BP202T · B.PHARM THEORY

BP202T Biochemistry

Unit IV — Amino Acid & Protein Metabolism

Pills & Python Notes
From-zero teaching standard: every technical term is defined before use.
Syllabus coverage: Unit IV (10 hours).

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UNIT IV — AMINO ACIDS AND PROTEIN METABOLISM (10 hours)

Syllabus topics: (a) Classification and biological functions of amino acids; structure and functions of proteins and plasma proteins; (b) Transamination, oxidative and non-oxidative deamination, decarboxylation; urea cycle; fate of carbon skeletons (glucogenic vs ketogenic); (c) Phenylalanine/tyrosine catabolism and disorders (phenylketonuria, albinism, alkaptonuria, tyrosinemia); inborn errors of branched-chain and aromatic amino acids; (d) Neurotransmitters/hormones from amino acids (serotonin, melatonin, dopamine, noradrenaline, adrenaline); (e) Heme catabolism and jaundice.

Chapter 8: Classification and Functions of Amino Acids

Learning objectives

- Define an amino acid and draw its general structure in words.
- Classify amino acids by nutrition (essential/non-essential) and by side-chain chemistry.
- List major biological functions of amino acids beyond protein building.

8.1 What is an amino acid? (from zero)

Concept: An amino acid is a small molecule with two signature groups: an **amino group (–NH_2)** and a **carboxylic acid group (–COOH)**, both attached to a central carbon (the α-carbon). A variable **side chain (R group)** makes each amino acid unique. **Simple explanation:** Think of 20 different Lego bricks that share the same connector shape (the amino + acid ends) but have different colours/shapes (the side chain). The body joins these bricks into long chains = proteins. **Example:** Glycine is the simplest (side chain = just a hydrogen); phenylalanine has a bulky ring side chain. **Analogy:** Amino acids are the 20 letters of the protein alphabet — arranged in different orders they spell different protein "words." **Key takeaway:** Amino acid = –NH_2 + –COOH + unique side chain on one central carbon. 20 standard types build all proteins.

8.2 Classification 1 — by nutritional need

- **Essential amino acids (9):** the body cannot make them → must come from food. Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan, Valine.

Mnemonic: "PVT TIM HALL" — **P**henylalanine, **V**aline, **T**hreonine, **T**ryptophan, **I**soleucine, **M**ethionine, **H**istidine, **A**rginine*, **L**eucine, **L**ysine (*arginine is semi-essential — essential in children/growth).

- **Non-essential:** the body can synthesise them (e.g., alanine, glutamate, aspartate, serine).
- **Semi-essential (conditionally essential):** needed from diet during growth, illness or stress (arginine, histidine in children; cysteine, tyrosine made from essential ones).

8.3 Classification 2 — by side-chain chemistry (exam favourite)

Class	Property (simple words)	Examples
Nonpolar, aliphatic	Water-hating, plain chains	Glycine, Alanine, Valine, Leucine, Isoleucine, Methionine, Proline
Aromatic	Ring-shaped side chains	Phenylalanine, Tyrosine, Tryptophan
Polar, uncharged	Water-loving, no charge	Serine, Threonine, Cysteine, Asparagine, Glutamine
Positively charged (basic)	Carry + charge	Lysine, Arginine, Histidine
Negatively charged (acidic)	Carry − charge	Aspartate (aspartic acid), Glutamate (glutamic acid)

Mnemonic for aromatics: "**P**he, **T**yr, **T**rp" → "**P**retty **T**all **T**rees" (all have rings). Charged ones: "**K**ings **A**re **H**appy" (Lysine, Arginine, Histidine = +); "**D**on't **E**at" (Aspartate, Glutamate = −) — using one-letter codes K, R, H and D, E.

8.4 Biological functions (beyond "building proteins")

1. **Protein building blocks** — the primary role.
2. **Energy source** — carbon skeletons can be burned for energy during starvation.
3. **Nitrogen carriers** — glutamine and alanine safely carry nitrogen in blood.
4. **Precursors of vital molecules** — neurotransmitters (serotonin, dopamine), hormones (adrenaline, thyroid hormones), heme, creatine, nucleotides (from glycine, aspartate, glutamine).
5. **pH buffers** — histidine side chains buffer pH inside cells and in haemoglobin.

Common confusions

- **Essential** = must be eaten, not "most important."
- **Aromatic amino acids** (Phe, Tyr, Trp) are a chemistry class; **essential amino acids** are a nutrition class — overlapping but different ideas.

Common mistakes

- Listing 10 essential amino acids by including arginine without the "semi-essential/children" note.
- Confusing asparagine/aspartate and glutamine/glutamate (amide vs acid forms).

Pharmacy relevance

Amino-acid infusions and protein supplements are pharmacy products; knowing essential amino acids explains why "complete protein" matters. Several drugs are amino-acid analogues.

India context

Cereal-based Indian diets can be low in lysine (cereals) while pulse-based diets complement them — the classic rice-dal / roti-dal combination gives complete essential amino acids. This is everyday protein complementation.

One-minute revision

Amino acid = NH_2 + COOH + R group; 20 standard. Essential 9: PVT TIM HALL (Arg semi-essential). Side-chain classes: nonpolar aliphatic, aromatic (Phe/Tyr/Trp), polar uncharged, basic (+: Lys/Arg/His), acidic (−: Asp/Glu). Functions: proteins, energy, nitrogen transport, precursors (neurotransmitters, heme, creatine), buffering.

Practice questions

MCQs

1. Which is an aromatic amino acid? (a) Alanine (b) Tryptophan (c) Serine (d) Lysine — **Answer: (b)**
2. "PVT TIM HALL" lists the: (a) Non-essential amino acids (b) Essential amino acids (c) Aromatic amino acids (d) Basic amino acids — **Answer: (b)**
3. Negatively charged amino acids are: (a) Lysine, arginine (b) Aspartate, glutamate (c) Serine, threonine (d) Glycine, alanine — **Answer: (b)**
4. The side chain is also called the: (a) R group (b) Amino group (c) Peptide group (d) Alpha helix — **Answer: (a)**

Short answers: Draw and label the general structure of an amino acid. Classify amino acids by side-chain chemistry with two examples each. Why is histidine listed as semi-essential? **Long answer:** Classify amino acids (nutritional and chemical) with examples and describe their biological functions. **Application-based:** A vegetarian student eats only rice. Using essential amino acid knowledge, explain why adding dal improves protein quality. **Viva:** How many standard amino acids are there? Which amino acid has no side chain (only H)? Name the sulphur-containing amino acids. (Methionine, cysteine.)

Chapter 9: Protein Structure and Plasma Proteins

Learning objectives

- Describe the four levels of protein structure in simple words.
- Explain denaturation.
- List the functions of proteins.
- Name the major plasma proteins and their functions.

9.1 Four levels of protein structure (from zero)

Concept: A protein is a chain of amino acids (linked by **peptide bonds**). Its working shape is built in four levels:

1. **Primary:** the *sequence* of amino acids — like the order of letters in a word. (A single wrong letter can cause disease — e.g., sickle-cell anaemia.)
2. **Secondary:** local folding into **α-helix** (spiral staircase) or **β-pleated sheet** (folded fan), held by hydrogen bonds.
3. **Tertiary:** the full 3D folding of one chain — the protein's working shape. Wrong folding → loss of function.
4. **Quaternary:** several chains fitted together (e.g., haemoglobin has 4 subunits).

Analogy: Primary = the written recipe; secondary = folding the paper; tertiary = the final dish's shape; quaternary = a thali with several dishes arranged together. **Key takeaway:** Sequence → local folds → 3D shape → multi-chain assembly. Shape decides function.

9.2 Denaturation (simple)

Concept: Denaturation = loss of the protein's natural 3D shape (and function), *without* breaking the amino-acid sequence. **Example:** Boiling an egg — heat unfolds the egg-white proteins irreversibly; the egg can never become raw again. Strong acids, alcohol and heavy metals also denature proteins (why alcohol is a disinfectant).

9.3 Functions of proteins (one-line each)

Structural (collagen, keratin), enzymes (all enzymes are proteins), transport (haemoglobin carries O_2), defence (antibodies/immunoglobulins), hormones (insulin), movement (actin, myosin in muscle), storage (ferritin stores iron), signalling (receptors).

9.4 Plasma proteins

Concept: Plasma proteins are proteins dissolved in the blood plasma. The three big groups:

Plasma protein	Made in	Main functions (simple words)
Albumin (most abundant)	Liver	Maintains blood's water balance (oncotic pressure); carries bilirubin, drugs, fatty acids, hormones
Globulins (α, β, γ)	Liver (α, β); immune cells (γ)	Transport (iron, copper, lipids); **γ-globulins = antibodies** (immunity)
Fibrinogen	Liver	Blood clotting (converted to fibrin)

Clinical links (general): low albumin suggests liver disease or protein malnutrition; abnormal globulin patterns appear in infections and immune disorders — interpreted by doctors from lab reports.

Common confusions

- **Plasma vs serum:** plasma = blood fluid *with* clotting factors; serum = plasma *without* fibrinogen (after clotting).
- Denaturation breaks *shape*, not the amino-acid *sequence*.

Common mistakes

- Saying all plasma proteins are made in the liver — γ-globulins (antibodies) are made by plasma cells of the immune system.

Mnemonic

Plasma proteins: "**A**lbumin **G**lobulin **F**ibrinogen" → "**A**lways **G**et **F**acts." Albumin jobs: "**W**ater balance, **C**arrier" ("**W**e **C**are").

Pharmacy relevance

Albumin binds many drugs — low albumin changes free (active) drug levels, which is why doctors adjust doses in liver disease. Plasma protein products (albumin infusions, clotting factors, immunoglobulins) are important pharmacy-stocked biologics.

India context

Protein-energy malnutrition (low albumin) remains a concern in vulnerable Indian populations; mid-day meal programmes partly address protein intake in schoolchildren.

One-minute revision

Protein structure: primary (sequence) → secondary (helix/sheet) → tertiary (3D) → quaternary (multi-chain). Denaturation = shape lost, sequence kept (boiled egg). Plasma proteins: albumin (water balance + carrier, liver), globulins (transport + antibodies), fibrinogen (clotting).

Practice questions

MCQs

1. The most abundant plasma protein is: (a) Fibrinogen (b) Albumin (c) Globulin (d) Collagen — **Answer: (b)**
2. γ-globulins are: (a) Clotting factors (b) Antibodies (c) Enzymes (d) Hormones — **Answer: (b)**
3. Quaternary structure refers to: (a) Amino acid sequence (b) Local helix/sheet (c) 3D folding of one chain (d) Assembly of multiple chains — **Answer: (d)**
4. Fibrinogen's role is in: (a) Immunity (b) Blood clotting (c) Oxygen transport (d) pH balance — **Answer: (b)**

Short answers: Describe the four levels of protein structure. What is denaturation? Give two examples. Name the three plasma protein groups with one function each. **Long answer:** Describe protein structure at four levels and the functions of the major plasma proteins. **Application-based:** Why might a doctor reduce the dose of a highly protein-bound drug in a patient with severe liver disease? (Low albumin → more free drug.) **Viva:** Where is albumin made? Which plasma protein is absent from serum?

Chapter 10: General Amino Acid Metabolism — Transamination, Deamination, Decarboxylation

Learning objectives

- Define transamination, oxidative deamination, non-oxidative deamination and decarboxylation.
- Explain the roles of ALT, AST, glutamate dehydrogenase and PLP (vitamin B6).
- State why nitrogen must be removed safely (ammonia toxicity).

10.1 Why strip the nitrogen? (from zero)

Concept: To burn an amino acid for energy (or turn it into glucose/fat), the body must first remove its nitrogen as **ammonia (NH_3)** — but ammonia is toxic, so it is quickly converted to safe **urea**. **Analogy:** Like removing the battery from an old phone before recycling the parts — the nitrogen "battery" (ammonia) is hazardous and must go to safe disposal (urea cycle). **Key takeaway:** Amino-acid breakdown = remove nitrogen (as ammonia → urea) + use the leftover carbon skeleton for energy/glucose.

10.2 Transamination

Concept: Transamination = moving an amino group from an amino acid to a keto acid, swapping identities. No nitrogen is lost — it is just relocated.

- **General reaction:** amino acid + α-ketoglutarate ⇌ keto acid + **glutamate**.
- **Enzymes: ALT** (alanine transaminase) and **AST** (aspartate transaminase); both need **vitamin B6 (PLP)** as coenzyme.
- **Clinical link:** ALT and AST leak into blood when liver cells are damaged — that is why they are measured in **liver function tests**.

Example: Alanine + α-ketoglutarate → pyruvate + glutamate (via ALT). Glutamate becomes the collection point for nitrogen from many amino acids.

10.3 Oxidative deamination

Concept: Removing the amino group *as free ammonia*, with oxidation.

- **Main enzyme: glutamate dehydrogenase** (in liver mitochondria) — glutamate → α-ketoglutarate + NH_3. Needs NAD^+/$NADP^+$.
- This is the chief route by which nitrogen is finally released as ammonia for the urea cycle.

Flow: many amino acids → (transamination) → glutamate → (oxidative deamination) → NH_3 → urea cycle.

10.4 Non-oxidative deamination

Concept: Direct removal of ammonia *without* oxidation, for a few specific amino acids.

- **Examples:** serine and threonine (via dehydratases) release ammonia directly; histidine → urocanate + NH_3 (via histidase).
- Minor routes compared with the transamination → glutamate → oxidative deamination highway.

10.5 Decarboxylation

Concept: Removing the –COOH group as CO_2, leaving a **biogenic amine**.

- **Enzymes:** decarboxylases needing **vitamin B6 (PLP)**.
- **Famous products:** histidine → **histamine** (allergy/inflammation); glutamate → **GABA** (calming neurotransmitter); DOPA → dopamine (details in Chapter 15).

Key takeaway: Decarboxylation turns amino acids into powerful signalling amines.

Summary table

Reaction	What happens	Key enzyme(s)	Product of nitrogen
Transamination	–NH_2 moved to a keto acid	ALT, AST (need B6/PLP)	Glutamate (nitrogen relocated)
Oxidative deamination	–NH_2 released as NH_3 with oxidation	Glutamate dehydrogenase	Free ammonia → urea
Non-oxidative deamination	–NH_2 released directly	Serine/threonine dehydratase, histidase	Free ammonia
Decarboxylation	–COOH removed as CO_2	Decarboxylases (need B6/PLP)	Amine (e.g., histamine, GABA)

Common confusions

- **Transamination vs deamination:** transamination *moves* nitrogen (nothing lost); deamination *removes* it as ammonia.
- ALT/AST are *transfer* enzymes, not deaminases — their blood levels reflect liver damage, not nitrogen disposal.

Common mistakes

- Forgetting vitamin B6 (PLP) is the coenzyme for transamination AND decarboxylation.
- Saying ammonia is excreted directly — in humans it is converted to urea first.

Mnemonic

"**T**ransfer **T**hen **T**rash": **T**ransamination (move N to glutamate) → **T**hen oxidative deamination (**T**rash N as ammonia). B6 rule: "**B**6 **B**oosts **B**oth transfer and decarboxylation."

Pharmacy relevance

ALT/AST are routine LFT markers pharmacists see on reports; several anti-tuberculosis and statin medicines require LFT monitoring — the pharmacist's role is reminding patients about scheduled tests and referring abnormal symptoms.

India context

Liver function tests including ALT/AST are part of routine health check-ups across India; drug-induced liver injury monitoring is especially relevant with widespread self-medication.

One-minute revision

Strip nitrogen before using amino-acid carbons. Transamination (ALT/AST, B6): moves NH_2 to make glutamate. Oxidative deamination (glutamate dehydrogenase): releases NH_3 → urea. Non-oxidative: direct NH_3 from serine/threonine/histidine. Decarboxylation (B6): –COOH → CO_2, makes amines (histamine, GABA).

Practice questions

MCQs

1. The coenzyme for transamination is: (a) NAD^+ (b) PLP (vitamin B6) (c) FAD (d) CoA — **Answer: (b)**
2. Oxidative deamination of glutamate is catalysed by: (a) ALT (b) AST (c) Glutamate dehydrogenase (d) Histidase — **Answer: (c)**
3. Decarboxylation of histidine gives: (a) Serotonin (b) Histamine (c) GABA (d) Dopamine — **Answer: (b)**
4. ALT and AST are measured clinically as markers of: (a) Kidney damage (b) Liver damage (c) Heart damage (d) Bone disease — **Answer: (b)**

Short answers: Distinguish transamination from deamination. Write the general transamination reaction. Why is ammonia converted to urea? **Long answer:** Describe the general reactions of amino acid metabolism: transamination, oxidative and non-oxidative deamination, and decarboxylation, with enzymes and significance. **Application-based:** A patient's LFT shows raised ALT/AST while on anti-TB medicines. What does this suggest and what is the pharmacist's role? (Possible liver injury; ensure doctor review, counsel adherence to monitoring — recognise and refer.) **Viva:** Which amino acid collects nitrogen from others? Name two biogenic amines and their parent amino acids.

Chapter 11: The Urea Cycle — Nitrogen Disposal and Detoxification

Learning objectives

- Explain why ammonia must be detoxified.
- Write the urea cycle steps in order with enzymes.
- State the cycle's location, energy cost and links to the TCA cycle.
- Describe the consequences of urea-cycle defects in general terms.

11.1 Why a urea cycle? (from zero)

Concept: Ammonia (NH_3) is a waste product of amino-acid breakdown and is **toxic to the brain**. The **urea cycle** (ornithine cycle) converts ammonia into **urea**, a safe, water-soluble molecule excreted in urine. **Simple explanation:** Ammonia is like wet garbage — smelly and dangerous to keep. The liver runs a "waste-processing plant" that packs it into sealed bags (urea) for the kidneys to throw out. **Analogy:** The urea cycle is the body's sewage-treatment plant: toxic ammonia in, harmless urea out. **Key takeaway:** Urea cycle = liver pathway that detoxifies ammonia into urea for urinary excretion.

11.2 The steps (Krebs–Henseleit ornithine cycle)

Site: liver — starts in mitochondria, continues in cytosol. **Key carrier: ornithine** (regenerated each turn, like a shuttle bus).

1. **NH_3 + CO_2 + 2 ATP → carbamoyl phosphate** — enzyme: **carbamoyl phosphate synthetase I (CPS-I)** (mitochondria; activated by N-acetylglutamate). *Costs 2 ATP.*
2. **Carbamoyl phosphate + ornithine → citrulline** — enzyme: **ornithine transcarbamoylase (OTC)**. Citrulline leaves the mitochondria.
3. **Citrulline + aspartate → argininosuccinate** — enzyme: **argininosuccinate synthetase**. *Costs 1 ATP (but 2 high-energy bonds, as ATP → AMP).* Aspartate donates the second nitrogen.
4. **Argininosuccinate → arginine + fumarate** — enzyme: **argininosuccinate lyase**. Fumarate links to the TCA cycle (the "Krebs bicycle" link).
5. **Arginine → ornithine + urea** — enzyme: **arginase**. Ornithine re-enters the mitochondria; urea goes to blood → kidneys → urine.

Flowchart: NH_3 + CO_2 →(CPS-I)→ carbamoyl-P →(+ ornithine, OTC)→ citrulline →(+ aspartate)→ argininosuccinate →(lyase)→ arginine + fumarate →(arginase)→ **urea** + ornithine (recycled).

Overall (simple): NH_3 + CO_2 + aspartate + 3 ATP → urea + fumarate + 2 ADP + AMP. Energy cost = **4 high-energy phosphate bonds**.

11.3 Regulation and links (simple)

- **N-acetylglutamate** activates CPS-I — made when amino acids are abundant (protein-rich meal) → cycle speeds up exactly when needed.
- **Fumarate** connects the urea cycle to the TCA cycle — the two cycles are sometimes drawn as interlinked ("Krebs bicycle").
- The two nitrogens of urea come from **ammonia** and **aspartate**.

11.4 Clinical significance (general)

Defects in urea-cycle enzymes (inherited) cause **hyperammonemia** — ammonia accumulates, harming the brain (vomiting, drowsiness, confusion, coma in severe cases). These are paediatric emergencies managed by specialists — recognise the danger, refer immediately. Acquired liver failure also impairs the cycle, contributing to hepatic confusion.

Common confusions

- **CPS-I vs CPS-II:** CPS-I (mitochondria, ammonia, urea cycle) vs CPS-II (cytosol, glutamine, **pyrimidine** synthesis — Chapter 17). Different enzymes, different pathways.
- Urea contains **two** nitrogens — from ammonia AND aspartate.

Common mistakes

- Saying the urea cycle occurs in the kidney. It is hepatic (liver); the kidney only excretes urea.
- Forgetting ornithine is regenerated (it is a catalyst-like carrier, not consumed).

Mnemonic

Enzyme order: "**C**PS-I → **O**TC → **S**ynthetase → **L**yase → **A**rginase" → "**C**ome **O**n **S**tudents, **L**earn **A**mmonia-disposal." Intermediates: "**O**rnithine → **C**itrulline → **A**rgininosuccinate → **A**rginine" → "**O**ur **C**ycle **A**lways **A**dvances."

Pharmacy relevance

Pharmacists must recognise that severe liver disease impairs ammonia detoxification — patients may be prescribed ammonia-lowering therapy (e.g., lactulose); counselling on adherence and recognising confusion/drowsiness as red flags is a key role.

India context

Neonatal screening for urea-cycle and other metabolic disorders is expanding in Indian tertiary centres; community pharmacists may be the first contact when parents report poor feeding and lethargy in newborns — refer urgently.

One-minute revision

Urea cycle (liver): NH_3 + CO_2 →(CPS-I, 2 ATP)→ carbamoyl-P →(+ornithine, OTC)→ citrulline →(+aspartate)→ argininosuccinate → arginine + fumarate →(arginase)→ urea + ornithine (recycled). Cost: 4 high-energy bonds. N-acetylglutamate activates CPS-I. Defects → hyperammonemia (brain danger).

Practice questions

MCQs

1. The urea cycle occurs mainly in the: (a) Kidney (b) Liver (c) Muscle (d) Brain — **Answer: (b)**
2. The first and rate-influencing enzyme of the urea cycle is: (a) Arginase (b) CPS-I (c) OTC (d) Lyase — **Answer: (b)**
3. The two nitrogen atoms of urea come from: (a) Two ammonias (b) Ammonia and aspartate (c) Glutamine and glycine (d) Two aspartates — **Answer: (b)**
4. Arginase converts arginine into: (a) Urea + ornithine (b) Citrulline + NO (c) Creatine (d) Agmatine — **Answer: (a)**

Short answers: Why must ammonia be converted to urea? Write the five steps of the urea cycle with enzymes. What activates CPS-I? **Long answer:** Describe the urea cycle (ornithine cycle) with its energetics, regulation and clinical significance. **Application-based:** A newborn is excessively sleepy with poor feeding and the doctor suspects a urea-cycle defect. Why is this an emergency? (Ammonia is neurotoxic; needs immediate specialist care.) **Viva:** Which molecule is regenerated in each turn of the cycle? Which cycle does fumarate link to?

Chapter 12: Fate of Carbon Skeletons — Glucogenic vs Ketogenic Amino Acids

Learning objectives

- Define "carbon skeleton."
- Classify amino acids as glucogenic, ketogenic, or both, with examples.
- Explain the physiological importance during starvation.

12.1 The concept (from zero)

Concept: After nitrogen is removed (Chapter 10), the leftover part of the amino acid — its **carbon skeleton** — is a keto acid that the body can burn or convert. **Simple explanation:** Once the hazardous "battery" (nitrogen) is removed, the remaining "phone parts" (carbons) are still useful — the body either burns them for energy, turns them into glucose, or turns them into fat/ketone bodies. **Two fates:**

- **Glucogenic amino acids:** their carbons can become **glucose** (via pyruvate or TCA-cycle intermediates → gluconeogenesis).
- **Ketogenic amino acids:** their carbons become **acetyl-CoA or acetoacetate** → fat or ketone bodies (acetyl-CoA cannot become glucose in humans).

Analogy: Glucogenic = convertible currency (can become glucose "cash"); ketogenic = store credit (only usable as fat/ketone "goods"). **Key takeaway:** Glucogenic → glucose possible; ketogenic → only fat/ketones.

12.2 The classification (must memorise)

Category	Amino acids	Memory aid
Strictly ketogenic (only 2)	**Leucine, Lysine**	"**L**eucine and **L**ysine are **L**onely ketogenics" (both start with L)
Both glucogenic and ketogenic (4)	**Isoleucine, Phenylalanine, Tryptophan, Tyrosine**	"**I P**ray **T**o **T**hy" — **I**soleucine, **P**henylalanine, **T**ryptophan, **T**yrosine ("PIT T": **P**he, **I**le, **T**rp, **T**yr)
Glucogenic	All the rest (14) — e.g., alanine, glutamate, aspartate, serine, glycine, valine	Default category

Exam logic: only 6 amino acids are ketogenic at all (2 strict + 4 both); everything else is purely glucogenic.

12.3 Why it matters — starvation logic

During prolonged starvation, muscle protein breaks down; glucogenic amino acids (especially **alanine** and **glutamine**) travel to the liver to make glucose for the brain (glucose–alanine cycle). This is why the body "eats its own muscle" when starving — a point that makes protein intake during illness clinically important.

Common confusions

- **Ketogenic amino acid vs ketone body:** the amino acid's carbons *can form* ketone bodies; it is not itself a ketone body.
- Acetyl-CoA → glucose is **not possible** in humans (no net conversion) — hence purely ketogenic amino acids can't make glucose.

Common mistakes

- Listing phenylalanine/tyrosine as purely ketogenic — they are *both*.
- Forgetting leucine and lysine are the only *strictly* ketogenic ones.

Pharmacy relevance

Understanding glucogenic amino acids explains why protein nutrition matters in recovery, and why alanine/glutamine appear in parenteral nutrition formulations.

India context

During prolonged illness or fasting without adequate protein, muscle wasting follows this exact biochemistry — relevant when counselling families on protein intake during convalescence (dal, milk, eggs where culturally acceptable).

One-minute revision

Carbon skeleton = amino acid minus nitrogen. Glucogenic → can make glucose (14, the default). Both (4): Ile, Phe, Trp, Tyr ("PITT"). Strictly ketogenic (2): Leu, Lys ("L-L"). Starvation: muscle alanine/glutamine → liver glucose.

Practice questions

MCQs

1. Which pair is strictly ketogenic? (a) Ala, Gly (b) Leu, Lys (c) Phe, Tyr (d) Ser, Thr — **Answer: (b)**
2. Which amino acid is both glucogenic and ketogenic? (a) Valine (b) Isoleucine (c) Alanine (d) Glutamate — **Answer: (b)**
3. Ketogenic amino acids are degraded to: (a) Pyruvate (b) Acetyl-CoA/acetoacetate (c) Oxaloacetate (d) Glucose — **Answer: (b)**
4. During starvation, muscle releases mainly ___ for liver gluconeogenesis: (a) Leucine (b) Alanine and glutamine (c) Lysine (d) Phenylalanine — **Answer: (b)**

Short answers: Define glucogenic and ketogenic amino acids with two examples each. Why can't acetyl-CoA form glucose in humans? **Long answer:** Classify amino acids by the fate of their carbon skeletons with examples and physiological significance. **Application-based:** Explain why doctors worry about muscle wasting in a patient starved for two weeks, using carbon-skeleton fates. **Viva:** Name the two strictly ketogenic amino acids. Which four are both?

Chapter 13: Phenylalanine and Tyrosine Catabolism — and Their Disorders

Learning objectives

- Trace phenylalanine → tyrosine → breakdown products.
- Explain the enzyme defect behind PKU, albinism, alkaptonuria and tyrosinemia.
- State the clinical features and management principles (general) of each disorder.

13.1 The pathway (from zero)

Concept: Phenylalanine (essential) is converted to **tyrosine** (non-essential, made from phenylalanine), and tyrosine is then broken down or used to build important molecules. **Steps (simple):**

1. Phenylalanine → **tyrosine** — enzyme: **phenylalanine hydroxylase** (needs **tetrahydrobiopterin, BH_4**, as cofactor; uses O_2).
2. Tyrosine has several fates:

- → **melanin** (skin/eye pigment) — enzyme: **tyrosinase**; - → **catecholamines** (dopamine → noradrenaline → adrenaline) and **thyroid hormones** (details in Chapter 15); - → breakdown: tyrosine → … → **homogentisate** → … → **fumarate + acetoacetate** (so tyrosine is *both* glucogenic and ketogenic — links to Chapter 12). **Analogy:** Phenylalanine is raw crude oil; tyrosine is refined petrol; from petrol you can run different engines — pigment (melanin), messengers (catecholamines), or burn it for energy (fumarate + acetoacetate). **Key takeaway:** Phe → Tyr (hydroxylase + BH_4); Tyr → melanin, catecholamines, thyroid hormones, or fumarate + acetoacetate.

13.2 The four disorders — one table (exam favourite)

Disorder	Defective enzyme	What accumulates / what's missing	Key features (general)
Phenylketonuria (PKU)	Phenylalanine hydroxylase (classic)	Phenylalanine accumulates; converted to phenyl ketones (urine)	Intellectual disability if untreated; musty body odour; fair skin/hair (less melanin). **Managed by low-phenylalanine diet from birth** — newborn screening
Albinism	Tyrosinase	Melanin missing	Very fair skin, white hair, vision problems, sun sensitivity
Alkaptonuria	Homogentisate oxidase	Homogentisate accumulates	Urine darkens on standing (oxidation); pigment deposits in joints/ears later in life
Tyrosinemia (type I, classic)	Fumarylacetoacetate hydrolase (last step)	Toxic metabolites (fumarylacetoacetate)	Liver/kidney damage in infancy; specialist management

PKU — the most exam-important: because phenylalanine can't become tyrosine, excess phenylalanine takes an abnormal side route → **phenylpyruvate/phenyl ketones** excreted in urine (hence the name). High phenylalanine damages the developing brain. **Early detection by newborn screening + strict low-phenylalanine diet prevents brain damage** — one of medicine's great preventive successes. Tyrosine becomes essential in PKU (must be supplied, since it can't be made).

13.3 Management principles (general, recognise-and-refer level)

- **PKU:** lifelong low-phenylalanine diet under specialist/dietitian supervision; special medical foods; maternal PKU needs pre-conception control.
- **Albinism:** sun protection, vision care.
- **Alkaptonuria/tyrosinemia:** specialist care; symptom-based management.
- Pharmacists: support adherence to special diets/medical foods, counsel families, and ensure newborn-screening follow-up is not missed.

Common confusions

- **PKU vs albinism:** PKU = *too much* phenylalanine (hydroxylase defect, brain damage risk); albinism = *no melanin* (tyrosinase defect, pigment/vision issues). Different enzymes, different problems.
- **Alkaptonuria vs tyrosinemia:** both are tyrosine-breakdown defects, but at different steps with different consequences.

Common mistakes

- Saying PKU is a tyrosine-hydroxylase defect — it is *phenylalanine* hydroxylase.
- Forgetting the BH_4 cofactor.

Mnemonic

Disorder order along the pathway: "**P**KU → **A**lbinism → **A**lkaptonuria → **T**yrosinemia" → "**P**lease **A**rrange **A** **T**est" (defects appear in pathway order). PKU diet: "**P**henylalanine **P**oor diet **P**rotects brain."

Pharmacy relevance

PKU medical foods and low-protein products are dispensed through pharmacies in some settings; pharmacists counsel on aspartame avoidance in PKU (aspartame contains phenylalanine — a classic counselling point on food/drug labels).

India context

Newborn screening for PKU and other inborn errors is growing in Indian metro hospitals but is not yet universal — pharmacists can raise awareness among new parents about screening availability.

One-minute revision

Phe →(hydroxylase + BH_4)→ Tyr → melanin (tyrosinase), catecholamines, thyroid hormones, or fumarate + acetoacetate. Defects: PKU (hydroxylase; brain damage; low-Phe diet from birth), albinism (tyrosinase; no melanin), alkaptonuria (homogentisate oxidase; dark urine), tyrosinemia (last-step enzyme; liver/kidney damage).

Practice questions

MCQs

1. PKU is due to deficiency of: (a) Tyrosinase (b) Phenylalanine hydroxylase (c) Homogentisate oxidase (d) Arginase — **Answer: (b)**
2. The cofactor for phenylalanine hydroxylase is: (a) BH_4 (b) PLP (c) NAD^+ (d) Biotin — **Answer: (a)**
3. Darkening of urine on standing occurs in: (a) PKU (b) Albinism (c) Alkaptonuria (d) Tyrosinemia — **Answer: (c)**
4. Albinism results from defective: (a) Melanin breakdown (b) Tyrosinase (c) Phenylalanine diet (d) Homogentisate oxidase — **Answer: (b)**

Short answers: Trace phenylalanine to tyrosine and list tyrosine's fates. Why does urine darken in alkaptonuria? Why is newborn screening critical in PKU? **Long answer:** Describe the catabolism of phenylalanine and tyrosine and the disorders resulting from their enzyme defects. **Application-based:** A mother of a PKU-diagnosed infant asks why the baby needs "special milk." Explain simply. (Normal milk protein contains phenylalanine, which her baby cannot process; special formula prevents brain damage.) **Viva:** Which disorder gives a musty odour? In PKU, which amino acid becomes essential?

Chapter 14: Inborn Errors of Branched-Chain and Aromatic Amino Acids

Learning objectives

- Define "inborn error of metabolism."
- Describe MSUD (branched-chain) and summarise other branched-chain disorders.
- Summarise the aromatic amino acid disorders as a group (linking to Chapter 13).
- State the general principles of diagnosis and management.

14.1 What is an inborn error of metabolism? (from zero)

Concept: An **inborn error of metabolism** is a genetic disorder present from birth in which a metabolic enzyme is defective, so a substance accumulates (often toxic) or a needed product is missing. **Simple explanation:** A factory machine installed broken from day one — raw material piles up, finished product never comes out. **General pattern:** enzyme block → substrate accumulates (toxic) → product deficient → clinical features. Management: restrict the substrate (diet), replace the product, or support the defective enzyme — always under specialist care.

14.2 Branched-chain amino acids (BCAAs) — first, who are they?

Leucine, isoleucine, valine — named for their branched side chains. All three are **essential**. Their breakdown shares common enzymes, so one defect affects all three.

14.3 Maple Syrup Urine Disease (MSUD) — the key BCAA disorder

Concept: Defect in the **branched-chain α-ketoacid dehydrogenase** complex — the shared breakdown enzyme for leucine, isoleucine and valine. **What happens:** BCAAs and their keto-acids accumulate in blood and tissues. **Key features (general):** sweet/maple-syrup odour of urine (and earwax), poor feeding, vomiting, drowsiness and developmental problems in the newborn period if untreated. **Management (general):** urgent specialist care; BCAA-restricted diet with special medical foods; treatment of acute crises. Early detection through newborn screening where available.

14.4 Other branched-chain disorders (names + one line each)

- **Isovaleric acidaemia:** defect in leucine breakdown → "sweaty feet" odour; vomiting, lethargy.
- **Methylmalonic acidaemia / propionic acidaemia:** defects further down the BCAA breakdown road (also involve vitamin B12-related steps for methylmalonic) → metabolic crises with vomiting and drowsiness.
- (Detail beyond this is postgraduate level; the syllabus asks for an overview — know the pattern, not every enzyme.)

14.5 Aromatic amino acid disorders — group recap

The aromatic amino acids are **phenylalanine, tyrosine, tryptophan**. Their inborn errors were detailed in Chapter 13:

- **Phenylketonuria** (phenylalanine hydroxylase) — brain damage if untreated; low-Phe diet.
- **Tyrosinemia** — liver/kidney damage.
- **Alkaptonuria** — dark urine, joint pigmentation.
- **Albinism** (tyrosinase) — pigment/vision.
- Tryptophan-pathway defects are rare and beyond syllabus scope — know tryptophan mainly as the serotonin/melatonin parent (Chapter 15).

Summary table

Group	Disorder	Defective step (simple)	Hallmark clue
Branched-chain	MSUD	Branched-chain α-ketoacid dehydrogenase	Maple-syrup urine odour
Branched-chain	Isovaleric acidaemia	Leucine breakdown	Sweaty-feet odour
Aromatic	PKU	Phenylalanine hydroxylase	Musty odour, developmental delay
Aromatic	Alkaptonuria	Homogentisate oxidase	Urine darkens on standing
Aromatic	Albinism	Tyrosinase	No pigment, vision issues

Common confusions

- **MSUD vs PKU:** both are amino-acid disorders with odd urine odours, but MSUD = branched-chain (leu/ile/val) enzyme defect; PKU = phenylalanine hydroxylase defect. Different diets, different management.
- "Aromatic" refers to the ring structure (Phe, Tyr, Trp), not to smell.

Common mistakes

- Calling MSUD a urea-cycle disorder. It is a BCAA catabolism defect.
- Suggesting home management of a metabolic crisis — these are emergencies for specialist centres.

Mnemonic

BCAAs: "**L**eucine, **I**soleucine, **V**aline" → "**L**ove **I**s **V**aluable." MSUD: "**M**aple **S**yrup = **M**etabolism **S**tuck (dehydrogenase defect)."

Pharmacy relevance

Special metabolic formulas and medical foods for these disorders pass through pharmacies; pharmacists ensure correct product supply, counsel on strict dietary adherence, and flag that intercurrent illness (fever, infection) can trigger a crisis → urgent medical review.

India context

Consanguinity in some communities raises the incidence of recessive inborn errors; genetic counselling awareness is a growing pharmacist role. Newborn screening panels in Indian tertiary hospitals increasingly include MSUD and PKU.

One-minute revision

Inborn error = broken enzyme from birth → substrate piles up / product missing. BCAAs = Leu, Ile, Val (all essential). MSUD = branched-chain α-ketoacid dehydrogenase defect → maple-syrup urine, neonatal emergency, BCAA-restricted diet. Aromatic disorders (Chapter 13): PKU, tyrosinemia, alkaptonuria, albinism.

Practice questions

MCQs

1. The branched-chain amino acids are: (a) Phe, Tyr, Trp (b) Leu, Ile, Val (c) Ala, Gly, Ser (d) Lys, Arg, His — **Answer: (b)**
2. MSUD is due to defective: (a) Phenylalanine hydroxylase (b) Branched-chain α-ketoacid dehydrogenase (c) Tyrosinase (d) Arginase — **Answer: (b)**
3. The characteristic odour in MSUD is: (a) Musty (b) Maple syrup (c) Sweaty feet (d) Fruity — **Answer: (b)**
4. Which is an aromatic amino acid disorder? (a) MSUD (b) PKU (c) Isovaleric acidaemia (d) Methylmalonic acidaemia — **Answer: (b)**

Short answers: Define inborn error of metabolism with the general pattern. Name the BCAAs. What is the enzyme defect in MSUD? **Long answer:** Describe the inborn errors of branched-chain and aromatic amino acid metabolism with their biochemical basis. **Application-based:** A newborn's urine smells like maple syrup and the baby feeds poorly. What should a pharmacist advise the parents? (Urgent hospital referral — possible MSUD; do not delay.) **Viva:** Which BCAAs are strictly ketogenic? (Leucine — links to Chapter 12.)

Chapter 15: Neurotransmitters and Hormones Derived from Amino Acids

Learning objectives

- Name the parent amino acid for each: serotonin, melatonin, dopamine, noradrenaline, adrenaline (plus histamine, GABA, thyroid hormones for completeness).
- Outline the synthesis steps in simple words.
- State one key function and one clinical link for each.

15.1 The big picture (from zero)

Concept: A few amino acids are "promoted" into powerful signalling molecules — **neurotransmitters** (nerve messengers) and **hormones** (blood messengers). **Simple explanation:** The body takes an ordinary building brick (amino acid) and remodels it — usually by **decarboxylation** (removing CO_2) and **hydroxylation** (adding OH) — into a messenger molecule. **Analogy:** Like converting a bicycle (amino acid) into a motorbike (neurotransmitter) — same base, new engine, much faster signalling. **Key takeaway:** Tyrosine → catecholamines (dopamine, noradrenaline, adrenaline) + thyroid hormones; tryptophan → serotonin → melatonin; histidine → histamine; glutamate → GABA.

15.2 The catecholamine family (from tyrosine)

Pathway: Tyrosine → **DOPA** (tyrosine hydroxylase — the rate-limiting step) → **dopamine** (decarboxylation, needs B6) → **noradrenaline** → **adrenaline** (in the adrenal medulla). **One-line roles:**

- **Dopamine:** movement control, reward/pleasure, motivation. Clinical link: low dopamine signalling → Parkinson's disease (tremor, rigidity); many antipsychotic drugs block dopamine receptors (pharmacology detail later).
- **Noradrenaline (norepinephrine):** alertness, attention, blood-pressure control via the sympathetic nervous system.
- **Adrenaline (epinephrine):** the "fight-or-flight" hormone — raises heart rate, blood pressure and blood glucose in emergencies. Clinical link: injected adrenaline is the emergency treatment for severe allergy (**anaphylaxis**).

Mnemonic: "**D**opamine → **N**oradrenaline → **A**drenaline" in order — "**D**o **N**ot **A**rgue" (pathway order).

15.3 Serotonin and melatonin (from tryptophan)

Pathway: Tryptophan → 5-hydroxytryptophan → **serotonin (5-HT)** → **melatonin** (in the pineal gland, at night).

- **Serotonin (5-HT):** mood, sleep, appetite, gut movement. Clinical link: low serotonin signalling is associated with depression; many antidepressants (SSRIs) raise serotonin signalling — you will study these in pharmacology.
- **Melatonin:** the "darkness hormone" — regulates the **sleep–wake cycle**. Released at night by the pineal gland; light suppresses it.

15.4 Others worth one line

- **Histamine** (from histidine): allergy and inflammation mediator; stomach-acid stimulation. Antihistamines block its effects.
- **GABA** (from glutamate): the brain's main *calming* (inhibitory) neurotransmitter; many anti-anxiety/sleep medicines enhance GABA signalling.
- **Thyroid hormones T3/T4** (from tyrosine + iodine): control metabolic rate. Iodine deficiency → goitre/hypothyroidism.

Master table

Molecule	Parent amino acid	Type	Key function (one line)
Dopamine	Tyrosine	Neurotransmitter	Movement, reward
Noradrenaline	Tyrosine (via dopamine)	Neurotransmitter/hormone	Alertness, BP control
Adrenaline	Tyrosine (via noradrenaline)	Hormone	Fight-or-flight
Serotonin (5-HT)	Tryptophan	Neurotransmitter	Mood, sleep, appetite
Melatonin	Tryptophan (via serotonin)	Hormone	Sleep–wake cycle
Histamine	Histidine	Mediator	Allergy, inflammation, gastric acid
GABA	Glutamate	Neurotransmitter	Brain's brake (inhibitory)
Thyroid hormones	Tyrosine (+ iodine)	Hormone	Metabolic rate

Common confusions

- **Noradrenaline vs adrenaline:** noradrenaline is mainly a nerve messenger; adrenaline is mainly the adrenal-gland hormone — one pathway step apart.
- **Serotonin vs melatonin:** serotonin is the day-active messenger; melatonin (made *from* serotonin) is the night-time sleep hormone.

Common mistakes

- Saying dopamine comes from tryptophan. Dopamine is from **tyrosine**; serotonin is from **tryptophan**.
- Forgetting iodine in thyroid-hormone synthesis.

Pharmacy relevance

This chapter is the biochemical foundation of neuropharmacology: antidepressants (serotonin), antipsychotics (dopamine), anti-Parkinson drugs (dopamine), antihistamines (histamine), anxiolytics (GABA), adrenaline injections (anaphylaxis kits). A pharmacist who knows the parent amino acids understands *why* these drug classes exist.

India context

Iodine-deficiency goitre was historically common in India's sub-Himalayan belt — the universal salt-iodisation programme is a public-health application of thyroid biochemistry. Pharmacists still counsel on iodised salt.

One-minute revision

Tyrosine → DOPA → dopamine → noradrenaline → adrenaline ("Do Not Argue"); tyrosine + iodine → thyroid hormones. Tryptophan → serotonin (mood) → melatonin (sleep). Histidine → histamine; glutamate → GABA (calming). Decarboxylation (B6) is the common remodelling step.

Practice questions

MCQs

1. Dopamine is synthesised from: (a) Tryptophan (b) Tyrosine (c) Histidine (d) Glutamate — **Answer: (b)**
2. Melatonin is produced by the: (a) Adrenal gland (b) Pineal gland (c) Thyroid (d) Pituitary — **Answer: (b)**
3. The rate-limiting step in catecholamine synthesis is: (a) DOPA decarboxylase (b) Tyrosine hydroxylase (c) MAO (d) COMT — **Answer: (b)**
4. GABA is derived from: (a) Glycine (b) Glutamate (c) Aspartate (d) Serine — **Answer: (b)**

Short answers: Trace tyrosine to adrenaline naming each intermediate. How is melatonin related to serotonin? Name the parent amino acids of histamine and GABA. **Long answer:** Describe the synthesis of catecholamines, serotonin and melatonin from amino acids, with one clinical link for each. **Application-based:** Why do doctors advise depressed patients that "medicines raise brain serotonin" rather than "give serotonin tablets"? (Serotonin from outside doesn't reach the brain well; drugs adjust signalling — keep the explanation general.) **Viva:** Which vitamin is needed for DOPA decarboxylation? Emergency injection for anaphylaxis? (Adrenaline.)

Chapter 16: Heme Catabolism and Jaundice

Learning objectives

- Define heme and state where it is broken down.
- Trace heme → biliverdin → bilirubin → conjugated bilirubin → bile → intestine.
- Distinguish conjugated vs unconjugated bilirubin.
- Classify jaundice into three types with the underlying defect.
- State the pharmacist's recognise-and-refer role.

16.1 What is heme? (from zero)

Concept: Heme is the iron-containing pigment part of **haemoglobin** (the oxygen-carrying protein of red blood cells). When old red blood cells die (after ~120 days), heme must be dismantled and discarded safely. **Simple explanation:** Red blood cells retire after about four months. Their haemoglobin is stripped: the protein part is recycled as amino acids, the iron is saved and reused, and the pigment part (heme) becomes a yellow waste called **bilirubin**. **Analogy:** Scrapping an old car — reusable parts (iron, amino acids) are salvaged; the paint (heme pigment) becomes waste (bilirubin) sent for disposal. **Key takeaway:** Heme (from dead RBCs) → bilirubin (yellow waste pigment) → liver processing → bile → intestine.

16.2 The breakdown pathway (step by step)

Site of first steps: macrophages of the spleen, liver and bone marrow (the reticuloendothelial system).

1. **Heme → biliverdin** (green pigment) — enzyme: **heme oxygenase**; iron is released (reused) and carbon monoxide is released.
2. **Biliverdin → bilirubin** (yellow pigment) — enzyme: **biliverdin reductase**.
3. **Unconjugated (indirect) bilirubin** travels in blood bound to **albumin** (it is water-insoluble) to the liver.
4. In the liver: **bilirubin + glucuronic acid → conjugated (direct) bilirubin** — enzyme: **UDP-glucuronyl transferase**. Conjugation makes it water-soluble.
5. Conjugated bilirubin → **bile** → intestine → converted by gut bacteria to **urobilinogen** → mostly excreted as **stercobilin** (brown colour of stool); a little is reabsorbed and appears as **urobilin** (yellow colour of urine).

Flowchart: Old RBC → heme →(heme oxygenase)→ biliverdin →(reductase)→ unconjugated bilirubin →(albumin, blood)→ liver →(+ glucuronic acid, UDP-glucuronyl transferase)→ conjugated bilirubin → bile → intestine → urobilinogen → stercobilin (stool) / urobilin (urine).

16.3 Jaundice — yellow alert

Concept: Jaundice = yellow discoloration of skin and eyes due to excess bilirubin in blood. **Three types (exam favourite):**

Type	Also called	Defect (simple words)	Bilirubin raised
Hemolytic (pre-hepatic)	—	Too many RBCs breaking (e.g., haemolytic anaemias) — the liver is overwhelmed	Unconjugated
Hepatocellular (hepatic)	—	Liver cells damaged (hepatitis, toxins, drugs) — can't process bilirubin	Both
Obstructive (post-hepatic)	Cholestatic	Bile duct blocked (gallstone, tumour) — conjugated bilirubin can't reach intestine; pale stools, dark urine, itching	Conjugated

Physiological jaundice of newborns: mild, appears after day 2, because the newborn liver's conjugating enzyme is immature — usually resolves; doctors monitor it (severe cases need phototherapy — a medical decision).

16.4 Pharmacist's role (recognise and refer)

Yellow eyes/skin, dark urine with pale stools, or itching with jaundice → **refer to a doctor promptly**; do not diagnose the type. Counsel patients on prescribed liver medicines, and remind that several medicines (including some anti-TB drugs) can affect the liver — report warning symptoms early.

Common confusions

- **Unconjugated vs conjugated:** unconjugated = before liver processing (water-insoluble, albumin-bound); conjugated = after adding glucuronic acid (water-soluble, goes into bile).
- **Biliverdin (green) vs bilirubin (yellow):** a bruise shows both — green then yellow — as haemoglobin breaks down in the skin.

Common mistakes

- Saying bilirubin is excreted by the kidney. Conjugated bilirubin goes via **bile to the intestine**; only small amounts appear in urine.
- Confusing haem (heme) synthesis with breakdown — this chapter is *catabolism* (breakdown).

Mnemonic

Pathway: "**H**eme → **B**iliverdin → **B**ilirubin → **C**onjugated → **B**ile" → "**H**appy **B**abies **B**ring **C**olourful **B**alloons." Jaundice types: "**B**efore (pre-hepatic), **I**nside (hepatic), **A**fter (post-hepatic) the liver" → "**B**efore **I**t **A**rrives."

Pharmacy relevance

Bilirubin reports (direct/indirect) are common LFT components pharmacists encounter; understanding conjugation explains the two fractions. Drug-induced liver injury presents with jaundice — pharmacists are key sentinels for early reporting.

India context

Viral hepatitis (A and E) is a common cause of jaundice in India; neonatal jaundice monitoring is routine in Indian hospitals. Pharmacists counsel against alcohol during liver illness and on completing hepatitis-related prescriptions.

One-minute revision

Old RBC → heme →(heme oxygenase)→ biliverdin (green) → bilirubin (yellow, unconjugated, albumin-bound) → liver (+glucuronic acid, UDP-glucuronyl transferase) → conjugated → bile → intestine → stercobilin (stool brown). Jaundice = excess bilirubin: pre-hepatic (hemolysis, unconjugated), hepatic (liver damage, both), post-hepatic (blocked duct, conjugated; pale stool, dark urine).

Practice questions

MCQs

1. Heme is converted to biliverdin by: (a) Biliverdin reductase (b) Heme oxygenase (c) UDP-glucuronyl transferase (d) Arginase — **Answer: (b)**
2. Conjugation of bilirubin occurs in the: (a) Spleen (b) Liver (c) Kidney (d) Intestine — **Answer: (b)**
3. Obstructive jaundice shows raised: (a) Unconjugated bilirubin (b) Conjugated bilirubin (c) Biliverdin (d) Heme — **Answer: (b)**
4. The brown colour of stool is due to: (a) Bilirubin (b) Stercobilin (c) Biliverdin (d) Urobilin — **Answer: (b)**

Short answers: Trace heme to stercobilin. Distinguish conjugated and unconjugated bilirubin. Classify jaundice with one cause each. **Long answer:** Describe heme catabolism and explain the three types of jaundice with their biochemical basis. **Application-based:** A patient has yellow eyes, dark urine and pale, clay-coloured stools. Which type of jaundice does this suggest and what do you do? (Suggests obstructive/post-hepatic pattern; refer to a doctor — do not diagnose.) **Viva:** Why is unconjugated bilirubin carried on albumin? Which enzyme is immature in newborns?

UNIT IV — AMINO ACIDS AND PROTEIN METABOLISM (10 hours)

Chapter 8: Classification and Functions of Amino Acids

Amino acid = NH_2 + COOH + R group; 20 standard.

Chapter 9: Protein Structure and Plasma Proteins

Protein structure: primary (sequence) → secondary (helix/sheet) → tertiary (3D) → quaternary (multi-chain).

Chapter 10: General Amino Acid Metabolism — Transamination, Deamination, Decarboxylation

Strip nitrogen before using amino-acid carbons.

Chapter 11: The Urea Cycle — Nitrogen Disposal and Detoxification

Urea cycle (liver): NH_3 + CO_2 →(CPS-I, 2 ATP)→ carbamoyl-P →(+ornithine, OTC)→ citrulline →(+aspartate)→ argininosuccinate → arginine + fumarate →(arginase)→ urea + ornithine (recycled).

Chapter 12: Fate of Carbon Skeletons — Glucogenic vs Ketogenic Amino Acids

Carbon skeleton = amino acid minus nitrogen.

Chapter 13: Phenylalanine and Tyrosine Catabolism — and Their Disorders

Phe →(hydroxylase + BH_4)→ Tyr → melanin (tyrosinase), catecholamines, thyroid hormones, or fumarate + acetoacetate.

Chapter 14: Inborn Errors of Branched-Chain and Aromatic Amino Acids

Inborn error = broken enzyme from birth → substrate piles up / product missing.

Chapter 15: Neurotransmitters and Hormones Derived from Amino Acids

Tyrosine → DOPA → dopamine → noradrenaline → adrenaline ("Do Not Argue"); tyrosine + iodine → thyroid hormones.

Chapter 16: Heme Catabolism and Jaundice

Old RBC → heme →(heme oxygenase)→ biliverdin (green) → bilirubin (yellow, unconjugated, albumin-bound) → liver (+glucuronic acid, UDP-glucuronyl transferase) → conjugated → bile → intestine → stercobilin (stool brown).

Combined References (Units III–V)

As per the BP202T syllabus — Recommended References (preferably latest editions):

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