Most Updated and Latest Edition 2022

Covering all Recent Updates & Qs up to June 2022 Exams

A Comprehensive and Thoroughly Colored Book on Biochemistry with Most Innovative Approach Covering Concepts, 100+ IBQs, One Liners, Diagrammatic Approach to Difficult Topics, and Formulae to Solve Qs (First Time Given in Any Book)

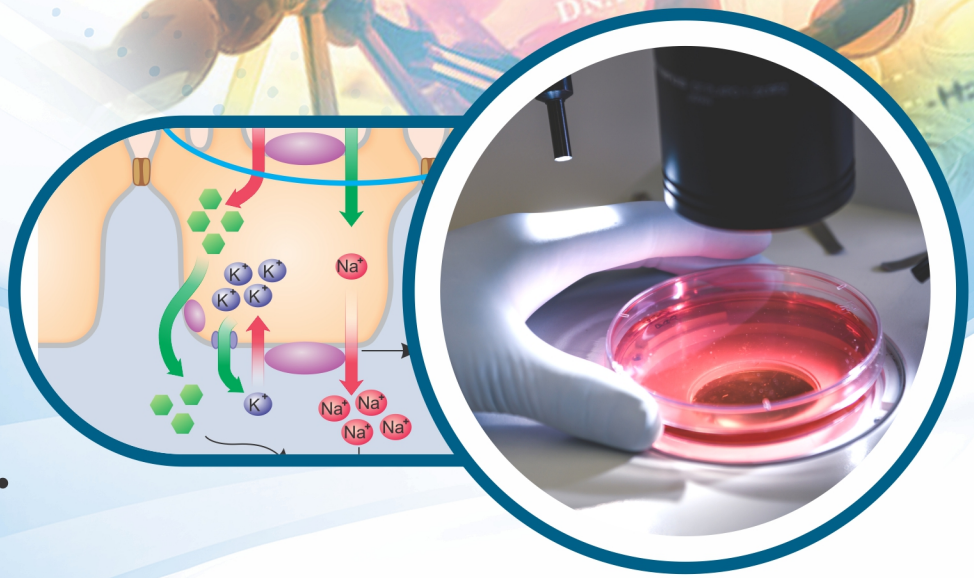
4th EDITION

Conceptual Review of

Biochemistry

As per the New Pattern Exams (NEXT) with many Clinical Case-Based Questions

References and Updates from Harper's 31/e, Lehninger's 7/e, Harrison's 20/e, Lippincott's 7/e, Teitz's 7/e, Devlin's 8/e



Papers Covered

- INI-CET 2022-2020
- Recent Qs 2022 – 2012
- AIIMS June 2020 – 2010
- Expected Clinical Case-Based Qs
- CBME-Based Subjective Qs with Chapter References

- Written and Compiled by Leading Faculty and Subject Expert of Biochemistry
- Enriched with Recent/Latest Updates

Includes

1500+	100+	100+	500+
MCQs of Recent Exams	CBQs	IBQs	Clinical Illustrations/Images

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Smily Pruthi Pahwa MBBS MD (Biochemistry)

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Preface

Biochemistry stands out as the most troublesome and unstable subject among the nineteen subjects that one needs to ace to cruise over the Pre-PG Exams. What makes biochemistry significantly more critical is its basics, which are connected to other subjects, like physiology, pharmacology and medicine. In recent Medical Entrance Exams, about **10–15 MCQs are given from biochemistry which include a mix of clinical case-based questions, simple memory-based questions, multiple answer type and image-based questions**.

Keeping all these facts in mind, the primary aim of this book is to enable you to develop basics with ease. Many self-made formulae are given in the book to make the subject easy and to help in solving most of the MCQs by using these formulae. The language of the book has been kept lucid so that all students can understand it easily. The Unit I, Concepts in Biochemistry, emphasizes how the subject is interrelated to other subjects. This will help you to create a link with other chapters. This book contains Six Units in toto. **This edition also includes a separate section on clinical case-based and conceptual questions in each chapter to prepare the students for latest changes in PG entrance exam pattern. Some recently asked short topics are also added to improve the strike rate and student's performance**.

The theme of the book is to keep it concise and straightforward with narrative approach. Several Flowcharts, Boxes, Tables and Illustrations have been added to build a Conceptual Learning. Your last-minute revision has been specially taken care of. For this, the important text has been highlighted and given in the boxes so that you can revise the subject at the eleventh hour. Very few mnemonics are included as the content of the book has been kept simple and title itself indicates the content included under it. Controversies in biochemistry have been carefully dealt with, wherever needed.

Finally, my suggestion to students is to build an understanding of biochemistry conceptually. Do not cram this interesting and easy subject. Just mugging up and cramming will not give long-term benefits. Go with the concepts and score well.

Good luck for your examinations! Feel free to get in touch with me for any doubt at my Facebook Group: www.facebook.com/groups/drsmilybiochem/

Smily Pruthi Pahwa

Contents

Preface ---- *v*
Acknowledgments ---- *vi*
CBME-Based Subjective Questions with Chapter References ---- *xi*
Latest Exam Questions 2022 ---- *xv*
INI-CET May 2022 (Recall Questions) ---- *xvi*
Recent Questions May 2022 ---- *xvi*

UNIT I CONCEPTS IN BIOCHEMISTRY

Chapter 1. Concepts in Biochemistry ---- 3–28
Theory ---- 3
Clinical Case-Based Questions ---- 18
Answers of Clinical Case-Based Questions ---- 18
Multiple Choice Questions ---- 19
Answers with Explanations ---- 22

UNIT II CARBOHYDRATES

Chapter 2. Chemistry of Carbohydrates ---- 31–61
Theory ---- 31
Clinical Case-Based Question ---- 50
Answer of Clinical Case-Based Question ---- 50
Multiple Choice Questions ---- 51
Answers with Explanations ---- 55

Chapter 3. Carbohydrate Metabolism ---- 62–137
Theory ---- 62
Clinical Case-Based Questions ---- 102
Answers of Clinical Case-Based Questions ---- 103
Multiple Choice Questions ---- 105
Answers with Explanations ---- 117

UNIT III ENZYMES, AMINO ACIDS AND PROTEINS

Chapter 4. Enzymes ---- 141–167
Theory ---- 141
Multiple Choice Questions ---- 159
Answers with Explanations ---- 162

Chapter 5. Chemistry and Metabolism of Amino Acids ---- 168–209
Theory ---- 168
Clinical Case-Based Questions ---- 195
Answers of Clinical Case-Based Questions ---- 196
Multiple Choice Questions ---- 197
Answers with Explanations ---- 201

Chapter 6. Urea Cycle ---- 210–224
Theory ---- 210
Clinical Case-Based Question ---- 218
Answer of Clinical Case-Based Question ---- 218
Multiple Choice Questions ---- 219
Answers with Explanations ---- 221

Chapter 7. Proteins ---- 225–255
Theory ---- 225
Clinical Case-Based Questions ---- 243
Answers of Clinical Case-Based Questions ---- 244
Multiple Choice Questions ---- 245
Answers with Explanations ---- 249

UNIT IV LIPIDS

Chapter 8. Chemistry of Lipids ---- 259–276
Theory ---- 259
Clinical Case-Based Questions ---- 268
Answers of Clinical Case-Based Questions ---- 268
Multiple Choice Questions ---- 269
Answers with Explanations ---- 272

Chapter 9. Lipoproteins ---- 277–291
Theory ---- 277
Clinical Case-Based Questions ---- 284
Answers of Clinical Case-Based Questions ---- 284
Multiple Choice Questions ---- 285
Answers with Explanations ---- 288

Chapter 10. Metabolism of Lipids ---- 292–314
Theory ---- 292
Clinical Case-Based Questions ---- 306
Answers of Clinical Case-Based Questions ---- 306
Multiple Choice Questions ---- 307
Answers with Explanations ---- 310

UNIT V MOLECULAR BIOLOGY

Chapter 11. Chemistry and Metabolism of Nucleotides ---- 317–330
Theory ---- 317
Clinical Case-Based Questions ---- 325
Answers of Clinical Case-Based Questions ---- 325
Multiple Choice Questions ---- 326
Answers with Explanations ---- 328

Chapter 12. Basics in Genetics ---- 331–362
Theory ---- 331
Multiple Choice Questions ---- 348
Answers with Explanations ---- 353

Chapter 13. Replication, Transcription, Translation ---- 363–396
Theory ---- 363
Clinical Case-Based Questions ---- 381
Answers of Clinical Case-Based Questions ---- 382
Multiple Choice Questions ---- 383
Answers with Explanations ---- 388

Chapter 14. Techniques in Molecular Biology ---- 397–424
Theory ---- 397
Clinical Case-Based Questions ---- 411
Answers of Clinical Case-Based Questions ---- 412
Multiple Choice Questions ---- 413
Answers with Explanations ---- 417

UNIT VI MISCELLANEOUS

Chapter 15. Miscellaneous ---- 427–477
Theory ---- 427
Clinical Case-Based Questions ---- 452
Answers of Clinical Case-Based Questions ---- 452
Multiple Choice Questions ---- 454
Answers with Explanations ---- 462

Extra Edge Tables ---- *479–481*
Image–Based Questions ---- *483–522*

CBME-Based Subjective Questions with Chapter References*

Competencies	Subjective Questions	For Answer Refer to Chapter
	Basic Biochemistry	
BI 1.1	Describe the molecular and functional organization of a cell and its sub-cellular components	Chapter 1
	Enzyme	
BI 2.1	Explain fundamental concepts of enzyme, isoenzyme, alloenzyme, coenzyme and co-factors. Enumerate the main classes of nomenclature	Chapter 4
BI 2.2	Observe the estimation of SGOT and SGPT	–
BI 11.13	Demonstrate the estimation of SGOT/SGPT	–
BI 2.3	Describe and explain the basic principles of enzyme activity	Chapter 4
BI 2.4	Describe and discuss enzyme inhibitors as poisons and drugs and as therapeutic enzymes	Chapter 4
BI 2.5	Describe and discuss the clinical utility of various serum enzymes as markers of pathological conditions	–
	Interpret laboratory results of enzymes activities and describe the clinical utility of various enzymes as markers of pathological conditions	Chapter 4
BI 2.6	Discuss use of enzymes in laboratory investigations (enzyme-based essays)	Chapter 2
	Chemistry and Metabolism of Carbohydrates	
BI 3.1	Discuss and differentiate monosaccharides, di-saccharides and polysaccharides giving examples of main carbohydrates as energy fuel, structural element and storage in the human body	Chapter 2
BI 3.2	Describe the processes involved in digestion and assimilation of carbohydrates and storage	Chapter 2
BI 3.3	Describe and discuss the digestion and assimilation of carbohydrates from food	Chapter 2
BI 3.4	Define and differentiate the pathways of carbohydrate metabolism (glycolysis, gluconeogenesis, glycogen metabolism, HMP shunt)	Chapter 3
BI 3.5	Describe and discuss the regulation, functions and integration of carbohydrate along with associated diseases/ disorders	Chapter 3
BI 3.6	Describe and discuss the concept of TCA cycle as an amphibolic pathway and its regulation	Chapter 3
BI 3.7	Describe the common poisons that inhibit crucial enzymes of carbohydrate metabolism (e.g., fluoride, arsenate)	Chapter 3
BI 3.8	Discuss and interpret laboratory results of analytes associated with metabolism of carbohydrates	–
BI 3.9	Discuss the mechanism and significance of blood glucose regulation in health and disease	Chapter 1 and 3
BI 3.10	Interpret the results of blood glucose levels and other laboratory investigations related to disorders of carbohydrate metabolism	Chapter 3
	Chemistry and Metabolism of Lipids	
BI 4.1	Describe and discuss main classes of lipids (essential/non-essential fatty acids, cholesterol and hormonal steroids, triglycerides, major phospholipids and sphingolipids) relevant to human system and their major functions	Chapter 8
BI 4.2	Describe the processes involved in digestion and absorption of dietary lipids and also the key features of their metabolism	Chapter 9

Contd...

** Important competency-based topics covered*

Latest Exam Questions 2022

1. INI-CET May 2022
2. Recent Questions May 2022

INI-CET MAY 2022 (RECALL QUESTIONS)

1. In MSUD (Maple Syrup Urine disorder), which of the following is not restricted?

a. Methionine b. Valine
c. Leucine d. Isoleucine

2. Uracil was found in genetic code. Which vitamin deficiency leads to this condition?

a. B_{12} b. B_6
c. Folate d. Vit E

3. Banding technique used for dicentric chromosomes is:

a. G b. NOR
c. C d. R

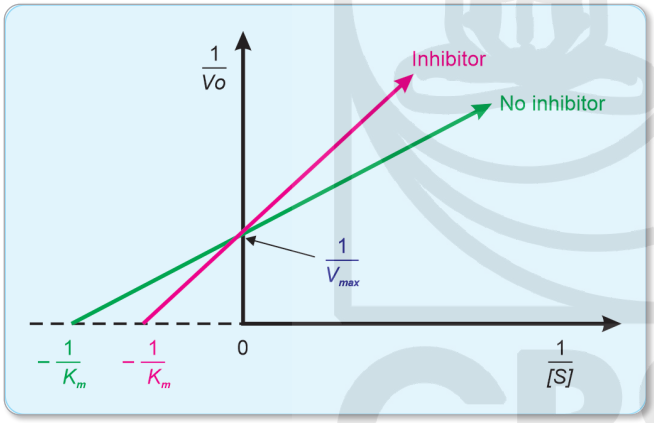
4. Eicosanoids are formed from:

a. Arachidonic acid b. Platelet aggregation
c. 4 fused rings d. Arginine

5. Deamination of methylated cytosine will form:

a. Uracil b. Guanine
c. Adenine d. Thymine

6. Identify the type of inhibitor in the graph.



a. Competitive inhibitor
b. Non-competitive inhibitor
c. Allosteric inhibitor
d. Uncompetitive inhibitor

7. You are expected to produce a protein of interest. Arrange the following steps in a sequence.

A. Lysis of bacterial cell
B. Incorporating gene of interest into bacteria
C. SDS-PAGE
D. Hybridization
E. Protein elution/extraction
F. Expression of protein

a. A-B-C-D-E-F b. B-C-D-A-F-E
c. B-D-A-C-E-F d. B-F-A-C-D-E
e. C-B-A-D-E-F

8. DNA-Protein interactions can be studied by using:

a. DNA fingerprinting
b. DNA footprinting
c. Northern Blotting
d. ELISA

9. Which of the following is correctly matched?

A. Oxygen: Simple Diffusion
B. Glucose: Facilitated diffusion and Na-dependent
C. Calcium: Active transport
D. Na: Secondary Active transport

a. Only B is correct
b. A and C are correct
c. A, B and C are correct
d. A, B, C and D are correct

10. Match the following transporters with the molecule they carry.

1. Hemopexin	a. Thyroxin
2. Haptoglobin	b. Free fatty acid
3. Pre-albumin	c. Heme
4. Albumin	d. Hemoglobin

a. 1b, 2a, 3c, 4d b. 1c, 2d, 3a, 4b
c. 1a , 2c, 3b, 4d d. 1c, 2a, 3d, 4b

11. Which of the following is false regarding Human genome project?

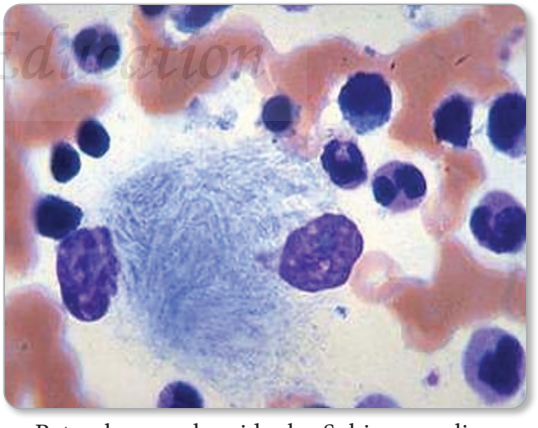
a. Collaboration of many countries
b. 20000 total genes were identified
c. It uses modern sequencing techniques
d. It took 2 years to discover

12. dd-NTPs in Sanger's Sequencing technique uses:

a. Its fluorescence
b. DNA polymerization
c. Termination of polymerase
d. Removal of primer

RECENT QUESTIONS MAY 2022

13. The following histological image is seen in a patient who is complaining of growth failure and abdominal distension. Signs found were anemia, thrombocytopenia and bony pain. Which enzyme is deficient in this patient?



a. Beta-glucocerebroside b. Sphingomyelinase
c. Hexosaminidase d. G-6-phosphatase
e. Alpha-glucocerebrosidase

Ans.

1. a
2. c
3. c
4. a
5. d
6. a
7. d
8. b
9. d
10. b
11. d
12. c
13. a

INI-CET MAY 2022 (RECALL QUESTIONS)

1. Ans. (a) Methionine

[Ref: Harper's 31st/e pg. 290]

Maple Syrup Urine Disorder (MSUD) occurs due to the inherited deficiency of branched Chain Keto-acid Decarboxylase resulting in defect in oxidative decarboxylation and catabolism of branched chain amino acids Valine, Isoleucine and Leucine. As a result, these amino acids accumulate and are excreted in urine. So, for the treatment, these BCAA should be restricted in diet. Methionine is a sulfur containing amino acid and do not require this enzyme for its metabolism. So, its restriction is not required in MSUD.

2. Ans. (c) Folate

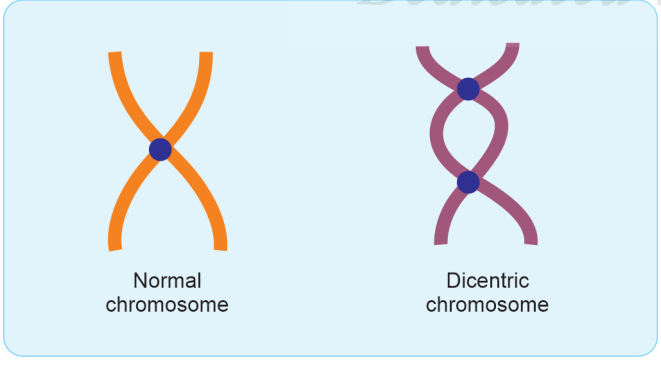
[Ref: Harper's 31st/e pg. 333]

Genetic code is related to DNA, but DNA does not contain Uracil. In pyrimidine synthesis, UMP is the first pyrimidine nucleotide to be synthesized and other two pyrimidines thymine and Cytosine are synthesized from it. Uracil to cytosine conversion requires amino group addition provided by glutamine. Uracil is converted to thymine by enzyme thymidylate synthase by methylation where methyl group is donated by methyl-THF. So, deficiency of Folate will result in thymine deficiency and may lead to uracil appearing in the DNA in place of thymine.

3. Ans. (c) C

[Ref: Robbins 10th Ed. / page- 262-263, 293]

Dicentric chromosome is an abnormal chromosome with two centromeres.



C-banding: Stains heterochromatin which are regions of the chromosomes at or near centromere. **So, C-banding will be most useful for dicentric chromosomes.**
Q-banding: Uses quinacrine dye (first used dye) and stains repetitive AT rich regions.
G-banding: Is the most common banding and uses Giemsa stain to stain AT rich regions also. It is developed as an alternative to Q-banding due to cumbersome nature of Q-banding.
R-Banding: Reverse pattern to G-banding and stains GC rich regions instead of AT.

4. Ans. (a) Arachidonic acid

[Ref: Harper's 31st/e pg. 224]

Arachidonic acid has 20 C, 4= and is synthesized from linoleic acid. Eicosanoids (Prostaglandins and leukotrienes) are synthesized from arachidonic acid. So, Linoleic acid is considered the most essential fatty acid.

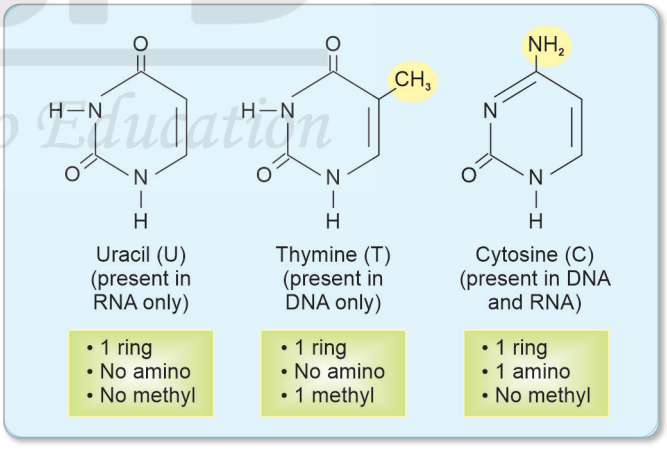
Extra Information on PUFAs

PUFAs/EFA	
Omega -3	**Omega – 6**
1. Cervonic Acid/DHA	1. γ-Linolenic Acid
2. α-Linolenic Acid	2. Linoleic Acid
3. Timnodonic Acid/EPA	3. Arachidonic Acid

5. Ans. (d) Thymine

[Ref: Harper's 31st/e pg. 323]

Thymine is a pyrimidine. The structures of different pyrimidines can be shown as:



Now, it is clear from the figure below that if methylated cytosine is deaminated, it will form thymine as:

Chapter 1

Concepts in Biochemistry ★★★★★

Overview of Chapter

- Cyclic AMP (cAMP)
- A Formula: Insulin and Glucagon in Fed and Fasting State
- Which are Anabolic and Catabolic Pathways?
- A Formula: Which Pathway Occurs in which Compartment?
- Sources of Blood Glucose and Main Fuel for Body
- Scene in Fasting State
- Fuel Used in Different Situations in Body
- Acetyl CoA in Fed and Fasting States
- Fats and Carbohydrates Interconversion: Full Story
- Diabetes
- Understanding Plan of Nature: How to Extract Energy from Macromolecules?
- Atkin's Diet
- Concepts of Enzymes
- Cell Organelles
- Bonds in Macromolecules

Fundamental Box

- **Fed state:** When we eat food (Within 2 hours of food intake is called fed state)
- **Fasting state:** In between meals, when we are not eating food (From 12 to 18 hours after food up to 48 hours is fasting)
- **Starvation:** Severe or complete lack of nutrients (since last 2–4 days)
- In between meals and night time is called fasting time. That's why Breakfast is named → **Break the night fast**

CYCLIC AMP (CAMP)

This is a second messenger synthesized from ATP, with the help of enzyme Adenyl Cyclase. cAMP activates kinases, which phosphorylate various proteins/enzymes in the body. Basically, cAMP leads to phosphorylation or we can say that adenyl cyclase leads to phosphorylation (Fig. 1.1).

cAMP is destroyed by enzyme Phosphodiesterase to 5′AMP. So, Phosphodiesterase causes dephosphorylation.

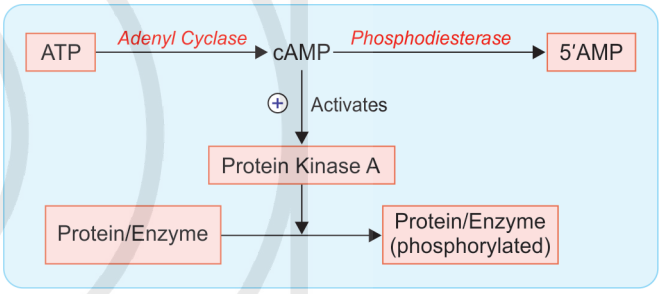


Fig. 1.1: cAMP synthesis and breakdown

A FORMULA: INSULIN AND GLUCAGON IN FED AND FASTING STATE

In fed state, we eat food, which is mainly carbohydrates (Glucose). Therefore, this glucose will cause Hyperglycemia. Insulin has to come to decrease this blood glucose. Hence, if Insulin comes in fed state that means Insulin is anabolic hormone, i.e., mainly, anabolism occurs in body in fed state. Insulin always causes Dephosphorylation by decreasing cAMP.

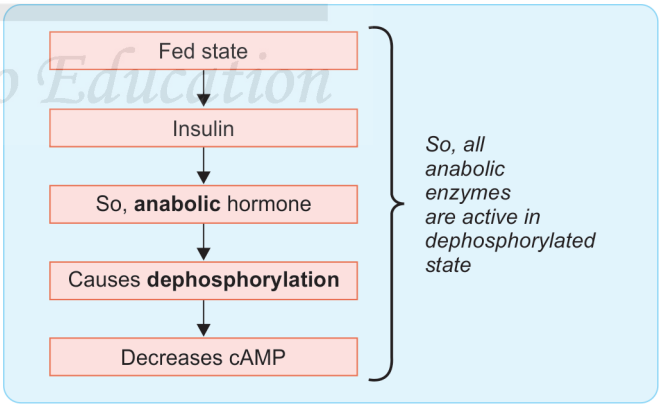


Fig. 1.2: Fed state

Formula Box

- **Insulin activates all anabolic pathway enzymes** (General rule)
- **Exception** → that Insulin activates two catabolic pathways:
  1. **Glycolysis** (6 C Glucose gets converted into two molecules of 3 C Pyruvate, so this is breakdown of Glucose, i.e., catabolic pathway)
  2. **Link reaction/Pyruvate Dehydrogenase step** (conversion of 3 C molecule Pyruvate to 2 C molecule Acetyl CoA. So, this is also breakdown of 3 C compound to a 2 C compound). So, these 2 things are catabolic, but activated by Insulin.

Formula Box

Now, the Opposite Formula for Fasting State

- In fasting state, Glucagon hormone is released. So, Glucagon is a catabolic hormone. Glucagon always causes phosphorylation by increasing cAMP.
- So, we can conclude that: Glucagon activates all catabolic pathway enzymes (General rule) **EXCEPT:** Glycolysis and Link reaction.

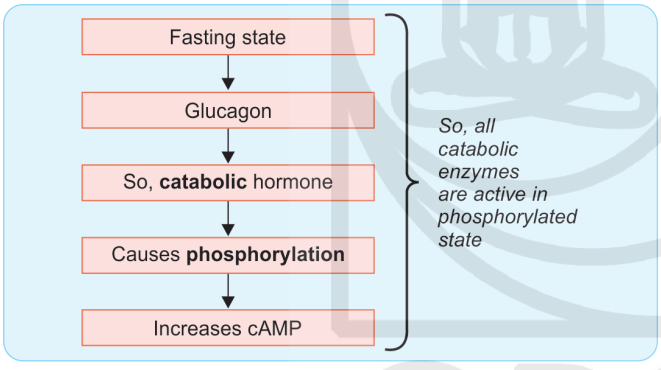


Fig. 1.3: Fasting state

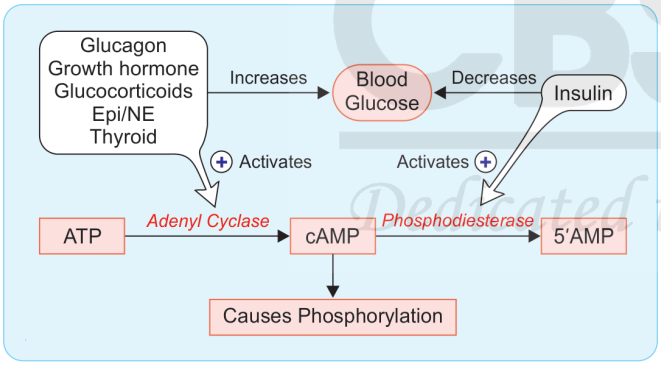


Fig. 1.4: Hormones and cAMP; Insulin is the only hormone which decreases blood glucose. The hormones which increase blood glucose are glucagon, growth hormone, glucocorticoids, epinephrine (Epi), nor-epinephrine (NE) and thyroid

Think

Q. So, we have so many hormones to increase blood Glucose but only one hormone to decrease blood Glucose. Why?

A. This is a survival benefit. Because Hypoglycemia is more dangerous than Hyperglycemia.

As Insulin causes dephosphorylation and Phosphodiesterase enzyme decreases cAMP, so we can conclude that insulin activates phosphodiesterase and thus it causes dephosphorylation.

All other hormones (Glucagon, Growth hormone, Glucocorticoids, Epinephrine, Norepinephrine) cause phosphorylation by activating enzyme Adenyl Cyclase.

Formula Box

All anabolic enzymes are active in dephosphorylated state and all catabolic enzymes are active in **phosphorylated state**.
EXCEPTION: ATP Citrate Lyase is anabolic enzyme involved in Fatty Acid Synthesis but this enzyme is active in phosphorylated state.

Additional Edge

All insulin antagonist hormones (Glucagon, Growth hormone, Glucocorticoids, Epinephrine, Nor-Epinephrine) activate Adenyl Cyclase **BUT** Thyroid hormone increases the synthesis of this enzyme (by working at the level of gene).

WHICH ARE ANABOLIC AND CATABOLIC PATHWAYS?

Anabolic means synthesis occurring in body. Anabolic pathways are glycogen synthesis (Glycogenesis), HMP (as HMP synthesizes Ribose-5-P and NADPH), fatty acid synthesis, cholesterol synthesis and TG synthesis.

Catabolic means breakdown occurring in body. Catabolic pathways are glycolysis (breakdown of 6 C Glucose to two molecules of 3 C Pyruvate), Pyruvate Dehydrogenase (Link reaction), glycogen breakdown (Glycogenolysis), Beta-oxidation of fatty acids, Gluconeogenesis, Ketone body synthesis, Ketone body utilization/breakdown.

NOTE: When I say pathway is anabolic means all enzymes in that pathway are anabolic.
When I say pathway is catabolic means all enzymes in that pathway are catabolic.

Clinical Case-Based Questions

Fuel for Body and Acetyl CoA

1. A 30-year-old female was admitted to emergency with intractable vomiting, nausea and fever for past 48 hours. This condition severely affected her ability to eat or drink. Despite her prolonged fasting state, liver is able to maintain a blood glucose level of 72 mg/dL as shown in her blood glucose analysis by converting the various pyruvate forming substances into glucose. Which among the following is most important activator for first step of gluconeogenic process?

a. Alanine
b. Citrate
c. Oxaloacetate
d. Lactate
e. Acetyl CoA

Organelles and Bonds in Macromolecules

2. In a drug efficacy study on artificially cultured liver cancerous cells, the cells are homogenized and passed through various steps of differential centrifugation to separate membranes, organelles and cytosolic homogenate with its proteins. Which of the following enzyme activities will be observed in this homogenate?

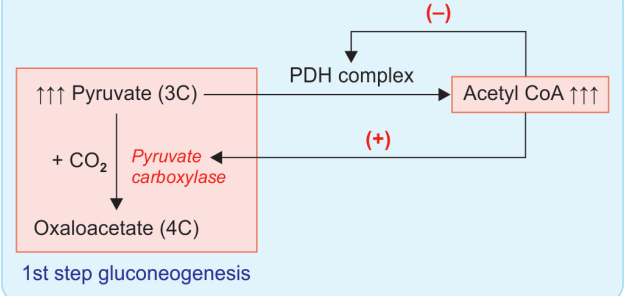
a. Carbamoyl phosphate synthase-I (CPS-I)
b. Transketolase
c. Isocitrate dehydrogenase
d. Pyruvate decarboxylase

Answers of Clinical Case-Based Questions

1. Ans. (e) Acetyl CoA

(Ref: Harper's 31st e/p 153)

- Fasting is lack of food for 12–18 hours while starvation is lack of food for 1-3 days or longer. Glycogen of the liver can maintain blood glucose for 12-18 hours. After that period, liver gluconeogenesis is the main source of blood glucose during fasting/starvation.
- During gluconeogenesis, pyruvate can be formed from gluconeogenic substrates such as lactate, glucogenic amino acids and glycerol. Pyruvate formed cannot give rise to phosphoenolpyruvate as this reaction is highly irreversible so pyruvate is first converted to oxaloacetate by carboxylation reaction. This step is catalyzed by pyruvate carboxylase and acetyl CoA which is abundantly available from fatty acid oxidation is allosteric activator of this step. Acetyl CoA is also a negative regulator of PDH complex (See figure).



- Oxaloacetate is then converted to malate in mitochondria which comes out in to cytosol and converted back to oxaloacetate by malate dehydrogenase. Oxaloacetate is then converted to phosphoenolpyruvate by PEP carboxykinase.

2. Ans. (b) Transketolase

(Ref: Harper's 31st e/p 185)

- Different biochemical reactions occur in different sites in the cell. Mostly the catabolic pathways such as beta-oxidation, citric acid cycle, parts of urea cycle generally occur in mitochondria and anabolic pathways such as fatty acid synthesis, gluconeogenesis, etc. generally occur in the cytosol.
- Transketolase is an enzyme involved in the pentose phosphate pathway which produces substrates NADPH and ribose 5-phosphate for anabolic pathways such as nucleic acid synthesis and all of reactions of this pathway occur in the cytoplasm. So, enzyme transketolase will be present in the cytosolic homogenate.
- All the other enzymes are involved in reaction occurring in the mitochondria so they will be removed by centrifugation.

Multiple Choice Questions

Formula Questions

(Insulin, Glucagon, Compartment, Phosphorylated State and Dephosphorylated State)

1. Insulin inhibits which of the following lipase enzymes? *(INI-CET July 2021)*
a. Hormone sensitive lipase
b. Lipoprotein lipase
c. Acid lipase
d. Alkaline lipase

2. Which enzyme is active during low insulin glucagon ratio? *(Recent Question 2020)*
a. Hexokinase
b. Glucokinase
c. Glucose-6-phosphatase
d. Phosphofructokinase

3. Which of the following binds to the tyrosine kinase receptors? *(Recent Question 2020)*
a. Insulin
b. Glucagon
c. Leptin
d. Thyroxine

4. Which of the following does not occur in mitochondria? FAQ *(AIIMS Nov 2016)*
a. Beta-oxidation
b. DNA synthesis
c. Fatty acid synthesis
d. Protein synthesis

5. Insulin promotes lipogenesis by all; EXCEPT:
a. Decreasing cAMP
b. Increase Glucose uptake
c. Inhibiting Pyruvate Dehydrogenase
d. Increasing Acetyl CoA

6. Mitochondria are involved in all of the following; EXCEPT: *(AIIMS Nov 2015)*
a. ATP production
b. Apoptosis
c. Tri-Carboxylic Acid cycle
d. Cholesterol Synthesis

7. Hormone Sensitive Lipase is not activated by: FAQ
a. Insulin
b. Glucagon
c. Catecholamines
d. T4

8. Which of the following is not seen in low insulin glucagon ratio?
a. Gluconeogenesis
b. Glycogen Breakdown
c. Ketogenesis
d. Glycogen Storage

9. Which of the following is active in dephosphorylated state? *(AIIMS May 2017)*
a. Glycogen Synthase
b. Pyruvate Carboxylase
c. Glycogen Phosphorylase
d. PEPCK

10. All occur in mitochondria; EXCEPT:
a. Glycolysis
b. TCA cycle
c. ETC
d. Ketogenesis

11. The biosynthesis of the enzyme Pyruvate Carboxylase is repressed by:
a. Insulin
b. Cortisol
c. Glucagon
d. Epinephrine

12. The enzyme activated with low Insulin: Glucagon ratio is: FAQ *(AIIMS Nov 2013)*
a. Glucose-6-phosphate dehydrogenase
b. Glucokinase
c. Pyruvate Kinase
d. Glucose-6-phosphatase

13. The gene expression of which of the following enzymes are not increased by insulin?
a. Pyruvate Carboxylase
b. Acetyl CoA Carboxylase
c. Phosphofructokinase-I
d. Pyruvate Dehydrogenase

14. Pathway which occurs both in fed and fasting state:
a. TCA
b. Glycolysis
c. HMP
d. Glycogenesis

15. Pathway which occurs both in cytoplasm and mitochondria is/are: FAQ
a. Urea cycle
b. Gluconeogenesis
c. Heme synthesis
d. All of the above

16. Effect of glucagon: FAQ *(FMGE June 2018)*
a. Retard Glycogenolysis
b. Retard Ketogenesis
c. Promote Gluconeogenesis
d. Decrease plasma amino acids

17. Which of the following enzyme activity decreases in fasting? *(AIIMS May 2018)*
a. Hormone Sensitive Lipase
b. Glycogen Phosphorylase
c. Acetyl CoA Carboxylase
d. Pyruvate Carboxylase

18. Which of the following is active in dephosphorylated state?
a. Glycogen Synthase
b. Pyruvate Carboxylase
c. Glycogen Phosphorylase
d. Acetyl CoA Carboxylase
e. Pyruvate Dehydrogenase

MCQs Ans.

1. a
2. c
3. a
4. c
5. c
6. d
7. a
8. d
9. a
10. a
11. a
12. d
13. a
14. a
15. d
16. c
17. c
18. a,d,e

Answers with Explanations

1. Ans. (a) Hormone sensitive lipase

[Ref: Harper's 31st/e pg. 240, 245]

Insulin is an anabolic hormone so activates anabolic enzymes and inhibits catabolic enzymes. Hormone sensitive lipase is a catabolic enzyme present in adipose tissue cells which causes release of fatty acids from stored TG during starvation. So, it is activated by catabolic enzyme Glucagon. Lipoprotein lipase on the other hand is an anabolic enzyme and releases FA from TG of VLDL and chylomicrons in fed state

2. Ans. (c) Glucose-6-phosphatase

[Ref: Harper's 31st/e pg. 137-138]

- Low insulin glucagon ratio means it is fasting state, as in fed state insulin is more. So in fasting state, glucose-6-phosphatase will be active as this enzyme is involved in gluconeogenesis, which occurs during fasting.
- Phosphofructokinase is involved in glycolysis. PFK-1 is active in any situation and PFK-2 is active only in fed state.
- Glucokinase phosphorylates glucose in liver and pancreas, active in fed state and is induced by insulin.
- Hexokinase also phosphorylates glucose and is present in all cells of the body. It is active in any situation in body as it is a general enzyme to phosphorylate glucose.

3. Ans. (a) Insulin

[Ref: Harper's 31st/e pg. 508]

- The insulin and IGF-I receptors have intrinsic ligand-activated tyrosine kinase activity. By binding to these receptors, these hormones will activate tyrosine kinases inside the cell which in turn phosphorylates important enzymes involved in a number of processes such as metabolism, growth and differentiation and also inflammatory response.
- Glucagon binds to G-protein coupled receptors. Leptin binds to cytokine receptor while thyroxine binds to nuclear receptors.

4. Ans. (c) Fatty acid synthesis

[Ref: Harper's 30th/e pg. 233]

- Fatty acid synthesis is anabolic pathway, so it occurs in cytoplasm. β-oxidation (option a) is catabolic pathway, so it occurs in mitochondria. DNA synthesis (Replication) and protein synthesis (Translation) of mitochondrial DNA occur in mitochondria (option b and d)

5. Ans. (c) Inhibiting pyruvate dehydrogenase

[Ref: Harper's 30th/e pg. 188]

- Insulin activates link reaction (enzyme Pyruvate Dehydrogenase) and thus increases Acetyl CoA.
- Insulin decreases cAMP, by activating enzyme Phosphodiesterase (option a).
- Insulin increases glucose uptake via activating GLUT-4 (present on peripheral tissues) (option b).

6. Ans. (d) Cholesterol Synthesis

[Ref: Harper's 30th/e pg. 267]

- The biochemical processes taking place in mitochondria are all catabolic pathways, Vital pathways, i.e., TCA and ETC, Replication, Transcription and Translation for mitochondrial DNA and apoptosis
- Cholesterol synthesis is anabolic pathway, so it occurs in cytoplasm (option d)

7. Ans. (a) Insulin

[Ref: Harper's 30th/e pg. 262]

- Hormone Sensitive Lipase (HSL) is a catabolic enzyme (enzyme which breaks down the triglycerides of adipose tissue). So, it is inhibited by insulin. Insulin activates all anabolic pathway enzymes. Rest all hormones like Glucagon, Thyroid, Epinephrine activate HSL.

8. Ans. (d) Glycogen Storage

[Ref: Harper's 30th/e pg. 176]

- Low insulin means catabolic situation in body. So, question is that which of the following is not seen in catabolic state. So, answer is Glycogen Storage, which is anabolic. Rest three pathways given are catabolic – Gluconeogenesis, Glycogen Breakdown and Ketogenesis.

9. Ans. (a) Glycogen Synthase

[Ref: Harper's 30th/e pg. 182]

- Glycogen Synthase is enzyme of glycogen synthesis, which is anabolic pathway. So, this enzyme is active in dephosphorylated state. Rest all enzymes are involved in catabolic pathways, which are active in phosphorylated state.
- Pyruvate carboxylase and PEPCK are in Gluconeogenesis. Glycogen Phosphorylase is in glycogenolysis.

Chapter 2

Chemistry of Carbohydrates

Overview of Chapter

- Definition of Carbohydrates
- Isomerism in Carbohydrates ★★★★★
- Classification of Carbohydrates ★★★★
- Glucose Transport ★★★★★

DEFINITION OF CARBOHYDRATES

- **Definition** → Polyhydroxy aldehydes or ketones
- **Polyhydroxy** → (Poly means many, Hydroxy means 'OH') means carbohydrates have many 'OH' groups

General Points about Hydroxy Group

- Any compound having –OH group is Polar. (Polar compounds are soluble in water.)
- Suffix for –OH is 'ol', e.g., GlycerOL, AlcohOL.
- CholesterOL means cholesterol has polar component. But we know that cholesterol is a lipid having nonpolar component also. So, cholesterol is Amphipathic (very clear from the name).
- OH group always has high tendency to bind phosphate. E.g., Glucose gets converted to Glucose-6-P immediately when Glucose enters the cell, as phosphate has high tendency to bind OH. (Also –OH containing amino acids have maximum tendency to bind phosphate).
- In case of Carbohydrates, number of OH groups are one less the number of Carbons. E.g., Glucose has 6 C and 5 –OH; Ribose has 5 C and 4 –OH groups.

What is Aldehyde and Keto?

These are the functional groups of Carbohydrates. Either Carbohydrate has Aldehyde group or Keto group. This is carbonyl group present at C1 or C2. (Do not consider 'OH' as functional group in carbohydrates)

Fundamental Box

- If C = O is present at C_1, it is Aldehyde group
- If C = O is present at C_2, it is Keto group

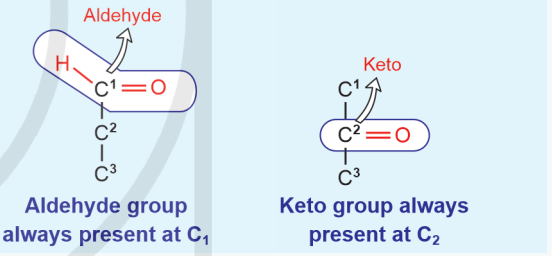


Fig. 2.1: Aldehyde and keto group

Functional Carbon is Symmetric

Functional carbon (Ald or Keto) is C = O, i.e., 2 valencies are occupied by same atom, i.e., Oxygen. So, functional carbon is Symmetric, but only in linear configuration. (In cyclic configuration, functional carbon becomes Asymmetric (See Anomerism).

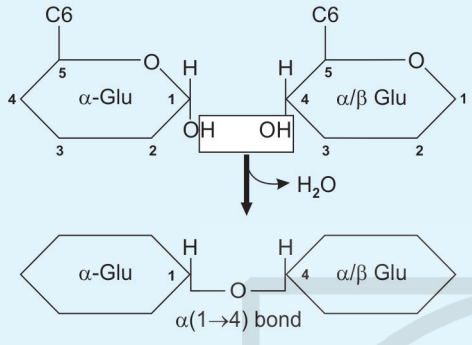
High Return

- Molecular Formula for Carbohydrates $(CH_2O)_n$
  Where n = Number of Total Carbons
- Number of total isomers possible for a compound is given by the formula = 2^n
  Where n = Number of Asymmetric Carbons

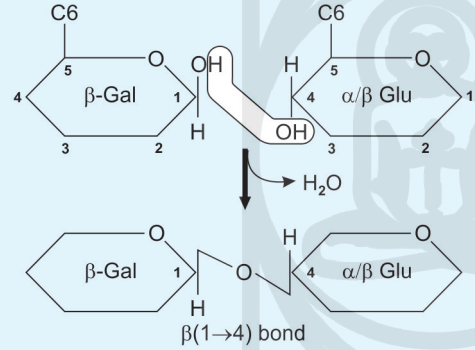
NOTE: Both formulas contain 'n' But this n is different.

Asymmetric Carbon (or Chiral Carbon)

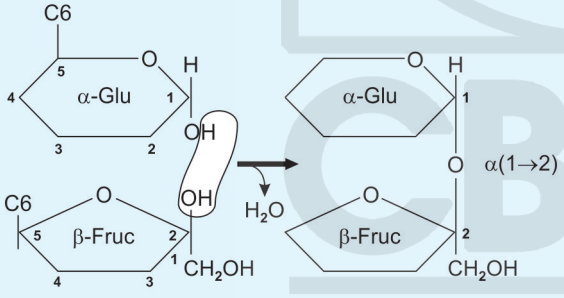
Valency of carbon is 4. If all these 4 valencies are occupied by different atoms or group of atoms, then the carbon is asymmetric.



Maltose = α Glucose + α/β Glucose



Lactose (Milk sugar) = β Galactose + α/β Glucose



Sucrose (Table sugar) = α-Glucose + β-Fructose

Fig. 2.9: Structure of disaccharides

Table 2.4: Tests given by monosaccharides and disaccharides

Test	Features
1. Molisch test	General test for **Carbohydrates.** But one condition is number of carbons should be 5 or more, only then Molisch test is positive
2. Benedict's test	Given positive by all **Reducing Sugars**
3. Barfoed's test	Distinguish between Monosaccharides and Disaccharides. It is given positive by **Monosaccharides.**
4. Seliwanoff's test	Distinguish between Aldehyde and Keto sugar. It is given positive by **Keto sugars**.

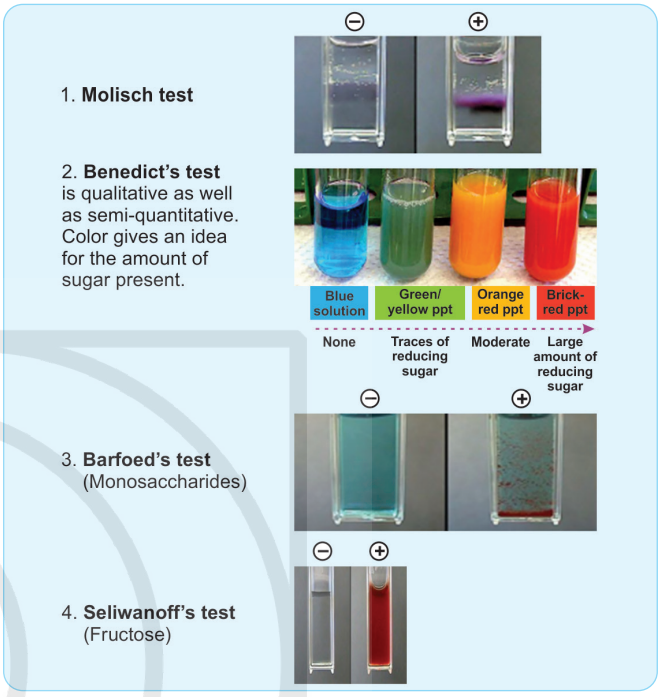


Fig. 2.10: Tests for carbohydrates

- **Osazones:** These are crystals and all reducing sugars form Osazones.

Table 2.5: Shapes of osazone crystals

Carbohydrate	Shape of Osazone crystal
Glucose, Fructose, Mannose	Needle shaped or broomstick like appearance
Galactose	Rhombic plate
Maltose	Sunflower shaped
Lactose	Powder puff/Hedgehog appearance

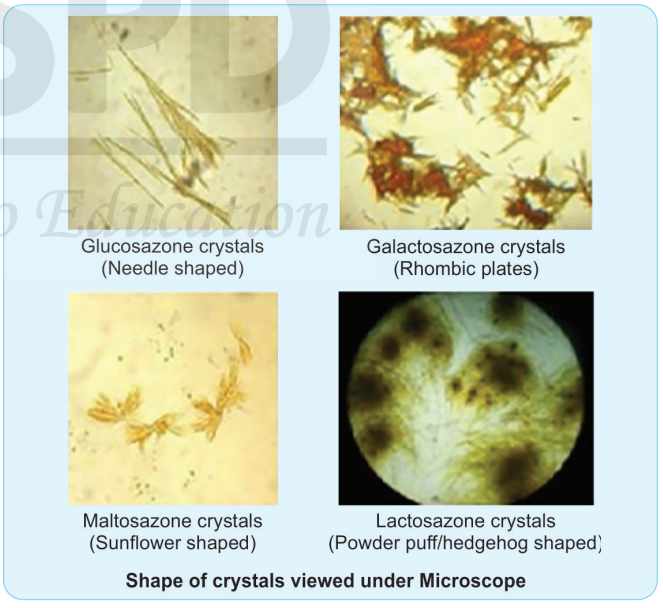


Fig. 2.11: Osazones

Pearls of the Chapter

- Hydroxy group always gives polarity, has high tendency to bind Phosphate.
- Aldehyde group always present at C_1
- Keto group always present at C_2
- Functional Isomerism → Functional group different (Ald or Keto)
- Enantiomerism → Different –H and –OH orientation around the Penultimate carbon
- Epimerism → Different –H and –OH orientation around only one carbon, other than the Penultimate carbon
- Anomerism → Different –H and –OH orientation around the Functional carbon.
- Functional carbon is Symmetric in linear configuration, but Asymmetric in cyclic configuration.
- In Molecular formula of Carbohydrates, n = Number of Total carbons.
- In Isomeric formula of Carbohydrates, n = Number of Asymmetric carbons.
- If all the four valencies of carbon are occupied by different atoms or group of atoms, then the carbon is Asymmetric.
- If any two, three or four valencies are occupied by same atoms or group of atoms, then the carbon is Symmetric.
- Any compound having Asymmetric carbon will show both optical and structural Isomerism
- GLUT -1 is in Brain, Placenta, Kidneys and also in RBC
- GLUT-3 is in Brain (neuronal), Placenta, Kidneys
- Phosphorylation of Glucose is done for the entrapment of Glucose inside the cells
- Affinity is inversely proportional to Substrate concentration
- Hypoglycemic action of Insulin is via GLUT-4
- Enantiomerism, also known as -D and -L Isomerism, also known as mirror images of each other
- Pentoses (5C) can exist only as Furanose
- Anomerism exists in Cyclic structures or in Solutions
- In cyclic structures, Functional Carbon makes a bond with second last carbon
- Mannose and Galactose are not Epimers of each other, as they differ in two carbons
- Monosaccharides on oxidation form Acids
- Monosaccharides on reduction form Alcohols
- Molisch Test: General test for Carbohydrates. But one condition → number of carbons should be 5 or more, only then Molisch test is positive
- Benedict's Test: Given positive by all Reducing sugars
- Barfoed's Test: Distinguish between Monosaccharides and Disaccharides. It is given positive by Monosaccharides.
- All Monosaccharides are Reducing
- Seliwanoff's Test: Distinguish between Aldehyde and Keto sugar. It is given positive by Keto sugars.
- Heteropolysaccharides and Cellulose are unbranched
- Glycogen is more branched than Starch
- Cellulose is not broken due to beta anomerism at C_1 and Inulin is not broken due to beta anomerism at C_2
- Beta bond is difficult to be broken but if beta bond is on one side of Galactose then it can be broken. Any such enzyme is known as Beta Galactosidase. E.g., Lactase and Beta Galactosyl Ceramidase
- Cellulose is most abundant polysaccharide in nature. Chitin is second most abundant.
- Pectin is a heteropolysaccharide made up of D-Galacturonic acid in α(1 → 4) linkages. It is a soluble dietary fiber in fruits. Softening of ripe tomato occurs by enzyme Polygalacturonase. Gene knockdown of this enzyme's gene helps to preserve tomatoes.
- Heparan Sulfate in excess is responsible for Mental Retardation
- Dermatan Sulfate in excess is responsible for Atherosclerosis
- No sulfate in Hyaluronic Acid
- Hyaluronic Acid is not attached to Proteins
- Heparan has highest negative charge
- Keratan Sulfate does not contain Uronic acid
- GAGs are slimy and slippery because of negative charge given by Carboxy, Sulfate and Acetate.
- Malt contains β-Amylase which hydrolyses Starch into Maltose by sequential removal of disaccharide units from the Non-reducing ends.
- Blood Group Antigens (A,B,O) are Glycosphingolipids in RBCs and Glycoproteins in secretions, where Carbohydrate is Oligosaccharide.
- D-Lyxose is a Pentose sugar and is a constituent of 'Lyxoflavin' isolated from human heart muscle.

Contd...

Multiple Choice Questions

Isomerism

1. Which of the following is NOT correct? *(Recent Question 2018)*

a. Parent carbohydrate which gives rise to other carbohydrates is Glycerol
b. Minimum number of carbons possible in a carbohydrate is 3
c. Minimum number of 'OH' group possible in a carbohydrate is 2
d. Minimum number of functional group possible in a carbohydrate is 1

2. Which of the following statement about isomerism is NOT correct? *(Recent Question 2016)*

a. Racemic mixture is equal D- and L-isomers present
b. Racemic mixture is optically inactive
c. Racemase enzyme interconverts D- and L-isomers into each other
d. Enantiomerism is also known as D- and L-isomerism

3. Dextrose is: FAQ *(Recent Question 2017)*

a. D + Glucose
b. D - Glucose
c. L + Glucose
d. L – Glucose

4. Number of isomers possible for Glucose are: FAQ *(Recent Question 2017)*

a. 32 b. 64
c. 16 d. 8

5. Parent alcohol in carbohydrates is: *(Recent Question 2016)*

a. Glycerol b. Ethanol
c. Methanol d. Cholesterol

6. Which form of Glucose and Fructose is predominant?

a. α b. β
c. Both d. Variable

7. Cellulose is not broken due to beta anomerism at: FAQ *(Recent Question 2018)*

a. C1 b. C2
c. C5 d. C6

8. Which of the following are epimers?

a. D-Galactose and D-Glucose
b. D-Galactose and L-Glucose
c. D-Mannose and L-Mannose
d. D-Mannose and L-Glucose
e. D-Glucose and L Glucose

9. Which of the following is a keto sugar?

a. Glucose b. Sorbitol
c. Fructose d. Sedoheptulose
e. Ribulose

Classification of Carbohydrates

10. Which of the following glycoprotein has both lubricant and protective action? *(AIIMS Nov 2019)*

a. Mucin b. Immunoglobulin
c. Collagen d. Albumin

11. All of the following are correct about Proteoglycans; EXCEPT: *(AIIMS Nov 2019)*

a. Chondroitin sulfate is a proteoglycan
b. Made of protein and sugar MPS
c. Carries negative charge
d. Does not hold water

12. Transparency of corneal endothelium is maintained by: *(Recent Question Sep 2021)*

a. Heparan sulfate
b. Keratan sulfate
c. Chondroitin sulfate
d. Hyaluronic acid

13. Which of the mucopolysaccharide/proteoglycan is present in glomerular basement membrane? *(Recent Question 2020)*

a. Heparan sulfate b. Chondroitin sulfate
c. Hyaluronic acid d. Keratan sulfate

14. Which of the following is insoluble in water? *(Recent Question 2020)*

a. Lignin b. Inulin
c. Amylose d. Chitin

15. Which of the following is a component of polysaccharide Chitin? FAQ

a. Ascorbic acid b. Glucosamine
c. Synovium d. Glucuronic acid

16. A young man finds that every time he eats dairy products, he feels very uncomfortable. His stomach becomes distended. He develops gas and diarrhea frequently. These symptoms do not appear when he eats food other than dairy products. Which of the following is most likely enzyme in which this young man is deficient: *(Recent Question 2016)*

a. Alpha amylase b. Beta galactosidase
c. Alpha glucosidase d. Sucrase

17. A male child presented with coarse facies, protuberant abdomen, frontal head enlargement, thickening of cardiac valve, hepatosplenomegaly, aggresive behavior, clear vision and hearing impairment. What is the most probable diagnosis? FAQ *(AIIMS Nov 2018)*

a. Hurler's disease b. Hunter's disease
c. Fragile X syndrome d. Tay-Sachs disease

MCQs Ans.

1. a
2. c
3. a
4. c
5. a
6. b
7. a
8. a,d
9. c,d,e
10. a
11. d
12. b
13. a
14. a
15. b
16. b
17. b

Answers with Explanations

1. Ans. (a) Parent carbohydrate which gives rise to other carbohydrates is Glycerol

[Ref: Lehninger's7th/e pg. 242]

Parent carbohydrate which gives rise to other carbohydrates is D-Glyceraldehyde (not Glycerol) and this is also the simplest carbohydrate which exists. So, Options b, c, d are correct as the simplest carbohydrate is Glyceraldehyde with 3 Carbons, 2 'OH' groups and one functional group, i.e., Aldehyde.

2. Ans. (c) Racemase enzyme interconverts D and L isomers into each other

[Ref: Harper's 30th/e pg. 154; Fig.15.2]

Racemase enzyme interconverts D- and L-isomers (Enantiomers) into each other in which D means OH is on right side of penultimate carbon. L means OH is on left side of penultimate carbon. The name Racemase is a misnomer.

- D and L (small d and l) are Optical isomers.
- **D (dextrorotatory)(+)**—means rotation of plane polarized light toward right side.
- **L (levorotatory)(–)**—means rotation of plane polarized light toward left side.
- Racemic mixture is equal D-and L-isomers present (option a). Racemic mixture is optically inactive (option b). Enantiomerism is also known as D and L-isomerism (option d).

3. Ans. (a) D + Glucose

[Ref: Harper's 30th/e pg. 154]

Solution of Glucose is known as Dextrose. 'D' means structural isomer, i.e., Enantiomer. Abundant form of carbohydrate is always 'D'.
(+) means dextrorotatory (d). Glucose is always dextro-rotatory (d) (+). Fructose is always levorotatory (l) (–).

4. Ans. (c) 16

[Ref: Harper's 30th/e pg. 154]

- Number of isomers possible for a compound is given by formula = 2^n, where n= number of asymmetric carbons.
- In case of Glucose, number of asymmetric carbons is 4 (C_2, C_3, C_4, C_5). C_1 is symmetric as it is C=O. C_6 is CH_2OH, so symmetric. Hence, in case of Glucose, isomers are 16.

5. Ans. (a) Glycerol

[Ref: Lehninger's7th/e pg. 242]

- Parent alcohol in carbohydrates is Glycerol.
- Parent carbohydrate, and simplest carbohydrate is D-Glyceraldehyde

6. Ans. (b) β

[Ref: Harper's 30th/e pg. 154]

β-Glucose and β-Fructose are more predominant than their α forms

7. Ans. (a) C1

[Ref: Harper's 30th/e pg. 153]

Anomerism is different –H and –OH orientation around the functional carbon. β-anomers cannot be broken in body.

Cellulose is made up of Glucose. In Glucose functional carbon is at C_1 (Aldehyde). So, Cellulose is not broken due to β-anomerism at C_1

- Inulin (Homopolysaccharide of β-Fructose) is not broken due to β-anomerism at C_2 because in fructose-(a keto sugar), functional carbon is at C_2.

8. Ans. (a); (d)

[Ref: Harper's 30th/e pg. 153]

In Epimerism, there is different –H and –OH orientation around only one carbon, other than the penultimate carbon. Mannose is epimer of Glucose at C_2. Galactose is epimer of Glucose at C_4. Galactose and Mannose are not epimers of each other.

9. Ans. (c); (d); (e)

[Ref: Harper's 30th/e pg. 153]

Glucose is aldehyde. Sorbitol is a sugar formed from reduction of Glucose. Ribulose is a 5C keto sugar; Fructose is a 6C keto sugar and Sedoheptulose is a 7C keto sugar.

10. Ans. (a) Mucin

[Ref: Harper's 31st/e pg. 547]

Mucins are a family of high molecular weight and heavily glycosylated proteins.

These large glycoproteins are secreted in mucus, the viscous fluid that protects and lubricates the epithelium of the gastrointestinal, genitourinary, and respiratory tracts. However, some mucins may be membrane associated and not secreted.

Chapter 5

Chemistry and Metabolism of Amino Acids

Overview of Chapter

- Amino acid Basics ★★★★
- Titration Curve ★★★
- Essential Amino Acids ★★★★
- Classification of Amino Acids with Diseases ★★★★★
- Polyamine Pathway ★★
- Fish Odor Syndrome ★★★
- Color Reaction of Proteins ★★

AMINO ACID BASICS

There are around 300 amino acids in nature, out of which 22 amino acids are found in mammalian proteins. 21st and 22nd are Selenocysteine and Pyrrolysine respectively.

There is nothing like 1st or 2nd or 5th amino acid (number does not specify any sequence but just total of these are 22). 21st and 22nd were discovered later that's why they are given a specific number.

These 22 amino acids are encoded by DNA, i.e., they are not formed by post translational modifications. They have codons in DNA. But derived amino acids are those which do not have codons.

Derived Amino Acids

Found in proteins	Not in proteins
• OH-Proline	• Ornithine, Citrulline } in Urea cycle
• OH-Lysine	• Homocysteine in methionine metabolism
• Y-carboxy Glutamate (in clotting proteins II, VII, IX, X)	

Why the name "Amino Acid"?

Amino group ($-NH_2$) is always on left side and acid group (–COOH) is always on right side. That's why the name–Amino acid (Fig. 5.1).

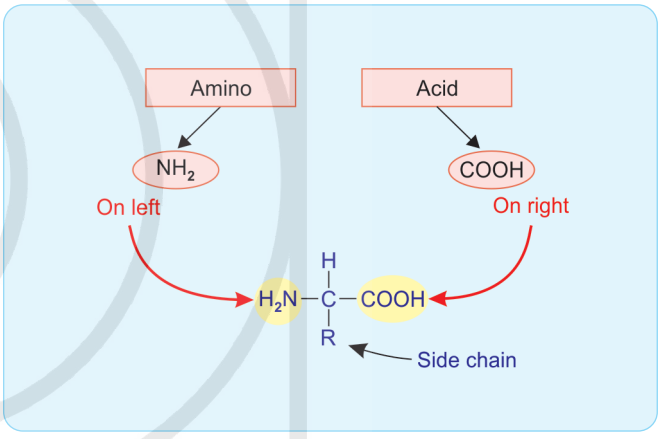


Fig. 5.1: Common structure of all amino acids. Each amino acid has a carboxyl group, a primary amino group and a side chain.

The carboxy and amino groups of all amino acids are joined by peptide bonds in proteins and these groups are therefore, not free for any chemical reactions (they can just make hydrogen bonds). So, the side chain of amino acid decides the role of that amino acid in protein.

The central carbon of any amino acid is asymmetric. So, amino acids show both optical and structural isomerism. (Any compound having asymmetric carbon shows both optical and structural isomerism).

High Return

"All amino acids have one asymmetric C"

Exceptions:

- 0 → Glycine
- 2 → Isoleucine, Threonine

Zwitterion

Amino acid ionizes to give negative charge on carboxy group and positive charge on amino group (Fig. 5.2).

High Return

All three aromatic amino acid hydroxylases are similar

1. Phenylalanine hydroxylase
2. Tyrosine hydroxylase
3. Tryptophan hydroxylase

} Require **NADPH** and **THB**

THB is mainly required for hydroxylases [Nitric Oxide Synthase (NOS) also requires THB].

Fundamental Box

Phenylalanine $\xrightarrow{\text{add OH}}$ Tyrosine

Alanine $\xrightarrow{\text{add OH}}$ Serine

High Return

Controversy for the polarity of Tyrosine

- Because of –OH group, it is polar and because of phenyl ring, it is non-polar. So, according to question, you have to decide Tyrosine is polar or non-polar (depends what are other options given in the question)

Summary Box

Phenylalanine

- Essential
- Non polar
- Both glucogenic and ketogenic

Tyrosine

- Non-essential
- Controversy for polarity
- Both glucogenic and ketogenic

Phenylketonuria (PKU) (Fig. 5.19)

- Most common metabolic disorder of amino acid.

PKU is of 2 types:

- Classical – Deficiency of Phenylalanine Hydroxylase (PAH).
- Nonclassical – Deficiency of Dihydrobiopterin (DHB). Reductase or GTP Cyclohydrolase.

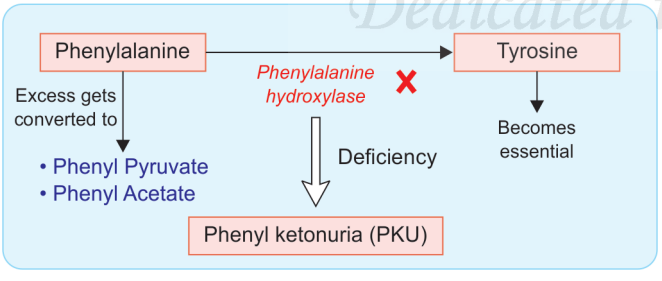


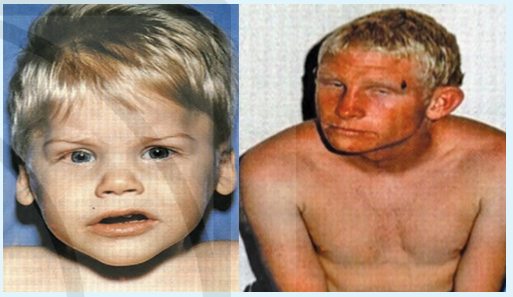
Fig. 5.19: Classic phenylketonuria (Defect in phenyl alanine hydroxylase)

Why this name of disease? Phenyl ketone in urine, i.e., Phenyl Pyruvate found in urine of these patients (Pyruvate is a Keto-acid).

Child is normal at birth as no problem in fetal development because maternal enzyme breaks down phenylalanine.

Clinical features:

- Body odor – mousy or musty because of phenylacetate
- Severe mental retardation due to excess Phenylalanine.
- Tyrosine becomes essential
- Deficiency of pigment **Melanin** (formed from Tyrosine), leads to fair skin, blue eyes and light hair color.



- **Other features:** Microcephaly, rash, hypertonia, seizures, hyperactivity, exaggerated tendon reflexes, wide spaced teeth, enamel hypoplasia.

High Return

- Mousy/musty odor → due to Phenylacetate
- Mental Retardation → due to Phenylalanine
- $FeCl_3$ Urine test → due to Phenyl Pyruvate

Maternal Phenylketonuria

If mother has PKU and levels of Phenylalanine are raised during pregnancy then infant has mental retardation, microcephaly, low birth weight, growth retardation and congenital heart defects.

Think

Q. Why brain is affected in PKU?

A. 1. Excess Phenylalanine from blood enters brain through L- aromatic amino acid transporter in brain capillaries. Other aromatic amino acids (Tyrosine, Tryptophan) cannot enter brain due to competitive inhibition. Tyrosine and Tryptophan synthesize many neurotransmitters which are required in brain.

2. Deficiency of Thyroxine as it is synthesized from Tyrosine.
3. Cerebral serotonin deficiency (as it is synthesized from tryptophan)

Diagnosis

1. $FeCl_3$ test is less sensitive and detects Phenyl Pyruvate in urine (Pyruvate is a keto acid). Positive test gives blue green color.

Multiple Choice Questions

Chemistry of Amino Acids

1. Which replacement of amino acid does not alter its normal function? *(AIIMS Nov 2019)*
a. Glutamine replaced by arginine
b. Glutamine replaced by alanine
c. Glutamine replaced by glutamate
d. Glutamine replaced by asparagine

2. Which of the following amino acid needs to be supplied in the diet of patients with Cystathionine beta synthase defect? *(Recent Question Sep 2021)*
a. Cysteine b. Methionine
c. Serine d. Homocysteine

3. Amino acid which absorbs UV light at 280 nm: *(Recent Question 2020)*
a. Tryptophan b. Histidine
c. Aspartate d. Ornithine

4. Essential amino acids is/are:
a. Threonine
b. Phenylalanine
c. Alanine
d. Methionine
e. Cysteine

5. Nitric oxide is synthesized from: *(Recent Question 2020)*
a. Ornithine
b. Alanine
c. Aspartic acid
d. L-arginine

6. During Fasting, which of the following is released from the muscles?
a. Alanine
b. Glutamine
c. Branched keto acid
d. Asparagine

7. Indole ring is present in:
a. Tryptophan b. Phenylalanine
c. Tyrosine d. Threonine

8. Which of the following is polar?
a. Tryptophan
b. Methionine
c. Glutamic acid
d. Isoleucine

9. Strength and rigidity in keratin is due to:
a. Leucine b. Cysteine
c. Lithium d. None of these

10. Creatine is made up of all; EXCEPT:
a. Arginine b. Alanine
c. Methionine d. Glycine

11. Amino acid with double chiral carbon: FAQ
a. Tyrosine b. Threonine
c. Tryptophan d. Phenylalanine

12. All of the following amino acids forms acetyl CoA via Pyruvate Dehydrogenase; EXCEPT:
a. Glycine b. Hydroxyproline
c. Tyrosine d. Alanine

13. Amino acid which is not stable in (incompatible with) alpha-helix is: FAQ
a. Proline b. Glutamine
c. Alanine d. Leucine

14. Sulphur containing amino acids metabolism needs:
a. Pyridoxine b. Folic acid
c. Vitamin B_{12} d. All of these

15. Coenzyme for Phenylalanine hydroxylase is: FAQ
a. S-Adenosyl Methionine
b. Tetra Hydro Biopterin
c. Tetra Hydro Folate
d. Pyridoxal phosphate

16. N Methyl Glycine is known as:
a. Betaine b. Sarcosine
c. Carnosine d. Ergothionine

17. Taurine is synthesized from which amino acid?
a. Tryptophan b. Phenylalanine
c. Cysteine d. Alanine

18. Which of the following does not contain β-alanine?
a. Carnosine b. Anserine
c. Homocarnosine d. Pantothenic acid

19. Polyamine like putrescine is derived from:
a. Arginine b. Ornithine
c. Yohimibine d. Arginosuccinate

20. Non-essential amino acid group is?
a. Acidic amino acid
b. Branched chain amino acid
c. Basic amino acid
d. Aromatic amino acid

21. Which amino acid has maximum tendency to bind phosphate?
a. Serine b. Alanine
c. Phenylalanine d. Tryptophan

22. After a point mutation, glutamic acid replaced by valine, which leads to formation of sickle cell Hb. The mobility of HbS as compared to normal Hb on gel electrophoresis will be :
a. Decreased
b. Increased
c. Dependent on HbS concentration
d. Unchanged

MCQs

Ans.

1. d
2. a
3. a
4. a,b,d
5. d
6. a
7. a
8. c
9. b
10. b
11. b
12. c
13. a
14. d
15. b
16. b
17. c
18. c
19. b
20. a
21. a
22. a

Answers with Explanations

1. Ans. (d) Glutamine replaced by asparagine

[Ref: Harper's 31st/e pg. 15-16]

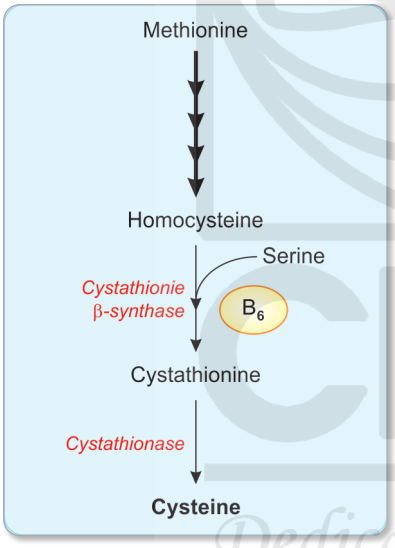
Glutamine and asparagine are uncharged polar amino acids. Both have amide group. So, exchange of these amino acids in a protein will not change the charge of the protein.

- Arginine is basic amino acid, so it is positively charged.
- Glutamate is acidic amino acid, so it is negatively charged.
- Alanine is non-polar

2. Ans. (a) Cysteine

Ref-Harper's 31st e/pg. 291

- Cystathionine beta synthase (CBS) is involved in the synthesis of cysteine from dietary methionine. Cysteine synthesis require methionine, serine and vitamin B_6. The reactions are summarized in the diagram:



- So, in case of CBS deficiency there will be no formation of cystathionine and cysteine. So, cysteine becomes essential and needs to be taken in diet.

3. Ans. (a) Tryptophan

[Ref: Harper's 31st/e pg. 20]

Proteins and amino acids absorb UV-light at 280 nm, due to aromatic nature of these amino acids & they have conjugated double bonds in the rings. Maximum absorption occurs by tryptophan as it has 2 rings in its side chain.

4. Ans. (a) Threonine; b. Phenylalanine; d. Methionine

[Ref: Harper's 31st/e pg. 264]

- **Essential amino acids:** Those which cannot be synthesized in body and are therefore, required in diet.
- **Non-essential amino acids:** Those which can be synthesized in body and therefore, are not required in diet.
- **Semi-essential amino acids:** Those which can be synthesized in body but to some extent. Examples are Arginine and Histidine.

Essential amino acids	Non-essential amino acids
1. Methionine-Sulfur containing	1. Alanine
2. Threonine –OH containing	2. Asparagine
Branched chain amino acids	3. Aspartic acid
3. Valine	4. Cysteine
4. Isoleucine	5. Proline
5. Leucine	
Basic amino acids	6. Serine
6. Lysine	7. Tyrosine
7. Arginine (Semi essential)	
Aromatic amino acids	8. Glycine
8.Phenylalanine	9. Glutamic acid
9. Tryptophan	
10. Histidine (Essential but semi-essential)	10. Glutamine

5. Ans. (d) L-arginine

[Ref: Harper's 31st/e pg. 624]

NO is also called as Endothelium Derived Relaxing Factor (EDRF). **NO (nitric oxide) is synthesized from arginine by enzyme NOS** (Nitric oxide synthase) in the endothelial cells. The vasodilator – nitroglycerin also enters smooth muscle cells, where its metabolism also leads to the formation of NO.

Extra information:

NO synthase

- There are three isoforms of NOS (Nitric oxide synthase)
  1. nNOS - neuronal
  2. iNOS- inducible
  3. eNOS- endothelial
- EC no. 1 (oxidoreductase)
- Monooxygenase (one oxygen is added in substrate)
- Synthases usually belongs to EC no 4 but NO synthase is an exception.

Chapter 7

Proteins

Overview of Chapter

- Amide/Peptide Bond ★★★
- Protein Digestion
- Absorption of Amino Acids
- Protein Structures ★★★★★
- Protein Sequencing ★★★
- Chaperones ★★★★★
- Glycoproteins ★★★★
- Heme ★★★★
- Fibrous Proteins ★★★
- Plasma Proteins ★★★★
- Chromatography ★★★★★
- Electrophoresis ★★★★★
- Protein Precipitation Reactions ★★★★★

- Proteins are polymers of amino acids.
- Amino acids are joined by strong covalent amide/peptide bond.

AMIDE/PEPTIDE BOND

Peptide bond is always formed between the alpha-carboxy group of one amino acid and the alpha-amino group of another.

- If amide bond is present in proteins → known as peptide bond.
- Peptide bond has partial-double bond character.
- Rigid and planar.
- Uncharged (neither gain nor loose protons) but polar (involved in hydrogen bonds).
- The double-bond is in transconfiguration (Fatty acids double-bond is in cis configuration).
- If <50 amino acids in a chain → known as a peptide
- If >50 amino acids then it is known as polypeptide or protein.

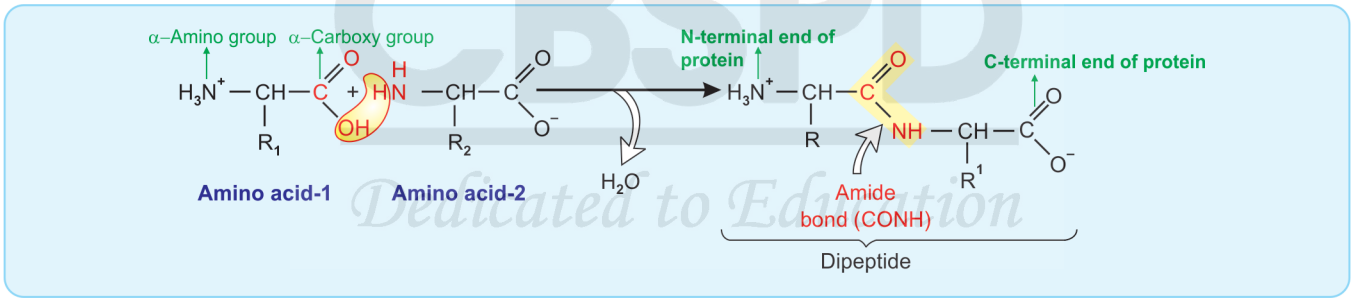


Fig. 7.1: Formation of amide/peptide bond by joining two amino acids. This amide/peptide bond is a strong covalent bond. Sequence of amino acid is read from N- to C-terminal

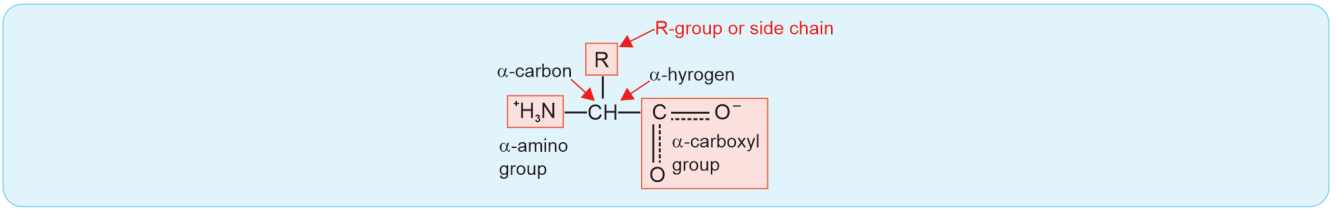
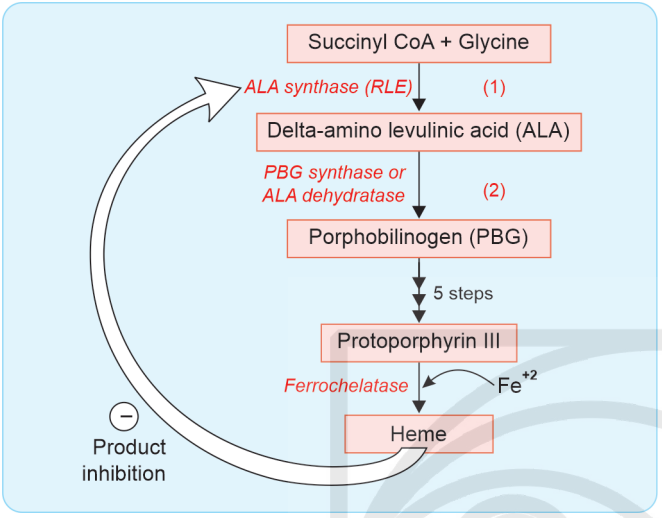


Fig. 7.2: Toward left is N-terminal and toward right is C-terminal of this tripeptide (sequence is always read from N- to C-terminal)



Additional Edge

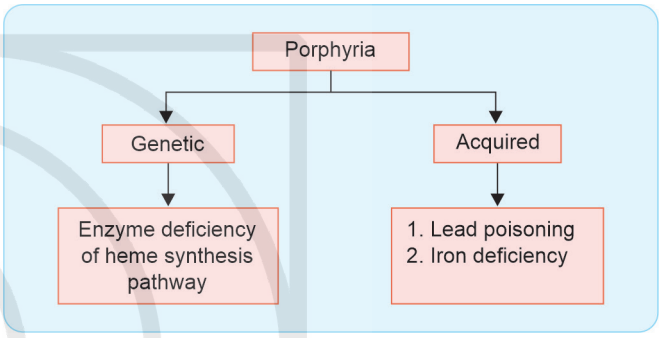
ALA-Synthase I	ALA-Synthase II
• Expressed throughout the body	• Expressed in erythroid tissues
• Rate limiting step in Liver	–
• Heme is the negative regulator	• No feedback inhibition

Porphyria

- Porphyria is deficiency of one of the heme synthesis enzymes, other than ALA-synthase.
- ALA-Synthase I deficiency is lethal.
- ALA-Synthase II deficiency is known as X-linked Sideroblastic anemia (It is not a porphyria).

Additional Edge

Isoniazid-induced Pyridoxine deficiency causes decreased heme formation in RBCs, leading to **Sideroblastic Anemia** with Isoniazid Therapy (ALA Synthase requires Vit. B_6)



Lead poisoning is the most common cause of acquired porphyria. Although iron deficiency is more common. But iron deficiency leading to porphyria is a rare thing. But lead poisoning will almost always lead to porphyria.

- Erythropoietin activates ALA synthase, So, erythropoietin deficiency which occurs in chronic renal failure, leads to anemia.
- Heme synthesis continues in liver cells according to metabolic needs. But in RBCs, it is a one time event, so no rate-limiting enzyme here.

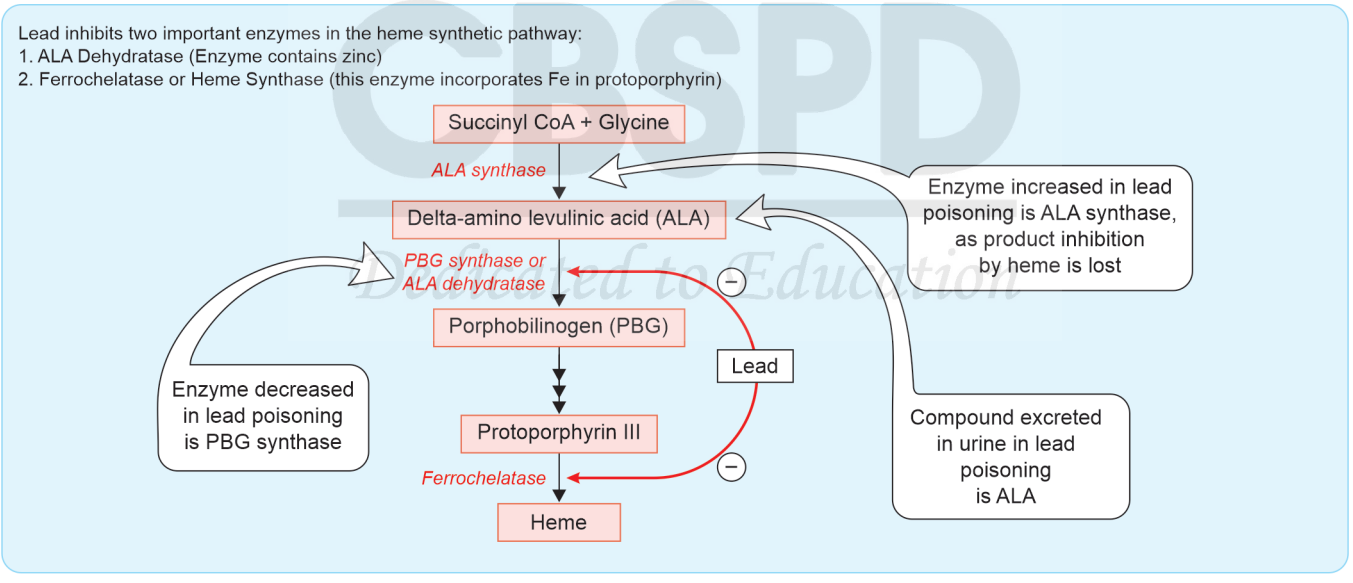
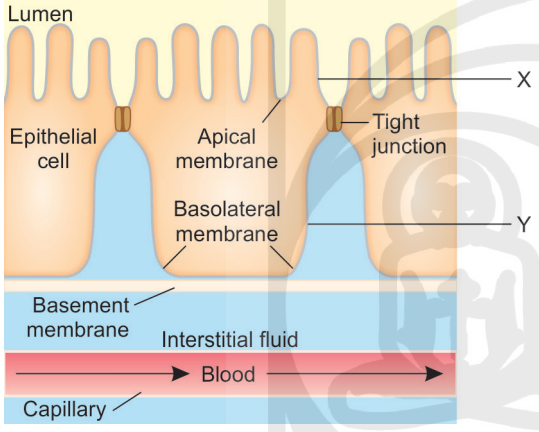


Fig. 7.6: Lead poisoning

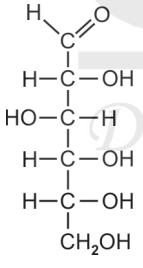
Image-Based Questions

1. Which glucose transport is present at points X and Y?



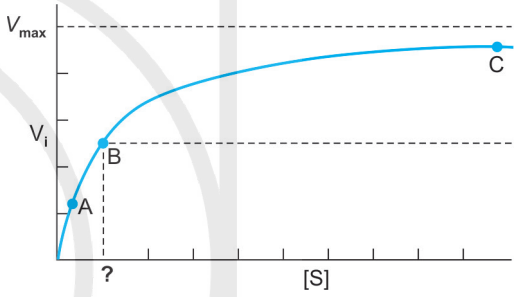
a. X-SGLT-2, Y-GLUT-2
b. X-GLUT-3, Y-SGLT-1
c. X-SGLT-1, Y-GLUT-2
d. X-GLUT-2, Y-SGLT-2

2. Number of isomers possible for the carbohydrate given is:



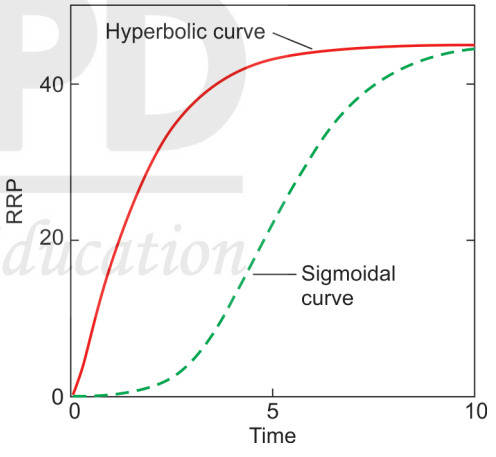
a. 32
b. 64
c. 16
d. 8

3. The following graph represents effect of substrate concentration on the initial velocity of an enzyme-catalyzed reaction. WRONG statement about this graph is:



a. The curve is hyperbolic in shape.
b. "?" here represents Km of the enzyme.
c. At point C, only a small amount of the enzyme is present as the Enzyme-Substrate complex.
d. At point C, Vi is independent of [S].

4. Which of the following is CORRECT about the enzyme which has sigmoidal graph?

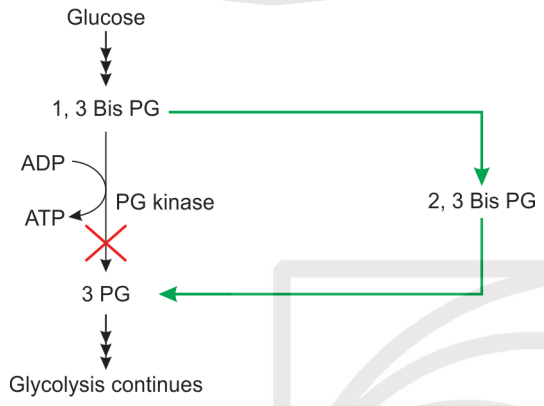


a. Allosteric modifier binds in a concentration dependent manner.
b. Modifier can affect the catalytic site by binding to the allosteric site.
c. Adding more substrate to the enzyme can displace the allosteric modifier.
d. Allosteric modifiers change the binding constant of the enzyme but not the velocity of reaction.

Ans.

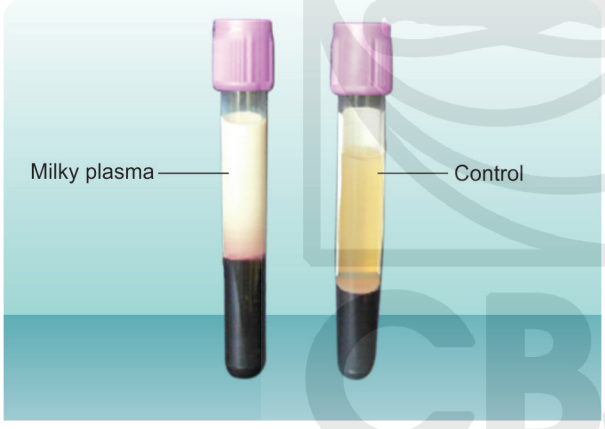
1. c
2. c
3. c
4. b

5. This pathway is occurring in which cell of the body?



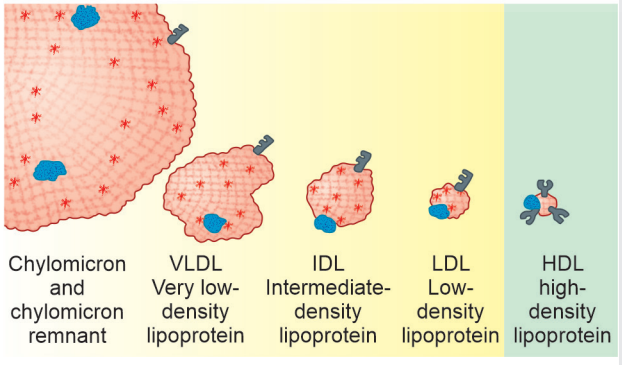
a. RBCs
b. Liver
c. Muscles
d. Brain

6. This serum of patient shows increased:



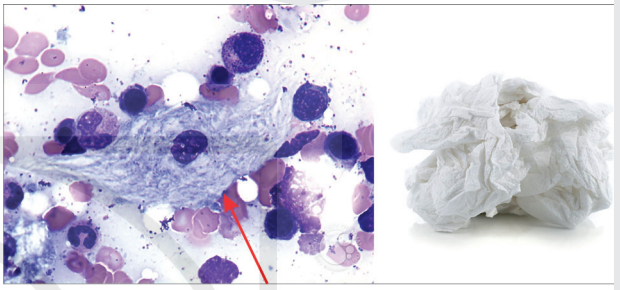
a. Cholesterol
b. LDL
c. VLDL
d. Chylomicrons

7. Which of the following is NOT found in lipid profile after an overnight fast?



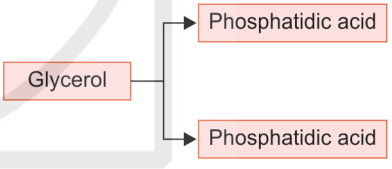
a. Chylomicrons
b. VLDL
c. LDL
d. HDL

8. A 48-year-old female presented with bony pain and hepatosplenomegaly. On examination of biopsy from spleen, crumpled tissue paper appearance is seen. Which of the following product is likely to have accumulated?



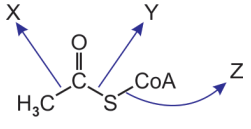
a. Ganglioside
b. Sulfatides
c. Sphingomyelin
d. Glucocerebroside

9. Products of complete hydrolysis of cardiolipin are:



a. 3 glycerol, 4 fatty acids, 2 phosphates
b. 3 glycerol, 4 fatty acids, 1 phosphate
c. 3 glycerol, 3 fatty acids, 2 phosphates
d. 5 glycerol, 4 fatty acids, 2 phosphates

10. In the structure of Acetyl CoA, which is thioester bond?



Acetyl CoA

a. X
b. Y
c. Z
d. All

Ans.

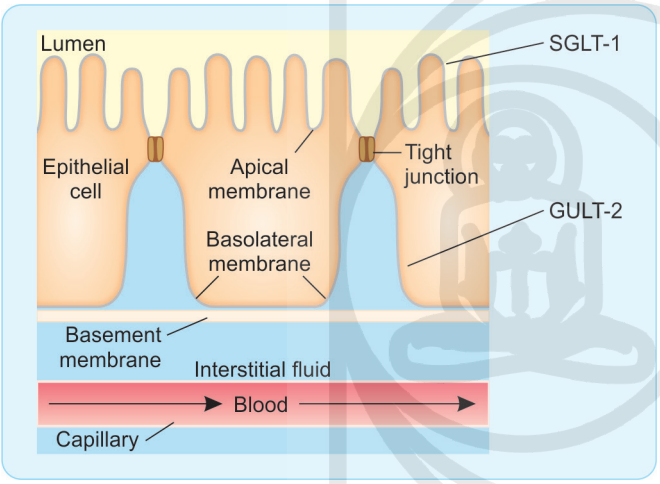
5. a
6. d
7. a
8. d
9. a
10. b

Answers with Explanations

1. Ans. (c) X—SGLT-1, Y—GLUT-2

[Ref: Harper 30th/e p. 191]

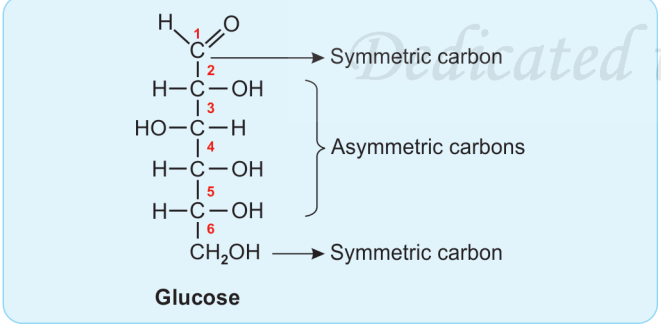
In intestine, both facilitative transport (GLUT) and secondary active (SGLT) transport are present. On apical side of intestinal cells (toward the lumen), SGLT-1 is present, i.e., sodium-dependent glucose transport, and at the basolateral membrane, facilitative transport, i.e., GLUT-2 is present.



2. Ans. (c) 16

[Ref: Harper 30th/e p. 153]

The structure shown here is linear structure of glucose. C1 and C6 of glucose are symmetric carbons. C2 to C5 are asymmetric carbons. Number of isomers possible for any compound is given by the formula where 2^n, n = number of asymmetric carbons. In case of glucose, number of asymmetric carbons is 4. So, total number of isomers possible are 16.



3. Ans. (c) At point C, only a small amount of the enzyme is present as the Enzyme-Substrate complex

[Ref: Harper 30th/e p. 79]

This is Michaelis-Menten graph (rectangular hyperbola). Km is Michaelis-Menten constant. Km is that substrate concentration at which velocity of reaction is half of Vmax. Here '?' point represents Km (on X-axis). At point C, maximum amount of enzyme is present as E-S complex. Initial portion of this graph has first order kinetics, i.e., velocity is directly proportional to substrate concentration and later portion of the graph has zero order kinetics, i.e., velocity is independent of substrate concentration.

4. Ans. (b) Modifier can affect the catalytic site by binding to the allosteric site

[Ref: Harper 30th/e p. 80]

Sigmoidal graph is for allosteric enzymes. They have active site where substrate binds. But they also have allosteric site, where allosteric modulator binds.

Allosteric modulators can be activators or inhibitors. They bind at allosteric/regulatory site and they induce changes in the active site, where substrate binds and they modulate the binding of substrate. Allosteric modifiers can change the binding constant of the enzyme and thus the velocity of reaction. Allosteric modifier binding is not concentration dependent. Adding more substrate to the enzyme cannot displace the allosteric modifier.

5. Ans. (a) RBCs

[Ref: Harper 30th/e p. 172]

This is RL shunt, i.e., Rapoport-Leubering shunt/ cycle. This occurs only in RBCs, for the production of 2,3 bisphosphoglycerate. This compound is required in RBCs to release oxygen from HbA at tissue level. In RL shunt, substrate level phosphorylation step by phospho glycerate kinase enzyme does not occur. Net gain of ATP in RL shunt is zero.

6. Ans. (d) Chylomicrons

[Ref: Harper 30th/e p. 257]

The sample taken from patient shows milky plasma, which is characteristic of increased chylomicrons in blood. Chylomicrons contain TGs (triglycerides).

7. Ans. (a) Chylomicrons

[Ref: Harper 30th/e p. 257]

Chylomicrons are formed by intestinal cells after taking a lipid-rich meal. Chylomicrons are removed from circulation within 2 hours of food intake. So after overnight fast, chylomicrons are not present in blood.

Conceptual Review of

Biochemistry

Salient Features

- Simple and easy-to-understand language is the hallmark of the book
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About the Author

Smily Pruthi Pahwa, *MBBS, MD (Biochemistry),* is a well-known faculty of Biochemistry. With incredible energy and enthusiasm for Biochemistry, she picked the subject as her first endeavor. After completing her MD from Dayanand Medical College and Hospital, Ludhiana, she engaged herself in imparting quality training to the students from different streams. Her innovative ideas and new approach to deal with the complex topics make her highly popular amongst the students. Her intuitive and simple lectures make the subject easy to understand. She is the National Level Workforce for Biochemistry. She is currently running India's No. 1 Biochemistry App, Biochemistry by Dr Smily Pruthi with video lectures. Students have the access to various MCQs for their entrance exams and also can be in touch with her for clearing any doubts. She is always concerned about her students and is always ready to help them.

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