Collegedunia NCERT Notes

The Ultimate NCERT Revision Guide for Class 12 Chemistry (2026-27 / New NCERT)

Chapter 10: Biomolecules

Class 12th Chemistry – The Chemistry of Life – Carbohydrates, Proteins, Enzymes, Vitamins, Nucleic Acids

What you will master in this chapter

Every living thing is built from a small library of organic molecules. In this chapter you will (i) recognise **carbohydrates** as polyhydroxy aldehydes/ketones, classify them into mono-, di- and polysaccharides, and master glucose's open chain (Fischer), cyclic pyranose (Haworth) and the meaning of α/β anomers, mutarotation and D/L configuration; (ii) understand **amino acids** as zwitterions, the difference between essential and non-essential, and the peptide bond that strings them into **proteins** with primary, secondary (α-helix, β-pleated sheet), tertiary and quaternary structure; (iii) explain **denaturation** and the protein-folding hierarchy; (iv) understand **enzymes** as biocatalysts and their lock-and-key mechanism; (v) classify **vitamins** as fat- and water-soluble and link each to its deficiency disease; (vi) decode **nucleic acids** – the chemistry of nucleosides, nucleotides, the phosphodiester linkage and the Watson–Crick double helix, including the differences between DNA and RNA; and (vii) catalogue **hormones** by chemical class and biological role. These topics are recurrent in both NEET (heavy weightage) and JEE Main.

Contents

Also see for this chapter

Step-by-step worked answers: NCERT Solutions for Class 12 Chemistry Chapter 10 Biomolecules.
One-page revision: Biomolecules Formula Sheet.
Tougher problems: NCERT Exemplar Solutions for Biomolecules.

1 Carbohydrates

Carbohydrates are the most abundant organic compounds on Earth, generated by green plants through photosynthesis. Chemically, a carbohydrate is an **optically active polyhydroxy aldehyde or ketone**, or any compound that produces such a unit on hydrolysis. The old name "carbon hydrate" comes from the general formula $C_x(H_2O)_y$ – glucose, $C_6H_{12}O_6$, fits this as $C_6(H_2O)_6$ – but the modern definition rests on functional groups, not formula. Sweet-tasting carbohydrates are called *sugars* or *saccharides* (Greek *sakcharon*). They power metabolism, store energy and build cell walls.

1.1 Classification of Carbohydrates

The single test is **hydrolysis**: how many sugar units does a carbohydrate release on hydrolysis?

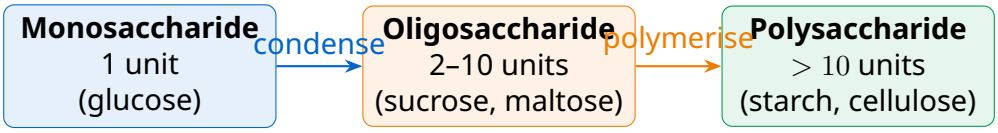
Three classes by hydrolysis

- **Monosaccharides** (1 unit): cannot be hydrolysed further. About 20 occur in nature. Examples: glucose, fructose, ribose, galactose.
- **Oligosaccharides** (2–10 units): named further as di-, tri-, tetrasaccharides. Most common are **disaccharides**. Examples: sucrose, maltose, lactose.
- **Polysaccharides** (> 10 units, often hundreds): high-MW polymers, usually not sweet (also called *non-sugars*). Examples: starch, cellulose, glycogen.

A second classification splits sugars by their *reducing* behaviour:

- **Reducing sugars** reduce Fehling's solution ($Cu^{2+} \longrightarrow Cu_2O$, red ppt) and Tollens' reagent ($Ag^{+} \longrightarrow Ag$, mirror) because their carbonyl group (or its hemiacetal form which opens) is free. **All monosaccharides** (aldoses and ketoses both) plus maltose and lactose are reducing.
- **Non-reducing sugars**: the carbonyl groups are locked into a glycosidic bond,

e.g. sucrose.



Sweet vs non-sweet

"Mono is sweet, poly is starch." Mono- and disaccharides taste sweet (glucose, sucrose); polysaccharides do not (starch and cellulose feel bland). The chain length determines both sweetness and solubility.

1.2 Monosaccharides – Aldoses and Ketoses

Monosaccharides are further classified by (a) the carbonyl group and (b) the number of carbons.

- Aldehyde carbonyl → **aldose**. Ketonic carbonyl → **ketose**.
- Three carbons → triose, four → tetrose, five → pentose, six → hexose, seven → heptose.
- Combine the two: glucose (C_6, –CHO) is an **aldohexose**; fructose (C_6, C=O) is a **ketohexose**; ribose (C_5, –CHO) is an **aldopentose**.

Carbons	General term	Aldose	Ketose
3	Triose	Aldotriose	Ketotriose
4	Tetrose	Aldotetrose	Ketotetrose
5	Pentose	Aldopentose	Ketopentose
6	Hexose	Aldohexose	Ketohexose
7	Heptose	Aldoheptose	Ketoheptose

1.3 Glucose – Preparation, Structure, Reactions

Glucose, $C_6H_{12}O_6$, is the most important monosaccharide. It is the universal cellular fuel, the monomer of starch, glycogen and cellulose, and the reference D-aldohexose against which all other sugars are described.

Preparation of glucose

Two industrial routes

(1) From sucrose – hydrolysis with dilute H_2SO_4 or HCl in alcohol:

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$

(sucrose) → glucose + fructose (equimolar)

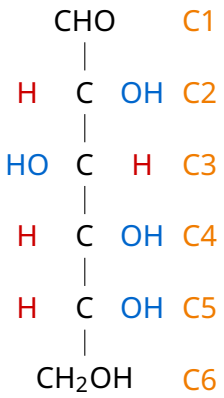
(2) From starch – industrial: hydrolyse with dilute H_2SO_4 at 393 K, 2–3 atm:

$$(C_6H_{10}O_5)_n + nH_2O \xrightarrow[393\ K,\ 2\text{-}3\ atm]{H^+} n\,C_6H_{12}O_6$$

Open chain (Fischer) structure of glucose

Glucose is correctly written as **D-(+)-glucose**. The molecule contains:

- one –CHO (C1), four –CHOH (C2–C5), one $-CH_2OH$ (C6) – in a straight chain.
- four asymmetric carbons (C2, C3, C4, C5) $\rightarrow 2^4 = 16$ possible stereoisomers; D-(+)-glucose is one of them.



Lowest asymmetric C
OH on *right* ⇒ **D**-config.

D-(+)-Glucose (Fischer projection)

Evidence for the Fischer structure

1. **Molecular formula** $C_6H_{12}O_6$ – elemental analysis.
2. **HI, Δ, prolonged $\rightarrow$ n-hexane**: confirms straight chain of six C.
3. **Reacts with NH_2OH** (oxime) and **HCN** (cyanohydrin) $\rightarrow$ carbonyl group present.
4. **Bromine water $\rightarrow$ gluconic acid** (a C_6 mono-carboxylic acid) $\rightarrow$ carbonyl is specifically an **aldehyde** (–CHO).
5. **Acetic anhydride $\rightarrow$ glucose pentaacetate** $\rightarrow$ five –OH groups, on different carbons.
6. **Concentrated HNO_3 $\rightarrow$ saccharic acid** (a dicarboxylic acid). Since both –CHO (C1) and a $-CH_2OH$ (C6) get oxidised to –COOH, glucose has a **primary alcohol** at C6.

The three diagnostic oxidations of glucose

$$\underbrace{CHO}_{C1}-(CHOH)_4-\underbrace{CH_2OH}_{C6} \xrightarrow{Br_2\ water} \underbrace{COOH}_{C1}-(CHOH)_4-\underbrace{CH_2OH}_{C6}\quad (\text{gluconic acid})$$

$$\text{glucose} \xrightarrow{HNO_3} \underbrace{COOH}_{C1}-(CHOH)_4-\underbrace{COOH}_{C6} \quad \text{(saccharic acid)}$$

Bromine water touches only the aldehyde (mild); HNO_3 oxidises both ends (strong).

Bromine water vs nitric acid

On reaction with **Br_2/water (mild)**, you only touch the $-CHO \rightarrow -COOH$. On reaction with **conc. HNO_3 (strong)**, both $-CHO$ and $-CH_2OH$ go to $-COOH$. This pair shows up in almost every board paper Long Answer.

D/L Configuration – the lowest asymmetric carbon rule

The letter **D** or **L** before a sugar name is a *relative* configuration, fixed by comparison with D-(+)-glyceraldehyde. The rule:

D/L Configuration of monosaccharides

Look at the **lowest asymmetric carbon** (the one nearest the $-CH_2OH$ end) of the Fischer projection. If the $-OH$ is on the **right**, the sugar is **D**. If on the **left**, it is **L**. The other asymmetric carbons are ignored for this assignment. Note: D/L is purely structural; the sign of rotation $(+)$ or $(-)$ must be determined experimentally. "D" does not imply $(+)$.

D is not the same as $(+)$

D refers to the spatial arrangement (relative to D-glyceraldehyde). $(+)$ refers to the direction of optical rotation (clockwise on a polarimeter). Most natural sugars are D; their rotations may be $(+)$ or $(-)$. For example, fructose is **D-(–)-fructose** – D in shape, laevorotatory in behaviour.

Cyclic structure of glucose – the pyranose form

The open-chain Fischer structure explained *most* of glucose's reactions but failed on three points:

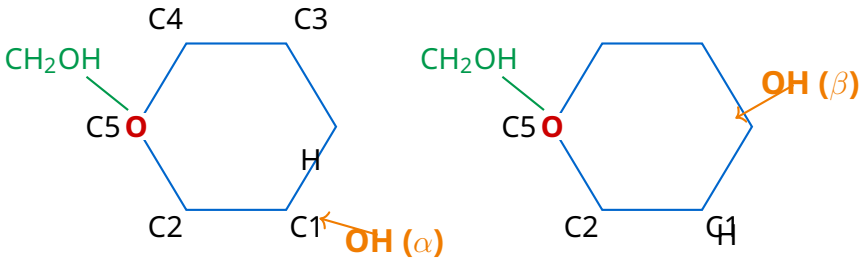
1. Glucose does **not** give Schiff's test, and does not form the $NaHSO_3$ addition product – both are characteristic aldehyde tests. So the $-CHO$ is not free.
2. Glucose pentaacetate does not react with hydroxylamine $\rightarrow$ no free $-CHO$.
3. Glucose exists in **two crystalline forms**: α-glucose (m.p. 419 K, $[\alpha]_D = +112°$, crystallised from cold solution) and β-glucose (m.p. 423 K, $[\alpha]_D = +19°$, crystallised from hot solution).

To explain these facts, the $-OH$ at C5 attacks the $-CHO$ at C1, forming a **six-membered cyclic hemiacetal** (one O in the ring, plus five C). The C1 carbon, now bearing one $-OH$ and the ring oxygen, becomes a **new asymmetric centre** called the **anomeric carbon**. The two configurations at C1 are the α and β **anomers**.

Pyranose ring and anomers

$$\text{Glucose (open chain)} \rightleftharpoons \alpha\text{-D-glucopyranose} \rightleftharpoons \beta\text{-D-glucopyranose}$$

- Six-membered ring with O *between C5 and C1* $\rightarrow$ called **pyranose** (by analogy with pyran).
- C1 is the anomeric carbon; its –OH can be **down (α)** or **up (β)** in the Haworth projection.
- In aqueous solution all three forms coexist; the mixture has $[\alpha]_D = +52.7°$ (mutarotation).



α-D-Glucopyranose **β-D-Glucopyranose**

Mutarotation

Dissolve pure α-D-glucose ($+112°$) in water and the rotation *drifts* to $+52.7°$. Likewise pure β-D-glucose ($+19°$) drifts upward to the same equilibrium value. This change of optical rotation with time is called **mutarotation**, and it is the experimental fingerprint of the open-chain $\rightleftharpoons$ cyclic equilibrium.

1.4 Fructose

Fructose is the major fruit sugar and the sweetest natural sugar. Like glucose, it has the formula $C_6H_{12}O_6$ but it is a **ketohexose** – the carbonyl sits at C2 as a ketone, not C1 as an aldehyde. It is **D-(–)-fructose**: D-configured (the –OH on the lowest asymmetric C5 is on the right) but laevorotatory.

Fructose cyclises differently from glucose. The C5 –OH attacks the C2 ketone, giving a **five-membered hemiketal ring** (one O + four C) – the **furanose** ring (by analogy with furan). Two anomers (α, β) exist.

Fructose ring system

- Open chain: C1 (CH_2OH) – C2 (C=O, ketone) – C3, C4, C5 (CHOH) – C6 (CH_2OH).
- Cyclic: five-membered **furanose** ring; C2 becomes the anomeric carbon.
- D-(–)-Fructose $[\alpha]_D = -92.4°$. The minus sign is why hydrolysis of sucrose ($+66°$) gives a laevorotatory mixture – "invert sugar".

Quick name recall. Pyran is the 6-membered ring with one O → **pyranose** = 6-membered sugar ring (glucose). Furan is the 5-membered ring with one O → **furanose** = 5-membered sugar ring (fructose). "Pyranose has more letters and more carbons (6); furanose has fewer of both (5)."

1.5 Disaccharides – Sucrose, Maltose, Lactose

In a disaccharide, two monosaccharides are joined by a **glycosidic linkage**, an oxide bridge formed by loss of H_2O between the anomeric –OH of one sugar and any –OH of the other. Whether the disaccharide is reducing depends on whether both anomeric carbons are tied up in the linkage.

Sucrose – table sugar, non-reducing

- Composition: α-D-glucose + β-D-fructose, linked C1(glucose)→C2(fructose).
- Both anomeric –OHs (C1 of glucose, C2 of fructose) are involved in the linkage – **no free hemiacetal** – so sucrose is a **non-reducing sugar**.
- Hydrolysis gives equimolar glucose + fructose; sucrose $[\alpha]_D = +66.5°$, hydrolysate $[\alpha]_D = -39.7°$ because $|-92.4| > |+52.5|$. The change of sign from $+$ to $-$ gives the hydrolysate the name **invert sugar** and the process is called **inversion of sucrose**.

Maltose – malt sugar, reducing

- Composition: two α-D-glucose units, linked C1(I)→C4(II) (α-1,4-glycosidic bond).
- C1 of the second glucose has its anomeric –OH free → open-chain –CHO possible in solution → **reducing sugar**.

Lactose – milk sugar, reducing

- Composition: β-D-galactose + β-D-glucose, linked C1(galactose)→C4(glucose) (β-1,4-glycosidic bond).
- Like maltose, C1 of glucose is free → **reducing sugar**.

Disaccharide	Composition	Reducing?	Glycosidic linkage
Sucrose	glucose + fructose	No	α-1,β-2
Maltose	glucose + glucose	Yes	α-1,4
Lactose	galactose + glucose	Yes	β-1,4

Quick recall. Sucrose keeps *both* anomeric ends locked, so it is **non-reducing**; maltose and lactose each have one free anomeric –OH, so both are **reducing**. "S for Sealed; M and L for Leaky."

> **Why honey doesn't crystallise quickly**
>
> Honey is mostly invert sugar (an equimolar glucose + fructose mixture, ∼80%

sugars total). Pure sucrose crystallises easily; a 50/50 glucose/fructose mix – with two different molecular shapes packing badly – stays liquid. Bees secrete the enzyme invertase in their honey-stomachs to convert nectar's sucrose into this stable liquid. Confectioners exploit the same trick: adding a pinch of acid to a sucrose syrup invert-hydrolyses it, preventing rock-hard sugar formation in fondants.

1.6 Polysaccharides – Starch, Cellulose, Glycogen

Polysaccharides serve as **food stores** (starch in plants, glycogen in animals) or **structural materials** (cellulose in plant cell walls). All are condensation polymers of D-glucose, but the *type of glycosidic linkage* drastically changes the function.

Starch (plant storage)

Starch is a mixture of two polymers:

- **Amylose** (15–20%, water-soluble): a long **unbranched** chain of 200–1000 α-D-glucose units, joined by α-1,4 glycosidic bonds. Coils into a helix; gives the deep-blue I_2 test.
- **Amylopectin** (80–85%, insoluble in water): **branched** chain. Main backbone is α-1,4; branches occur every $\sim$24–30 units via α-1,6 glycosidic bonds.

Cellulose (plant structure)

Cellulose is the most abundant organic substance in the plant kingdom and the chief constituent of plant cell walls. It is a long **unbranched** chain of β-D-glucose units joined by β-1,4 glycosidic bonds. The β linkage produces a straight, ribbon-like chain; parallel chains hydrogen-bond into fibrils of enormous tensile strength.

Glycogen (animal storage)

Glycogen is the storage polysaccharide of animals (often called *animal starch*). Its structure is similar to **amylopectin but more highly branched**. Found chiefly in **liver and muscle**; when the body needs glucose, enzymes break glycogen down on demand.

Polymer	Monomer	Linkage	Function / Branching
Amylose	α-D-glucose	α-1,4	Unbranched, food store (plants)
Amylopectin	α-D-glucose	α-1,4 + α-1,6	Branched, food store (plants)
Glycogen	α-D-glucose	α-1,4 + α-1,6	Highly branched, food store (animals)
Cellulose	β-D-glucose	β-1,4	Unbranched, structural (plants)

α vs β linkage – the whole story

A single configurational switch (α vs β) at C1 of glucose changes everything. With **α-1,4 bonds** (amylose, glycogen) the chain coils into a helix – digestible by humans (we have α-amylase). With **β-1,4 bonds** (cellulose) the chain is straight, packed tight, and our enzymes cannot hydrolyse it – so cellulose passes through as dietary fibre. The same monomer; different geometry; food vs fibre.

Why humans can't digest grass

Cows can digest cellulose because they harbour gut microbes producing **cellulase** (β-1,4 glycoside hydrolase). Humans lack cellulase entirely; we can only handle α-1,4 (amylase). Question to remember: "Why is cellulose called dietary fibre but starch is dietary fuel?" Answer: β-1,4 vs α-1,4.

1.7 Importance of Carbohydrates

- Major share of human food: starch in cereals, sucrose in cane and beet, lactose in milk, glucose in fruits.
- Storage molecules: starch (plants), glycogen (animals, liver and muscle).
- Structural materials: cellulose – wood, cotton, paper, textiles, lacquers.
- Constituents of nucleic acids: D-**ribose** (in RNA) and 2-deoxy-D-**ribose** (in DNA) are aldopentoses – see Section 6.
- Glycoproteins and glycolipids: carbohydrates attached to proteins or lipids on cell surfaces, responsible for cell recognition (blood groups, hormonal targeting).

2 Proteins

Proteins (Greek *proteios*, "of prime importance") are the most abundant biomolecules of the living system. They make up muscle, enzymes, antibodies, hair, nails, transport molecules (haemoglobin, albumin) and most hormones. Chemically, every protein is a **polymer of α-amino acids** held together by peptide bonds. About twenty amino acids contribute to natural proteins; the order in which they are strung determines whether the protein becomes haemoglobin or keratin.

2.1 Amino Acids

An amino acid contains both an amino group ($-NH_2$) and a carboxyl group ($-COOH$) on the same carbon skeleton. Their relative positions give the names: α-, β-, γ- etc. **Only α-amino acids** are released on hydrolysis of natural proteins – both groups sit on the very same carbon (the α-carbon).

Structure of an α-amino acid

$$R - \underset{|\ \ \mathrm{NH_2}}{\overset{\alpha}{C}}H - \mathrm{COOH}$$

- **R** = side chain (the only thing that varies between the 20 amino acids).
- Except glycine (R = H), the α-carbon bears four different groups $\rightarrow$ **chiral** $\rightarrow$ optically active.
- Most natural amino acids have the **L-configuration** ($-NH_2$ on the left in the Fischer projection).

Trivial vs systematic names

The trivial names reflect a property or source. Glycine is sweet (Greek *glykos*, sweet); tyrosine was isolated from cheese (*tyros*, cheese). Each amino acid has a **three-letter code** (Gly, Ala, Val, Leu, ...) used in peptide notation, and a **one-letter code** (G, A, V, L, ...) used in long protein sequences.

The twenty natural amino acids

#	Name	R (side chain)	3-letter	1-letter
1	Glycine	H	Gly	G
2	Alanine	$-CH_3$	Ala	A
3	Valine*	$(CH_3)_2CH^-$	Val	V
4	Leucine*	$(CH_3)_2CHCH_2^-$	Leu	L
5	Isoleucine*	$CH_3CH_2CH(CH_3)^-$	Ile	I
6	Arginine*	$HN=C(NH_2)NH(CH_2)_3^-$	Arg	R
7	Lysine*	$H_2N(CH_2)_4^-$	Lys	K
8	Glutamic acid	$HOOC(CH_2)_2^-$	Glu	E
9	Aspartic acid	$HOOC-CH_2^-$	Asp	D
10	Glutamine	$H_2N-CO(CH_2)_2^-$	Gln	Q
11	Asparagine	$H_2N-CO-CH_2^-$	Asn	N
12	Threonine*	CH_3-CHOH^-	Thr	T
13	Serine	$HO-CH_2^-$	Ser	S
14	Cysteine	$HS-CH_2^-$	Cys	C
15	Methionine*	$CH_3-S-(CH_2)_2^-$	Met	M
16	Phenylalanine*	$C_6H_5-CH_2^-$	Phe	F
17	Tyrosine	p-$HO-C_6H_4-CH_2^-$	Tyr	Y
18	Tryptophan*	(indolyl)$-CH_2^-$	Trp	W
19	Histidine*	(imidazolyl)$-CH_2^-$	His	H
20	Proline	cyclic $(CH_2)_3-N$ (imino acid)	Pro	P

$*$ *Essential amino acid (must be obtained from diet).*

2.2 Classification of Amino Acids – Acidic, Basic, Neutral; Essential vs Non-essential

By side-chain chemistry

- **Acidic** (more $-COOH$ than $-NH_2$): aspartic acid, glutamic acid.
- **Basic** (more $-NH_2$ than $-COOH$): lysine, arginine, histidine.
- **Neutral** (equal numbers): all the rest – the bulk of the 20.

By nutritional requirement

- **Essential** (10): the body cannot synthesise them; *must* come from diet – Val, Leu, Ile, Arg, Lys, Thr, Met, Phe, Trp, His. (Asterisks in the table.)
- **Non-essential** (10): synthesised in the body – Gly, Ala, Glu, Asp, Gln, Asn, Ser, Cys, Tyr, Pro.

Essential amino acids – "PVT. TIM HALL"

A standard mnemonic for the ten essential amino acids: **PVT. TIM HALL** → **P**henylalanine, **V**aline, **T**hreonine, **T**ryptophan, **I**soleucine, **M**ethionine, **H**istidine, **A**rginine, **L**eucine, **L**ysine. Think of "Private Tim Hall" as the soldier who can't make his own protein and lives on diet supplements.

Physical properties – the zwitterion

Amino acids are colourless, crystalline, high-melting solids; they are *very* soluble in water but poorly soluble in non-polar solvents – behaviour you'd expect from a **salt**, not a typical amine or acid. The reason: in aqueous solution the $-COOH$ (a stronger acid) protonates the $-NH_2$ (a stronger base) of the *same* molecule, giving a **dipolar ion (zwitterion)** that is neutral overall but carries both $+$ and $-$ charges.

$$\underset{\text{Open neutral form (uncommon)}}{H_2N-CHR-COOH} \xrightarrow[H^+ \text{ transfer}]{\text{intramolecular}} \underset{\text{Zwitterion (dominant in solid \& solution)}}{{}^{+}H_3N-CHR-COO^{-}}$$

This is also why amino acids are **amphoteric** – they react with both acids *and* bases:

- In acidic solution: the $-COO^-$ picks up a proton → cation ${}^{+}H_3N-CHR-COOH$.
- In basic solution: the ${}^{+}NH_3$ loses a proton → anion $H_2N-CHR-COO^-$.
- The pH at which the molecule has *net* zero charge is the **isoelectric point** (pI). At pI the amino acid is least soluble and does not migrate in an electric field.

Why amino acids melt so high

A typical amine like methylamine boils at $-6\,^\circ C$; a typical carboxylic acid like acetic acid melts at $17\,^\circ C$. Glycine, a far smaller molecule than either, *melts*

at 233 °C. Reason: the zwitterion behaves as an ionic lattice, like NaCl. The strong electrostatic bonds between NH_3^+ and COO^- require huge energy to break.

2.3 Structure of Proteins – Peptide Bond and the Four Levels

The peptide bond

The $-NH_2$ of one amino acid attacks the $-COOH$ of another, eliminates H_2O, and forms an **amide bond** – in protein context called the **peptide bond** or **peptide linkage**, $-CO-NH-$. Two amino acids joined this way make a **dipeptide**; three a **tripeptide**; ten or more a **polypeptide**; and a polypeptide with > 100 amino acid residues (mass $> 10\,000$ u) is conventionally called a **protein**.

$$\underset{\text{Glycine}}{H_2N-CH_2-COOH} \;+\; \underset{\text{Alanine}}{H_2N-CH(CH_3)-COOH}$$

$$\downarrow -H_2O$$

$$H_2N-CH_2-\underline{CO-NH}-CH(CH_3)-COOH$$

Glycyl-alanine (Gly-Ala): peptide bond underlined

N-terminus and C-terminus

A peptide chain is always written with the free α-amino group on the *left* (the **N-terminus**) and the free α-carboxyl group on the *right* (the **C-terminus**). The three-letter codes are read in the same order. So "Gly-Ala" means glycine donates the $-COOH$ and alanine donates the $-NH_2$; this is a different molecule from "Ala-Gly".

Fibrous vs globular proteins

By gross molecular shape, proteins are split into two camps:

- **Fibrous proteins** – polypeptide chains run *parallel*, held together by hydrogen and disulphide bonds. Long, thread-like, water-insoluble. Examples: **keratin** (hair, wool, nails, silk), **myosin** (muscle), **collagen** (skin, bone, tendon).
- **Globular proteins** – chains coil into compact, spherical shapes. Usually water-soluble. Examples: **insulin**, **albumin**, **haemoglobin**, most enzymes.

The four levels of protein structure

(i) Primary structure – the *sequence* of amino acids in a polypeptide chain. Any change in this sequence creates a different protein (sickle-cell anaemia is a single Glu $\rightarrow$ Val substitution).

(ii) Secondary structure – regular folding of the backbone, stabilised by hydrogen bonds between the $C=O$ and $-NH-$ of peptide bonds. Two patterns dominate:

- α**-Helix**: the chain twists into a right-handed coil; every –NH bonds to the C=O four residues ahead. Common in keratin and the helical regions of haemoglobin.
- β**-Pleated sheet**: chains are stretched almost fully and lay side-by-side; –NH of one strand H-bonds with C=O of the neighbouring strand. The sheet looks like the pleated folds of drapery. Found in silk fibroin.

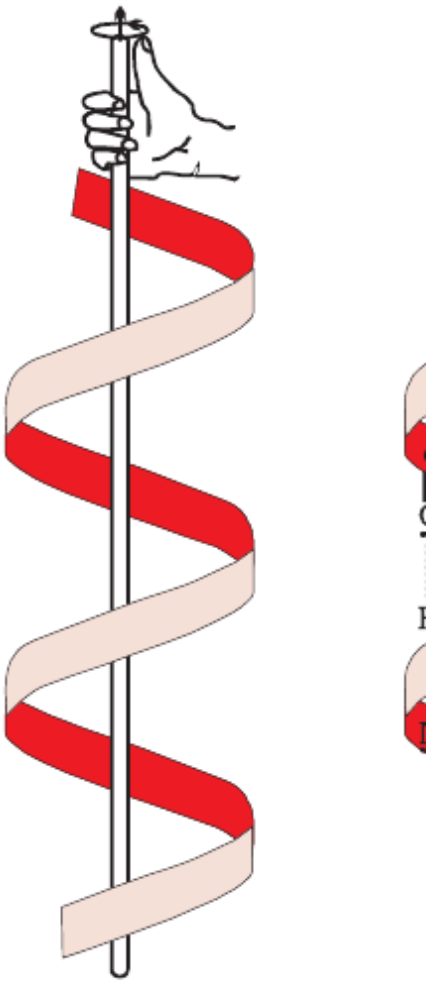


Fig. 10.1: α-Helix

Fig. 10.1 (NCERT): α-Helix structure of proteins – right-handed coil with hydrogen bonds running parallel to the helix axis.

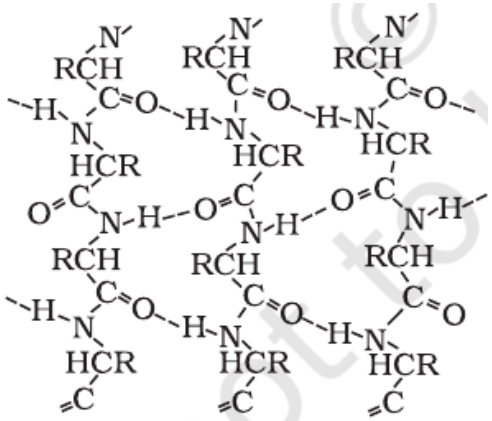


Fig. 10.2: *β-Pleated sheet structure of proteins*

Fig. 10.2 (NCERT): β-Pleated sheet structure of proteins – chains laid side by side, hydrogen-bonded across the sheet.

(iii) Tertiary structure – the overall 3-D folding of the secondary-structure elements into a compact shape (the "fibrous" or "globular" identity emerges here). Forces involved: hydrogen bonds, **disulphide (−S−S−) linkages** between Cys residues, van der Waals interactions, and electrostatic attractions between charged side chains.

(iv) Quaternary structure – the assembly of two or more polypeptide chains (called subunits) into a single functional unit. **Haemoglobin** is the classic example: four subunits (two α, two β), each holding a haem group with iron.

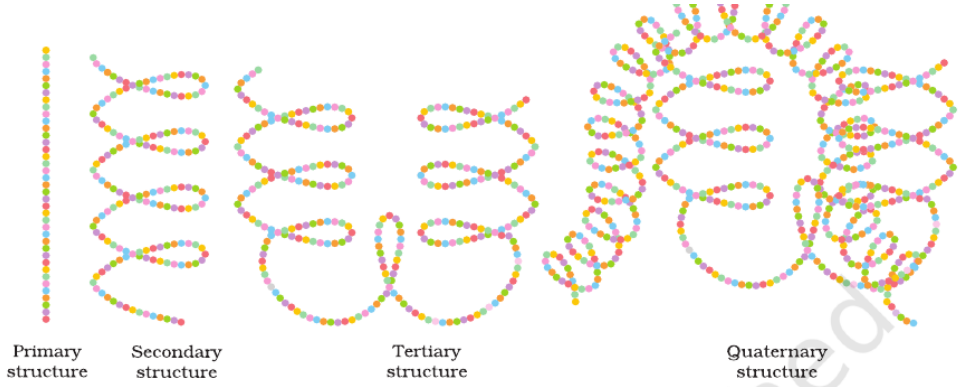


Fig. 10.3: *Diagrammatic representation of protein structure (two sub-units of two types in quaternary structure)*

Fig. 10.3 (NCERT): Diagrammatic representation of the four protein structures. Each coloured ball represents one amino acid; secondary → tertiary → quaternary build up from the primary sequence.

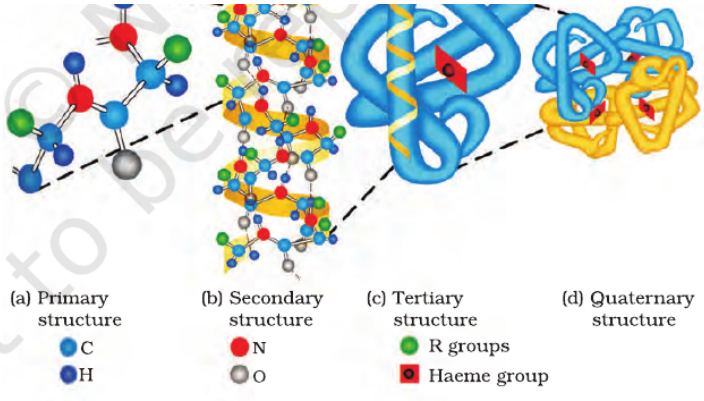


Fig. 10.4: Primary, secondary, tertiary and quaternary structures of haemoglobin

Fig. 10.4 (NCERT): Primary, secondary, tertiary and quaternary structures of haemoglobin – one of the most studied proteins. Note the haem group (red, with central Fe) embedded in each globin subunit.

The four-level summary

Level	What it describes	Held by
Primary	sequence of amino acids	peptide (–CO–NH–) bonds
Secondary	α-helix or β-pleated sheet	H-bonds along the backbone
Tertiary	overall 3-D folding	H-bonds, –S–S–, vdW, ionic
Quaternary	multiple subunits assembled	non-covalent contacts between subunits

Quick recall. The four levels answer four questions in order: **Sequence** → **Helix/sheet** → **Fold** → **Link** (SHFL).

2.4 Denaturation of Proteins

A protein in its native (working) conformation is essential for biological activity. When the environment is changed (**heat, change of pH, organic solvents, urea, heavy-metal ions**, ultrasound) the non-covalent bonds that hold the secondary, tertiary and quaternary structures collapse. The polypeptide *unfolds*; the helix uncoils; the protein loses activity. This is **denaturation**.

What survives denaturation?

Denaturation breaks **H-bonds, disulphide bridges, ionic and hydrophobic interactions** – so the **secondary, tertiary and quaternary** structures are destroyed. The **primary structure (sequence of peptide bonds) survives**, because the peptide bond is a strong covalent bond unaffected by mild heat or pH change.

Two everyday examples

- **Boiling an egg**: the soluble globular protein *albumin* unfolds and aggregates into a white, water-insoluble mass. The water originally bound inside the

folded protein gets squeezed out as the molecule opens up.

- **Curdling of milk**: bacteria in milk produce lactic acid; the drop in pH protonates carboxylate groups on the milk protein *casein*, killing the ionic interactions that kept it soluble; the protein precipitates as curd.

Denaturation in cooking and medicine

Almost every cooking technique relies on denaturation: searing meat (heat unfolds collagen into gelatin), whipping egg whites (mechanical denaturation), marinading in lemon juice (acid denaturation), cheese-making (rennet acidifies milk). Hospitals exploit it too – ethanol-based hand sanitiser kills microbes by denaturing surface proteins; autoclave steam sterilises by heat-denaturing every protein in the pathogen.

3 Enzymes

Life depends on thousands of chemical reactions happening simultaneously and at near-room temperature. The catalysts that make this possible are called **enzymes**. Almost all enzymes are **globular proteins**; they are very specific (one substrate, one reaction) and astonishingly efficient.

3.1 Nature, Naming and Specificity

- Globular proteins of molecular mass 10 kDa to many MDa.
- Each enzyme is specific for *one* substrate or one class of substrates (**substrate specificity**) and catalyses *one* type of reaction (**reaction specificity**).
- Most enzymes are named by adding the suffix **-ase** to the substrate name (**maltase** hydrolyses maltose; **urease** hydrolyses urea) or to the reaction type (**oxidoreductase** couples oxidation/reduction).
- Some retain trivial names: *trypsin*, *pepsin*, *papain*, *rennin*.

A textbook enzyme reaction

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{maltase}} 2\ C_6H_{12}O_6$$

maltose $\rightarrow$ two molecules of glucose.

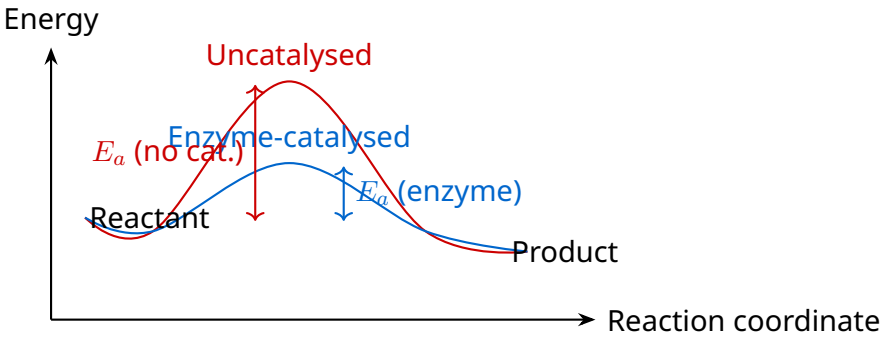
The enzyme (maltase) is regenerated unchanged; only a few maltase molecules can process thousands of substrate molecules per second.

3.2 Mechanism – Lowering Activation Energy

Like every catalyst, an enzyme **lowers the activation energy** (E_a) of the reaction it catalyses. For sucrose hydrolysis:

- Acid-catalysed: $E_a = 6.22$ kJ mol^{-1}.
- Sucrase-catalysed: $E_a = 2.15$ kJ mol^{-1}.

The drop in E_a enormously accelerates the rate (recall Arrhenius: $k \propto \exp(-E_a/RT)$).



Lock-and-key model (Fischer, 1894): the enzyme's **active site** has a shape complementary to the substrate; only the right "key" fits the "lock". A more refined picture (**induced fit**, Koshland) lets the active site flex slightly to accept the substrate. Once bound, the enzyme strains the substrate, presenting catalytic groups (–COOH, –NH_2, –OH) that lower E_a.

A single molecule of carbonic anhydrase can hydrate $\sim 10^6$ molecules of CO_2 per second – without it the body could not eliminate the CO_2 produced during respiration. Enzyme acceleration factors of 10^9–10^{12} are routine, which is why purely chemical (acid/base) catalysts cannot replace enzymes for biological reactions.

Enzymes change rate, not equilibrium

A catalyst (enzyme or otherwise) lowers E_a of both forward and reverse reactions *equally*. So an enzyme **accelerates the approach to equilibrium** but does *not* shift the equilibrium position. Adding enzyme to a 50/50 reactant-product mixture at equilibrium changes nothing – it just brings the system to that mixture faster.

3.3 Factors Affecting Enzyme Activity – JEE/NEET Extension

Although NCERT keeps this brief, JEE and NEET routinely test:

- **Temperature**: rate rises with T till an optimum ($\sim 37\,^\circ$C for human enzymes), then falls sharply as the protein denatures.
- **pH**: each enzyme has an optimum pH (pepsin $\sim$2, trypsin $\sim$8, salivary amylase $\sim$6.8). Outside this range, ionisable side-chains at the active site change protonation and lose activity.
- **Substrate concentration**: rate increases with [S] till saturation (all active sites occupied) – the basis of Michaelis–Menten kinetics.

- **Inhibitors**: competitive (resemble substrate, occupy active site – e.g. methotrexate vs folate) and non-competitive (bind elsewhere and distort the active site).

4 Vitamins

Vitamins are **organic compounds required in small amounts** in our diet, whose absence causes **specific deficiency diseases**. The body cannot synthesise most of them (plants and intestinal bacteria do), so they must come from food. The name was coined as *vita* + *amine* because early-identified vitamins (B1, B12) had amino groups; later vitamins (C, D) did not, so the "e" was dropped.

4.1 Classification of Vitamins

Vitamins are classified by their **solubility**:

- **Fat-soluble vitamins** – soluble in fats and oils, insoluble in water. Stored in liver and adipose tissue. Group: **A, D, E, K**.
- **Water-soluble vitamins** – soluble in water. Must be replenished regularly because they are excreted in urine and cannot be stockpiled (**exception: B12** is stored in liver). Group: B-complex (B1, B2, B6, B12, . . .) and **C**.

> **"Always Dress Extremely Kute" for fat-soluble**
>
> The fat-soluble vitamins are **A, D, E, K**. Remember the dressing-up phrase "**A**lways **D**ress **E**xtremely **K**ute". All the rest (B-complex and C) are water-soluble.

4.2 Sources and Deficiency Diseases

The exam-staple table:

Vitamin	Sources	Deficiency disease
A (retinol)	fish liver oil, carrots, butter, milk	Xerophthalmia (corneal hardening); night blindness
B_1 (thiamine)	yeast, milk, green vegetables, cereals	Beri beri (loss of appetite, retarded growth)
B_2 (riboflavin)	milk, egg white, liver, kidney	Cheilosis (fissures at corners of mouth), digestive disorders, skin burning
B_6 (pyridoxine)	yeast, milk, egg yolk, cereals, grams	Convulsions
B_{12} (cobalamin)	meat, fish, egg, curd	Pernicious anaemia (RBCs deficient in haemoglobin)

C (ascorbic acid)	citrus fruits, amla, green leafy vegetables	Scurvy (bleeding gums)
D (calciferol)	sunlight, fish, egg yolk	Rickets (bone deformities in children); osteomalacia (soft bones in adults)
E (tocopherol)	wheat germ oil, sunflower oil	Increased RBC fragility; muscular weakness
K (phylloquinone)	green leafy vegetables	Increased blood clotting time

Why fat-soluble vitamins can be toxic – but water-soluble usually aren't

Fat-soluble vitamins (A, D, E, K) accumulate in fat depots and liver. Daily overdosing leads to **hypervitaminosis** – vitamin A toxicity causes headache and liver damage; vitamin D toxicity causes Ca^{2+} deposition in soft tissues. Water-soluble vitamins (B, C) are excreted within hours in urine, so toxicity is rare – but, conversely, they must be replenished daily.

Vitamin C and the storage rule

Vitamin C (ascorbic acid) is water-soluble, so it **cannot be stored** in the body – you need it from food every day. Why is vitamin B12 the exception that *is* stored? Because B12 is bound to a special carrier protein (intrinsic factor) and held in the liver; you can survive years on liver stores. The NCERT Intext Question 10.6 ("why cannot vitamin C be stored?") is just asking you to invoke water solubility.

Why iodised salt prevents goitre

Thyroxine, the principal thyroid hormone, is an *iodinated* derivative of the amino acid tyrosine. Low dietary iodine $\rightarrow$ low thyroxine $\rightarrow$ **hypothyroidism** and the thyroid gland enlarges (goitre). Adding sodium iodide ($\sim$15–30 ppm) to commercial table salt ensures every household gets enough iodine. This is one of the cheapest, most effective public-health interventions in modern medicine – about half a paisa per person per day.

5 Nucleic Acids – DNA and RNA

Inheritance – the transmission of physical and biochemical characters from parent to offspring – is carried by **nucleic acids**. Found in the nuclei of all living cells,

they are long-chain polymers of **nucleotides**, hence the alternative name **polynucleotides**. Two great families exist: **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)**.

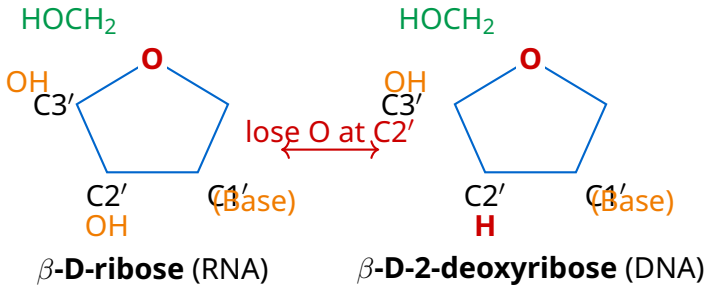
5.1 Chemical Composition of Nucleic Acids

Complete hydrolysis of either DNA or RNA gives three classes of fragments:

1. A **pentose sugar**.
2. **Phosphoric acid (H_3PO_4)**.
3. Four **nitrogen-containing heterocyclic bases**.

The sugar differs between DNA and RNA – this is the single chemical feature that gives the two acids their names:

- DNA $\rightarrow$ β**-D-2-deoxyribose** (no –OH on C2′).
- RNA $\rightarrow$ β**-D-ribose** (–OH present on C2′).



β**-D-ribose** (RNA) β**-D-2-deoxyribose** (DNA)

The bases are nitrogen heterocycles. They fall into two classes:

- **Purines** (bicyclic): **Adenine (A)** and **Guanine (G)**.
- **Pyrimidines** (monocyclic): **Cytosine (C)**, **Thymine (T)** and **Uracil (U)**.

Which base appears in which acid?

- DNA: A, G, C, **T** (thymine).
- RNA: A, G, C, **U** (uracil). Thymine is replaced by uracil; chemically, uracil is just thymine without its methyl group.

Bases in DNA vs RNA – "T for Day, U for Night"

- Pure-and-simple pneumonic: "**Pure As Gold**" – **Pur**ines are **A** and **G**.
- Three bases (A, G, C) sit in both. **T**hymine for **D**NA. **U**racil for **R**NA.
- Or chemistry-style: "Uracil = Thymine minus a methyl". T has $-CH_3$ at C5; U has H at C5.

5.2 Nucleosides and Nucleotides

A **nucleoside** is a *base* covalently linked to the C1′ of the sugar via a β-N-glycosidic bond. A **nucleotide** is a nucleoside in which an –OH of the sugar (usually C5′) is esterified by phosphoric acid.

Base → Nucleoside → Nucleotide

$$\text{Base} + \text{Sugar} \rightarrow \textbf{Nucleoside} \quad (\text{glycosidic bond at } 1')$$

$$\text{Nucleoside} + H_3PO_4 \rightarrow \textbf{Nucleotide} \quad (\text{phosphoester at } 5')$$

Examples: adenine + ribose = adenosine (a nucleoside). Adenosine + phosphate = AMP, a nucleotide (the energy carrier; AMP → ADP → ATP).

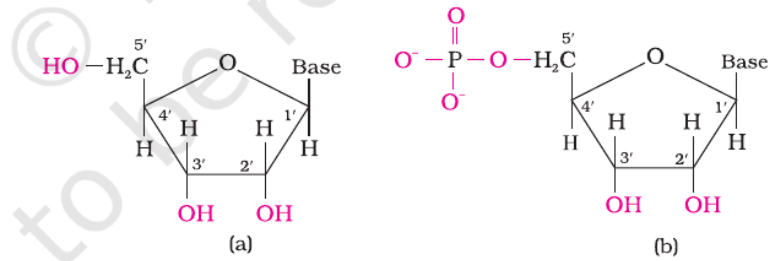


Fig. 10.5: Structure of (a) a nucleoside and (b) a nucleotide

Fig. 10.5 (NCERT): (a) Nucleoside = base attached to C1′ of pentose. (b) Nucleotide = nucleoside with a phosphate ester at C5′.

Nucleoside vs nucleotide – the missing phosphate

The two words differ by a single letter and a single phosphate group. Memorise: **Nucleo-tide has phos-phate** (both have "t"). **Nucleo-side has the base sitting on the side of the sugar**, no phosphate. NCERT Intext 10.7 ("products of hydrolysing a thymine nucleotide of DNA") is testing exactly this – answer: deoxyribose + thymine + phosphoric acid.

5.3 Nucleic Acid Chain – Phosphodiester Linkage and Primary Structure

Many nucleotides polymerise into a long chain by **phosphodiester linkages**: the phosphate group on the C5′ of one nucleotide forms a second ester with the C3′ –OH of the next nucleotide. This produces a sugar–phosphate–sugar–phosphate backbone with bases sticking out.

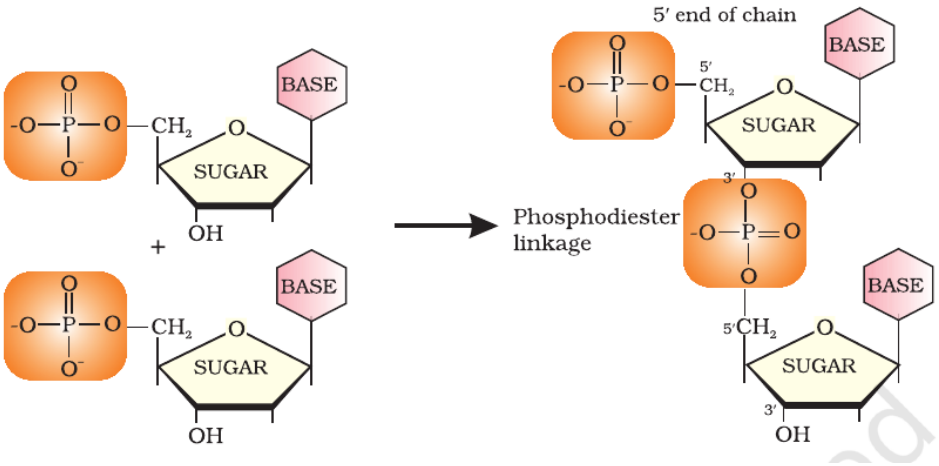


Fig. 10.6 (NCERT): Formation of a dinucleotide – two nucleotides linked by a phosphodiester bond between the C3′ of the first sugar and the C5′ of the second.

The sequence of bases along the chain is called the **primary structure** of the nucleic acid – the analogue of amino-acid sequence in a protein. A short notation: 5′-A-G-C-T-3′ describes a tetranucleotide.

Polarity of the chain

Every nucleic acid chain has direction: the **5′ end** (free phosphate or –OH at C5′) and the **3′ end** (free –OH at C3′). DNA replication and protein synthesis read the chain in fixed directions; reversing the direction reverses the meaning. By convention sequences are written 5′ → 3′.

5.4 Secondary Structure – The Watson–Crick Double Helix

In 1953 J. D. Watson and F. H. C. Crick proposed that DNA is a **double-stranded right-handed helix**: two polynucleotide chains coil around a common axis, the sugar–phosphate backbones running on the outside, the bases stacked inside the helix and pointing toward each other.

The two strands are held together by **hydrogen bonds** between specific base pairs – the basis of Chargaff's rule (%A = %T, %G = %C):

Watson–Crick base pairing

A ··· T (2 H-bonds)	G ··· C (3 H-bonds)

The two strands are **antiparallel** (one runs 5′ → 3′, the other 3′ → 5′) and **complementary**: knowing one strand gives you the other. This complementarity is what allows DNA to replicate itself – each old strand is the template for a new one.

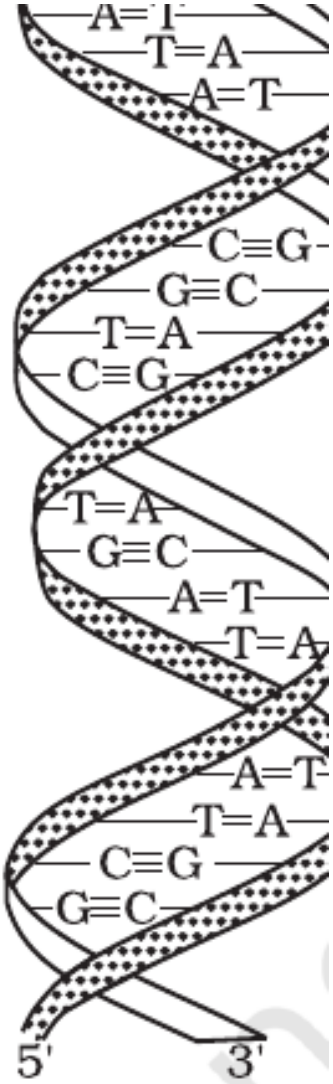


Fig. 10.7: Double str

Fig. 10.7 (NCERT): Double-strand helix structure of DNA. The two sugar–phosphate backbones run antiparallel; A–T and G–C base pairs lie in the interior, perpendicular to the helix axis.

RNA secondary structure

RNA is normally **single-stranded**, but it can fold back on itself to give short double-helical regions stabilised by intramolecular A–U and G–C pairs. Three functional types occur in every cell:

- **Messenger RNA (mRNA)**: carries the genetic message from DNA to ribosomes.
- **Ribosomal RNA (rRNA)**: structural and catalytic component of ribosomes.

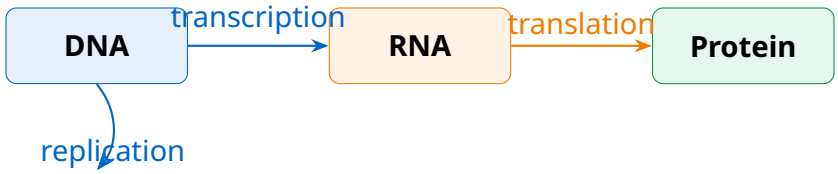
- **Transfer RNA (tRNA)**: shuttles activated amino acids to the ribosome during translation.

Bond-count cue. A–T has **2** H-bonds, G–C has **3**: "At Two bonds, Great Clasp." The triple H-bond explains why GC-rich DNA (bacterial genomes from hot springs) has higher melting points (a common JEE/NEET twist).

5.5 Biological Functions of Nucleic Acids

DNA stores the genetic information of an organism. Every cell of a species has the same DNA sequence; this is what keeps species distinct across millions of years. During cell division, DNA self-replicates so each daughter cell receives an identical copy.

RNA executes the information. A gene's DNA sequence is first *transcribed* into mRNA; the mRNA is then *translated* on a ribosome (rRNA + protein), with tRNA delivering the correct amino acids one by one. The end product is a specific protein. This is the central dogma of molecular biology:



DNA fingerprinting

Every individual (except identical twins) has a unique pattern of repeated sequences in their DNA. PCR-amplifying and comparing a handful of these *variable number tandem repeat* (VNTR) regions gives a profile so distinctive that the chance of two random people matching is below 1 in 10^{12}. Real-world uses: identifying criminals from biological evidence at a crime scene; confirming paternity; identifying victims of disasters by comparing DNA with that of relatives; tracing population migrations across history.

5.6 DNA vs RNA – Comparison Table

A high-yield revision table for the boards:

Feature	DNA	RNA
Sugar	β-D-2-deoxyribose	β-D-ribose
Bases	A, G, C, **T**	A, G, C, **U**
Strands	Double (helix)	Single (some loops)
Location in cell	Nucleus (and mitochondria)	Mostly cytoplasm (ribosomes)
Stability	High; chemically stable	Less stable; easily hydrolysed
Function	Store and transmit genetic information	Translate information into proteins
Types	One (genomic)	Three: mRNA, rRNA, tRNA
Self-replicating?	Yes	No (mostly)

6 Hormones

Hormones are **intercellular chemical messengers**: produced by endocrine glands, released into the bloodstream, and delivered to target organs where they regulate physiology. The body integrates dozens of hormones to keep blood glucose, blood pressure, ion balance, growth rate and reproduction within tight limits.

6.1 Chemical Classification of Hormones

By chemical nature, hormones fall into three families:

- **Steroid hormones** – derived from cholesterol. Examples: **estrogens** (estradiol), **androgens** (testosterone), **progesterone**, the adrenal cortex hormones **glucocorticoids** and **mineralocorticoids**.
- **Polypeptide / protein hormones** – short chains of amino acids. Examples: **insulin** (51 aa), **glucagon**, **endorphins**, growth hormone.
- **Amino-acid derivatives** – simple molecules built from one amino acid (often tyrosine). Examples: **epinephrine** (adrenaline), **norepinephrine**, **thyroxine**.

How chemical class predicts mode of action

Polypeptide hormones (insulin) and amino-acid derivatives (adrenaline) are *water-soluble* and cannot cross cell membranes; they act through surface receptors and second-messenger cascades – their action is *fast* (seconds). Steroid hormones are *lipid-soluble*, cross the membrane, bind intracellular receptors, and modulate gene transcription – their action is *slow but long-lasting* (hours to days). This chemistry-to-physiology link is a favourite NEET trap.

6.2 Major Hormones and Their Roles

Blood-glucose pair – insulin and glucagon

- **Insulin** (from pancreatic β-cells) is released when blood glucose is high; it stimulates uptake into liver and muscle (as glycogen), *lowering* blood glucose.
- **Glucagon** (from pancreatic α-cells) is released when blood glucose is low; it stimulates glycogen breakdown in liver, *raising* blood glucose.

Diabetes mellitus results when insulin is absent (Type 1) or its receptors are unresponsive (Type 2).

Stress hormones – epinephrine and norepinephrine

Released by the adrenal medulla in response to external stimuli, they mediate the "fight or flight" response – raise heart rate, dilate pupils, mobilise glucose. Both are derived from **tyrosine**.

Thyroid hormone – thyroxine

Thyroxine, made in the thyroid gland, is an *iodinated* derivative of tyrosine. It regulates basal metabolic rate.

- Low thyroxine $\rightarrow$ **hypothyroidism**: lethargy, weight gain, low body temperature.
- High thyroxine $\rightarrow$ **hyperthyroidism**: weight loss, sweating, palpitations.
- Dietary iodine deficiency $\rightarrow$ hypothyroidism + thyroid enlargement (**goitre**); preventable by iodised salt.

Steroid hormones – adrenal cortex and gonads

- **Glucocorticoids** (cortisol): control carbohydrate metabolism; modulate inflammation; involved in stress response.
- **Mineralocorticoids** (aldosterone): control Na^+/K^+ balance and water excretion by kidneys.
- Adrenal cortex hypofunction $\rightarrow$ **Addison's disease** (hypoglycemia, weakness, susceptibility to stress); treated with replacement glucocorticoids and mineralocorticoids.
- **Testosterone** (testes): development of secondary male characters (deep voice, facial hair).
- **Estradiol** (ovaries): development of secondary female characters; participates in menstrual cycle.
- **Progesterone** (ovaries): prepares the uterus for implantation of the fertilised egg.

Hormone	Class	Source	Principal effect
Insulin	Polypeptide	Pancreas (β)	Lowers blood glucose
Glucagon	Polypeptide	Pancreas (α)	Raises blood glucose
Epinephrine	Tyrosine derivative	Adrenal medulla	Fight-or-flight response
Thyroxine	Tyrosine derivative (iodinated)	Thyroid	Sets basal metabolic rate
Cortisol	Steroid	Adrenal cortex	Carbohydrate metabolism, anti-inflammatory
Aldosterone	Steroid	Adrenal cortex	Na^+/water balance
Testosterone	Steroid	Testes	Male secondary characters
Estradiol	Steroid	Ovaries	Female secondary characters, menstrual cycle
Progesterone	Steroid	Ovaries	Maintains pregnancy

"Insulin and glucagon: the gas pedal and the brake"

Insulin pushes glucose *into* cells (lowers blood sugar); glucagon pulls glucose *out* of liver glycogen (raises blood sugar). They oppose each other and keep blood glucose in a narrow window ($\sim$70–110 mg/dL). Memorise: insulin = "**I**n" (sugar into cells); glucagon = "**G**o" (glucose go out to blood).

7 Quick Reference Summary

A single page to revise the night before the exam.

7.1 Carbohydrates – key reactions of glucose

Glucose reactions cheat sheet

Reagent	Product	Diagnostic for
HI, Δ (long)	n-hexane	Straight 6-C chain
NH_2OH	Glucose oxime	Carbonyl (C = O)
HCN	Cyanohydrin	Carbonyl (C = O)
Br_2/water	Gluconic acid (C_6, mono-COOH)	– CHO
Conc. HNO_3	Saccharic acid (C_6, di-COOH)	– CHO + – CH_2OH
$(CH_3CO)_2O$	Glucose pentaacetate	Five – OH

7.2 Carbohydrate classification – one-line summary

- Mono: glucose (α-pyranose), fructose (β-furanose), ribose, galactose. All reducing.
- Di: sucrose (Glc+Fru, non-reducing); maltose (Glc+Glc, reducing); lactose (Gal+Glc, reducing).
- Poly: starch (= amylose + amylopectin, α-1,4 + α-1,6); glycogen (animal starch, more branched); cellulose (β-1,4, unbranched, structural).

7.3 Proteins – the essentials

- Monomer: α-amino acid (20 natural; 10 essential).
- Bond: **peptide bond** – CO – NH – (amide).
- In solution: **zwitterion** (^+H_3N – CHR – COO^-). Amphoteric. Isoelectric point pI.
- Structures: Primary (sequence) $\rightarrow$ Secondary (α-helix, β-sheet) $\rightarrow$ Tertiary (folded) $\rightarrow$ Quaternary (subunits, e.g. haemoglobin).
- Denaturation destroys 2°, 3°, 4° structure; 1° survives. Examples: egg white, curd.

7.4 Enzymes

- Almost all are globular proteins. End in **"-ase"**.
- Catalyse by **lowering** E_a. Lock-and-key / induced-fit binding.
- Highly specific (substrate + reaction).
- Sensitive to T, pH; denatured outside optimum.

7.5 Vitamins

- Fat-soluble: **A, D, E, K**. Stored in liver/fat.
- Water-soluble: **B-complex, C**. Excreted in urine (except B12).
- Memorise the 9-row deficiency-disease table.

7.6 Nucleic acids

- Hydrolysis products: pentose + H_3PO_4 + bases.
- DNA: 2-deoxyribose; A, G, C, T; double helix.
- RNA: ribose; A, G, C, U; single strand; types mRNA, rRNA, tRNA.
- Base pairing: **A–T** (2 H-bonds), **G–C** (3 H-bonds).
- Backbone: phosphodiester $5' \to 3'$. Strands antiparallel and complementary.
- Function: DNA stores; RNA executes (central dogma DNA $\to$ RNA $\to$ protein).

7.7 Hormones – a high-yield set

- Insulin/Glucagon: blood glucose regulators (polypeptide).
- Epinephrine, thyroxine: amino-acid derivatives. Thyroxine is iodinated tyrosine.
- Testosterone, estradiol, progesterone, cortisol, aldosterone: **steroids**.
- Deficiency examples: hypothyroidism (low thyroxine, treat with iodised salt); diabetes (low insulin); Addison's disease (low cortisol).

7.8 Frequently-tested numerical and conceptual cues

Five MCQ patterns every year

1. "Which is a non-reducing sugar?" $\to$ sucrose.
2. "Which sugar gives both glucose and fructose on hydrolysis?" $\to$ sucrose.
3. "Identify α-1,4 vs β-1,4" $\to$ amylose (α) vs cellulose (β).
4. "Number of essential amino acids" $\to$ 10.
5. "Which nucleotide hydrolysis gives thymine?" $\to$ a DNA nucleotide (deoxyribose + thymine + H_3PO_4).

Three things to take into the hall

1. **Functional group + chain length** drives every classification (aldose vs ketose; pentose vs hexose; mono vs poly).
2. Whenever a question asks "why does X behave like a salt?" check for a **zwitterion** (amino acids) or an **ionic glycosidic open form** (reducing sugar).
3. Match **bond hierarchy** to **structure level**: peptide bond $\to$ primary; H-bond along backbone $\to$ secondary; disulphide + ionic + H-bond + vdW $\to$ tertiary; non-covalent subunit contacts $\to$ quaternary.

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