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Proteins and Amino Acids

Biochemistry

Definition, classification, structure and functions of proteins, essential and non-essential amino acids, protein digestion, absorption, metabolism and clinical significance.

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CHAPTER 03

Proteins and Amino Acids

Amino acid classification, protein structure, digestion and clinical significance

1. Definition and chemical structure

Proteins are polymers of amino acids joined by peptide bonds. An amino acid has a central alpha-carbon attached to an amino group, carboxyl group, hydrogen and a variable side chain (except that glycine has two hydrogens). At physiological pH many amino acids are zwitterions. A peptide bond forms between the carboxyl group of one amino acid and the amino group of another.

2. Classification of amino acids

Nutritional class	Examples
Essential (adult)	Histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine
Non-essential	Alanine, aspartate, asparagine, glutamate, serine
Conditionally essential	Arginine, cysteine, glutamine, glycine, proline, tyrosine (requirements may exceed synthesis in some conditions)

Classification by side chain: nonpolar (valine, leucine), polar uncharged (serine, threonine), acidic (aspartate, glutamate), basic (lysine, arginine, histidine). Leucine and lysine are exclusively ketogenic; other amino acids may be glucogenic or both.

3. Classification of proteins

Basis	Types and examples
Shape	Fibrous (collagen, keratin); globular (albumin, enzymes); membrane proteins
Composition	Simple (albumin); conjugated (haemoglobin, glycoproteins); derived (protein breakdown products, traditional grouping)
Function	Structural, catalytic, transport, immune, contractile, receptor and regulatory

4. Levels of protein structure

- Primary: amino acid sequence.
- Secondary: local alpha-helices and beta-sheets stabilized mainly by backbone hydrogen bonds.
- Tertiary: overall three-dimensional folding of a single polypeptide, stabilized by hydrophobic interactions, hydrogen bonds, ionic interactions and disulfide bonds.
- Quaternary: arrangement of multiple polypeptide subunits, e.g., haemoglobin.

Denaturation disrupts native folding and often function without ordinarily breaking the primary peptide sequence. Heat, pH extremes and some chemicals may cause denaturation.

5. Functions of proteins

Enzymes catalyse reactions; collagen supports tissues; haemoglobin transports oxygen; albumin contributes to plasma oncotic pressure; antibodies provide immune defence; actin and myosin support contraction. Protein provides approximately 4 kcal/g when metabolized, but its primary functions are structural and functional.

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6. Digestion and absorption

Site	Process
Stomach	HCl denatures proteins and activates pepsinogen to pepsin; peptides form
Small intestine	Enteropeptidase activates trypsinogen; trypsin activates other pancreatic proteases
Intestinal lumen	Trypsin, chymotrypsin, elastase and carboxypeptidases cleave proteins
Brush border and enterocytes	Peptidases produce amino acids; amino acids and small peptides are absorbed

Amino acids use several transporters, many sodium-dependent; di- and tripeptides enter by H+-coupled PEPT1 and are mostly hydrolysed in enterocytes. Amino acids enter portal blood and reach the liver.

7. Metabolism and clinical significance

The body has no dedicated protein storage depot. Amino acids are used for synthesis or catabolized; nitrogen is removed and converted mainly into urea in the liver. Carbon skeletons enter energy pathways or form glucose, ketones or lipids. Protein-energy malnutrition may cause muscle loss, impaired immunity and poor healing. Low albumin can reflect inflammation, liver disease, renal loss or dilution, not simply dietary deficiency. Some inherited amino acid disorders require specialist dietary management.

8. Chemical properties of amino acids

Amino acids are amphoteric: they can donate or accept protons. The isoelectric point is the pH at which an amino acid or protein has no net electrical charge. This principle supports electrophoretic separation. Side-chain properties influence folding, solubility and biological activity. Cysteine can form disulfide bonds, which stabilize many extracellular proteins.

9. Functional classification of proteins

Function	Examples and importance
Structural	Collagen supports connective tissue; keratin contributes to skin and hair
Transport	Haemoglobin carries oxygen; transferrin carries iron
Storage	Ferritin stores iron; myoglobin binds oxygen in muscle
Catalytic	Amylase, lipase and other enzymes accelerate reactions
Defence	Immunoglobulins recognize antigens; complement participates in immunity
Contractile	Actin and myosin enable muscle contraction
Regulatory	Insulin and other peptide hormones regulate metabolism

10. Protein quality and nutritional significance

A protein source provides amino acids in varying proportions. Protein quality depends on digestibility and the availability of indispensable amino acids relative to human requirements. Cereals and legumes can complement one another because their limiting amino acids often differ. Total dietary intake, energy availability and disease state also influence protein utilization.

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Clinical protein abnormalities

- Hypoalbuminaemia may accompany inflammation, liver dysfunction, renal protein loss or dilution. Reduced oncotic pressure can contribute to oedema, but oedema has multiple causes.
- Proteinuria indicates urinary protein loss; persistent findings require evaluation.
- Abnormal protein folding or aggregation occurs in selected diseases; it is not inferred from serum protein values alone.

11. Nursing applications

Assess intake, weight trends, swallowing and wound healing. Monitor renal and hepatic function where relevant. Support prescribed nutrition; do not interpret albumin alone as nutritional status.

12. Important Examination Questions

Long Answer Questions

1. 1. Explain protein classification, structure, digestion and absorption.
2. 2. Describe the four levels of protein structure and explain denaturation.
3. 3. Classify amino acids and discuss the functions of proteins in the body.

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Short Answer Questions

1. 1. Write a short note on Essential amino acids.
2. 2. Write a short note on denaturation.
3. 3. Write a short note on peptide bond.

Very Short Answer Questions

1. 1. Name two exclusively ketogenic amino acids. - Leucine and lysine.
2. 2. What is a peptide bond? - An amide bond between amino acid residues.
3. 3. Which stomach enzyme begins major protein digestion? - Pepsin.
4. 4. What is quaternary structure? - Arrangement of multiple polypeptide subunits.

Additional objective question

Which level involves multiple polypeptide chains? - Quaternary.

13. Quick Revision

- Nine amino acids are nutritionally essential for healthy adults.
- Peptide bonds connect amino acids; hydrogen bonds stabilize secondary structures.
- Proteases digest proteins into smaller peptides and amino acids.
- The liver disposes of much amino nitrogen through urea synthesis.

Conclusion

Protein chemistry is essential to understanding enzymes, tissue repair, immunity, nutritional assessment and the biochemical basis of disease.

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Practice questions

Choose one best answer. The answer key and explanations follow the questions.

1. What type of bond joins amino acids in proteins?

A. Peptide
B. Glycosidic
C. Phosphodiester
D. Ester

2. Which level of protein structure describes the arrangement of multiple polypeptide subunits?

A. Primary
B. Quaternary
C. Secondary
D. Tertiary

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3. Which enzyme activates trypsinogen in the small intestine?

A. Pepsin

B. Amylase

C. Enteropeptidase

D. Lipase

4. A patient with a low serum albumin level develops peripheral oedema. Which mechanism best explains the association?

A. Increased plasma oncotic pressure draws water into tissues

B. Reduced plasma oncotic pressure favours movement of fluid into tissues

C. Higher red-cell haemoglobin forces water out of capillaries

D. Reduced tissue hydrostatic pressure prevents all fluid movement

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Answer key and explanations

1. A - Peptide

Proteins are amino acid polymers joined by peptide bonds.

2. B - Quaternary

Quaternary structure describes multiple-subunit assembly, as in haemoglobin.

3. C - Enteropeptidase

Enteropeptidase activates trypsinogen; trypsin then activates other pancreatic proteases.

4. B - Reduced plasma oncotic pressure favours movement of fluid into tissues

Albumin contributes to plasma oncotic pressure. A marked reduction can promote fluid movement into the interstitial space, although oedema may have several causes.

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