine (Val)
Hydrophobic



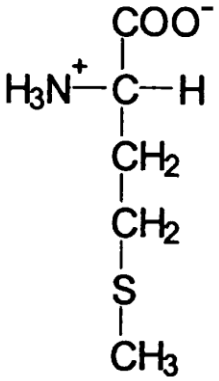
Leucine (Leu)
Hydrophobic



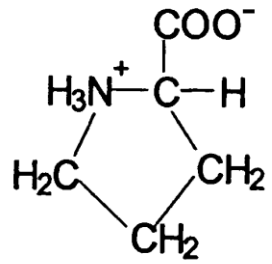
Isoleucine (Ile)
Hydrophobic



Methionine (Met)
Hydrophobic



Proline (Pro)
Hydrophobic



The order of hydrophilicity and hydrophobicity of various amino acids is as follows :

- Hydrophilic (= polar) amino acids :

  Tyr > Ser > Asp > Glu > Asn > Gln > Arg

- Hydrophobic (= apolar) amino acids :

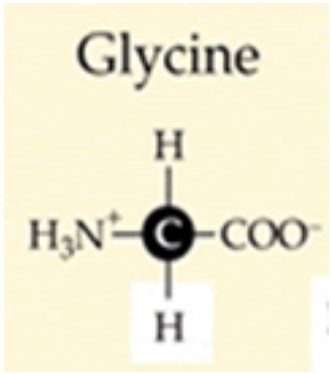
  Phe > Ala > Val > Gly > Leu > Cys

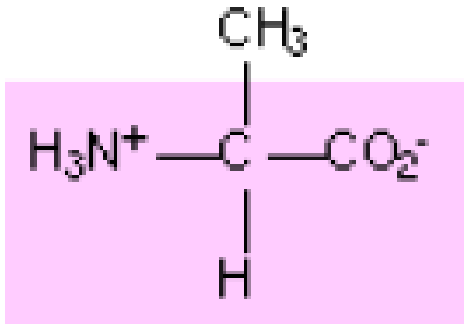
Based on the composition of the side chain

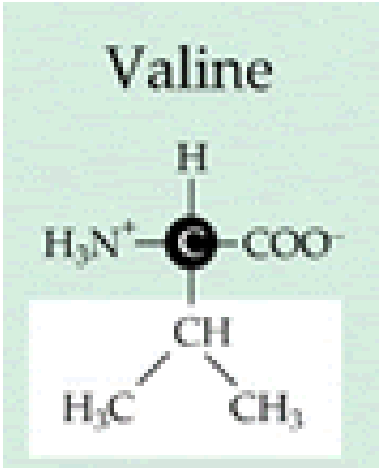
1. Simple amino acids
2. Hydroxy amino acids
3. Sulfur-containing amino acids
4. Acidic amino acids
5. Amide amino acids
6. Basic amino acids
7. Heterocyclic amino acids
8. Aromatic amino acids

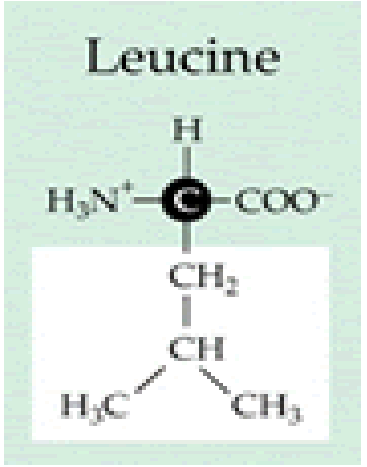
Simple amino acids:

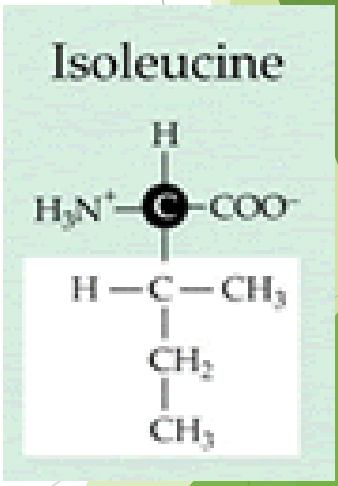
These have no functional group in the side chain, e.g., glycine, alanine, valine, leucine and isoleucine



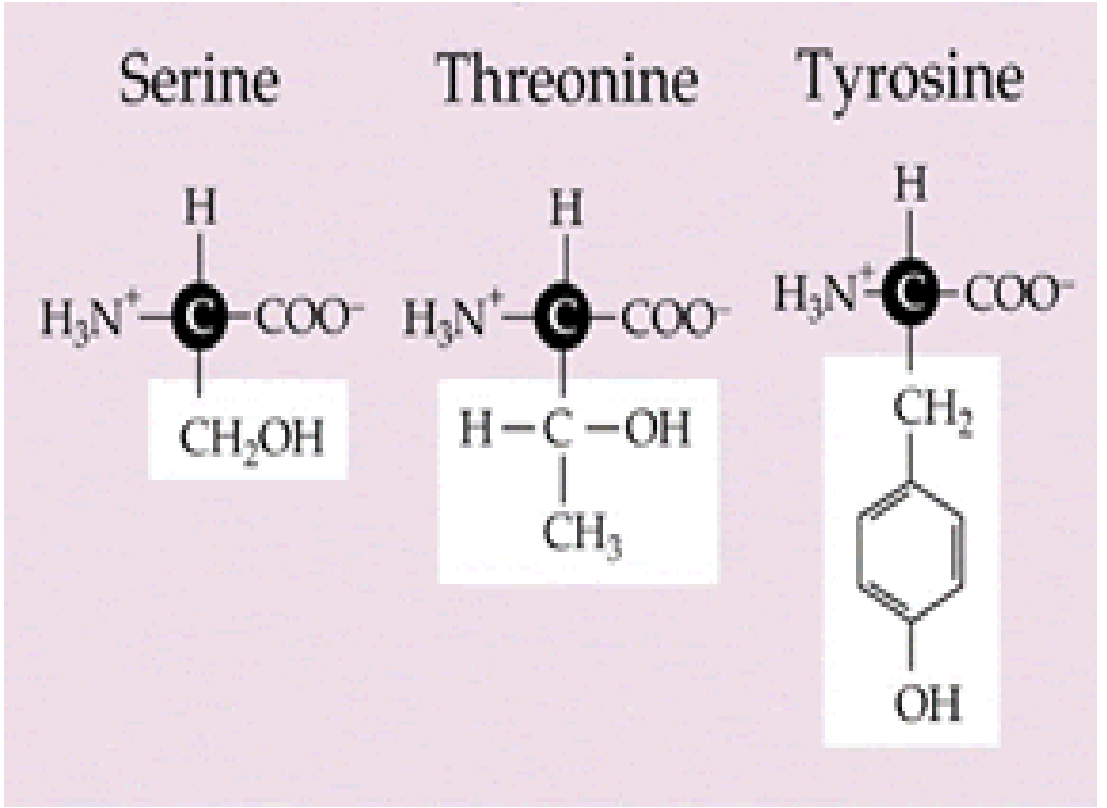






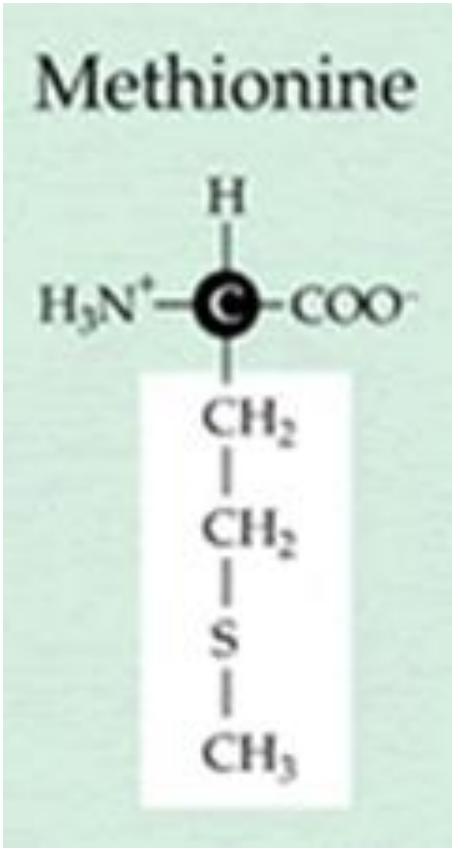


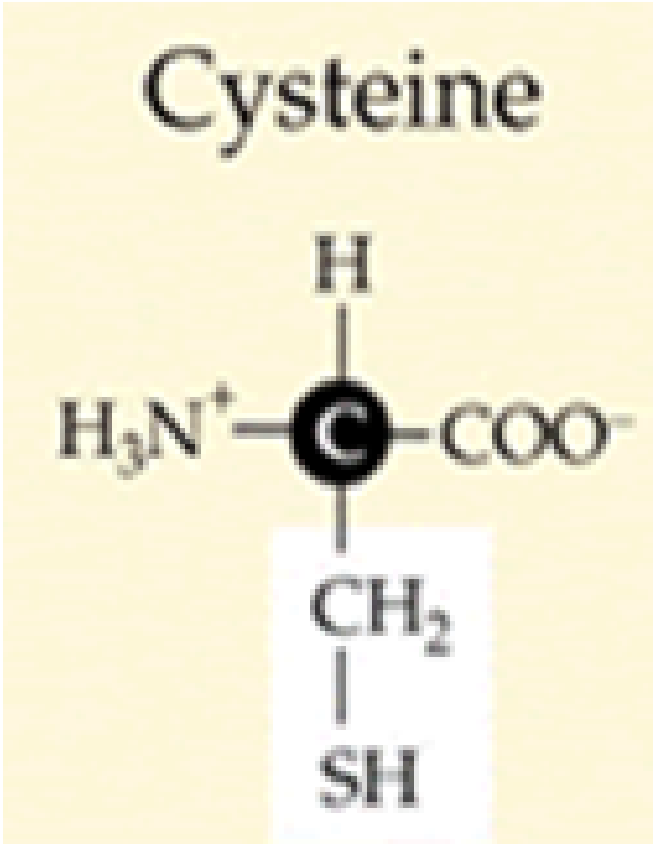
Hydroxylated amino acids



p-hydroxy phenylalanine

Sulfur-containing amino acids

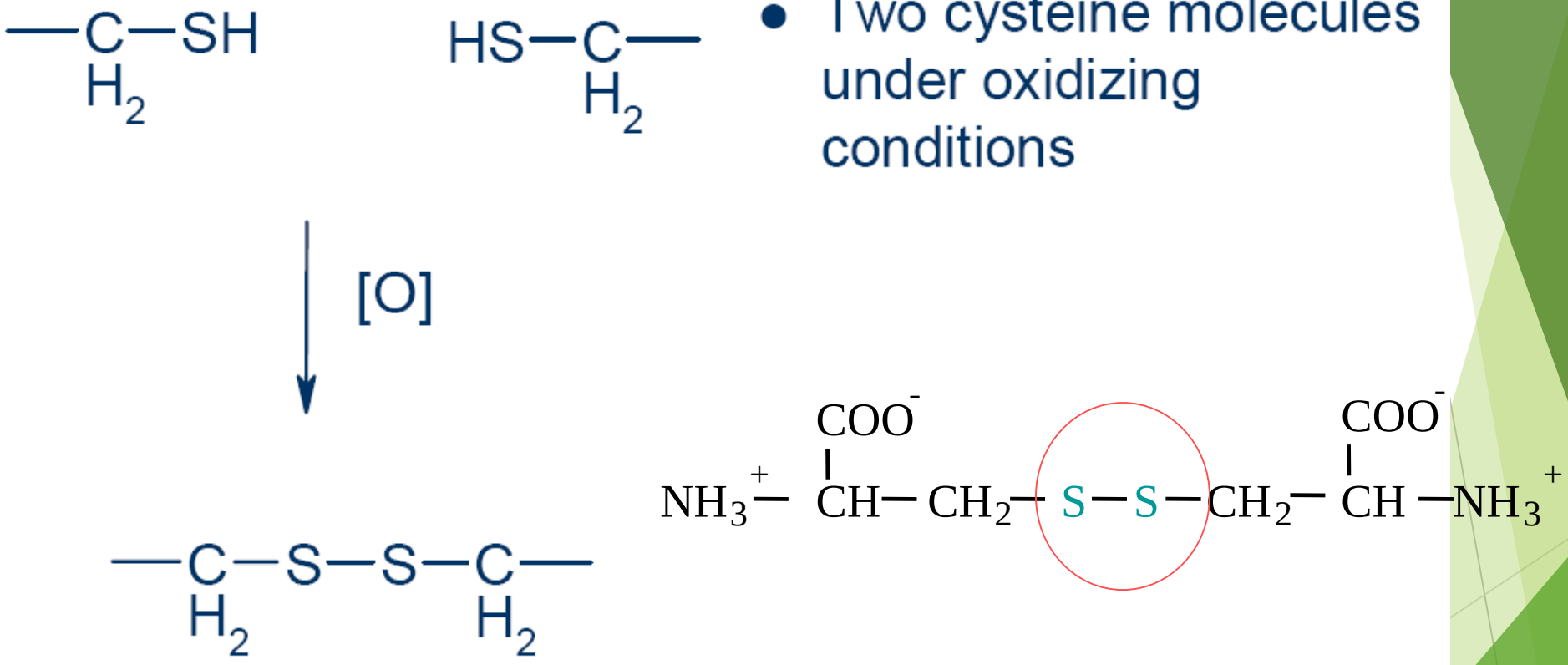




Met : methyl thioester group

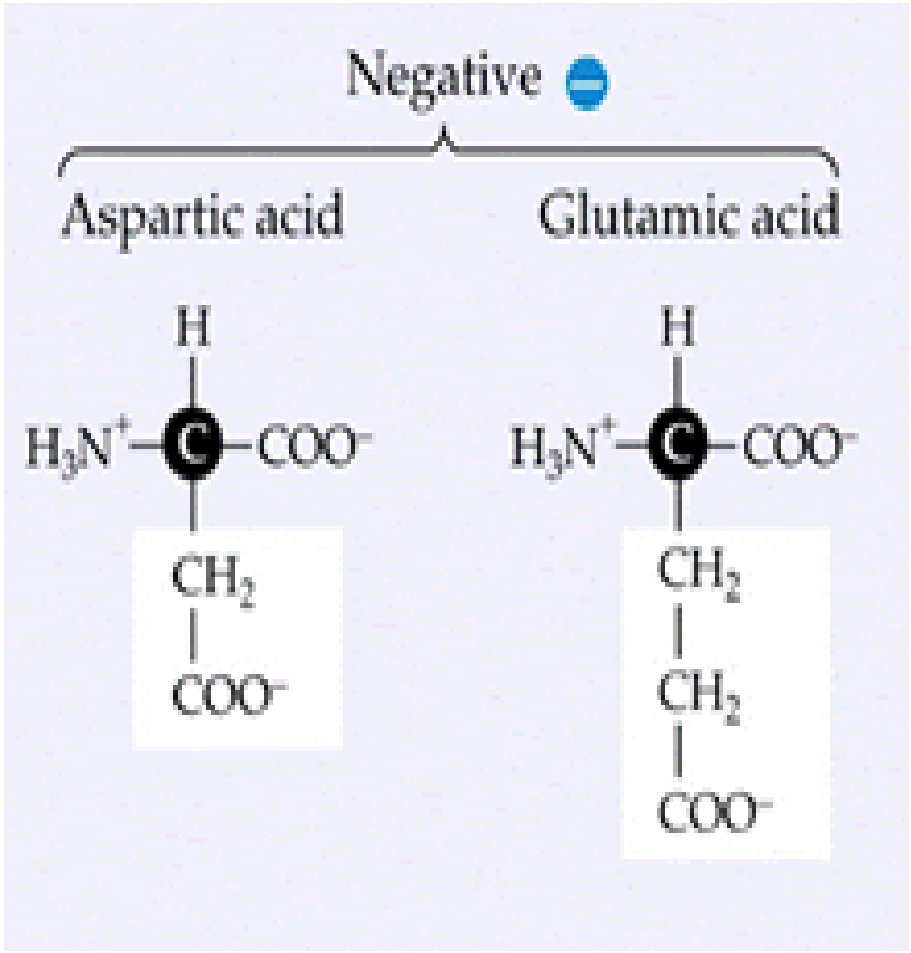
Sys : Cystine (disulfide bond)

در اثر دهیدروژناسیون به سیستین تبدیل می شود.



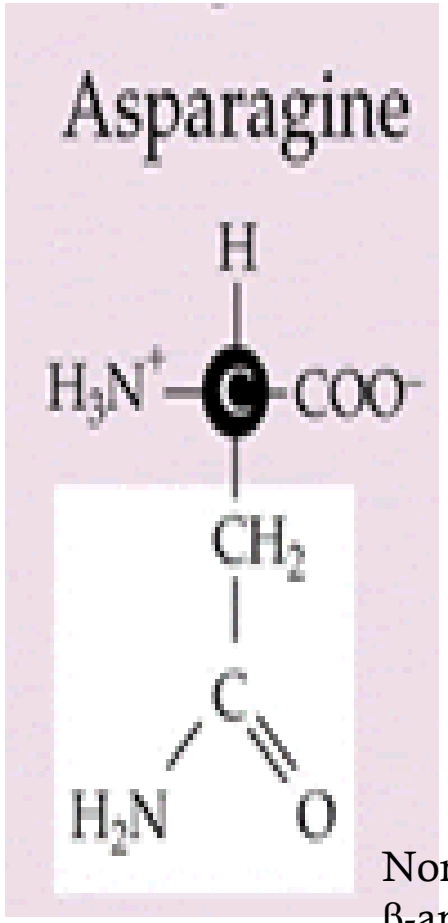
Acidic Amino acid

These have a carboxyl group in the side chain, e.g., aspartic acid and glutamic acid

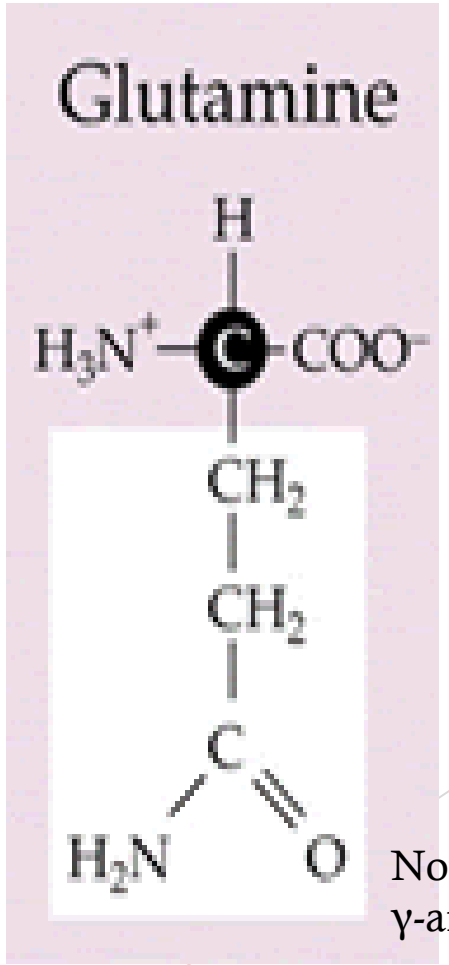


Amino acid amides

These are derivatives of acidic amino acids in which one of the carboxyl group has been transformed into an amide group (CO.NH 2), e.g., asparagine and glutamine.



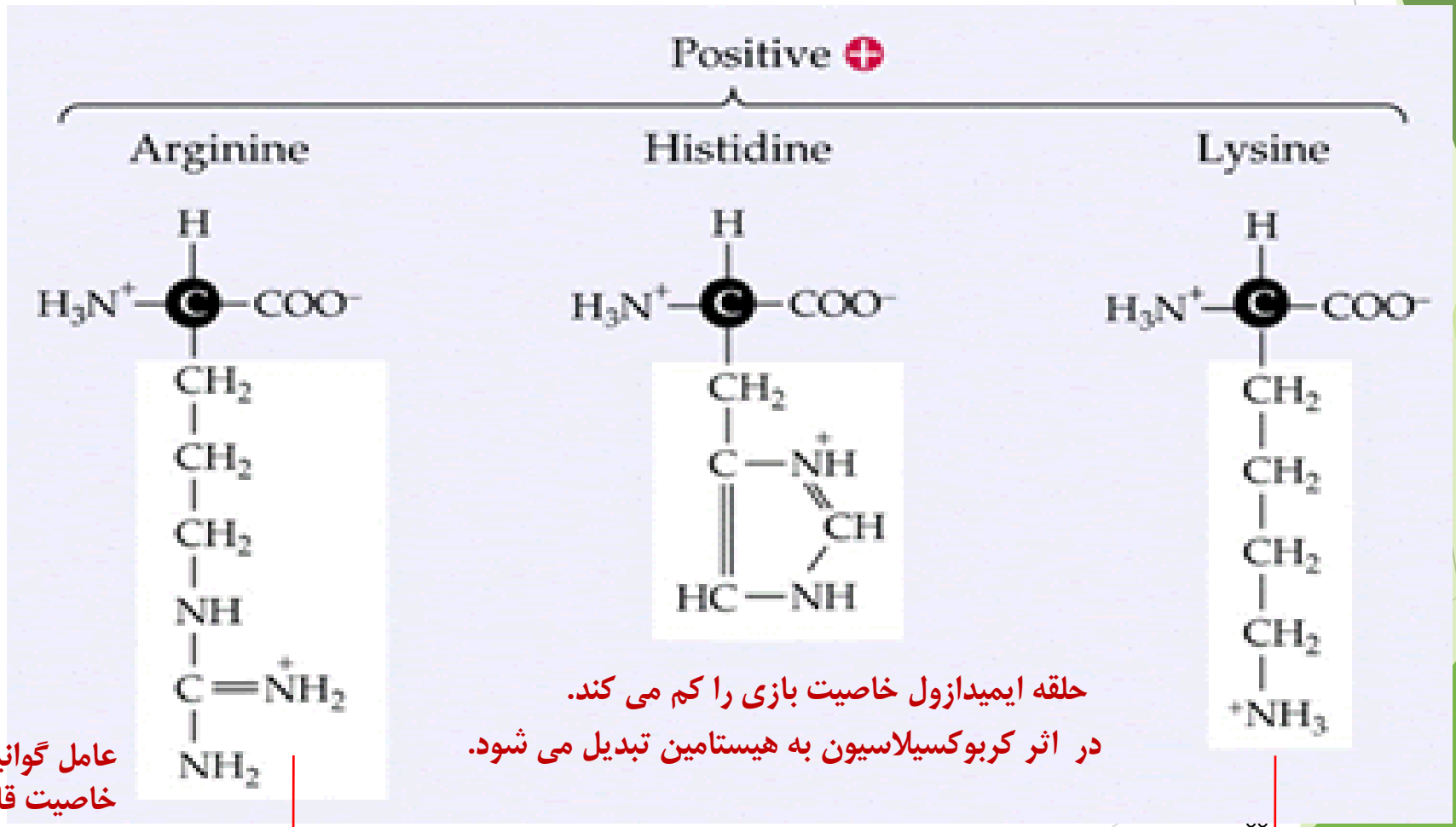
Nontitratable amide group
β-amide aspartic acid



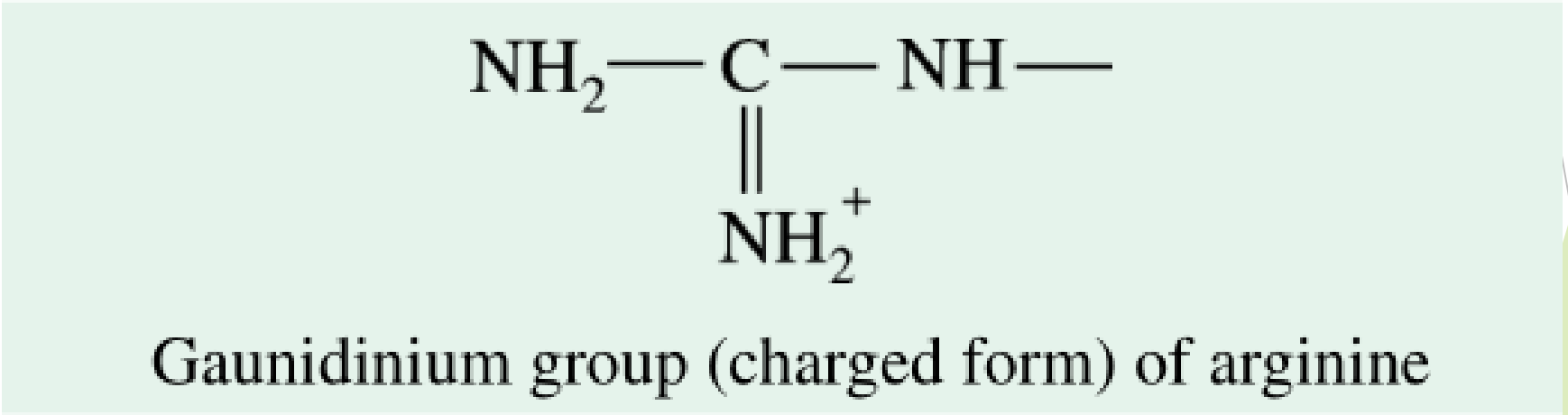
Nontitratable amide group
γ-amide glutamic acid

Basic amino acids

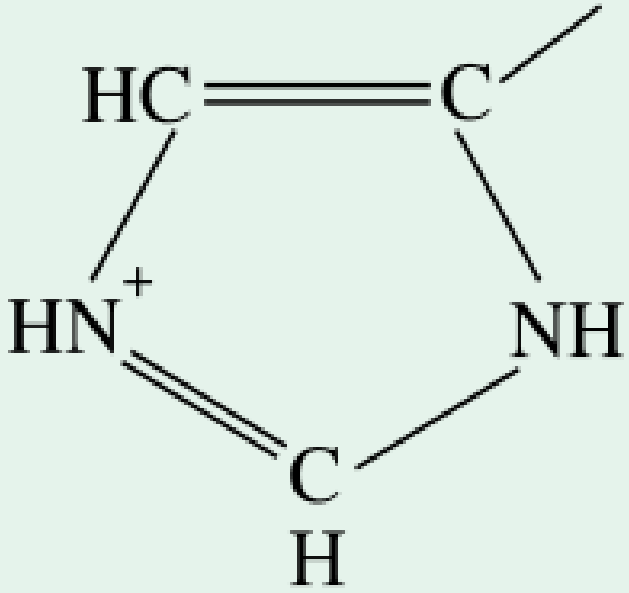
These possess an amino group in the side chain, e.g., lysine and arginine



Arginine is unique in possessing the guanidinium group, and due to which it is more strongly basic than lysine. Protonation of the guanidinium group provides ionic charges



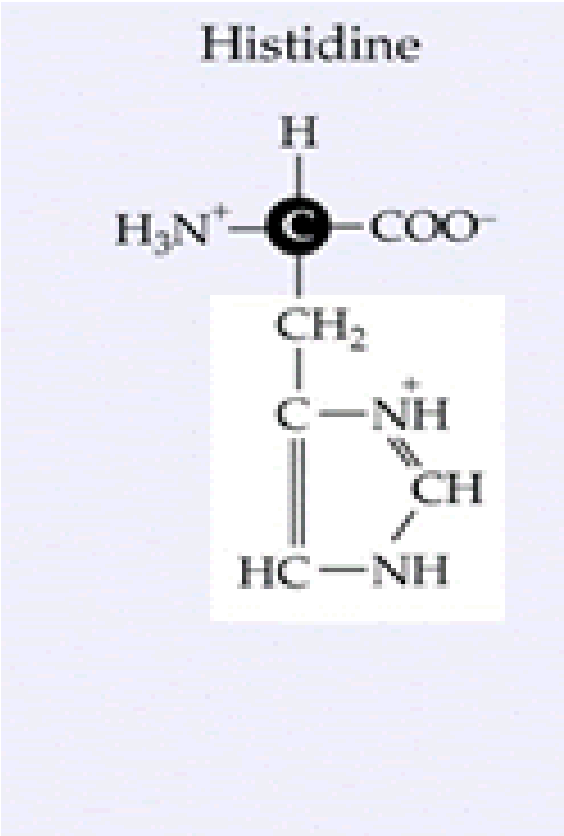
Gaunidinium group (charged form) of arginine

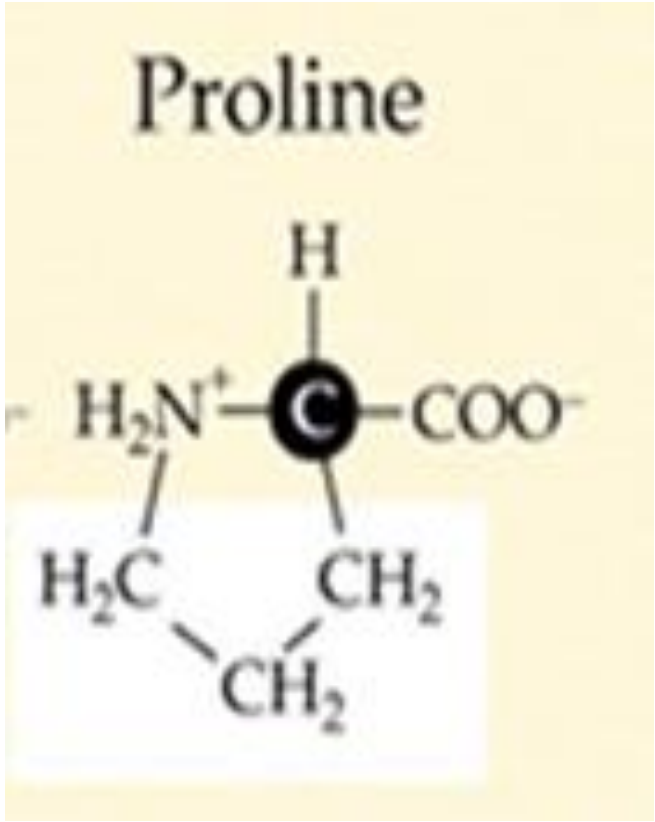


Imidazolium group (charged form) of histidine

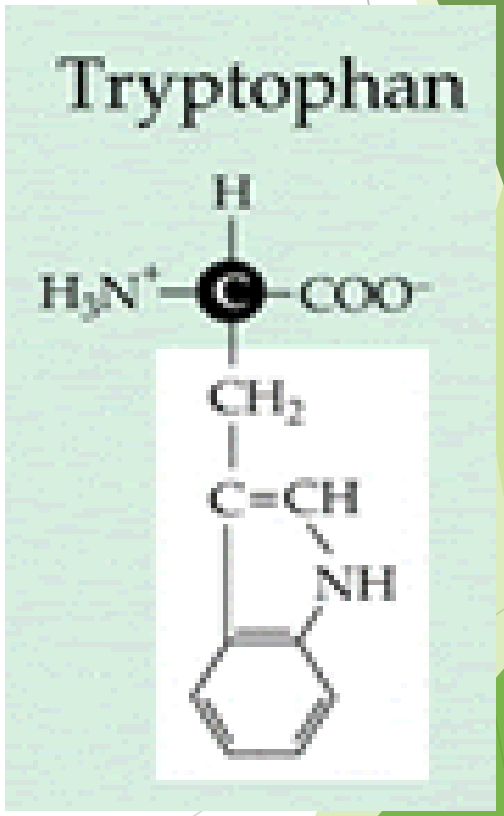
Heterocyclic amino acids

These amino acids have in their side chain a ring which possesses at least one atom other than the carbon, e.g., tryptophan, histidine and proline.





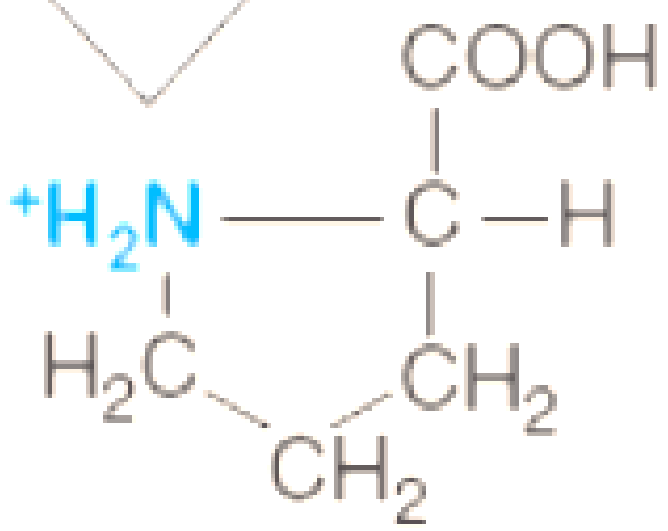
Imino acid
Pyrrolidine ring



bicyclic indole ring

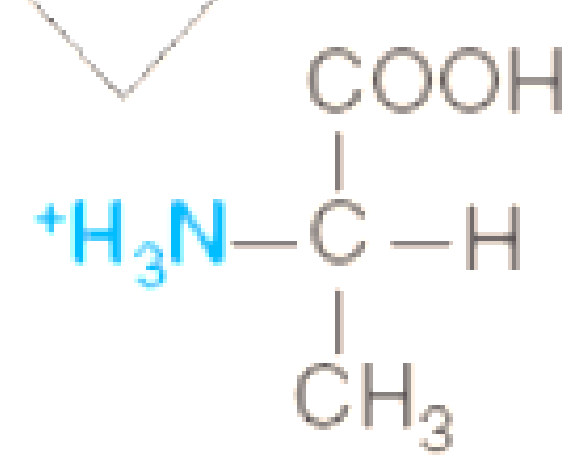
Bulky Amino Acid

Secondary amino group



Proline

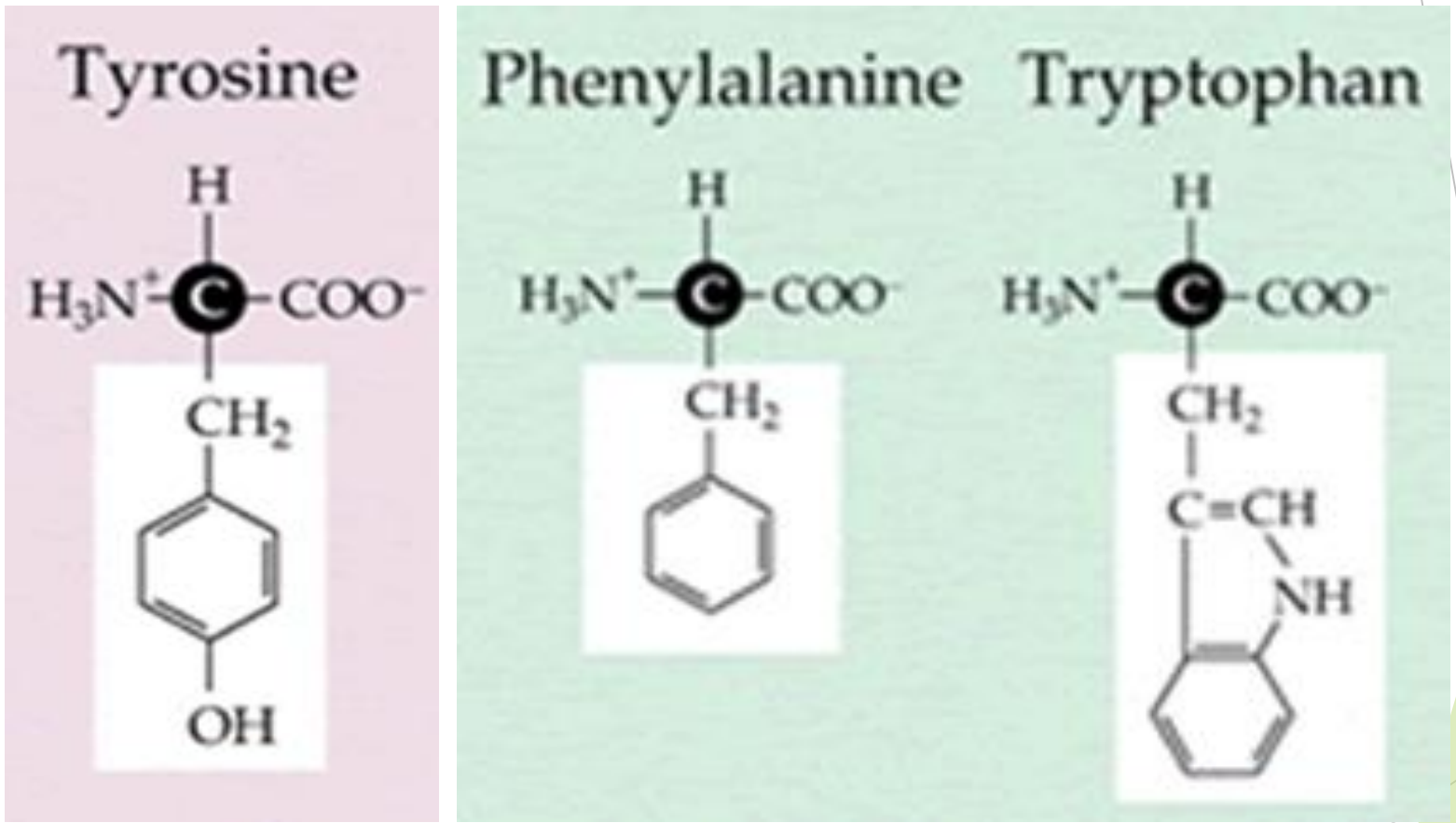
Primary amino group



Alanine

Aromatic amino acids :

These have a benzene ring in the side chain, e.g., phenylalanine and tyrosine.



Trp & Tyr : λ_m = 275 – 280 nm

Phe : λ_m = 260 nm

تقسیم بندی اسیدهای آمینه از نظر تغذیه ای

اسید های آمینه ضروری(اساسی)

- در بدن حیوانات تولید نمی شوند و لازم است از طریق رژیم غذایی وارد بدن شوند.
- لوسین- ایزولوسین- والین- فنیل آلانین- ترئونین- متیونین- تریپتوفان- لیزین
- هیستیدین برای نوزاد انسان و آرژنین برای نوزاد حیوانات اساسی است.

اسیدآمینه غیر ضروری

گلایسین- آلانین- پرولین - سرین و..... غیر از موارد بالا

- The pulse are notable as they lack S-containing amino acid, methionine (Met) but contain good amount of the basic amino acid, lysine (Lys); whereas cereals lack lysine but have sufficient quantity of methionine.

- When combined, these make good the deficiency of each other through mutual supplementation and are therefore better utilized in human body

- **On the basis of the number of amino and carboxylic groups**

I. Monoamino-monocarboxylic amino acids :

1. Unsubstituted ▫ Glycine Alanine, Valine, Leucine, Isoleucine
2. Heterocyclic ▫ Proline
3. Aromatic ▫ Phenylalanine, Tyrosine,Tryptophan
4. Thioether ▫ Methionine
5. Hydroxy ▫ Serine, Threonine
6. Mercapto ▫ Cysteine
7. Carboxamide ▫ Asparagine, Glutamine

II. Monoamino-dicarboxylic amnino acids : Aspartic acid, Glutamic acid

III. Diamino-monocaryboxylic amino acids : Lysine, Arginine, Histidine

Some properties associated with the standard amino acids

The dissociable α-COOH and α-NH 3 + groups are responsible for the two characteristic:

pK values (pK 1 for —COOH and pK 2 for —NH 3 +) of α-amino acids.

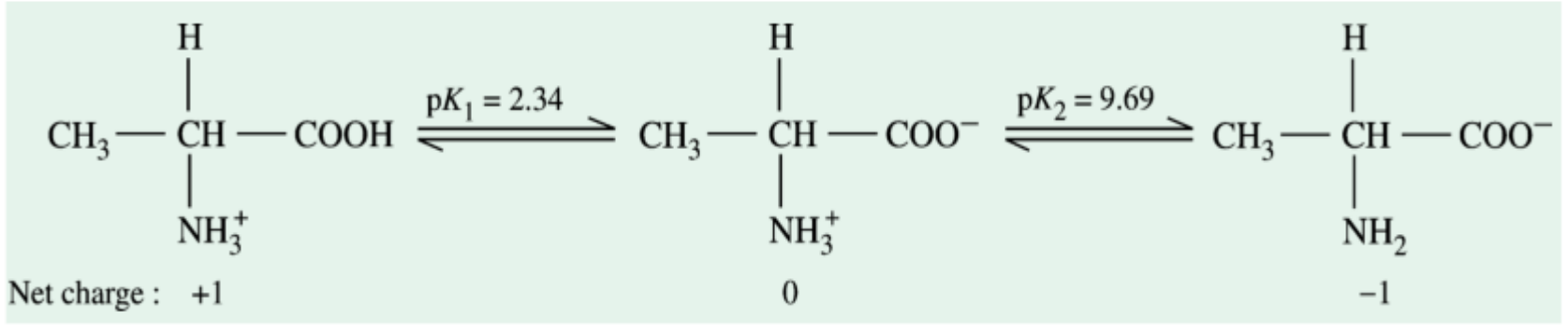
An amino acid with a third dissociable group in its side chain (i.e., R group) exhibits an additional pK R value.

Amino acid	*Mr*	pK_1 (—*COOH*)	pK_2 (—NH_3^+)	p*KR* (*R group*)	*pI*	*Hydropathy index**	*Occurrence in proteins (%)†*
Nonpolar R groups							
Alanine	89	2.34	9.69		6.01	1.8	9.0
Valine	117	2.32	9.62		5.97	4.2	6.9
Leucine	131	2.36	9.60		5.98	3.8	7.5
Isoleucine	131	2.36	9.68		6.02	4.5	4.6
Proline	115	1.99	10.96		6.48	– 1.6	4.6
Phenylalanine	165	1.83	9.13		5.48	2.8	3.5
Tryptophan	204	2.38	9.39		5.89	– 0.9	1.1
Methionine	149	2.28	9.21		5.74	1.9	1.7
Polar, uncharged R groups							
Glycine	75	2.34	9.60		5.97	– 0.4	7.5
Serine	105	2.21	9.15	13.60	5.68	–0.8	7.1
Threonine	119	2.11	9.62	13.60	5.87	– 0.7	6.0
Tyrosine	181	2.20	9.11	10.07	5.66	– 1.3	3.5
Cysteine	121	1.96	8.18	10.28	5.07	2.5	2.8
Asparagine	132	2.02	8.80		5.41	– 3.5	4.4
Glutamine	146	2.17	9.13		5.65	– 3.5	3.9
Negatively-charged R groups							
Aspartate	133	1.88	9.60	3.65	2.77	– 3.5	5.5
Glutamate	147	2.19	9.67	4.25	3.22	– 3.5	6.2
Positively-charged R groups							
Lysine	146	2.18	8.95	10.53	9.74	– 3.9	7.0
Arginine	174	2.17	9.04	12.48	10.76	– 4.5	4.7
Histidine	154	1.82	9.17	6.00	7.59	– 3.2	2.1

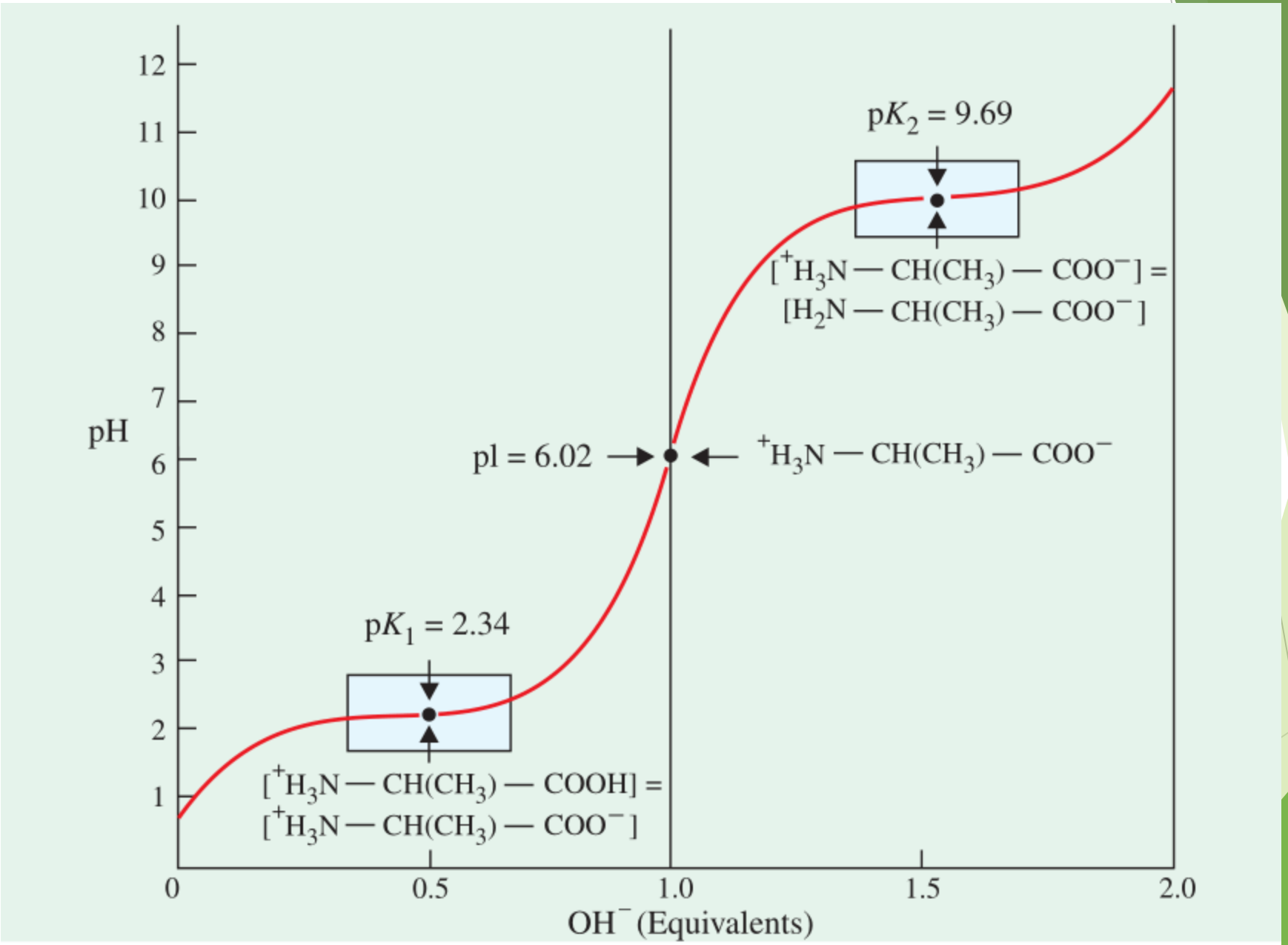
* A scale combining hydrophobicity and hydrophilicity ; can be used to predict which amino acid will be found in an aqueous environment (-values) and which will be found in a hydrophobic environment (+ values).

† Average occurrence in over 200 proteins

Note that in nature, the commonest amino acid is alanine and the rarest amino acid is tryptophan.

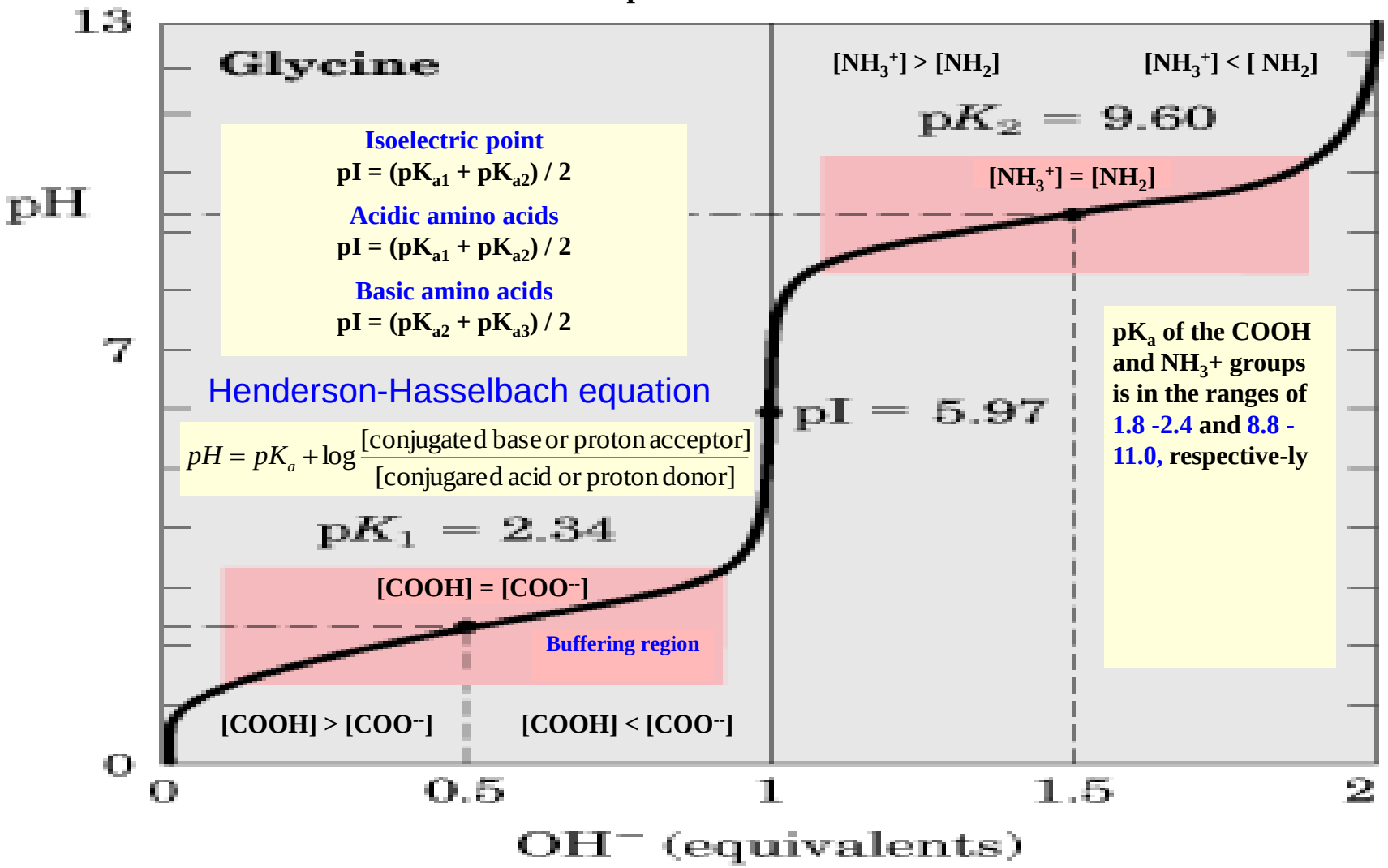


The two dissociations of L-alanine



The titration curve of alanine

Dipolar ion or zwitterion



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

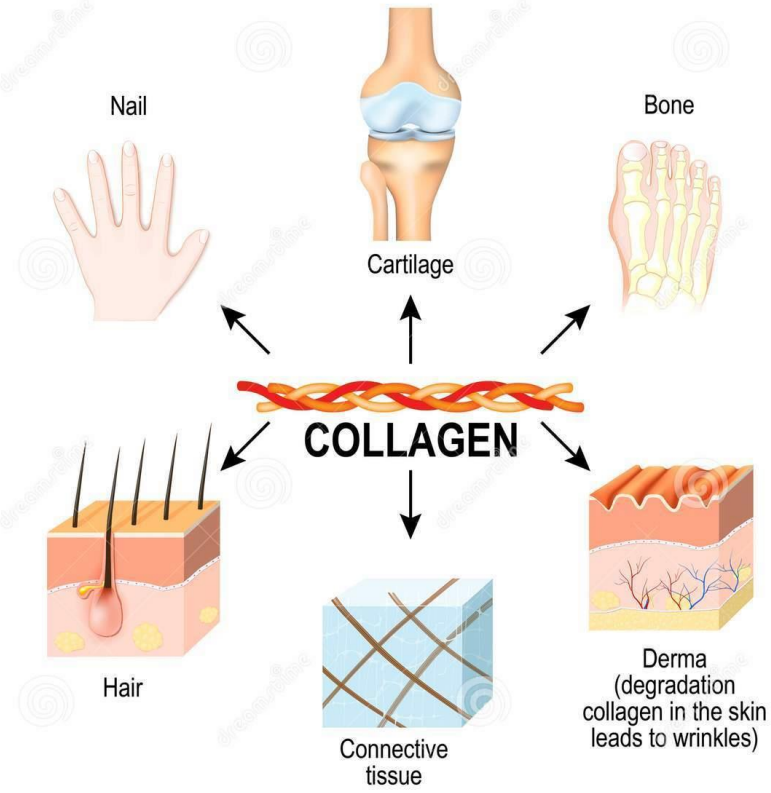
Non-standard (Rare) Protein Amino Acids

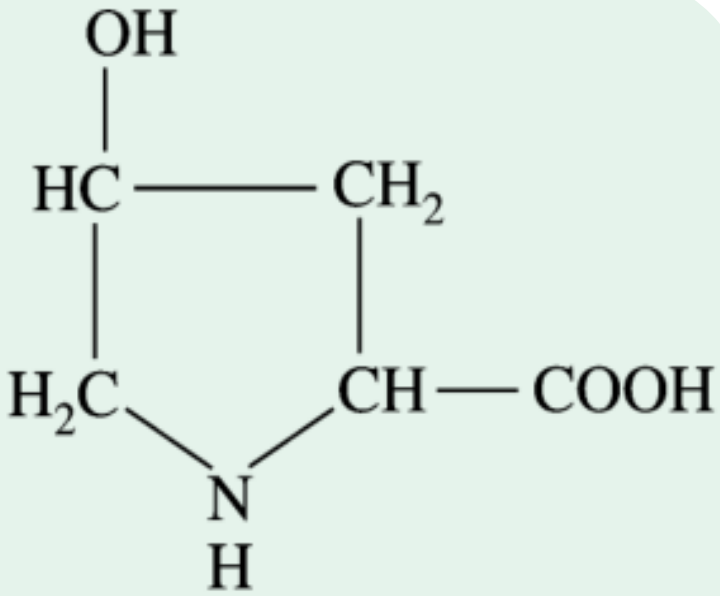
Proteins Classification

Non-standard Protein Amino Acids

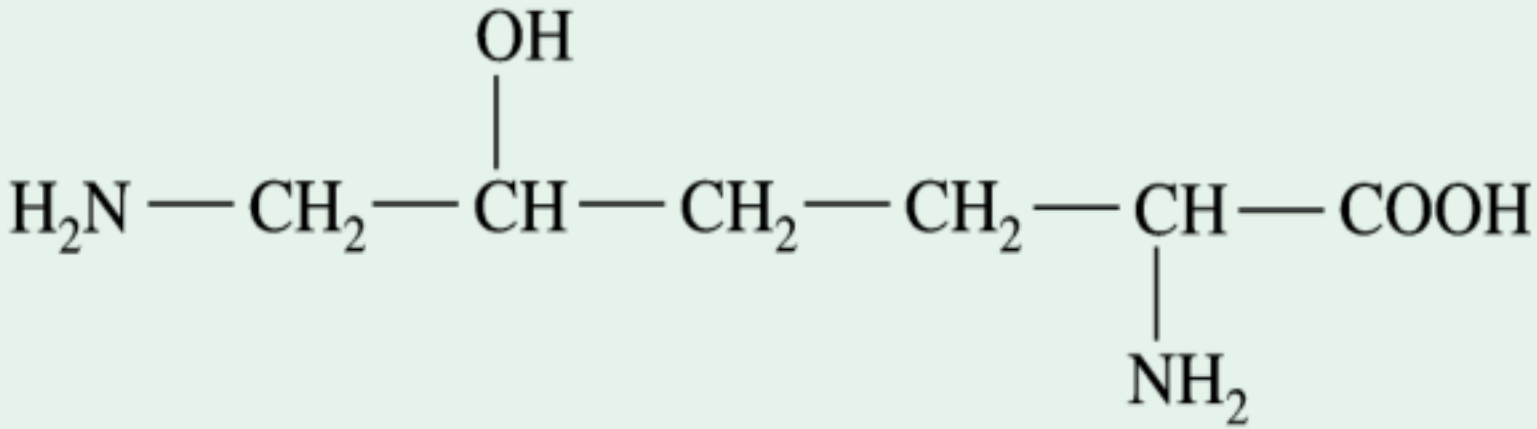
- These have a limited distribution but may be present in high amounts in a few proteins and hence deserve mention
- Hydroxyproline has a limited distribution in nature but constitutes as much as 12% of the composition of collagen, an important structural protein of animals.

- Hydroxylysine is also a component of collagen, where it accounts for about 1% of the total amino acids





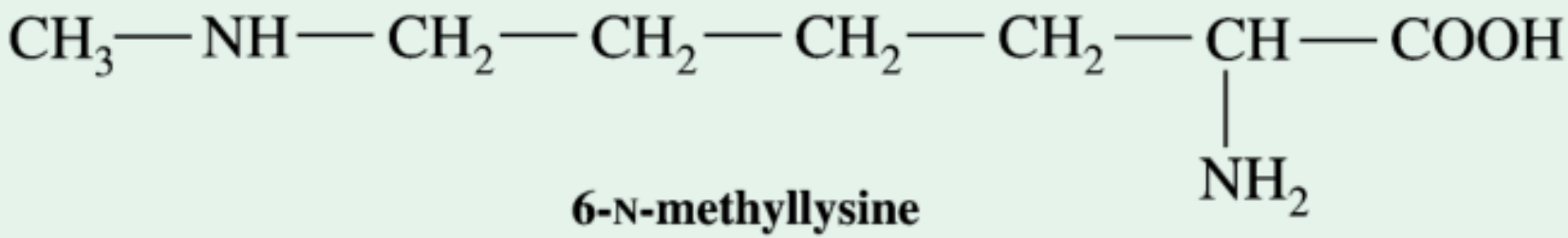
L-hydroxyproline
(erythro-4-hydroxy-L-proline)



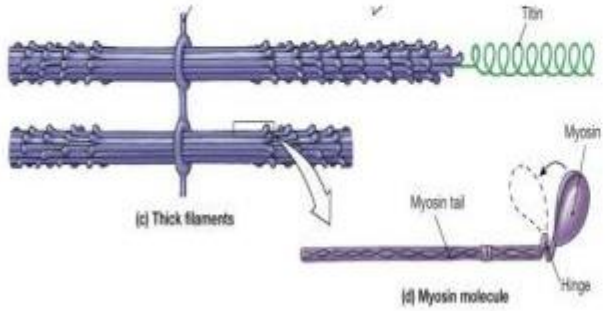
L-hydroxylysine
(erythro-5-hydroxy-L-lysine)

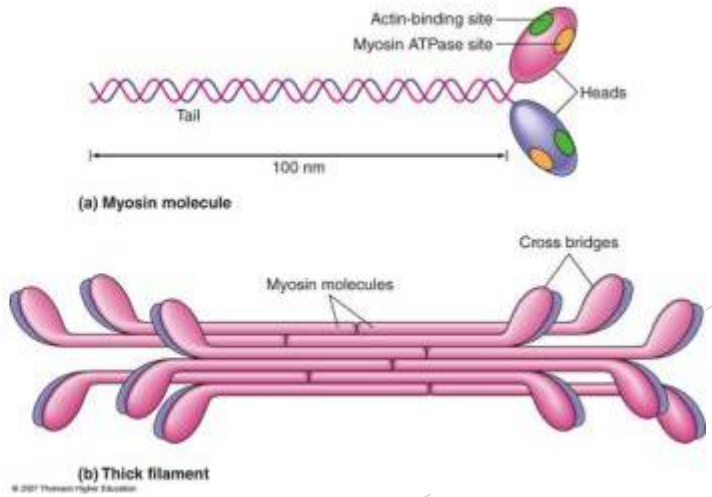
Non-standard Protein Amino Acids

- N-methyllysine is found in myosin, a contractile protein of muscle.



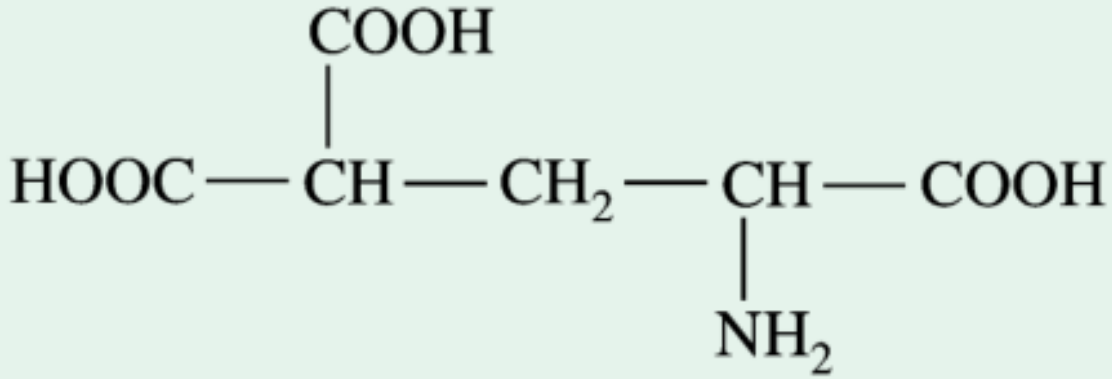
6-N-methyllysine





Non-standard Protein Amino Acids

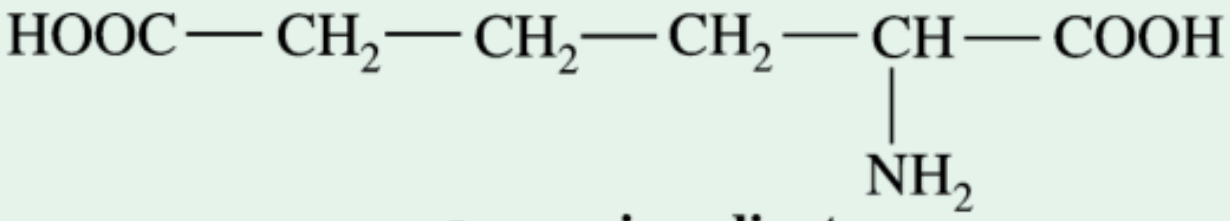
- γ-carboxyglutamate is found in the blood-clotting protein, prothrombin as well as in certain other proteins that bind Ca 2+ in their biological function.



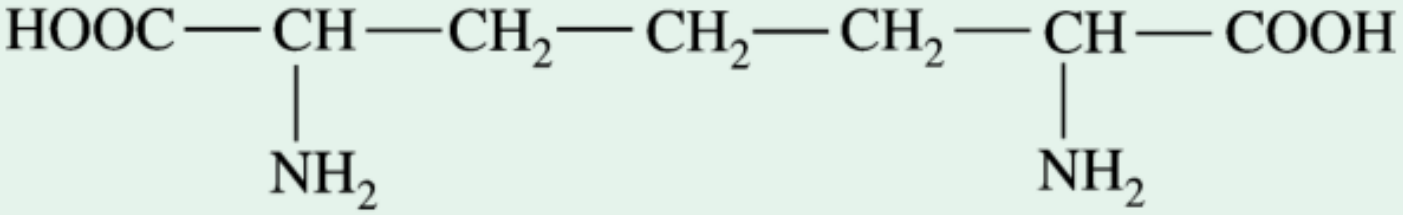
γ-carboxyglutamate

Non-standard Protein Amino Acids

In protein from corn, **α-aminoadipate** has been detected. It has one CH_2 group more than glutamic acid. Another amino acid, **α-ε-diaminopimelate** has been found in bacterial protein.



L-α-aminoadipate



L, L-α, ε-diaminopimelate

Non- Protein Amino Acids

Non- Protein Amino Acids

- There are some 300 additional amino acids which are never found as constituents of proteins but which either play metabolic roles or occur as natural products.
- Among the important nonprotein amino acids, which play metabolic roles, are L -ornithine, L -citrulline, β-alanine, creatine and γ-aminobutyrate.

- L-ornithine and L-citrulline occur in free state in the animal tissues and are metabolic intermediates in the urea cycle. L -ornithine possesses one CH 2 group less than its homologue, lysine.
- β-alanine, an isomer of alanine, occurs free in nature and also as a constituent of an important vitamin pantothenic acid and of coneyzme.

Non- Protein Amino Acids

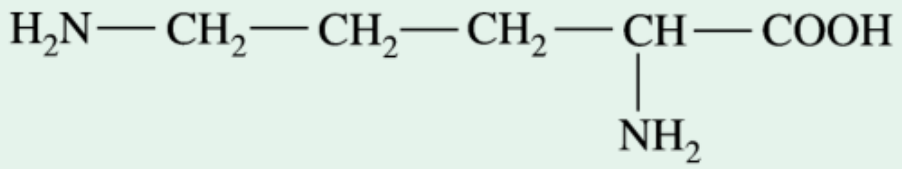
- β-alanine, an isomer of alanine, occurs free in nature and also as a constituent of an important vitamin pantothenic acid and of coneyzme A. It is also found in the naturally occurring peptides, carnosine and anserine

Non- Protein Amino Acids

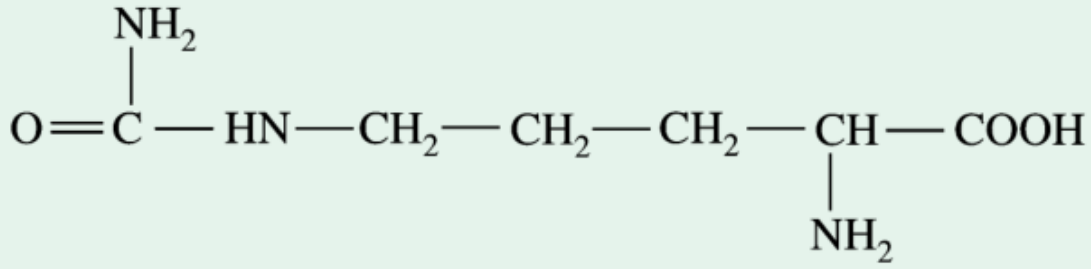
- The quaternary amine creatine, a derivative of glycine, plays an important role in the energy storage process in vertebrates where it is phosphorylated and converted to creatine phosphate.

- γ-aminobutyrate is found in free form in the brain.

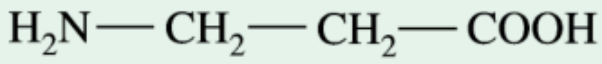
Non- Protein Amino Acids



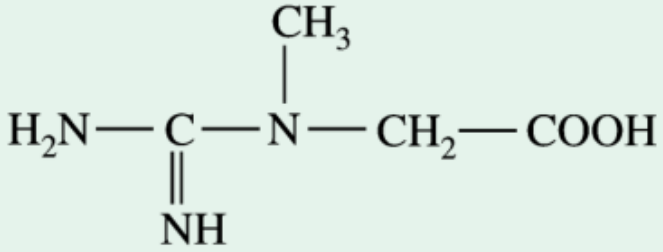
L-ornithine



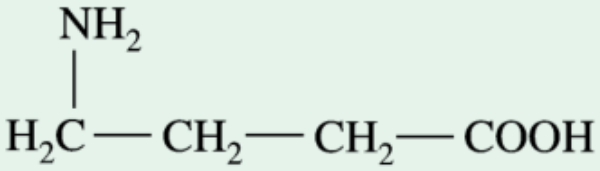
L-citrulline



β-alanine



Creatine



γ-aminobutyrate

Non- Protein Amino Acids

- Higher plants are especially rich in nonprotein amino acids. These nonprotein amino acids are usually related to the protein amino acids as homologues or substituted derivatives.
- They have a limited distribution, sometimes to a single species even.
- Thus, L -azetidine-2-carboxylic acid, a homologue of proline, accounts for 50% of the nitrogen present in the rhizome of *Solomon's seal*, *Polygonatum multiflorum*.

- Orcylalanine is found in the seed of *cornocockle*, *Agrostemma githago*. It may be considered as a substituted phenylalanine.

- Furthermore, in the toxic polypeptides of *Amanita phalloides*, in addition to hydroxyleucine, allo-threonine is also found.

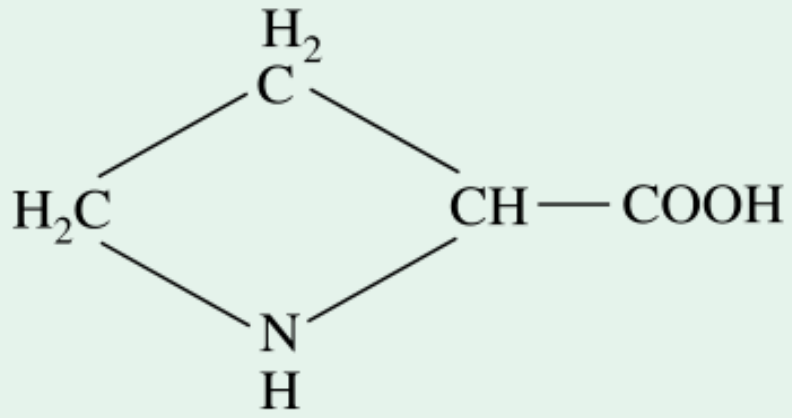
Solomon's seal

مُهر سلیمان (همچنین: شقاقل ایرانی، هزارگره، خاتَم سُلیمان، عقداء، ساژَینای خمیده) [1] (نام علمی: ***Polygonatum***نام یک سرده از گیاهان گلدار است. قسمت زیرزمینی این گیاه شامل یک ریزوم افقی بلند و گوشت دارست که اثر زخم ساقه های این بین رفته سالیان قبل در روی آن مشخص‌است

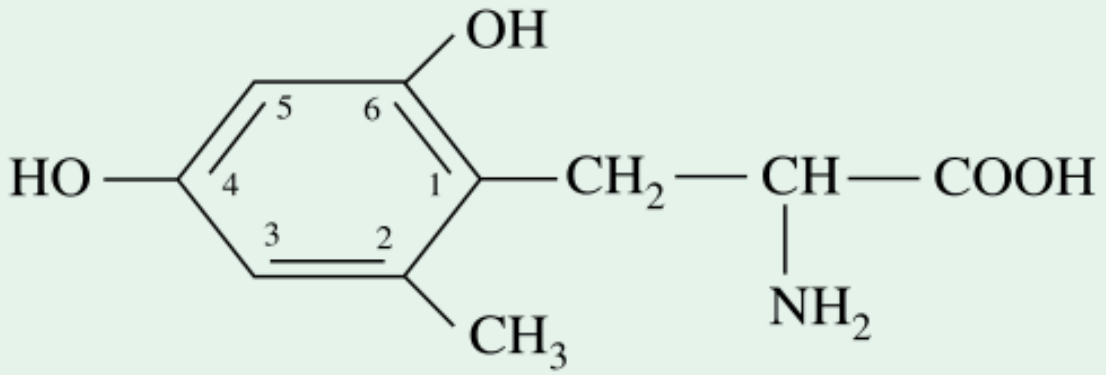
سیاه دانه (Agrostemma githago

قارچ مگس یا آمانیتا موسکاریا (نام علمی: *Amanita muscaria*) یک گونه قارچ سمی

Non- Protein Amino Acids



L-azetidine-2-carboxylic acid



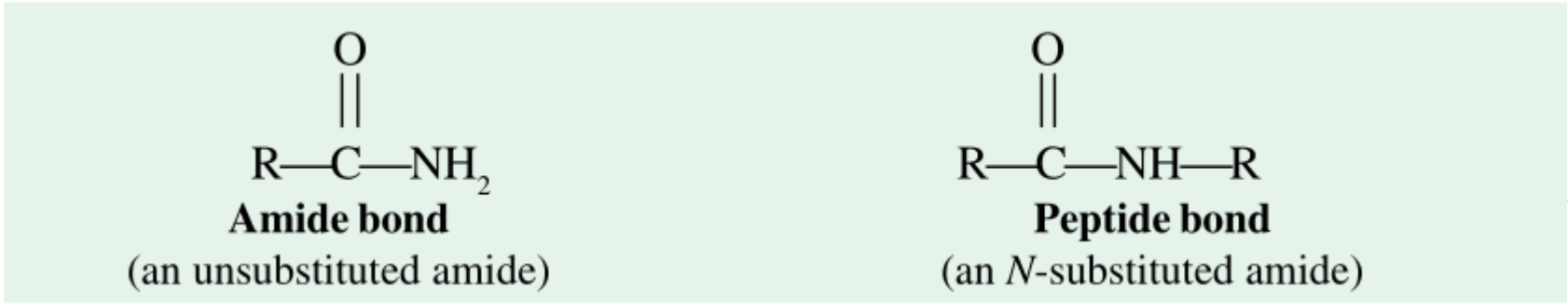
Orcyl-L-alanine
(4, 6-dihydroxy-2-methyl phenyl–L-alanine)

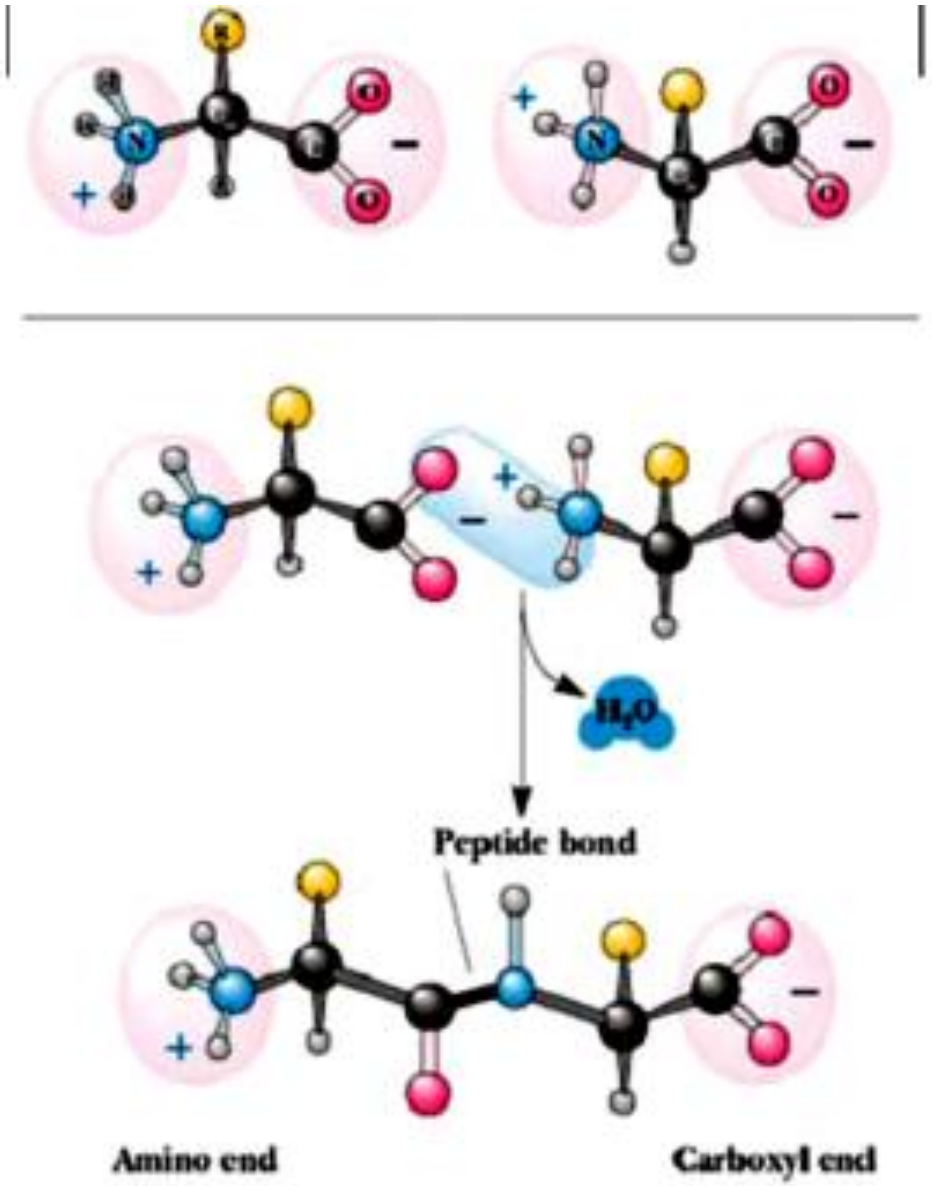
Peptides

Peptides

- The amino acid units are linked together through the carboxyl and amino groups to produce the primary structure of the protein chain.

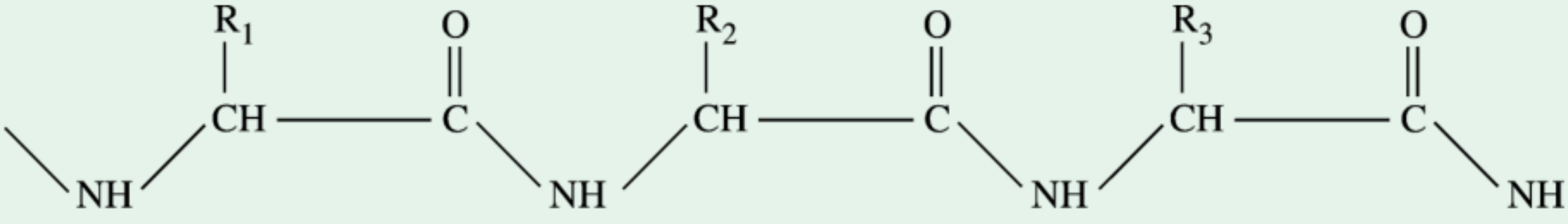
- The bond between two adjacent amino acids is a special type of amide bond, in which the hydrogen atom of amino (-NH 2) group is replaced by an R radical.
- Such a substituted amide bond is known as the peptide bond. And the chain, thus formed, by linkingtogether of many amino acid units is called a peptide chain



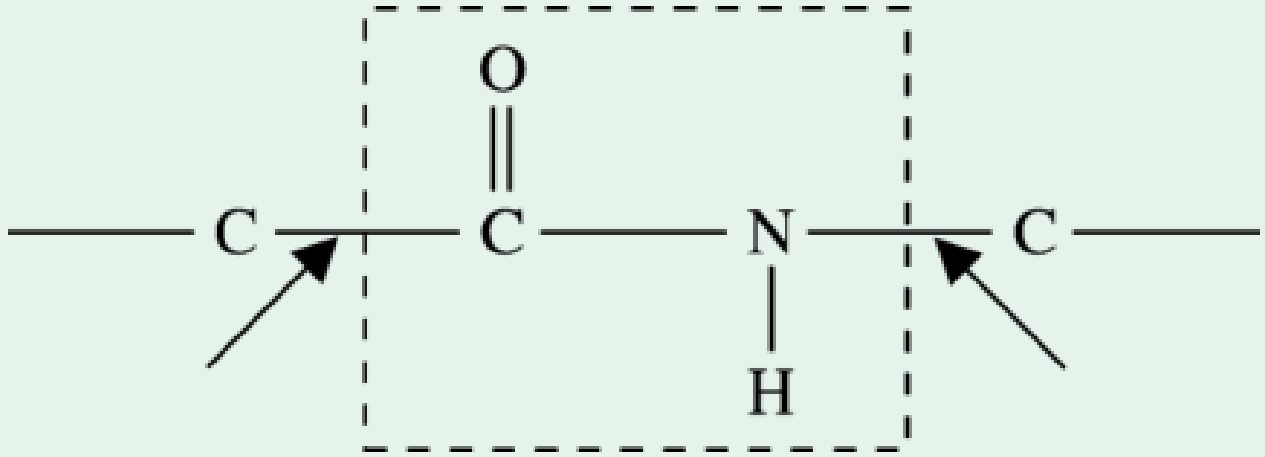


پیوند پپتیدی

Peptide chain



Peptide bond



The peptide bond is shown enclosed in the dashed box. The four atoms (C, O, N, H) of the peptide bond form a rigid planar unit.

There is no freedom of rotation about the C□N bond. On the contrary, the 2 single bonds (shown with arrows) on either side of the rigid peptide unit, exhibit a high degree of rotational freedom.

- 20 amino acids
- 1 – 10 : oligopeptide
  - or peptides
  - di, tri, …peptide
- 10 – 50 : polypeptide

  Sometimes, the word ‘proteinoids’ is used for short polypeptides containing up to 18 amino acids (Fried GH, 1990).
- > 50 : protein (> 5000 D)

  Polypeptides when they are made up of over 100 amino acids are, sometimes, called as macropeptides.

Peptides

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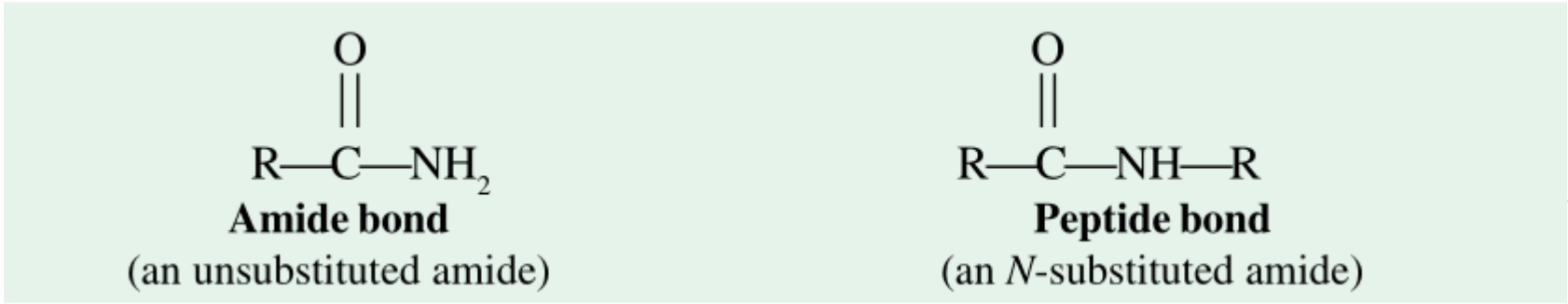
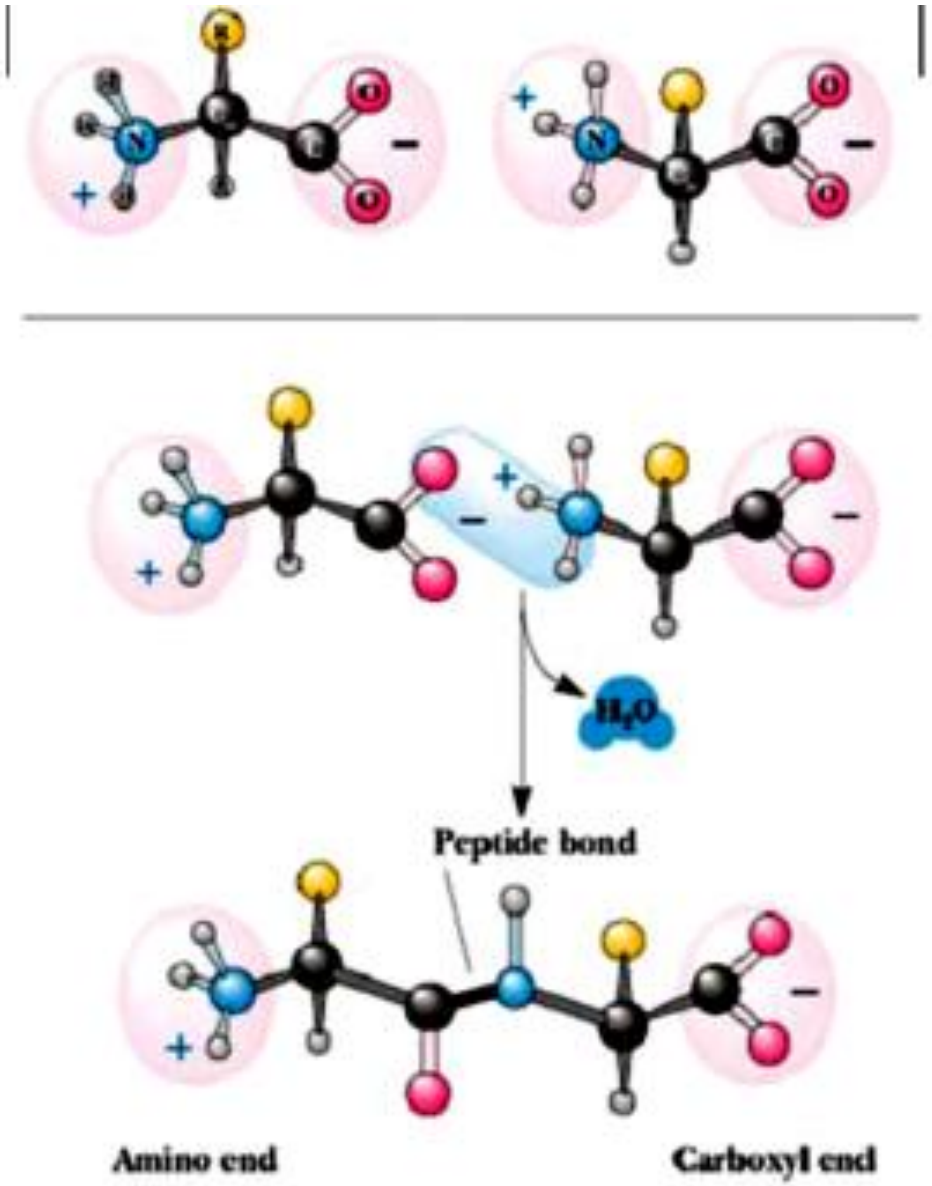
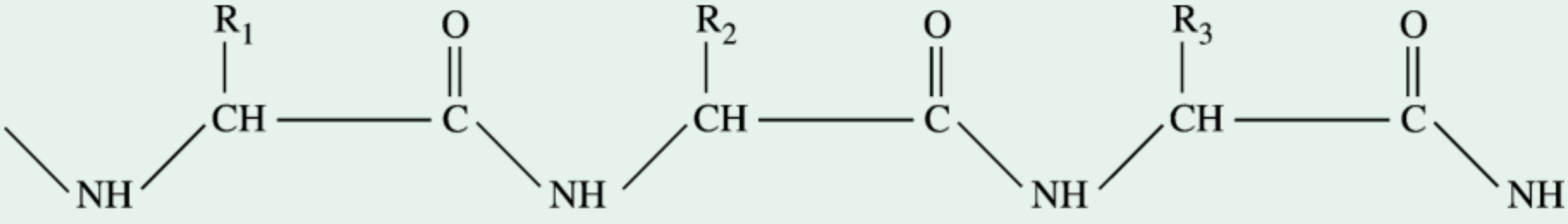


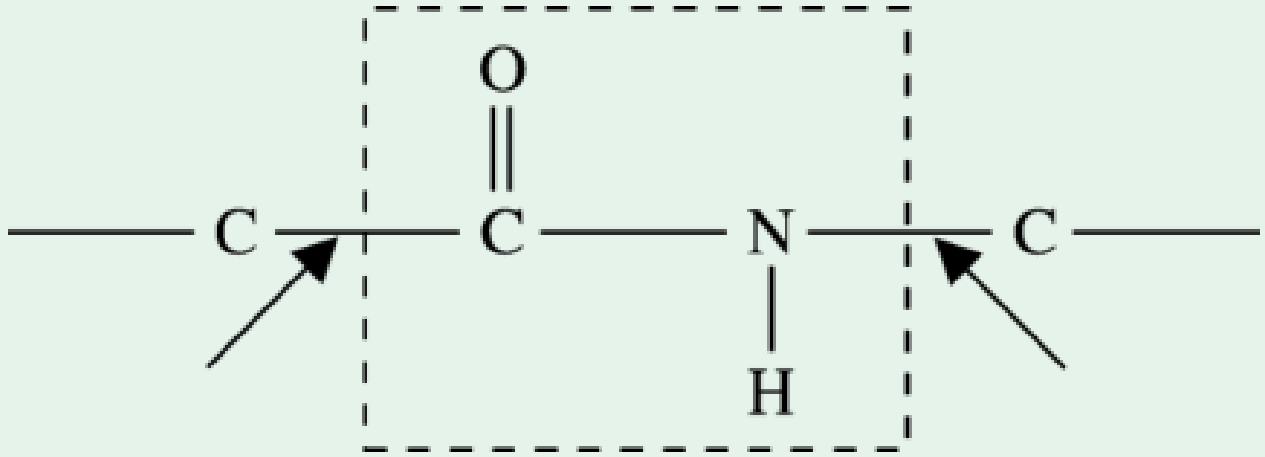


پیوند پپتیدی

Peptide chain



Peptide bond



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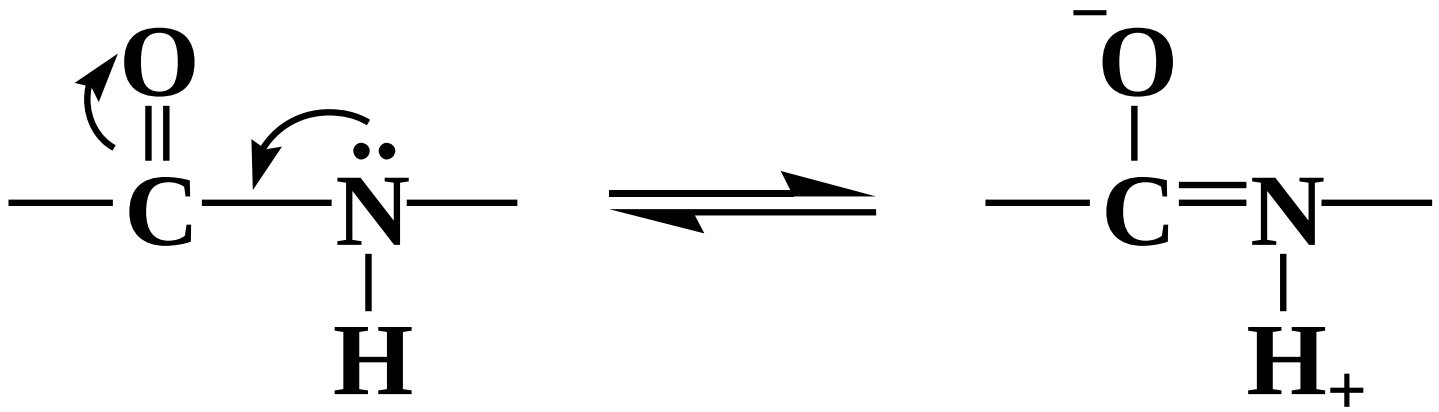
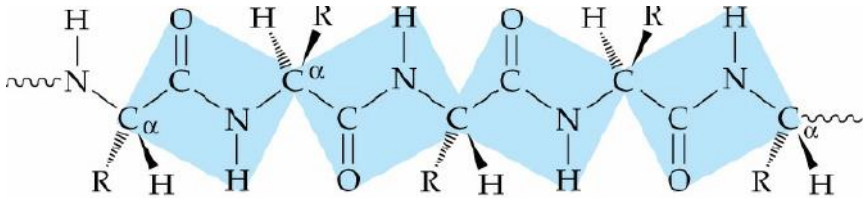
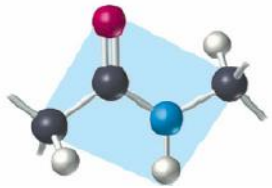
پیوندهای پپتیدی بسیار پایدار بوده ، از نوع ترانس هستند و براحتی هیدرولیز نمی شوند. پیوند کربن –نیتروژن در آنها بدلیل رزونانس الکترونی تا ۴۰٪ دارای خواص پیوندهای دوگانه می باشند.







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  - di, tri, …peptide
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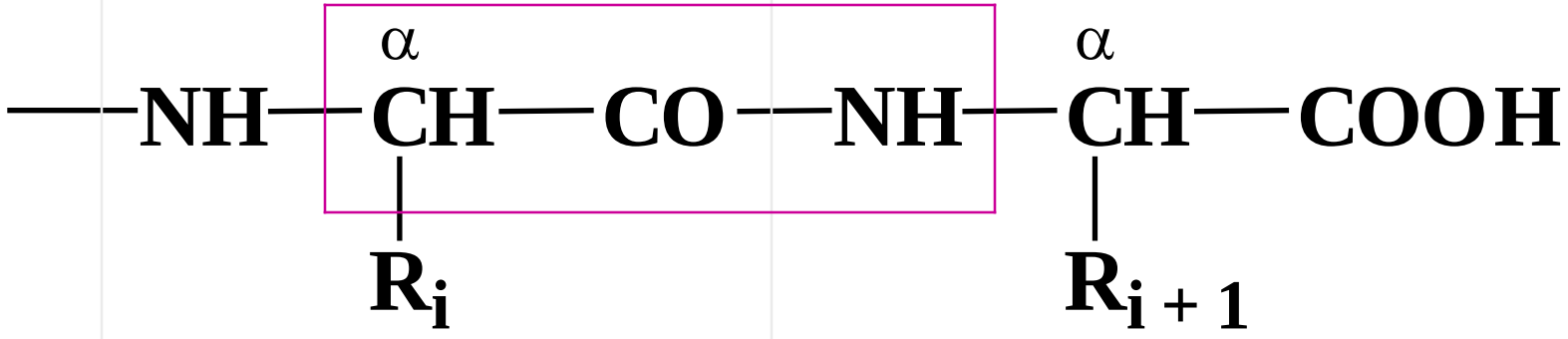
  Sometimes, the word ‘proteinoids’ is used for short polypeptides containing up to 18 amino acids (Fried GH, 1990).
- > 50 : protein (> 5000 D)

  Polypeptides when they are made up of over 100 amino acids are, sometimes, called as macropeptides.

- Protein synthesis is a multiple dehydration process.
- The net structure of a protein becomes possible as a result of linking together of various amino acid units.

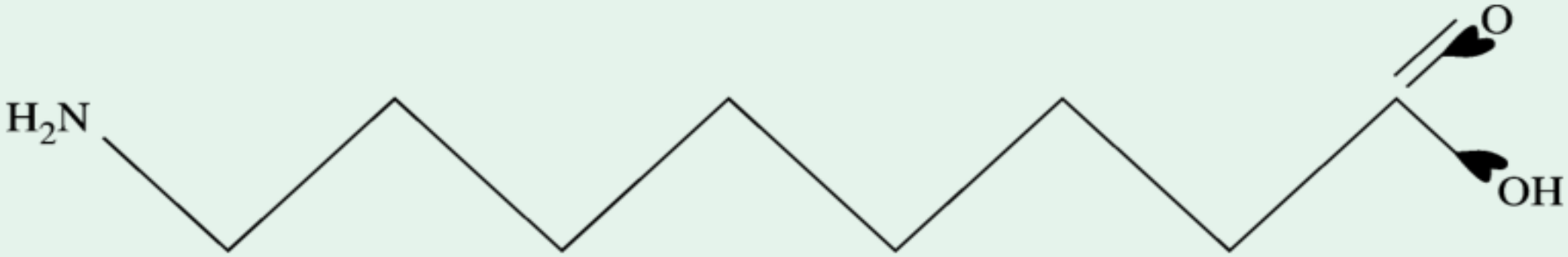
Amino acid residue

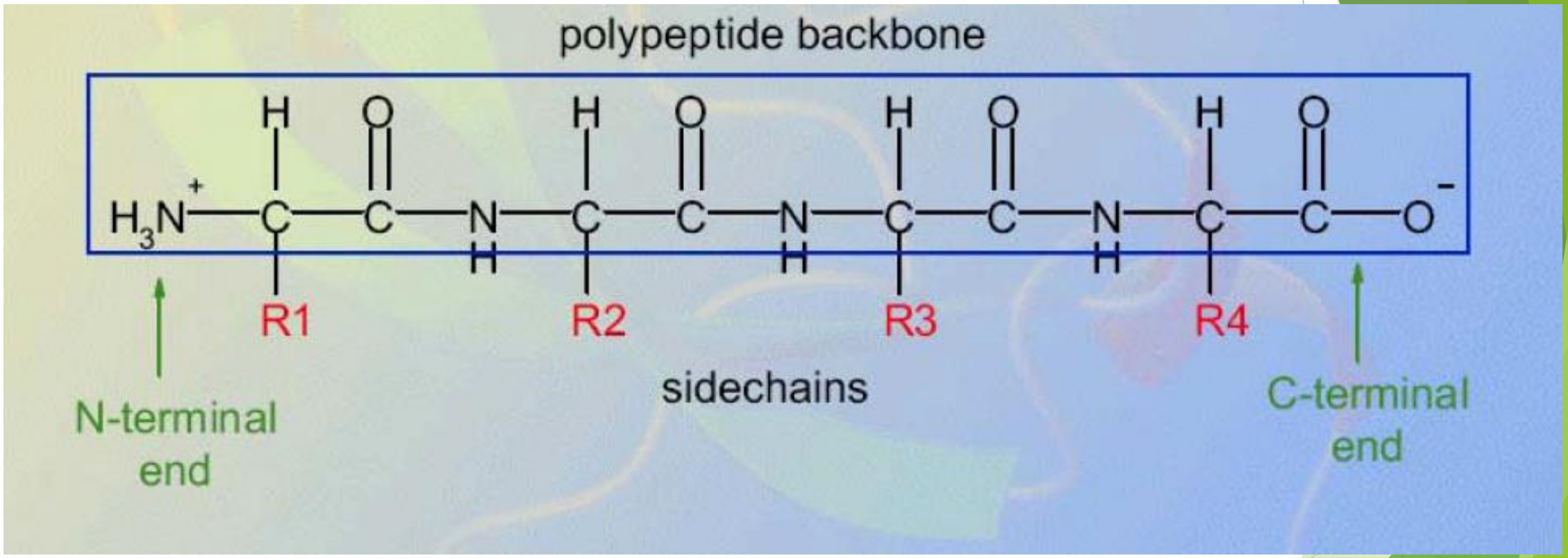
Peptide unit



- ✓ Each amino acid in the chain is termed a residue.
- ✓ The two ends of the peptide chain are named as amino terminal (N-terminal) and carboxyl terminal (C-terminal).
- ✓ These two terminal groups, one basic and another acidic, are **the only ionizable groups of any peptide chain except those present in the side chain**.

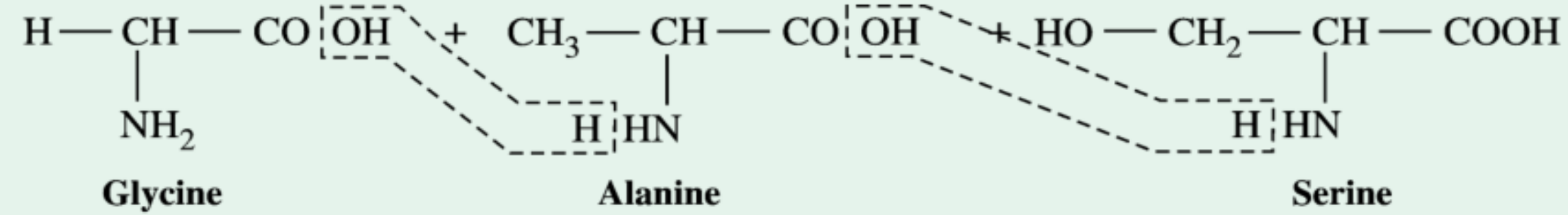
- ✓ The terminal amino acid with the free amino group is called as the N-terminal amino acid and the one with the free carboxyl group at the other end as C-terminal amino acid.

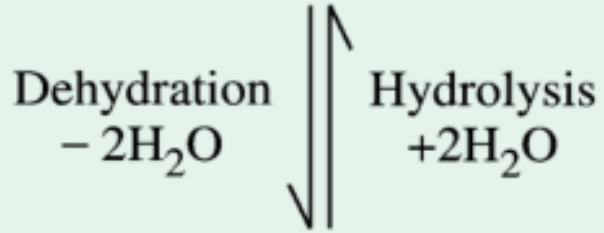


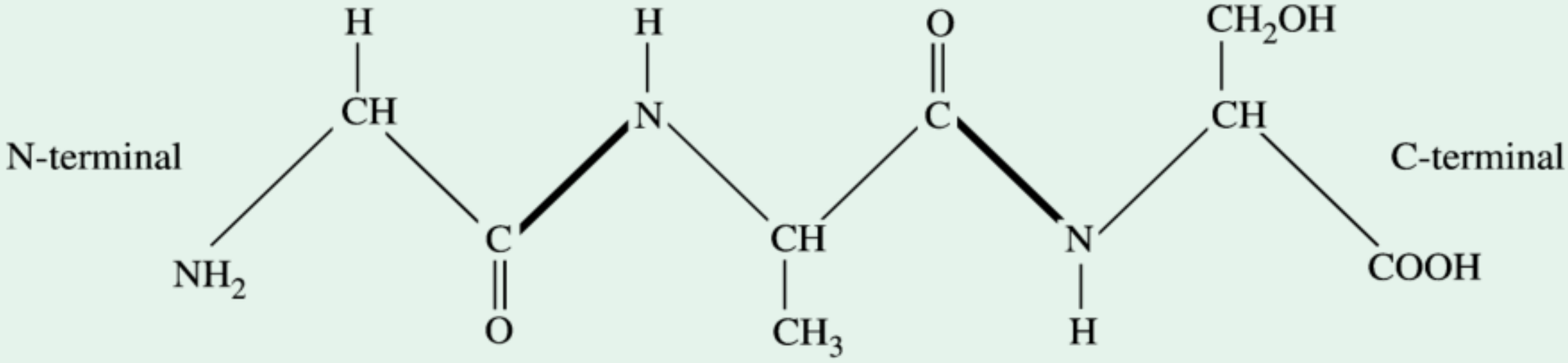

polypeptide backbone
H3N+
C
C
O
N
H
C
C
O
N
H
C
C
O
N
H
C
C
O
O-
R1
R2
R3
R4
sidechains
N-terminal end
C-terminal end

Naming of Peptide Chain

Construction of a tripeptide chain from three different amino acids







Glycyl-L-alanyl-L-serine

N-terminal residue is written first

Further, the names of all the amino acid residues, except the last one, are written by adding the suffix -yl because all these are the acyl groups.

A tripeptide containing glycine, alanine and serine is named as glycyl- L -alanyl- L -serine and abbreviated as Gly-Ala-Ser.

abbreviation would be (Gly, Ala, Ser) if sequence of amino acid in such a tripeptide is not known

- Glutathione or GSH (a tripeptide containing glutamic acid, cysteine and glycine)
  - γ-glutamyl-cysteyl-glycine
  - Glu-Cys-Gly.

- Glutathione is a naturally occurring and widely distributed polypeptide.

Ala $_2$, Arg, Glu, Gly, Leu, Lys $_2$, Phe, Tyr $_2$

dodecapeptide

C-terminal amino acid?

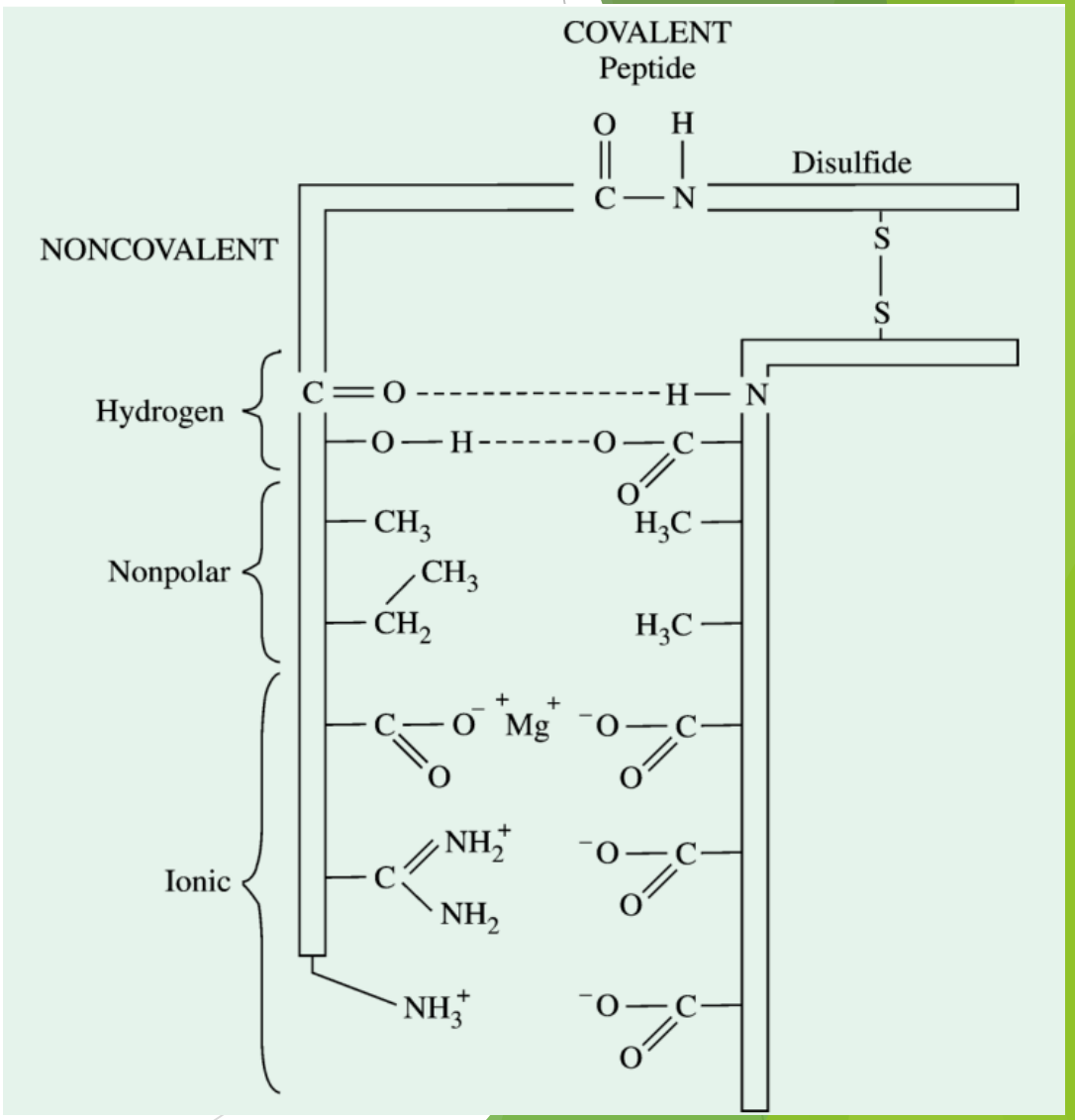
Peptides participate in a number of biological activities

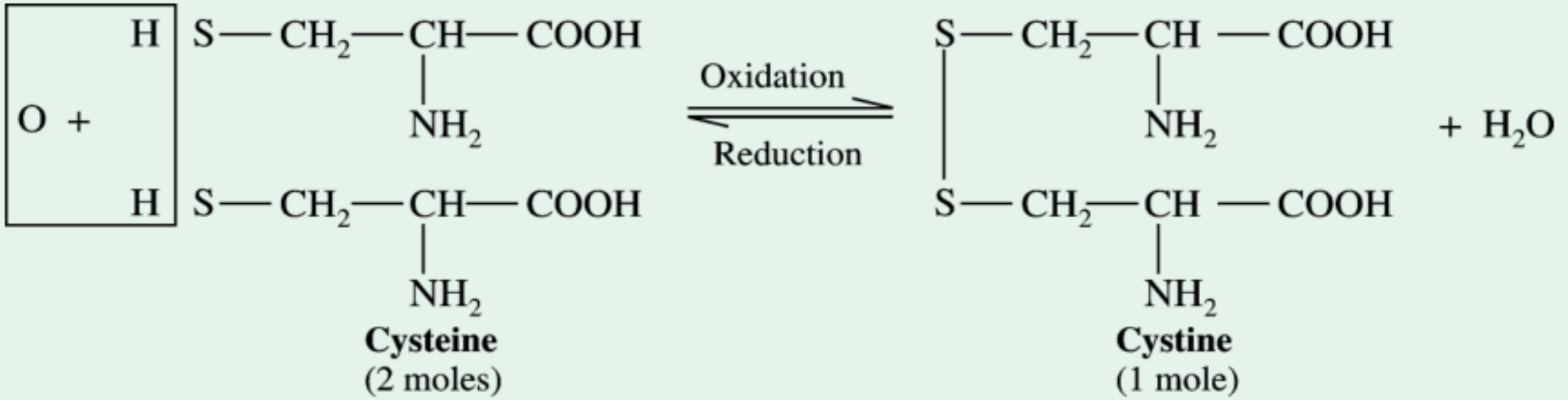
- Intermediates in the formation of proteins
- constituents in a group of compounds called alkaloids
- Antibacterial activities
- Growth factors
- hormones
- Controlling the oxidation-reduction potential of the cell

Chemical bonds involved in protein structure

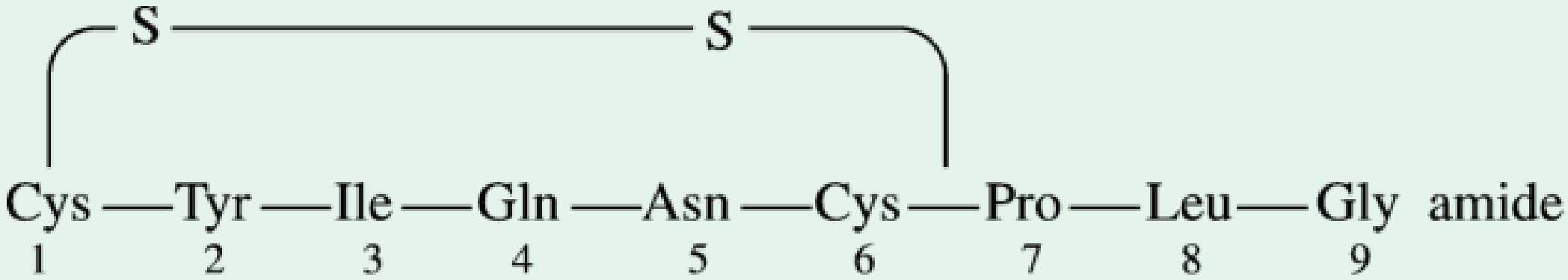
Types of chemical bonds involved in protein structure

A. Primary Bond
B. Secondary Bonds
   1. Disulfide Bond
   2. Hydrogen Bond
   3. Nonpolar or Hydrophobic Bond
   4. Ionic or Electrostatic Bond or Salt linkage or Salt bridge

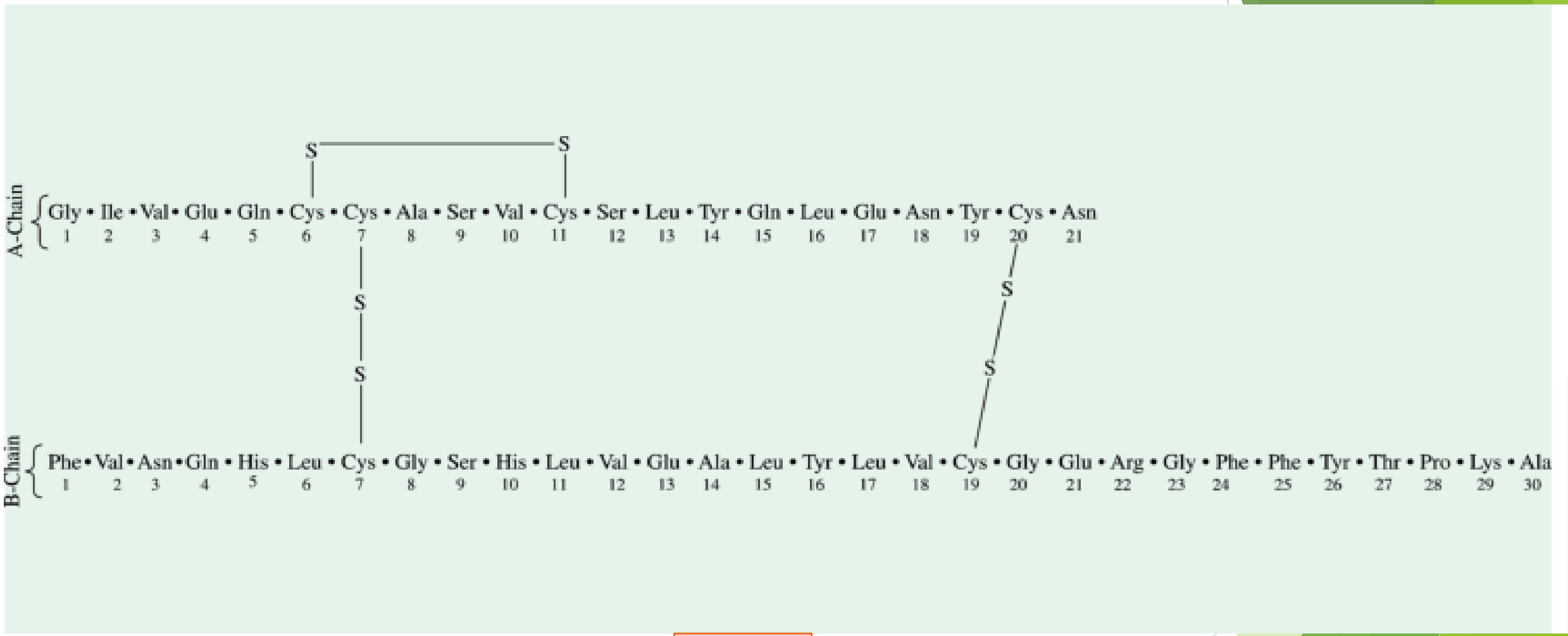




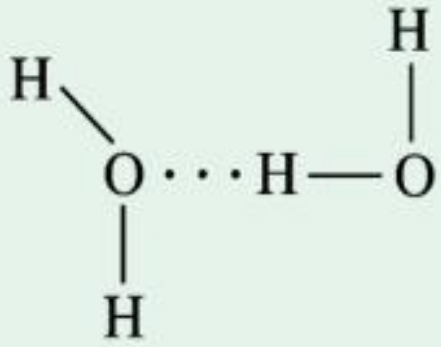
Formation of cystine (= dicysteine)

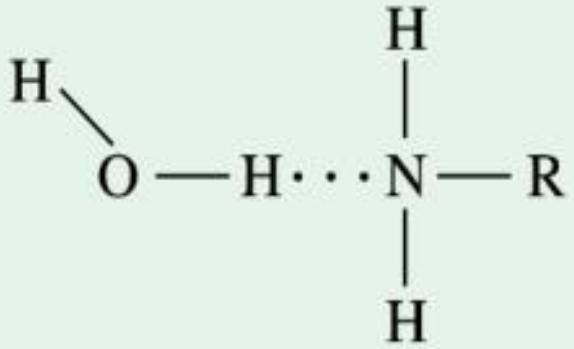


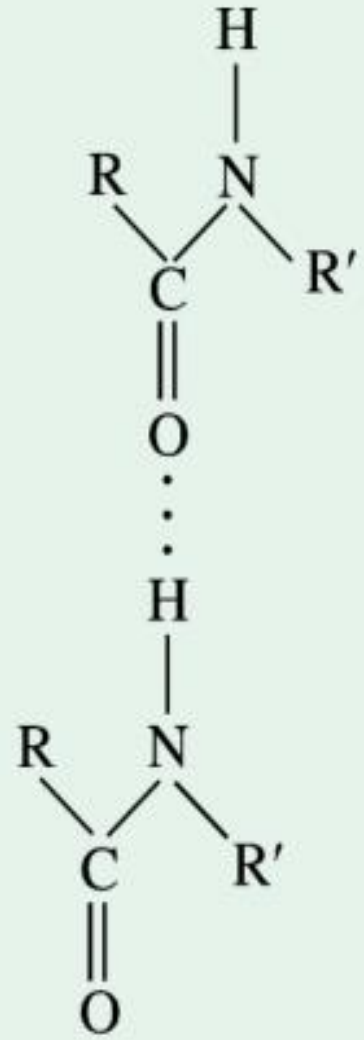
Structure of ocytocin


A-Chain
Gly • Ile • Val • Glu • Gln • Cys • Cys • Ala • Ser • Val • Cys • Ser • Leu • Tyr • Gln • Leu • Glu • Asn • Tyr • Cys • Asn
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
S
S
S
S
S
S
B-Chain
Phe • Val • Asn • Gln • His • Leu • Cys • Gly • Ser • His • Leu • Val • Glu • Ala • Leu • Tyr • Leu • Val • Cys • Gly • Glu • Arg • Gly • Phe • Phe • Tyr • Thr • Pro • Lys • Ala
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

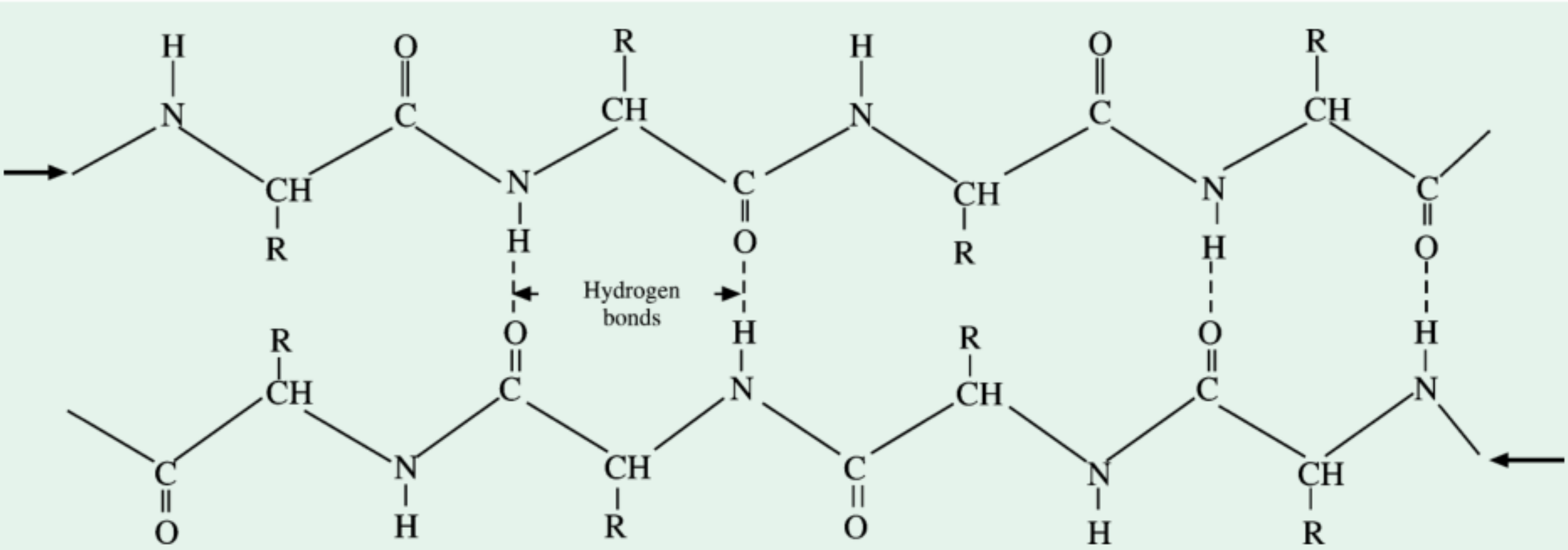
Insulin



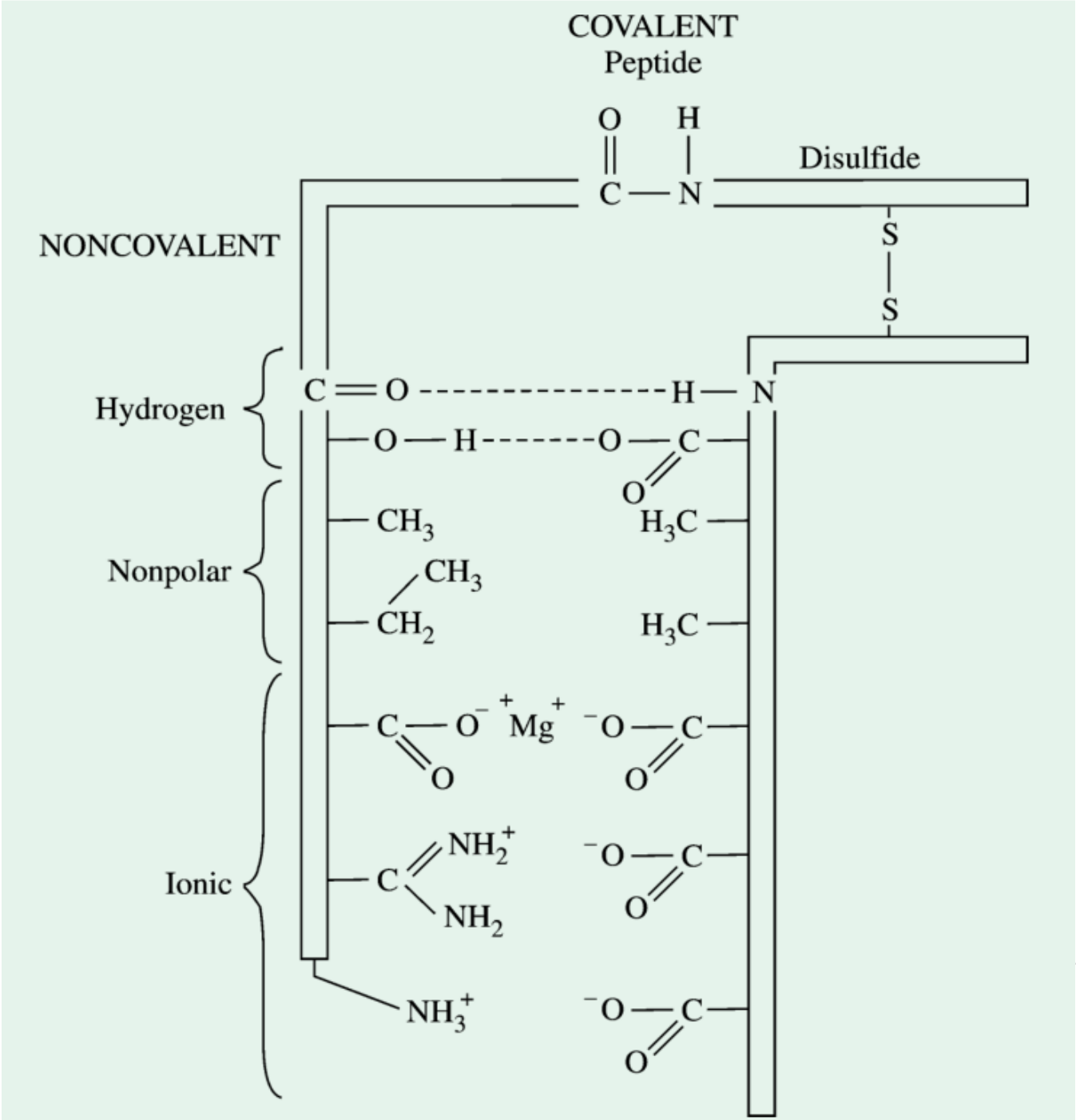




The hydrogen bonds between two water molecules, water and an amine, two amide groups.



A portion of two chains of silk fibroin


COVALENT
Peptide
Disulfide
NONCOVALENT
Hydrogen
Nonpolar
Ionic

Protein Configuration

4 basic structural levels (1°, 2°, 3° and 4°) of organization of proteins based on the degree of complexity of their molecule.

Linderström–Lang

Three of these structural levels (primary, secondary and tertiary) can exist in molecules composed of a single polypeptide chain.

The fourth (i.e., quarternary) involves interactions of polypeptides within a multichained protein molecule.

20 Amino Acids

Primary

Secondary

Tertiary

Quaternary

Denatured

Primary Structure : Amino Acid Sequence

- The primary structure of a protein refers to the number and sequence of amino acids, the constituent units of the polypeptide chain.
- The main mode of linkage of the amino acids in proteins is the peptide bond which links the α-carboxyl group of one amino acid residue to the α-amino group of the other.
- The proteins may consist either of one or of more linear peptide chains.

- ساختار اول پروتئین ها در مورد پیوندهای پپتیدی بین اسیدهای آمینه، نوع ،ترکیب و توالی اسیدهای آمینه صحبت می کند.
- در این ساختار گروه های R بیرون زنجیر بوده و هیچ پیوندی ندارند.
- ساختمان اول تعیین کننده شکل خاص فضایی یعنی ساختمان های دیگر پروتئین ها است.
- کاملترین روش برای تعیین ترتیب قرار گرفتن اسید های آمینه تجزیه ادمن است.

Secondary Structure : Helix Formation or Local Folding

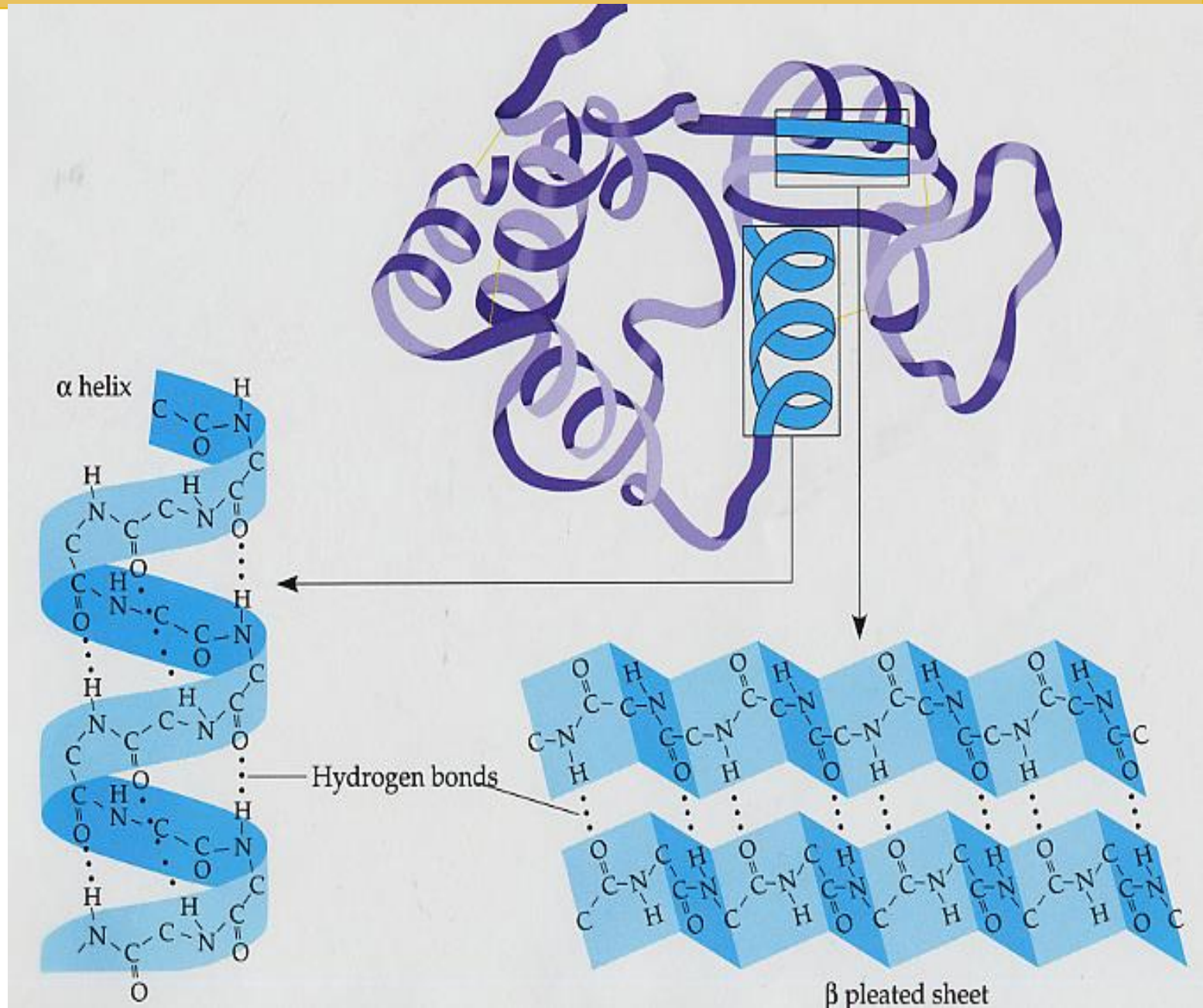
- If the peptide bonds were the only type of linkage present in proteins, these molecules would have behaved as irregularly coiled peptide chains of considerable length.
- But the globular proteins, however, do show some regular characteristic properties, indicating the presence of a regular coiled structure in these molecules. This involves the folding of the chain which is mainly due to the presence of hydrogen bonds. Thus, folding and hydrogen bonding between neighbouring amino acids results in the formation of a rigid and tubular structure called a helix.

- This constitutes the secondary structure of proteins, which refers to the steric or spatial relationship of amino acids that are near to each other in the amino acid sequence.

Secondary Structure : Helix Formation or Local Folding

Based on the nature of hydrogen bonding (whether intramolecular or intermolecular), Pauling and Corey (1951) identified two regular types of secondary structure in proteins :

1. alpha helix (α-helix)
2. beta pleated sheet (ß-pleated sheet).

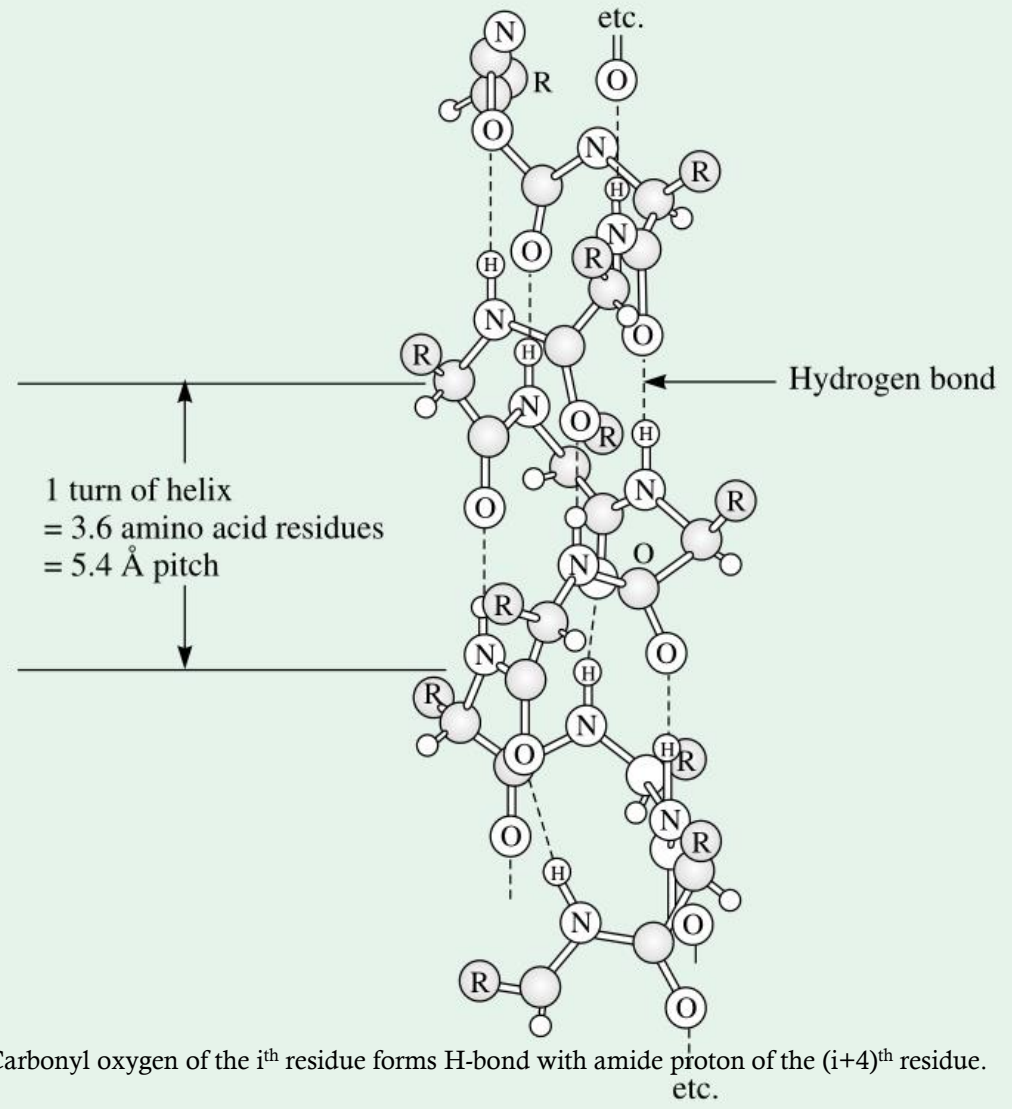


α - Helix

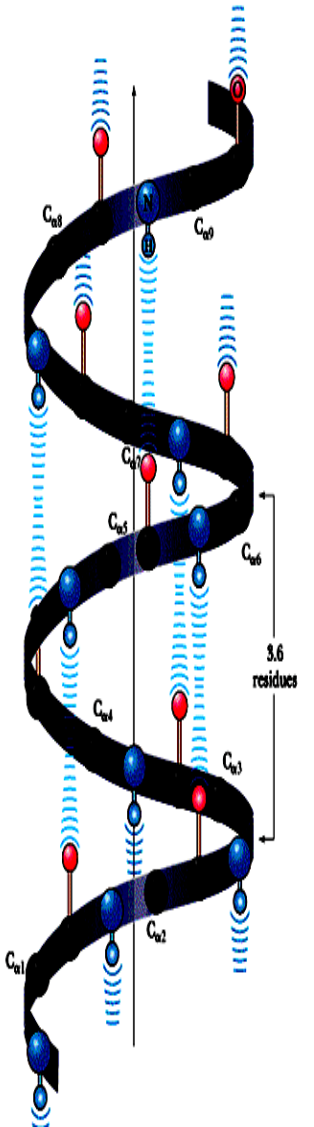
The helix is so named because of the mobility of α-carbon atoms

- The α-helix is a rodlike structure. The tightly coiled polypeptide main chain forms the inner part of the rod, and the side chains extend outward in a helical array.
- The α-helix is stabilized by hydrogen bonds between the NH and CO groups of the main chain.
- The CO group of each amino acid is hydrogen-bonded to the NH group of the amino acid that is situated four residues ahead in the linear sequence.
- Thus, all the main chain CO and NH groups are hydrogen-bonded.

13 backbone atoms are in this hydrogen-bonded loop (3.6_{13}-helix, 3.6: residues per turn or pitch).



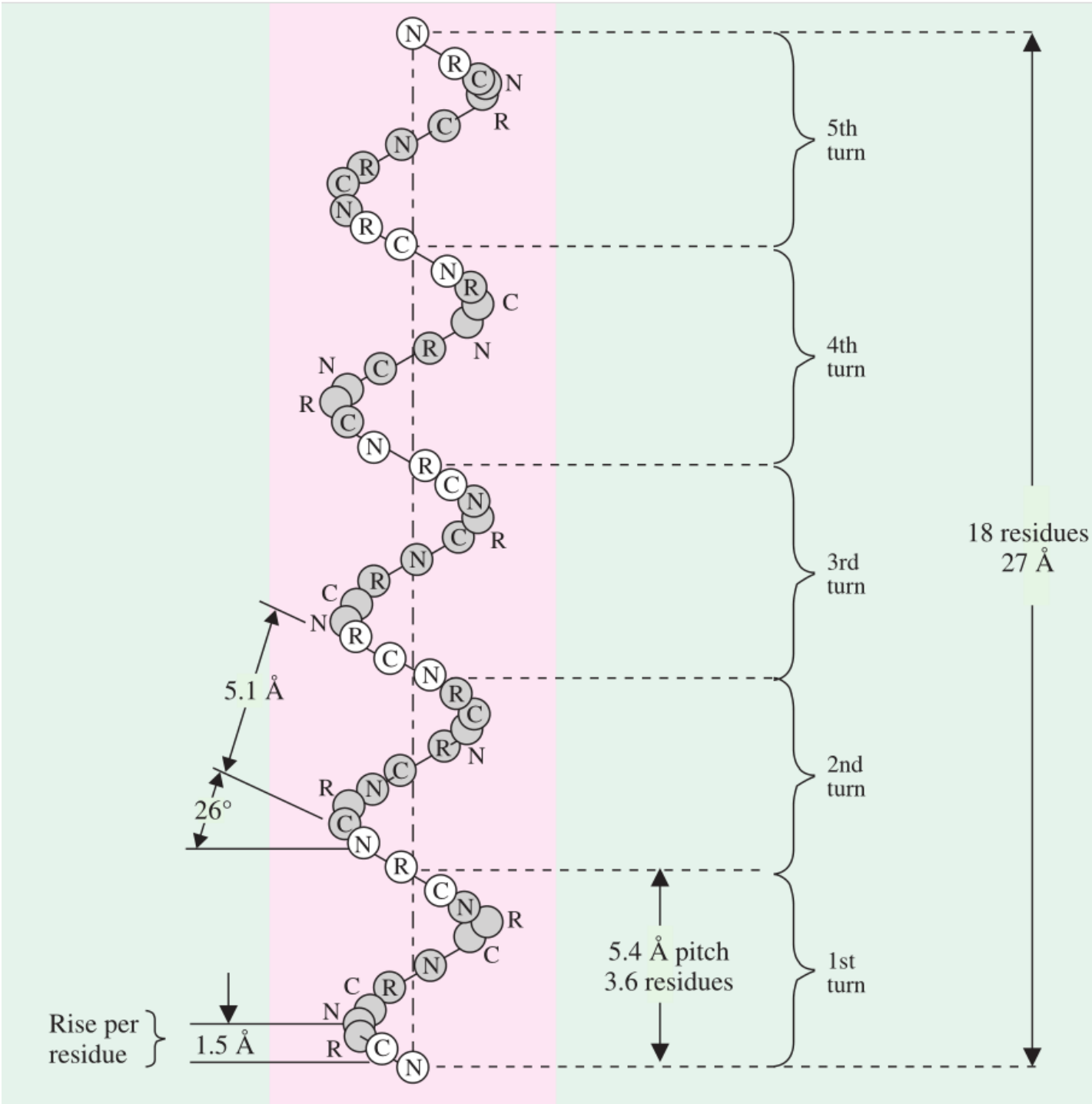
Carbonyl oxygen of the i^{th} residue forms H-bond with amide proton of the $(i+4)^{th}$ residue.



- α-helical structure depends on the intramolecular (= intrachain) hyrogen bonding between the NH and CO groups of peptide bonds.

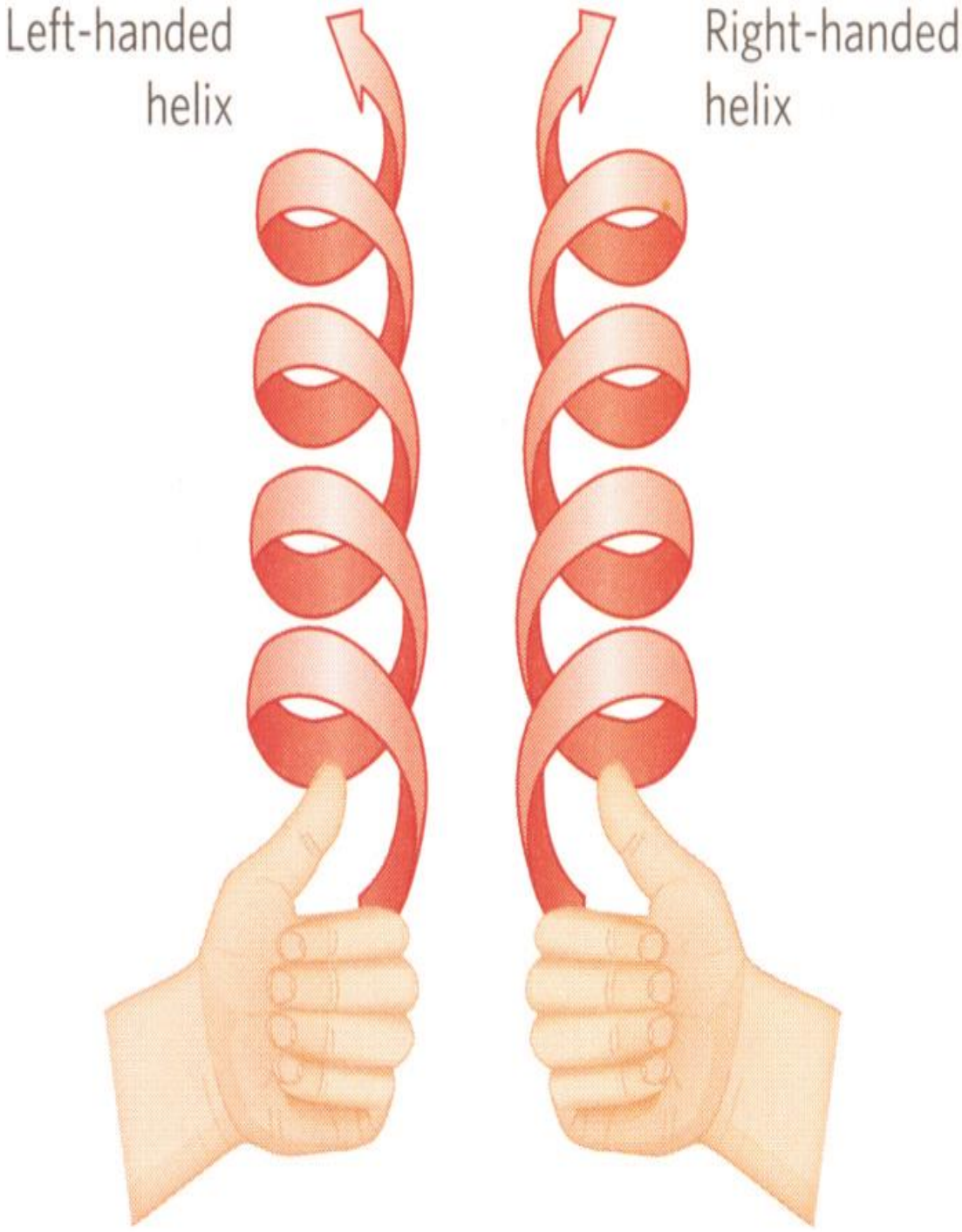
- The hydrogen bonding occurs spontaneously and, as a result, a polypeptide can assume a rod-like structure with well-defined dimensions.

- The α-helix (or α-conformation, as it is also called) has a pitch of 5.4 Å(= 0.54 nm) and contains 3.6 amino acids per turn of the helix, thereby giving a rise per residue of 5.4/3.6 = 1.5 Å (= 0.15 nm), which is the identity period of α-helix.



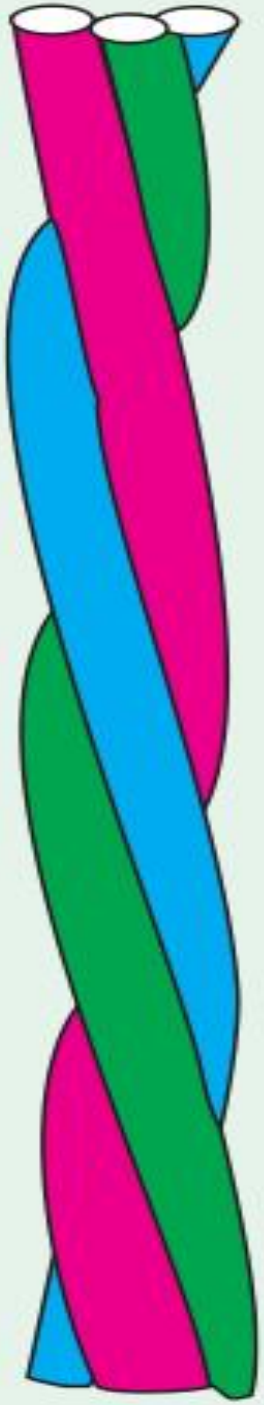
- A helix can be right-handed (clockwise) or left-handed (anticlockwise)

α-helices of known polypeptides (i.e., L -amino acids) are right-handed.



- α-helix occurs in the protein, found in skin and its appendages such as hair, nails and feathers and constitutes almost the entire dry weight of hair, wool, feathers, nails, claws, quills, scales, horns, hooves, tortoise shell, and much of the outer layer of skin.

- The basic structural unit of **α-keratin** usually consists of 3 right-handed helical polypeptides in a left-handed coil that is stabilized by crosslinking disulfide bonds



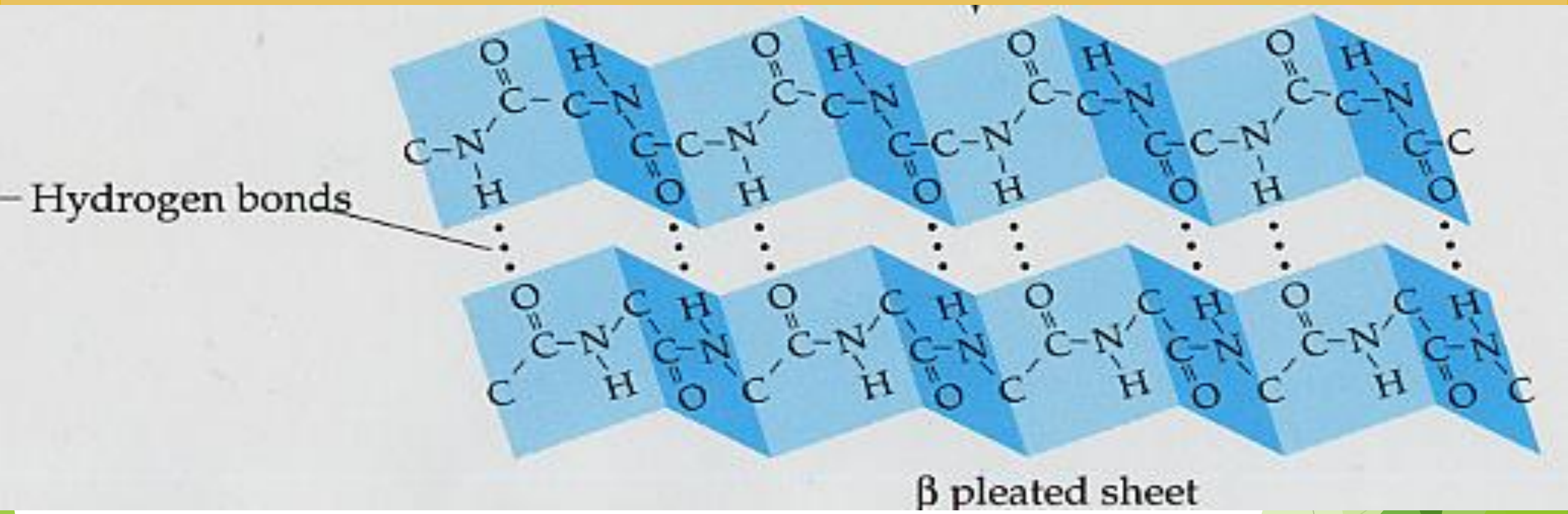
Destabilization of α-helical conformation by certain amino acid residues can occur in various ways :

1. A prolyl reisdue has its α-N atom in a rigid ring system and cannot participate in α-helical structure ; instead, it creates a sharp bend in the helix.
2. A sequence of aspartyl and/or glutamyl residues can destabilize α-helical structure because the negatively-charged side chains repel one another (electrostatic repulsion), and the forces of repulsion are greater than those of hydrogen bonding.
3. A cluster of isoleucyl residues, because of steric hindrance imposed by their bulky R groups, also disrupts helical conformation.
4. Glycine, with a small hydrogen atom as an R group, is another destabilizer. The lack of a side chain on glycine allows for a great degree of rotation about the amino acid's α carbon ; hence, conformations other than a helical bond angles are possible.

Amino acids affecting α-helical structure

Destabilize α-helix		*Create bends in α-helix*
Aspartic acid	Glycine	Proline
Glutamic acid	Serine	Hydroxyproline
Lysine	Isoleucine	
Arginine	Threonine	

β-Pleated Sheet



- A second type of repetitive, minimum-energy or stable conformation
- The formation of β-pleated sheets depends on intermolecular (= interchain) hydrogen bonding, although intramolecular hydrogen bonds are also present.
- The β sheet structures are quite common in nature and are favoured by the presence of amino acids, glycine and alanine.
- Silk and certain synthetic fibres such as nylon and orlon are composed of β-structures.

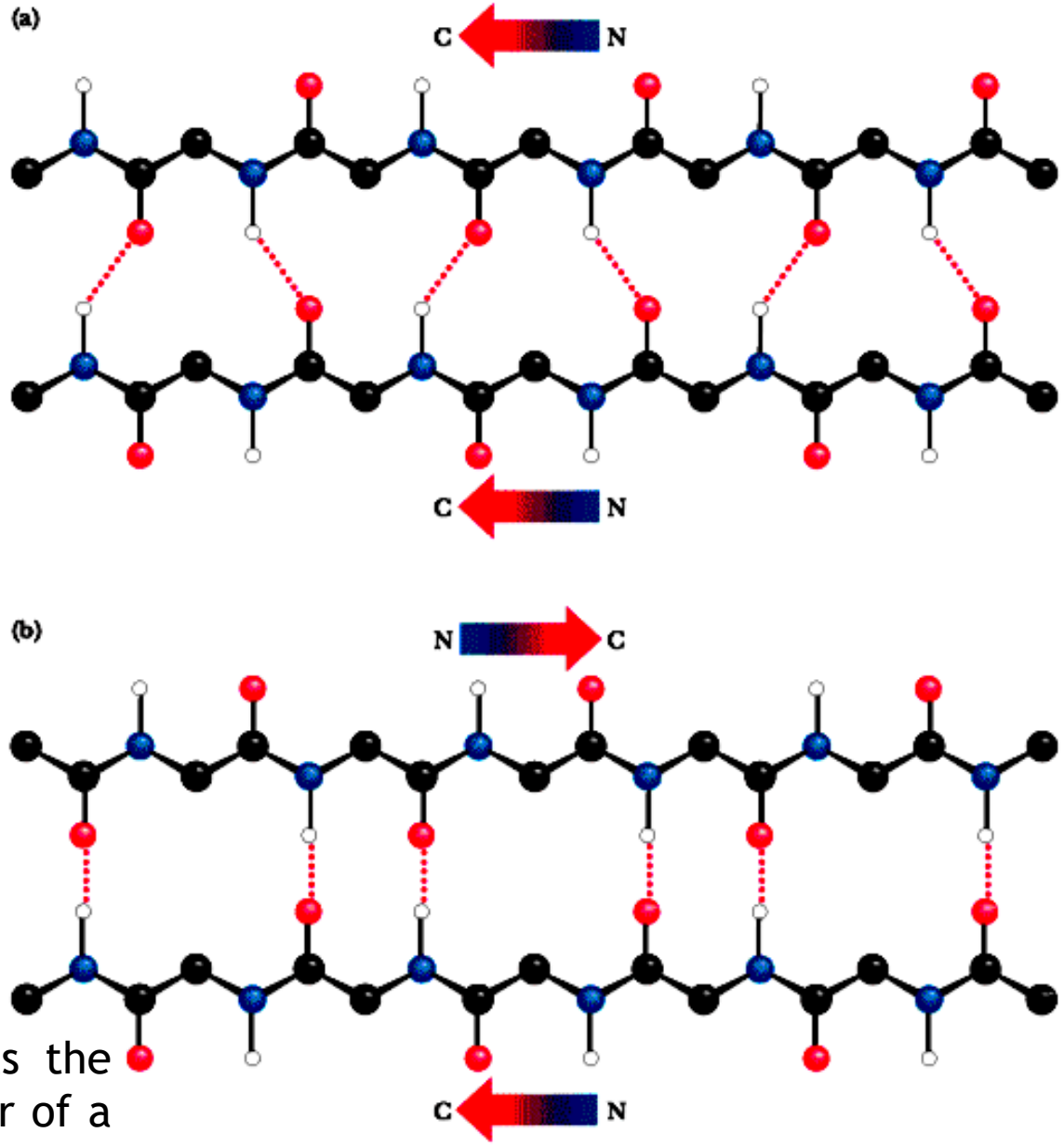
The β-pleated sheet differs markedly from the rodlike α-helix :

1. A polypeptide chain in a β-pleated sheet, called a β-strand, has fully extended conformation, rather than being tightly coiled as in the α-helix.

2. The axial distance between adjacent amino acids in β-pleated sheets is 3.5 Å, in contrast with 1.5 Å for the α-helix.

3. β-sheet is stabilized by hydrogen bonds between NH and CO groups in different polypeptide strands, whereas in the α-helix, the hydrogen bonds are between NH and CO groups in the same strand

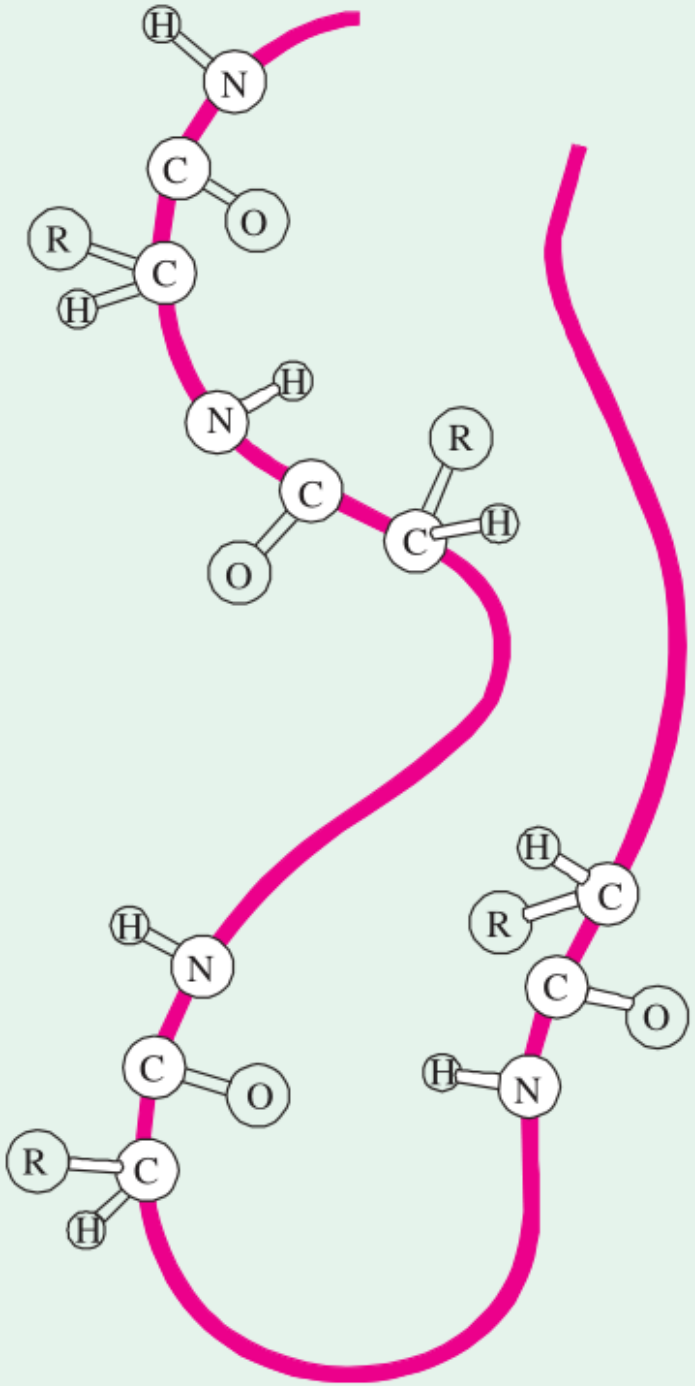
- An extended structure comprisin β-strands.
- Depending on the N→C directio orientations of the strands:
  - Parallel β-strands (0.325 nm between two residues)
  - Antiparallel β-strands (0.347 r between two residues)



Silk fibroin is one example of a protein that has the antiparallel pleated sheet structure. It is a member of a class of fibrillar proteins called α-keratins.

Random Coil

- A third type of secondary structure in proteins.
- When a polypeptide contains adjacent bulky residues such as isoleucine or charged residues such as glutamic acid and aspartic acid, repulsion between these groups causes the polypeptide to assume a
- random coil configuration .
- Thus, we see that the R groups distributed along the polypeptide backbone determine the secondary structure adopted by different portions of the polypeptide (α-helix or ß-pleated sheet), or the lack
- of a well-defined structure (random coil).



Other Secondary Structures

β Turn or β Bend or Hairpin Bend

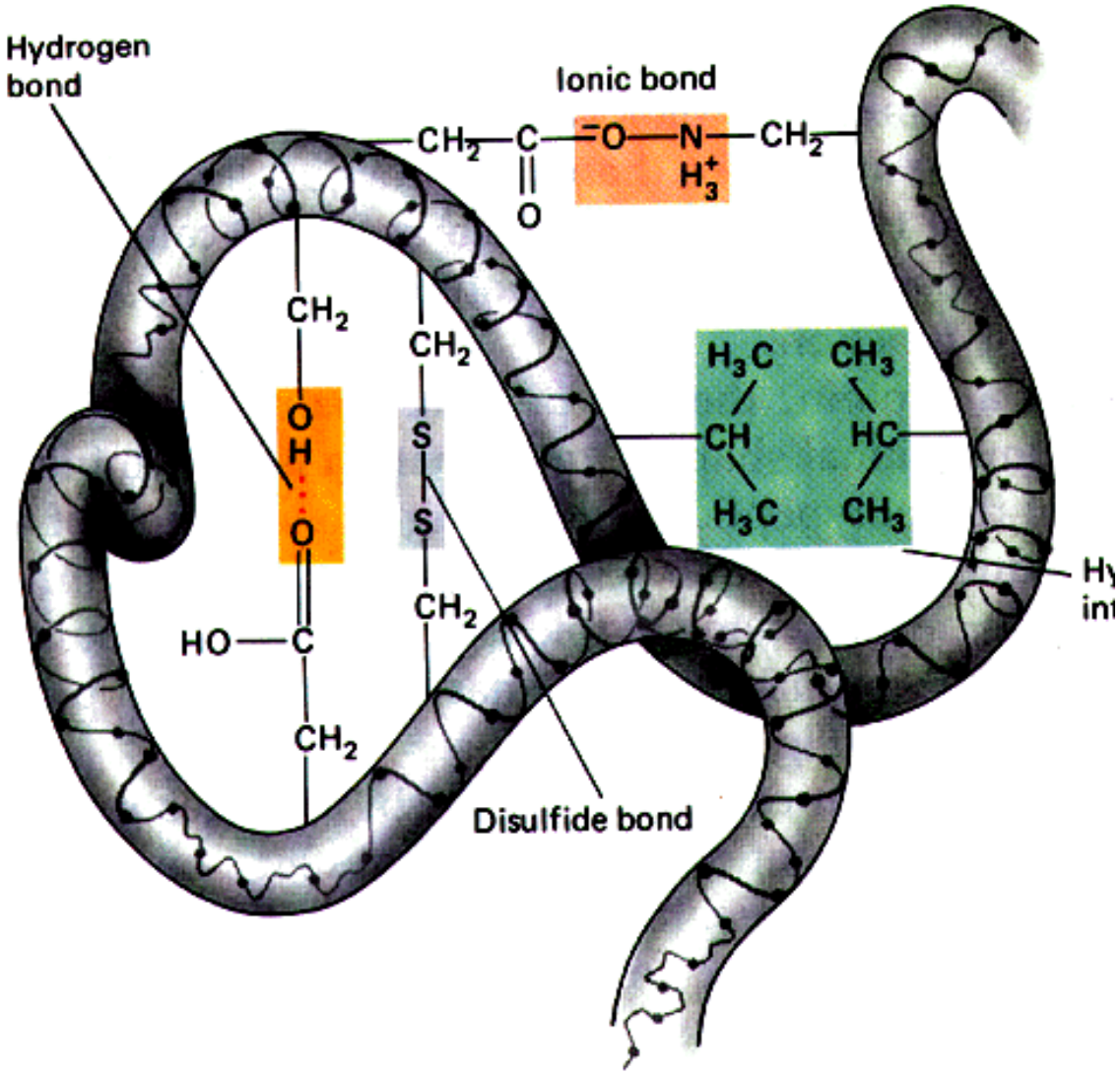
Collagen Triple Helix

Elastin

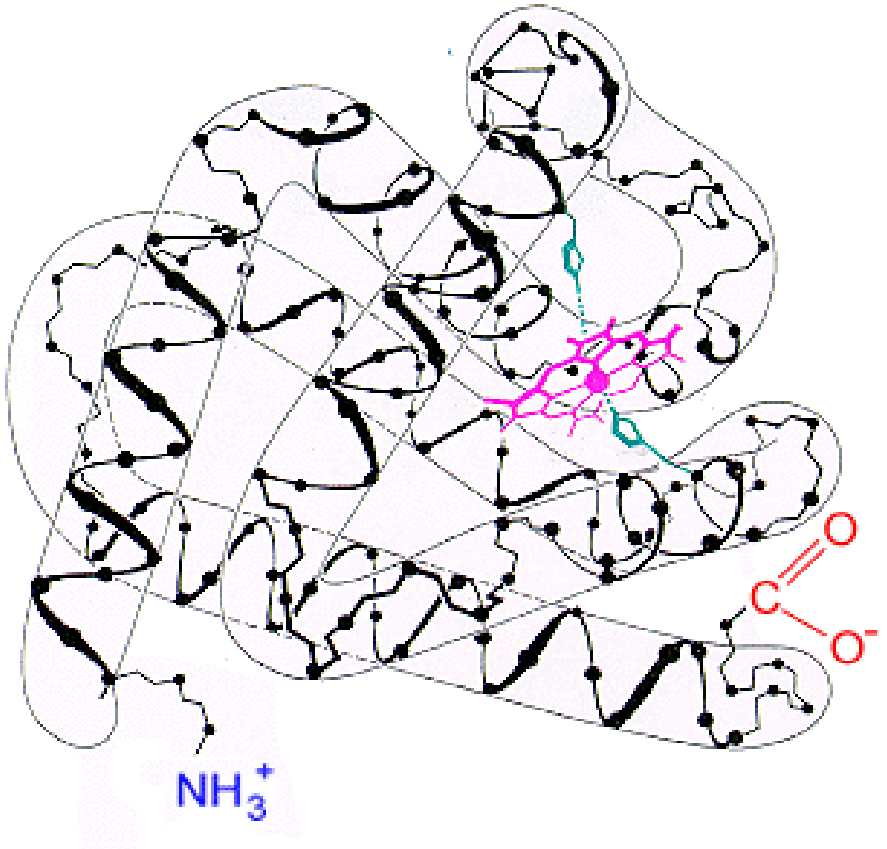
Hydrogen-bonding Potentiality of Proteins

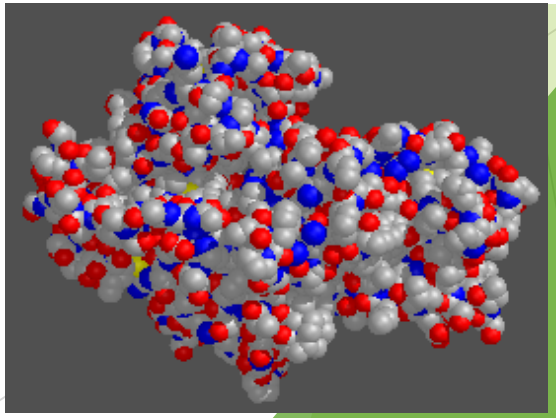
Tertiary Structure : Folding of the Chain or Overall Folding

- If the globular proteins consisted only of a small helix, these molecules would have been elongated structures with considerable length and a small cross-sectional area (i.e., a large axial ratio).
- But as we now know about the existence of globular proteins, the helix must, therefore, possess many other types of bonds placed at regular intervals.
- These additional bonds include disulfide, hydrogen, hydrophobic and ionic. In such globular proteins (including enzymes, transport proteins, some peptide hormones and immunoglobulins), polar groups because of their hydrophobicity are most often located on the molecule's exterior and nonpolar R groups in the interior, where their interactions create a hydrophobic environment.
- The tertiary structure, thus, involves the folding of the helices of globular
- proteins. It refers to the spatial arrangement of amino acids that are far apart in linear sequence and to the pattern of disulfide bonds.



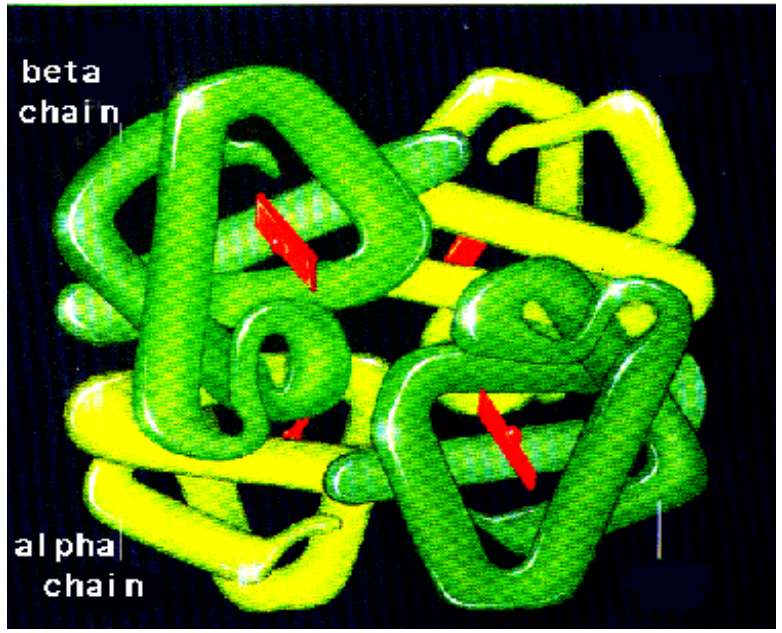
Myoglobin - a tertiary structure

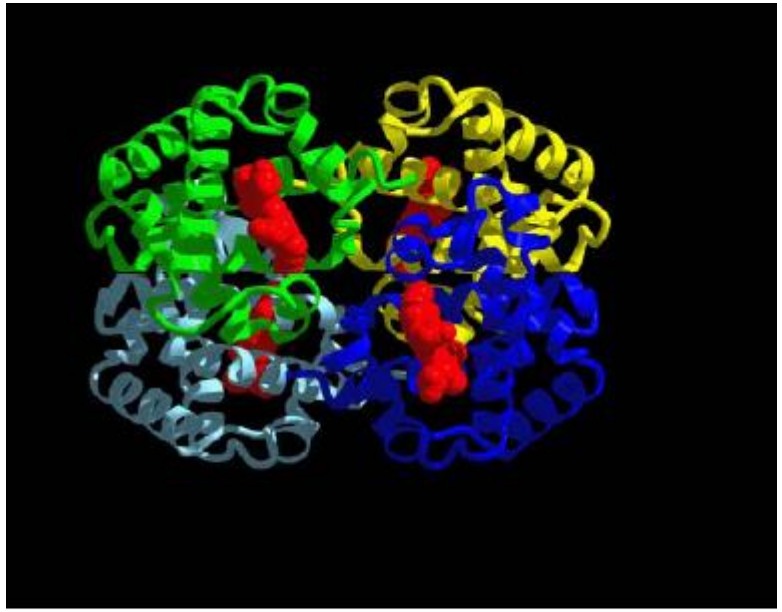




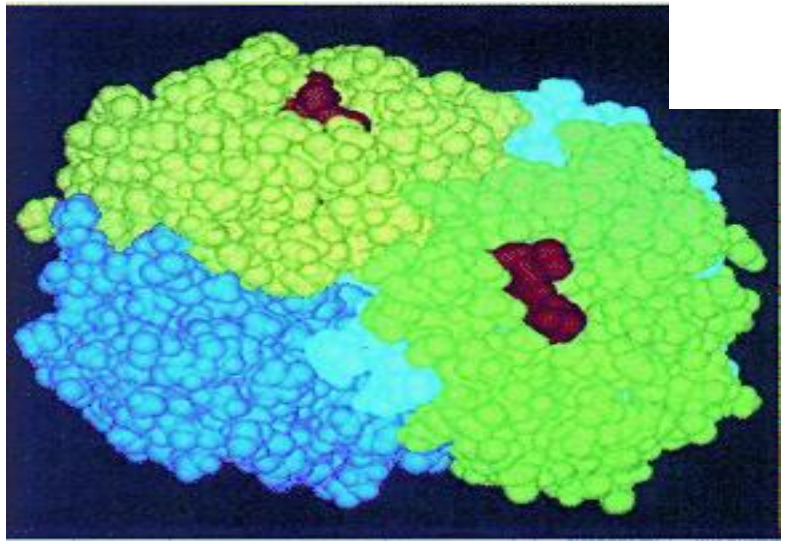
Quaternary Structure : Protein-Protein Interactions or Multichain Association

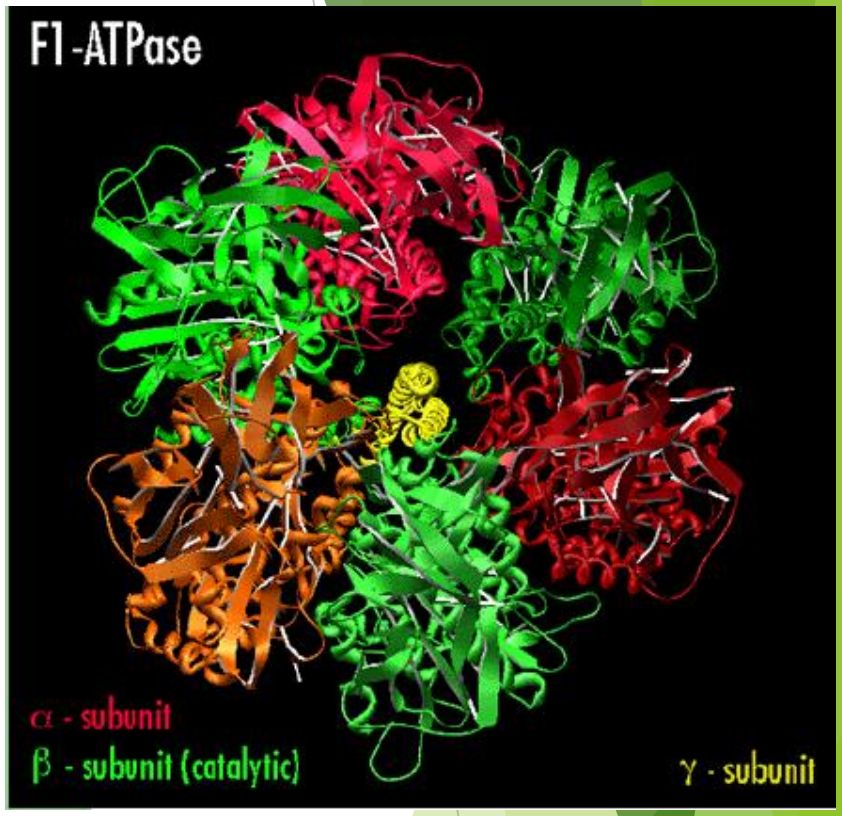
- A fourth degree of complexity in protein structure has recently been recognized to be of great value in many proteins.
- Some globular proteins consist of 2 or more interacting peptide chains.
- Each peptide chain in such a protein is called a subunit.
- These chains may be identical or different in their primary structure. This specific association of a number of subunits into complex large-sized molecules is referred to as the quaternary structure.
- In other words, quaternary structure refers to the spatial arrangement of subunits and the nature of their contact. The same forces (disulfide, hydrogen, hydrophobic and ionic bonds) involved in the formation of tertiary structure of proteins are also involved here to link the various polypeptide chains.

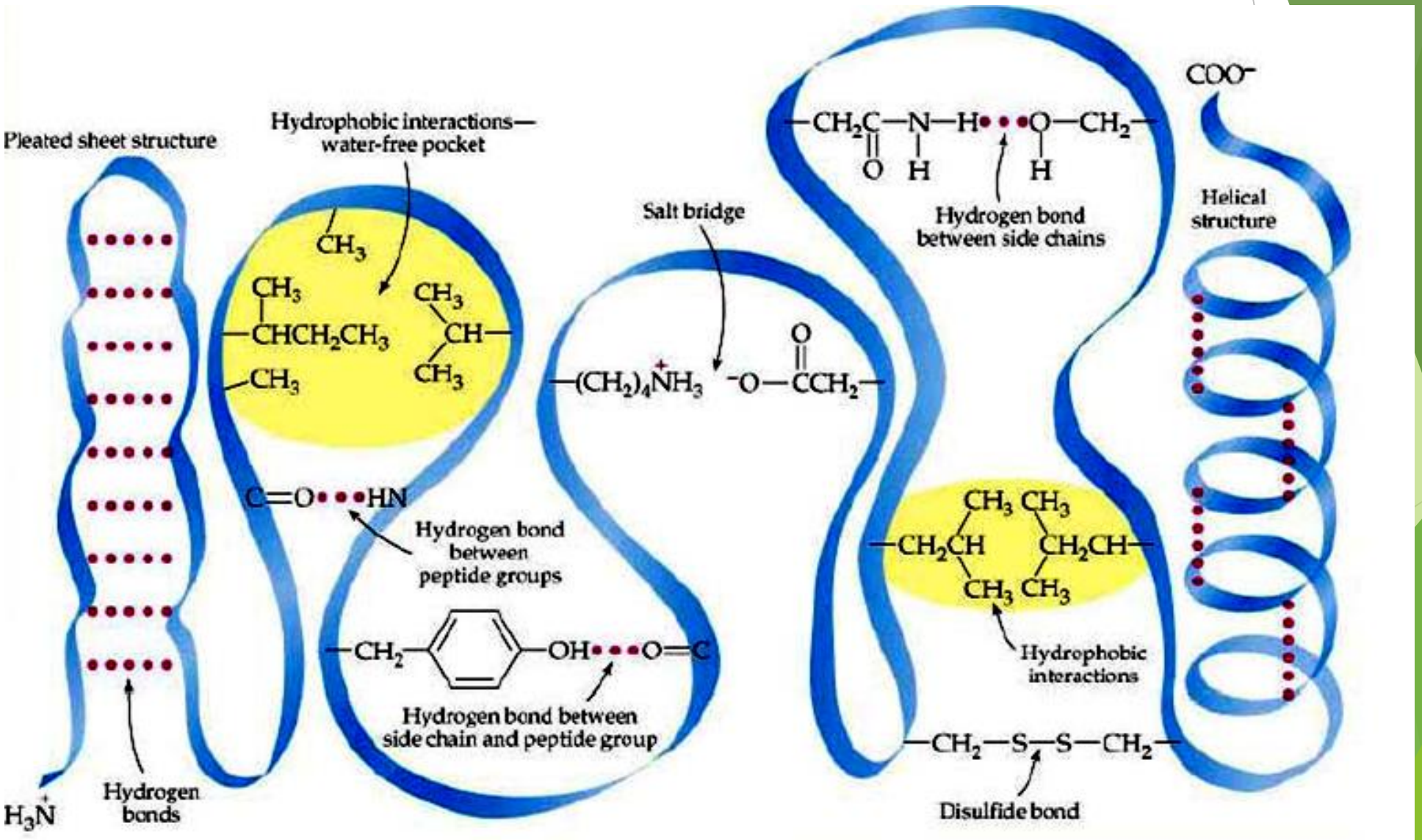

beta
chain
alpha
chain



Hemoglobin




F1-ATPase
α - subunit
β - subunit (catalytic)
γ - subunit


Pleated sheet structure
Hydrophobic interactions—
water-free pocket
Salt bridge
Hydrogen bond
between side chains
Helical
structure
Hydrogen bond
between
peptide groups
Hydrophobic
interactions
Hydrogen bond between
side chain and peptide group
Hydrogen
bonds
Disulfide bond

Categories of proteins based on shape

(1) Fibrous

a. Collagens
b. Elastins
c. Keratins

(1) Globular

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)

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)