

7. Given below are the two statements

Statement I: Glucose-6-phosphate can be formed from glucose, but not from glycogen

Statement II: Glucose-1-phosphate may be hydrolyzed to yield free glucose in liver

Choose the most appropriate answer from the options given below [GPAT-2022]

- (a) Both Statement I and Statement II are correct
- (b) Both Statement I and Statement II are incorrect
- (c) Statement I is correct but Statement II is incorrect
- (d) Statement I is incorrect but Statement II is correct

8. Glucose upon treatment with nitric acid yields [GPAT-2021]

- (a) Gluconic acid
- (b) Glucaric acid
- (c) Glucitol
- (d) Heptanoic acid

9. Which of the following is false about HMP shunt [GPAT-2021]

- (a) No ATP formation
- (b) Formation of NADPH
- (c) Synthesis of ribose-5-phosphate
- (d) Non-oxidative phase of HMP pathway is irreversible

10. An aldopentose can be converted into aldohexose by [GPAT-2020]

- (a) Ruffs degradation method
- (b) Wohl's method
- (c) Kiliani-Fischer synthesis
- (d) Hoffmann degradation method

11. Which of the following is the example of "Invert Sugar" [GPAT-2020]

- (a) Sucralose
- (b) Lactulose
- (c) Lactose
- (d) Sucrose

12. If two monosaccharides differ in their structure around a single carbon atom, they are called as [GPAT-2020]

- (a) Epimers
- (b) Dimers
- (c) Trioses
- (d) Trimers

13. Amylopectin, a component of starch gives colour with iodine [GPAT-2019]

- (a) No colour
- (b) Green
- (c) Blue
- (d) Red-purple

14. Von Gierke's glycogen storage disease is due to defect of which enzyme [GPAT-2019]

- (a) Phosphofructokinase
- (b) Glucosyl 4-6 transferase
- (c) Glycogen phosphorylase
- (d) Glucose-6-phosphatase

15. Galactose and Glucose are [GPAT-2018]

- (a) Epimers (b) Anomers
(c) Isomers (d) Ketose Aldose isomers

16. The hexose monophosphate pathway produces distinctively two useful products.**Identify these products with the ratio in which they are produced [GPAT-2018]**

- (a) One NADPH to two ribose-6-phosphate
(b) Two NADPH to one ribulose-5-phosphate
(c) Two NADPH to one ribose-5-phosphate
(d) Two NADPH to one fructose-6-phosphate

17. The major component of liquid glucose and is prepared from [GPAT-2017]

- (a) Maltose, Pectin (b) Dextrin, Starch
(c) Dextrose, Starch (d) Glucose, Starch

18. Match the following [GPAT-2016]

- | | |
|--|-------------------------------------|
| 1. Mirror image of each other | [P] Acidic KMnO_4 solution |
| 2. α and β -cyclic forms of D-glucose | [Q] Aqueous bromine solution |
| 3. Two monosaccharides differ from each other in their configuration around a specific carbon atom | [R] Anomer |
| 4. Structure of glucosene | [S] Enantiomer |
| (a) 1-(5), 2-[Q], 3-[P], 4-[R] | (b) 1-[S], 2-[R], 3-[P], 4-[Q] |
| (c) 1-[P], 2-[R], 3-[S], 4-[Q] | (d) 1-[S], 2-[P], 3-[R], 4-[Q] |

19. Which of the following reactions generates ATP [GPAT-2016]

- (a) Glucose-6-phosphate to fructose-6-phosphate
(b) Glucose to glucose-6-phosphate
(c) Fructose-6-phosphate to fructose-1,6-diphosphate
(d) Phosphoenolpyruvate to pyruvate

20. Chitin gets converted in to Chitosan upon [GPAT-2014]

- (a) Acetylation (b) Deacetylation
(c) Oxidation (d) Reduction

21. A compound with an -OH group and -OR group bonded to the same carbon atom is **[GPAT-2013]**
- (a) An acetal (b) A hemiacetal
(c) A simple ether (d) An aldol
22. Glucose is the only source of energy for one of the following. Identify that **[GPAT-2012]**
- (a) Cardiac cells (b) Nephron (c) RBCs (d) Thrombocytes
23. Read the following statements **[GPAT-2012]**
- [P] Caramelization occurs in acidic conditions**
[Q] Caramel is optically inactive glucose
[R] Caramel is obtained by burning of glucose
[S] Caramel is obtained by degradation of fructose
- (a) P & Q are true but R & S are false (b) P & S are true but Q & R are false
(c) Q & R are true but P & S are false (d) R & S are true but P & Q are false
24. Among the following which one is not only a non-reducing sugar but also does not exhibit mutarotation **[GPAT-2012]**
- (a) Glucose (b) Maltose (c) Lactose (d) Sucrose
25. In the TCA cycle, at which of the following enzyme-catalyzed steps, incorporation of elements of water into an intermediate of the cycle takes place **[GPAT-2010]**
- (a) Citrate synthase (b) Aconitase
(c) Maleate dehydrogenase (d) Succinyl Co-A synthase

CARBOHYDRATES

Carbohydrates

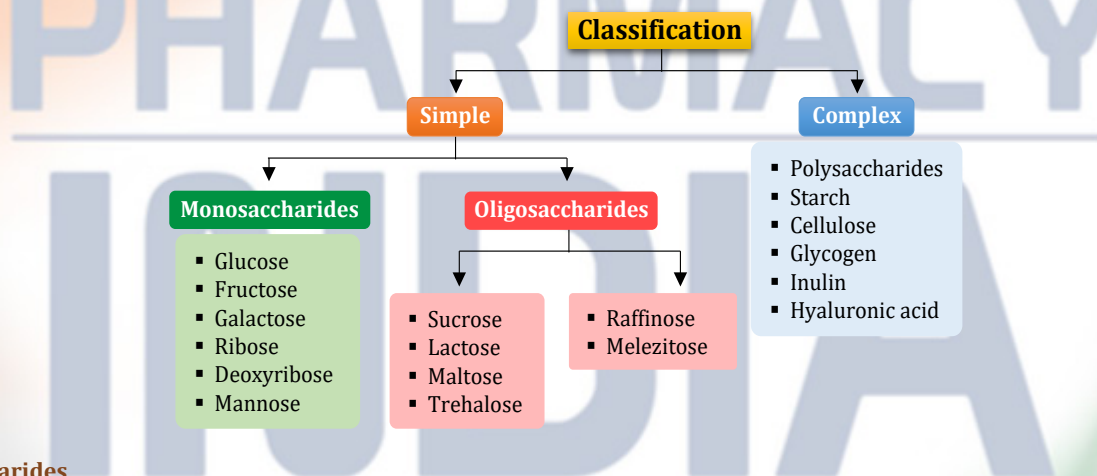
- Carbohydrates are the most abundant organic molecules in nature.
- They are made up of three elements — carbon, hydrogen, and oxygen, usually in the ratio of 1:2:1.
- The word "carbohydrate" comes from "hydrates of carbon," because their structure looks like carbon combined with water.
- "Carbohydrates may be defined as polyhydroxy aldehydes or ketones or compounds which produce them on hydrolysis".

History

- **1811:** Andreas Marggraf isolated **glucose** from raisins — first major sugar discovery.
- **1838:** The term "carbohydrate" was coined by Schmidt and Tollens.
- **1854:** Louis Pasteur discovered that yeast ferments sugar, linking carbohydrates to metabolism.
- **Late 1800s:** Emil Fischer studied sugar structures, stereochemistry, and introduced D/L system.

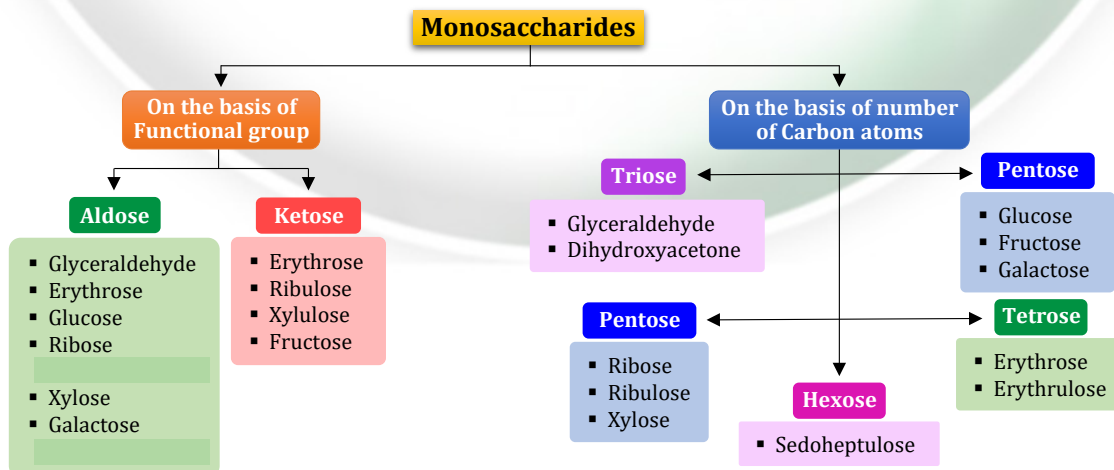
Functions of carbohydrates

1. They are the most abundant dietary source of energy (**4 Cal/g**) for all organisms.
2. Carbohydrates (as glycoproteins and glycolipids) participate in the structure of **cell membrane**.
3. Carbohydrates also serve as the storage form of energy (**glycogen**) to meet the immediate energy demands of the body.



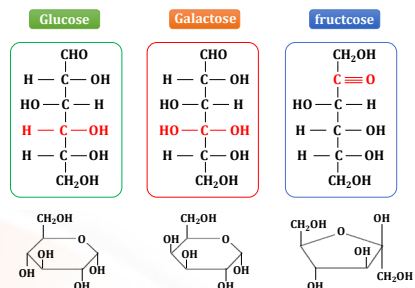
Monosaccharides

- Monosaccharides are the simplest form of carbohydrates that **cannot be hydrolyzed** into smaller sugar units.
- They are also called **simple sugars** and act as the building blocks for di-, tri-, and polysaccharides.



Reduction of Monosaccharides:

- **Glucose** → Sorbitol (also called Glucitol)
- **Galactose** → Dulcitol (also called Galactitol)
- **Mannose** → Mannitol
- **Fructose** → Sorbitol + Mannitol



Difference between Aldose and Ketose

Feature	Aldose	Ketose
Functional Group	Contains an aldehyde group (-CHO)	Contains a ketone group (=CO)
Position of Carbonyl	Carbonyl group is at end of chain	Carbonyl group is at second carbon
First Member (3C)	Glyceraldehyde	Dihydroxyacetone
Examples	Glucose, Galactose, Ribose	Fructose, Ribulose, Xylulose
Reducing Ability	All aldoses are reducing sugars	Most ketoses are also reducing, via tautomerism
Reaction with Tollen's or Fehling's reagent	Positive (forms red precipitate)	Also positive (after isomerization)

Disaccharides

- **Disaccharides** are carbohydrates composed of **two monosaccharide units** joined together by a **glycosidic bond** (a type of covalent bond formed between sugar molecules).
- They are **soluble in water**, usually **sweet**, and can be **reducing or non-reducing sugars** depending on the type of glycosidic linkage.
- Formed by **dehydration reaction** (removal of H₂O) between two monosaccharides

Disaccharide	Monosaccharides	Bond	Structure
Sucrose (Invert sugar, Cane sugar)	Glucose + Fructose	α-1,2-glycosidic bond	
Lactose (milk sugar)	Glucose + Galactose	β-1,4-glycosidic bond	
Maltose	Glucose + Glucose	α-1,4-glycosidic bond	

Polysaccharides

- **Polysaccharides** are **complex carbohydrates** made up of long chains of **more than 10 monosaccharide units** linked together by **glycosidic bonds**.
- They can be **linear** or **branched** and may contain **hundreds to thousands of sugar units**.

Properties of Polysaccharides:

- **Generally** insoluble in water
- Tasteless **and not sweet**
- **Act** as storage or structural **materials**
- **Form** colloidal solutions **or gels**

Polymer	Example	Monomer Unit	Type of Bond	Function
Homo Polysaccharides /Homoglycans	Starch	Glucose (Amylose & Amylopectin)	α-1,4 (linear), α-1,6 (branched)	Energy storage in plants

	Glycogen	Glucose	α -1,4 & α -1,6 (more branched)	Energy storage in animals
	Cellulose	Glucose	β -1,4-glycosidic	Structural support in plant cell walls
	Inulin	Fructose	β -2,1-glycosidic	Storage carbohydrate in some plants
	Chitin	N-acetylglucosamine	β -1,4-glycosidic	Structural support in exoskeletons & fungi
Hetero polysaccharides/ Heteroglycans	Hyaluronic acid	D-Glucuronic acid + N-acetyl-D-glucosamine	β -1,3 and β -1,4 linkages	lubrication in joints, cell migration, tissue repair
	Chondroitin sulfate	D-glucuronic acid + N-acetyl-D-galactosamine sulfate	β -1,3 and β -1,4 linkages	Provides resistance and elasticity to cartilage
	Heparin	L-iduronic acid + D-glucosamine sulfate	α and β linkage	Anticoagulant (inhibits blood clotting)
	Keratan sulfate	D-galactose + N-acetyl-D-glucosamine	β -1,4 and β -1,3 linkages	Corneal transparency, cartilage strength

☐ Reducing and Non - Reducing Sugar

Feature	Reducing Sugars	Non-Reducing Sugars
Definition	Sugars that can reduce Fehling's or Benedict's reagent due to a free aldehyde or ketone group	Sugars that cannot reduce Fehling's or Benedict's reagent because the carbonyl group is blocked
Presence of Free Group	Have a free anomeric carbon ($-\text{CHO}$ or $=\text{CO}$)	Anomeric carbon is involved in glycosidic bond
Mutarotation	Show mutarotation in solution	Do not show mutarotation
Examples	All monosaccharides, Maltose, Lactose	Mostly polysaccharides, Sucrose, Trehalose
Color Reaction	Give red/orange precipitate with Benedict's or Fehling's solution	No color change with these reagents
Use in Tests	Can be tested with Tollen's, Fehling's, or Benedict's reagent	Give negative result in these test

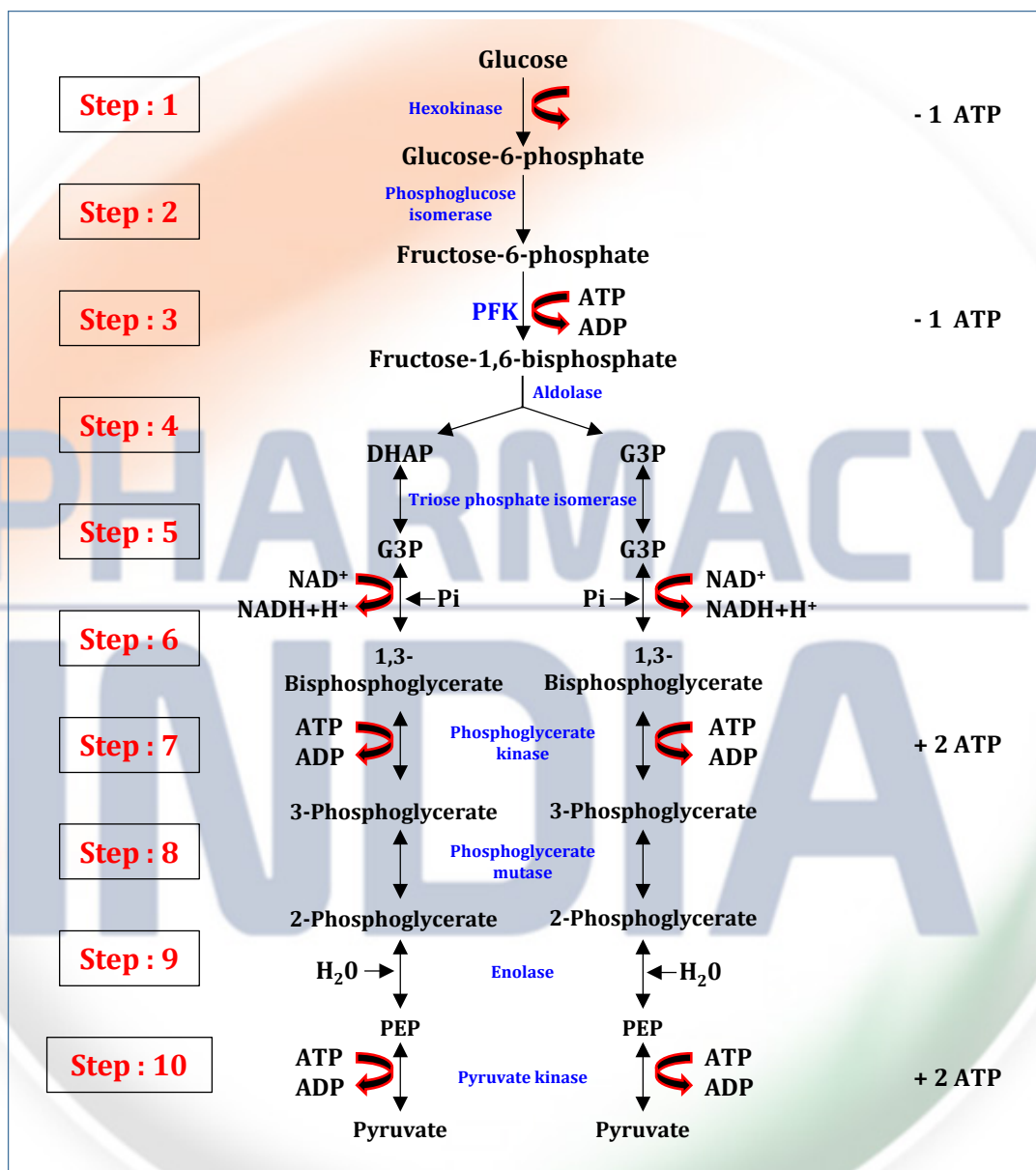
Epimers

- **Epimers** are a type of **stereoisomers** in which **two compounds differ in configuration at only one specific carbon atom, excluding the anomeric carbon** (which defines α or β forms in cyclic sugars).
- They have the **same molecular formula** and same **functional groups, but differ at one chiral center.**
- All epimers are diastereomers, but **not all diastereomers are epimers.**

Sugar 1	Sugar 2	Epimer at Carbon	Structure
Glucose	Galactose	C4	<p>D-Glucose D-Galactose</p>
Glucose	Mannose	C2	<p>D-glucose D-mannose</p>
Ribose	Arabinose	C2	<p>D-Ribose D-Arabinose</p>

Glycolysis

- **Glycolysis** is a **metabolic pathway** in which **one molecule of glucose (6-carbon)** is broken down into **two molecules of pyruvate (3-carbon)** with the **net production of ATP and NADH**.
- It is the **first step of cellular respiration** and occurs in the **cytoplasm** of all living cells — **with or without oxygen**.



Energetics of Glucose Metabolism

Stage	Process	Molecules Produced	ATP Yield (via OxPhos)
Glycolysis	Substrate-level phosphorylation	2 ATP (direct)	2 ATP
	$\text{NAD}^+ \rightarrow 2 \text{NADH}$	$2 \text{NADH} \times 2.5 \text{ ATP} = 5 \text{ ATP}$	5 ATP
Link Reaction	Pyruvate \rightarrow Acetyl-CoA	$2 \text{NADH} \times 2.5 \text{ ATP} = 5 \text{ ATP}$	5 ATP
TCA Cycle (Krebs)	$2 \text{ Acetyl-CoA} \rightarrow 2 \text{ GTP (ATP equivalent)}$	$2 \text{ GTP} = 2 \text{ ATP}$	2 ATP
	$6 \text{ NADH} \times 2.5 \text{ ATP}$	$6 \times 2.5 = 15 \text{ ATP}$	15 ATP
	$2 \text{ FADH}_2 \times 1.5 \text{ ATP}$	$2 \times 1.5 = 3 \text{ ATP}$	3 ATP

Total (per 1 glucose)	Direct: 4 ATP (2 from glycolysis, 2 from TCA)	4 ATP
	From NADH & FADH ₂ : 28 ATP	28 ATP
Grand Total		32 ATP (Net yield)

Metabolic Pathway	Location	End Product(s)	Rate-Limiting Enzyme	Regulation
Glycolysis	Cytoplasm	2 Pyruvate, 2 ATP, 2 NADH	Phosphofructokinase-1 (PFK-1)	Activated by: AMP, Fructose-2, 6-bisphosphate Inhibited by: ATP, Citrate
Gluconeogenesis	Liver (mainly), Kidney cortex	Glucose	Fructose-1,6-bisphosphatase	Activated by: ATP, Citrate Inhibited by: AMP, Fructose-2, 6-bisphosphate
Glycogenesis	Liver & Muscle (cytoplasm)	Glycogen	Glycogen Synthase	Activated by: Glucose-6-phosphate, Insulin Inhibited by: Glucagon, Epinephrine
Glycogenolysis	Liver & Muscle (cytoplasm)	Glucose-1-phosphate	Glycogen Phosphorylase	Activated by: Glucagon (liver), AMP (muscle), Epinephrine Inhibited by: ATP, Insulin
Pentose Phosphate Pathway	Cytoplasm (liver, fat, adrenal cortex)	NADPH, Rbose-5-phosphate, CO ₂	Glucose-6-phosphate Dehydrogenase	Activated by: NADP ⁺ Inhibited by: NADPH
TCA Cycle (Krebs Cycle)	Mitochondrial matrix	CO ₂ , 3 NADH, 1 FADH ₂ , 1 GTP (per cycle)	Isocitrate Dehydrogenase	Activated by: ADP, Ca ²⁺ Inhibited by: ATP, NADH
Lactic Acid Fermentation	Cytoplasm (muscle, RBCs, anaerobic cells)	Lactate, NAD ⁺	Lactate Dehydrogenase (LDH)	Activated when O ₂ is low, NADH present Inhibited when NAD ⁺ is scar

☐ **Glycogen Storage Diseases**

Type	Name	Deficient Enzyme	Affected Organ(s)	Key Features / Symptoms
Type I	Von Gierke's disease	Glucose-6-phosphatase	Liver, kidney	Severe fasting hypoglycemia, lactic acidosis, hepatomegaly
Type II	Pompe's disease	Lysosomal acid α-glucosidase	All organs (esp. muscle)	Cardiomegaly, muscle weakness, early death in infants
Type III	Cori's disease / Forbes disease	Debranching enzyme (α-1,6-glucosidase)	Liver, muscle	Milder hypoglycemia, hepatomegaly, muscle weakness
Type IV	Andersen's disease	Branching enzyme	Liver, spleen	Hepatosplenomegaly, cirrhosis, failure to thrive
Type V	McArdle's disease	Muscle glycogen phosphorylase	Skeletal muscle	Muscle cramps, exercise intolerance, myoglobinuria
Type VI	Hers disease	Liver glycogen phosphorylase	Liver	Mild hypoglycemia, hepatomegaly
Type VII	Tarui disease	Phosphofructokinase (muscle type)	Muscle	Similar to Type V, with hemolysis

☐ **Chemical Tests for Carbohydrates**

S.No	Test Name	Reagent Used	Detects	Positive Result
1	Molisch's Test	α-Naphthol + Conc. H ₂ SO ₄	All carbohydrates	Violet/purple ring at junction
2	Benedict's Test	Benedict's solution (CuSO ₄ , Na ₂ CO ₃ , citrate)	Reducing sugars	Green/yellow/orange/red ppt
3	Fehling's Test	Fehling A (CuSO ₄) + Fehling B (alkaline tartrate)	Reducing sugars	Brick red precipitate
4	Barfoed's Test	CuSO ₄ in acidic medium	Monosaccharides	Red ppt within 2-3 minutes

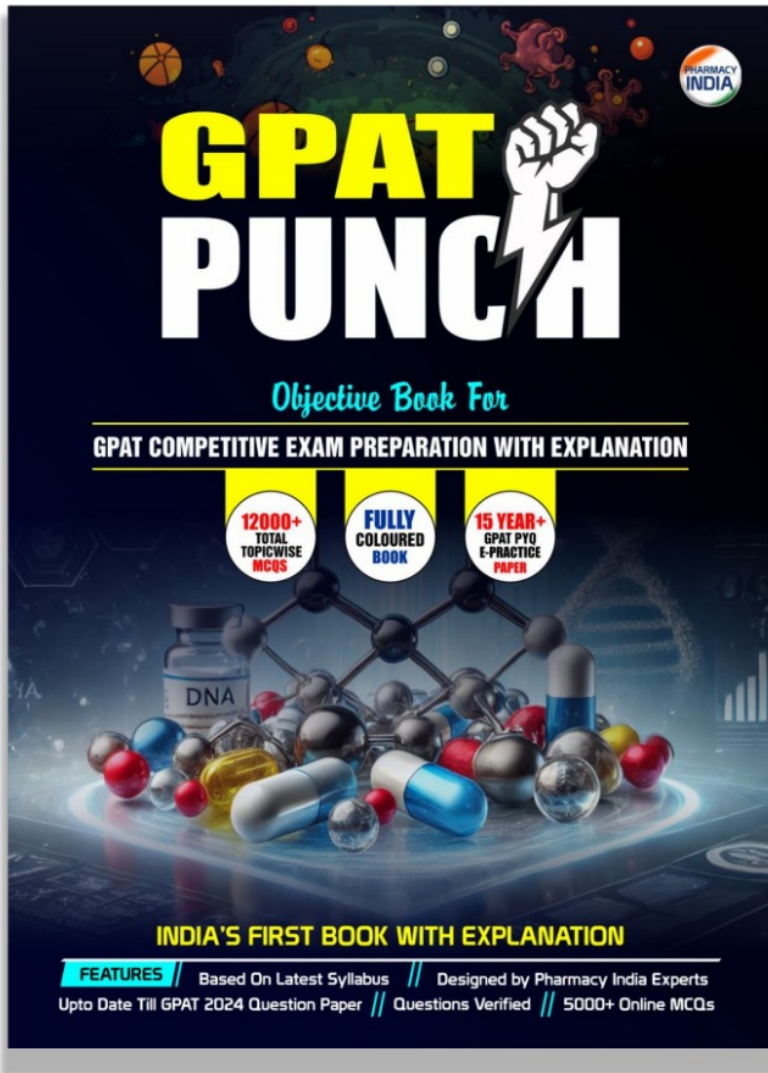
5	Seliwanoff's Test	Resorcinol + Conc. HCl	Ketoses (e.g., fructose)	Cherry red color (quickly)
6	Bial's Test	Orcinol + HCl + FeCl ₃	Pentoses (e.g., ribose)	Bluish-green color
7	Iodine Test	Iodine in potassium iodide (I ₂ + KI)	Polysaccharides	Starch: blue-black, Glycogen: red-brown
8	Osazone Test	Phenylhydrazine + sodium acetate	Reducing sugars (ID by shape)	Characteristic crystals (microscopy)



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