

# Proteomics Course

## LECTURE-4 Proteins: Amino acids and structural levels of proteins



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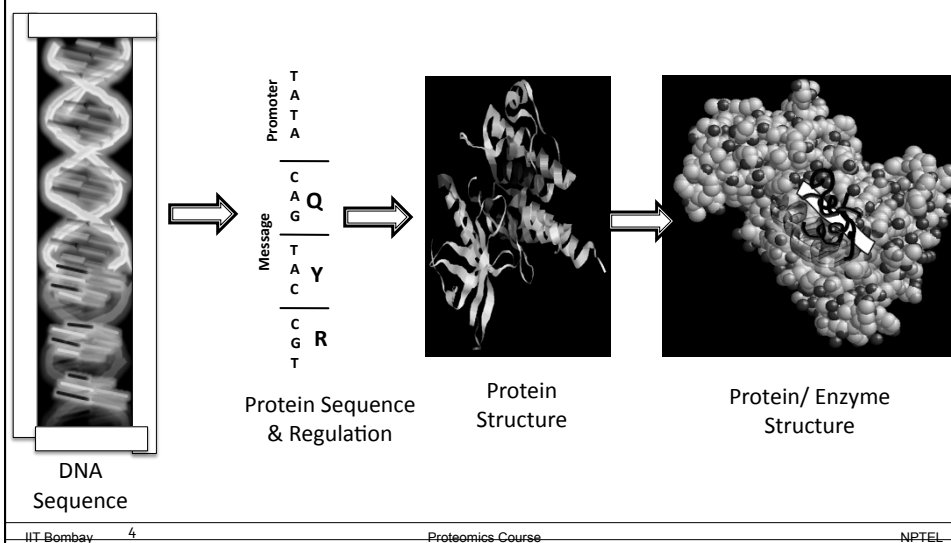
## Lecture outline

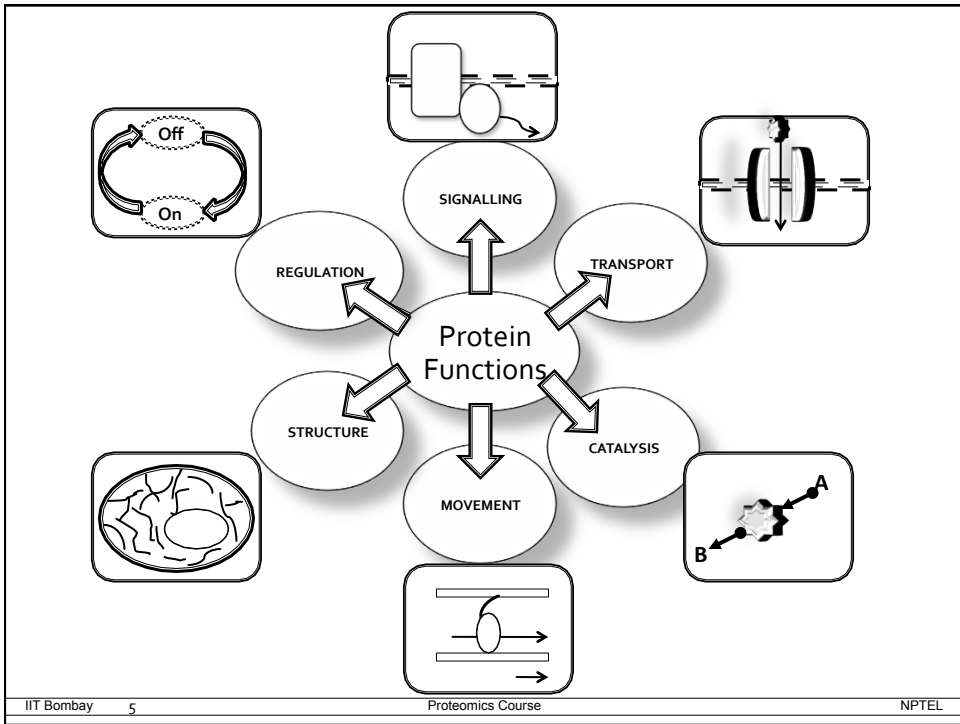
- Proteins and its function
- Amino acids: building blocks
- Different levels of protein structure
  - Primary, Secondary, Tertiary, Quaternary

# Proteins

- Derived from Greek “Proteios”
- Linear polymers built of monomers (amino acids)
- Most versatile macromolecules in living systems
- Play key structural and functional roles

## Proteins transform 1-D sequences to 3-D functional molecules



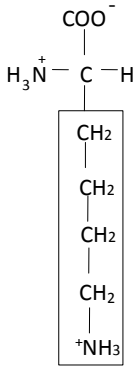


## Amino acids: building blocks of proteins

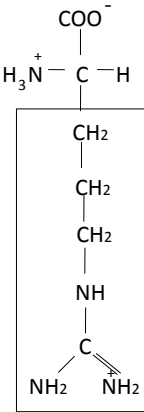
Nonpolar, aliphatic R groups			
$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{H} \\   \\ \boxed{\text{H}} \end{array}$ <p>Glycine</p>	$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{H} \\   \\ \boxed{\text{CH}_3} \end{array}$ <p>Alanine</p>	$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_2\text{N}^+ - \text{C} - \text{H} \\   \quad   \\ \text{H}_2\text{C} \quad \text{CH}_2 \\   \quad   \\ \text{H}_2\text{C} \quad \text{CH}_2 \end{array}$ <p>Proline</p>	$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{H} \\   \\ \boxed{\begin{array}{c} \text{CH} \\ / \quad \backslash \\ \text{CH}_3 \quad \text{CH}_3 \end{array}} \end{array}$ <p>Valine</p>
$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{H} \\   \\ \boxed{\begin{array}{c} \text{CH}_2 \\   \\ \text{CH} \\ / \quad \backslash \\ \text{CH}_3 \quad \text{CH}_3 \end{array}} \end{array}$ <p>Leucine</p>	$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{H} \\   \\ \boxed{\begin{array}{c} \text{H} - \text{C} - \text{CH}_3 \\   \\ \text{CH}_2 \\   \\ \text{CH}_3 \end{array}} \end{array}$ <p>Isoleucine</p>	$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{H} \\   \\ \boxed{\begin{array}{c} \text{CH}_2 \\   \\ \text{CH}_2 \\   \\ \text{S} \\   \\ \text{CH}_3 \end{array}} \end{array}$ <p>Methionine</p>	
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Polar, uncharged R groups		
$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{H} \\   \\ \boxed{\text{CH}_2\text{OH}} \end{array}$ <p>Serine</p>	$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{H} \\   \\ \boxed{\begin{array}{c} \text{H} - \text{C} - \text{OH} \\   \\ \text{CH}_3 \end{array}} \end{array}$ <p>Threonine</p>	$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{H} \\   \\ \boxed{\begin{array}{c} \text{CH}_2 \\   \\ \text{SH} \end{array}} \end{array}$ <p>Cysteine</p>
$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{H} \\   \\ \boxed{\begin{array}{c} \text{CH}_2 \\   \\ \text{C} \\ / \quad \backslash \\ \text{H}_2\text{N} \quad \text{O} \end{array}} \end{array}$ <p>Asparagine</p>	$\begin{array}{c} \text{COO}^- \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{H} \\   \\ \boxed{\begin{array}{c} \text{CH}_2 \\   \\ \text{CH}_2 \\   \\ \text{C} \\ / \quad \backslash \\ \text{H}_2\text{N} \quad \text{O} \end{array}} \end{array}$ <p>Glutamine</p>	
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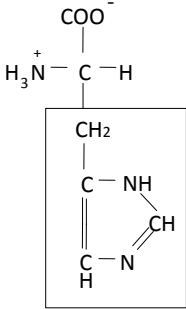
## Positively charged R groups



Lysine

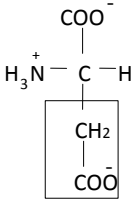


Arginine

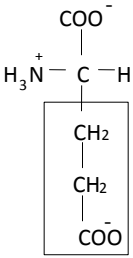


Histidine

## Negatively charged R groups



Aspartate



Glutamate

### Aromatic R groups

[NH3+]C(Cc1ccccc1)C(=O)[O-]

Phenylalanine

[NH3+]C(Cc1ccc(O)cc1)C(=O)[O-]

Tyrosine

[NH3+]C(Cc1c[nH]c2ccccc12)C(=O)[O-]

Tryptophan

Hydrophobic character

Hydrophobic

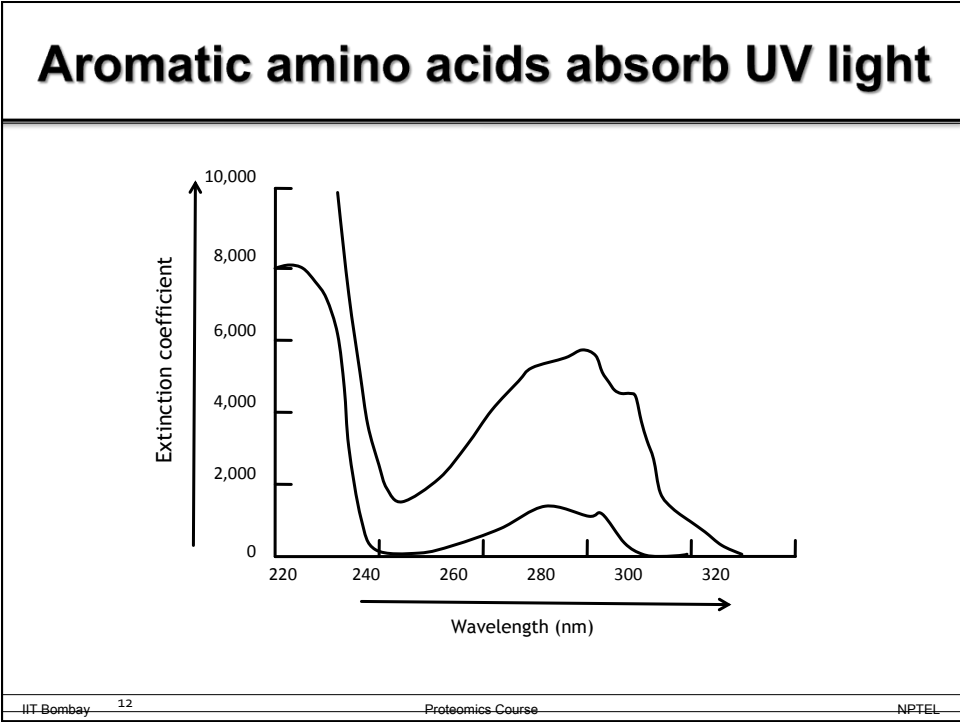
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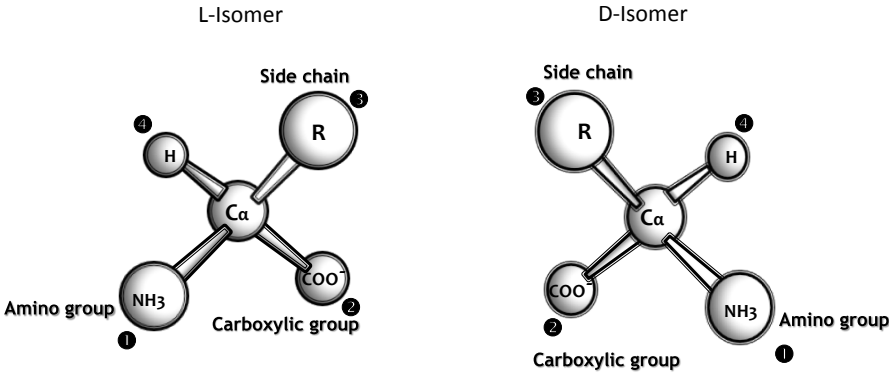
Hydrophilic

→

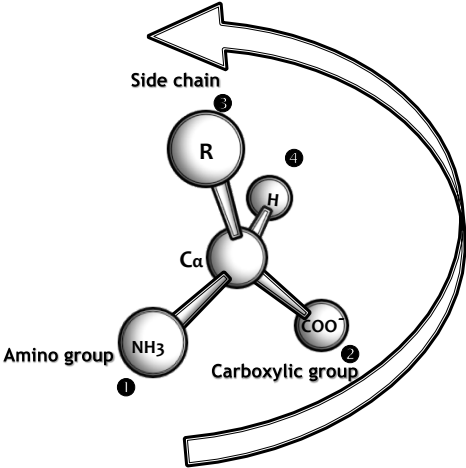
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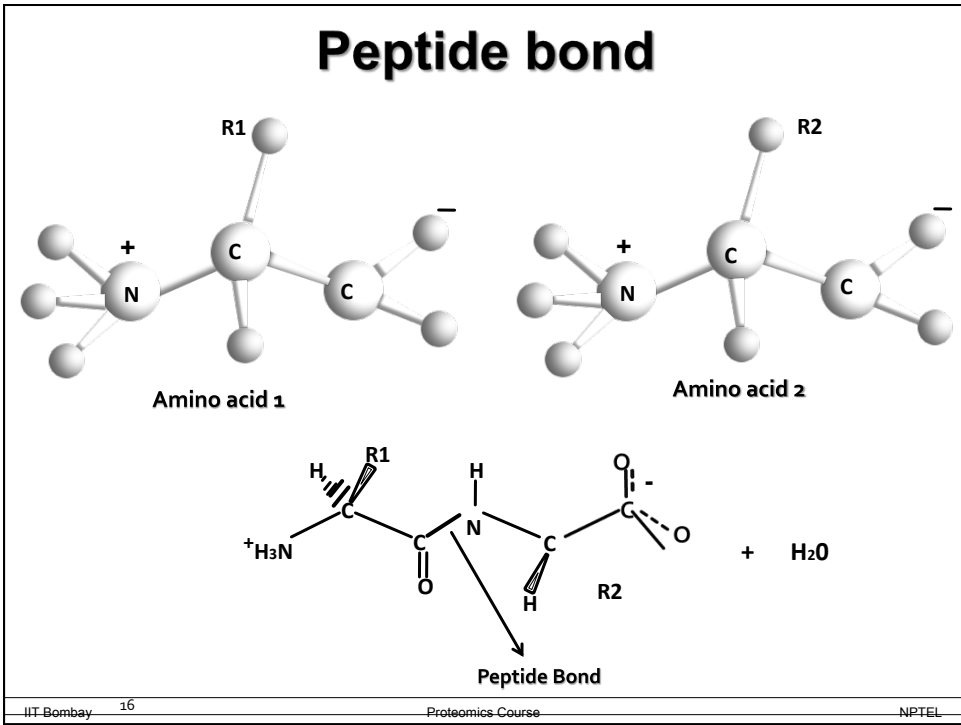
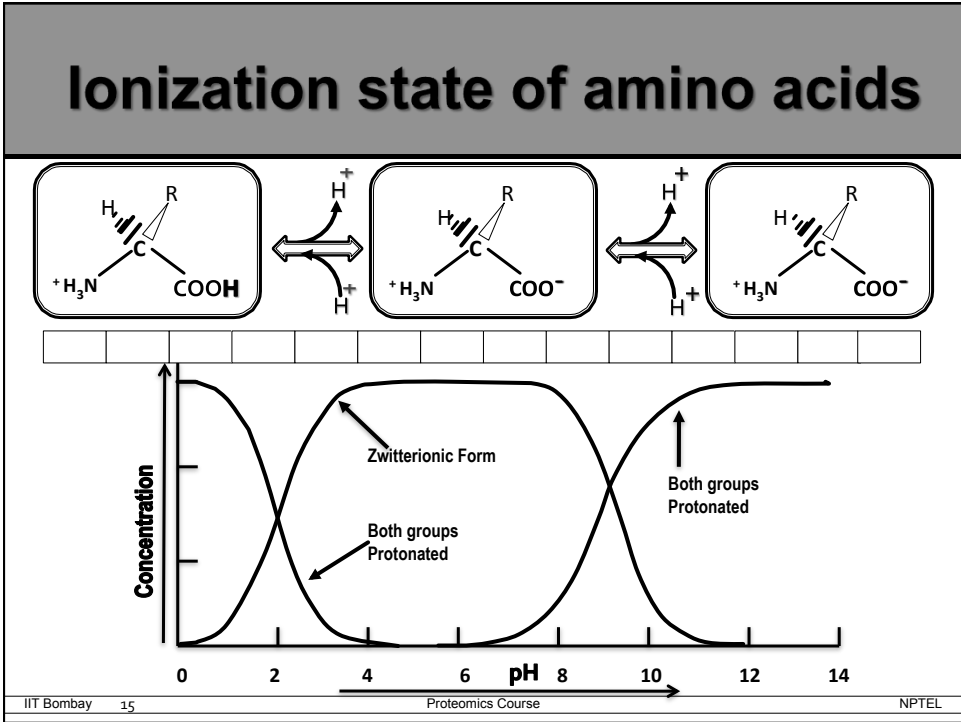


# Amino acids: L and D isomers

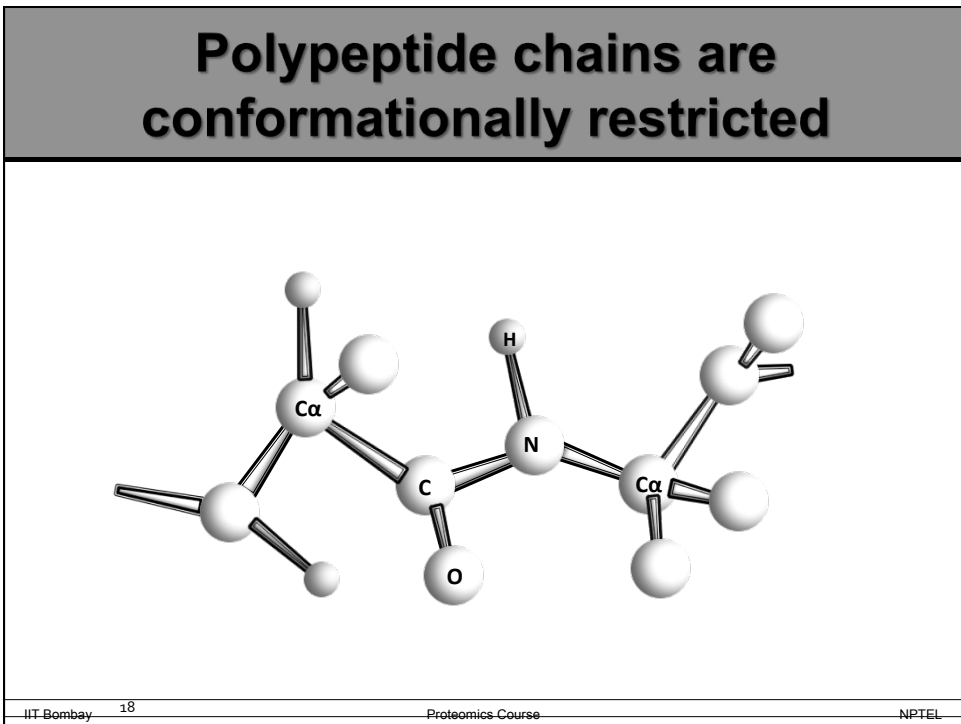
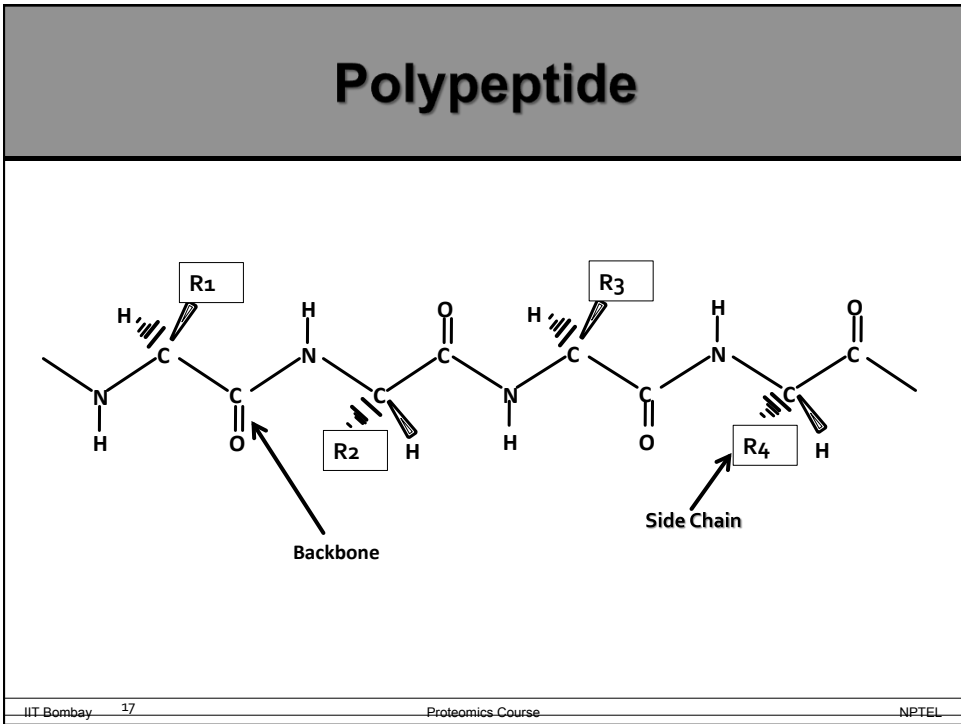


# L amino acids in proteins

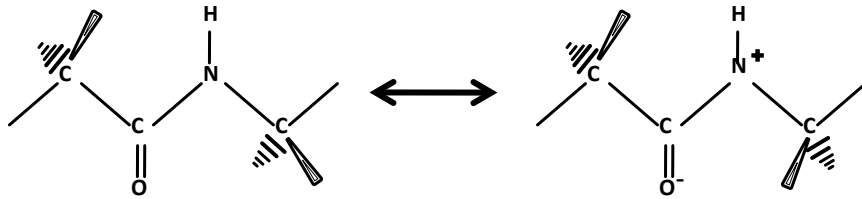




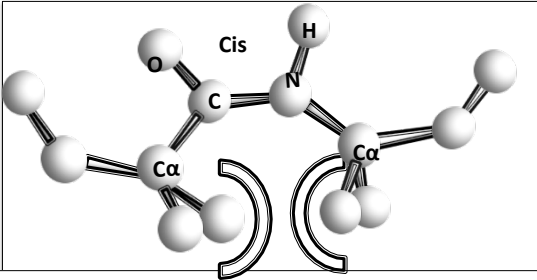
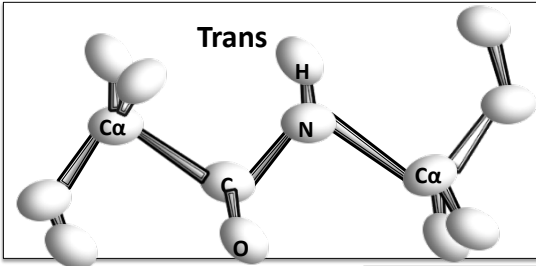


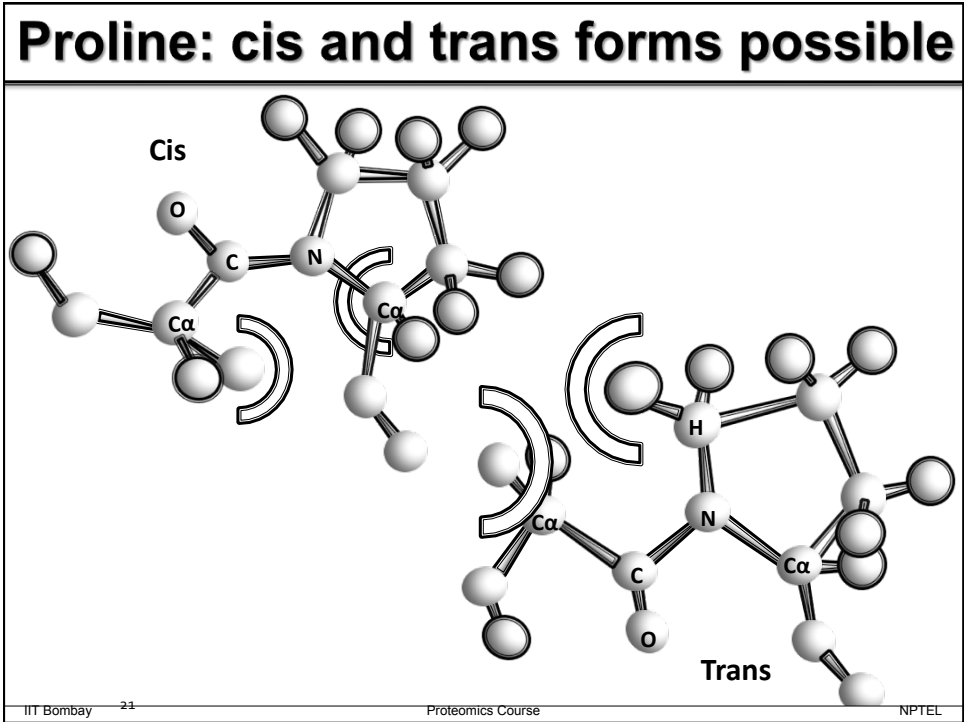


## Peptide bond is stabilized by resonance structure



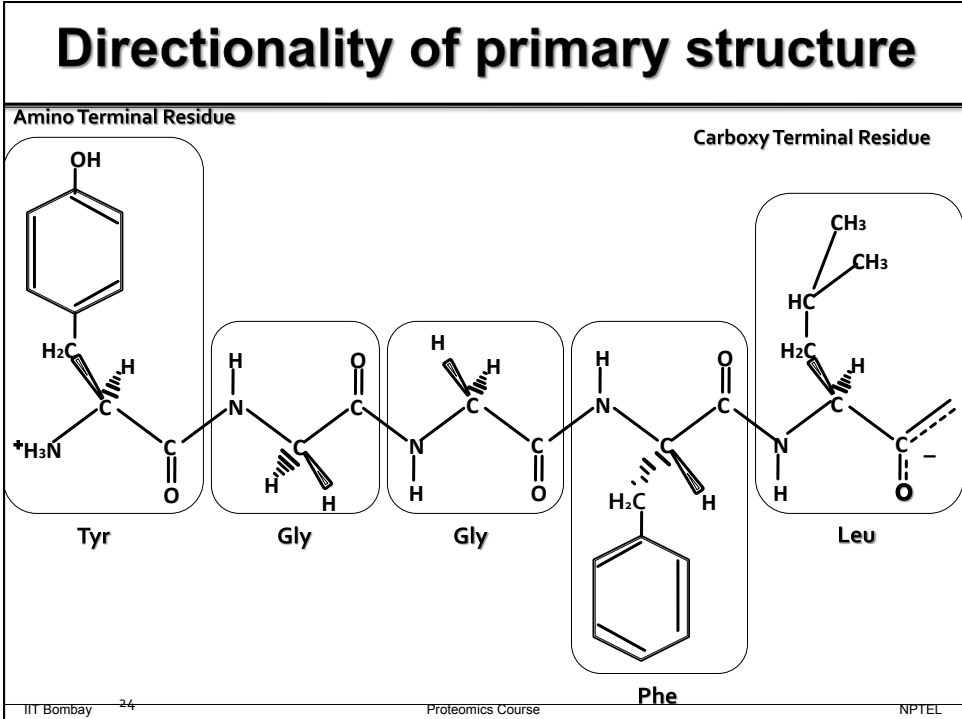
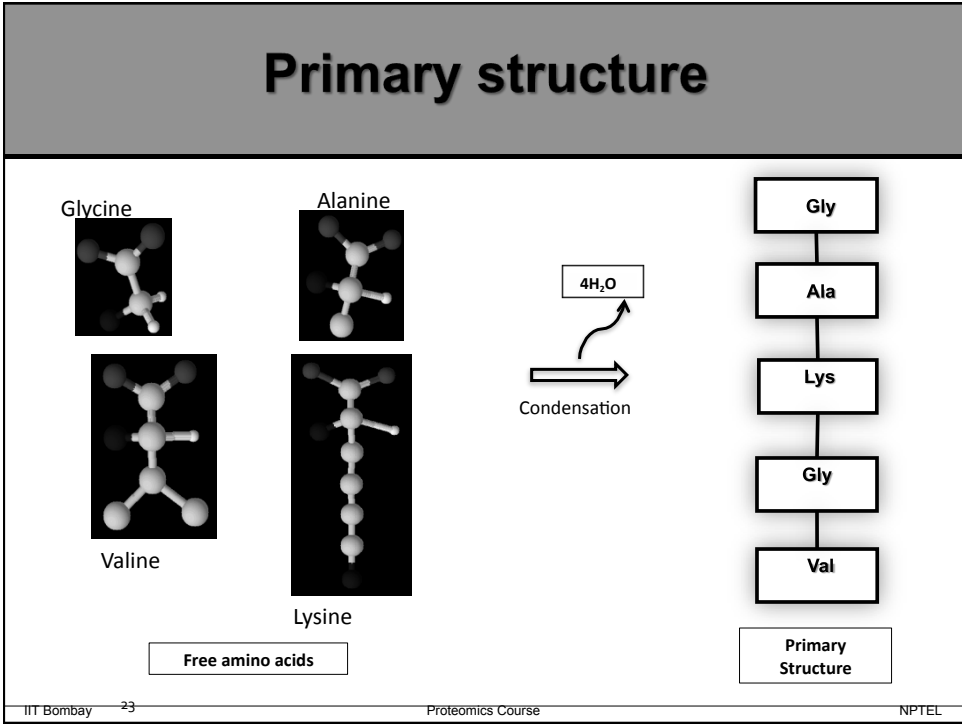
## Peptide bonds in protein exist in trans form





# Primary structure

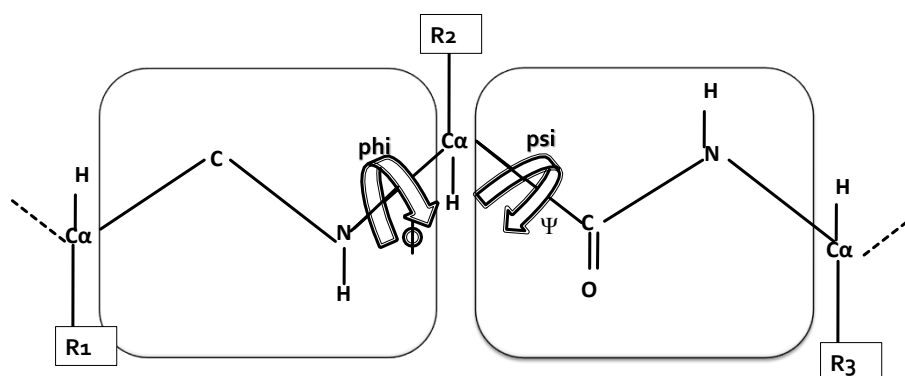
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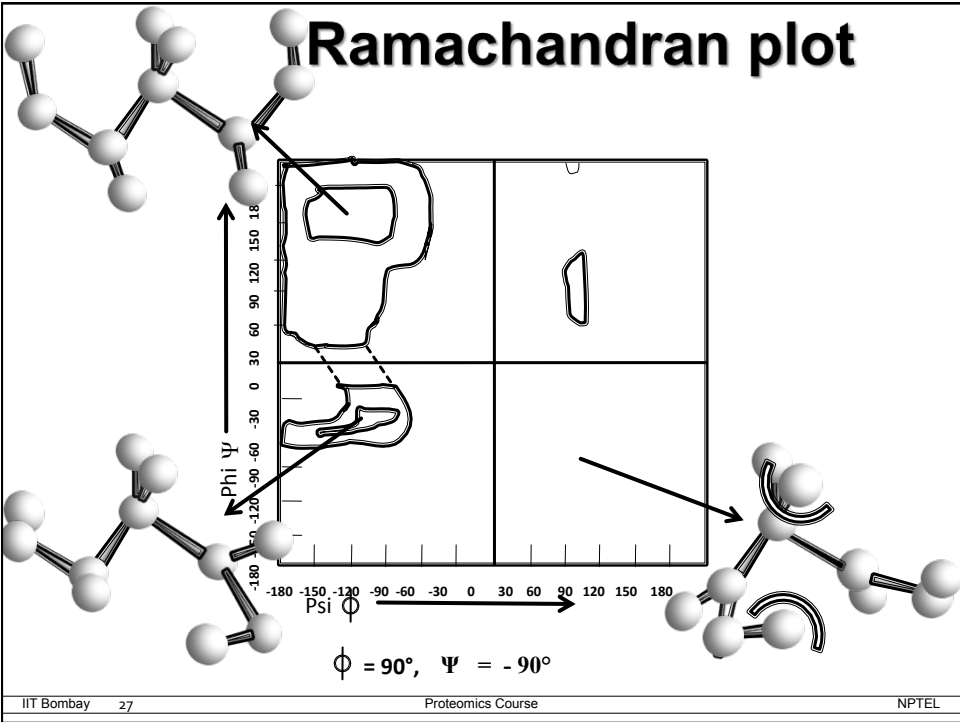


## Amino acid sequence: significance

- Essential for elucidation of its mechanism of action
- Determines 3-D structure of proteins
- Amino acid alteration can produce abnormality
- Sequence tells us an evolutionary history of protein

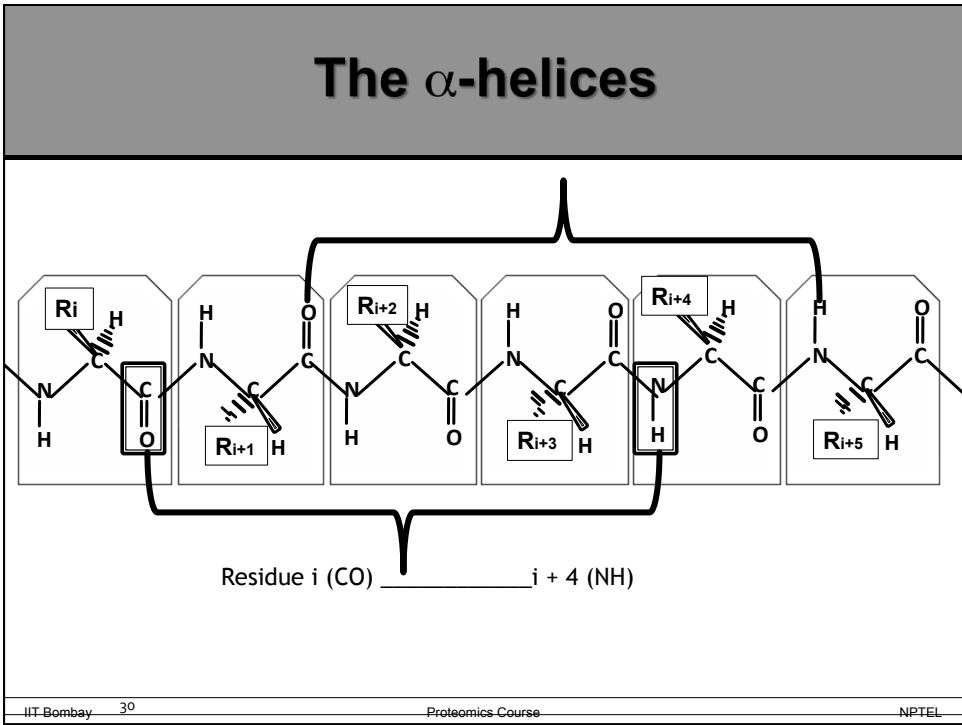
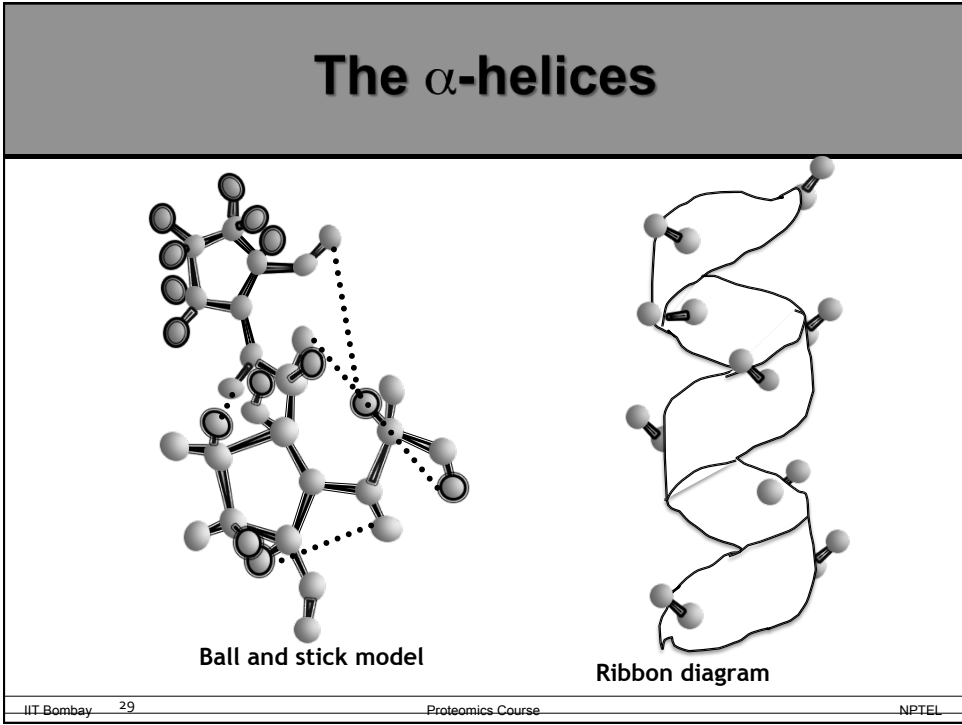
## Ramachandran plot





## Secondary structure

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## Special type of $\alpha$ -helices

- $\alpha$ -Keratin
  - Two  $\alpha$  helices wrap to form a stable structure
- Collagen
  - It contains 3 helical polypeptide chain

## $\beta$ - sheets

- $\beta$  sheets: another common, periodic structural motif
- Fully extended structure
- Parallel
- Anti-parallel



## Turns and loops

- More elaborate structures loops or omega turns
- Loops are rigid, no periodic structures
- Turns and loops on surfaces
- Participate in protein and other molecule interactions

## Difference in $\alpha$ helix and $\beta$ sheet

$\alpha$ helix	$\beta$ sheets
Polypeptide chain tightly coiled	Polypeptide chain fully extended
Rod like structure	Sheet like structure
Axial distance 1.5 A	Axial distance 3.5 A
H-bond between NH and CO groups in same polypeptide chains	H-bond between NH and CO groups in different polypeptide chains
Examples - Ferritin, keratin, collagen	Fatty acid binding protein

## Tertiary structure

## Tertiary structure

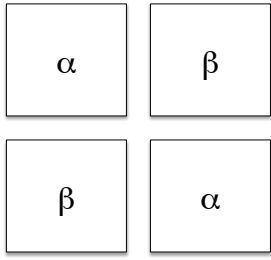
- Three dimensional compactly folded structure of proteins
- Overall organization of secondary structural elements in 3-D space

## Quaternary structure

## Quaternary structures

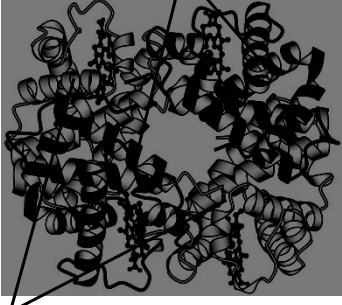
- Final level of protein structure
- Spatial arrangement of subunits and their interactions
- Polypeptide chains assemble to form multisubunit structure

## Hemoglobin: tetramer quaternary structure



Individual polypeptide chains

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α- subunits  
β- subunits

Quaternary structure  
(Hemoglobin)

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## Understanding protein function is key to biology


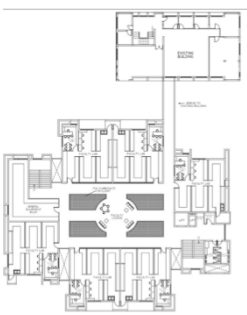

DNA  
Genetic  
blueprint

→

RNA  
molecular  
photocopy

→

Proteins  
Building  
blocks

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## Summary

- Proteins and its function
- Amino acids: building blocks
- Different levels of protein structure
  - Primary, Secondary, Tertiary, Quaternary
  - Myoglobin and Hemoglobin
- Proteins and diseases

## REFERENCES

- Berg J., Tymoczko J. & Stryer L., Biochemistry fifth ed., W. H. Freeman & company, 2002. ISBN: 0716746840.
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