Structure of Amino Acids

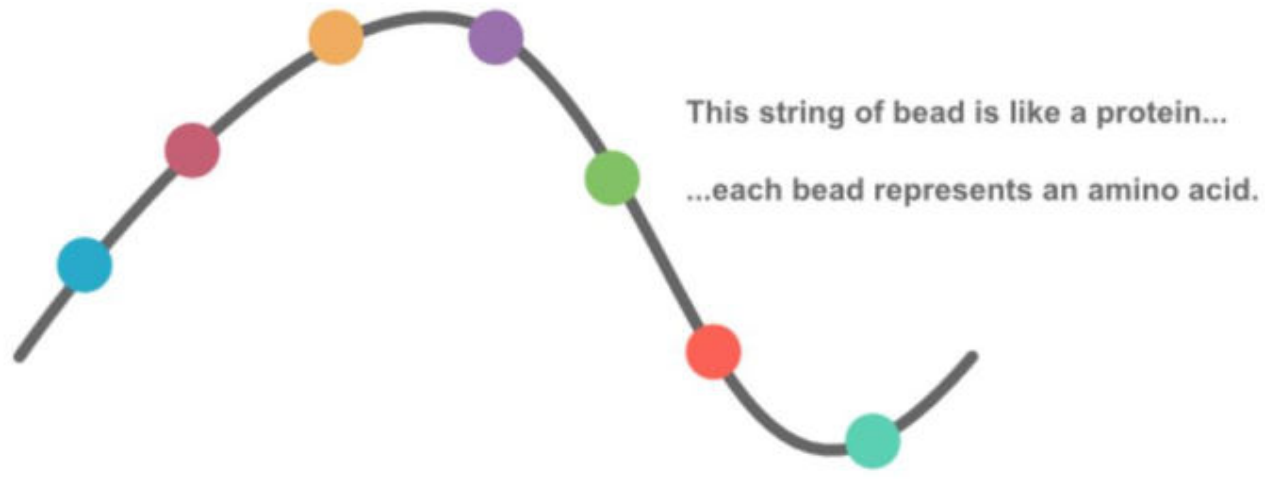
Specific learning objectives

- Diverse functions of Proteins.
- Amino acids classification based on position of amino group and composition of R-group and nutritional requirement.
- Properties of Amino Acids.

Introduction

- Proteins are made up of hundreds of smaller units called **amino acids** that are attached to one another by peptide bonds, forming a long chain.

- Protein as a string of beads where each bead is an amino acid.



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Diverse Functions of Proteins

- **Enzymes:** Serve as biological catalysts.

- **Defense:** Immunoglobulins and Interferon are proteins that protect the human against bacterial and viral infections.

- **Signaling:** Provide recognition/markers on surface of cells or organelles and can illicit intracellular responses.

- **Movement:** Motor proteins provide contractile movement/energy transformation.

Cont---

- **Structural related proteins:** Make up the structural-architecture of the cell or tissues.

- **Storage related proteins:** provide amino acids storage for growth and reproduction.

- **Transport proteins:** move molecules through membranes.

Amino-Acids Classification Based on Standard and Non-Standard Amino Acids

- Standard amino-acids
- Non-Standard amino-acids

General Structure of Common Amino Acids

- All proteins are composed of the 20 “standard "amino acids.
- Common central alpha (α)-carbon atom bound to a carboxylic acid group, an amino group and a hydrogen atom are covalently bonded.
- They have a primary amino group and a carboxylic acid group substituent on the same carbon atom, with the exception of proline, (has a secondary amino group).

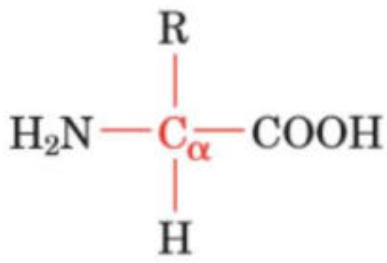

Fig.4.1. Biochemistry. 4th edition by Donald Voet and Judith G. Voet

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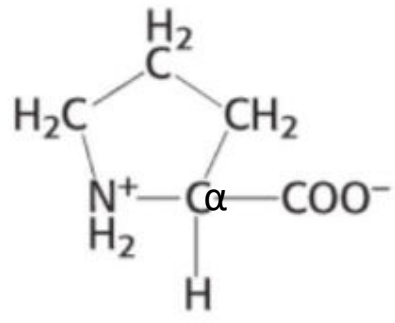
- Proline classified as an imino acid, its α-amine is a secondary amine with its a nitrogen having two covalent bonds to carbon (to the α-carbon and side chain carbon), rather than primary amine.



Proline
(Pro, P)

- Incorporation of the amino nitrogen into a five membered ring constrains the rotational freedom around the $–N_{\alpha}$-C_{α}-bond in proline to specific rotational angle, reduces the structural flexibility of polypeptide regions containing proline.

Cont---

- Ionized form of a common amino acid in solution at physiological pH.
- Ionization state of an amino acid varies with pH.
- α-Amino group is protonated and in its ammonium ion form
- Carboxylic acid group is in its deprotonated or carboxylate ion form.

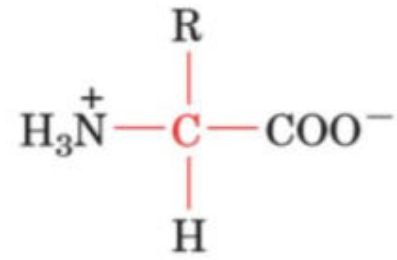


Fig.4.2. Biochemistry. 4th edition by Donald Voet and Judith G. Voet

Selenocysteine, the 21st Protein L-α-Amino Acids

- Selenocysteine are non-standard amino-acid.
- Selenium atom replaces the sulfur of its elemental analog, cysteine.
- Selenocysteine is not the product of a posttranslational modification, but is inserted directly into a growing polypeptide during translation.
- Incorporation of selenocysteine is specified by a large and complex genetic element for the unusual tRNA called $tRNA_{Sec}$ which utilizes the UGA anticodon that normally signals STOP.

L-α-Amino Acids Serve Additional Role

- L-α amino acids and their derivatives participate in cellular functions (nerve transmission and biosynthesis of porphyrins, purines, pyrimidines, and urea).

- Thyroid hormones are formed from tyrosine; glutamate serves as a neurotransmitter as well as the precursor of g-aminobutyric acid (GABA).

- Ornithine and citrulline are intermediates in urea biosynthesis.

Cont--

- Homocysteine, homoserine, and glutamate-γ-semialdehyde participate in the intermediary metabolism of the protein amino acids.

- The protein amino acids phenylalanine and tyrosine serve as precursors of epinephrine, norepinephrine, and DOPA (dihydroxyphenylalanine).

Amino Acids Classified on the Basis of Nutritional Requirement

- Essential proteinogenic amino acids.
- Non-essential proteinogenic amino acids.

Amino-Acid Requirements of Humans

Nutritionally Essential	Nutritionally Nonessential
Arginine[1]	Alanine
Histidine	Asparagine
Isoleucine	Aspartate
Leucine	Cysteine
Lysine	Glutamate
Methionine	Glutamine
Phenylalanine	Glycine
Threonine	Hydroxyproline[2]
Tryptophan	Hydroxylysine[2]
Valine	Proline
	Serine
	Tyrosine

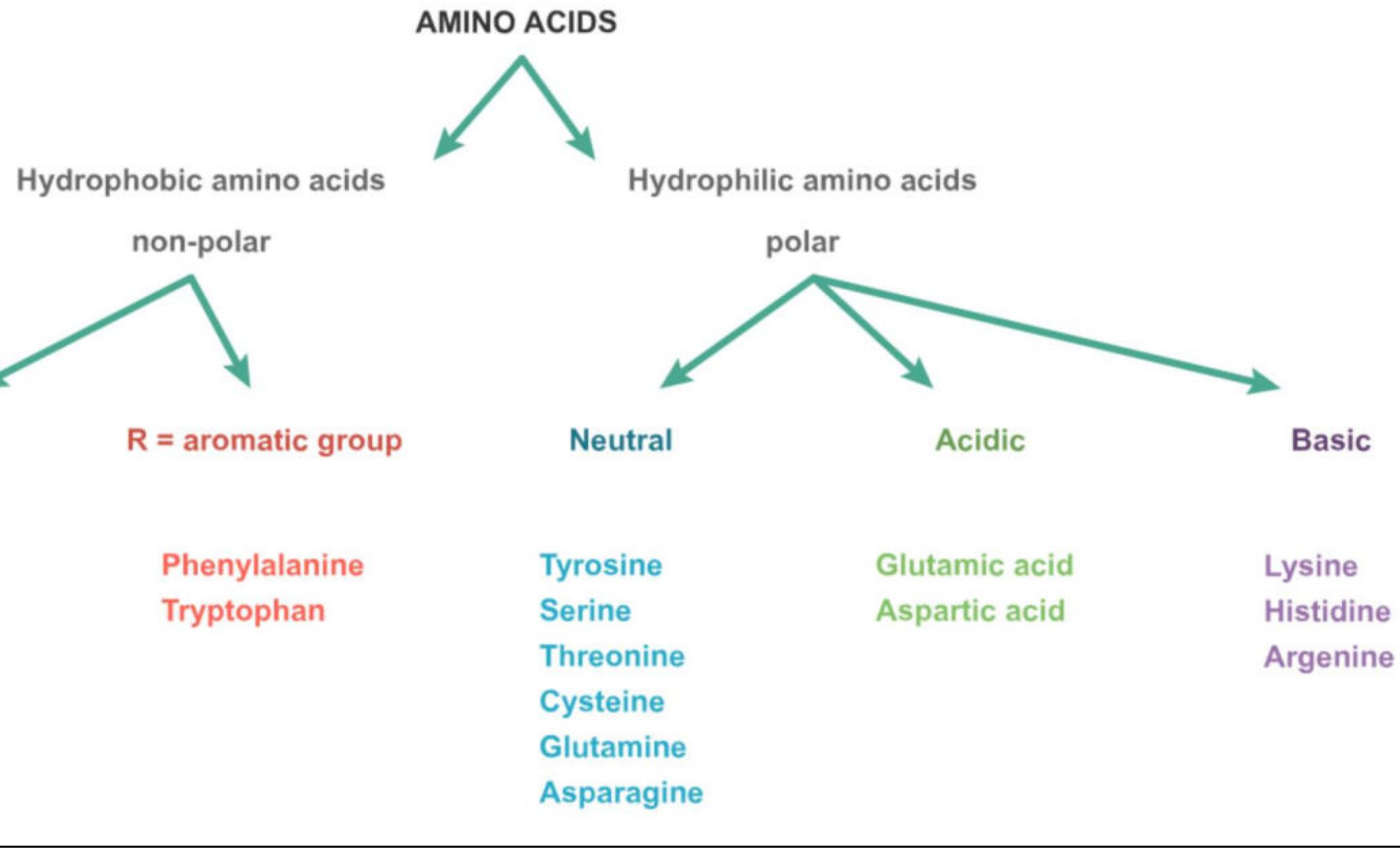
Table 28.1. Harper's Illustrated Biochemistry 26th edition

Amino-Acids Classification Based on Side Chain Groups

- Based on the **type of functional group (R group)** present amino acids are classified as: Aliphatic, aromatic, acidic, basic, acid amide, sulfur and cyclic amino acids.

- Based on the **characteristic of the functional group** amino acids are classified as: polar and non-polar amino acids.

- Based on the **site of attachment of the functional group**. They are also classified as: alpha, beta, gamma and delta amino acids.



Amino Acids Classification

Cont--

TABLE 3–1 L-α-Amino Acids Present in Proteins

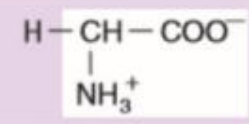
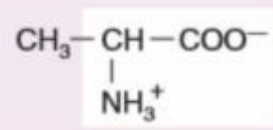
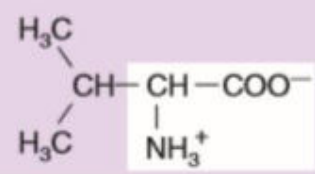
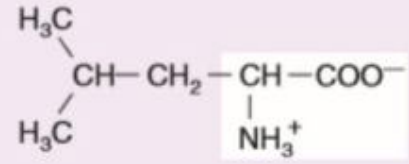
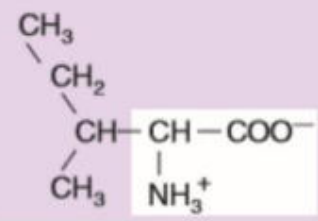
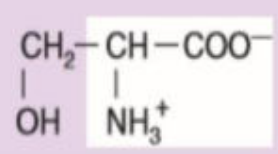
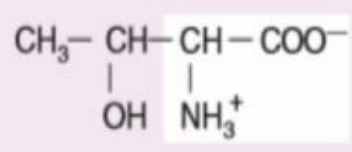
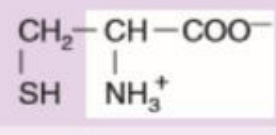
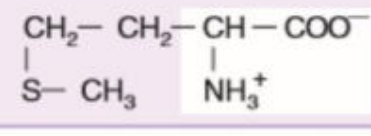
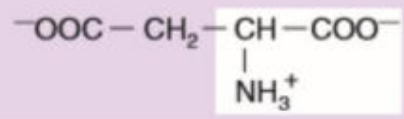
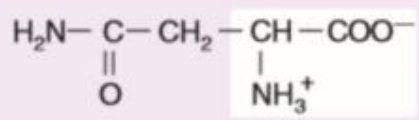
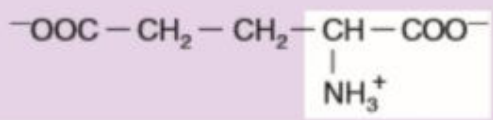
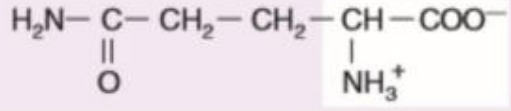
Name	Symbol	Structural Formula	pK_1	pK_2	pK_3
With Aliphatic Side Chains **Nonpolar/Hydrophobic**			α-COOH	α-NH_3^+	R Group
Glycine	Gly [G]		2.4	9.8	
Alanine	Ala [A]		2.4	9.9	**Methyl R group**
Valine	Val [V]		2.2	9.7	**Isopropyl R group**
Leucine	Leu [L]		2.3	9.7	**Branching in isobutyl side chain on γ carbon of amino acid**
Isoleucine	Ile [I]		2.3	9.8	**Branching in isobutyl side chain on β carbon of amino acid**

Table 3.1. Harper's Illustrated Biochemistry 30 edition

Cont--

Name	Symbol	Structural Formula	pK_1	pK_2	pK_3
With Side Chains Containing Hydroxylic (OH) Groups					
Serine **Polar, uncharged-R group**	Ser [S]		2.2	9.2	about 13
					Hydroxymethyl R group
Threonine **Polar, uncharged-R group**	Thr [T]		2.1	9.1	about 13
					Secondary Alcohol structure
Tyrosine	Tyr [Y]	Mentioned in amino acids with aromatic rings section			
With Side Chains Containing Sulfur Atoms			α-COOH	α-NH_3^+	R Group
Cysteine **Polar, uncharged-R group**	Cys [C]		1.9	10.8	8.3
					Thiolmethyl/Sulfhydryl R group
Methionine **Nonpolar**	Met [M]		2.1	9.3	
					Methyl ethyl thiol ether R group

Cont--

Name	Symbol	Structural Formula	pK_1	pK_2	pK_3
With Side Chains Containing Acidic Groups or Their Amides					
Aspartic acid	Asp [D]		2.1	9.9	3.9
Asparagine	Asn [N]		2.1	8.8	
Glutamic acid	Glu [E]		2.1	9.5	4.1
Glutamine	Gin [Q]		2.2	9.1	

Negatively charged R group

β-COOH R group

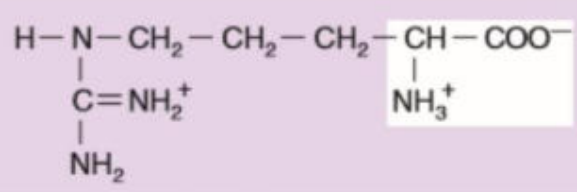
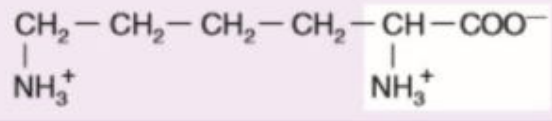
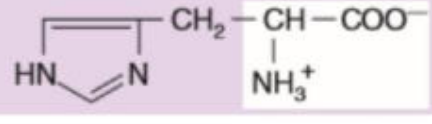
Polar, Uncharged-R group

Negatively charged R group

γ-COOH R group

Polar, Uncharged-R group

Cont--

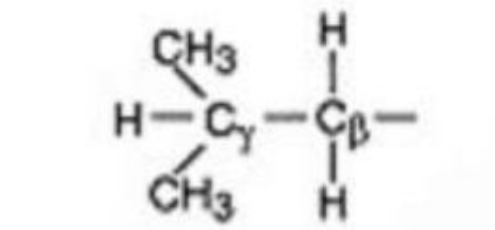
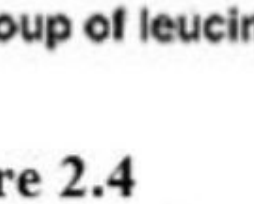
Name	Symbol	Structural Formula	pK_1	pK_2	pK_3
With Side Chains Containing Basic Groups		**Positively charged R groups**			
Arginine	Arg [R]		1.8	9.0	12.5
Lysine	Lys [K]		2.2	9.2	10.8
Histidine	His [H]		1.8	9.3	6.0

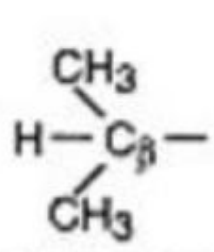
Guanidinium R group

ε-NH_{+3} R group

Imidazolium R group

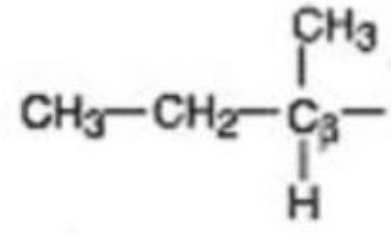
Cont--

Name	Symbol	Structural Formula	pK_1	pK_2	pK_3
Containing Aromatic Rings					
Histidine	His [H]	Mentioned in amino acids with basic groups section			
Phenylalanine	Phe [F]		2.2	9.2	
		Benzene ring R group			
Tyrosine	Tyr [Y]		2.2	9.1	10.1
		Phenol R group			
Tryptophan	Trp [W]		2.4	9.4	
		Heterocyclic structure, indole R group			
Imino Acid					
Proline	Pro [P]		2.0	10.6	
		Imino group belongs to a five-member ring			



Isopropyl R group of valine

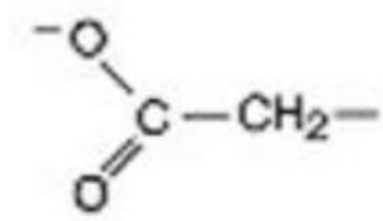
Isobutyl R group of leucine



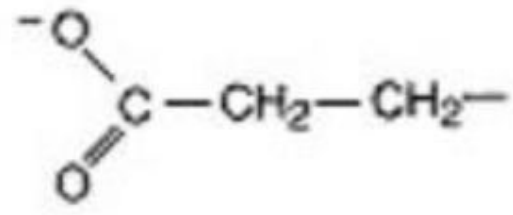
Isobutyl R group of isoleucine

Figure 2.4
Alkyl side chains of valine, leucine, and isoleucine.

Fig. 2.4. Textbook of Biochemistry with Clinical Correlations, 4th edition by Thomas M Devlin



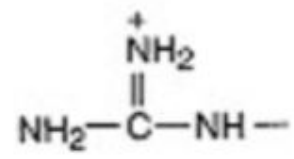
Aspartate R group



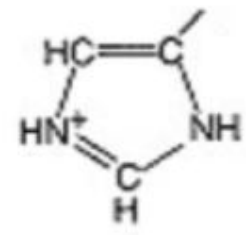
Glutamate R group

Figure 2.5
Side chains
of aspartate
and glutamate.

Fig. 2.5. Textbook of Biochemistry with Clinical Correlations, 4th edition by Thomas M Devlin



Guanidinium group (charged form) of arginine



Imidazolium group of histidine

Figure 2.6
Guanidinium and imidazolium groups
of arginine and histidine.

Fig. 2.6. Textbook of Biochemistry with Clinical Correlations, 4th edition by Thomas M Devlin

Properties of Amino Acids

Genetic Code Specifies 20 L-α-Amino Acids

- Proteins are synthesized from the set of 20 L-α-amino acids encoded by nucleotide triplets called codons.

- Common amino acids are those for which at least one specific codon exists in the DNA genetic code.

- Sequences of peptides and proteins represent by using one- and three letter abbreviations for each amino acid.

Cont---

Genetic information is transcribed from a DNA sequence into mRNA and then translated to the amino acid sequence of a protein

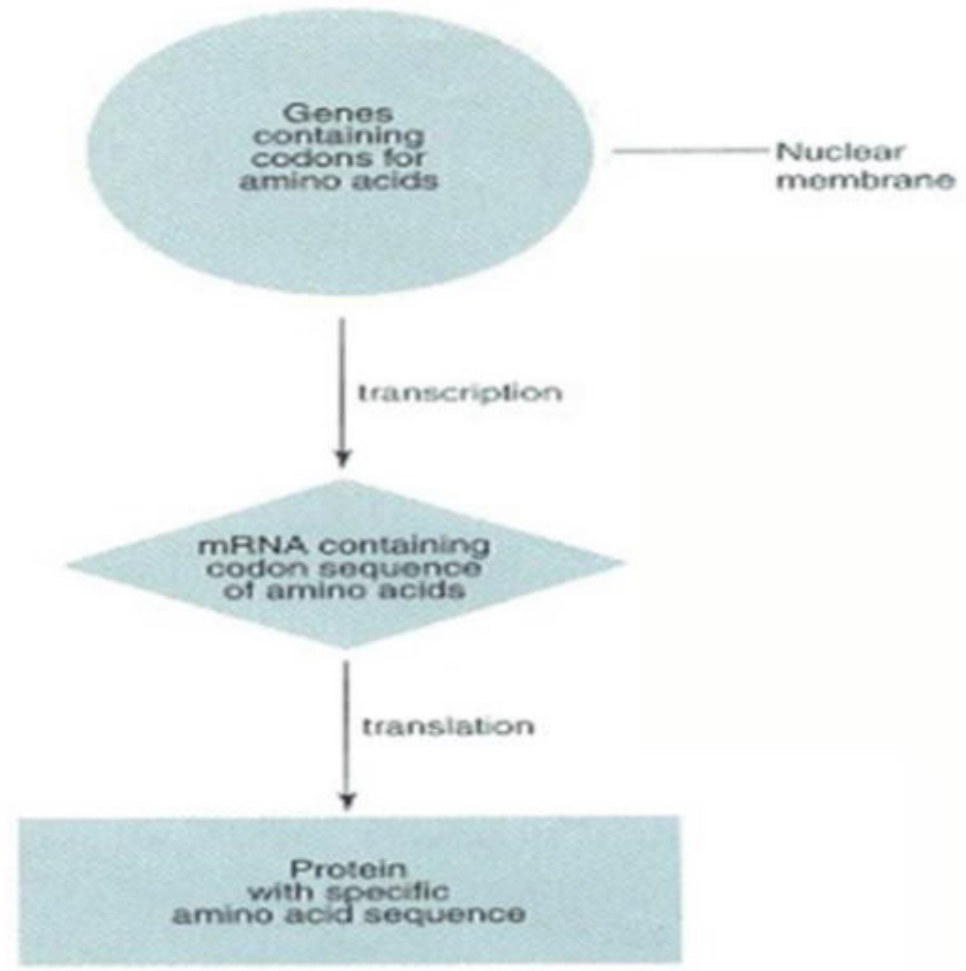


Fig. 2.1. Textbook of Biochemistry with Clinical Correlations, 4th edition by Thomas M Devlin

Summary

- Functions of Proteins: transport, defense, movement, storage, signaling etc.
- Both α-amino acids and non-α-amino acids occur in nature, but proteins are synthesized using only L-α-amino acids.
- The R groups of amino acids determine their unique biochemical functions.
- Amino acids are classified as basic, acidic, aromatic, aliphatic, or sulfur-containing based on the composition and properties of their R groups.

Interaction with students

- Distributed subtopics of class to students to participate in group discussion in next class.

Reference Books

1) Harper's Illustrated Biochemistry-30th edition
2) Textbook of Biochemistry with Clinical Correlations. 4th edition. Thomas M. Devlin.
3) Biochemistry. 4th edition. Donald Voet and Judith G. Voet.
4) Biochemistry 7th edition by Jeremy M. Berg, John L. Tymoczko and Lubert Stryer
5) Lehninger Principles of Biochemistry

Thank you