

GPAT

2027-28



BIOCHEMISTRY

CLASS- 16



TIME- 8 : 30 P.M

CARBOHYDRATES

UPDATED QUESTIONS TILL GPAT 2026

GPAT



VIDEO
LECTURE



PDF



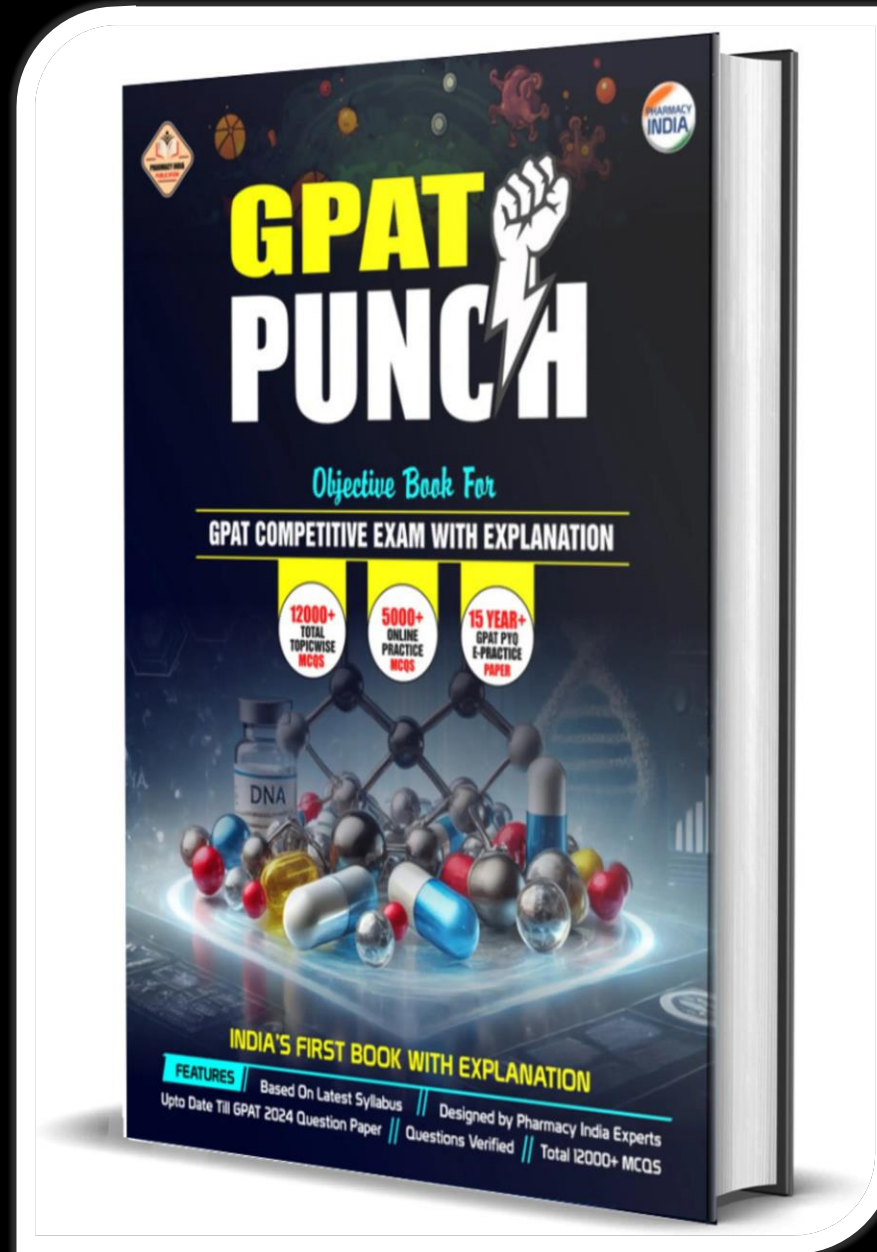
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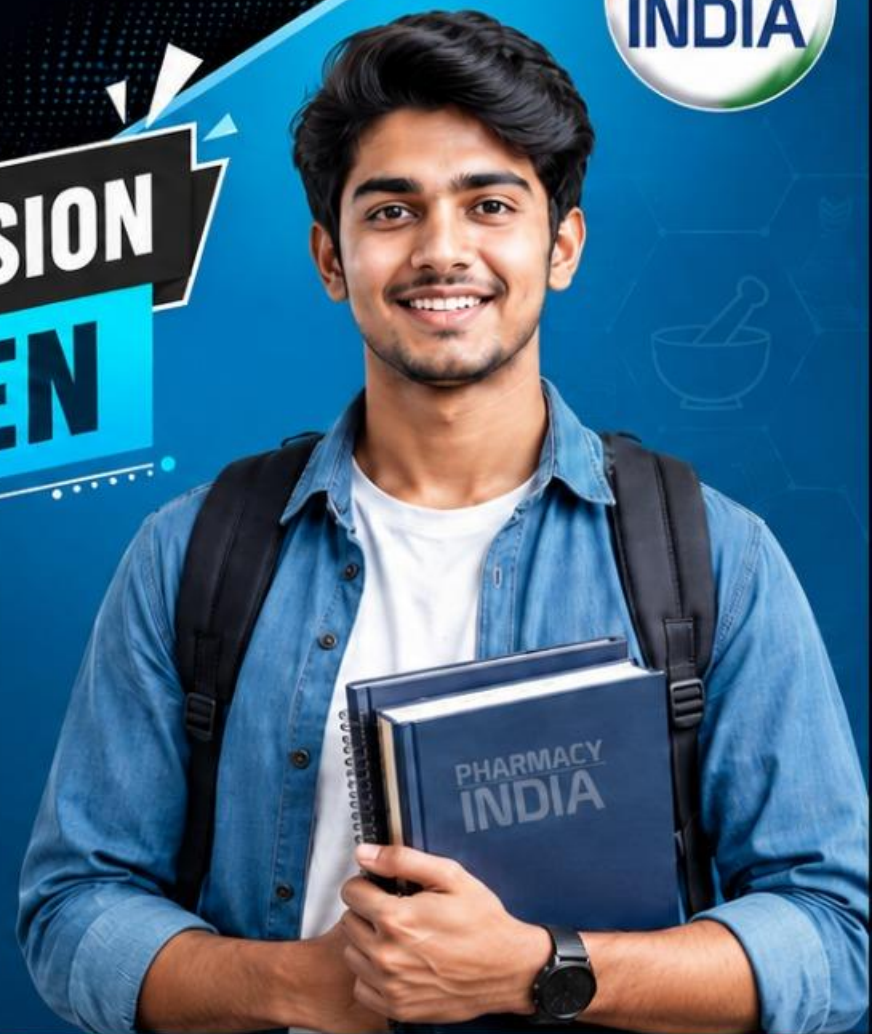
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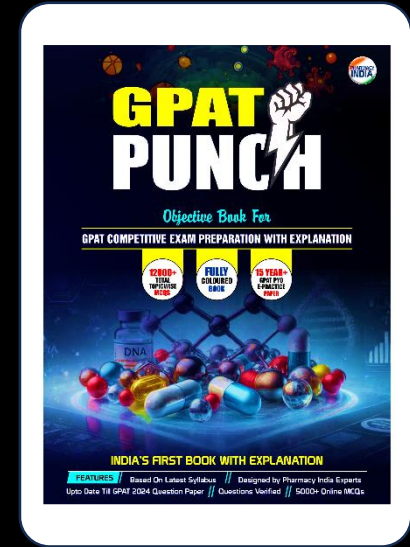


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01. **Glycogenic amino acids enter in TCA cycle except:**

[GPAT-2025]

- (a) Aspartate
- (b) Alanine
- (c) Glycine
- (d) Glutamate



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01. Glycogenic amino acids enter in TCA cycle except:

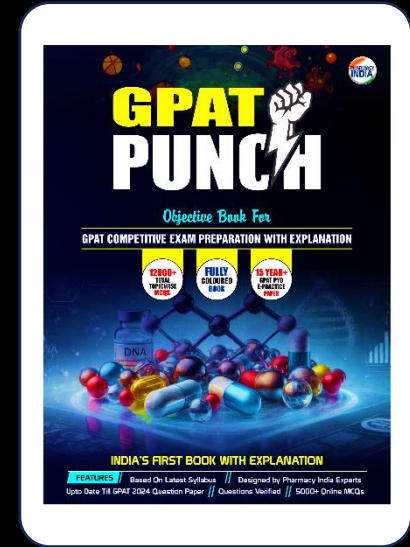
[GPAT-2025]

(a) Aspartate

(b) Alanine

(c) Glycine

(d) Glutamate



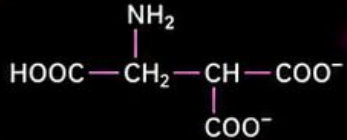
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GLYCOGENIC AMINO ACIDS AND TCA-CYCLE ENTRY

These amino acids feed into the TCA cycle to support glucose production (**gluconeogenesis**)

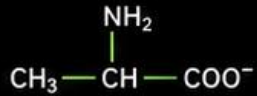
GLYCOGENIC AMINO ACIDS (DIRECT TCA ENTRY)

1 ASPARTATE



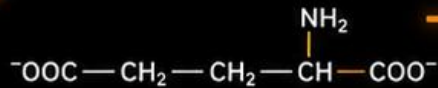
OXALOACETATE
(OAA)

2 ALANINE



PYRUVATE

3 GLUTAMATE



α -KETOGLUTARATE
(α -KG)

TCA CYCLE (KREBS CYCLE)

CITRATE

ISOCITRATE

α -KETOGLUTARATE
(α -KG)

SUCCINYL-CoA

SUCCINATE

FUMARATE

MALATE

OXALOACETATE
(OAA)

KEY TAKEAWAYS



Aspartate → Oxaloacetate (OAA)
Direct entry into the TCA cycle.



Alanine → Pyruvate
Pyruvate enters the TCA via conversion to OAA.



Glutamate → α -Ketoglutarate (α -KG)
Directly enters the TCA cycle.



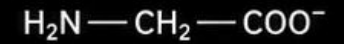
These entries are **anaplerotic** and support TCA function and **gluconeogenesis**.



Glycine is **NOT** a direct TCA entry in this context (it converts to serine first).

DIRECT ENTRY EXCEPTION

GLYCINE



NOT A DIRECT TCA ENTRY HERE

Glycine is converted to serine, then to **pyruvate** or other intermediates — not a direct entry point.

GLYCINE → SERINE → **PYRUVATE (or other)**

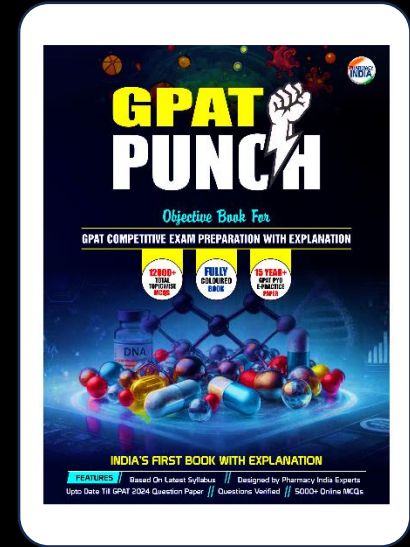
★ **Remember:** Aspartate, Alanine, and Glutamate are glycogenic via OAA, Pyruvate, and α -KG respectively. Glycine is not the direct TCA-entry choice here.



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02. Which one is not the characteristic of the Hexose Monophosphate Pathway? [GPAT-2023 SHIFT-I]

- (a) It requires ATP for phosphorylation
- (b) It produces CO_2
- (c) It is controlled by inhibition of glucose-6-phosphate dehydrogenase by NADPH
- (d) It produces ribose-5-phosphate



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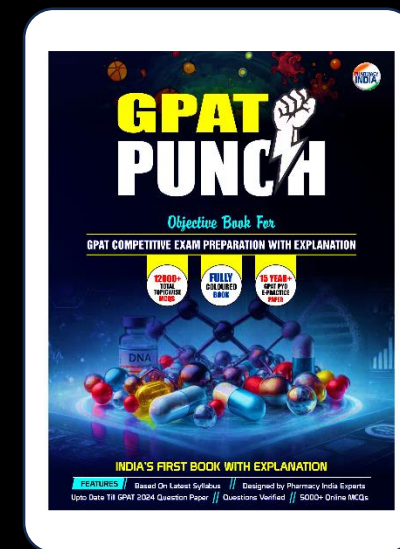
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HEXOSE MONOPHOSPHATE PATHWAY (HMP SHUNT)



OVERVIEW

An alternative pathway of **glucose metabolism** occurring in the **cytosol**.



**NO ATP
REQUIRED**



**PRODUCES
NADPH**

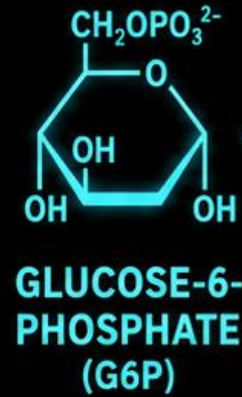


**PRODUCES
RIBOSE-5-P**



**RELEASES
CO₂**

NO ATP REQUIRED



HMP SHUNT

Oxidative Phase
(Irreversible)

Non-oxidative Phase
(Reversible)

**GLUCOSE-6-PHOSPHATE
DEHYDROGENASE
(G6PD)**

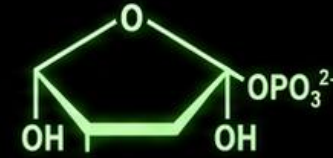
FEEDBACK INHIBITION

Excess **NADPH** inhibits **G6PD** to prevent overproduction.

NADPH

Reductive biosynthesis
(fatty acids, steroids)

Maintains reduced
glutathione (GSH)
(Antioxidant defense)



For nucleotide
(DNA, RNA)
synthesis

CO₂

Released during
oxidative decarboxylation

WHERE IT OCCURS



Active in all cells; especially
liver, **adipose tissue**, **lactating
mammary gland**, **RBCs**, **adrenal cortex**.

★ KEY POINTS

- ✓ HMP pathway does **NOT** require **ATP**.
- ✓ Generates **NADPH** for biosynthesis & antioxidant defense.
- ✓ Produces **ribose-5-phosphate** for nucleotide synthesis.
- ✓ Releases **CO₂** during oxidative decarboxylation.
- ✓ **Glucose-6-phosphate dehydrogenase (G6PD)** is feedback-inhibited by **NADPH**.

NET OUTCOMES OF HMP SHUNT

NADPH + **RIBOSE-5-P** + **CO₂**
(Reducing Power) (Nucleotide Synthesis) (Waste By-product)

LEGEND

- Substrate flow
- - - - - Enzyme action
- ⊥ Feedback inhibition
- ★ Major product



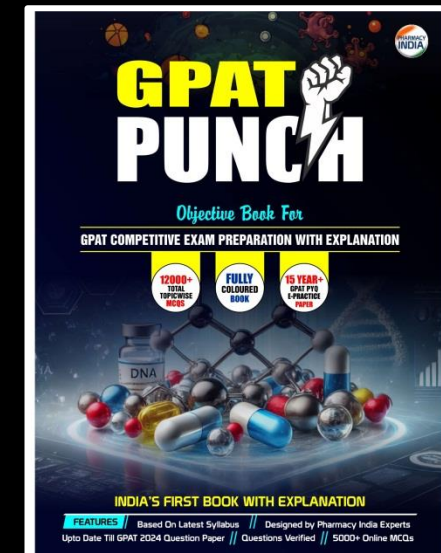
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03.

The C-2 epimer of D-glucose is: [GPAT-2023 SHIFT-II]

- (a) D-Mannose
- (b) L-Fructose
- (c) D-Glucopyranose
- (d) L-Arabinose



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03.

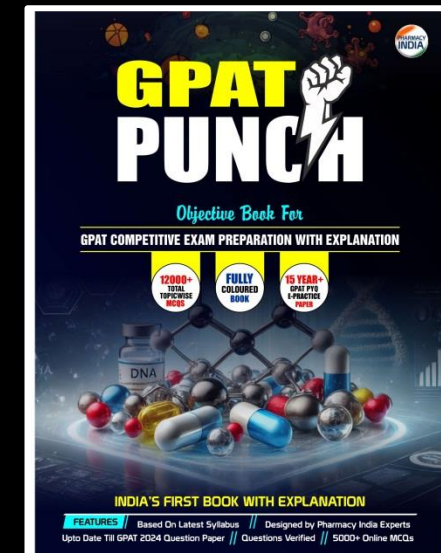
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(d) L-Arabinose



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D-MANNANOSE: C-2 EPIMER OF D-GLUCOSE

★ They differ **only** in configuration at carbon 2 ★



SAME BACKBONE

Both are aldohexoses with identical carbon skeleton.



DIFFER ONLY AT C-2

Configuration at carbon 2 is different.



EPIMER

Stereoisomers differing at one chiral center are epimers.



IDENTICAL PROPERTIES

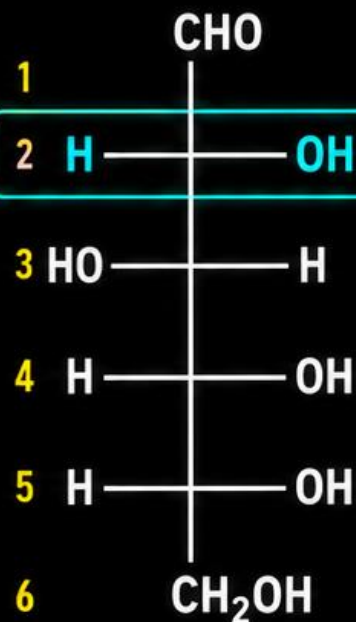
Physical & many chemical properties are very similar.



IMPORTANCE

D-mannose occurs in nature; important in glycoproteins & N-linked glycans.

D-GLUCOSE



OH at C-2 is on **RIGHT**

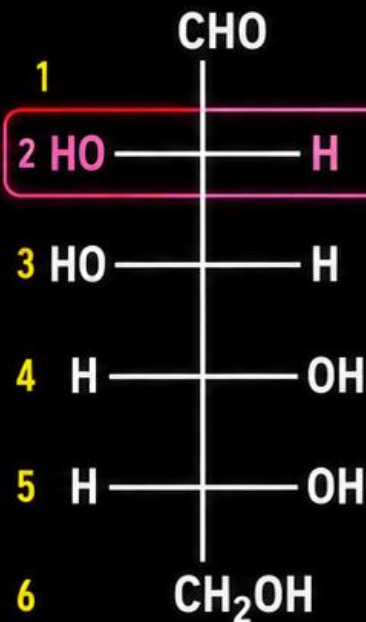
DIFFERENT
ONLY AT
C-2



EPIMER

ALL OTHER
CHIRAL CENTERS
ARE THE SAME

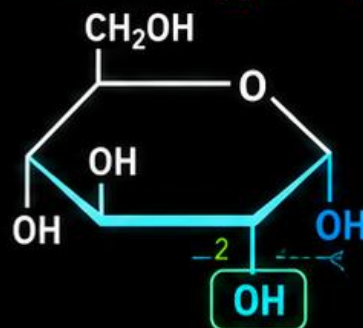
D-MANNOSE



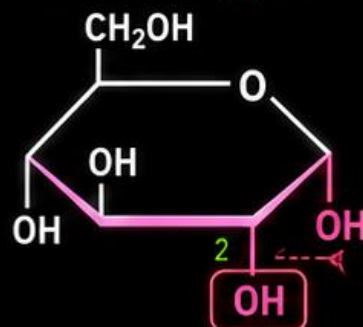
OH at C-2 is on **LEFT**

3D PERSPECTIVE

D-GLUCOSE (pyranose)



D-MANNOSE (pyranose)



D-Mannose is the **C-2 epimer** of D-glucose because they **differ only** at carbon 2.



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04.

Carbohydrates have hydrogen oxygen atom ratio of:

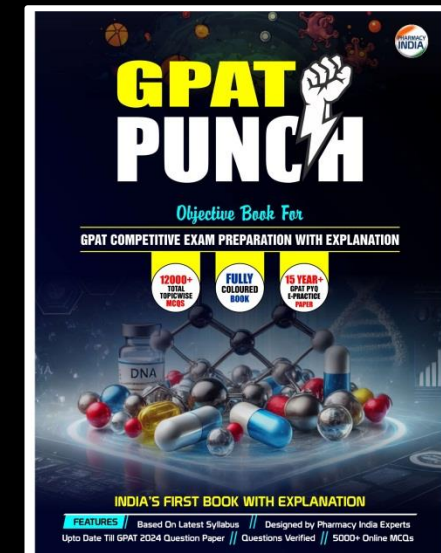
[GPAT-2023 SHIFT-II]

(a) 1:2

(b) 3:1

(c) 1:3

(d) 2:1



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04.

Carbohydrates have hydrogen oxygen atom ratio of:

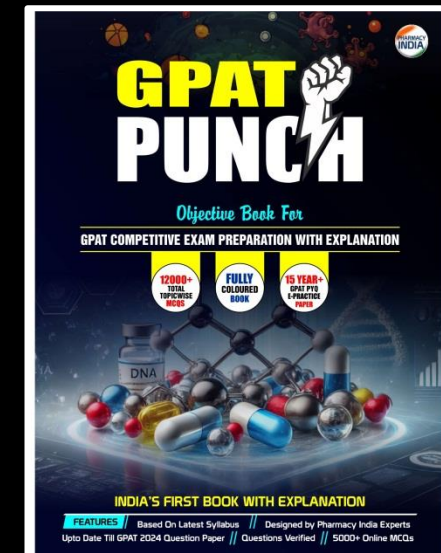
[GPAT-2023 SHIFT-II]

(a) 1:2

(b) 3:1

(c) 1:3

(d) 2:1



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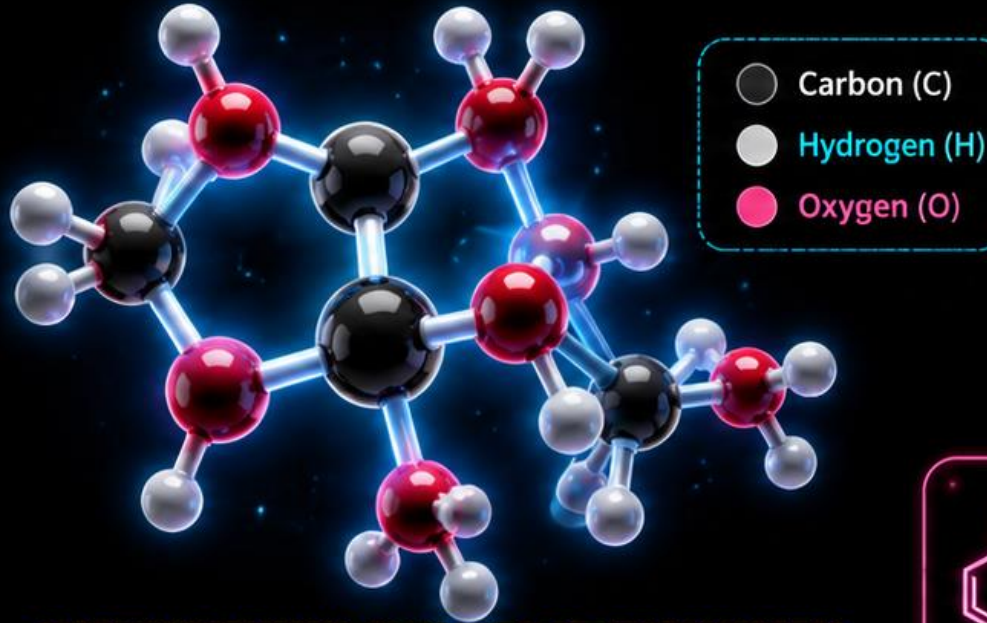
BASIC COMPOSITION OF CARBOHYDRATES

Most carbohydrates follow the empirical formula $C_n(H_2O)_n$,
so the **hydrogen** to **oxygen** ratio is **2:1**.

GENERAL FORMULA



Empirical formula of
most carbohydrates



EXAMPLE: GLUCOSE



Hydrogen : Oxygen
12 : 6

$$H:O = 12:6 = 2:1$$



HYDRATE OF CARBON CONCEPT

Carbohydrates can be viewed as
"hydrates of carbon".



COMMON RATIO

Most carbohydrates maintain
a hydrogen to oxygen ratio
of **2:1**.

KEY TAKEAWAY



Most carbohydrates follow $C_n(H_2O)_n$,
so the **hydrogen** to **oxygen** ratio is **2:1**.



VARIATION IN n

The value of n varies, giving rise to
different monosaccharides,
disaccharides, polysaccharides.



FOUND IN NATURE

Present in plants, animals and
microorganisms as energy sources
and structural components.

MORE
EXAMPLES →



FRUCTOSE



SUCROSE



STARCH (REPEATING UNIT)





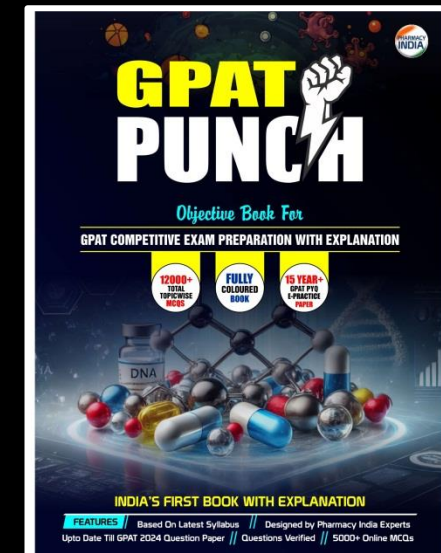
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05.

Identify the pair of C-4 epimers. [GPAT-2023 SHIFT-II]

- (a) D-glucose and D-galactose
- (b) D-glucose and D-fructose
- (c) D-glucose and D-mannose
- (d) D-glucose and D-xylulose



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05.

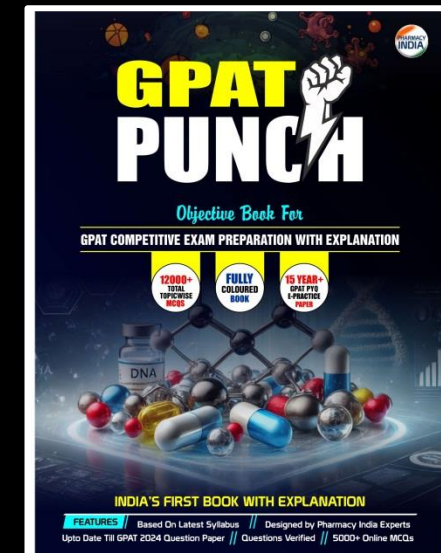
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(c) D-glucose and D-mannose

(d) D-glucose and D-xylulose

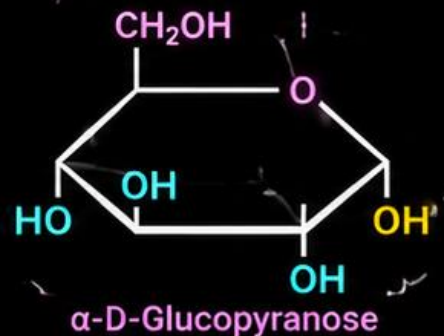
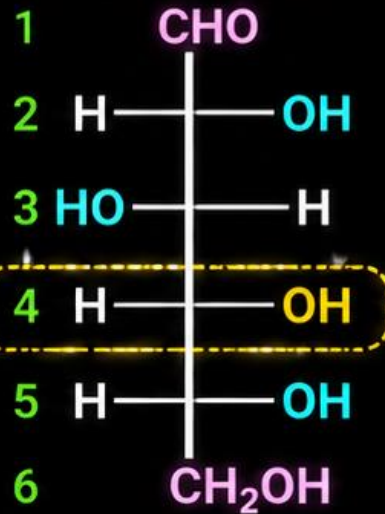


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C-4 EPIMERS

D-GLUCOSE AND D-GALACTOSE DIFFER ONLY AT CARBON 4

D-GLUCOSE



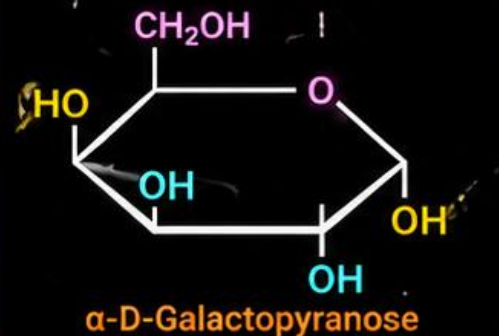
EPIMERS



DIFFERENCE
ONLY AT
C-4

SAME
CARBON
SKELETON

D-GALACTOSE



EPIMERS: Stereoisomers that differ in configuration at **one (and only one)** chiral center.



D-Glucose and D-Galactose differ only at **carbon 4 (C-4)**.



Same molecular formula (**C₆H₁₂O₆**) and same carbon skeleton.



At C-4:
• D-Glucose → **OH** on right
• D-Galactose → **OH** on left



They show **different** physical and biological properties due to this single configuration change.

KEY TAKEAWAY: D-GLUCOSE AND D-GALACTOSE ARE C-4 EPIMERS BECAUSE THEY DIFFER ONLY AT CARBON 4.



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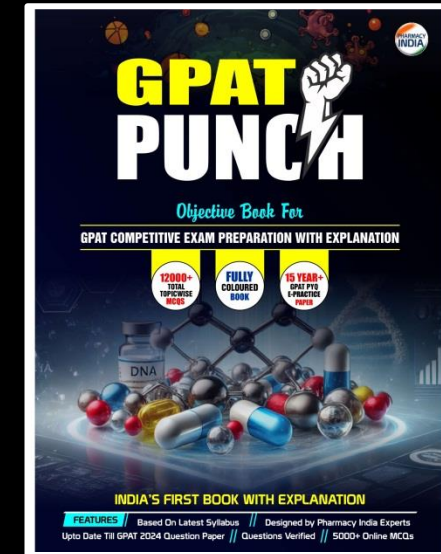
06. Citric acid cycle is the final pathway during the oxidation of: [GPAT-2022]

(a) Carbohydrates

(b) Lipids

(c) Proteins

(d) All of these



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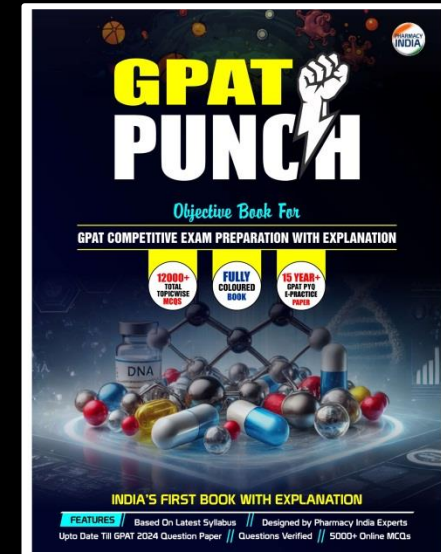
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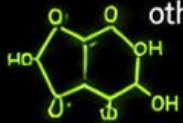
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CITRIC ACID CYCLE AS THE FINAL COMMON PATHWAY

Carbohydrates, lipids, and proteins are ultimately oxidized through the TCA cycle after conversion to acetyl-CoA or other TCA intermediates.

CARBOHYDRATES

Glucose, glycogen,
other sugars



Glycolysis



Pyruvate

LIPIDS

Triglycerides, fatty acids,
glycerol



β -Oxidation



Acetyl-CoA

PROTEINS

Amino acids



Deamination
& Transamination

TCA Intermediates

KEY OUTPUTS



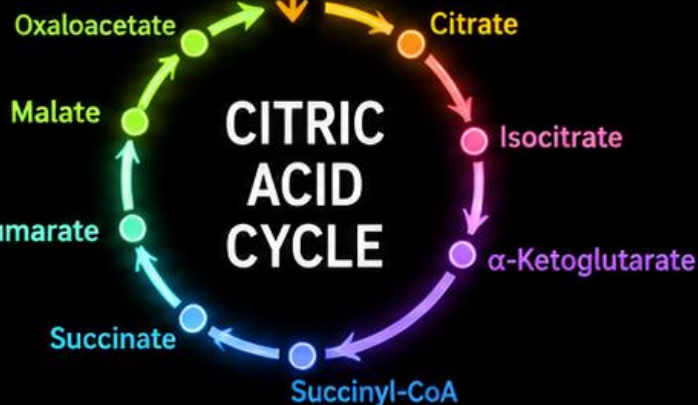
NADH, FADH₂
(electron carriers)



GTP / ATP
(energy)



CO₂
(by-product)



FINAL COMMON OXIDATIVE PATHWAY

All major nutrients converge here for complete oxidation to CO₂ and H₂O.



CENTRAL ENERGY HUB

Generates high-energy electron carriers (NADH, FADH₂) that drive ATP production in the electron transport chain.



INTERMEDIATE FLEXIBILITY

TCA intermediates are used for biosynthesis of amino acids, heme, nucleotides, and fatty acids.



AMPHIBOLIC ROLE

Functions in both catabolic (energy production) and anabolic (biosynthesis) pathways.



UNIVERSAL & ESSENTIAL

Present in all aerobic cells—central to metabolism and survival.



Different inputs, one destination: **the Citric Acid Cycle**

The final common pathway for energy extraction from carbohydrates, lipids, and proteins.



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07.

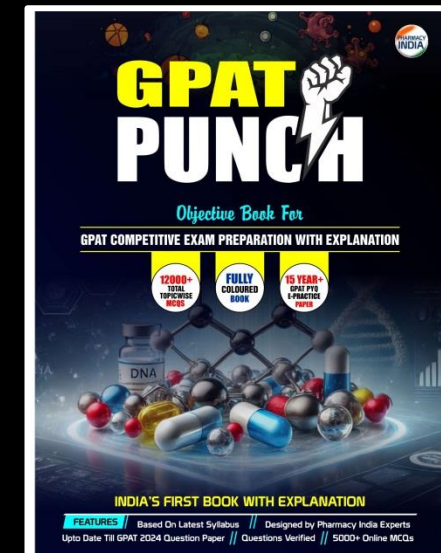
Given below are two statements. [GPAT-2022]

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:

- (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



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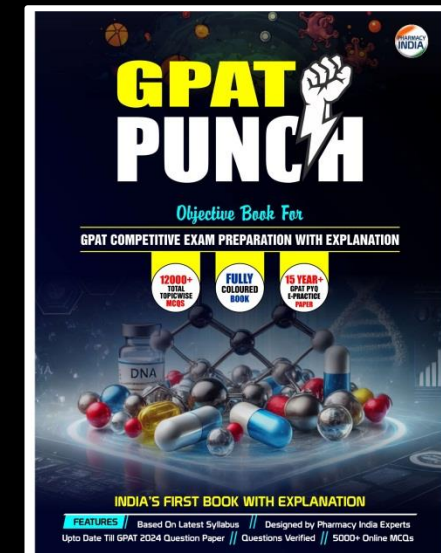
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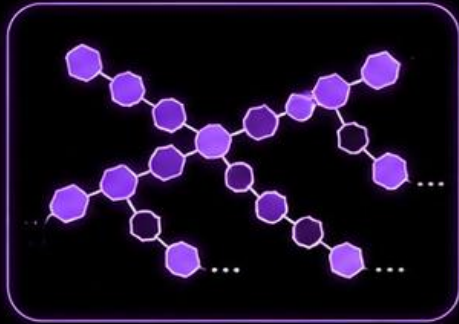
GLYCOGEN BREAKDOWN AND FREE GLUCOSE FORMATION IN LIVER



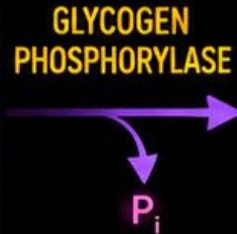
HIGH-YIELD TAKEAWAY

Liver converts stored glycogen into **FREE GLUCOSE** for blood.

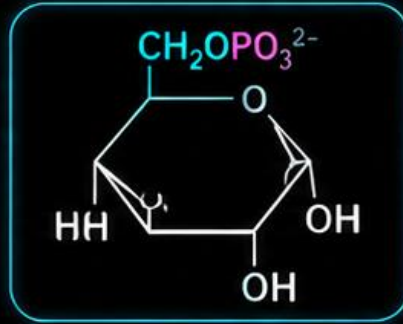
1 GLYCOGEN



Stored form of glucose
in liver



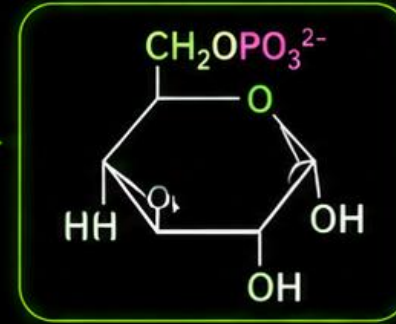
2 GLUCOSE-1-PHOSPHATE (G1P)



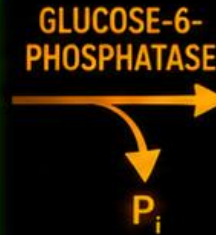
First product of glycogen
breakdown



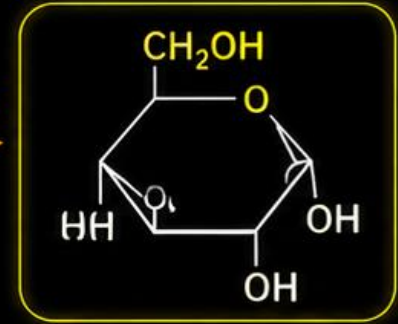
3 GLUCOSE-6-PHOSPHATE (G6P)



Interconverted from G1P;
key intermediate



4 FREE GLUCOSE



Released into blood
for energy

★ KEY POINTS

- Glycogen phosphorylase removes glucose units using P_i to form **GLUCOSE-1-PHOSPHATE (G1P)**.
- PHOSPHOGLUCOMUTASE** converts $G1P \rightleftharpoons$ **GLUCOSE-6-PHOSPHATE (G6P)**.
- GLUCOSE-6-PHOSPHATASE** hydrolyzes $G6P \rightarrow$ **FREE GLUCOSE** + P_i in the liver (and kidney).
- GLUCOSE-1-PHOSPHATE** is **NOT** directly hydrolyzed to free glucose.
- Liver (and kidney) can release **FREE GLUCOSE** into blood; muscle lacks **G6Pase**.



LIVER FOCUS



Maintains blood glucose during fasting
and between meals.



Free glucose is transported to blood
via **GLUT2**.



Supports brain, RBCs, and other
glucose-dependent tissues.



Key for whole-body glucose balance
(homeostasis).



REMEMBER

G1P

≠

**FREE
GLUCOSE**

It must first
become **G6P**.



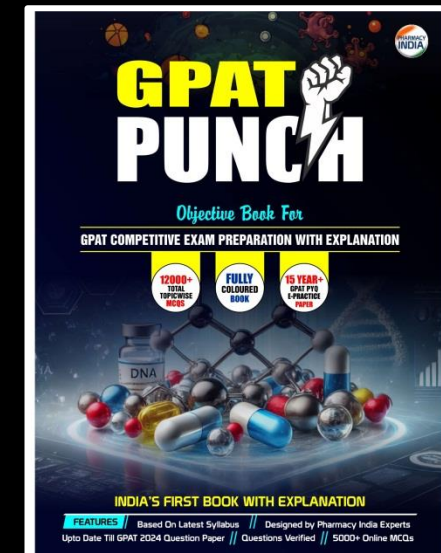
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08.

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

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



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08.

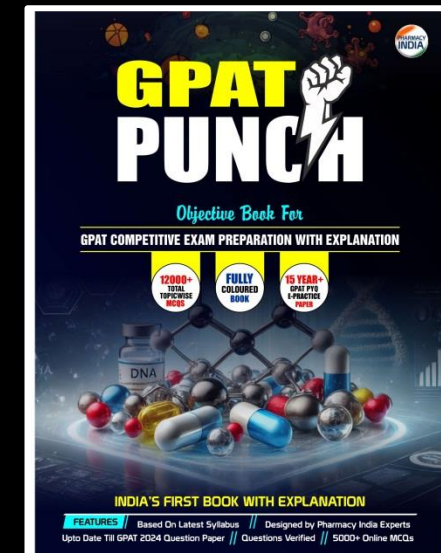
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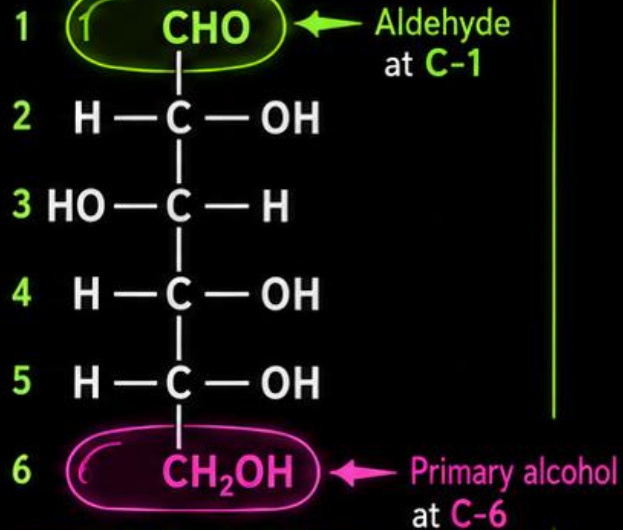


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OXIDATION OF GLUCOSE BY NITRIC ACID

Nitric acid oxidizes both the aldehyde group at **C-1** and the primary alcohol group at **C-6** of glucose, producing **glucaric acid** (a dicarboxylic acid).

GLUCOSE



Aldohexose
(open chain form)

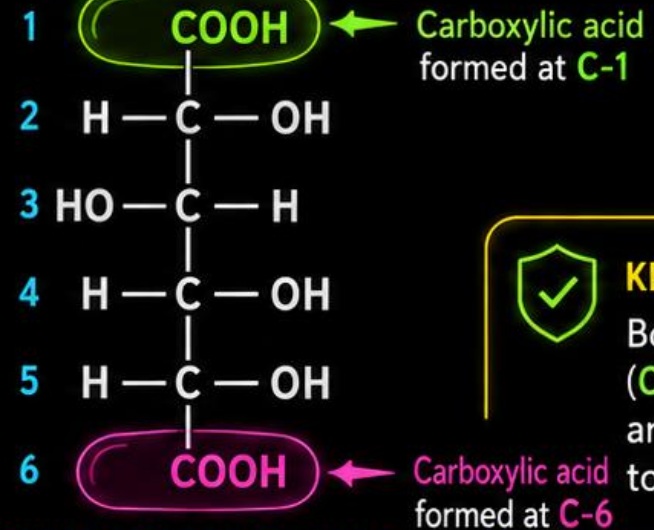
OXIDIZING AGENT



NITRIC ACID
(Strong Oxidation)

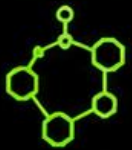
- ✓ Strong oxidation
- ✓ **C-1** + **C-6** oxidized
- ✓ Carbon chain preserved

GLUCARIC ACID



Dicarboxylic acid
(Glucaric acid)

 **KEY POINT**
Both ends (**C-1** and **C-6**) are oxidized to **-COOH**.



Nitric acid is a powerful oxidizing agent.



Oxidizes **aldehyde** at **C-1** to **-COOH**.



Oxidizes primary alcohol at **C-6** to **-COOH**.



Carbon skeleton remains intact.



Product:
Glucaric acid
(a dicarboxylic acid).



Overall Transformation: Aldehyde (**C-1** — **CHO**) + Primary alcohol (**C-6** — **CH₂OH**) → Two Carboxylic Acids (**-COOH** at both ends)



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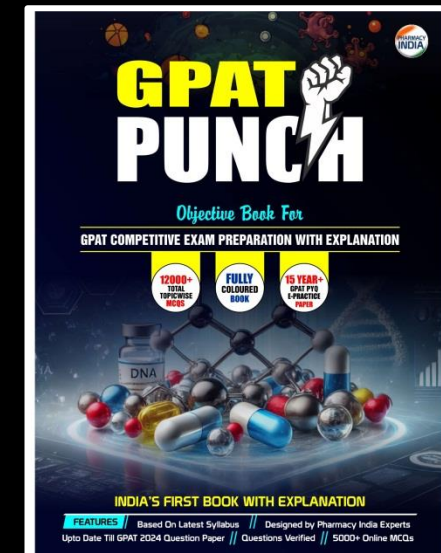


09.

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



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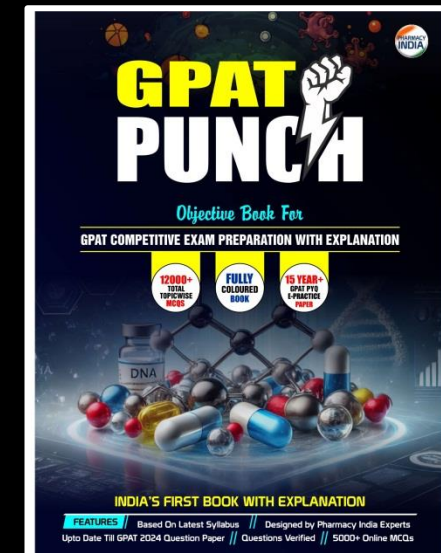


09.

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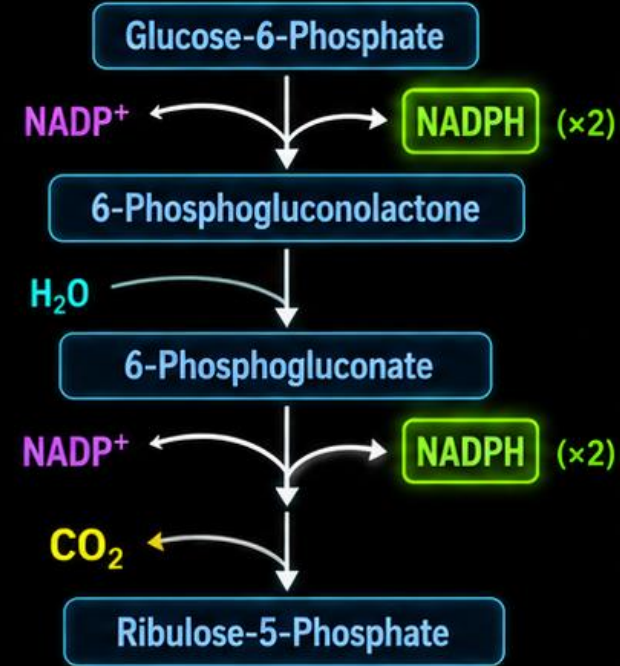
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HMP SHUNT — REVERSIBLE NON-OXIDATIVE PHASE

 **NO ATP FORMED**

Function: Forms **NADPH** and **Ribose-5-Phosphate** • Does **NOT** Generate ATP • Non-oxidative Phase is **Reversible**

1 OXIDATIVE PHASE *Irreversible*



 **NADPH**
(Reducing power)

 **CO₂**
(Released)

HMP SHUNT (PENTOSE PHOSPHATE PATHWAY)

2 NON-OXIDATIVE PHASE *Reversible*

Ribulose-5-Phosphate

Pentose Phosphates

Ribose-5-Phosphate

Xylulose-5-Phosphate

 **REVERSIBLE**

Glycolytic Intermediates

Fructose-6-Phosphate

+

Glyceraldehyde-3-Phosphate

KEY POINTS



Produces **NADPH** for reductive biosynthesis and antioxidant defense.



Produces **Ribose-5-Phosphate** for nucleotide synthesis.



No ATP generated in either phase.



Non-oxidative phase is **REVERSIBLE**.



Links carbohydrate metabolism with nucleotide synthesis.

Location: Cytosol • **Major Role:** Reductive biosynthesis & antioxidant defense



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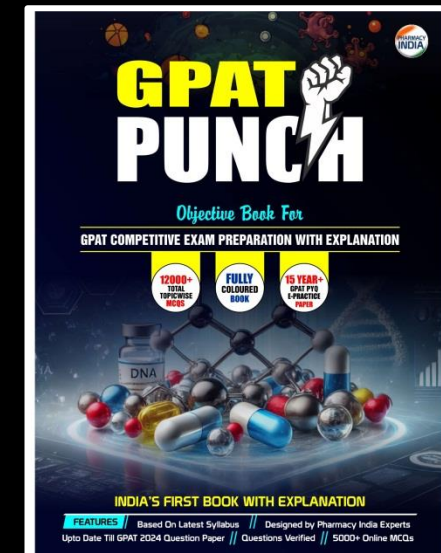


10.

An aldopentose can be converted into aldohexose by:

[GPAT-2020]

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



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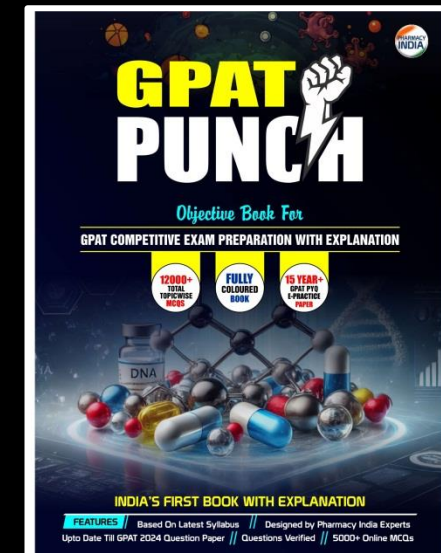


10.

An aldopentose can be converted into aldohexose by:

[GPAT-2020]

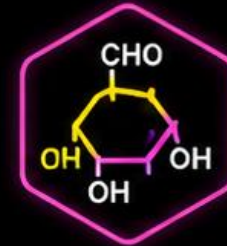
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- (b) Wohl's method
- (c) Kiliani-Fischer synthesis
- (d) Hoffmann degradation method



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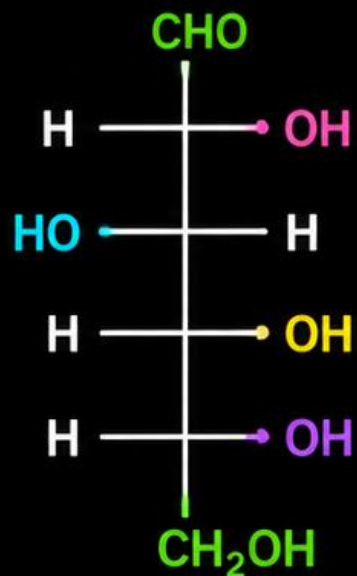


KILIANI-FISCHER SYNTHESIS



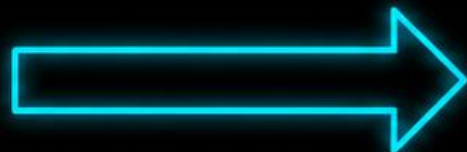
CHAIN LENGTHENING OF AN ALDOSE BY ONE CARBON

ALDOPENTOSE
(5 CARBONS)



Example: D-Ribose

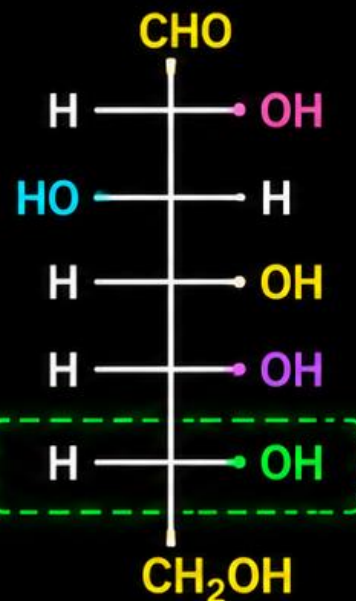
**+1
CARBON**



- 1) HCN
- 2) Hydrolysis
- 3) Cyclization

Creates a new
chiral center
(Epimers formed)

ALDOHEXOSE
(6 CARBONS)



Example: D-Glucose



KEY IDEA

Kiliani-Fischer synthesis increases the carbon chain of an aldose by **one carbon**.



TRANSFORMATION

Aldopentose → Aldohexose
(n carbons → n+1 carbons)



CLASSIC METHOD

Uses HCN addition, hydrolysis, and cyclization.



STEREOCHEMISTRY

Creates a new chiral center → two **epimeric** aldohexoses.



HIGH-YIELD FACT

Fundamental route in carbohydrate chemistry and structural studies.



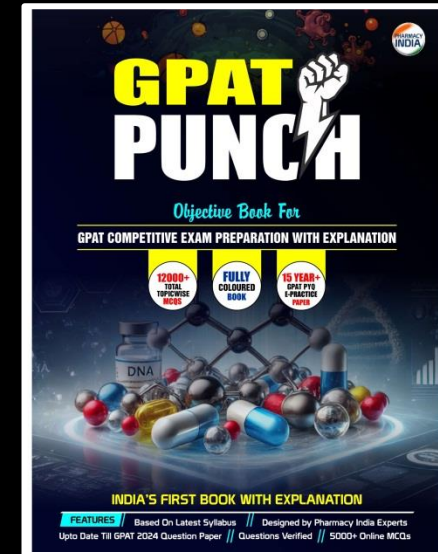
IN SHORT: Kiliani-Fischer synthesis = Chain extension of aldose by **+1 carbon** (aldopentose → aldohexose).



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11. Which of the following is the example/source of invert sugar? [GPAT-2020]

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



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11.

Which of the following is the example/source of invert sugar? [GPAT-2020]

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



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INVERT SUGAR

HYDROLYSIS OF SUCROSE PRODUCES A 1:1 MIXTURE OF GLUCOSE AND FRUCTOSE



WHAT IS INVERT SUGAR?

Invert sugar is formed by hydrolysis of sucrose.



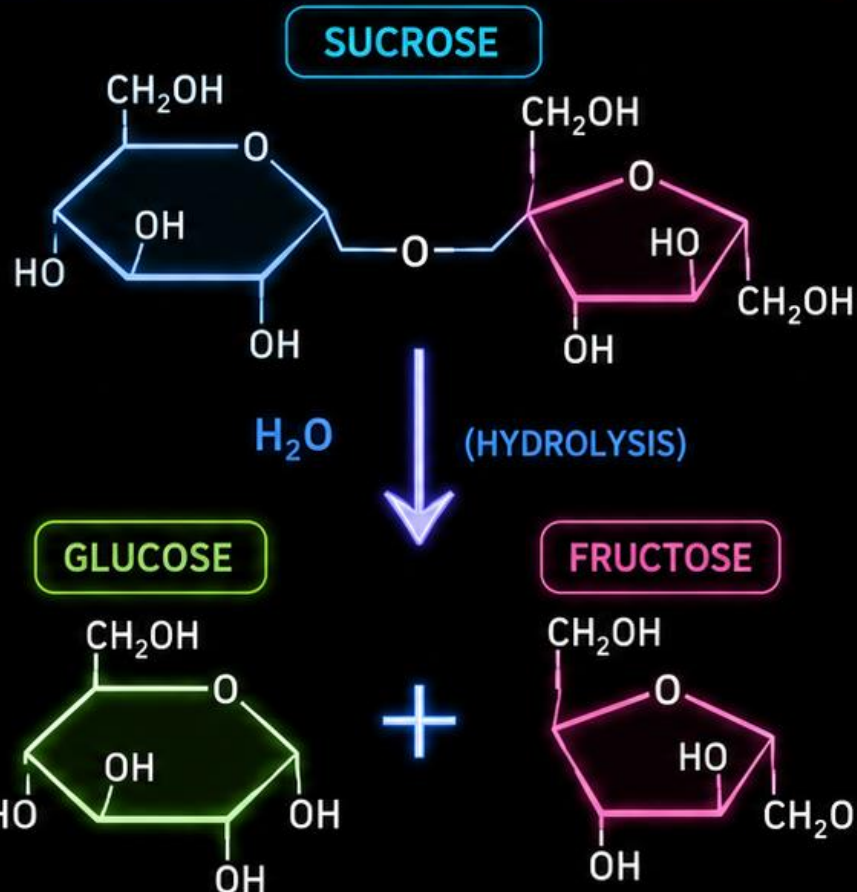
SUCROSE SPLITS

Sucrose splits into glucose + fructose.



EQUAL PARTS MIXTURE

It is a mixture of equal parts glucose and fructose.



OPTICAL ROTATION CHANGE

SUCROSE
(DEXTROROTATORY)



(+)

Rotates plane of light to the right



INVERT SUGAR
(LEVOROTATORY)



(-)

Rotates plane of light to the left



KEY TAKEAWAY

- Invert sugar is formed by hydrolysis of sucrose.
- Sucrose splits into glucose + fructose.
- Optical rotation changes from dextrorotatory to levorotatory.
- It is a mixture of equal parts glucose and fructose.



INVERT SUGAR = 50% GLUCOSE + 50% FRUCTOSE



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12.

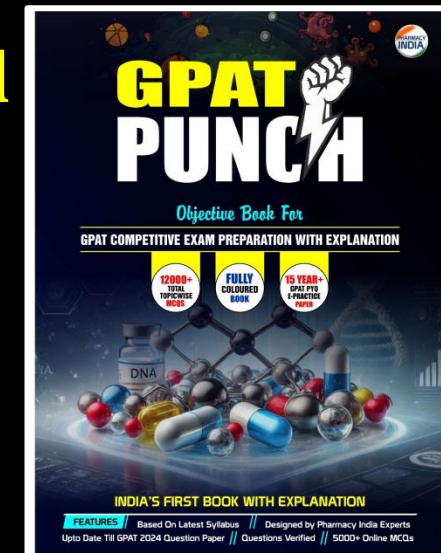
If two monosaccharides differ in their structure around a single carbon atom, they are called as: [GPAT-2020]

(a) Epimers

(b) Dimers

(c) Trioses

(d) Trimers



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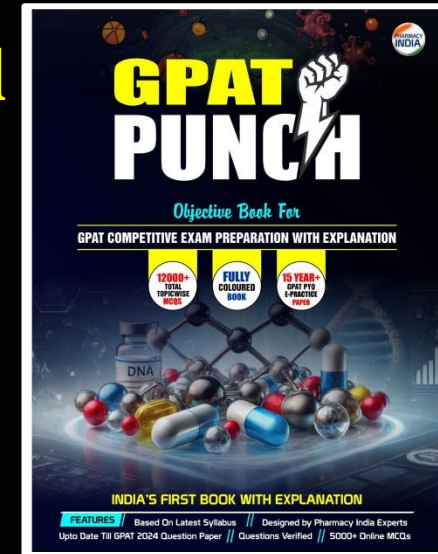
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(a) Epimers

(b) Dimers

(c) Trioses

(d) Trimers



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EPIMERS

STEREoisomers THAT DIFFER AT ONLY **ONE** CHIRAL CARBON ATOM



WHAT ARE EPIMERS?

Stereoisomers that differ at **ONLY ONE** chiral carbon atom.



SAME FORMULA

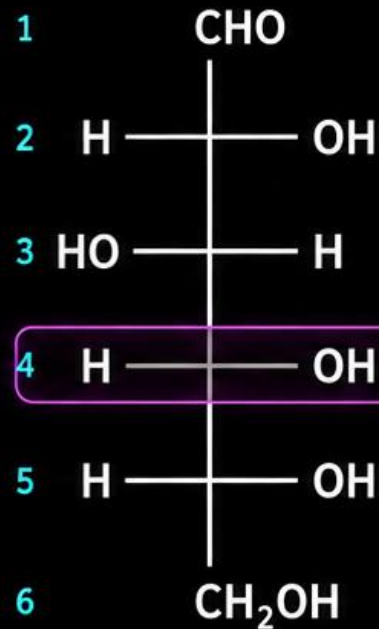
Epimers have the same molecular formula.



RELATIONSHIP

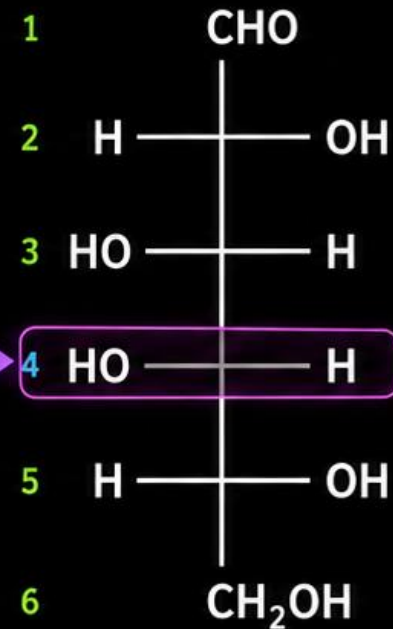
All epimers are diastereomers (not mirror images).

D-GLUCOSE



ONLY
DIFFERENCE
AT C-4

D-GALACTOSE



KEY POINT

Epimers differ in configuration at **ONLY ONE** specific chiral carbon.



EXAMPLES

- D-Glucose & D-Galactose
- D-Glucose & D-Mannose



REMEMBER

The rest of the molecule is **IDENTICAL**.



IN SUMMARY



Stereoisomers



Same molecular formula



Differ at **ONLY ONE** chiral carbon



Diastereomers (not mirror images)



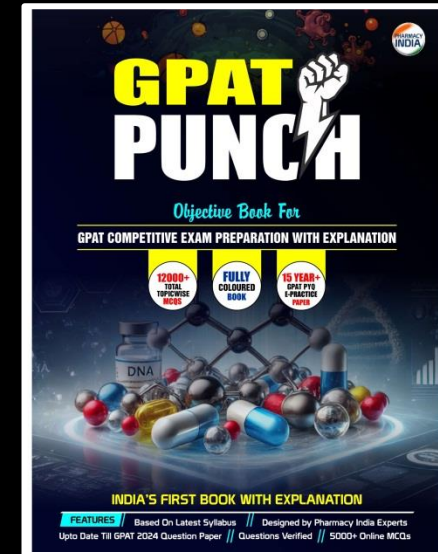
Example:
D-Glucose &
D-Galactose /
D-Mannose



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

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



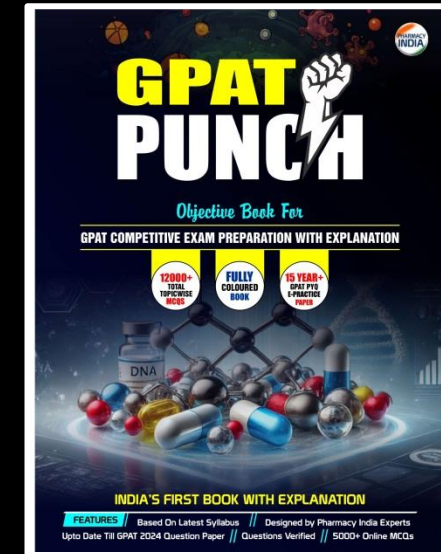
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- (a) No colour
- (b) Green
- (c) Blue
- (d) Red-purple



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AMYLOPECTIN + IODINE TEST

BRANCHED STARCH GIVES RED-PURPLE COLOR WITH IODINE



WHAT IS AMYLOPECTIN?

- Amylopectin is a branched component of starch.



IODINE REACTION

- With iodine (I_2/KI), amylopectin produces a **red-purple** or **reddish-purple** color.



IMPORTANT COMPARISON

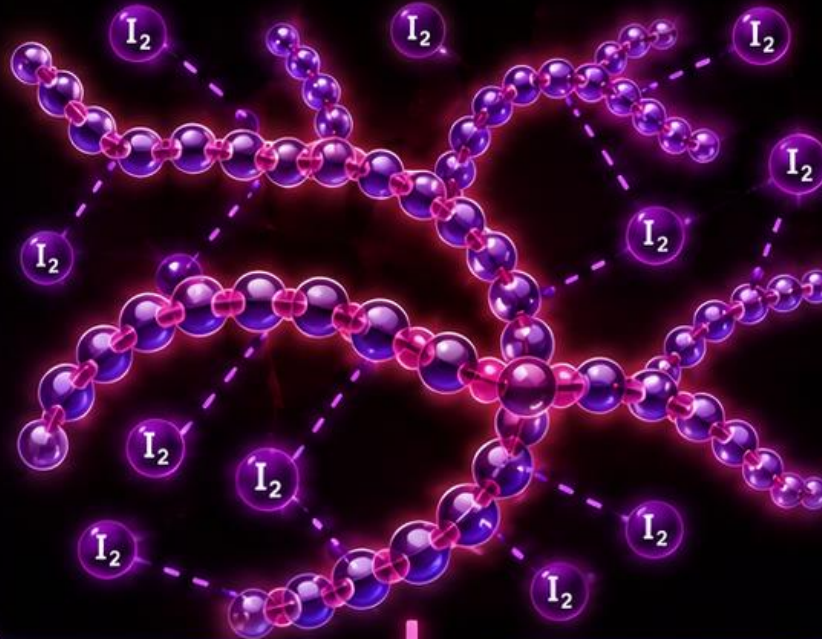
- Amylose (linear starch) gives a **blue** color with iodine.
- Color difference is important.



KEY POINT

- Branching in amylopectin influences the iodine complex color.

AMYLOPECTIN + IODINE (I_2)



RESULT: RED-PURPLE

Characteristic color of amylopectin with iodine.

HOW IT WORKS



- Iodine molecules (I_2) fit into helical regions and interact with the branched structure.

WHY RED-PURPLE?



- Branch points distort and shorten helices.
- This changes the iodine complex, giving a **red-purple** color.

QUICK REFERENCE



AMYLOSE



BLUE



AMYLOPECTIN



RED-PURPLE



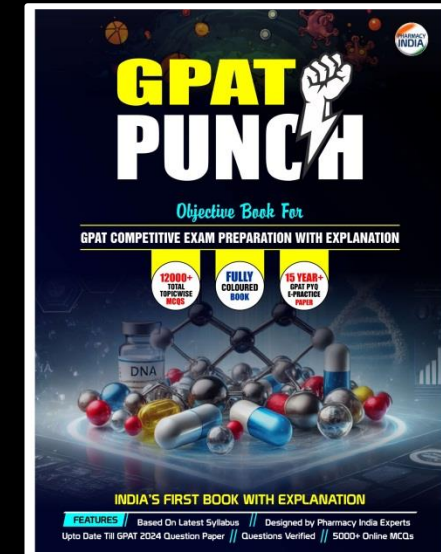
REMEMBER: SAME TEST, DIFFERENT COLOR → DIFFERENT STRUCTURE



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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



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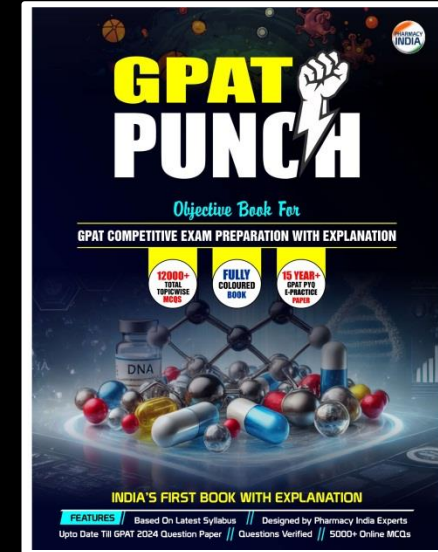
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14.

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



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VON GIERKE DISEASE

GLYCOGEN STORAGE DISEASE TYPE I



WHAT IT IS

Glycogen storage disease type I.



CAUSE

Deficiency of glucose-6-phosphatase.



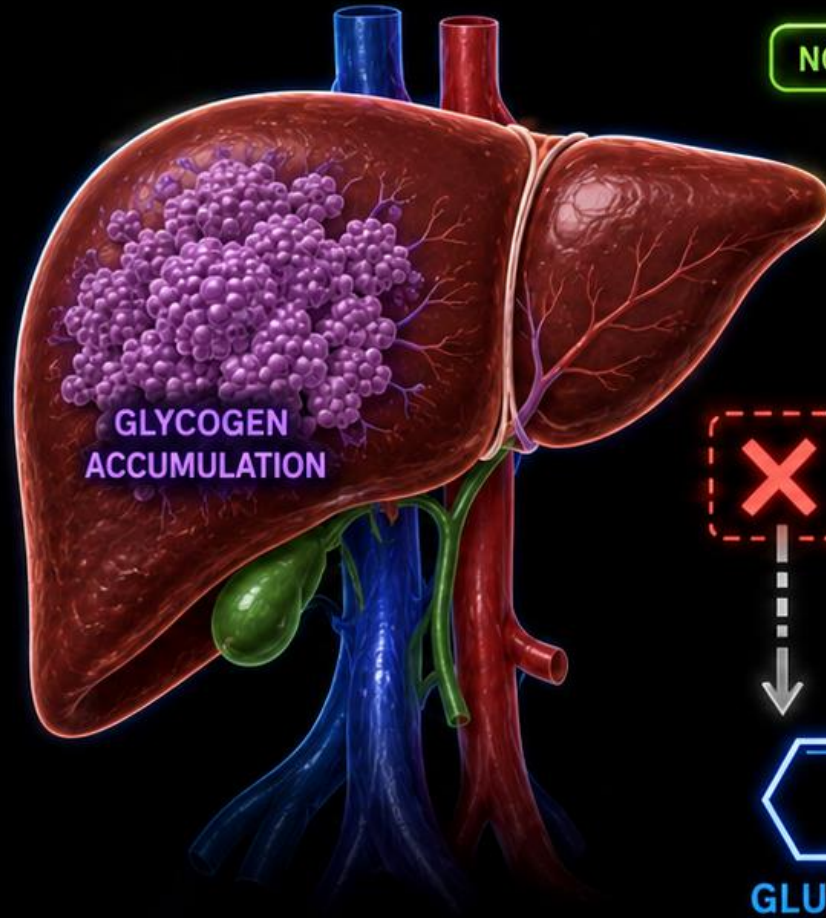
DEFECT

Glucose-6-phosphate cannot be converted to free glucose.

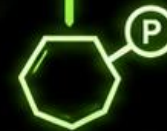


CONSEQUENCE

Glycogen accumulation and severe fasting hypoglycemia.



NORMAL PATHWAY



GLUCOSE-6-PHOSPHATE



GLUCOSE-6-PHOSPHATASE (DEFICIENCY)



GLUCOSE



KEY ORGAN

Liver involvement is important.



CLINICAL IMPACT

- Fasting hypoglycemia
- Hepatomegaly
- Lactic acidosis
- Hyperuricemia
- Hyperlipidemia



MANAGEMENT PRINCIPLES

- Frequent feeds / cornstarch
- Avoid prolonged fasting
- Monitor glucose and metabolic complications



ENZYME DEFICIENCY BLOCKS THE CONVERSION OF **GLUCOSE-6-PHOSPHATE** TO **GLUCOSE**, CAUSING **GLYCOGEN ACCUMULATION** IN THE LIVER AND **LIFE-THREATENING HYPOGLYCEMIA**.





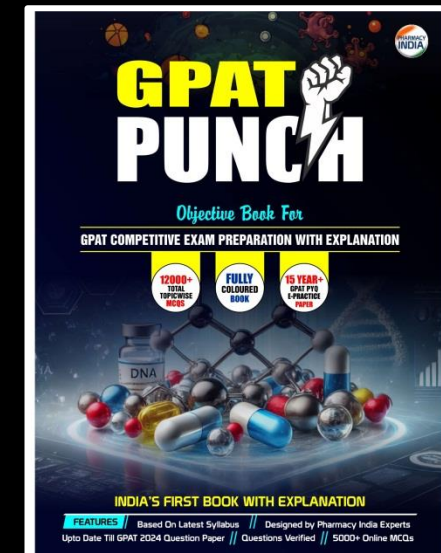
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15.

Galactose and glucose are: [GPAT-2018]

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



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15.

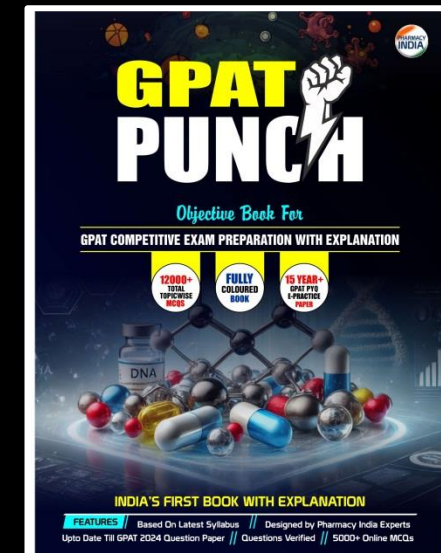
Galactose and glucose are: [GPAT-2018]

(a) Epimers

(b) Anomers

(c) Isomers

(d) Ketose-aldose isomers



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GLUCOSE AND GALACTOSE

• A CLASSIC C-4 EPIMER PAIR •



EPIMERS

Glucose and galactose are epimers.



DIFFER AT C-4

They differ only at carbon-4.



ALDOHEXOSES

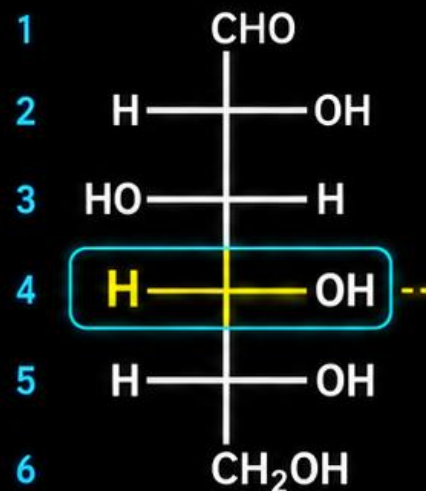
Both are aldohexoses.



IMPORTANCE

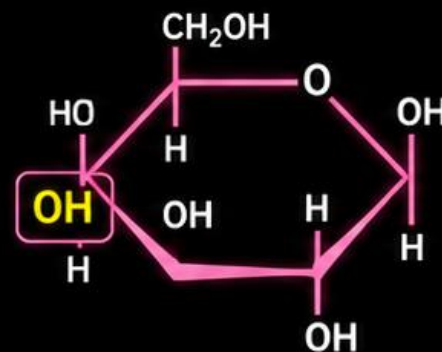
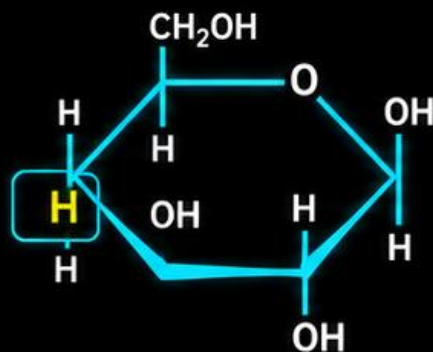
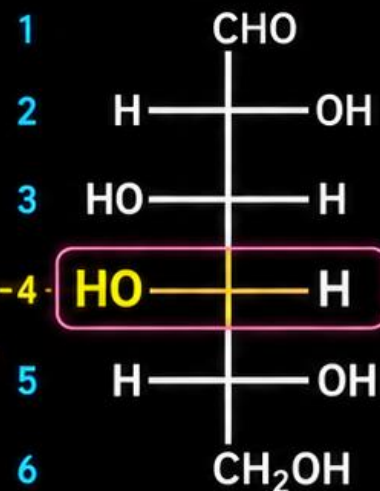
Important in metabolism and biochemistry.

GLUCOSE



C-4
DIFFERENCE

GALACTOSE



DEFINITION

Epimers are diastereomers that differ at only one chiral carbon.



STRUCTURE

Mirror images at carbon-4 create different spatial arrangements.



NATURAL OCCURRENCE

Glucose: abundant energy source.
Galactose: component of lactose.



KEY TAKEAWAY

Same formula, same function class, different configuration at C-4.



GLUCOSE AND **GALACTOSE** are **ALDOHEXOSES** that differ **ONLY** at **CARBON-4**.
This makes them a **CLASSIC C-4 EPIMER PAIR**.

ARJUNA SERIES

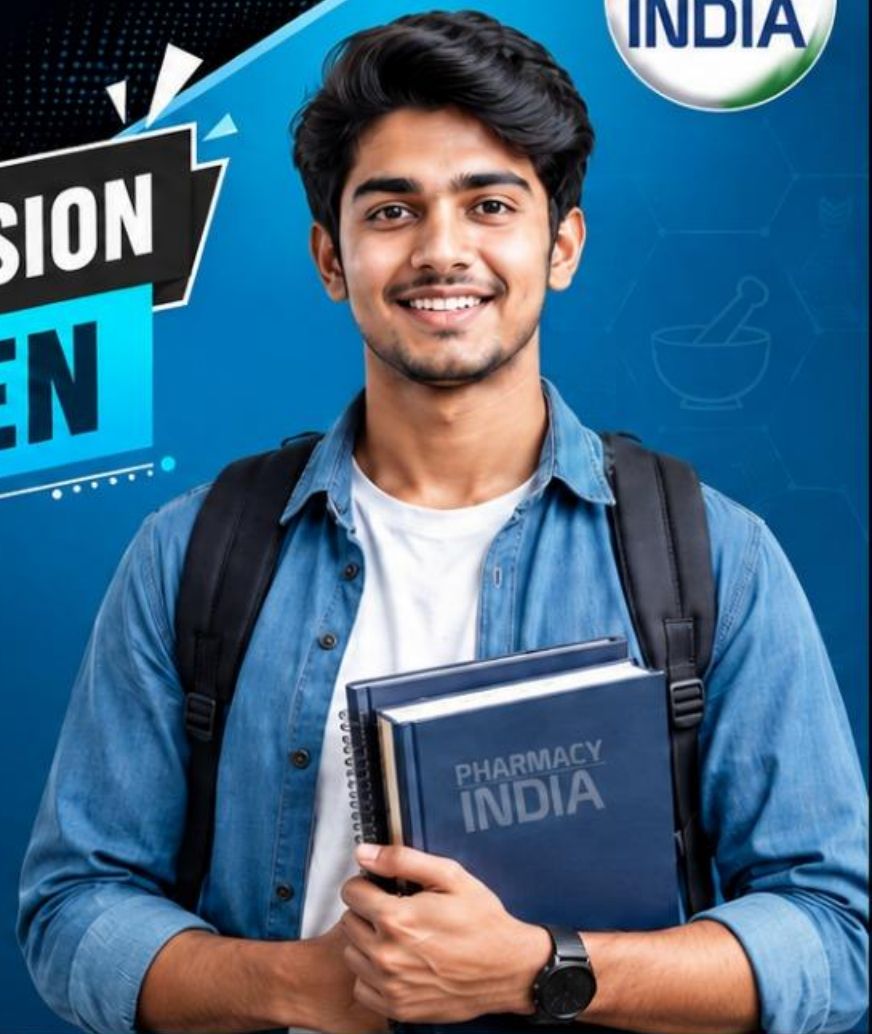
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16.

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



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16.

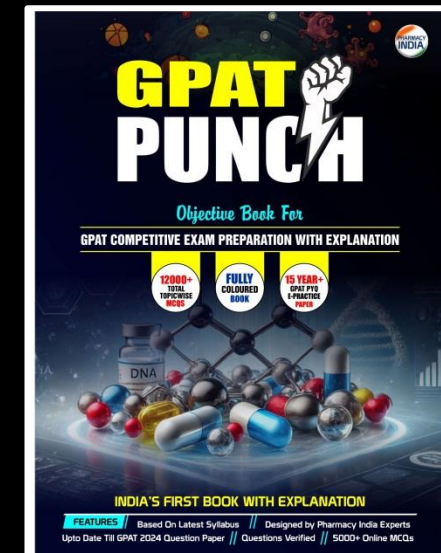
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(c) Two NADPH to one ribulose-5-phosphate

(d) Two NADPH to one fructose-6-phosphate



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HEXOSE MONOPHOSPHATE PATHWAY

Also known as Pentose Phosphate Pathway (PPP)



WHAT IS IT?

A parallel pathway to glycolysis operating in the cytosol.



WHERE?

Cytosol of all cells; especially active in liver, adipose tissue, lactating mammary gland, RBCs.



STARTING SUBSTRATE

Glucose-6-phosphate enters the pathway.

GLUCOSE-6-PHOSPHATE

MAIN USEFUL PRODUCTS

OXIDATIVE PHASE

Irreversible, produces NADPH and CO₂.

NADPH

NADPH

NON-OXIDATIVE PHASE

Reversible, rearranges sugar carbons.

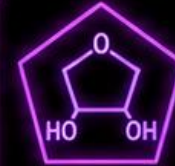
RIBOSE-5-PHOSPHATE



NADPH FUNCTIONS

NADPH

- Provides reducing power for reductive biosynthesis (fatty acids, cholesterol, steroids).
- Maintains reduced glutathione and supports antioxidant defense against oxidative stress.



RIBOSE-5-PHOSPHATE

- Essential precursor for nucleotide synthesis (DNA, RNA, ATP, GTP).



OUTPUT RATIO

2 NADPH : 1 RIBOSE-5-PHOSPHATE



KEY TAKEAWAY

The Hexose Monophosphate Pathway generates **2 NADPH** and **1 ribose-5-phosphate**, fueling reductive biosynthesis, antioxidant defense, and nucleotide synthesis.

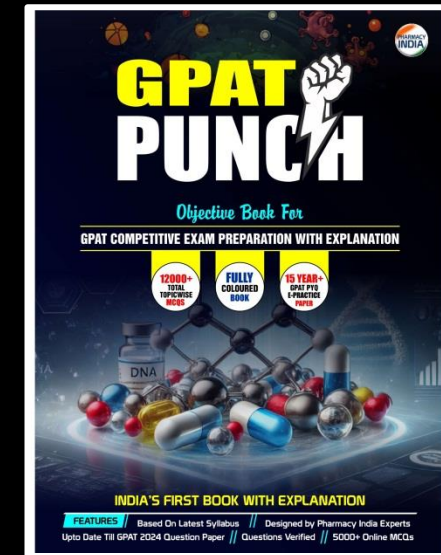


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17. The major component of liquid glucose is _____ and is prepared from: [GPAT-2017]

- (a) Maltose, pectin
- (b) Dextrin, starch
- (c) Dextrose, starch
- (d) Glucose, starch



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17.

The major component of liquid glucose is _____ and is prepared from: [GPAT-2017]

- (a) Maltose, pectin
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- (c) Dextrose, starch
- (d) Glucose, starch



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LIQUID GLUCOSE

STARCH TO DEXTROSE • NATURAL • SAFE • VERSATILE



MAJOR COMPONENT

The major component is **DEXTROSE**.



PREPARED BY HYDROLYSIS

Prepared by **HYDROLYSIS** of **STARCH**.



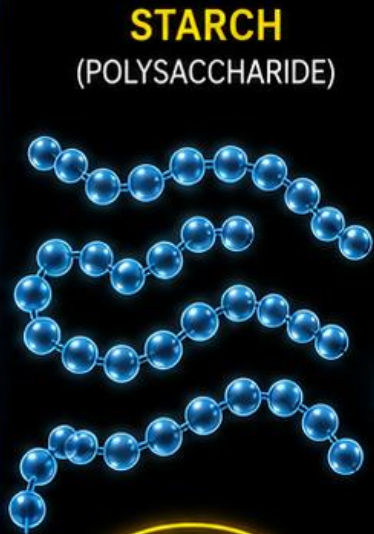
SYRUPY NATURE

It is a **SYRUPY** carbohydrate preparation.



STARTING RAW MATERIAL

STARCH is the starting raw material.



STARCH
(RAW MATERIAL)

HYDROLYSIS



WATER



LIQUID GLUCOSE
(DEXTROSE SYRUP)



QUICK ENERGY

Readily absorbed source of energy.



HIGH SOLUBILITY

Easily soluble in water; forms clear solutions.



HUMECTANT

Helps retain moisture in products.



SWEET & MILD

Mild sweetness with good stability.



WIDELY USED

Used in foods, beverages, pharmaceuticals and confections.



LIQUID GLUCOSE (DEXTROSE) – A **NATURAL**, **SYRUPY** CARBOHYDRATE MADE BY **HYDROLYSIS** OF **STARCH**.

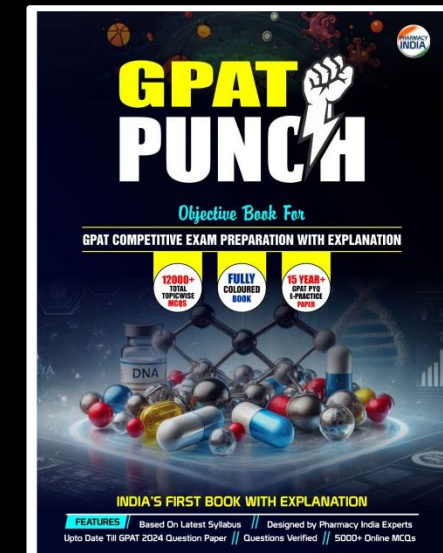




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18. Match the following. [GPAT-2016]

1. Mirror image of each other	[P] Epimer
2. α and β -cyclic forms of D-glucose	[Q] Pyranose and furanose form
3. Two monosaccharides differ around a specific carbon atom	[R] Anomer
4. Structure of glucose	[S] Enantiomer



(a) 1-[S], 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]



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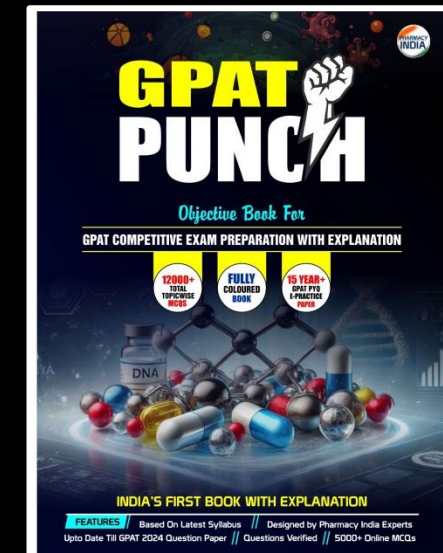
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(a) 1-[S], 2-[Q], 3-[P], 4-[R]

(c) 1-[P], 2-[R], 3-[S], 4-[Q]

(b) 1-[S], 2-[R], 3-[P], 4-[Q]

(d) 1-[S], 2-[P], 3-[R], 4-[Q]



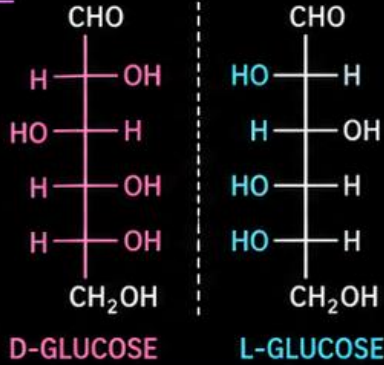
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CARBOHYDRATE RELATIONSHIPS



ENANTIOMER

- Mirror images of each other.
- Non-superimposable mirror forms.
- All D-sugars have L-enantiomers.



ENANTIOMER

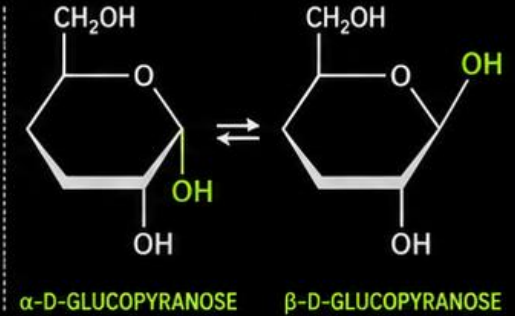


ANOMER



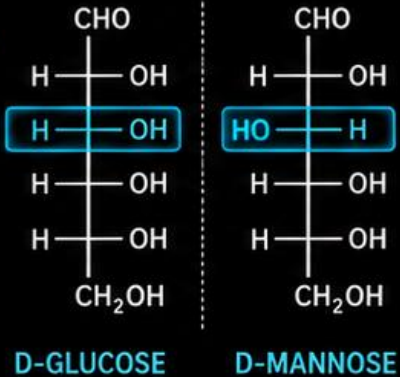
ANOMER

- Alpha and beta cyclic forms are anomers.
- They differ at the anomeric carbon (C1 in aldoses).
- Interconvert in solution.



EPIMER

- Monosaccharides differing at one (and only one) chiral carbon.
- Examples: D-glucose & D-mannose (C2 epimers).



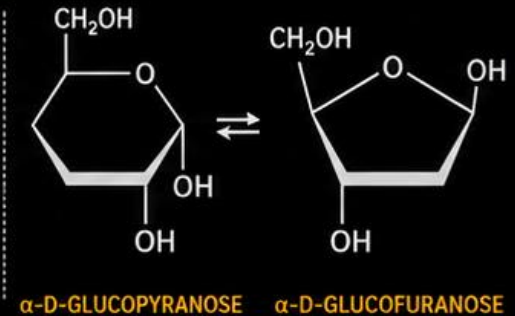
EPIMER

PYRANOSE / FURANOSE



PYRANOSE / FURANOSE

- Glucose can exist in pyranose (6-membered) and furanose (5-membered) ring forms.
- Interconvert in solution.



Same molecular formula, different relationships: **Mirror images (Enantiomers)** | **Anomeric difference (Anomers)** | **Single carbon difference (Epimers)** | **Ring size difference (Pyranose/Furanose)**



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-bisphosphate
- (d) Phosphoenolpyruvate to pyruvate



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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-bisphosphate
- (d) Phosphoenolpyruvate to pyruvate**



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≡ ATP GENERATION IN GLYCOLYSIS ≡

→ THE FINAL STEP THAT PAYS OFF →



WHAT HAPPENS

Phosphoenolpyruvate converts to **pyruvate**.



ENZYME

Pyruvate kinase catalyzes this step.



ATP GENERATED

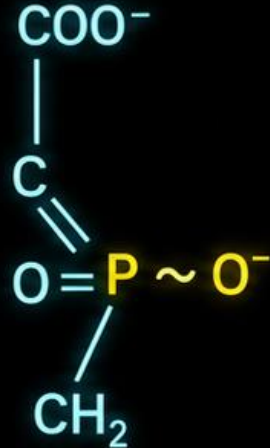
This step generates **ATP**.



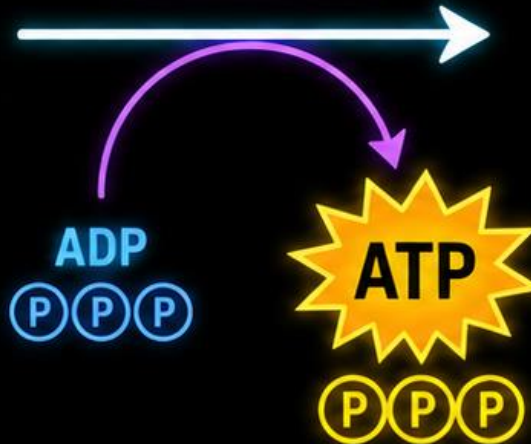
KEY POINT

It is a **substrate-level phosphorylation** step.

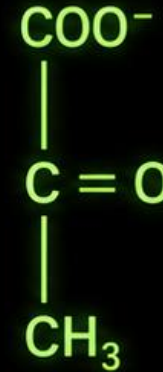
PHOSPHOENOLPYRUVATE
(PEP)



PYRUVATE
KINASE



PYRUVATE



WHERE IN GLYCOLYSIS

This is **Step 10**, the final step.



NET ATP YIELD

Generates **1 ATP** per PEP.



WHY IT MATTERS

Provides energy and enables regeneration of **NAD⁺** earlier.



REMEMBER

PEP has high-energy phosphate that drives **ATP** formation.



IN SHORT

PEP (high-energy phosphate) + **ADP** → **Pyruvate** + **ATP** via **pyruvate kinase**.

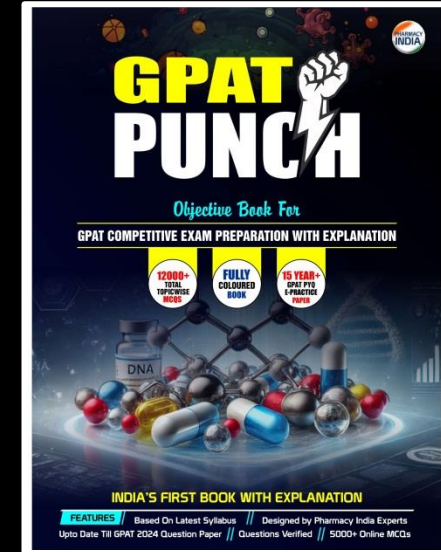


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20.

Chitin gets converted into chitosan upon: [GPAT-2014]

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



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20.

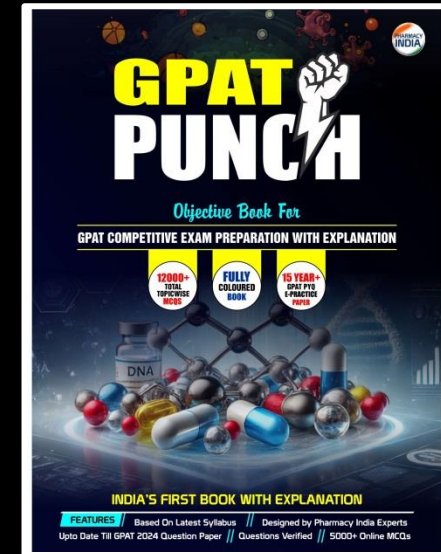
Chitin gets converted into chitosan upon: [GPAT-2014]

(a) Acetylation

(b) Deacetylation

(c) Oxidation

(d) Reduction



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CHITOSAN FORMATION

From Chitin to Chitosan by Deacetylation



NATURAL SOURCE

Chitin is a natural polysaccharide found in the exoskeletons of crustaceans, insects and fungal cell walls.

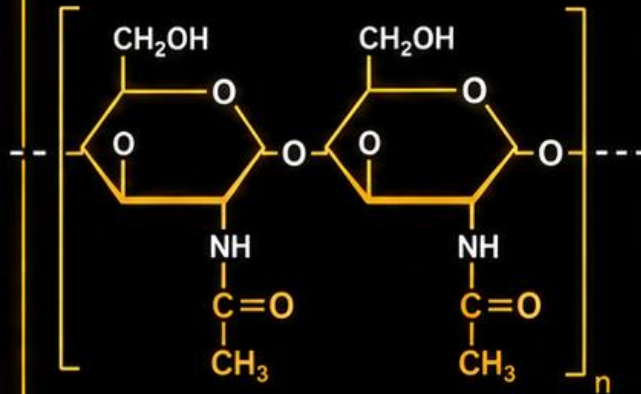


POLYSACCHARIDE

Chitin and chitosan are linear polysaccharide polymers.

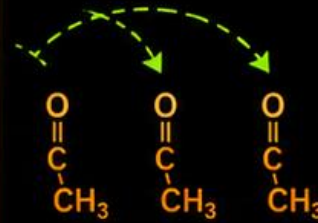
CHITIN

N-acetyl-D-glucosamine polymer



● Acetyl group ($-\text{COCH}_3$) present on amino group

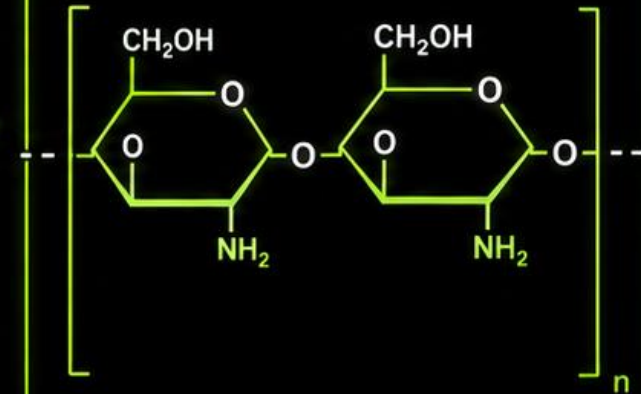
DEACETYLATION



Acetyl groups removed

CHITOSAN

D-glucosamine polymer



● Amino group ($-\text{NH}_2$) after deacetylation



DEACETYLATION

Chitosan is obtained from chitin through deacetylation, typically using alkaline treatment.



POLYMER CHANGE

Removal of acetyl groups converts N-acetyl-D-glucosamine units into D-glucosamine units.

KEY TAKEAWAYS



BIODEGRADABLE

Both chitin and chitosan are biodegradable and biocompatible.



BIOACTIVE

Chitosan exhibits antimicrobial, antioxidant and immune-modulating properties.



WATER-SOLUBLE IN ACID

Chitosan dissolves in acidic solutions due to protonation of $-\text{NH}_2$ groups.



WIDE APPLICATIONS

Used in biomedical, food, pharmaceutical, agriculture and environmental applications.



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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



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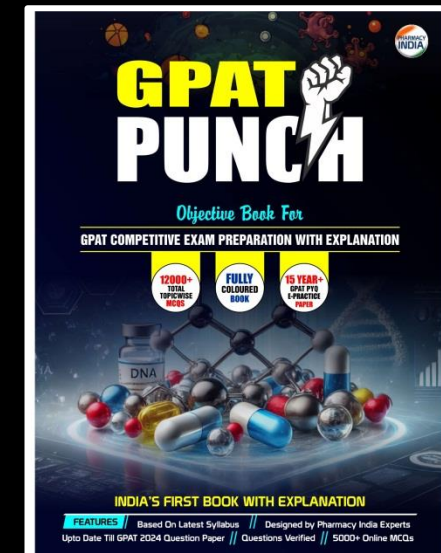
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- (a) An acetal
- (b) A hemiacetal
- (c) A simple ether
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DEFINITION

A hemiacetal carbon carries one -OH and one -OR group.



FORMATION

Commonly formed during cyclization of **monosaccharides**.



ANOMERIC CARBON

The hemiacetal carbon is the **anomeric carbon**.



FREE HYDROXYL

Contains a free anomeric hydroxyl group (-OH).



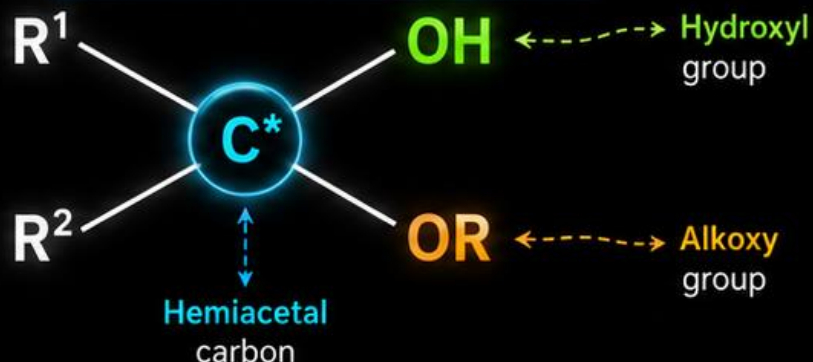
KEY POINTS

- A hemiacetal has both -OH and -OR on the same carbon.
- In sugars, this carbon is the **anomeric carbon**.
- It can exist as α and β anomers.
- It can further react to form **acetal / glycoside**.

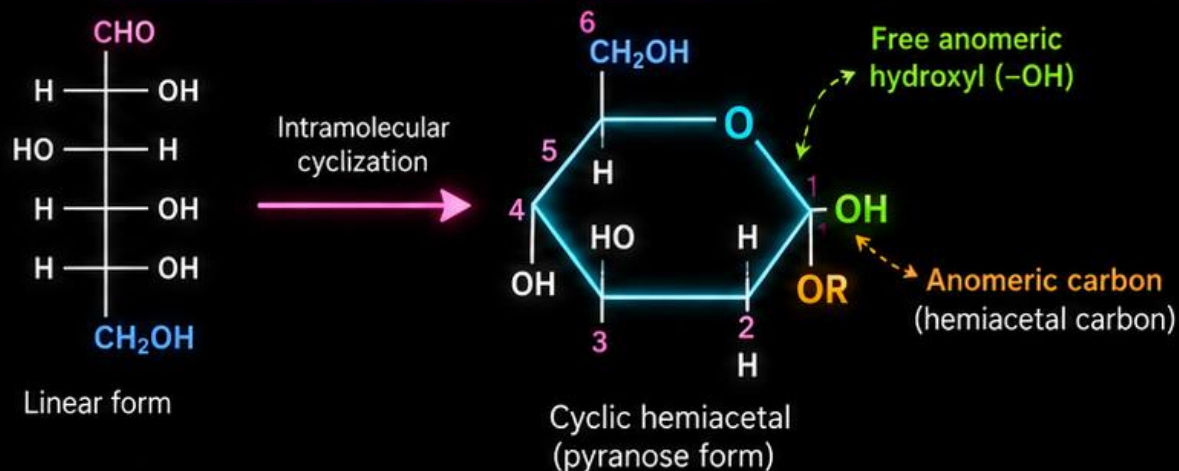
HEMIACETAL

A functional group with one -OH and one -OR attached to the same carbon

GENERAL STRUCTURE



EXAMPLE: CYCLIC SUGAR (GLUCOSE)



REACTIVITY

Can react with another alcohol to form an **acetal (glycoside)**.



CAN FORM ACETAL

The hemiacetal can be converted to an **acetal** in presence of acid.



IMPORTANCE

Key in **carbohydrate** structure, **mutarotation** and **glycoside bond** formation.



FATE

HEMIACETAL

+ ROH (alcohol)
 H^+ (acid catalyst)

ACETAL (GLYCOSIDE)

The free -OH is replaced by -OR to form acetal.



REMEMBER: One carbon • One -OH • One -OR = **HEMIACETAL**



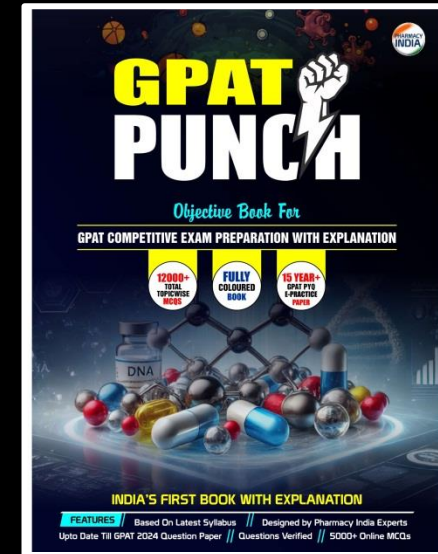
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22.

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



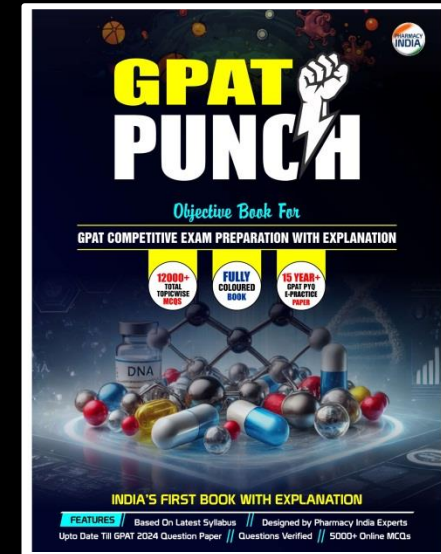
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GLUCOSE IS THE ESSENTIAL FUEL

RBCs rely solely on glucose for energy



ATP POWERS VITAL FUNCTIONS

- Membrane ion pumps (Na^+/K^+ ATPase)
- Cell shape & flexibility
- Hemoglobin function



GLYCOLYSIS PRODUCES 2,3-BPG

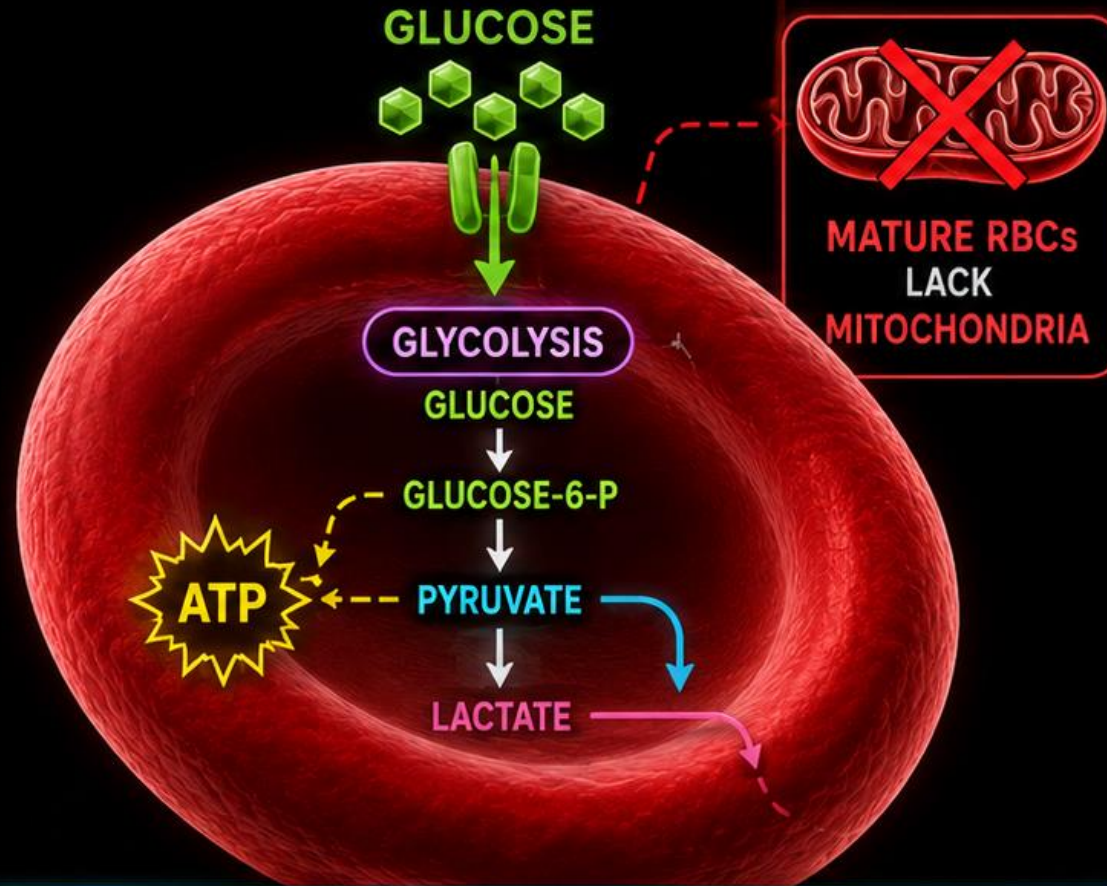
Regulates oxygen release from hemoglobin



NO NUCLEUS, NO MITOCHONDRIA

Specialized only for oxygen transport

RBCs DEPEND ON GLUCOSE



ATP IS PRODUCED BY ANAEROBIC GLYCOLYSIS

No oxygen required



FATTY ACID OXIDATION AND TCA CYCLE DO NOT OCCUR

No mitochondria = no aerobic respiration



LACTATE IS THE MAJOR END PRODUCT

Exported to plasma



RBCs CANNOT STORE GLYCOGEN IN LARGE AMOUNTS

Continuous glucose supply is essential



GLUCOSE ENTERS RBC



ANAEROBIC GLYCOLYSIS



ATP PRODUCED



LACTATE RELEASED

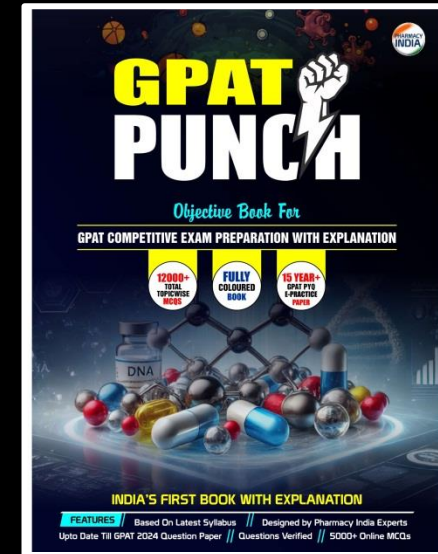


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23.

Which of the following is an example of a heteropolysaccharide?

- (a) Starch
- (b) Glycogen
- (c) Inulin
- (d) Hyaluronic acid



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23.

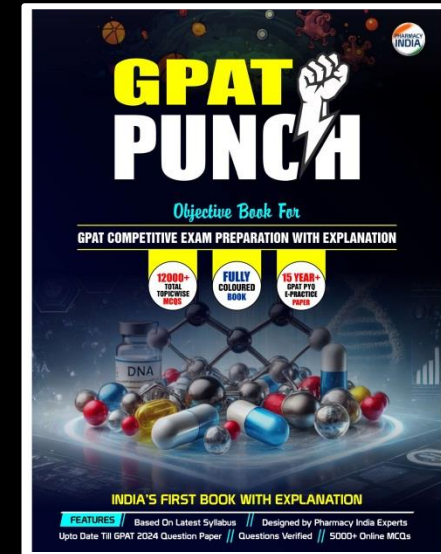
Which of the following is an example of a heteropolysaccharide?

(a) Starch

(b) Glycogen

(c) Inulin

(d) Hyaluronic acid



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WHAT IS IT?

A high molecular weight, **non-sulfated**, linear **heteropolysaccharide**.



HYALURONIC ACID



Hyaluronic acid is a heteropolysaccharide



STRUCTURE

Built from repeating **disaccharide** units. Long, unbranched polymer.



COMPOSITION

Contains **glucuronic acid** + **N-acetylglucosamine** (**GlcA** + **GlcNAc**).



CHEMICAL NATURE

Anionic due to carboxyl group of glucuronic acid. Highly hydrophilic.



HYDRATION POWER

Can bind up to **1000** times its weight in water.



VISCOELASTIC

Provides both viscous and elastic properties to tissues.



PROTECTIVE

Cushions tissues and protects against compression.



ROLE IN HEALING

Promotes cell migration, proliferation and wound healing.



CLINICAL USES

Used in injections (osteoarthritis), dermal fillers, and eye surgery.



BIOSYNTHESIS

Synthesized at the inner surface of plasma membrane by hyaluronan synthase enzymes.



QUICK FACT

Hyaluronic acid is not sulfated and is one of the few glycosaminoglycans that is not covalently attached to a core protein.



HIGHLY IMPORTANT

Essential for tissue hydration, joint health, and extracellular matrix integrity.



WHERE IS IT FOUND?

Abundant in connective tissue, synovial fluid, vitreous humor, and extracellular matrix.



KEY FUNCTIONS

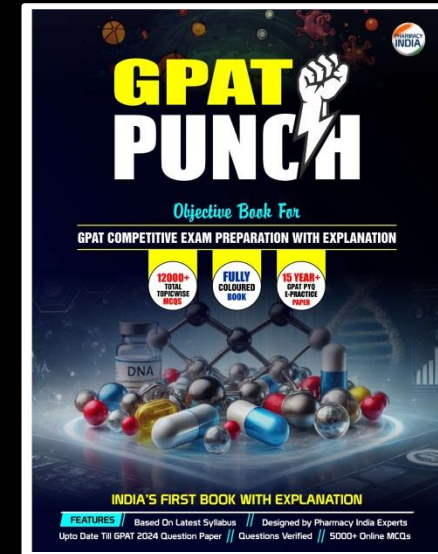
- ✓ Lubrication (reduces friction)
- ✓ Hydration (binds water)
- ✓ Shock absorption
- ✓ Supports tissue repair
- ✓ Maintains viscoelasticity



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24. Among the following, which one is non-reducing and also does not exhibit mutarotation? [GPAT-2012]

- (a) Glucose
- (b) Maltose
- (c) Lactose
- (d) Sucrose



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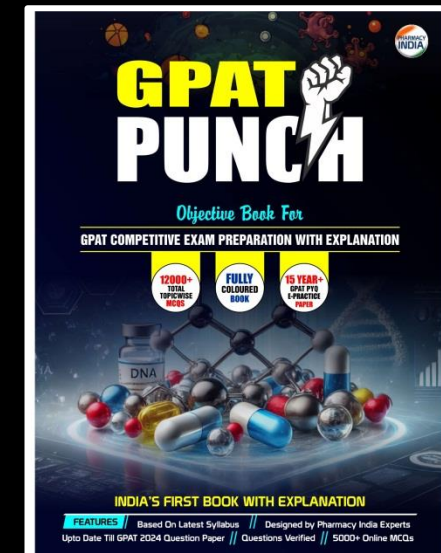
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- (a) Glucose
- (b) Maltose
- (c) Lactose
- (d) Sucrose



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SUCROSE IS A
NON-REDUCING
DISACCHARIDE



BOTH ANOMERIC
CARBONS ARE
INVOLVED IN THE
GLYCOSIDIC BOND



NO FREE
ANOMERIC
CARBON
REMAINS



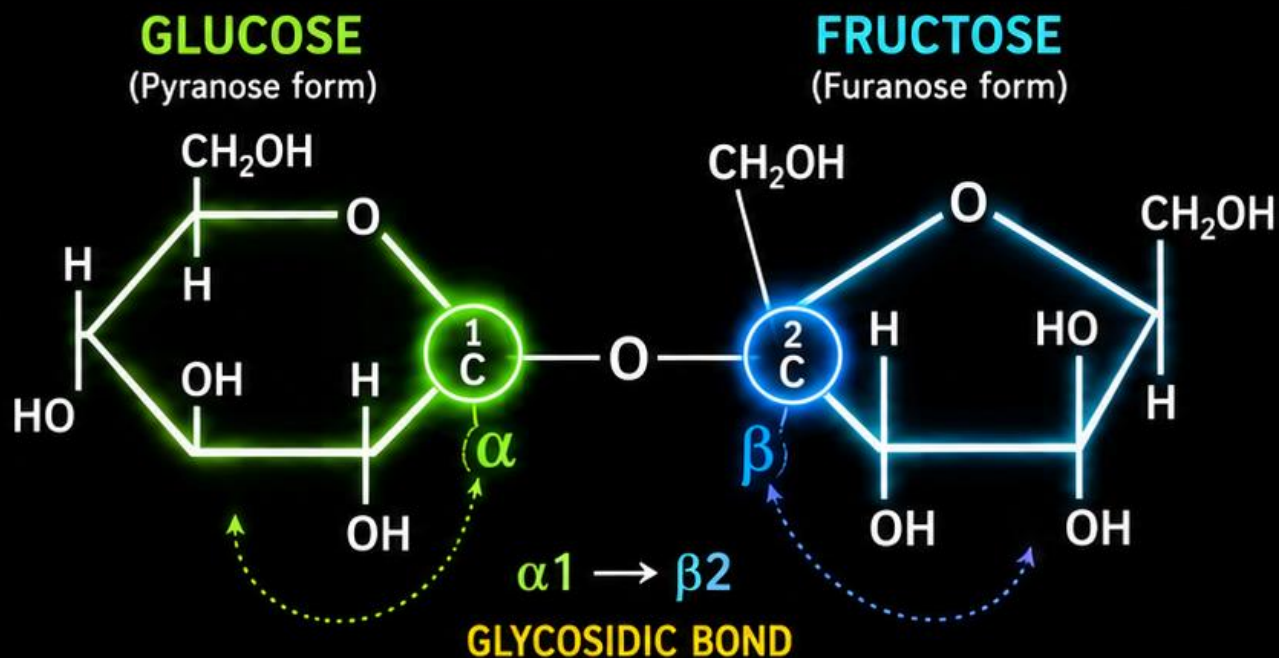
DOES NOT
SHOW
MUTAROTATION



STABLE IN
NEUTRAL
SOLUTION

SUCROSE

The Table Sugar



COMPOSED OF
GLUCOSE + **FRUCTOSE**



Molecular Formula



NON-REDUCING
DISACCHARIDE



No free anomeric
carbon to open ring
and act as reducing
agent

NON-REDUCING



DOES NOT REDUCE
TOLLENS' OR FEHLING'S
SOLUTION

KEY TAKEAWAYS



COMMON TABLE
SUGAR



SWEET TASTE &
ENERGY SOURCE



FOUND IN SUGARCANE,
SUGAR BEET, FRUITS



STABLE IN NEUTRAL
SOLUTION



MELTING POINT
~186 °C



HIGHLY SOLUBLE
IN WATER





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25.

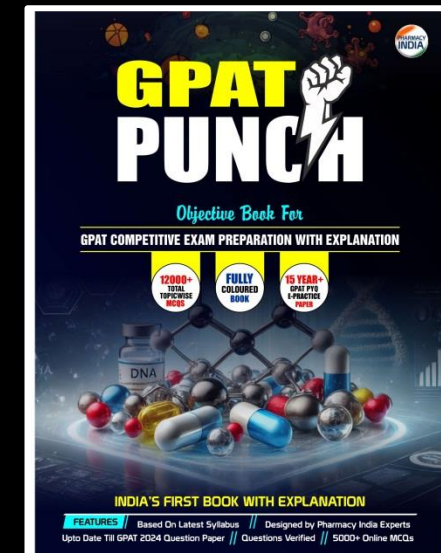
Establishing a complete structure of _____ is more complex problem than others. [GPAT-2023 SHIFT-I]

(a) Polysaccharide

(b) Protein

(c) Nucleic acid

(d) Peptide



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25.

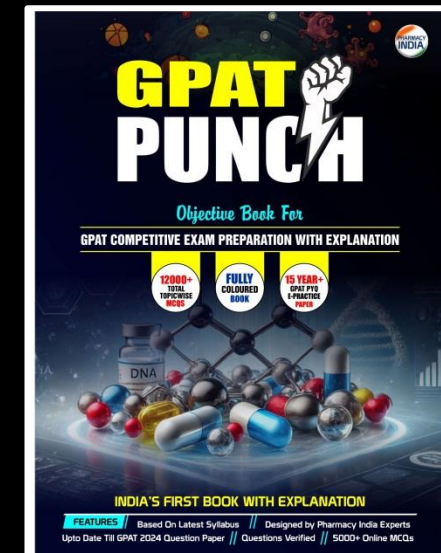
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(c) Nucleic acid

(d) Peptide



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POLYSACCHARIDES ARE STRUCTURALLY COMPLEX



POLYSACCHARIDES HAVE COMPLEX THREE-DIMENSIONAL STRUCTURE



DIFFERENT MONOSACCHARIDES MAY BE PRESENT



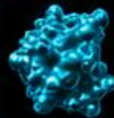
LINKAGES MAY BE α OR β



BOND POSITIONS VARY 1 $\rightarrow$ 4, 1 $\rightarrow$ 6, ETC.



BRANCHING GREATLY INCREASES COMPLEXITY



STRUCTURE DETERMINATION IS MORE DIFFICULT THAN SIMPLE BIOMOLECULES

Long chains of monosaccharides linked by glycosidic bonds

LINEAR POLYSACCHARIDE



EXAMPLE UNIT SEQUENCE



LINKAGE PATTERN

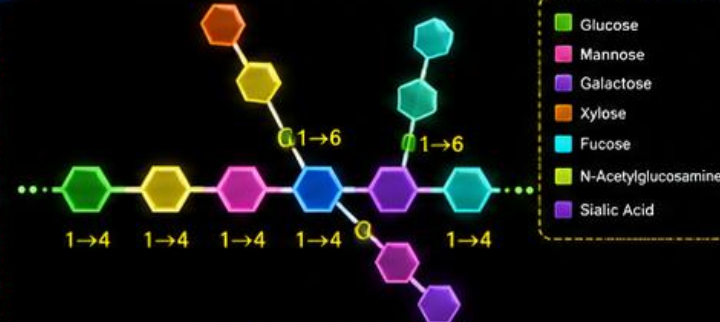
$\rightarrow$ 4) α -D-Glc-(1 $\rightarrow$ 4) α -D-Glc-(1 $\rightarrow$ 4) α -D-Man-(1 $\rightarrow$ 4) ...

KEY FEATURES

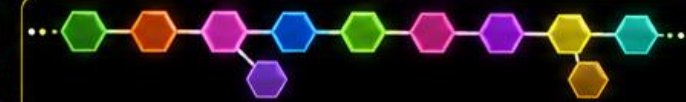
- Uniform or repeating linkage pattern
- Straight chains
- Fewer structural variations
- Example: Starch (amylose), Cellulose

VS

BRANCHED POLYSACCHARIDE



EXAMPLE UNIT SEQUENCE



LINKAGE PATTERN

$\rightarrow$ 4) α -D-Glc-(1 $\rightarrow$ 4) α -D-Glc-(1 $\rightarrow$ 6) α -D-Glc-(1 $\rightarrow$ 4) β -D-Gal-(1 $\rightarrow$ 4) ...

KEY FEATURES

- Multiple linkage types (1 $\rightarrow$ 4, 1 $\rightarrow$ 6, etc.)
- Branch points create diverse architectures
- Many possible sequences and shapes
- Example: Glycogen, Amylopectin, Peptidoglycan



HIGH DIVERSITY
Many monosaccharides and linkages create enormous variety



THREE-DIMENSIONAL FOLDING
Chains fold into complex 3D conformations



FUNCTION DEPENDS ON STRUCTURE
Storage, structural support, recognition, protection



ANALYTICAL CHALLENGE
Large size and branching make analysis and structure determination more difficult



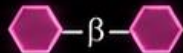
STRUCTURAL COMPLEXITY = BIOLOGICAL VERSATILITY
Complex structures enable polysaccharides to perform essential life functions

COMMON LINKAGE TYPES

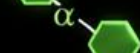
α (1 $\rightarrow$ 4)



β (1 $\rightarrow$ 4)



α (1 $\rightarrow$ 6)



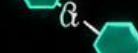
α (1 $\rightarrow$ 3)



β (1 $\rightarrow$ 3)



α (1 $\rightarrow$ 2)



α (2 $\rightarrow$ 6)





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26.

Two possible targets against which inhibitors can be designed for use in diabetes treatment are: [GATE-2006]

[P] Carbonic anhydrase

[Q] Insulin

[R] Glycogen phosphorylase

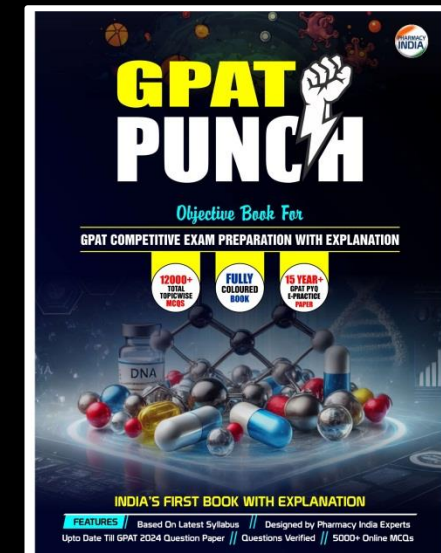
[S] Glucose-6-phosphatase

(a) [Q], [S]

(b) [R], [S]

(c) [P], [R]

(d) [Q], [R]



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Two possible targets against which inhibitors can be designed for use in diabetes treatment are: [GATE-2006]

[P] Carbonic anhydrase

[Q] Insulin

[R] Glycogen phosphorylase

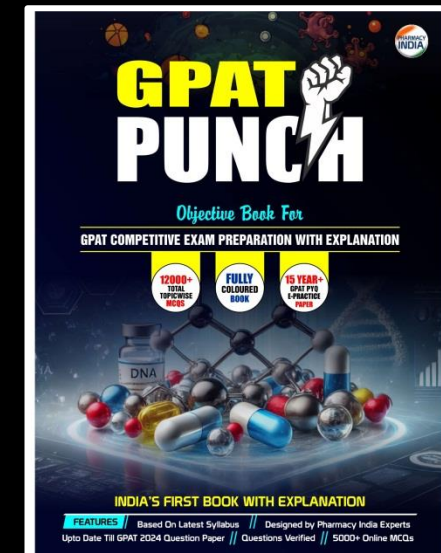
[S] Glucose-6-phosphatase

(a) [Q], [S]

(b) [R], [S]

(c) [P], [R]

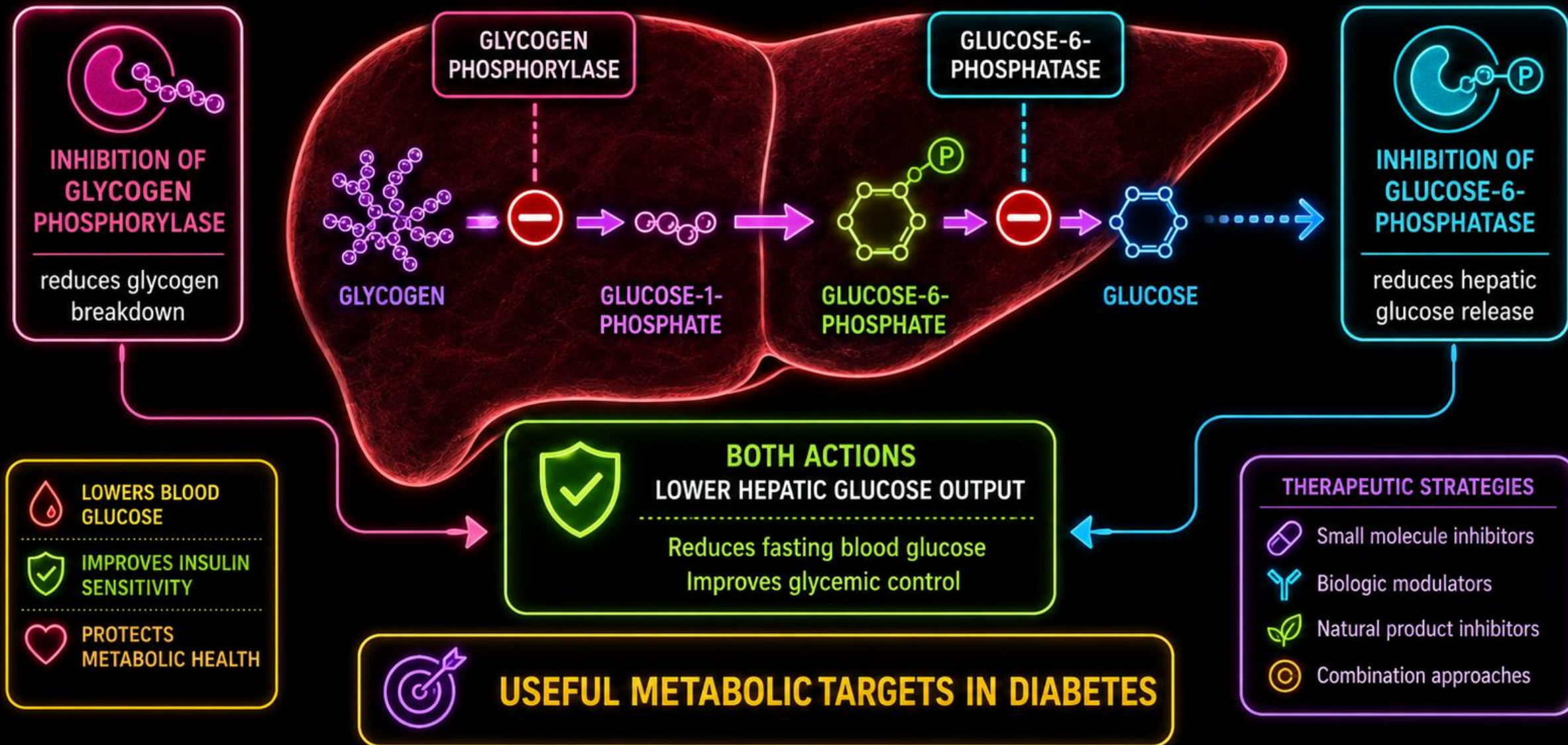
(d) [Q], [R]



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DIABETES THERAPEUTIC TARGETS

• KEY HEPATIC PATHWAY FOR GLUCOSE PRODUCTION •



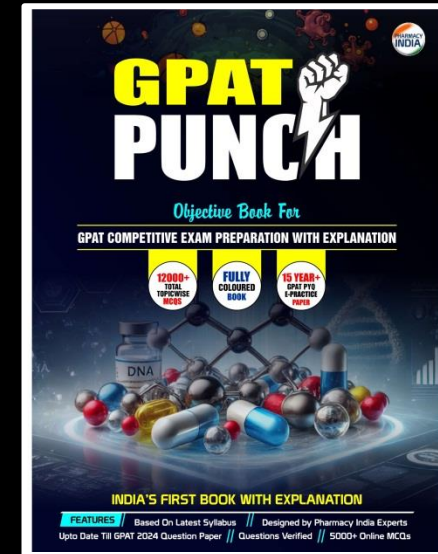


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27.

In glucose metabolism, name the enzyme catalyzing the conversion of glucose to glucose-6-phosphate. [GATE-2004]

- (a) Hexokinase
- (b) Glucose-6-phosphate dehydrogenase
- (c) Glycogen phosphorylase
- (d) Glycogen synthase



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- (c) Glycogen phosphorylase
- (d) Glycogen synthase



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HEXOKINASE

Hexokinase catalyzes the **first step** of **glycolysis**



WHAT IT DOES

Phosphorylates glucose to **glucose-6-phosphate**.



USES ATP

Transfers a phosphate group from **ATP**.



TRAPS GLUCOSE

Produces G-6-P, which cannot cross the cell membrane easily.



REGULATES ENTRY

Controls glucose entry into glycolysis.



LIVER NOTE

In liver, **glucokinase** performs a similar role.



WHERE IT WORKS

Found in the **cytoplasm** of most cells.

ROLE IN GLYCOLYSIS



This is **Step 1** of glycolysis.

REQUIRES



Magnesium

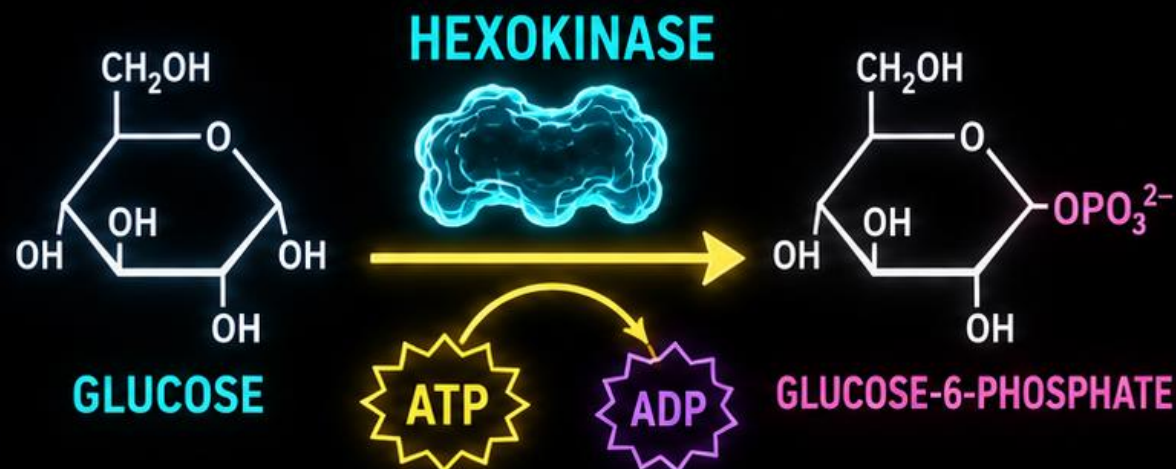


ATP

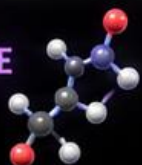
PHYSIOLOGICAL IMPORTANCE



Essential for energy production and maintaining **low blood glucose**.



GLUCOSE



1
HEXOKINASE

2
PHOSPHOGLUCOSE
ISOMERASE

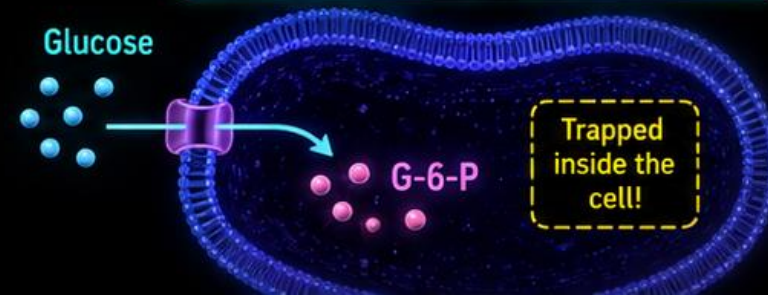
3
PHOSPHOFRUCTOKINASE-1

4
ALDOLASE

PYRUVATE



Glucose

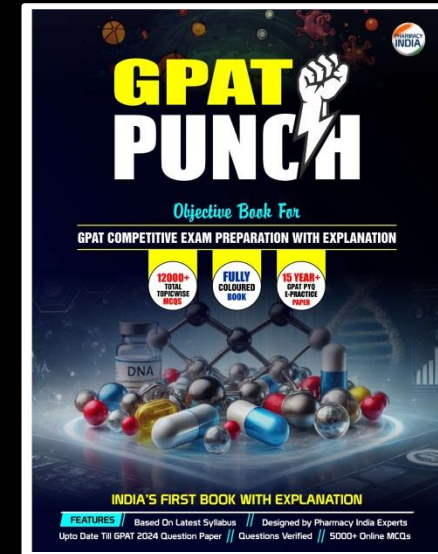




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28. Conversion of 2-phosphoglycerate to phosphoenolpyruvate is catalyzed by: [GATE-2004]

- (a) Pyruvate kinase
- (b) Phosphoglycerate mutase
- (c) Phosphoglycerate kinase
- (d) Enolase



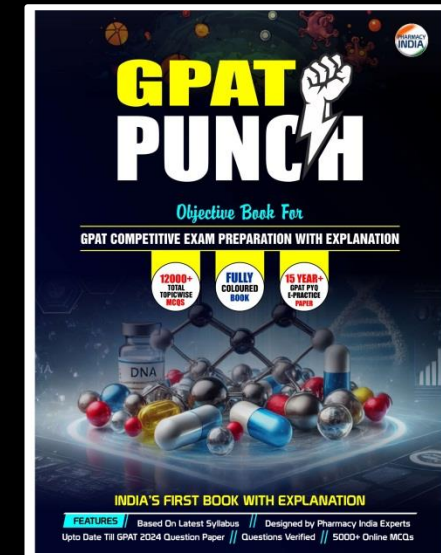
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- (a) Pyruvate kinase
- (b) Phosphoglycerate mutase
- (c) Phosphoglycerate kinase
- (d) Enolase



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ENOLASE



Enolase
catalyzes conversion
of 2-phosphoglycerate
to phosphoenolpyruvate



This is a
dehydration
reaction



PEP is a
high-energy
intermediate

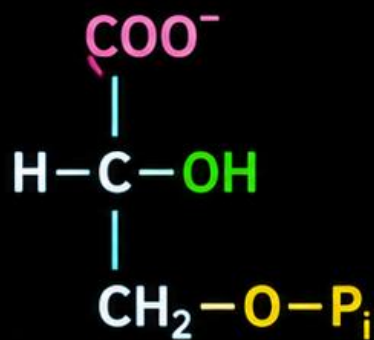


This step
belongs to
glycolysis



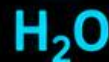
Essential for
energy
production

Enolase catalyzes conversion of
2-phosphoglycerate to phosphoenolpyruvate



2-PHOSPHOGLYCERATE

ENOLASE



PHOSPHOENOLPYRUVATE
(PEP)

KEY POINTS



Dehydration
reaction



Forms a
high-energy
compound (PEP)

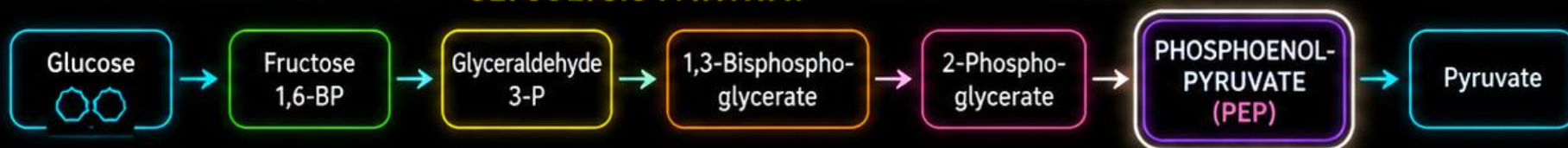


Prepares substrate
for **ATP**
generation



Reversible
under cellular
conditions

GLYCOLYSIS PATHWAY





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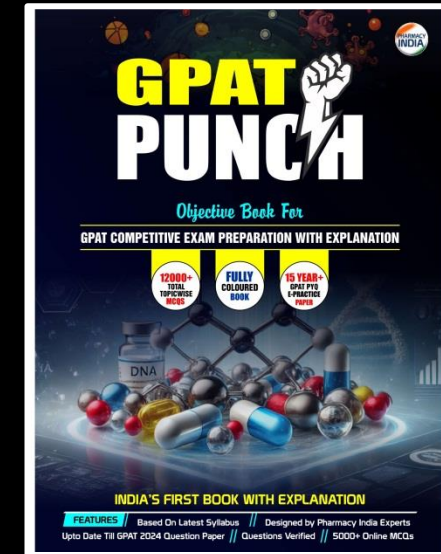


29.

Lactose intolerance is because of the lack of:

[GATE-2003]

- (a) Acid phosphatase
- (b) Lactate dehydrogenase
- (c) Galactose-1-phosphate uridyl transferase
- (d) Lactase



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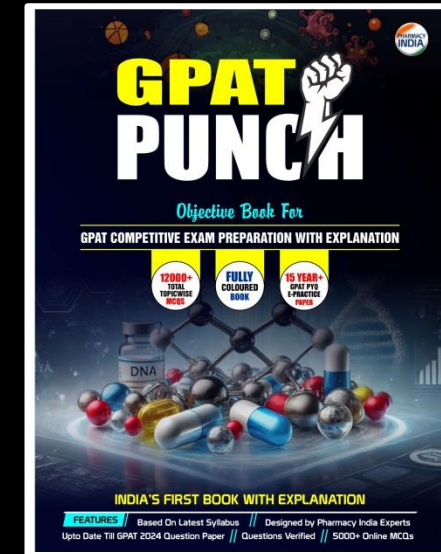


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- (c) Galactose-1-phosphate uridyl transferase
- (d) Lactase**



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LACTOSE INTOLERANCE



WHAT IS IT?

Inability to digest lactose, the sugar found in milk and dairy products.

NORMAL DIGESTION



Lactase hydrolyzes lactose into **glucose** + **galactose**



KEY FACT

Lactase is located in the intestinal **brush border**.



MILK



CHEESE



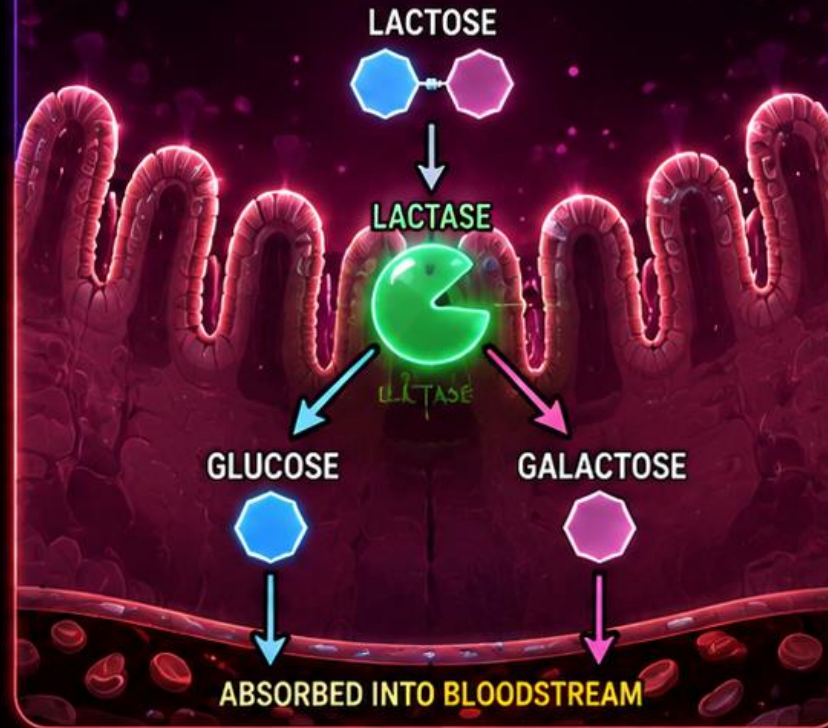
YOGURT



ICE CREAM

COMMON SOURCES

THE INTESTINAL BRUSH BORDER



LACTASE DEFICIENCY

LACTOSE



Deficiency of lactase causes **lactose intolerance**.

WHAT HAPPENS?



Undigested lactose reaches the colon, where bacteria ferment it.



GAS



BLOATING



DIARRHEA



ABDOMINAL CRAMPS

WHO IS AFFECTED?



More common in Asian, African, Hispanic, and Native American populations.

TIPS



Use lactose-free products



Lactase enzyme supplements



Small amounts may be tolerated



Ensure adequate calcium & vitamin D



ENZYME DEFICIENCY. REAL SYMPTOMS. EASY MANAGEMENT. | UNDERSTAND IT. MANAGE IT. LIVE COMFORTABLY.



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30.

The conversion of fructose-1,6-bisphosphate to glyceraldehyde-3-phosphate is catalyzed by: [GATE-2001]

- (a) Phosphoglycerate kinase
- (b) Enolase
- (c) Aldolase
- (d) Triose phosphate isomerase



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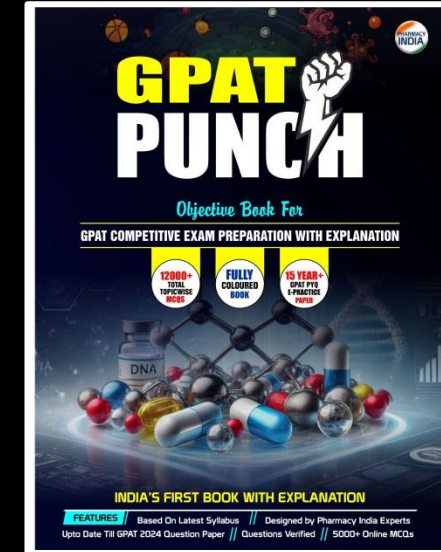
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- (a) Phosphoglycerate kinase
- (b) Enolase
- (c) Aldolase
- (d) Triose phosphate isomerase



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WHAT IT DOES

Aldolase **cleaves** fructose-1,6-bisphosphate.



REACTION TYPE

Aldol (C-C bond) cleavage.



PRODUCTS

Products are **G3P** and **DHAP**.



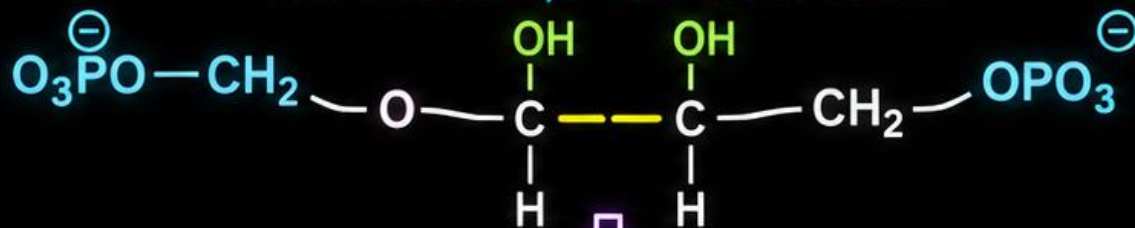
KEY STEP

This is a key cleavage step in glycolysis.

ALDOLASE

GLYCOLYSIS – CLEAVAGE STEP

FRUCTOSE-1,6-BISPHOSPHATE



ALDOLASE



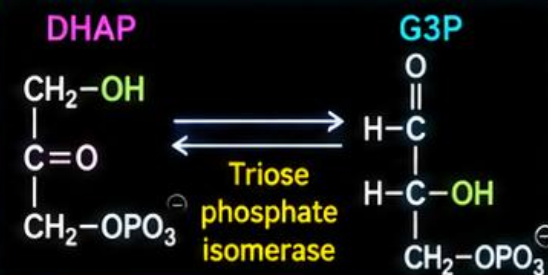
AT A GLANCE

- **Enzyme:** Aldolase
- **Step:** 4 of Glycolysis
- **Location:** Cytosol
- **Function:** Cleaves a 6-carbon sugar into two 3-carbon sugars



ISOMERIZATION

DHAP can be converted to **G3P** by **triose phosphate isomerase**.



Aldolase cleaves **fructose-1,6-bisphosphate** into **G3P** and **DHAP**.



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31.

Match the correct pathways of the following. [GATE-2000]

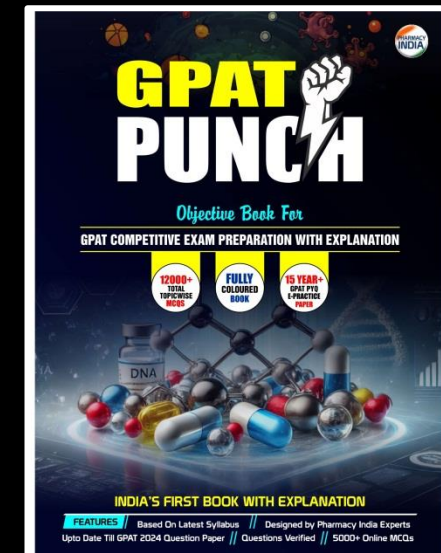
1. Glyceraldehyde-3-phosphate	[P] Cholesterol synthesis pathway
2. Arachidonic acid	[Q] Citric acid cycle
	[R] Glycolysis
	[S] Prostaglandin synthesis pathway

(a) 1-[Q], 2-[S]

(b) 1-[R], 2-[S]

(c) 1-[R], 2-[P]

(d) 1-[P], 2-[S]



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Match the correct pathways of the following. [GATE-2000]

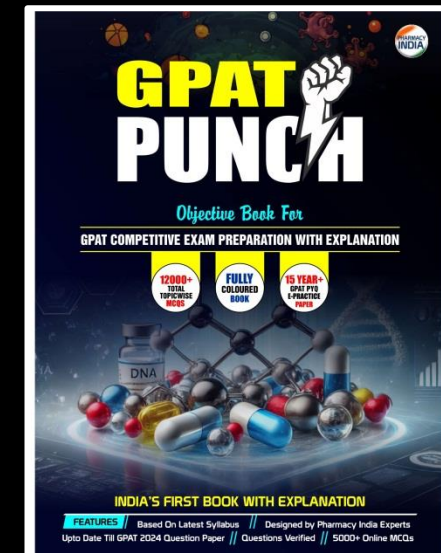
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(b) 1-[R], 2-[S]

(c) 1-[R], 2-[P]

(d) 1-[P], 2-[S]



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KEY PATHWAY MATCHES

1 G3P: GLYCOLYTIC INTERMEDIATE



- Glyceraldehyde-3-phosphate (G3P) is a 3-carbon intermediate of glycolysis.

2 CARBOHYDRATE BREAKDOWN



- G3P is formed during breakdown of glucose for energy production.

3 ARACHIDONIC ACID: POLYUNSATURATED FATTY ACID



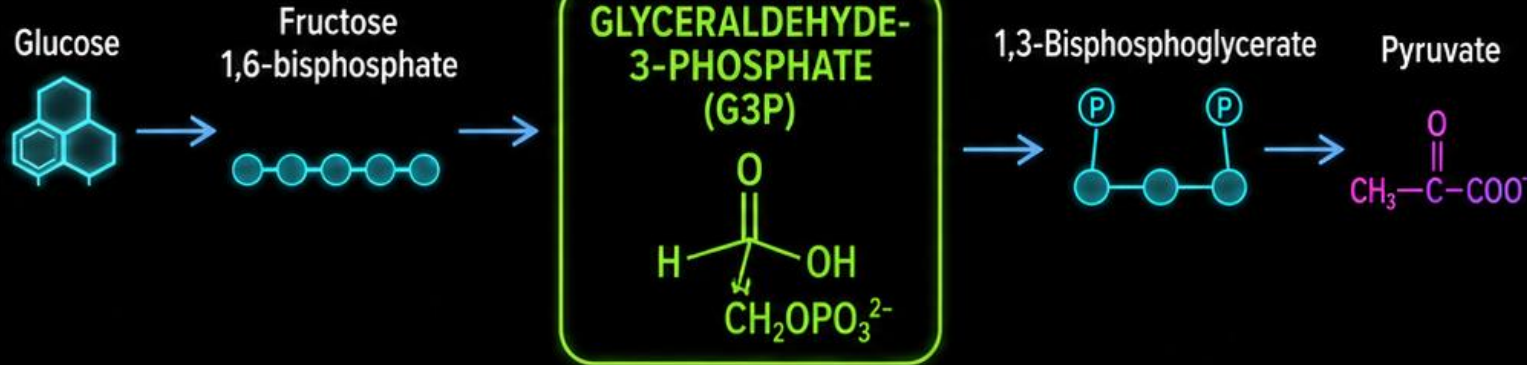
- A 20-carbon, ω -6 polyunsaturated fatty acid stored in membrane phospholipids.

4 PROSTAGLANDIN SYNTHESIS ENTRY



- Arachidonic acid is released by phospholipase A_2 and enters the COX pathway to form prostaglandins.

GLYCOLYSIS



5 PROSTAGLANDINS: EICOSANOIDS



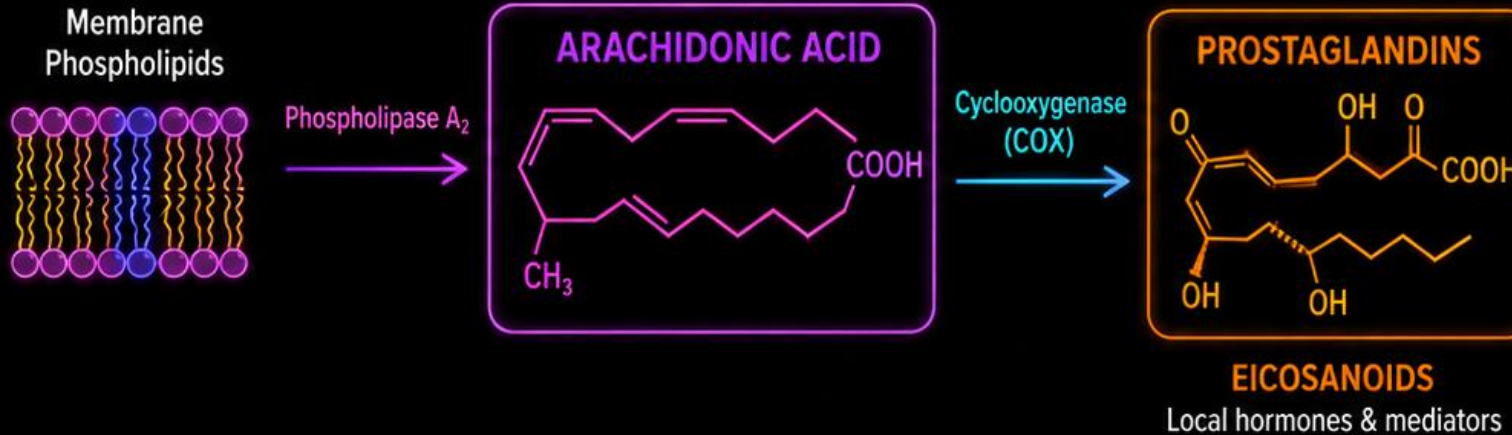
- Prostaglandins are eicosanoids derived from arachidonic acid.

6 PHYSIOLOGICAL ROLES



- Mediate inflammation
- Pain & fever regulation
- Vascular tone & platelet function
- Gastroprotection

PROSTAGLANDIN SYNTHESIS PATHWAY



KEY TAKEAWAY



G3P = glycolysis intermediate

Arachidonic acid = precursor for prostaglandin synthesis



G3P powers cells. **Arachidonic acid** powers signals.



Metabolism fuels life.
Signals drive response.



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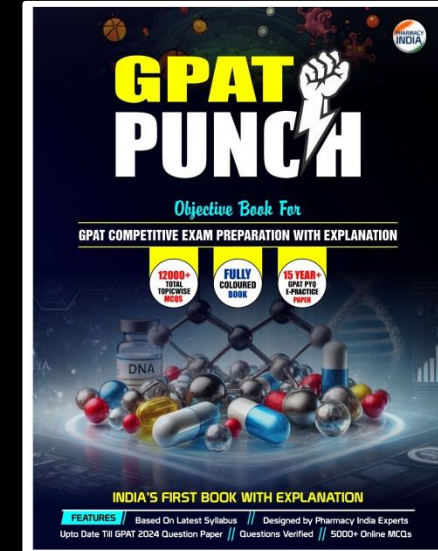
32.

Listed below are some tests; match them correctly.

[GATE-1997]

1. Benedict's test	[P] Bile salt
2. Hay's test	[Q] Cholesterol
3. Gmelin's test	[R] Bile pigments
4. Salkowski's test	[S] Glucose

- (a) 1-[S], 2-[P], 3-[R], 4-[Q]
- (b) 1-[P], 2-[R], 3-[S], 4-[Q]
- (c) 1-[R], 2-[S], 3-[Q], 4-[P]
- (d) 1-[Q], 2-[P], 3-[R], 4-[S]



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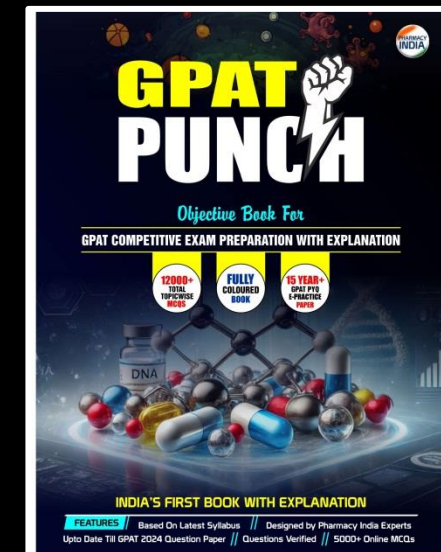
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(c) 1-[R], 2-[S], 3-[Q], 4-[P]
(d) 1-[Q], 2-[P], 3-[R], 4-[S]



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IMPORTANT DIAGNOSTIC BIOCHEMICAL TESTS



BENEDICT'S TEST

- Detects: **Glucose / Reducing sugars**
- Principle: Reducing sugars reduce Cu^{2+} to Cu_2O
- Positive: **Green** → **Yellow** → **Orange** → **Brick-red ppt**



GMELIN'S TEST

- Detects: **Bile pigments** (Bilirubin)
- Principle: Bilirubin gives colored ring with **nitric acid**
- Positive: **Blue-green ring** at the junction



BENEDICT'S TEST



GMELIN'S TEST



HAY'S TEST



SALKOWSKI'S TEST

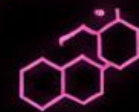


NOTE: These are **classical qualitative tests** used for preliminary detection and screening in biochemical diagnosis.



HAY'S TEST

- Detects: **Bile salts**
- Principle: Bile salts produce stable froth due to their **detergent property**
- Positive: **Persistent froth** (≥ 2 cm) for ≥ 15 minutes



SALKOWSKI'S TEST

- Detects: **Cholesterol**
- Principle: Cholesterol gives red color with **conc. H_2SO_4**
- Positive: **Red color** in chloroform layer



CARBOHYDRATE



LIVER FUNCTION



BIOCHEMISTRY



LAB DIAGNOSIS



CLINICAL RELEVANCE



RELIABLE RESULTS



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33.

D-Fructose on simple reduction gives: [GATE-1992]

- (a) Only L-fructose
- (b) Only sorbitol
- (c) Only mannitol
- (d) Mixture of mannitol and sorbitol



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33.

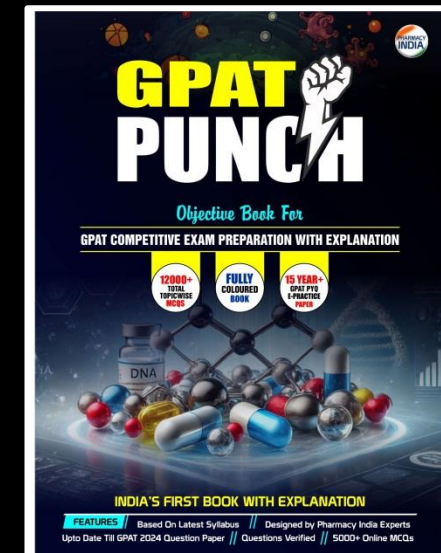
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(a) Only L-fructose

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(d) Mixture of mannitol and sorbitol



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REDUCTION OF D-FRUCTOSE

KETOSE REDUCTION → TWO SUGAR ALCOHOLS



D-FRUCTOSE IS A KETOSE

The carbonyl group is at C-2 (ketone).
C-1 is a primary alcohol (CH₂OH).



REDUCTION TARGET

Reduction converts the ketone (C=O at C-2) to a secondary alcohol (CHOH).



NEW CHIRAL CENTER

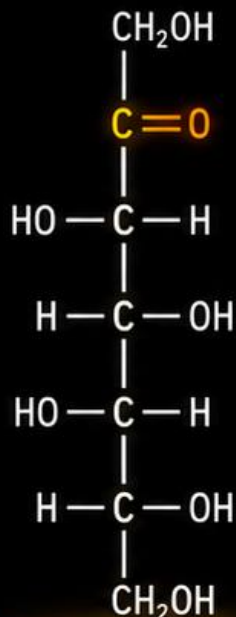
C-2 becomes a new chiral center after reduction.



TWO POSSIBLE CONFIGURATIONS

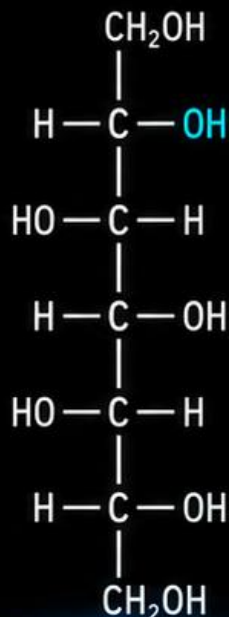
Attack from either face of the carbonyl forms two stereoisomers.

D-FRUCTOSE (KETOSE)

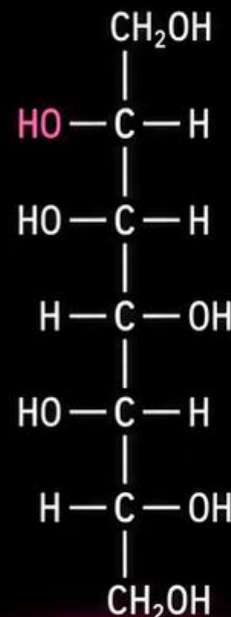


REDUCTION
(NaBH₄ / H₂ or HI)

SORBITOL (D-GLUCITOL)



MANNITOL (D-MANNITOL)



MIXTURE OF PRODUCTS

Reduction of D-fructose yields a mixture of Sorbitol and Mannitol (C-2 epimers).



SUGAR ALCOHOLS

Both products are hexitols (sugar alcohols) with six -OH groups.



NO RING FORMATION

Products are open-chain polyols; no cyclic structure.



HIGH-YIELD CONCEPT

Ketose reduction creates a new stereocenter → two epimeric sugar alcohols.



KEY TAKEAWAYS

● D-Fructose is a ketose with a carbonyl at C-2.

● Reduction converts the ketone to a secondary alcohol.

● C-2 becomes a new chiral center.

● Two stereoisomers form: Sorbitol (C-2 OH right), Mannitol (C-2 OH left).

● Result: mixture of sorbitol and mannitol (sugar alcohols).



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34.

Which of the following enzymes is not involved in gluconeogenesis?

- (a) Pyruvate carboxylase
- (b) Phosphoenolpyruvate carboxykinase
- (c) Fructose-1,6-bisphosphatase
- (d) Hexokinase



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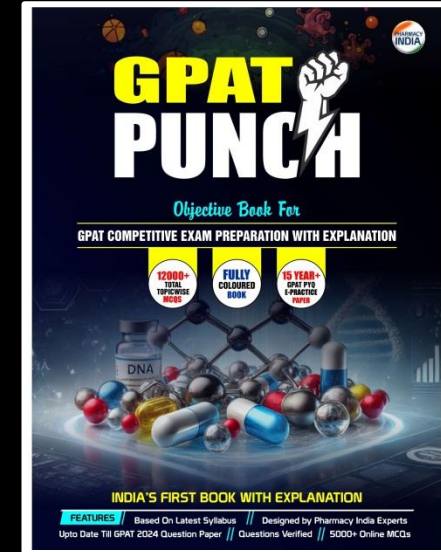


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- (d) Hexokinase



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ENZYMES OF GLUCONEOGENESIS



3 KEY BYPASS ENZYMES

- Overcome the 3 irreversible steps of glycolysis.
- Enable net synthesis of glucose from non-carbohydrate precursors.



PYRUVATE CARBOXYLASE (PC)

- Mitochondrial enzyme.
- Uses ATP and Biotin.
- Forms Oxaloacetate (OAA) from Pyruvate.



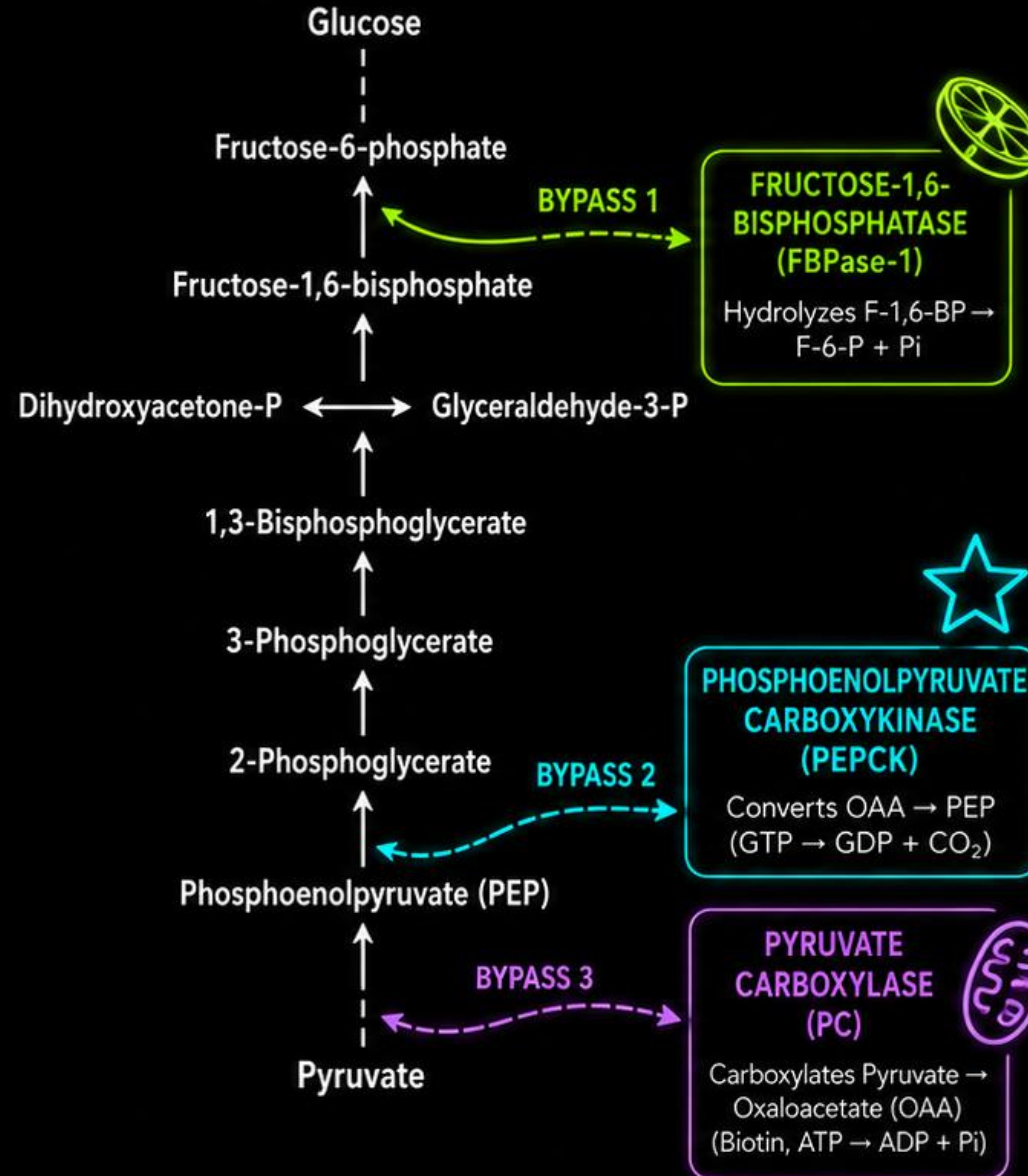
PEP CARBOXYKINASE (PEPCK)

- Exists in mitochondrial and cytosolic forms.
- Uses GTP.
- Converts OAA to PEP.



FRUCTOSE-1,6-BISPHOSPHATASE (FBPase-1)

- Cytosolic enzyme.
- Hydrolyzes F-1,6-BP to F-6-P.
- Key regulatory control point.



HEXOKINASE (NOT IN GLUCONEOGENESIS)

- Phosphorylates Glucose → Glucose-6-phosphate.
- This is a glycolytic enzyme, not used in gluconeogenesis.
- Gluconeogenesis uses glucose-6-phosphatase (in liver/kidney) to make free glucose.

GLYCOLYSIS vs GLUCONEOGENESIS

GLYCOLYSIS

- Catabolic
- Degrades glucose to pyruvate
- Uses 3 irreversible steps

GLUCONEOGENESIS

- Anabolic
- Synthesizes glucose from precursors
- Bypasses the 3 irreversible steps



HIGH-YIELD TAKEAWAYS

- ✓ PC, PEPCK, and FBPase-1 are the 3 key bypass enzymes.
- ✓ They replace the irreversible steps of glycolysis.
- ✓ Hexokinase is a glycolytic enzyme and not part of gluconeogenesis.
- ✓ Gluconeogenesis allows synthesis of glucose from lactate, glycerol, and glucogenic amino acids.

— BYPASS 1 (FBPase-1) — BYPASS 2 (PEPCK) — BYPASS 3 (PC) — — — Reversible steps —————> Glutinous arrow direction



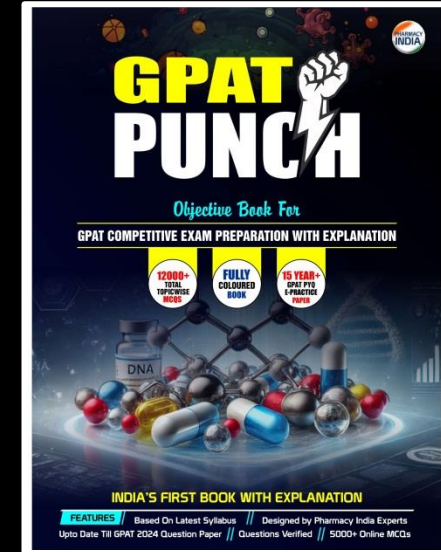
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35.

Muscle glycogen is not available for maintenance of blood glucose concentration because:

- (a) Muscle lacks glucose-6-phosphatase activity
- (b) There is insufficient glycogen in muscle
- (c) Muscle lacks glucose transporter GLUT-4
- (d) Muscle lacks glucagon receptors



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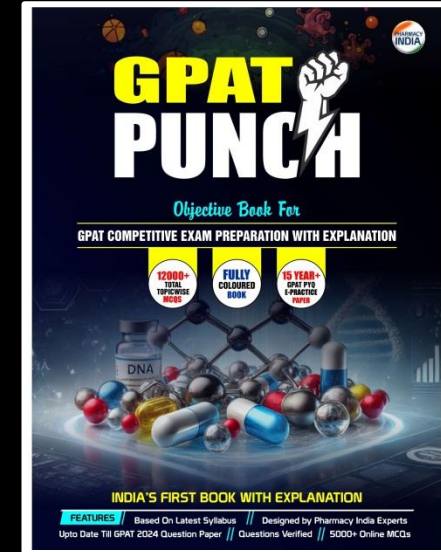


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- (b) There is insufficient glycogen in muscle**
- (c) Muscle lacks glucose transporter GLUT-4**
- (d) Muscle lacks glucagon receptors**



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WHY MUSCLE GLYCOGEN CANNOT MAINTAIN BLOOD GLUCOSE



1. GLYCOGENOLYSIS IN MUSCLE

Muscle glycogen is broken down by glycogen phosphorylase to glucose-1-phosphate, then converted to **glucose-6-phosphate (G6P)**.



2. NO GLUCOSE-6-PHOSPHATASE

Skeletal muscle lacks the enzyme **glucose-6-phosphatase** that converts G6P to free glucose.



3. NO FREE GLUCOSE RELEASE

Without this enzyme, muscle G6P cannot be dephosphorylated to free glucose, so it cannot **exit the cell** into blood.

MUSCLE



Glucose-1-Phosphate



Glucose-6-Phosphate (G6P)



NO GLUCOSE-6-PHOSPHATASE

Used Locally for Energy



VS

LIVER



Glucose-1-Phosphate



Glucose-6-Phosphate (G6P)



Glucose-6-Phosphatase (P removed)

Free Glucose



Released into Blood



4. USED LOCALLY FOR ENERGY

G6P is used within the muscle for glycolysis to produce **ATP** and for other metabolic pathways.



5. LIVER MAINTAINS BLOOD GLUCOSE

Liver glycogen can be converted to free glucose (via **glucose-6-phosphatase**) and released into blood.



6. KEY TAKEAWAY

Muscle glycogen = for muscle energy.
Liver glycogen = for blood glucose maintenance.



MUSCLE LACKS GLUCOSE-6-PHOSPHATASE → G6P CANNOT BECOME FREE GLUCOSE → **CANNOT ENTER BLOOD**
THEREFORE, **MUSCLE GLYCOGEN CANNOT MAINTAIN BLOOD GLUCOSE.**



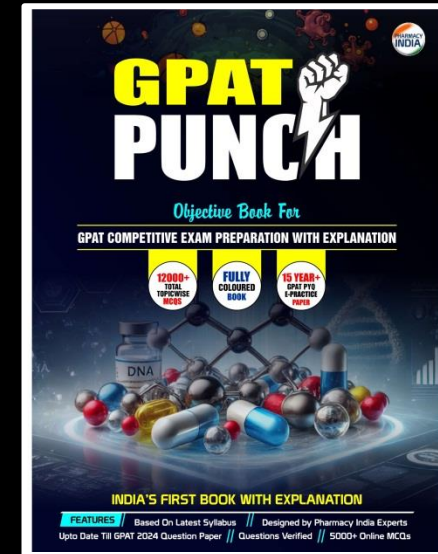
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36.

What is the rate-limiting enzyme of glycogenesis?

- (a) Phosphofructokinase
- (b) Glycogen synthase
- (c) Phosphorylase
- (d) Glucose-6-phosphate dehydrogenase



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36.

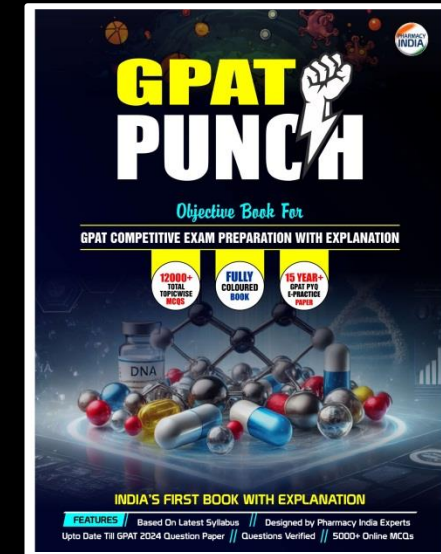
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(a) Phosphofructokinase

(b) Glycogen synthase

(c) Phosphorylase

(d) Glucose-6-phosphate dehydrogenase



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RATE-LIMITING ENZYME OF GLYCOGENESIS



KEY FACT

Glycogen synthase is the **rate-limiting** enzyme of **glycogenesis**.



FUNCTION

Catalyzes the addition of glucose residues (from UDP-glucose) to the **non-reducing ends** of glycogen.



ACTION

Elongates $\alpha(1 \rightarrow 4)$ chains; branching enzyme (amylo-1,4 $\rightarrow$ 1,6-transglycosylase) creates $\alpha(1 \rightarrow 6)$ branches.

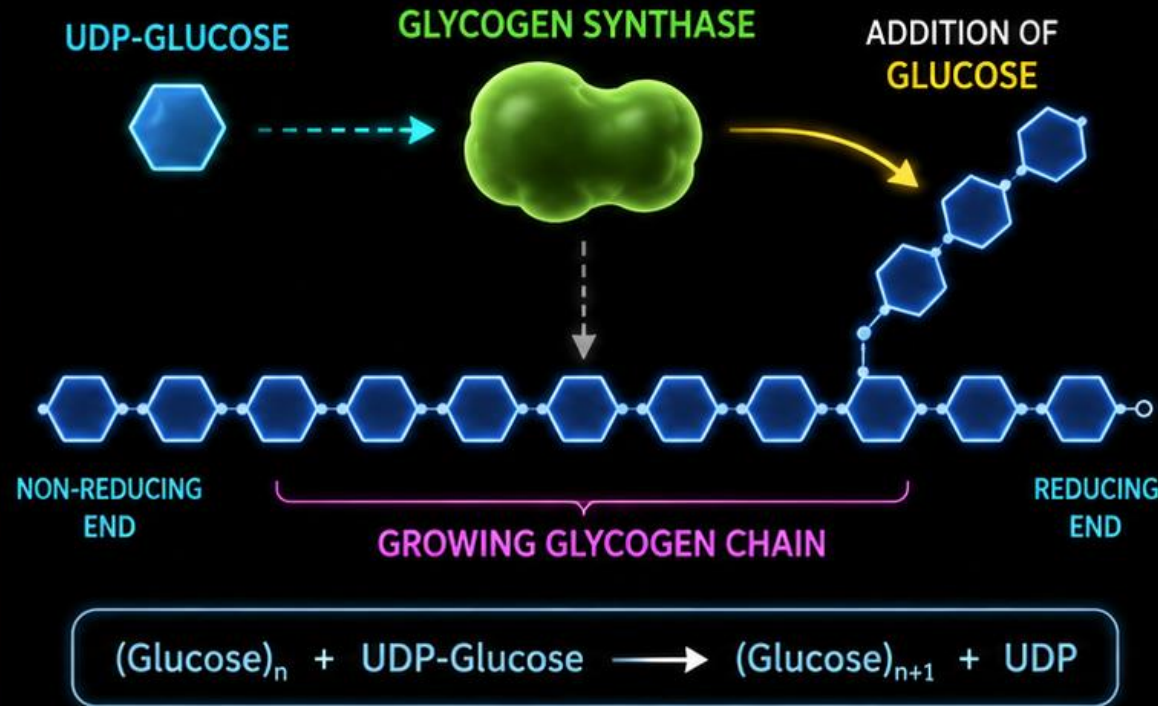


RATE-LIMITING

Controls the **overall** rate of glycogen synthesis in hepatocytes & muscle cells.

GLYCOGEN SYNTHASE

Key regulatory & rate-limiting enzyme of glycogenesis



BOTTOM LINE

Glycogen **synthase** adds glucose from **UDP-glucose** to the growing glycogen chain. It is the key regulatory & rate-limiting enzyme, activated in the **fed (insulin) state**.



FED / INSULIN STATE

- **Insulin** activates glycogen synthase.
- Promotes glycogenesis in liver & muscle.
- Occurs **after a meal** (high glucose).



ACTIVATION (INSULIN)

- **Dephosphorylation** (protein phosphatase 1) activates glycogen synthase (a form).
- $\uparrow$ **Glucose-6-phosphate** activates allosterically.



INHIBITION (FASTING)

- Phosphorylation by **PKA / GSK-3** inactivates glycogen synthase.
- $\uparrow$ **Glucagon, epinephrine** inhibit glycogenesis.



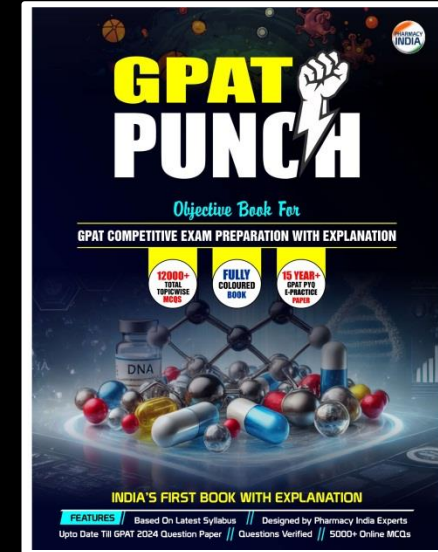
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37.

Which mammalian cell does not have aerobic pathway of glucose catabolism?

- (a) Nerve cell
- (b) Sperm cell
- (c) Ovum
- (d) Red cell



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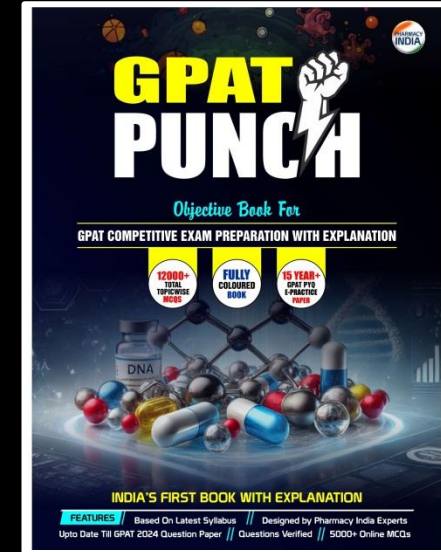


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MAMMALIAN CELL WITHOUT AEROBIC GLUCOSE CATABOLISM



NO MITOCHONDRIA

RBCs expel mitochondria during maturation → no TCA cycle, no ETC



ANAEROBIC GLYCOLYSIS

Glucose → Pyruvate → Lactate (via LDH) in the cytosol



ATP YIELD

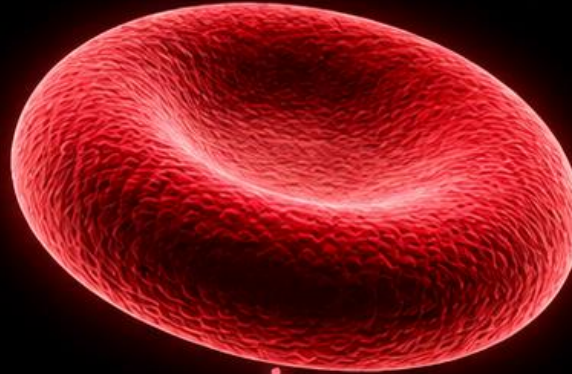
Net 2 ATP per glucose (substrate-level phosphorylation)



NAD⁺ REGENERATION

Pyruvate → Lactate regenerates NAD⁺, sustaining glycolysis

Mature Red Blood Cells (RBCs) lack mitochondria



Cannot perform TCA cycle or oxidative phosphorylation

Depend entirely on **ANAEROBIC GLYCOLYSIS** for ATP



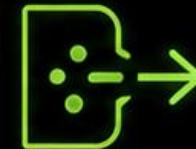
FUNCTIONAL PURPOSE

Provides ATP to maintain ion gradients, membrane integrity & cell shape



OXYGEN INDEPENDENT

Works under all oxygen conditions; essential in low O₂ environments



LACTATE EXPORT

Lactate diffuses out to plasma → carried to liver (Cori cycle)



HIGHLY SPECIALIZED

Sacrifices aerobic capacity for flexibility, longevity & efficient O₂ delivery



RBCs are a classic example of a mammalian cell that depends entirely on **anaerobic glycolysis** because they **lack mitochondria** and cannot perform aerobic glucose catabolism.





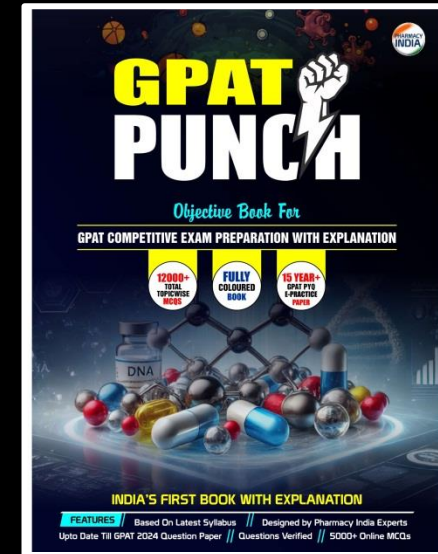
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38.

Which of the following step is not involved in substrate-level phosphorylation?

- (a) Dihydroxyacetone phosphate → glyceraldehyde-3-phosphate
- (b) 1,3-bisphosphoglycerate → 3-phosphoglycerate
- (c) Succinyl-CoA → succinate
- (d) Phosphoenolpyruvate → pyruvate



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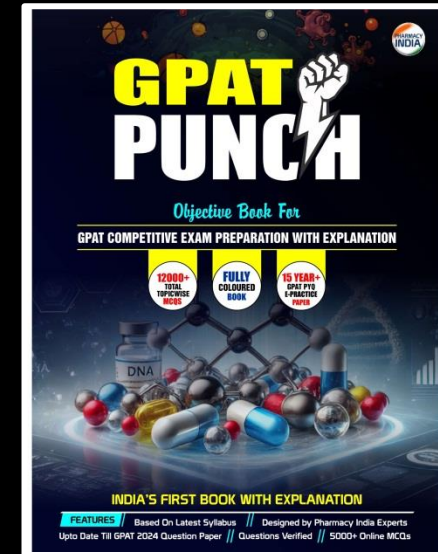
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SUBSTRATE-LEVEL PHOSPHORYLATION

ATP MADE BY DIRECT TRANSFER OF A PHOSPHATE FROM A HIGH-ENERGY SUBSTRATE

1. WHAT IS SLP?

High-energy phosphate group is transferred directly to ADP → ATP.
No electron transport chain required.

2. ISOMERIZATION STEP

Dihydroxyacetone phosphate $\rightleftharpoons$ Glyceraldehyde-3-phosphate is an isomerization reaction.
It does NOT produce ATP or GTP.

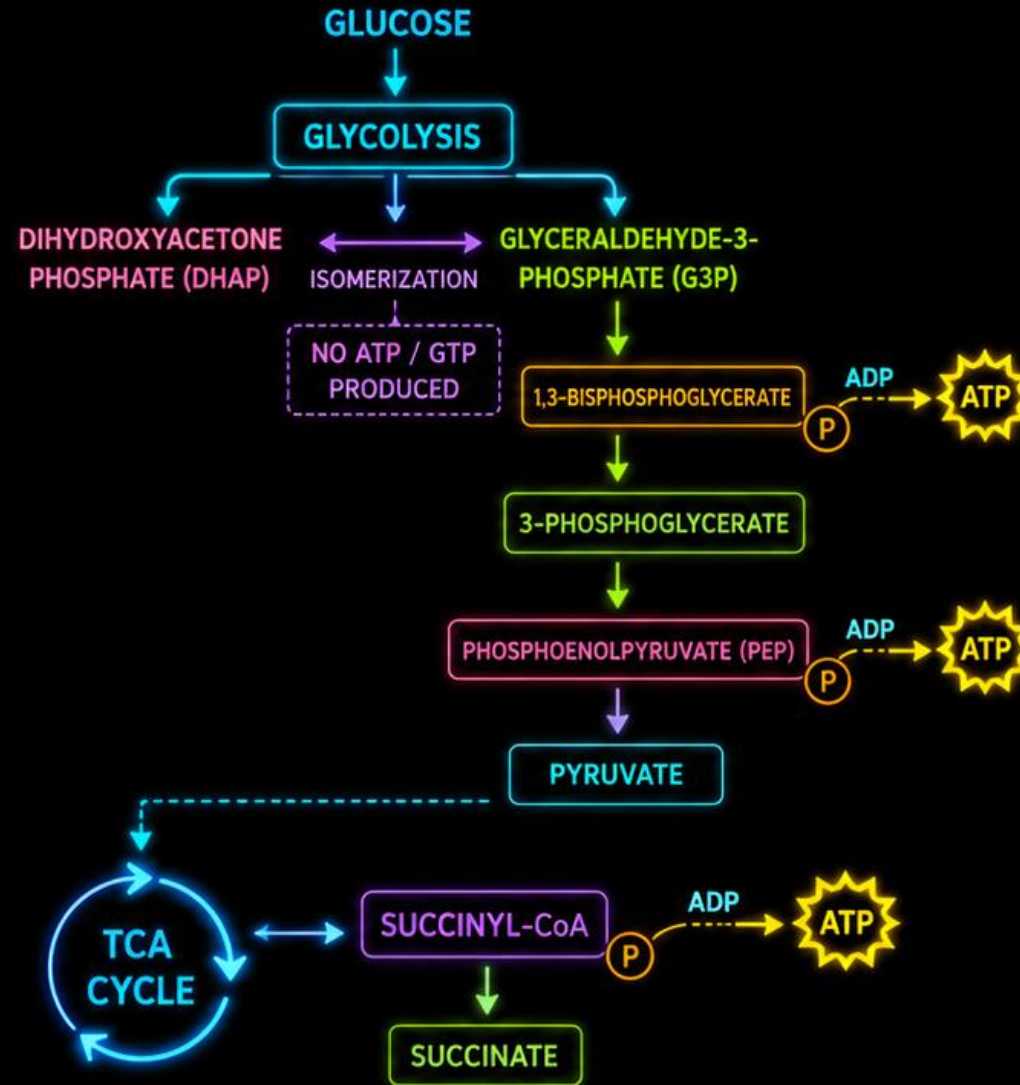
3. TRUE SLP STEPS (ATP)

- 1,3-Bisphosphoglycerate → 3-Phosphoglycerate
- Phosphoenolpyruvate → Pyruvate
- Succinyl-CoA → Succinate

These are the only ATP-generating SLP steps in central metabolism.

4. WHY IT MATTERS

- Fast ATP generation.
- Functions in anaerobic conditions.
- Essential in glycolysis and TCA cycle.



5. KEY POINTS

- SLP = substrate donates phosphate directly to ADP.
- Occurs in cytosol (glycolysis) and mitochondria (TCA).
- Total ATP by SLP per glucose: 4 (2 in glycolysis + 2 in TCA cycle).

6. QUICK RECAP

- DHAP $\rightleftharpoons$ G3P → isomerization only (no ATP/GTP).
- Real SLP steps:
 - 1,3-BPG → 3-PG
 - PEP → Pyruvate
 - Succinyl-CoA → Succinate
- Direct phosphate transfer = ATP.

LEGEND

- ATP produced (SLP)
- ADP Adenosine diphosphate
- P Phosphate group
- Isomerization (no ATP/GTP)



REMEMBER: Only direct phosphate transfer to ADP makes ATP. Isomerization ≠ ATP production.



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39.

How many ATP molecules are produced in the citric acid cycle itself?

- (a) One
- (b) Two
- (c) Twelve
- (d) Fifteen



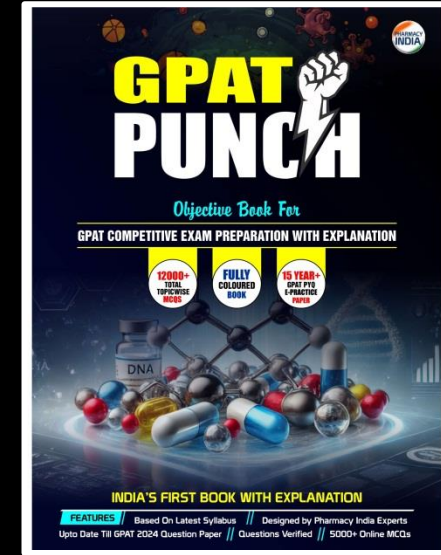
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39. How many ATP molecules are produced in the citric acid cycle itself?

- (a) One
- (b) Two
- (c) Twelve
- (d) Fifteen



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ATP PRODUCED IN THE CITRIC ACID CYCLE



KEY POINT

The citric acid cycle directly produces **1 GTP** per turn.



WHERE?

During conversion of **Succinyl-CoA** to **Succinate**



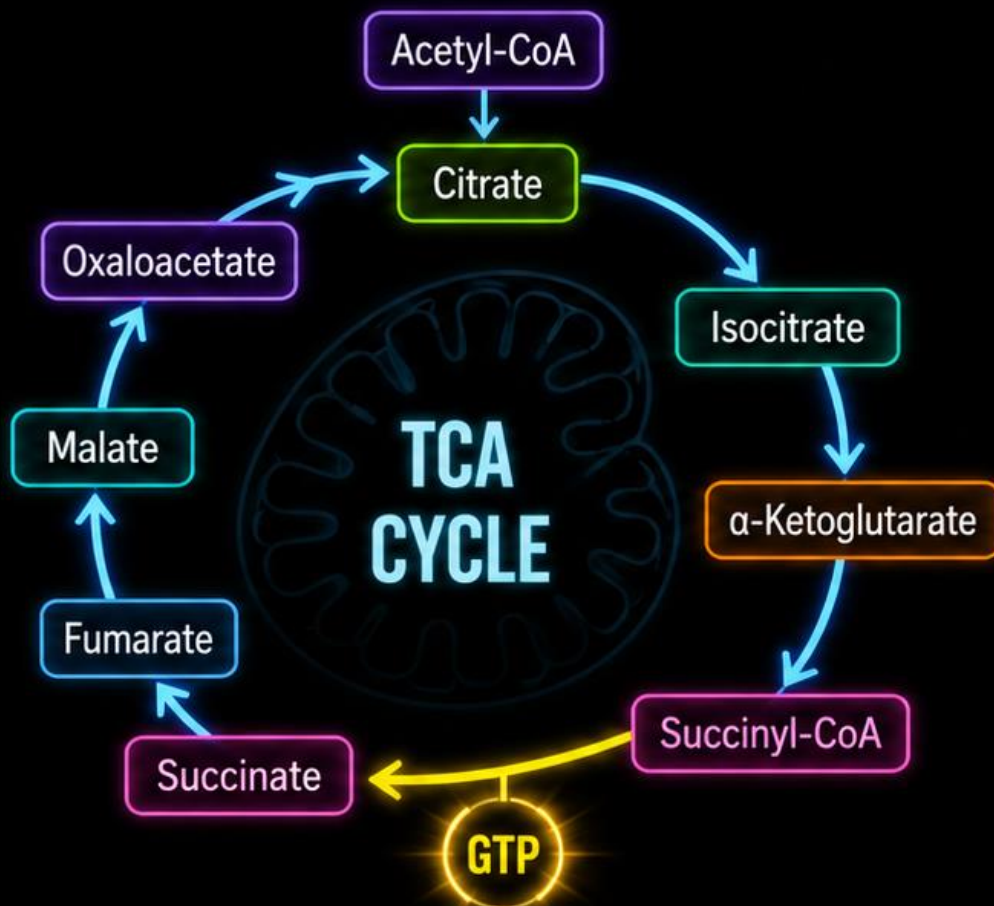
HOW?

Succinyl-CoA synthetase catalyzes substrate-level phosphorylation.



ENERGY EQUIVALENT

GTP is energetically equivalent to **ATP**.



**DIRECTLY FORMED
1 GTP PER TURN**



HIGHLIGHTS

- **1 GTP** formed per turn
- Occurs at the **succinyl-CoA → succinate** step
- By **substrate-level** phosphorylation
- **GTP ≈ ATP** in energy value



EQUIVALENCE



Interconvertible in cells
(NDP kinase)



REMEMBER

TCA cycle yields **1 GTP** directly;
rest of ATP comes indirectly via **NADH/FADH₂**.



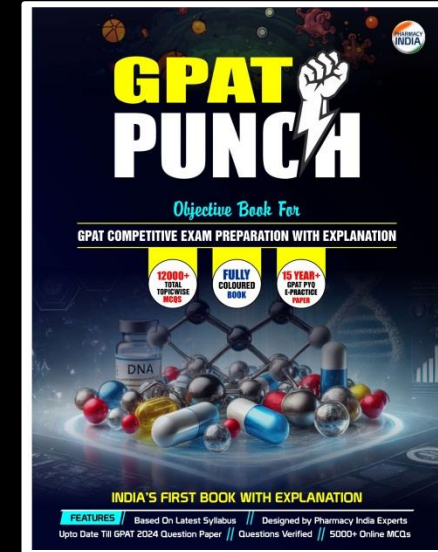
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40.

The TCA cycle is suppressed by higher concentrations of:

- (a) ATP
- (b) NAD
- (c) Citrate
- (d) Oxaloacetate



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40.

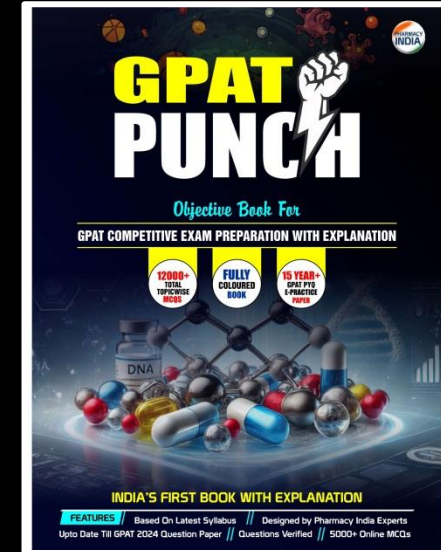
The TCA cycle is suppressed by higher concentrations of:

(a) ATP

(b) NAD

(c) Citrate

(d) Oxaloacetate



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REGULATION OF THE TCA CYCLE BY ATP



ENERGY SENSOR

High ATP (and NADH) indicates sufficient cellular energy.



HIGH ATP = HIGH ENERGY STATUS

Signals that energy is abundant → suppresses the TCA cycle to prevent unnecessary fuel oxidation.



PRIMARY TARGET

ATP inhibits **isocitrate dehydrogenase** (rate-limiting step).



FEEDBACK INHIBITION

ATP allosterically inhibits key TCA enzymes, especially **isocitrate dehydrogenase**.



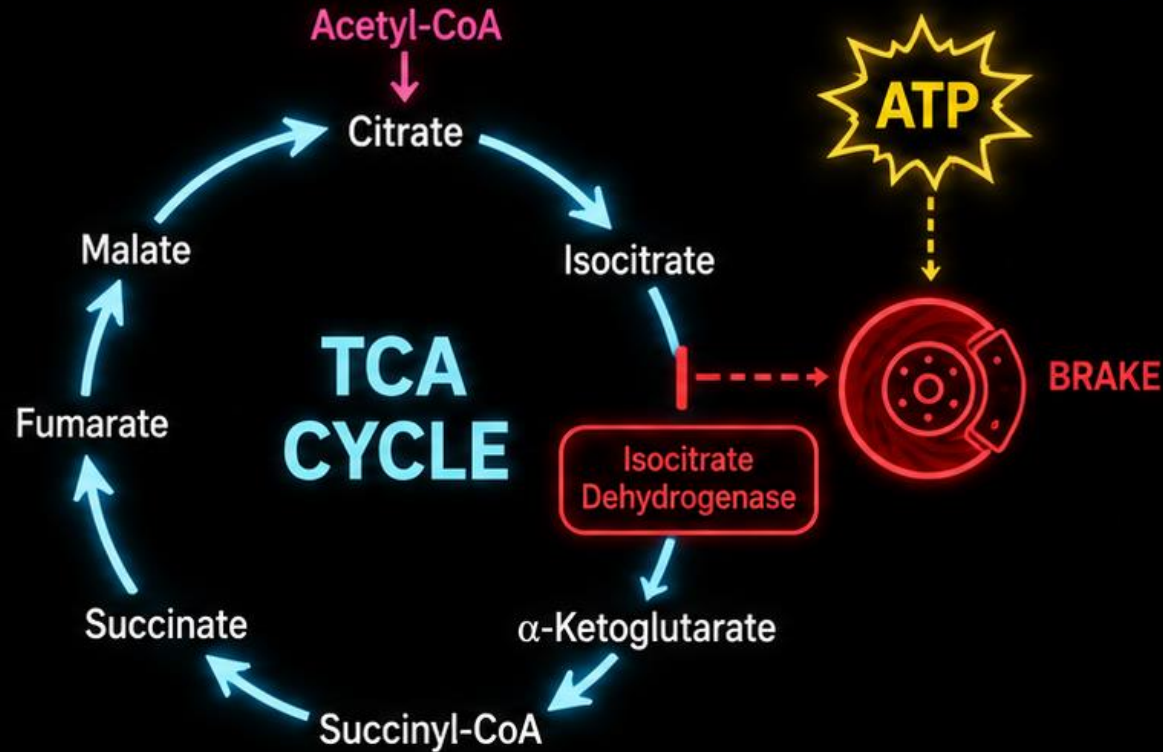
SLOWS FLUX

Reduced activity lowers NADH & FADH₂ production and ATP generation.



ENERGY CONSERVATION

Prevents wastage of substrates and conserves intermediates for other biosynthetic needs.



ALSO AFFECTS

High ATP can inhibit **citrate synthase** and **α-ketoglutarate dehydrogenase**.



LOW ATP (OPPOSITE)

Relieves inhibition, activates TCA enzymes, and increases ATP production.



KEY TAKEAWAY

ATP acts as a **brake** on the TCA cycle, matching energy production to need.



RESULT: SLOWED ACETYL-CoA OXIDATION

Lower TCA cycle flux → less NADH/FADH₂ → less ATP
Balances energy production with cellular demand.



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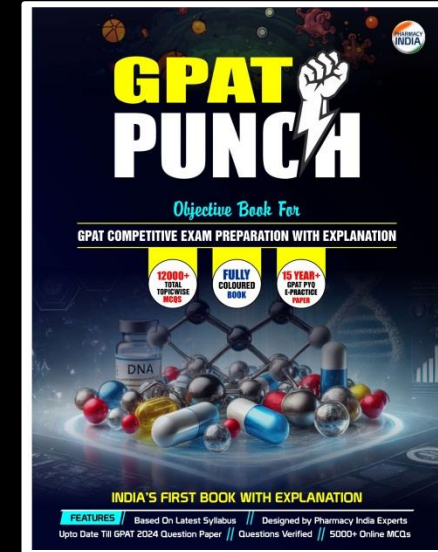


41.

A male patient's urine shows positive Benedict's test.

Which sugar is unlikely to occur in it?

- (a) Glucose
- (b) Galactose
- (c) Lactose
- (d) Pentose



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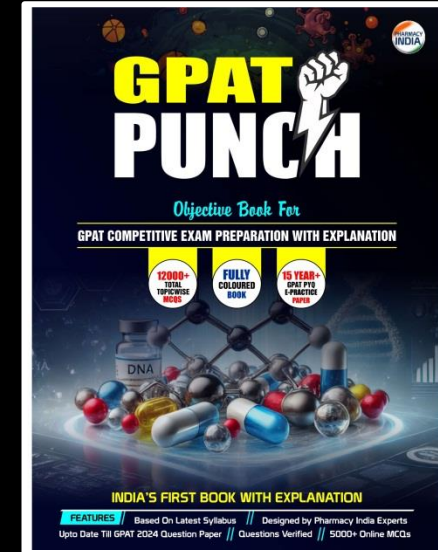


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- (c) Lactose
- (d) Pentose



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BENEDICT'S TEST IN URINE

A SIMPLE TEST TO DETECT REDUCING SUGARS



WHAT IS IT?

A chemical test used to detect **reducing sugars** in urine.



PRINCIPLE

Reducing sugars reduce Cu^{2+} (blue) to Cu_2O (brick-red precipitate) in alkaline medium on heating.



SUGAR LEVEL GUIDE

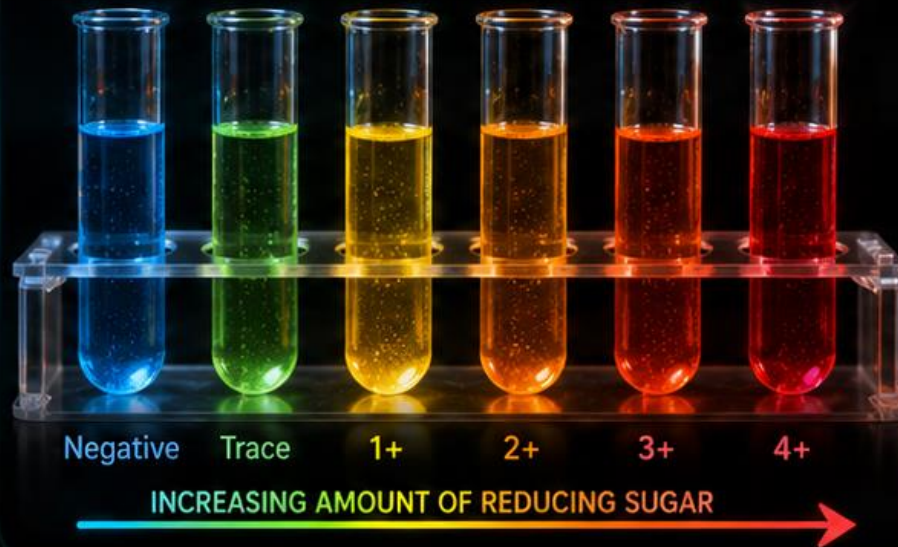
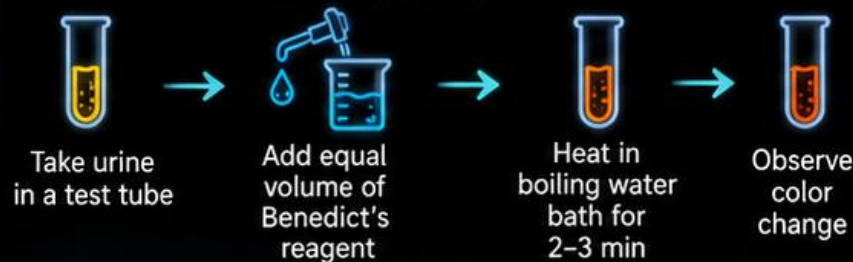
	Result	Appearance (After Heating)
+	Negative	Blue (no change)
++	Trace	Greenish
+++	1+ (Low)	Yellow
++++	2+ (Moderate)	Orange
++++	3+ (High)	Brick-Red
++++	4+ (Very High)	Deep Brick-Red



NOTE

Benedict's test is not specific for glucose; it detects all **reducing sugars**.

THE TEST



INTERPRETATION

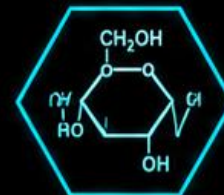
Color change indicates presence and approximate amount of **reducing sugars** in urine.



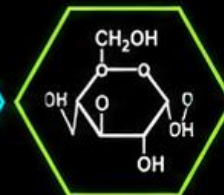
CLINICAL USE: Screening test for glycosuria.



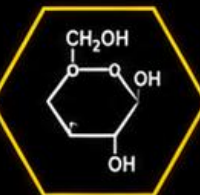
SUGARS THAT GIVE POSITIVE TEST



GLUCOSE



GALACTOSE



PENTOSE
(e.g., xylose)

These are **reducing sugars**.



LACTOSE IN URINE

Lactose may appear in urine during **pregnancy** and **lactation** due to physiological glycosuria.



IN MALE PATIENT

Lactose is **unlikely** to be present in male urine.

KEY TAKEAWAY



LACTOSE UNCOMMON IN MALE URINE



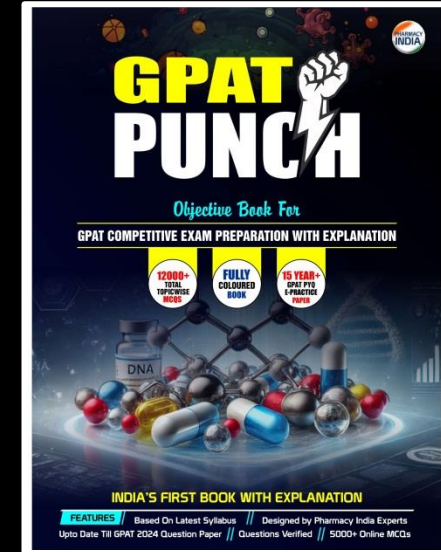
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42.

The deficiency of disaccharidase _____ is very common in humans.

- (a) Sucrase
- (b) Maltase
- (c) Lactase
- (d) None of these



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42.

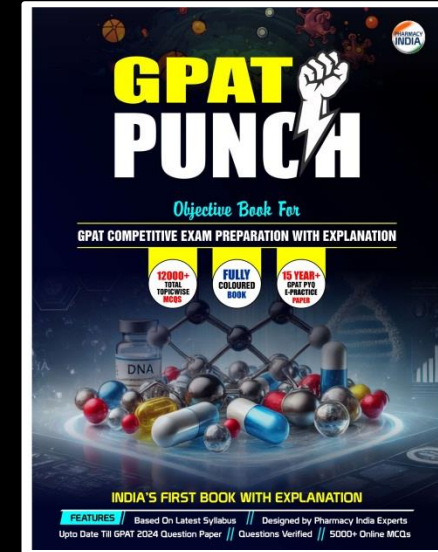
The deficiency of disaccharidase _____ is very common in humans.

(a) Sucrase

(b) Maltase

(c) Lactase

(d) None of these



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LACTASE DEFICIENCY

WHEN LACTOSE CAN'T BE DIGESTED



1. MOST COMMONLY DEFICIENT DISACCHARIDASE

Lactase is the most commonly deficient disaccharidase in humans.



2. CAUSES LACTOSE INTOLERANCE

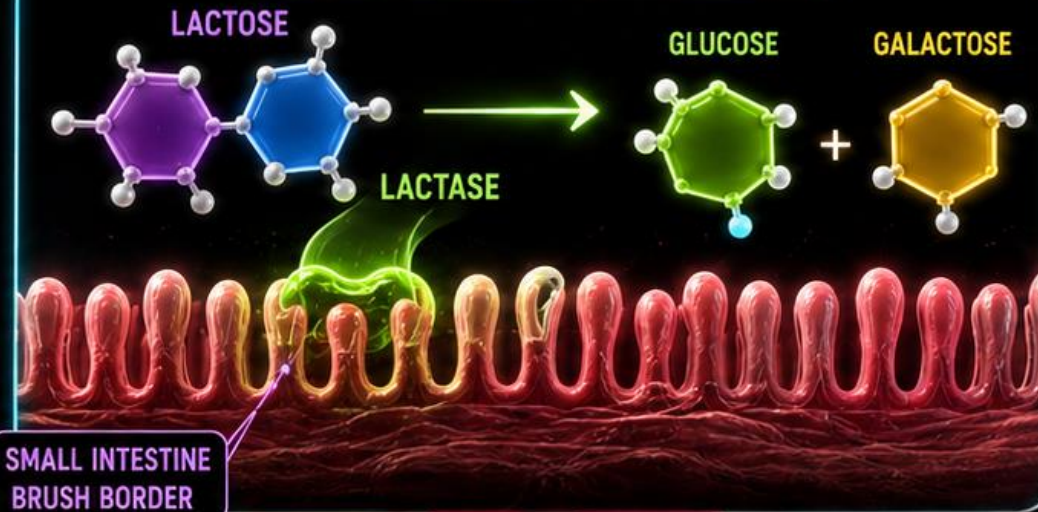
Deficiency of lactase enzyme leads to lactose intolerance.



3. LACTOSE REMAINS UNDIGESTED

Lactose is not split in the small intestine and remains in the lumen.

NORMAL DIGESTION (WITH LACTASE)



LACTASE DEFICIENCY



4. FERMENTATION CAUSES SYMPTOMS

In the colon, bacteria ferment lactose → gas & acids → bloating, cramps, and diarrhea.



BLOATING



CRAMPS



DIARRHEA



5. MANAGEMENT & RELIEF

- ✓ Limit lactose-containing foods.
- ✓ Use lactase enzyme supplements.
- ✓ Choose lactose-free alternatives.
- ✓ Symptoms improve with lactose restriction or lactase support.



IN SHORT: LOW LACTASE → UNDIGESTED LACTOSE → COLON FERMENTATION → SYMPTOMS → RELIEF WITH DIETARY MANAGEMENT OR LACTASE SUPPORT





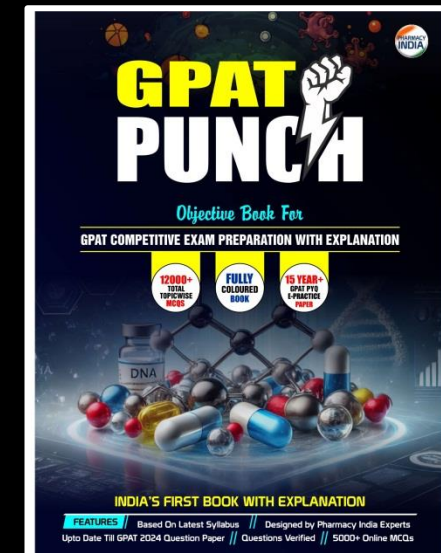
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43.

D-galactose and D-glucose are:

- (a) Epimers of each other
- (b) Enantiomers of each other
- (c) Anomers of each other
- (d) Mirror images of each other



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43.

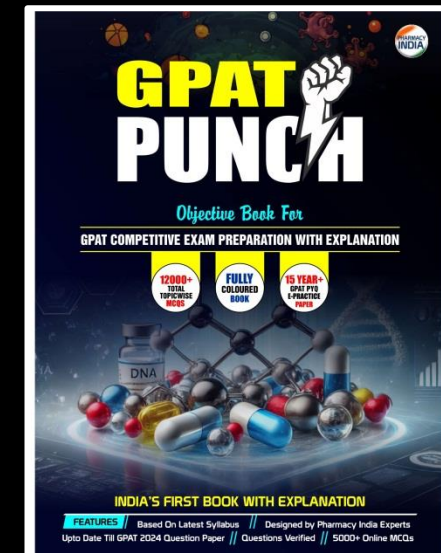
D-galactose and D-glucose are:

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(b) Enantiomers of each other

(c) Anomers of each other

(d) Mirror images of each other



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D-GLUCOSE AND D-GALACTOSE

★ C-4 EPIMERS ★



CLASS

Aldohexoses
(6-carbon sugars)



MOLECULAR FORMULA

$C_6H_{12}O_6$



ISOMERIC RELATION

Epimers



OCCURRENCE

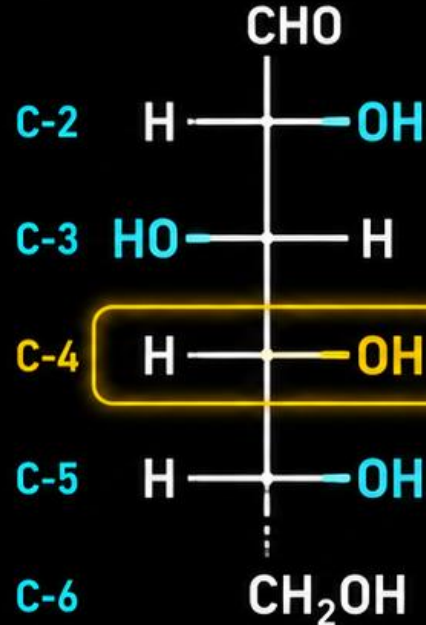
Naturally occurring
monosaccharides



SIGNIFICANCE

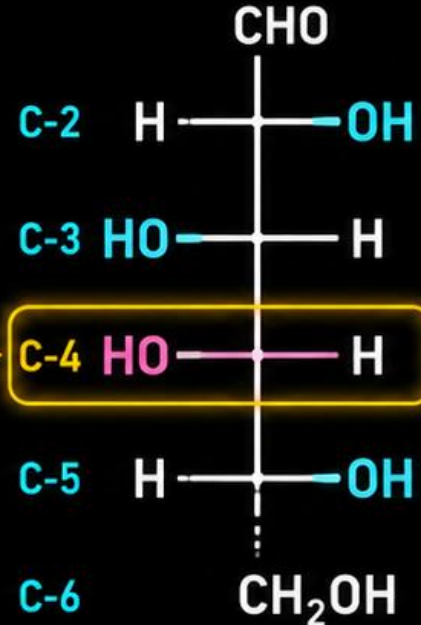
Important in
metabolism & food

D-GLUCOSE



D-GLUCOSE

D-GALACTOSE



D-GALACTOSE

DIFFER ONLY
AT C-4

SAME
MOLECULAR
FORMULA

$C_6H_{12}O_6$

1 EPIMERS

D-Glucose and
D-Galactose are
epimers.



2 DIFFER AT C-4

They differ only at
carbon-4.

3 DEFINITION

Epimers differ at
one chiral carbon.

4 BOTH ALDOHEXOSES

Both are aldohexoses
with same functional
groups.

5 STEREOCHEMISTRY CHANGE

This difference changes
stereochemistry but not
the molecular formula.



SAME FORMULA

$C_6H_{12}O_6$



STRUCTURAL ISOMERS

Different arrangement
at one chiral center



BOTH ARE SUGARS

Involved in energy,
glycoproteins & glycolipids



KEY TAKEAWAY

C-4 epimers: Same formula,
different stereochemistry

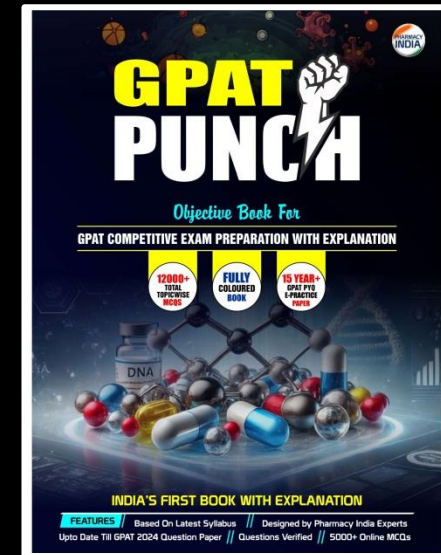


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44.

The primary metabolic fate of lactate released from muscle during intense exercise is:

- (a) Excretion in urine
- (b) Transported to liver for replenishment of blood glucose by gluconeogenesis
- (c) Conversion to pyruvate
- (d) Gradual reuptake in muscle during recovery phase following exercise



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44.

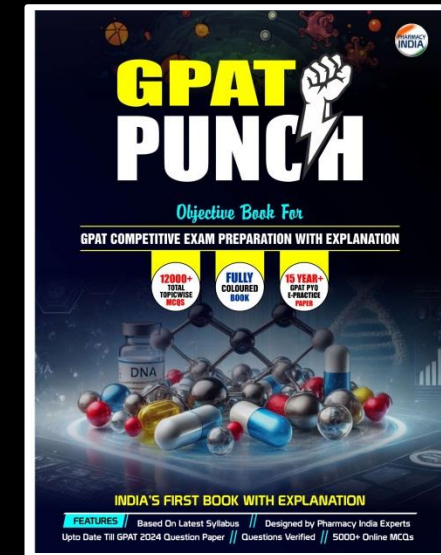
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(c) Conversion to pyruvate

(d) Gradual reuptake in muscle during recovery phase following exercise



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CORI CYCLE

FATE OF LACTATE FROM EXERCISING MUSCLE

A CONTINUOUS LOOP THAT RECYCLES LACTATE AND MAINTAINS ENERGY SUPPLY

1 INTENSE EXERCISE

During high-intensity exercise, muscle demand for ATP exceeds oxygen supply. Anaerobic glycolysis occurs.

2 LACTATE FORMS IN MUSCLE

Pyruvate (from glycolysis) is converted to lactate by lactate dehydrogenase to regenerate NAD⁺.

3 LACTATE TRANSPORT

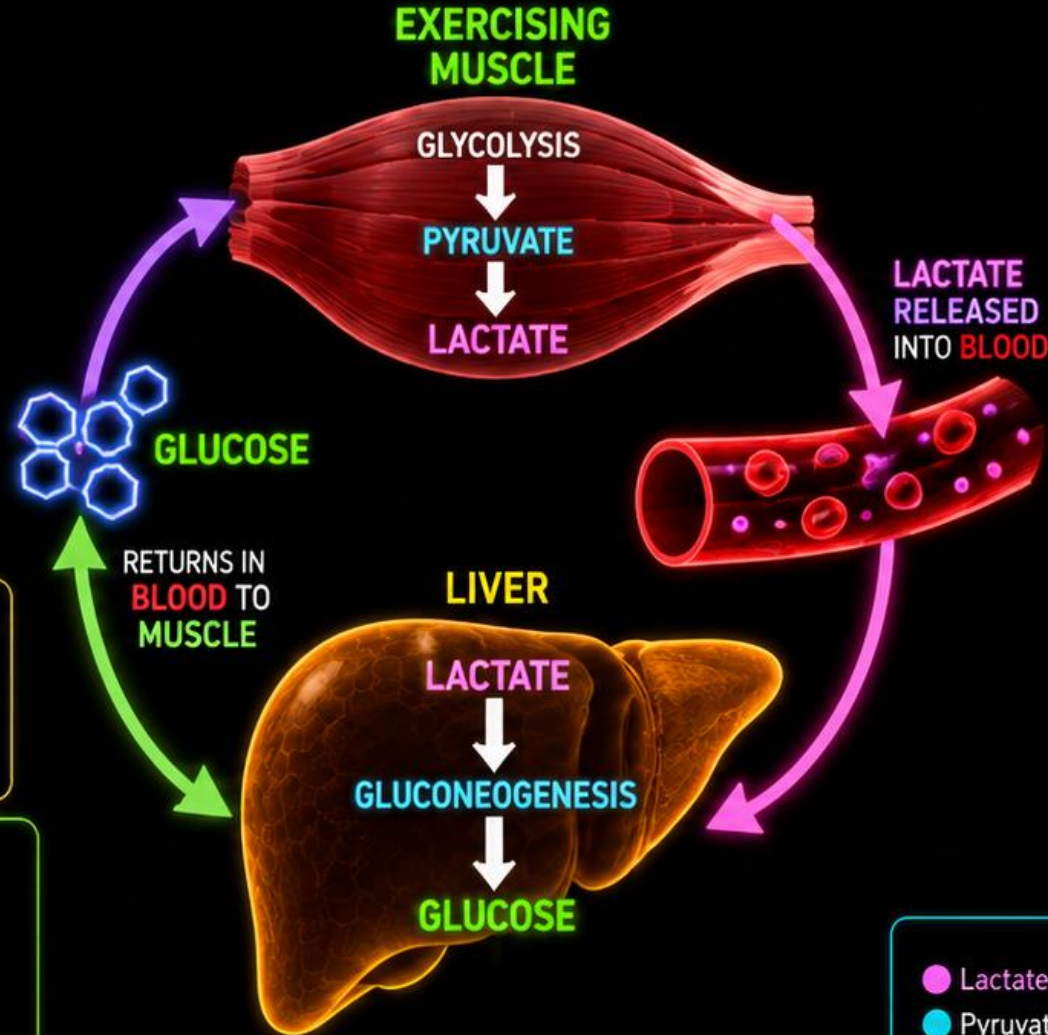
Lactate is released from muscle into the blood and transported to the liver.

4 LACTATE TO GLUCOSE IN LIVER

In the liver, lactate is converted back to glucose through gluconeogenesis (uses ATP).

5 GLUCOSE RETURNS

Glucose is released into the blood and taken up by muscles for energy, completing the cycle.



CORI CYCLE AT A GLANCE



Occurs during **intense** exercise.



Prevents **lactate** accumulation in muscles.



Maintains blood **glucose** levels.



Energy recycling between muscle and liver.

★ KEY TAKEAWAY

The **Cori cycle** removes **lactate** from **muscles** and converts it into **glucose** in the **liver**, which is returned to **muscles** to be used as fuel.

LEGEND

● Lactate ● Glucose ● Blood ● Muscle ● Liver
● Pyruvate ● Process ● Energy (ATP) ● Transport

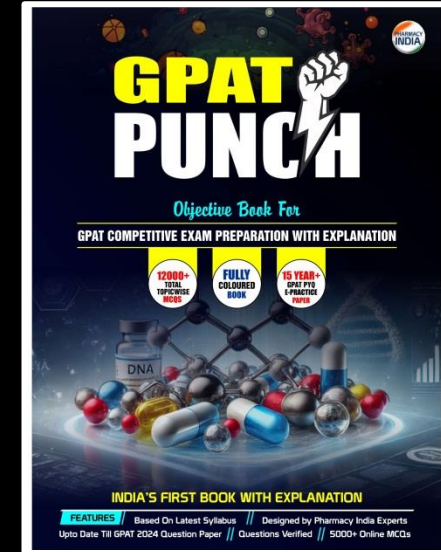


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45.

Gluconeogenesis must bypass irreversible reactions of glycolysis, except:

- (a) Hexokinase
- (b) Phosphohexose isomerase
- (c) Pyruvate kinase
- (d) Phosphofructokinase



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45.

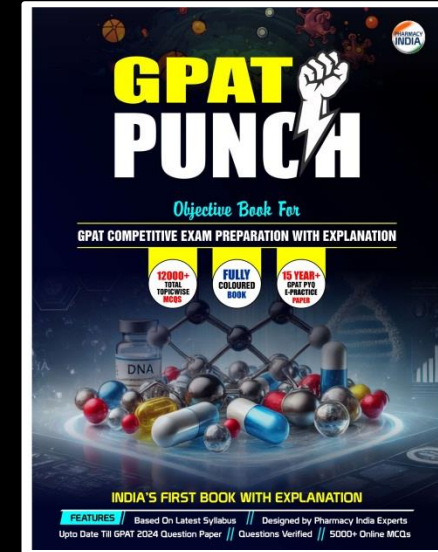
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(a) Hexokinase

(b) Phosphohexose isomerase

(c) Pyruvate kinase

(d) Phosphofructokinase



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GLUCONEOGENESIS BYPASS STEPS

WHY BYPASS?



Glycolysis has 3 **irreversible** steps that cannot run backward.



Gluconeogenesis uses 3 **specific** bypass enzymes to overcome these roadblocks.



All other glycolytic steps are **reversible** and used in reverse.



Net result: **Glucose** is synthesized from lactate, glycerol, and glucogenic amino acids.

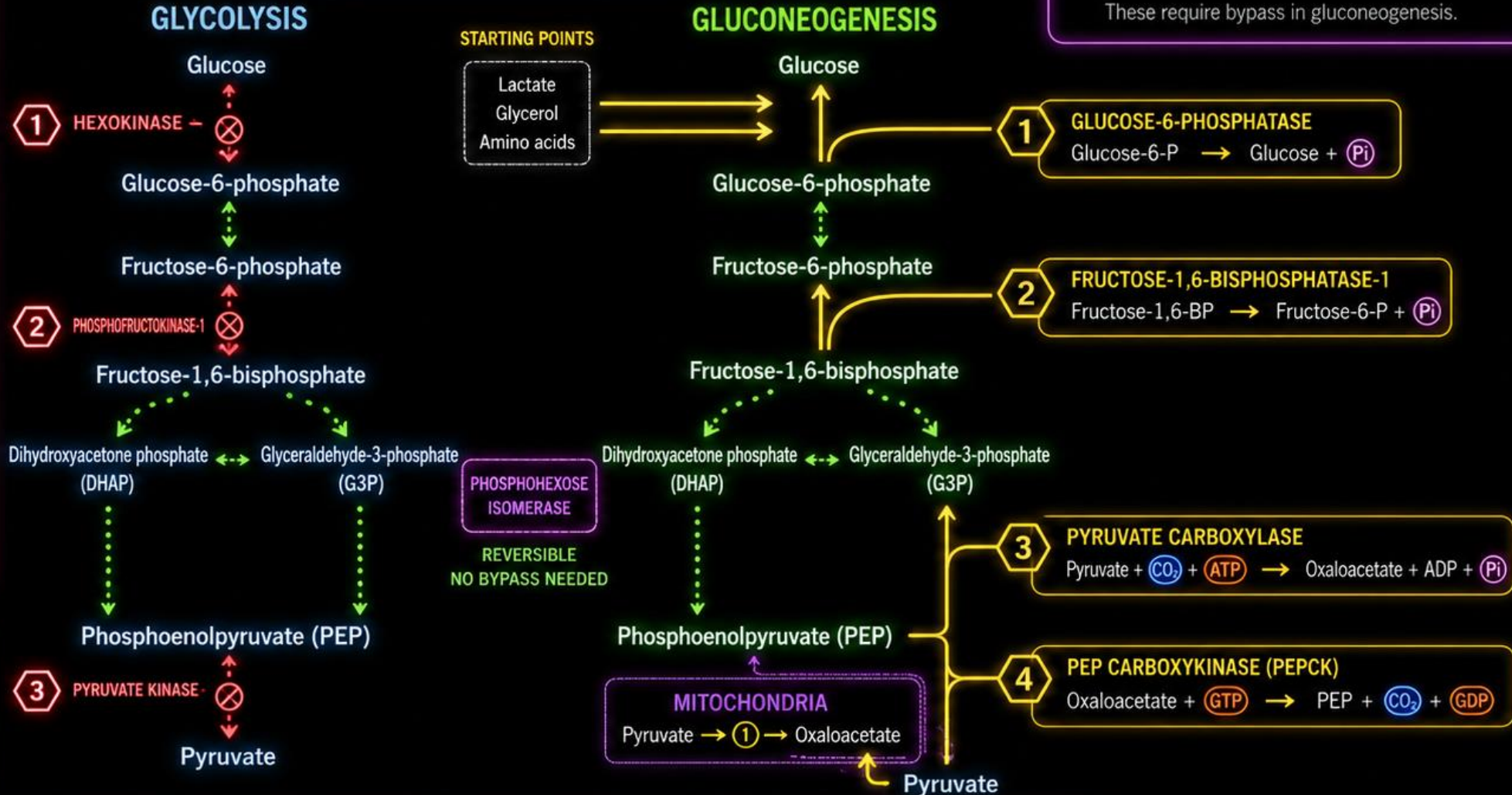


Occurs mainly in **liver** and, to a lesser extent, **kidney**.

LEGEND

- Irreversible step (Glycolysis)
- Reversible step (used in reverse)
- Bypass in Gluconeogenesis

How the body makes glucose from non-carbohydrate sources



KEY TAKEAWAY: Gluconeogenesis bypasses 3 irreversible glycolytic reactions using 4 unique enzymes. Phosphohexose isomerase is **reversible** and does not require a bypass.



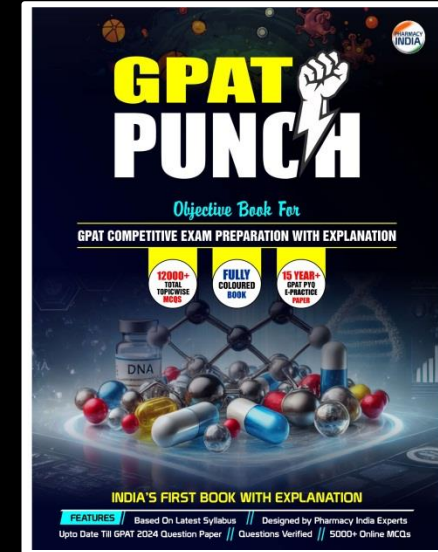
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46.

Gluconeogenesis can proceed from all of the following, except:

- (a) Pyruvate
- (b) Palmitic acid
- (c) Propionyl-CoA
- (d) Oxaloacetate



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46.

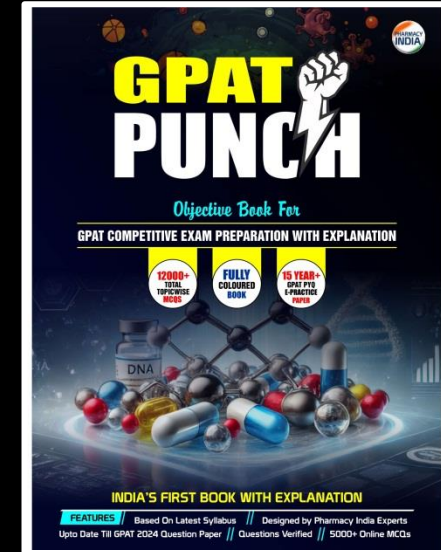
Gluconeogenesis can proceed from all of the following, except:

(a) Pyruvate

(b) Palmitic acid

(c) Propionyl-CoA

(d) Oxaloacetate



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WHY PALMITIC ACID CANNOT FORM GLUCOSE



① EVEN-CHAIN FATTY ACID

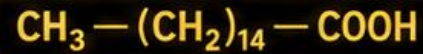
- Palmitic acid (C16:0) is an even-chain saturated fatty acid.



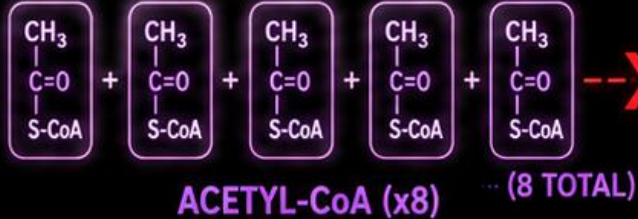
② β-OXIDATION → ACETYL-CoA

- Palmitic acid undergoes β-oxidation in mitochondria to yield **8 acetyl-CoA**.

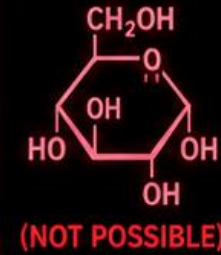
PALMITIC ACID (C16:0)



β-OXIDATION (MITOCHONDRIA)

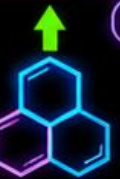


NET GLUCOSE



③ NO NET GLUCOSE FROM ACETYL-CoA (HUMANS)

- Acetyl-CoA enters the TCA cycle and is fully oxidized to $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{energy}$.
- There is **no pathway** to convert acetyl-CoA into **net glucose**.



④ PRECURSORS THAT CAN FORM GLUCOSE

- Pyruvate, Oxaloacetate, and Propionyl-CoA provide carbon that enters **gluconeogenesis**.

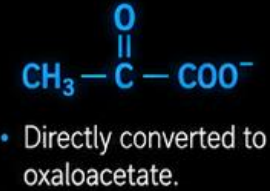


⑤ CONCLUSION

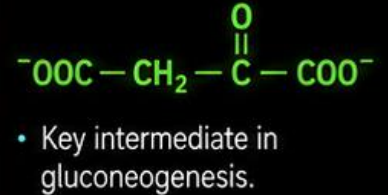
- As an even-chain fatty acid, palmitic acid yields only acetyl-CoA → therefore, it **cannot form net glucose**.

GLUCONEOGENIC PRECURSORS (CAN FORM GLUCOSE)

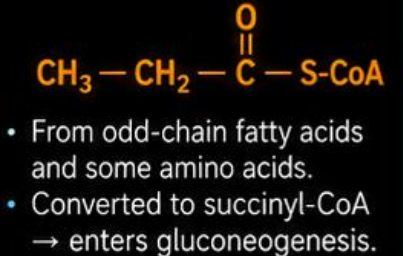
PYRUVATE



OXALOACETATE



PROPIONYL-CoA



GLUCONEOGENESIS



NET GLUCOSE (POSSIBLE)

TCA CYCLE



ENERGY (ATP)



BOTTOM LINE:

Palmitic acid → acetyl-CoA → TCA cycle → energy.
It **CANNOT** be converted into **net glucose** in humans.





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47.

The following are functions of pentose phosphate pathway, except:

- (a) Interconverts hexoses and pentoses
- (b) Produces NADPH
- (c) Supplies ribose-5-phosphate
- (d) Converts glucose to galactose



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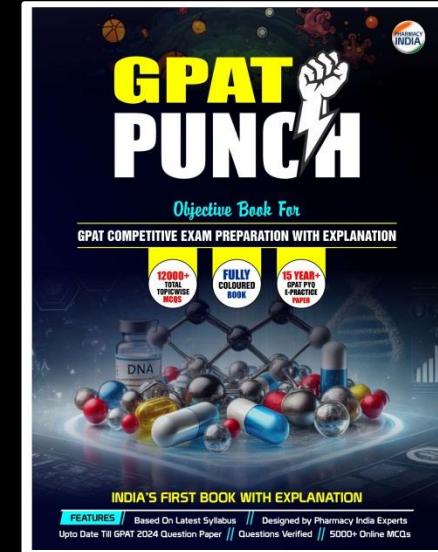
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- (d) Converts glucose to galactose



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PENTOSE PHOSPHATE PATHWAY (PPP)

An alternative pathway of glucose metabolism in the cytosol

1 PPP PRODUCES NADPH



Generates NADPH in the oxidative phase for reductive biosynthesis and antioxidant defense.

2 SUPPLIES RIBOSE-5-PHOSPHATE



Provides ribose-5-phosphate for nucleotide and nucleic acid synthesis.

3 INTERCONVERTS SUGARS



Non-oxidative phase interconverts pentoses and hexoses as needed by the cell.

4 SUPPORTS REDUCTIVE BIOSYNTHESIS & ANTIOXIDANT DEFENSE



NADPH is essential for fatty acid & steroid synthesis and for maintaining reduced glutathione.

5 EXCEPTION (IMPORTANT!)

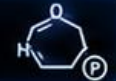


Conversion of glucose to galactose is NOT a function of PPP.

OXIDATIVE PHASE

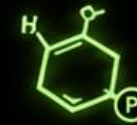
Irreversible

GLUCOSE-6-PHOSPHATE (G6P)



- 1 GLUCOSE-6-PHOSPHATE DEHYDROGENASE
Yields NADP^+ and $\text{NADPH} + \text{H}^+$
- 2 6-PHOSPHOGLUCONOLACTONE HYDROLASE
Yields H_2O
- 3 6-PHOSPHOGLUCONATE DEHYDROGENASE
Yields NADP^+ and $\text{NADPH} + \text{H}^+$, and CO_2

NADPH



For reductive biosynthesis & antioxidant defense

RIBULOSE-5-PHOSPHATE (Ru5P)

NON-OXIDATIVE PHASE

Reversible

RIBOSE-5-PHOSPHATE (R5P)



INTERCONVERSION OF SUGARS

Xylulose-5-Phosphate (Xu5P)



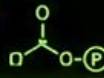
Sedoheptulose-7-Phosphate (S7P)



Fructose-6-Phosphate (F6P)



Glyceraldehyde-3-Phosphate (G3P)



MAIN FUNCTIONS

- Produces NADPH
- Supplies ribose-5-phosphate
- Interconverts pentoses and hexoses
- Supports reductive biosynthesis
- Maintains antioxidant defense

WHERE IT OCCURS

Cytosol in all cells

KEY ENZYMES (OXIDATIVE PHASE)

- 1 Glucose-6-Phosphate Dehydrogenase
- 2 6-Phosphogluconolactone Hydrolase
- 3 6-Phosphogluconate Dehydrogenase

EXCEPTION (IMPORTANT!)

Conversion of glucose to galactose (via Leloir pathway) is NOT a function of PPP.



LEGEND

- Generates
- Uses/Consumes
- Yields
- Irreversible Step
- ↔ Reversible Step
- ⬡ Pentose (5C Sugar)
- ⬡ Hexose (6C Sugar)
- ⬡ Phosphate Group



48.

Anomers, such as α and β forms of D-glucose, differ in configuration specifically around which carbon atom?

- (a) The chiral carbon furthest from carbonyl group
- (b) The carbon involved in branching
- (c) A specific single carbon like C-4
- (d) The anomeric carbon C-1



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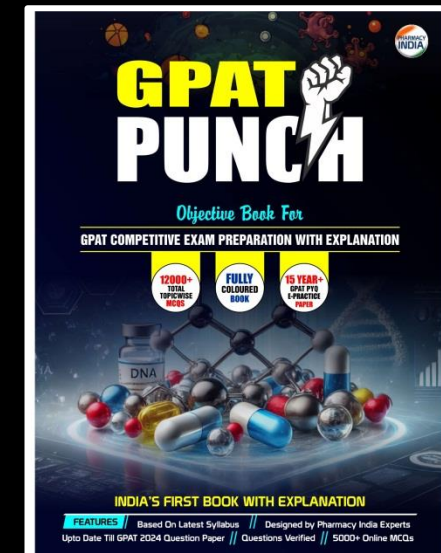
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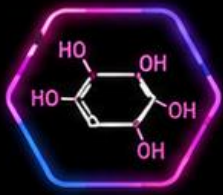
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ANOMERS OF D-GLUCOSE



Same molecule • Different orientation at **C-1** • Different **anomer**



1. **ANOMERS DIFFER**
AT THE ANOMERIC
CARBON.

1

2. IN GLUCOSE,
THIS IS **CARBON-1**
(C-1).



3. **α** AND **β** FORMS ARE
CYCLIC ISOMERS.



4. **MUTAROTATION**
OCCURS VIA
INTERCONVERSION.

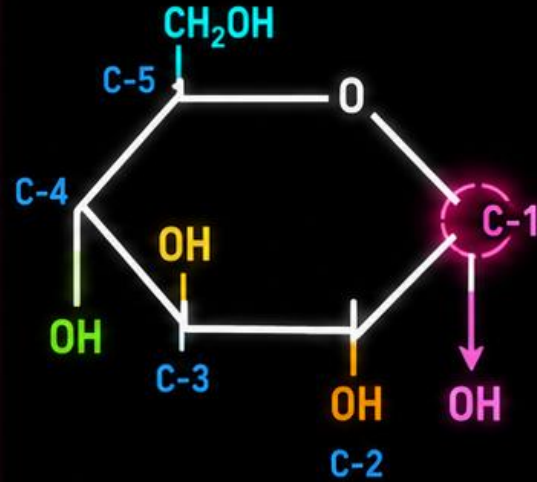


5. THIS IS NOT THE SAME
AS **EPIMERISM** AT
OTHER CARBONS.

RING FORMS (PYRANOSE)

α-D-GLUCOSE

(Alpha Anomer)



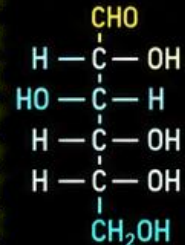
OH at C-1 is **DOWN**
(trans to CH₂OH)

ONLY CHANGE
AT **C-1**:
ORIENTATION
OF **OH** GROUP



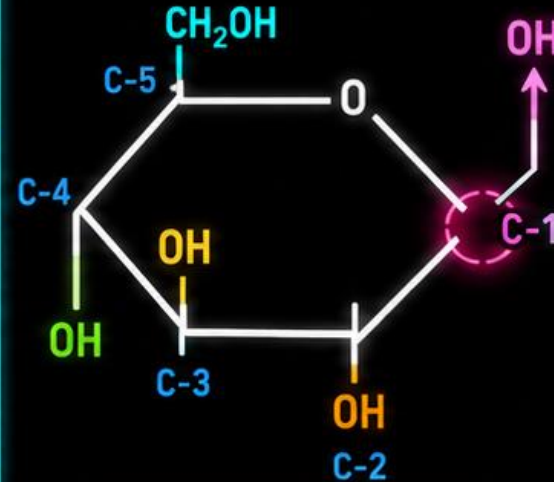
MUTAROTATION
Via open-chain
intermediate

D-GLUCOSE
(OPEN CHAIN)



β-D-GLUCOSE

(Beta Anomer)



OH at C-1 is **UP**
(cis to CH₂OH)



KEY POINT

Anomers arise due to
formation of a new
chiral center at **C-1**
during ring closure.



REMEMBER

In D-sugars,
CH₂OH group is
UP in Haworth
projection.



STABILITY (IN WATER)

Both α and β forms
exist; **β-D-glucose**
is slightly more
abundant (~64%).



WHY IT MATTERS

Affects reactivity,
recognition by enzymes,
and biological function
of carbohydrates.

COLOR GUIDE (WHAT'S WHAT)

C-1

Anomeric
Carbon
(Key Site)

CH₂OH

Reference
Group
(UP in D-Sugars)

OH

Hydroxyl
Groups

α

OH Down
(Trans to
CH₂OH)

β

OH Up
(Cis to
CH₂OH)



Mutarotation
(Interconversion
in Solution)



Not Epimerism
(Change only
at C-1)

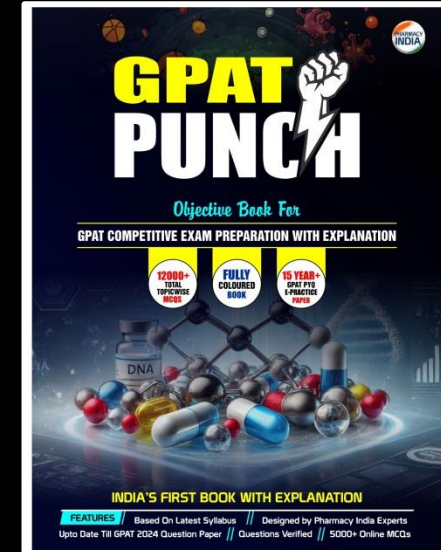


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49.

McArdle's syndrome involves a deficiency of which enzyme?

- (a) Hepatic phosphorylase
- (b) Muscle phosphorylase
- (c) Branching enzyme
- (d) Hepatic glycogen synthase



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49.

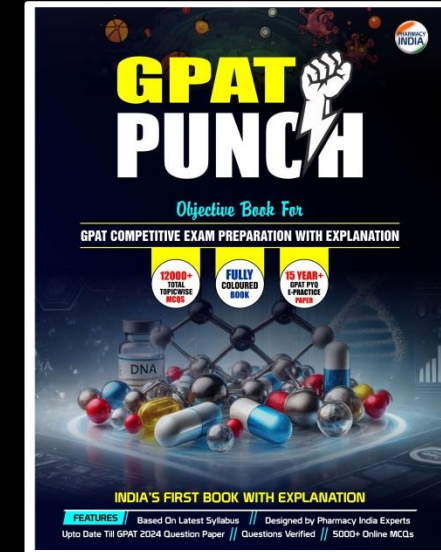
McArdle's syndrome involves a deficiency of which enzyme?

(a) Hepatic phosphorylase

(b) Muscle phosphorylase

(c) Branching enzyme

(d) Hepatic glycogen synthase



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MCARDLE SYNDROME

SKELETAL MUSCLE GLYCOGEN BREAKDOWN

MUSCLE PHOSPHORYLASE DEFICIENCY



1. GLYCOGEN STORAGE DISEASE TYPE V

McArdle disease is
GSD type V.



2. ENZYME DEFICIENCY

Due to deficiency of
**MUSCLE GLYCOGEN
PHOSPHORYLASE.**



3. IMPAIRED GLYCOGENOLYSIS

Muscle glycogen
cannot be properly
broken down.



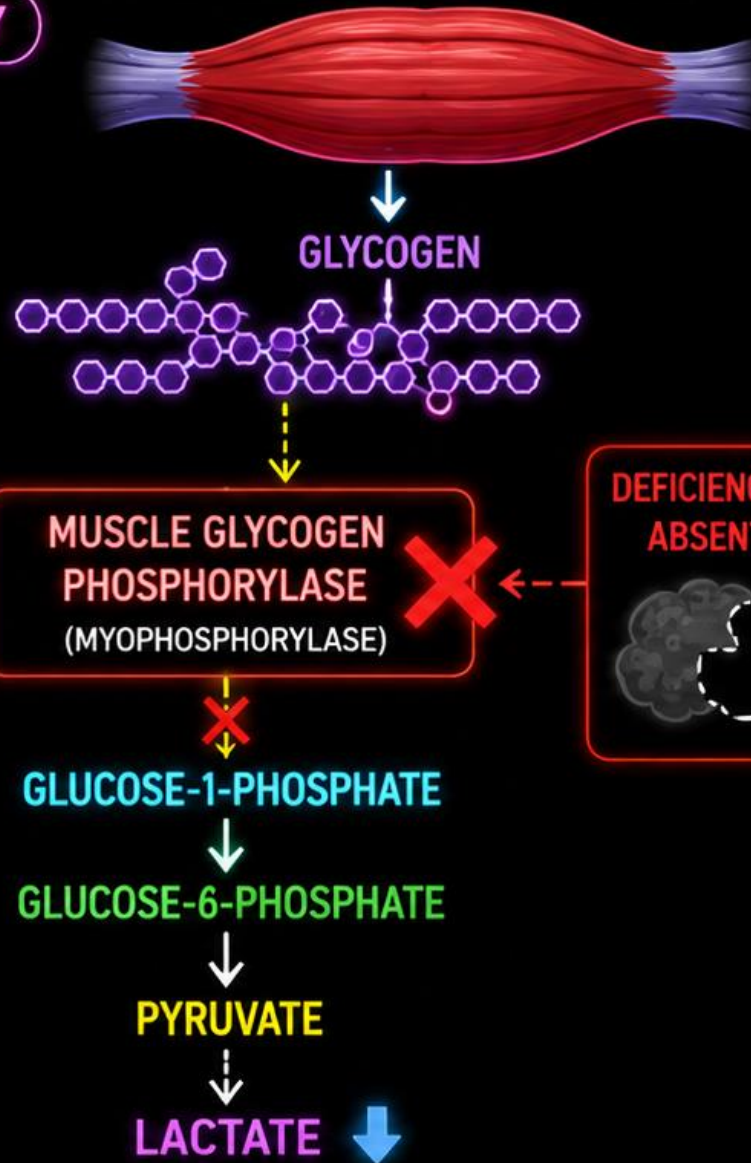
4. CLINICAL FEATURES

Exercise intolerance
and muscle cramps
are common.



5. LACTATE RESPONSE

Blood lactate rise
after exercise is
REDUCED.



KEY POINT

Deficiency of muscle
glycogen phosphorylase
blocks glycogen breakdown
in skeletal muscle.



WHAT HAPPENS?

During exercise, muscle
cannot use its glycogen
stores for energy.
Early fatigue and pain
occur.



LAB FINDING

Little or no rise in
blood lactate after
exercise.



MANAGEMENT

Avoid intense exercise,
warm-up regularly,
moderate activity,
and balanced diet.

★ **REMEMBER: MUSCLE PHOSPHORYLASE DEFICIENCY = BLOCKED GLYCOGEN BREAKDOWN = EXERCISE INTOLERANCE**



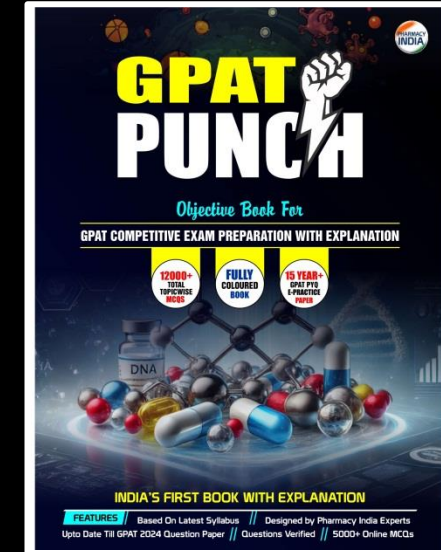
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50.

Deficiency of glucose-6-phosphate dehydrogenase causes:

- (a) Cataract
- (b) Hypoglycemia
- (c) Hemolytic anemia
- (d) Galactosemia



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50.

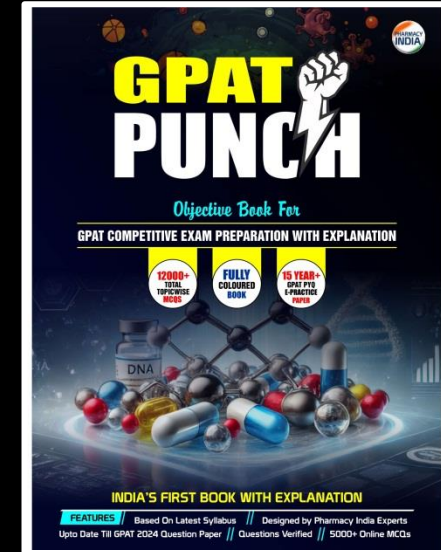
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(a) Cataract

(b) Hypoglycemia

(c) Hemolytic anemia

(d) Galactosemia



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G6PD DEFICIENCY AND HEMOLYTIC ANEMIA

1



G6PD GENERATES NADPH IN RBCs

Glucose-6-phosphate dehydrogenase is the first enzyme of the pentose phosphate pathway.

2



NADPH KEEPS GLUTATHIONE IN REDUCED FORM

NADPH reduces glutathione (GSSG → GSH) which detoxifies harmful peroxides.

3



DEFICIENCY MAKES RBCs VULNERABLE TO OXIDATIVE STRESS

Low NADPH → low GSH → oxidative damage to hemoglobin and membrane.

4



TRIGGERS CAN CAUSE HEMOLYSIS

Drugs, infections, fava beans and chemicals increase oxidative stress.

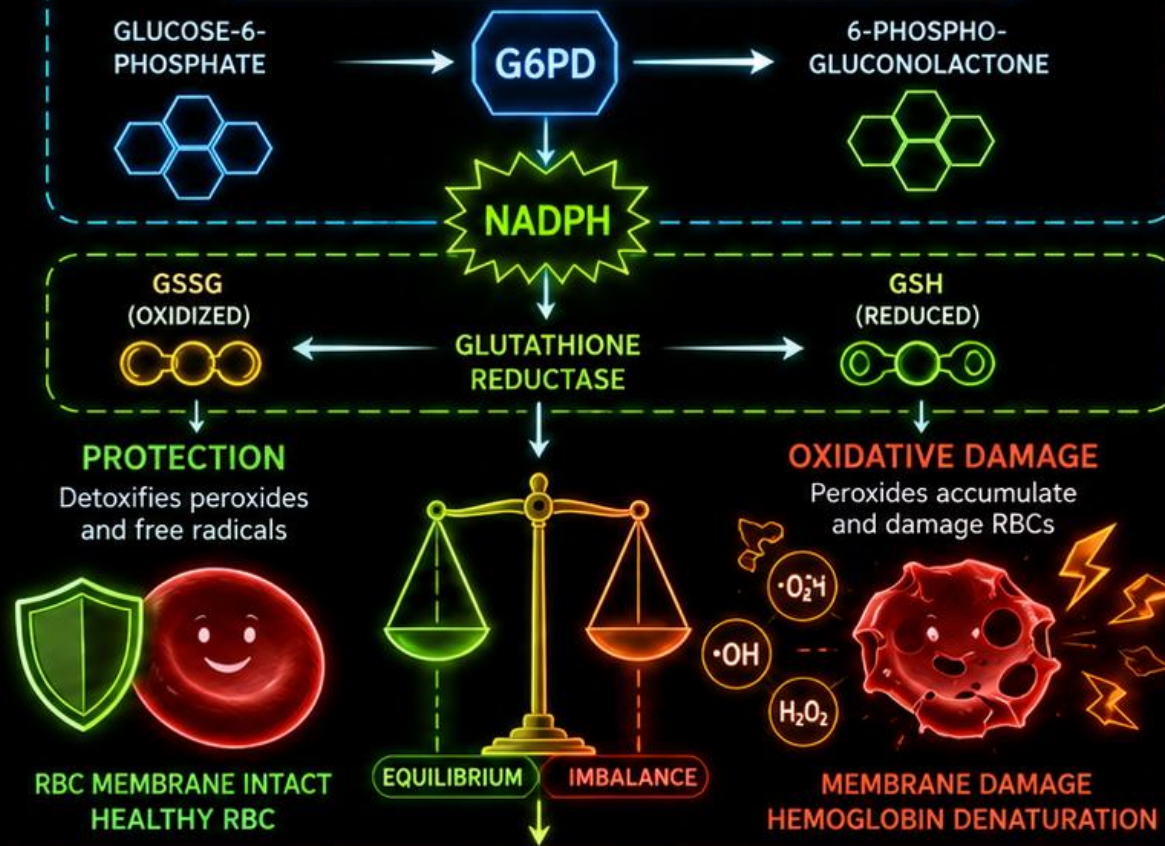
5



RESULT: HEMOLYTIC ANEMIA

Premature RBC destruction leads to anemia, jaundice and dark urine.

NADPH: THE RBC ANTIOXIDANT SHIELD



COMMON TRIGGERS



Certain Drugs
(e.g., sulfa drugs, dapsone, primaquine, nitrofurantoin)



Infections
(bacterial or viral)



Fava Beans
(favism)



Chemicals
(naphthalene, mothballs, oxidant dyes)

RESULTING FEATURES



Fatigue, Pallor



Jaundice



Dark (tea-colored) Urine



Reticulocytosis



↑ Indirect Bilirubin, ↑ LDH
↓ Haptoglobin



X-LINKED RECESSIVE DISORDER

More common in males.



KEY TAKEAWAY:

G6PD produces **NADPH**, which keeps **glutathione** reduced (GSH) and protects RBCs from oxidative damage.
Deficiency → oxidative stress → hemolysis → hemolytic anemia.

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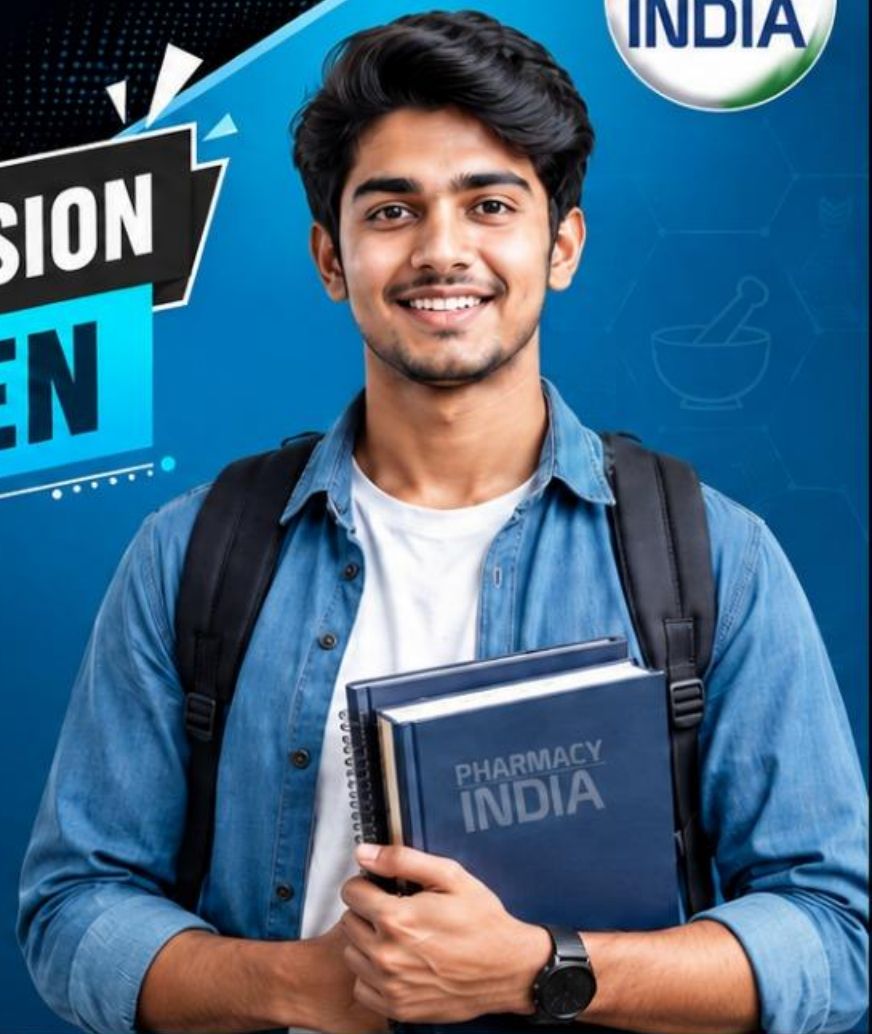
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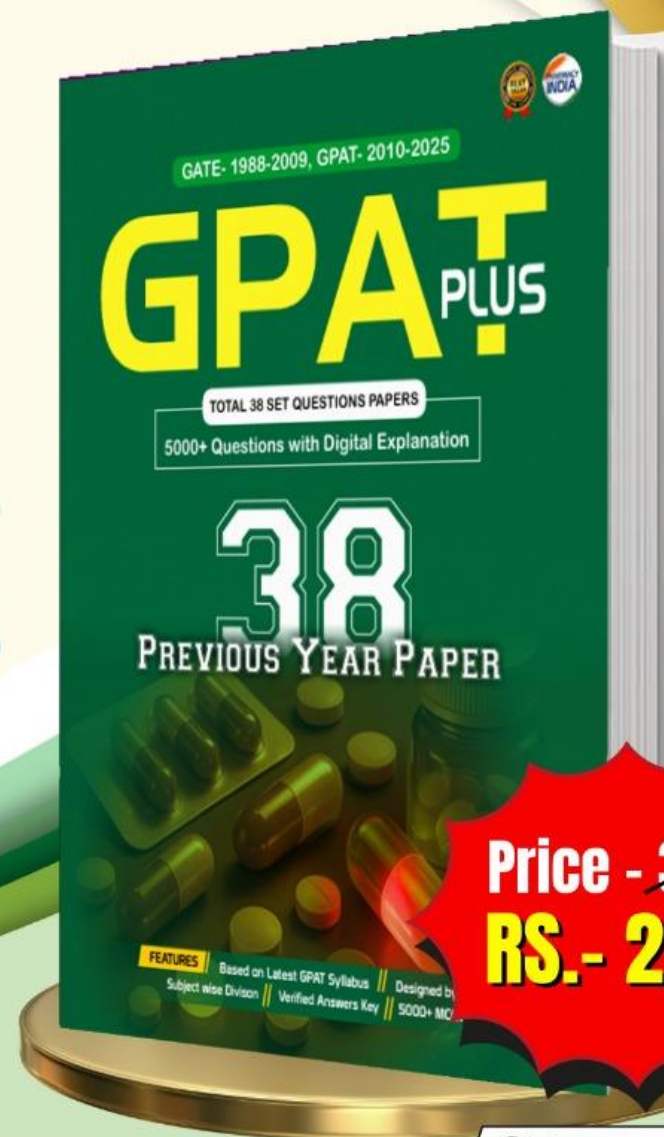
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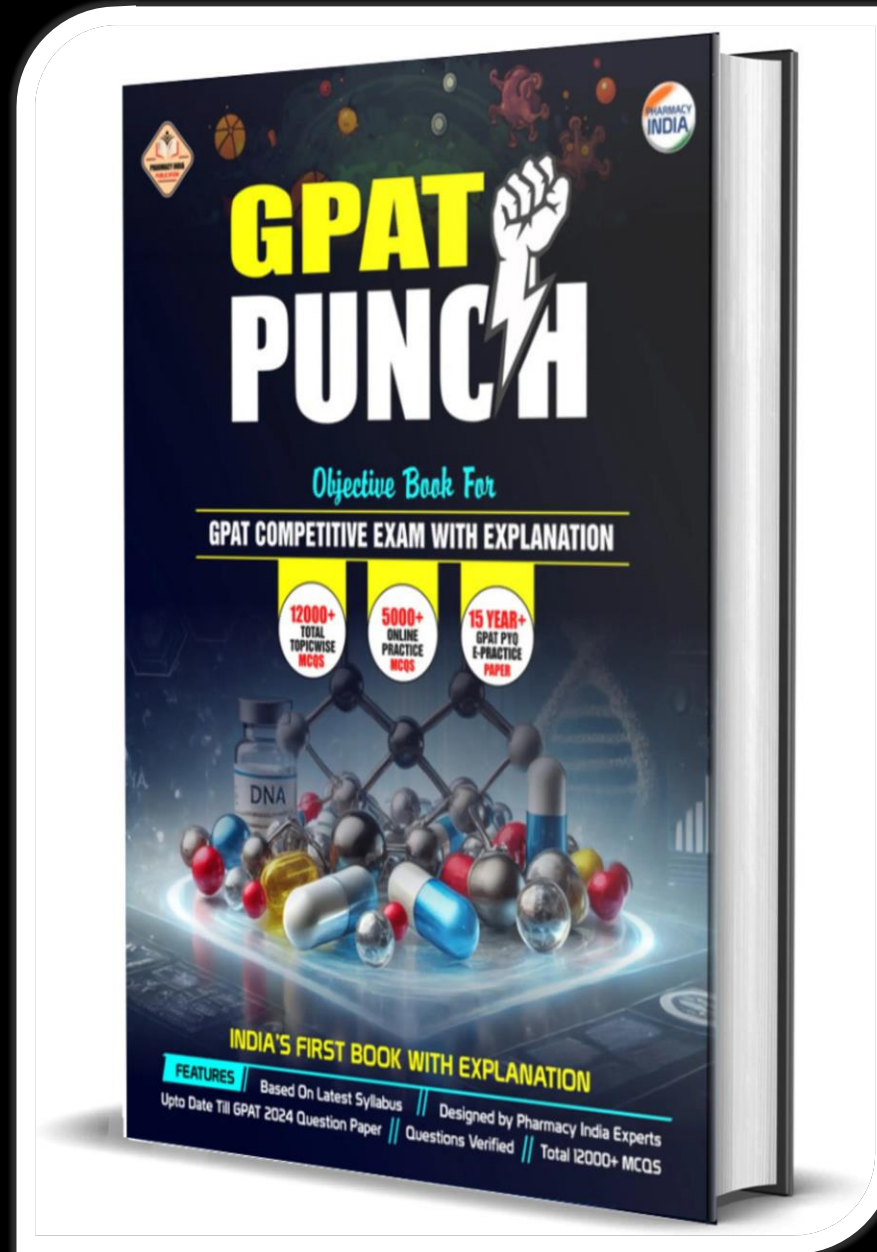


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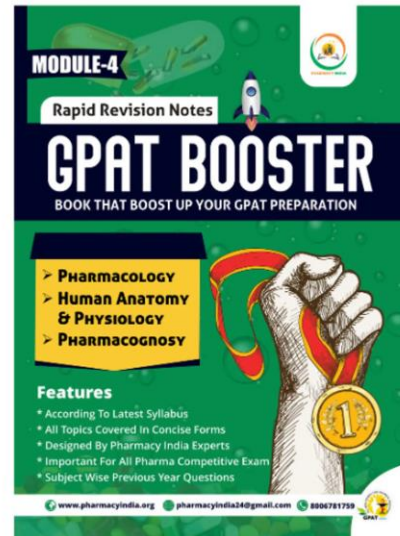
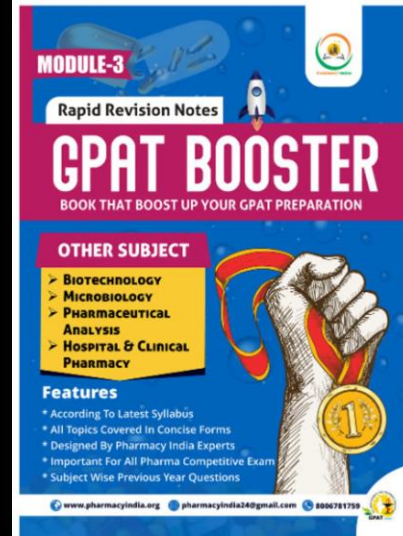
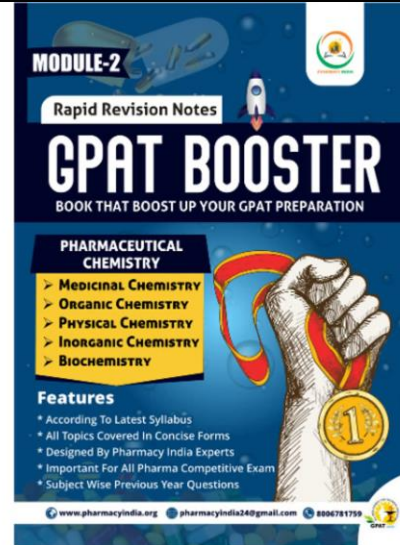
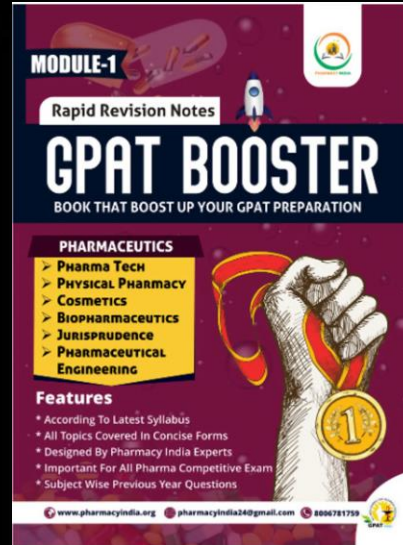
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