

**DC-1**

**SEM-2**

**Paper:4**

**Lesson: Introduction to amino acids, peptides and proteins Lesson Author: Dr Taruna Arora**

**College/Dept: Institute of home economics,  
University of Delhi**

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## Introduction to amino acids, peptides and proteins

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### **Introduction**

Protein, a Greek word representing proteins is correctly coined for this biomolecule of utmost importance. Protein is a molecule of prime significance and is undoubtedly one of the most copious molecules of the cell as it acquires more than 50% of the total cellular dry weight. They are present ubiquitously in every organism and are acknowledged to play an integral role in maintaining not only the cellular structure but also execute a plethora of functions within the cell. Protein is an eventual product of expression from the genetic information present in the nucleus and work as enzymes, hormones, antibodies, transporters, muscle fibers, milk proteins, antibiotics etc. Proteins are not only special in terms of biological functions but also in terms of their structure and size which array from a small peptide to a huge polymer with molecular mass ranging in millions.

## Introduction to amino acids, peptides and proteins

The way a language is comprised of alphabets, the varied group of proteins is biosynthesized by a small monomer called amino acid which works as a building block and are covalently bonded as a unique linear sequence. Around 20 such amino acids are available in the nature and omnipresent in character in being present from bacteria to human being. These amino acids are different from each other in terms of a side chain which is exclusive and enjoy distinctive chemical properties and come in concert in numerous diverse permutation and arrangement.

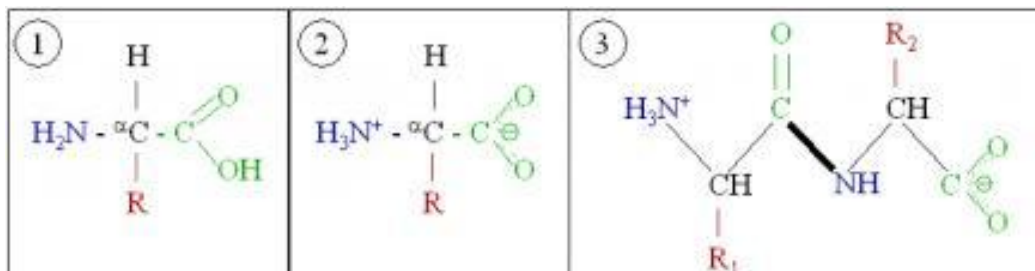


Figure: The various conformations of amino acids in biological samples  
[http://www.mysciencebox.org/files/images/Amino\\_acid.preview.png](http://www.mysciencebox.org/files/images/Amino_acid.preview.png)

### Amino acid- the alphabets of protein language

Polymerization of amino acids which are linked with each other using a covalent linkage form a linear polypeptide or a protein. Every amino acid present in the linear sequence is called a residue because the linkage leads to the release of water moiety on every linkage. Amongst the 20 common amino acids, the asparagine was the first to be discovered in 1806 while threonine was the last one to be discovered around 1938. However several modified amino acid residues present in proteins as well as uncommon free occurring amino acid forms have been found in nature.

#### Amino acids – the building blocks

The reasons behind the amino acids being the building blocks include:

1. An enormously assorted group with a extensive array of structural and chemical features.
2. One of the initial molecules created and readily existing during prebiotic reactions.
3. Extreme inherent reactivity may have eliminated other potential amino acids.
4. The cyclic forms of amino acids like homoserine and homocysteine (five-membered cyclic structure) have a propensity to potentially put an unfavorable strain leading to peptide bond cleavage. forms that limit their use in proteins; the alternative amino acids that are found in proteins serine and cysteine do not readily cyclize, because the rings in their cyclic forms are too small.

#### Nomenclature

Earlier the nomenclature of amino acid was in many cases based on the source from where they were found like asparagine was found in asparagus, glutamate was discovered in wheat gluten and tyrosine was first isolated from cheese.

Presently the amino acids are represented in the form a three letter as well as a single letter abbreviation. The three letter abbreviations are usually the first three letters of the amino acid (Exceptions include asparagine (Asn), glutamine (Gln), isoleucine (Ile), and tryptophan (Trp)) while the one letter symbols are usually either

## Introduction to amino acids, peptides and proteins

the first letter of the amino acids or phonetic in nature. The codes can specially be useful when the entire linear sequence of the protein is represented typically as a shorthand notation particularly now for bioinformatics studies. The entire notations are represented in the form of a table.

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

Figure: The formulas and abbreviations of the 20 standard amino acids

Source:

<http://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/Images3/aminacid.gif>

### Amino acid- the structure

A single archetypal amino acid is comprised of a tetrahedral  $\alpha$  carbon. Attached to this  $\alpha$  carbon are a hydrogen (H) moiety, an amino ( $\text{NH}_2$ ) group and a carboxylic acid ( $\text{COOH}$ ) functional group along with a variable side chain (R). While these three functional groups are universal in every amino acid, the fourth variable R chain is unique in every amino acid. Owing to the presence of four different functional groups being attached to the alpha carbon except in Glycine (Where two H groups are there), a carbon is asymmetric in nature thereby making every amino acid, chiral in nature.

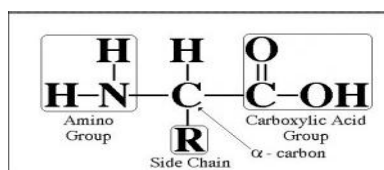


Figure: Structure of a typical amino acid

Source: [https://biology12-lum.wikispaces.com/file/view/amino\\_acid\\_structure\\_2-300x200%5B1%5D.jpg/163584737/479x314/amino\\_acid\\_structure\\_2-300x200%5B1%5D.jpg](https://biology12-lum.wikispaces.com/file/view/amino_acid_structure_2-300x200%5B1%5D.jpg/163584737/479x314/amino_acid_structure_2-300x200%5B1%5D.jpg)

### Peptide Bonds- the amino acid linkage

The two neighboring amino acids are joined with each other with a covalent linkage wherein the carboxylic acid group of one amino acid is joined with the amino group of the other amino acid by an amide linkage while a water molecule is released in the process. The amide bond formed through condensation reaction between the adjacent amino acid is characteristically seen in peptides and proteins and is aptly called Peptide bond. The peptide bond possesses high activation energy and thus the bond is quite stable in nature and has a long half life of 7 years. Even though peptide bond is a single bond, it has a partial double bond character which in turn brings in a voluntarily forced firmness to the protein molecule typically imperative during the formation of conformation.

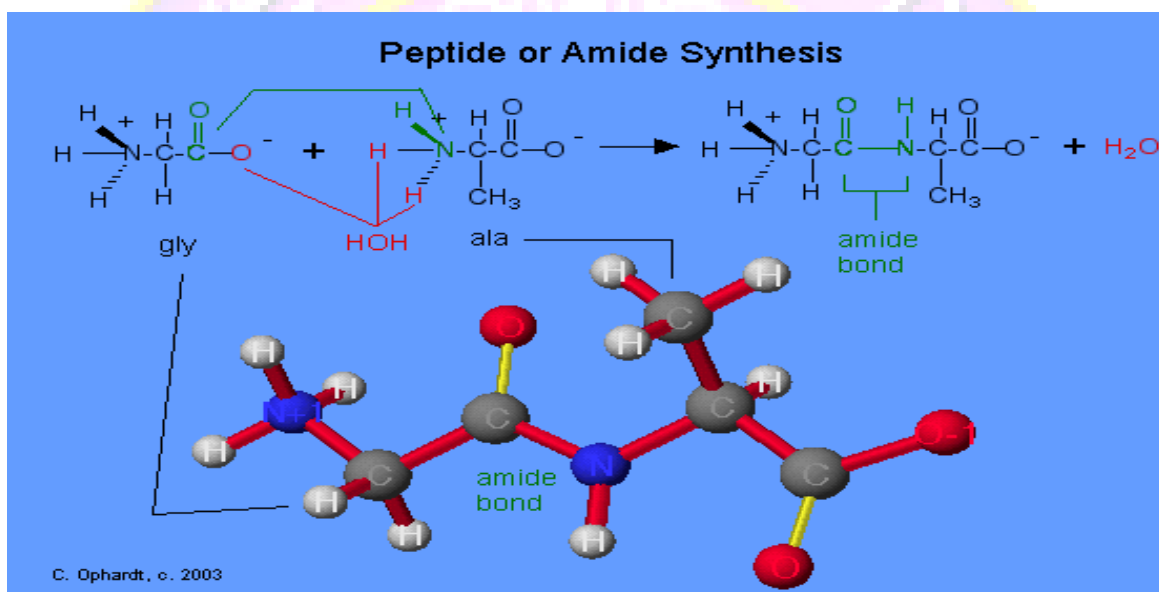


Figure: Formation of a peptide bond

Source: <http://chemwiki.ucdavis.edu/@api/deki/files/6239/=564glyala.gif>

### The Variations in the R- chains of the amino acid- their role and structure

The R functional groups which are diverse in terms of size, shape, charge, hydrogen-bonding capacity, hydrophobic character, and chemical reactivity are known to be responsible for the versatility in proteins. In fact amino acids can be classified in several ways on the basis of these properties. These R- groups also play a crucial role in the conformation of the protein. This is particularly seen in the case of several amino acids like Glycine which being the smallest amino acid occupies the unapproachable turns and twists. Similarly the non polar amino acids (Both aliphatic and aromatic) occupy the inner cytosolic space while the basic and the acidic amino acids are known to present non covalent interactions so as to stabilize the conformations of the proteins and are critically involved with the activity especially in

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the case of enzymes especially histidine and serine moieties. Further serine, tyrosine, and threonine are also known to regulate enzyme activity through their phosphorylation.

In general 6 broad categories of amino acids can be formed they are:

1. Nonpolar aliphatic amino acids
2. Polar and neutral amino acids
3. Acidic amino acids
4. Basic amino acids
5. Aromatic amino acids
6. Sulphur containing amino acids

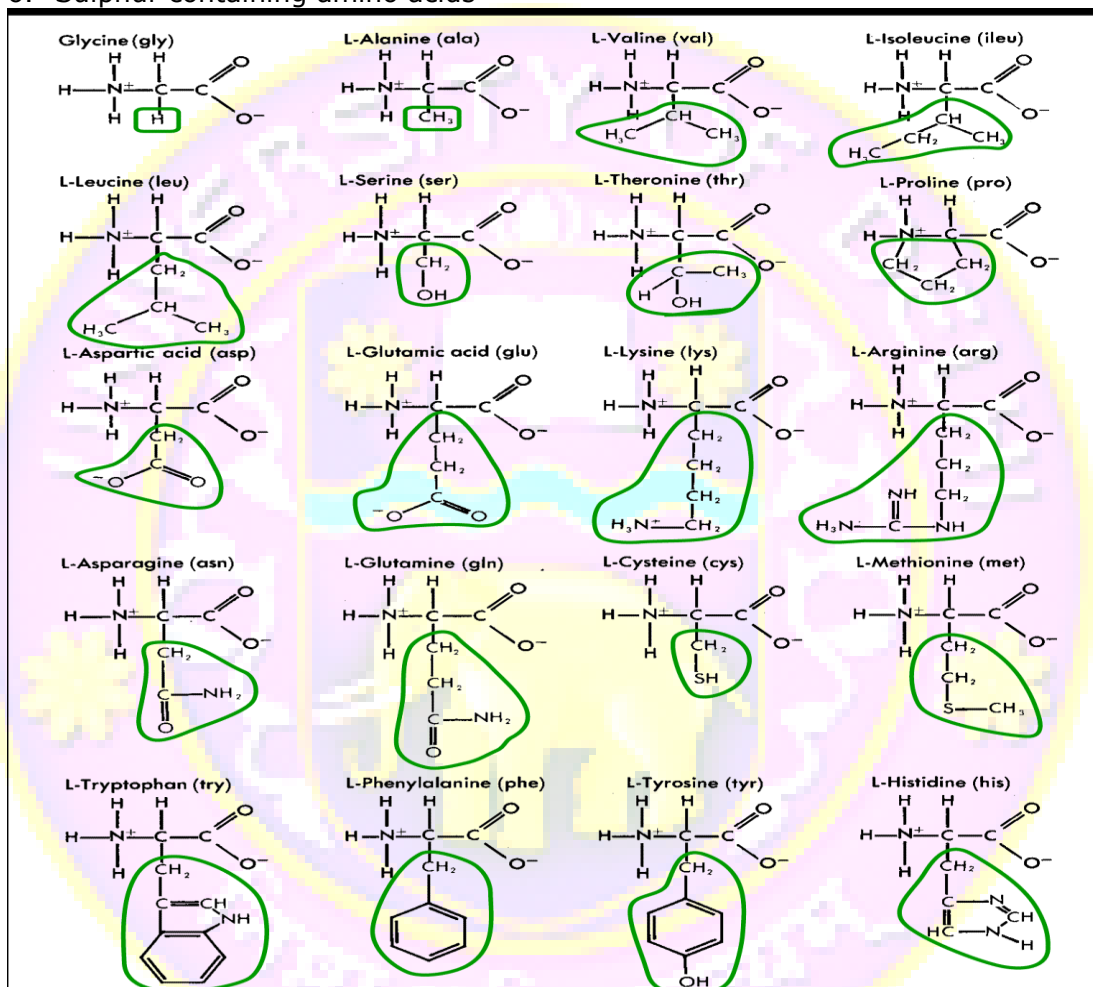


Figure: The conformations of the 20 amino acids with their specific R- side chains

Source: [http://www.contexo.info/DNA\\_Basics/images/aminoacidsweb.gif](http://www.contexo.info/DNA_Basics/images/aminoacidsweb.gif)

### Nonpolar aliphatic amino acids

Amino acids like Alanine, Valine, leucine, and isoleucine contain long aliphatic chains which tend to reside together and are predominantly hydrophobic in nature. Glycine being the simplest amino acid even though non polar does not contribute significantly to the hydrophobic forces present in the protein structure. Isoleucine and threonine (polar hydroxyl group containing amino acid) are unique in the sense that they have two chiral carbon wherein one of the asymmetric carbon resides in the R- chain however only one isomer form is prevalent in the naturally occurring proteins. Proline is another aliphatic amino acid which is present in the proteins



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however it has an unusual cyclic R- chain and its secondary imino group offers rigidity and hence less flexibility in the folding of the protein. Methionine even though is sulfur containing amino acid has a predominant non polar thioether group in its side chain. Numerous proteins containing these amino acids are soluble in water owing to these proteins acquiring a 3 dimensional conformation achieved due to the hydrophobic effect caused by the clustering of these amino acids together.

### **Polar and neutral amino acids**

This group is characteristic because all the amino acids present in this group are water soluble because of their polar R- moiety which can form hydrogen bonds with water. This group includes serine, threonine, cysteine, asparagine, and glutamine. While serine and threonine possess aliphatic hydroxyl moiety, cysteine contains sulfhydryl group; asparagine and glutamine have carboxamide groups wherein all of these functional group possess good hydrogen bond forming features. Glycine is a unique molecule in the sense that as it has only H as its side chain and the amino acid is unable to form hydrogen bond with water but the polar amino and carboxyl groups present contribute towards providing solubility in water and hence it is more apt that glycine should belong to this category.

### **Sulphur containing amino acids**

Cysteine and Methionine are two amino acids which belong to this category. While Methionine is non polar in nature cysteine is a polar molecule. Cysteine readily oxidizes into a covalently linked dimeric amino acid called cystine, where the two cysteine molecules are coupled by a disulfide link. These residues are specially important when two polypeptides or parts of the same protein are linked with each other as two sulfhydryl groups in proximity tend to readily form disulfide bonds and the disulphide linkage (Inter and Intra) is the only covalent connection between different polypeptide chains as all the other linkages vital for the folding of any multimeric protein are non covalent in nature.

### **Aromatic amino acids**

Phenylalanine, Tyrosine and tryptophan belong to this category. Predominantly nonpolar and hydrophobic in nature they basically belong to the first group however there is the presence of an aromatic ring nucleus. Tyrosine because of the hydroxyl residue becomes charged at high pH and can form hydrogen bonds. Both Tyrosine and tryptophan are notably more polar than phenylalanine, because of the presence of hydroxyl group in tyrosine and the nitrogen of the tryptophan indole ring. These molecules (Tryptophan and tyrosine, and to a much lesser extent phenylalanine) are particularly useful during the estimation of protein content as these residues have delocalized  $\pi$  electrons and hence have an ability to absorb ultraviolet light and thus proteins can be measured for their concentration at a wavelength of 280 nm.

### **Acidic amino acids**

Aspartic acid and glutamic acid with a carboxylic acid as their R- moieties are usually negatively charged at neutral pH owing to the presence of two carboxylic acid groups. These amino acids are usually found in metal binding sites of the metalloproteins and behave as nucleophiles in electrostatic bonding interactions.

### **Basic amino acids**

Histidine, arginine, and lysine have net positive charges at pH 7.0 owing to the presence of imidazole group in histidine, guanidinium moiety in arginine and protonated alkyl amino group in lysine. Besides histidine-containing peptides being significant biological buffers, histidine also behaves as a good proton donor/acceptor. Also Arginine and lysine side chains are critical for electrostatic interactions in proteins.



## Introduction to amino acids, peptides and proteins

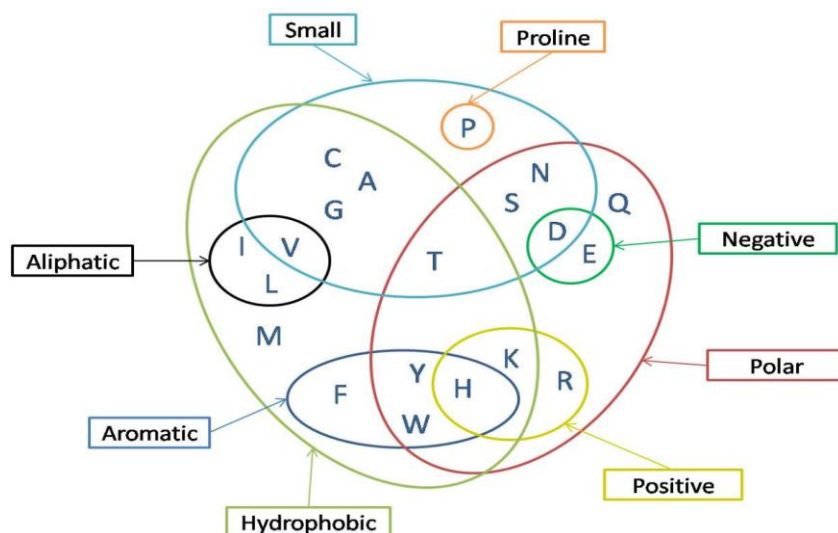


Figure: The various categories of amino acids

Source: <http://www.biomedcentral.com/content/figures/1471-2105-10-113-3-1.jpg>

### Free and rare occurring amino acids

There are several amino acids as well as their derivatives which are not an integral component of the proteins or peptides but still are involved in several key metabolic phenomena. They are:

- **Aminobutyric acid** or **GABA**- a product of decarboxylation of glutamic acid and a potent neurotransmitter.
- **Histamine** and **serotonin** - produced by decarboxylation of Histidine and derived from tryptophan respectively, both perform as neurotransmitters and regulators.
- **$\beta$ -Alanine**- present in peptides
- **Carnosine and anserine** -a constituent of pantothenic acid (a vitamin), which in turn is a part of coenzyme A.
- **Epinephrine/ adrenaline** - synthesized from tyrosine, a hormone and a neurotransmitter.
- **Penicillamine** - present in penicillin antibiotics.
- **Ornithine, betaine, homocysteine, and homoserine** - important metabolic intermediates.
- **Citrulline** - precursor of Arginine, involved in urea synthesis.

Some uncommon amino acids are present in living systems and they have specific functions to perform. They include:

- **Hydroxylysine** and **hydroxyproline**, present in collagen, gelatin proteins and plant cell wall proteins.
- Methylated amino acids like **methylhistidine,  $\epsilon$ -N,N,N-trimethyllysine** and  **$\epsilon$ -N-methyllysine** are usually present in muscle proteins like myosin.
- **Thyroxine** and **3, 3', 5-triiodothyronine**, iodinated amino acids conjugated with thyroglobulin, a protein formed by the thyroid gland. They act as hormones to regulate growth and development.
- **$\gamma$ -Carboxyglutamic acid** present in proteins concerned in blood clotting,
- **Pyroglutamic acid** found in bacteriorhodopsin which is a light-driven proton-pump.
- Phosphorylated serine, threonine, and tyrosine - Reversible process and mainly involved with cell growth and regulation.

## Introduction to amino acids, peptides and proteins

- **Amino adipic acid** proteins present in corn.
- **N-methylarginine** and **N-acetyllysine** - present in histone proteins coupled with chromosomes.
- **Desmosine**, a four Lys residues derivative, found in elastin a fibrous protein.
- **Selenocysteine** established during protein synthesis, contains selenium rather than the sulfur of cysteine. a component of just a small number of identified proteins.

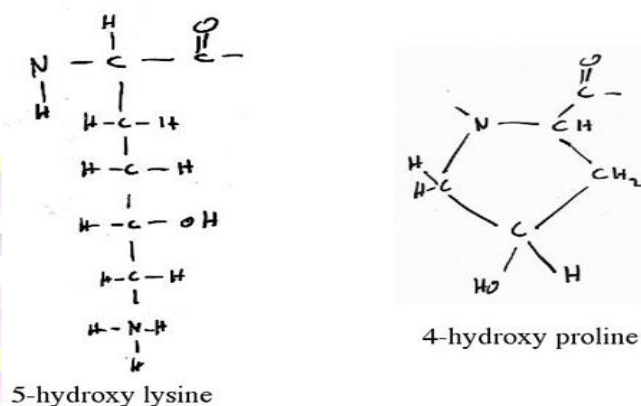


Figure: Structure of uncommon amino acids

Source: [http://web.sls.hw.ac.uk/teaching/Derek\\_J/A13MM1-web/Lectures/files/collagen/files/1\\_1.jpg](http://web.sls.hw.ac.uk/teaching/Derek_J/A13MM1-web/Lectures/files/collagen/files/1_1.jpg)

## Properties of amino acids

### Acid base properties

An amino acid when dissolved in water becomes zwitterions. This happens because an amino acid has an acidic ( $\alpha$ -COOH) as well as a basic group ( $\alpha$ -NH<sub>2</sub>) and hence can both donate as well as accept protons and can behave both as an acid as well as a base. This twofold behavior of amino acids makes them an amphoteric electrolyte. Being a weak polyprotic acid, amino acids are weakly dissociating which is dependent on the pH of the solution. All these amino acids have a minimum of two hydrogens which can be dissociated and the number can increase on the basis of their R functional group.

In a typical titration involving slow addition or elimination of protons for the simplest amino acid like Glycine, at low pH the protonation of both the groups occur and the Glycine molecule acquired a net positive charge. With the increase in pH, the carboxylic group first dissociates leading to the formation of neutral zwitterions. With the additional raise in pH ultimately the amino group dissociates and a net positive charge is acquired by the Glycine residue. Hence the plotting of a typical titration curve of Glycine will represent two discrete stages where each of them will be similar to the titration curve of a monoprotic acid. At a physiological pH of 7.4 usually a dissociated carboxylic acid moiety with no dissociation of amino group is observed. The titration curve helps us in determining the pKa of the two ionizable groups of amino acid. The presence of a neighboring dissociable group effects the dissociation constant of the first thereby making it more vulnerable than a simple carboxylic acid or amino group. Therefore because of the strong electron-withdrawing amino group, its positive charge exerts a strong field on the carboxylic acid group thereby making the carboxylic acid more acidic and it acquires a low pKa. This further stabilizes the carboxylate anion and consequently it readily donates protons. A similar condition occurs for the amino group also. This phenomenon helps us in understanding the

## Introduction to amino acids, peptides and proteins

enzymatic reactions where a strong effect of the neighboring functional groups, intra molecular interactions and chemical environment influences the pKa values of the functional residues present in the active sites.

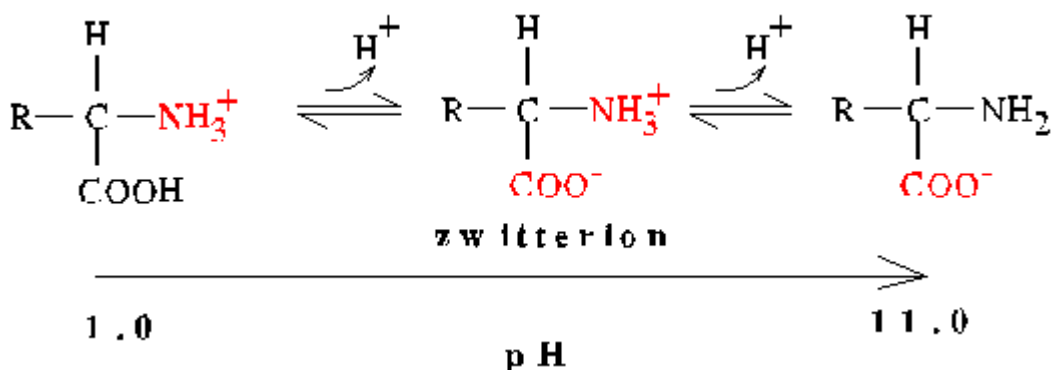


Figure: The various forms of amino acids along with zwitterion formation with change in pH values

Source: <http://www.tulane.edu/~biochem/med/zwit.gif>

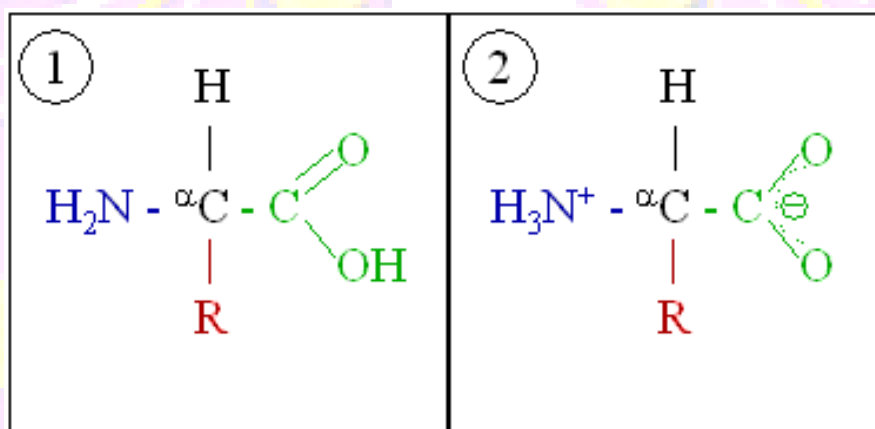


Figure: The zwitterion formation in amino acid

Source: [http://upload.wikimedia.org/wikipedia/en/0/04/Amino\\_acid\\_zwitterions.png](http://upload.wikimedia.org/wikipedia/en/0/04/Amino_acid_zwitterions.png)

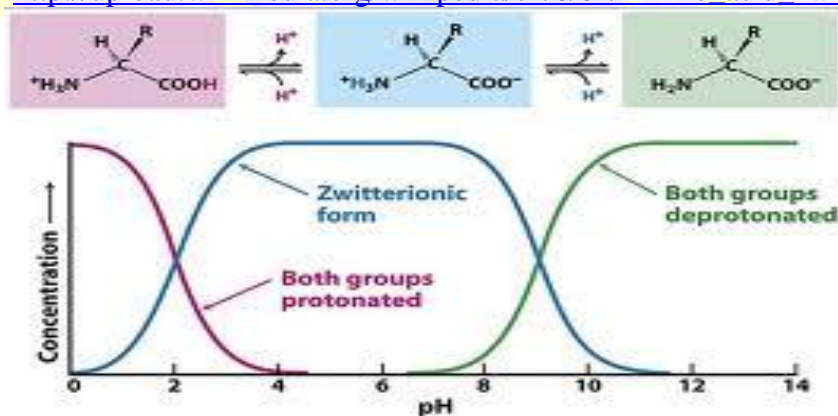


Figure 2-6  
Biochemistry, Sixth Edition  
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Figure: A typical titration of amino acids along the pH range






# Introduction to amino acids, peptides and proteins

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## Role of side chains in ionization

Acidic amino acids like aspartic and glutamic acids and basic amino acids like Lysine Arginine and Histidine are known to contain an additional dissociable groups besides the  $\alpha$  carboxyl and  $\alpha$  amino group. The  $pK_a$  values of these R- group containing amino acids are higher to  $\alpha$  dissociable groups but lesser or similar to the aliphatic acids or bases. This is because the side chain ionizable groups are several residues away from the  $\alpha$ -carbon and hence this lessens the effect of the side chain moieties. Besides these amino acids only the para-OH group of tyrosine and the OSH group of cysteine shows some degree of dissociation.

**Amino Acid  $pK_a$  Values and Side Chain Identities**

Amino Acid	pKa Values		Side	Side Chain (Z) – “fully” protonated
	$\alpha$ -CO <sub>2</sub> H	$\alpha$ -NH <sub>3</sub> <sup>+</sup>		
Alanine	2.34	9.69		-CH <sub>3</sub>
Arginine	2.17	9.04	12.48	+NH <sub>2</sub> H <sub>2</sub> NCONHCH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> -
Asparagine	2.02	8.84		H <sub>2</sub> NCOCH <sub>2</sub> -
Aspartic Acid	2.09	9.82	3.86	-CH <sub>2</sub> CO <sub>2</sub> H
Cysteine	1.71	10.78	8.33	-CH <sub>2</sub> SH
Glutamic Acid	2.19	9.67	4.25	-CH <sub>2</sub> CH <sub>2</sub> CO <sub>2</sub> H
Glutamine	2.17	9.13		H <sub>2</sub> NCOCH <sub>2</sub> CH <sub>2</sub> -
Glycine	2.34	9.60		-H
Histidine	1.82	9.17	6.04	
Isoleucine	2.36	9.68		-CH(CH <sub>3</sub> )CH <sub>2</sub> CH <sub>3</sub>
Leucine	2.36	9.60		-CH <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub>
Lysine	2.18	8.95	10.79	-CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> NH <sub>3</sub> <sup>+</sup>
Methionine	2.28	9.21		-CH <sub>2</sub> CH <sub>2</sub> SCH <sub>3</sub>
Phenylalanine	1.83	9.13		
Proline	1.99	10.60		
Serine	2.21	9.15		-CH <sub>2</sub> OH
Threonine	2.63	9.10		-CH(OH)CH <sub>3</sub>
Tryptophan	2.38	9.39		
Tyrosine	2.20	9.11	10.07	
Valine	2.32	9.62		-CH(CH <sub>3</sub> ) <sub>2</sub>



Dr. Kline – Santa Monica College – 2006

Figure: The  $pK_a$  values of the various ionized side chains for the 20 amino acids

Source: <http://img.docstoccdn.com/thumb/orig/88520986.png>

## Titration curves

While a simple amino acid like Glycine shows a two stage titration curve characteristic of the two  $\alpha$  ionizable groups in the amino acid. However amino acids which have an ionizable R group have a more complex *three* stage titration curves which represent the three dissociation steps observed with the changes in pH and having three unique  $pK_a$  values.

## Introduction to amino acids, peptides and proteins

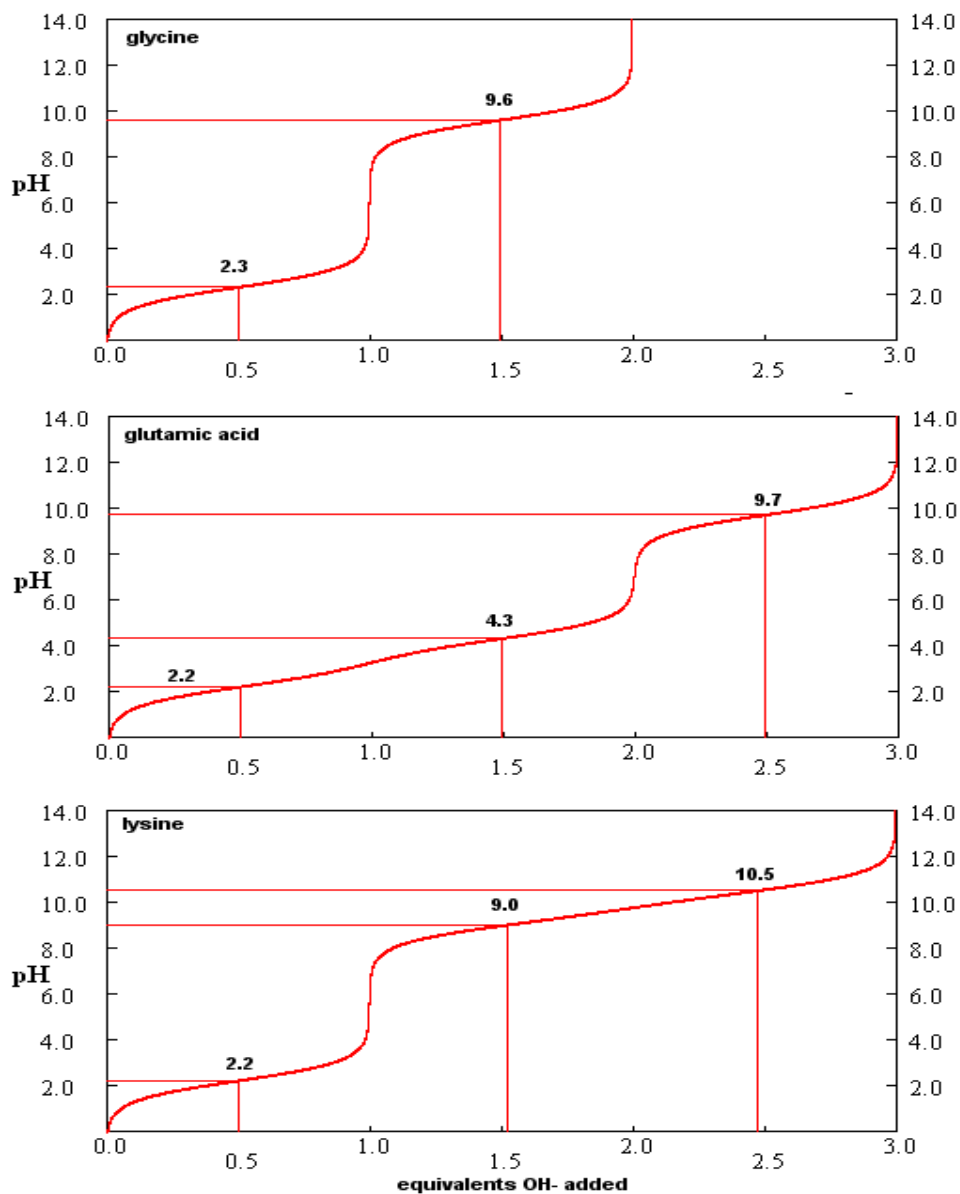


Figure: Titration curves of various amino acids

Source: <http://biowiki.ucdavis.edu/@api/deki/files/505/=04titcurve3aa.gif>

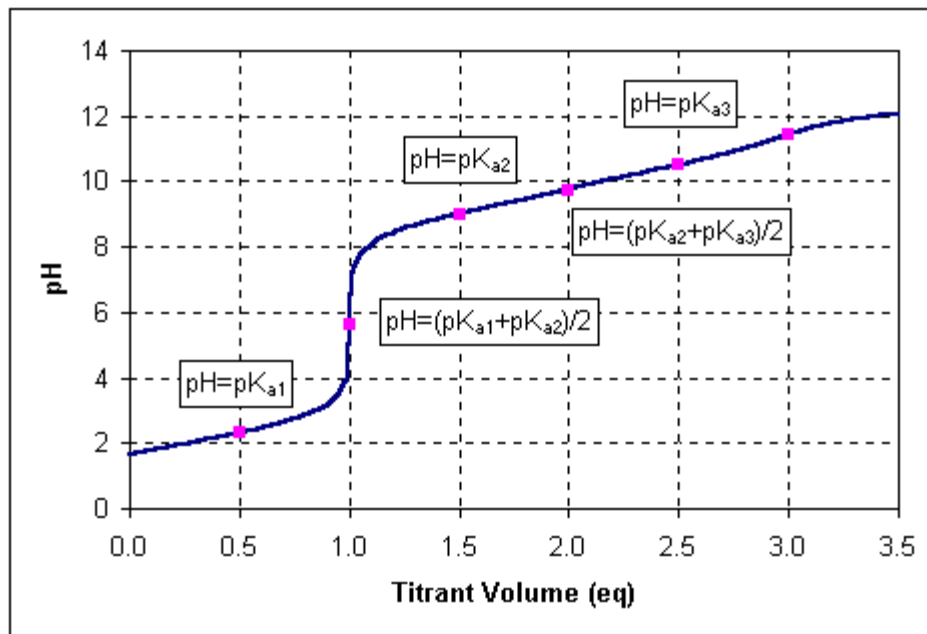


Figure: Calculation of pKa values from a typical titration curve of an amino acid  
 Source: <http://ion.chem.usu.edu/~sbialkow/Classes/3600/Overheads/H3A/Image140.gif>

The neighboring charged groups, the pH, the solvent used and location of the amino acids are some of the important parameters which decide the pKa of a functional group.

$$pH = pK_a + \log \frac{[base]}{[acid]}$$

Figure: The relationship between pH and pKa  
 Source: <http://upload.wikimedia.org/math/f/0/0/f0097faf1d1d2656ad9e4fe46ed04eb1.png>

The titration curves of different amino acids perform the following role: They help us in determining the distinct isoelectric point (pI) of the amino acid at which there is no net charge on the amino acid which in turn reflects the nature of the R- group chains. The pI of the given amino acid can be calculated from:

$$pI = \frac{pKa + pKb}{2}$$

Figure: The formula for pI calculation  
 Source: <http://upload.wikimedia.org/math/6/e/c/6ec6fe56aa030a9c22e7d3f5809e616a.png>

- The pI values are especially significant for understanding the mobility of proteins in electrophoretic field or during the chromatographic separations in ion exchange chromatography.
- These curves exhibit the pH values around which these amino acids behave like buffers. This can be understood with the help of the titration curve of Glycine where two such regions as a flat portion in the curve are observed. While the first one is near the first pKa of 2.34 the second one is near the second pKa of 9.6. At both places a buffering region of ± 1 pH is observed.

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Under the normal physiological pH of 7.4, only Histidine is found to have the buffering power.

- They help us in determining a correlation between the net electric charge of the amino acid and the pH of the solution. The distance of the pH of the solution from its pI determines the charge content on the amino acid. Larger the distance from the pI, the higher is the net charge. This property can indeed be used for the separation of amino acids, peptides and proteins by altering the pH.
- For the amino acids with no ionizable group in the R chain, their pKa is the mean of the pKa of the two  $\alpha$  ionizable groups is calculated and their titration curve resembles that of Glycine.

### Optical and stereochemical properties

As discussed earlier every amino acid except Glycine possesses an asymmetric or a chiral  $\alpha$  carbon. The tetrahedral display of the bonding orbitals in turn leads to the presence of possible configurations of two non superimposable mirror image stereoisomers which are also known as enantiomers. A unique feature of enantiomer is the presence of optical activity i.e. they contain an ability to rotate the plane polarized light either to the left or to the right. The molecules which rotate the light to the right are called dextrorotatory compounds while the ones which rotate light to the left are called laevorotatory molecules. However the amount of rotation or the directions are the typical prerogatives of the amino acids. Besides this several physicochemical features like the temperature, the wavelength of the plane polarized light used, the ionization state of the amino acid, and the pH of the solution affect optical rotation. A  $\pm$  sign or d, l alphabets are usually used to depict optical rotation. The dextro rotation is represented by + or d while the laevo rotation is depicted by - or l.

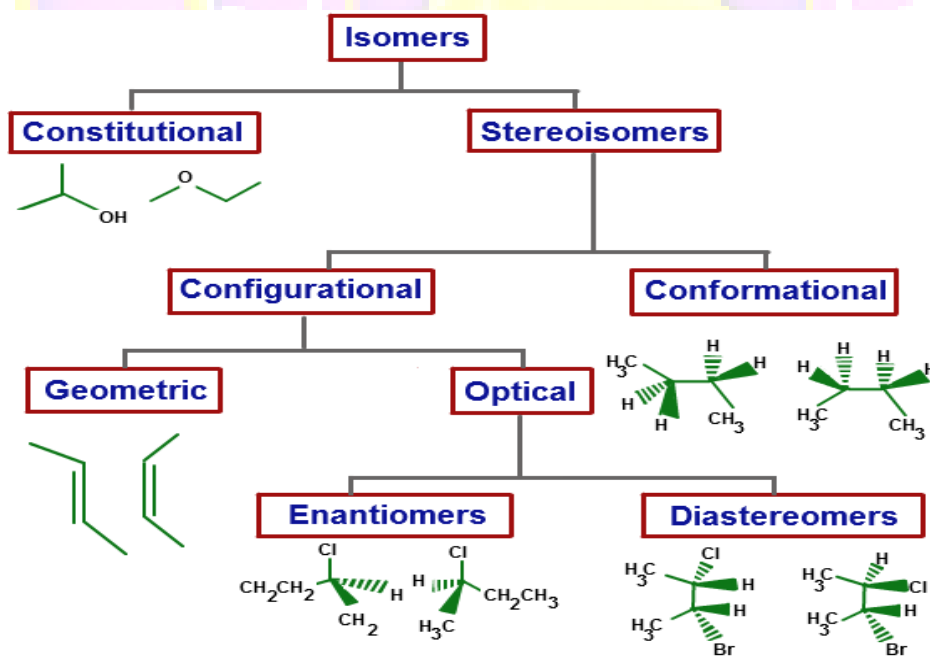


Figure: The various types of Isomers

Source: <http://images.tutorvista.com/cms/images/81/types-of-isomers1.png>



## Nomenclature of isomers

The chiral molecules are further represented through two other types of nomenclatures i.e. the D, L type projected by Emil Fischer in 1891 and the R, S type. In the D and L type of nomenclature Glyceraldehyde is taken as the reference molecule to determine the configuration wherein the + and the - are designated as D and L form respectively and every molecule which gets the D and L nomenclature should have an alignment which is similar to the D and L isomer of glyceraldehydes. It may be observed that d and l isomers are not analogous to D and L configuration and that D and L represent the absolute configurations and do not depict the optical rotation. Equal ratio of both the forms as it happens in ordinary chemical synthesis leads to the formation of a racemic mixture. It is interesting to note that while all the naturally occurring amino acids are of L- type except for in the peptidoglycan network of a few microorganisms and in certain peptide antibiotics while all the naturally occurring sugars are of D- type. This oblique preference of L form of amino acid by the nature could be attributed to the fact that in order to synthesize a stable protein requires a specific stereoisomer and L- form is favored over the other and subsequently stereo specificity is observed even in the biochemical reactions occurring in the living systems.

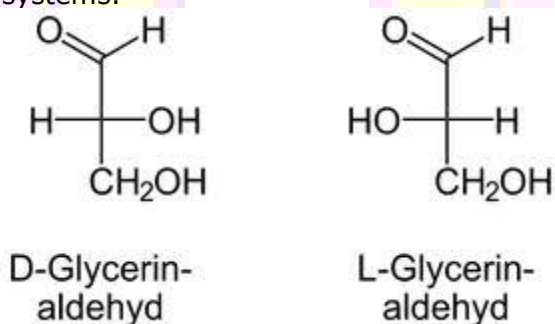


Figure: The two isomers of Glyceraldehyde

Source: <https://encrypted-tbn1.gstatic.com/images?q=tbn:ANd9GcRuUHAjd6z63vGWDcykpCu09GxgObkn0enQYbY9ya2wv9CIegs9>

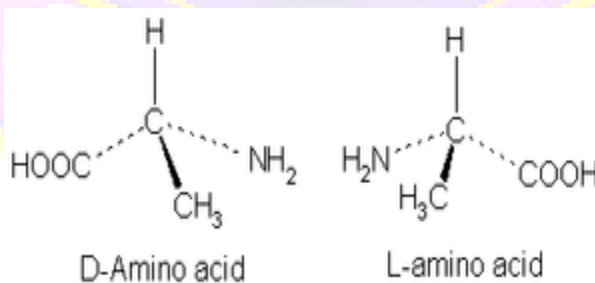


Figure: the two isomers of amino acids

Source: [http://upload.wikimedia.org/wikipedia/commons/thumb/3/30/Op\\_isomer.png/300px-Op\\_isomer.png](http://upload.wikimedia.org/wikipedia/commons/thumb/3/30/Op_isomer.png/300px-Op_isomer.png)

## Introduction to amino acids, peptides and proteins

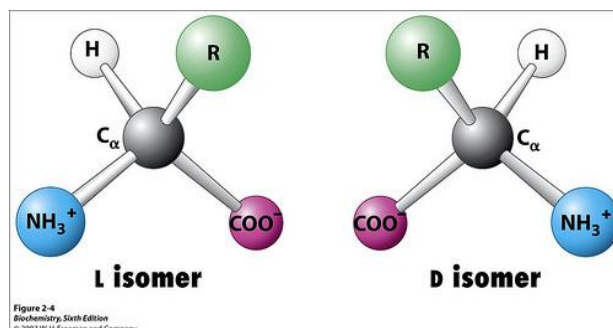


Figure: the pin and ball model of the two isomers of amino acids

Source: [http://farm5.static.flickr.com/4039/4318185906\\_eb83f7098a.jpg](http://farm5.static.flickr.com/4039/4318185906_eb83f7098a.jpg)

However this form of nomenclature was vague for all those molecules which contained more than one chiral center. Hence a new improved nomenclature system was devised which addressed this problem of chiral molecules and was named as R, S system. This system kept in consideration the atomic number of the functional groups attached to the asymmetric carbon and preferences were set up accordingly wherein a higher atomic number moiety achieved higher priority. Thus a molecule with n number of asymmetric carbons had  $2^n$  isomers or two pairs of enantiomers. Non-mirror image isomers which vary in configuration at only one of the chiral carbon are known as diastereomers. All the amino acids possessing more than one chiral carbon use this system like L- isoleucine is (2S,3S)-isoleucine while its diastereomer is known as L-alloisoleucine.

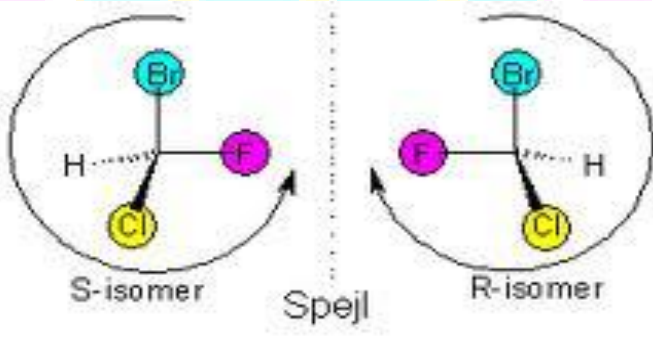


Figure: The R and S isomers

Source: [https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQHxXnZ6h\\_vY4ARCd9kf9koxgl\\_iAGLRULGtnGdIovKIGhsMM-kc](https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQHxXnZ6h_vY4ARCd9kf9koxgl_iAGLRULGtnGdIovKIGhsMM-kc)

## Spectroscopic Properties

### UV-visible spectroscopy

Spectroscopy as a technique has reached vast ending proportions in terms of understanding the conformations of proteins and dynamics of their folding and their chemistry. If the complete spectrum of light is analyzed for their absorption by amino acid, it is observed that while there is no absorption of visible region by the amino acids, aromatic amino acids like phenylalanine, tyrosine, and tryptophan demonstrate considerable ultraviolet absorption around 250 nm with absorption maxima at 280 nm and this adsorption phenomenon can be used for the estimation of protein content. All amino acids absorb the infrared rays. It has been observed

## Introduction to amino acids, peptides and proteins

that aromatic amino acid also exhibit property of intrinsic fluorescence albeit weak. Tryptophan also displays phosphorescence.

### Nuclear Magnetic Resonance

NMR as a spectroscopy technique is assisting in understanding the chemical structure of peptides and even small proteins. Based on the NMR the following features pertaining to amino acids were inferred. They are:

- NMR usually expresses its signals in terms of chemical shift which reflects the disparity in resonant frequency amid the observed signal and a suitable reference signal. In the case of proton NMR of amino acids, the **chemical shift** relies on the status of ionization of the amino acid which in turn depends on the chemical milieu around them particularly pH.
- The proton NMR of amino acids through its chemical shift also reveals that electrons tend to move throughout the carbon chain in the aliphatic chains of both the aliphatic and aromatic amino acids during titrations.
- Another parameter of NMR which helps in understanding the structural association between the two nuclei is known as the coupling constant. In proton NMR of amino acids the scale of the **coupling constants** among protons on flanking carbons relies on the ionization state of a few amino acids. The values of coupling constant also vary because a few conformations are preferred over the others during dissociations.

## Peptides and Proteins

When 2 or more than 2 amino acids residues covalently link with each other using a peptide bond the resultant polymer is called a peptide. When 2 amino acids are linked with each other it is called a dipeptide and subsequent amino acid linkages are known as a tripeptide (3 amino acids), oligo peptide (3-10 amino acids) or a polypeptide (> 10 amino acids). Even though most of the peptides and proteins are composed of L-amino acids many peptides contain unusual amino acids. Even though polypeptides and proteins are analogous in nature however polypeptide have lesser molecular weight (below 10000 Da) compared to proteins which have higher molecular mass. Also one or more linear polypeptide chains linked together through covalent or non covalent bonds constitute a protein and they contain an average of 40-34,000 amino acid residues. A large versatile group of proteins with diverse physicochemical features is feasible owing to large potential combinations of 20 amino acids.

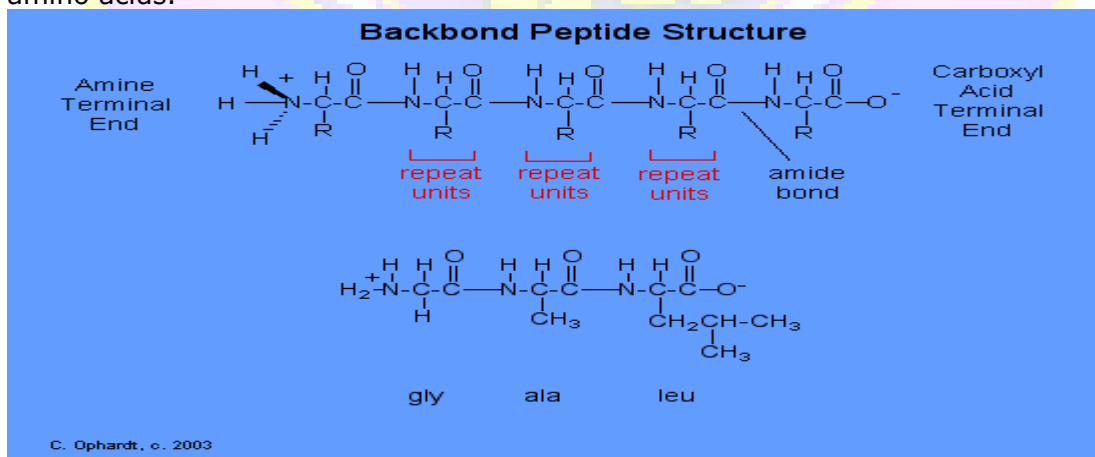


Figure: A typical peptide structure

Source: <http://www.elmhurst.edu/~chm/vchembook/images/564glyalaleu.gif>

## Ionization of peptides

Every polypeptide is a polyelectrolyte and has only one free amino group and a carboxylic acid group on the either ends of the polypeptide chain and the two ends are known as the N-terminus and the C-terminus respectively. The rest of the ionization groups in the polypeptide lose their charge owing to the formation of peptide bonds. The ionization behavior of these two ends is analogous to a free amino acid however the dissociation constant may be varied as there is no effect of neighboring ionic groups as is seen in the case of a free amino acid but some consequence of the nature and quantity of R- chains can be observed on the acid-base properties of the polypeptide. A peptide also possesses its own unique titration curve with a distinct pKa value and isoelectric point (pI), features which help in their isolation and characterization in a variety of techniques like electrophoresis and chromatography. The pKa value of a peptide is found to be dependent on a number of factors which includes the alteration of charge on the  $\alpha$  carboxyl and  $\alpha$  amino terminus, the relation with other R- functional moieties present in the peptide and environmental conditions like solvent and pH reduction.

## Biologically Active Peptides and Polypeptides

Peptides even though smaller than proteins have an ability to perform biological functions in living systems. Even a dipeptide can be biologically active in nature. Peptides can perform a variety of functions which include them working as growth factors, hormones and antibiotics.

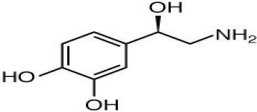
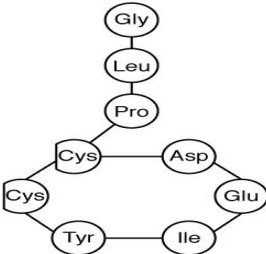
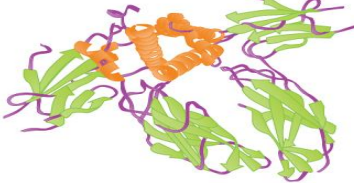
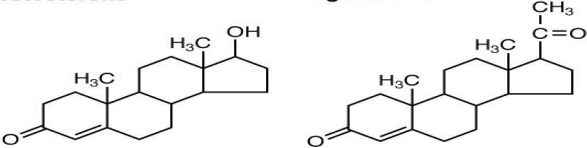
Hormone Class	Components	Example(s)
<b>Amine Hormone</b>	Amino acids with modified groups (e.g. norepinephrine's carboxyl group is replaced with a benzene ring)	<p><b>Norepinephrine</b></p> 
<b>Peptide Hormone</b>	Short chains of linked amino acids	<p><b>Oxytocin</b></p> 
<b>Protein Hormone</b>	Long chains of linked amino acids	<p><b>Human Growth Hormone</b></p> 
<b>Steroid Hormones</b>	Derived from the lipid cholesterol	<p><b>Testosterone</b>      <b>Progesterone</b></p> 

Figure: The various classes of hormones

## Introduction to amino acids, peptides and proteins

Source: [http://cnx.org/content/m46667/latest/1802\\_Examples\\_of\\_Amine\\_Peptide\\_Protein\\_and\\_Steroid\\_Hormone\\_Structure.jpg](http://cnx.org/content/m46667/latest/1802_Examples_of_Amine_Peptide_Protein_and_Steroid_Hormone_Structure.jpg)

### Peptides as hormones

A variety of peptide hormones are produced in the body by many different organs and tissues. Many of these hormones are produced in the pituitary gland. While the anterior portion produces prolactin which acts on the mammary glands, adrenocorticotrophic hormone (ACTH), which through the secretion of glucocorticoids regulates the adrenal cortex and growth hormone, which controls the entire growth and metabolism including bone, muscle, and the liver. The posterior portion of the pituitary gland secretes vasopressin also called antidiuretic hormone and oxytocin. Vasopressin with nine amino acid residues plays a crucial role in blood pressure regulation it also regulates a wide variety of functions like water balance, appetite, body temperature and sleep. Vasopressin is very similar in structure to oxytocin which stimulates milk ejection during lactation from mammary glands besides it is also involved with uterine contractions. As the structure of vasopressin and oxytocin is similar thus many functions of the two are similar hence oxytocin is mildly diuretic in nature while vasopressin behaves like oxytocin.

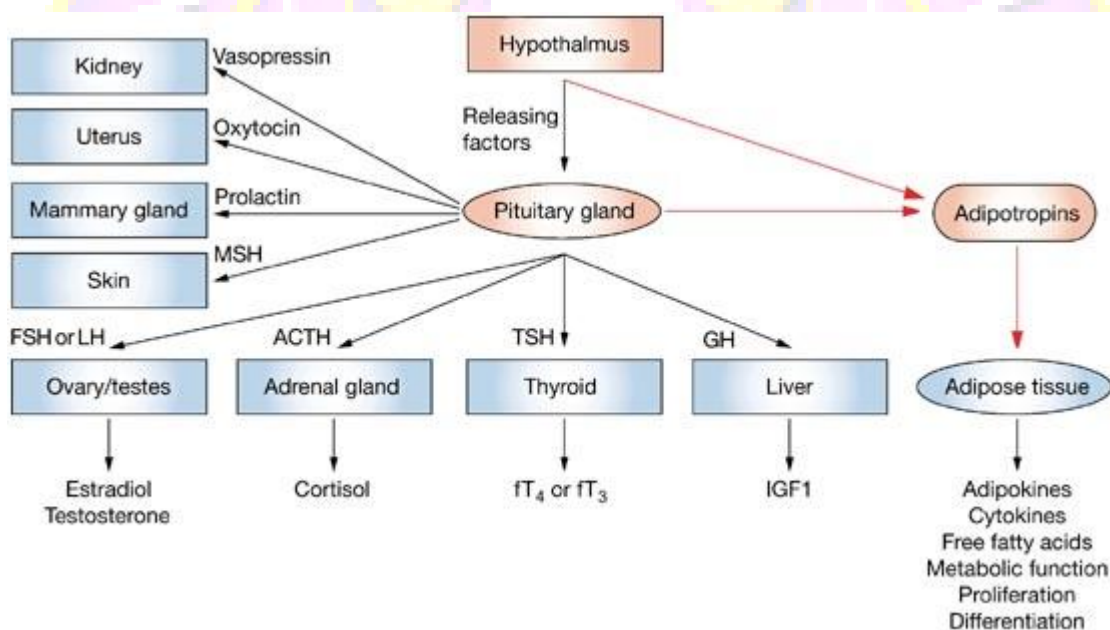


Figure: The various peptide hormones released from pituitary gland

Source: <http://www.nature.com/nrendo/journal/v2/n7/images/ncpendmet0197-f2.jpg>

Other organs also secrete a variety of hormones like heart which produces atrial-natriuretic peptide (ANP) or atrial natriuretic factor (ANF)), pancreas which produces important hormones like insulin and somatostatin and the gastrointestinal tract which secretes cholecystokinin and gastrin, thyrotropin-releasing factor possessing three residues, which is formed in the hypothalamus and stimulates the release of another hormone, thyrotropin, from the anterior pituitary gland and adipose tissue which stores leptin. There are other peptides like bradykinin which contains nine residues and inhibits inflammation of tissues; Glutathione is a tripeptide found in



## Introduction to amino acids, peptides and proteins

almost all organisms and has a crucial role in protein and DNA biosynthesis, drug and environmental toxin metabolism, amino acid transport etc.

### Peptides as antibiotics

Many antibiotic or anti microbial compounds are also peptides in nature .They include actinomycin, bacitracin, colistin, and polymyxin B. Many of these antibiotics are very toxic and hence can only be used as a topical preparation for superficial wounds. Actinomycin D is known to be cytotoxic in nature by binding DNA and inhibiting RNA synthesis and presently it is being used in cancer chemotherapy. Being an integral part of the innate immunity of the individual, they protect an individual by disrupting various key cellular processes. They have a propensity to assume a distinct membrane-bound amphipathic conformation even though they are particularly heterogeneous in structure.

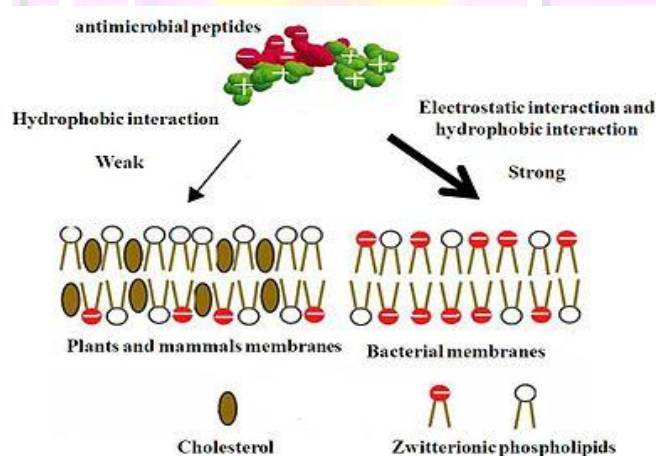
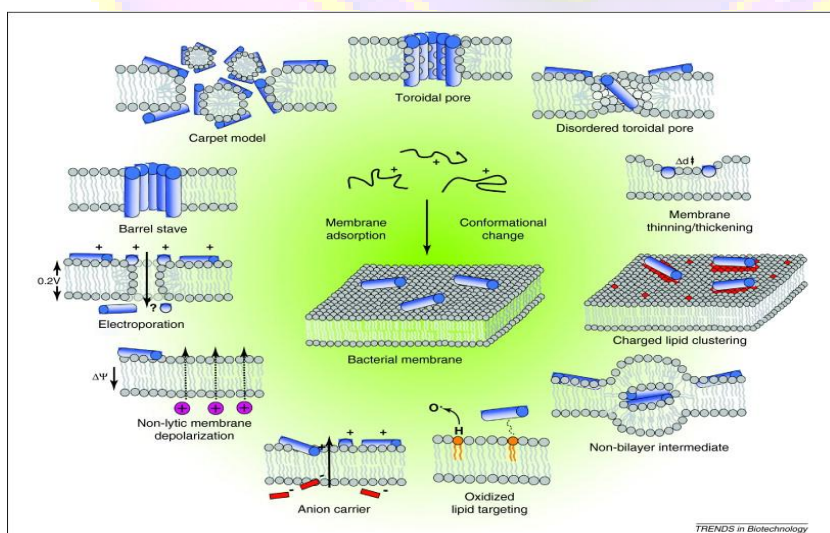


Figure: The mechanism of selectivity of antimicrobial peptide

Source: [http://upload.wikimedia.org/wikipedia/commons/thumb/c/cd/Mechanism\\_of\\_Selectivity\\_of\\_Antimicrobial\\_Peptides.jpg/400px-Mechanism\\_of\\_Selectivity\\_of\\_Antimicrobial\\_Peptides.jpg](http://upload.wikimedia.org/wikipedia/commons/thumb/c/cd/Mechanism_of_Selectivity_of_Antimicrobial_Peptides.jpg/400px-Mechanism_of_Selectivity_of_Antimicrobial_Peptides.jpg)



## Introduction to amino acids, peptides and proteins

Figure: The mechanism of action of anti microbial peptides

Source: <http://ars.els-cdn.com/content/image/1-s2.0-S0167779911000886-gr1.jpg>

### Peptides as growth factors

Peptides also have an ability to work as signaling molecule for intracellular regulation or homeostasis. Many of the peptides work as neurotransmitters besides performing as a hormone in the nervous system. These molecules have an ability to stimulate and regulate cellular growth and differentiation or maturation. A plethora of peptide growth factors are present in living system which perform a variety of functions pertaining to cellular proliferation like bone morphogenic proteins stimulate bone cell differentiation, while blood vessel differentiation (angiogenesis) is stimulated by fibroblast growth factors and vascular endothelial growth factors. There is an endless list of growth factors which regulate an array of metabolic activities. Recently people have started using these growth factors to treat a variety of hematologic, oncologic and cardiovascular diseases.

### Proteins

One of the most flexible biomolecule, protein is diverse both in terms of types as well as in terms of function. Starting from a linear polypeptide sequence, the molecule folds itself into a complex three dimensional conformation with the help of numerous non-covalent attachments. The structure of a protein is quite intricate in terms of flexibility with parts of it being rigid creating bends and hinges which are critical functionally. It is comprised of a wide array of functional moieties like thiols, thioethers, carboxylic acids, carboxamides, and a range of basic groups which execute an assortment of functions. They tend to network with other proteins as well as other biomolecule to form complexes further diverging into metabolic process like DNA replication, signal transduction, cellular regulation being a few of them.

### Various types of proteins

#### Multimeric Proteins

A protein could be possessing a single or more than one polypeptide chain. If it contains more than polypeptide chain it is called a multimeric protein. The different polypeptides are known as the subunits of the proteins. These subunits could be different or identical in nature or a mixture of the two .Presence of a minimum of two identical subunits in protein is called oligomeric while the one with identical subunits are called protomers. These subunits are linked with each other through noncovalent linkages but many a times a covalent disulfide linkage is also observed between the two cysteine residues of the two polypeptides. An important example of a multimeric protein is hemoglobin. It is comprised of 4 subunit linked non-covalently. The subunits are two types namely  $\alpha$  and  $\beta$  which are in two copies each. The hemoglobin molecule is therefore either a tetramer or a dimer of  $\alpha\beta$  protomers. Usually the multimeric proteins have all the four levels of structural organizations typically seen. The functions performed by these proteins are performed with the help of all the subunits and the so called functional conformation is an amalgamation of the conformational features of all the subunits.

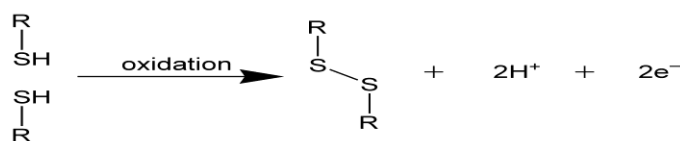




Figure: formation of a disulfide bond

Source: <http://upload.wikimedia.org/wikipedia/commons/8/82/Disulfide-bond.png>

### Conjugated proteins

A conjugated protein could be a monomer or a multimer however these proteins besides possessing the peptides also require specialized chemical groups attached by covalent bonds or by weak interactions. These proteins are comprised of a non amino part which is usually called a prosthetic group which could be more than one also in a single molecule. Most of the prosthetic groups in conjugated proteins are vitamins. Besides vitamins, lipids, sugars, metals, flavanoids and heme are some of the other chemical groups which constitute a prosthetic group and the conjugated proteins are classified accordingly.

The most abundant and extensive group of conjugated proteins is glycoproteins which are present extensively and perform a variety of functions like cell surface component to being an immunoglobulin which confers immunity to the individual.

Multimeric protein like hemoglobin also requires a prosthetic group called heme containing iron. Hemoglobin without heme is unable to carry oxygen as the iron ion present in heme prosthetic group is required to perform this function.

Some of the examples of the conjugated proteins are:

1. Lipoproteins -  $\beta$ -lipoprotein of blood (lipids)
2. glycoproteins - Immunoglobulin G(sugars), interferon
3. phosphoproteins - milk protein Casein (phosphorus),
4. hemeproteins - Hemoglobin (Heme-Iron Porphyrin)
5. flavoproteins - Succinic dehydrogenase (Flavin nucleotides)
6. metalloproteins - Ferritin (Iron), Alcohol dehydrogenase (zinc), Calmodulin (calcium), Plastocyanin (Copper), Dinitrogenase (Molybdenum)
7. Nucleoprotein - Ribosome (RNA), viruses

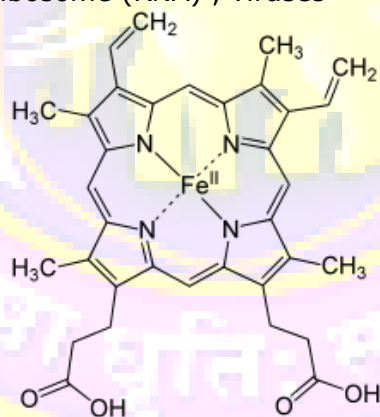


Figure: structure of Hemoglobin

Source: [http://wpcontent.answcdn.com/wikipedia/commons/thumb/b/be/Heme\\_b.svg/220px-Heme\\_b.svg.png](http://wpcontent.answcdn.com/wikipedia/commons/thumb/b/be/Heme_b.svg/220px-Heme_b.svg.png)

### Fluorescent proteins

Fluorescent proteins are proteins which have an ability to fluoresce i.e. they can emit visible light on the absorption of light from the near UV range. These proteins can themselves produce visible light from a sequence of 3 amino acids within their own polypeptide sequence. As discussed earlier every protein containing aromatic amino acids i.e. tryptophan, tyrosine, or phenylalanine residues are able to fluoresce as

## Introduction to amino acids, peptides and proteins

they are also known as intrinsic fluorophores. Besides this however an entire range of other proteins like the phycobiliproteins, can also fluoresce as they contain non-proteinaceous chromophores associated with the protein.

However an important molecule which has changed the entire concept of fluorescence is the discovery of the green fluorescent protein (GFP) obtained from the bioluminescent organs of *Aequorea victoria* jellyfish. Subsequent development of structural homologs of these molecules has improved the technique many folds.

*Aequorea* and *Renilla*, the bioluminescent organisms possess a partnership between their fluorescent proteins and bioluminescent proteins aequorin and luciferase, respectively. The fluorescent protein works like an acceptor for the bioluminescence energy and resonates such that the blue emission of the bioluminescent protein is converted into a longer wavelength green emission.

These fluorescent proteins mainly provide photo protection to symbiotic photosynthetic algae in high light conditions. The unique colors associated with these fluorescent proteins also help in species identification by reef fish.

These isolated fluorescent proteins are extensively being used for microscopic analysis and understanding of physiological and cellular processes in different cells and organelles. The formation of fluorescent cells and tissues has now become a relatively routine practice in biology.



Figure: The Green fluorescent protein

Source: [http://1.bp.blogspot.com/\\_LmBTQNXEYvY/SY-n3ZKCKyI/AAAAAAAAAFk/d8XOpYwwlfQ/s400/green+animate.jpg](http://1.bp.blogspot.com/_LmBTQNXEYvY/SY-n3ZKCKyI/AAAAAAAAAFk/d8XOpYwwlfQ/s400/green+animate.jpg)

### Diversity of function

Proteins are very diverse in nature. They are able to perform an assortment of role in the living systems like enzymes, transporters, storage molecules, signal transmitters, growth regulators being a few of them. Besides being involved with cellular metabolism, proteins provide structural features as well as provide energy at the time of need. Listing the entire plethora of functions performed by proteins is a daunting task however we make an attempt to list a few of the important ones.

#### Enzymes and catalysis

## Introduction to amino acids, peptides and proteins

The entire biochemical machinery for metabolically running the organism is dependent on thousands of enzymes which facilitate the process by working as a catalyst for an entire range of processes associated with catabolism, anabolism and energy generation. They are highly specific in nature and have an ability to increase the rate of reaction ( $10^6$  to  $10^{12}$  times) and require very mild conditions of pH and temperature (7.4 and 37 °C). A defective or lower level of enzymes is ensued by a deficiency disease. A few examples include enzymes like Lactate dehydrogenase which can oxidize lactate. One of the most abundant and an important photosynthetic enzyme is ribulose biphosphate carboxylase (RUBISCO).

### **Transport and storage**

Due to the proteins being amphipathic, they work as excellent transporters across the cell membranes. They can easily carry molecules and ions and Na K ATPase and glucose transporters are some of the important examples. Hemoglobin present in erythrocytes is an extremely important oxygen transporter for the body. The same function can also be performed by another protein myoglobin. Another important carrier protein in the body is Serum albumin which transports fatty acids in blood and Ferritin or transferrin which helps in the storage of iron and stores blood in the liver. Also lipoproteins like LDL and HDL as well as ceruloplasmin are some of the other carriers in the body which assist in the transport of lipids like cholesterol and copper.

Proteins also help in storing vital nutrients within the body as is seen in the case of bird egg and milk where all the important nutrients are reserved in ovalbumin and casein. Similarly Gliadin is a storage seed protein of wheat while Zein is a seed protein of corn.

### **Cell growth and its regulation**

Protein is not only essential for maintaining the integrity of the body but is also required to sustain them. A continuous requirement of proteins as amino acid is required through the diet as body needs it for an incessant construction of proteins which are required to build and maintain cells and subsequently tissues and organs. With every cell having a definite life span, it is necessary that the protein levels should be in abundance in the body. Several proteinaceous hormones and growth factors are produced within the body such as insulin, glucagon and GH etc. and growth factors like PDGF and EGF which manage cell division.

### **Structural and mechanical support**

One of the most important fibrous protein of the human body, collagen is extensively used for providing mechanical strength and structural support to skin and bone. The body continually synthesizes new collagen so as to heal injuries as well as to keep the joints in good physical shape. Besides collagen, fibroin is also involved with structural support while elastin, another fibrous protein provides elasticity to several tissues.

### **Movement, contraction and coordination**

## Introduction to amino acids, peptides and proteins

Movement of living system heavily relies on proteins. In multi cellular organisms a variety of fibrous proteins like actin, tubulins etc are key constituents in muscle activity. Myosin (Thick filaments) and Actin (Thin filaments) in myofibril are involved with the contraction of the muscles. Besides this a range of cellular movements like endocytosis, exocytosis, and amoeboid movement in WBC as well as cell movement associated with cell division are also performed with the help of these proteins. While in unicellular organisms, cellular structures like flagella and cilia regulate locomotion.

### **Protection, Immunity and defense**

The defense of a living organism is quite varied. One of the primary defenses of an animal system is in the form of antibodies. These antibodies which are also known as immunoglobulin are glycoproteins in nature and are circulating in the blood to detect foreign substances which are rendered inactive with the help of a plethora of immune cells. Also the skin is constitutive of keratin which protects against wounds and injuries while thrombin and fibrinogen assist in blood clotting to avoid blood loss. Besides this organism like snakes produce toxins like bungaratoxin in their poison while ricin protein from castor beans are present to counter predators. Further Diphtheria toxin is a bacterial toxin produced by *Clostridium botulinum* and causes bacterial food poisoning

### **Neuronal regulation**

The nervous system which regulates the body is usually proffered in the form of an ionic or an electrical impulse which is transferred to the master organ brain to the receptive organ. However the nerve impulse transmission cannot provide the requisite information till the organ contains the required protein receptors which are an integral part of nervous systems.

### **Fluid equilibrium and buffering capacity**

Protein as an ionic molecule is able to regulate the osmotic pressure which in turn maintains the liquid flow within the cell. Proteins are also known to behave as buffers to balance the physiological pH in the body.

### **Response to stress**

Every cell during its life span encounters a variety of stress which involves exposure to toxic contaminants and metals, high temperature etc. Cells produce an array of proteins like cytochromes P450 which makes derivatives of toxic organic contaminants which can be easily degraded; metallothionine which can easily sequester lethal heavy metals like cadmium, silver and mercury and heat shock proteins which under high temperature conditions help in the conformational repairs of the denatured DNA and even degrades them if they can't be repaired.

### **• Summary**

- The abundant and varied group of proteins is biosynthesized by a small monomer called amino acid is like an alphabet for the protein language and are covalently bonded as a unique linear sequence.

## Introduction to amino acids, peptides and proteins

- Around 20 standard amino acids exist in the nature and are universal in character.
- These amino acids are distinct from each other in terms of a side chain which is exclusive and enjoy distinctive chemical properties and form innumerable types of proteins.
- Attached to the  $\alpha$  carbon of amino acid are a hydrogen (H) moiety, an amino ( $\text{NH}_2$ ) group and a carboxylic acid ( $\text{COOH}$ ) functional group along with a variable side chain (R).
- As four different functional groups are attached to the alpha carbon except in Glycine (Where two H groups are there),  $\alpha$  carbon is asymmetric or chiral in nature. These molecules can have two non superimposable mirror image stereoisomers which are also known as enantiomers. Enantiomers are also optically active in nature.
- The amide bond formed through condensation reaction between the adjacent amino acid is called Peptide bond and is typically seen in peptides and proteins.
- Nonpolar aliphatic amino acids, Polar and neutral amino acids, Acidic amino acids, Basic amino acids, Aromatic amino acids and Sulphur containing amino acids are some of the forms in which amino acids can be sorted.
- There are several amino acids (Free forms as well as uncommon) as well as their derivatives which are not regularly seen in the proteins or peptides but still are critically involved in several important metabolic processes.
- An amino acid when dissolved in water becomes a zwitterion.
- A simple amino acid like Glycine portrays a two stage titration curve, a trait of the two  $\alpha$  ionizable groups in the amino acid. But amino acids with an ionizable R group form a more complex *three* stage titration curves symbolizing the three dissociation steps observed with the changes in pH and include three unique pKa values.
- Aromatic amino acids like phenylalanine, tyrosine, and tryptophan exhibit significant ultraviolet absorption around 250 nm with absorption maxima at 280 nm and this property can be used for the estimation of protein content.
- Polypeptides and proteins are comparable in character however polypeptide have lesser molecular weight (below 10000 Da) compared to proteins which have higher molecular mass. Peptides can execute an assortment of functions which comprise them working as growth factors, hormones and antibiotics.
- Starting from a linear polypeptide sequence, the protein folds itself into a complex three dimensional structure with the help of numerous non-covalent attachments.
- A protein possessing more than one polypeptide chain in the form of subunits is called a multimeric protein. If at least two subunits are identical they are called oligomers but if all the subunits are identical they are called protomers.
- Proteins which besides possessing the peptides also require specialized chemical groups called prosthetic groups attached by covalent bonds or by weak interactions are called conjugated protein.
- Fluorescent proteins are proteins which have an ability to fluoresce i.e. they can emit visible light on the absorption of light from the near UV range.



## Introduction to amino acids, peptides and proteins

- Proteins are very diverse in nature. They are able to perform an assortment of role in the living systems like enzymes, transporters, storage molecules, signal transmitters, growth regulators being a few of them. Besides being involved with cellular metabolism, proteins provide structural features as well as provide energy at the time of need.

### • Exercise/ Practice

Fill in the blanks

1. Optical rotation is not observed with glycine because its functional moiety is--  
----
2. All amino acids except--- contain an amino group.
3. For the amino acids which are neutral in nature, if the pH of the solution is decreased below the isoelectric pH of the amino acids, the amino acids will acquire a net ----- charge.
4. The formation of an amide bond with a concomitant release of water is an instance of a(n) \_\_\_\_\_ reaction.
5. A tetra peptide at its isoelectric pH possesses --- ionic charge.
6. Prosthetic groups in the class of proteins known as flavoproteins are composed of-----
7. Every protein containing----- amino acids residues are able to fluoresce as they are also known as intrinsic flours.
8. -----is obtained from the \_\_\_\_\_ bioluminescent organs of *Aequorea victoria* jellyfish.
9. The tetrahedral display of the bonding orbitals which leads to the presence of possible configurations of two non superimposable mirror image stereoisomers are also known as -----.
10. ----- are constituent of pantothenic acid (a vitamin), which in turn is a part of coenzyme A.

Answers: 1. hydrogen atom; 2. Proline; 3. Positive; 4. Condensation; 5. Four; 6. Flavin nucleotides; 7. Aromatic; 8. Green fluorescent protein (GFP); 9. Enantiomers; 10. Carnosine and anserine

State true or false

1. Tryptophan absorbs more ultraviolet light than tyrosine on a molar basis.
2. The reduction of a disulfide bond into a thiol leads to the release of two cystines.
3. Amino acids are ampholytes because they can function as either a polar or a non polar molecule
4. Proteins with different functions usually differ significantly in their amino acid composition.
5. In a conjugated protein, a prosthetic group is a part of the protein that is not composed of amino acids.
6. With the increase in pH, the amino group first dissociates leading to the formation of neutral zwitterions.
7. The pKa values of the R- group containing amino acids are higher to a dissociable groups but lesser or similar to the aliphatic acids or bases.
8. Glycine shows a one stage titration curve characteristic of the two  $\alpha$  ionizable groups in the amino acid.
9. Anti microbial peptides include actinomycin, bacitracin, colistin, and polymyxin B.
10. Ceruloplasmins are carriers in the body which assist in the transport of lipids like cholesterol.

## Introduction to amino acids, peptides and proteins

Answers: 1. True; 2. False; 3. False; 4. True; 5. True; 6. False; 7. True; 8. False;  
9. True; 10. False

### Short answer questions

1. Why is the average molecular weight of the 20 standard amino acids used for calculating the number of amino acids in a protein of known molecular weight?
2. Discuss the common structural features of amino acids found in naturally occurring proteins?
3. How do uncommon amino acids insert themselves into proteins? Give any two examples.
4. How does the profile of a titration curve verify that the fact that the buffering capacity for an amino acid solution is around its  $pK$ 's?
5. What is  $pI$ , and how can one determine its value for a neutral amino acid?
6. What is the characteristic acid-base property of Histidine R group?
7. How is it possible for a polypeptide to comprise only one free amino group and one free carboxyl group barring its R- chain groups?
8. Why does only cysteine and not methionine form disulfides?
9. Why is aspartate and not phenylalanine very soluble in water?
10. Which proteins are involved with structural support and providing elasticity?

### • **Glossary**

- Chiral carbon- asymmetric carbon, a tetrahedral carbon containing four different functional moieties
- Peptide bond- An amide linkage between two adjacent amino acids
- Hydrophobic- water hating
- Aromatic- a molecule containing a benzene nucleus
- Amphoteric- possessing both the positive and negative charge, they behave as both acids & bases
- Zwitterion- having an acidic ( $\alpha$  -COOH) as well as a basic group ( $\alpha$ -NH<sub>2</sub>)
- Ionization- dissociation of a molecule into ions
- Isoelectric point- the pH at which the neutral zwitterion form of the amino acid predominates
- Enantiomers- possible configurations of two non superimposable mirror image stereoisomers
- Optical rotation- an ability to rotate the plane polarized light either to the left or to the right.
- Racemic- Equal ratio of both the D and L forms
- Chemical shift- disparity in resonant frequency amid the observed signal and a suitable reference signal
- Prosthetic group- non amino part usually a vitamins, lipids, sugars, metals, flavonoids and heme
- Fluorescence- Fluorescence a form of luminescence. It is the emission of visible light by a substance that has absorbed near UV light or other electromagnetic radiation.

### • **References/ Bibliography/ Further Reading**

- Lehninger Principles of Biochemistry (Hardcover) by David L. Nelson , Michael M. Cox
- Lippincott's Illustrated Reviews: Biochemistry by Pamela C. Champe, Richard A. Harvey, Denise R. Ferrier



## Introduction to amino acids, peptides and proteins

- Harper's Illustrated Biochemistry by Robert K. Murray, Darryl K. Granner, Peter A. Mayes
- Biochemistry by Donald Voet, Judith G. Voet
- Biochemistry by Jeremy M. Berg, John L. Tymoczko, Lubert Stryer
- Biochemistry by Mary K. Campbell, Shawn O. Farrell

