



JAYPEE

# Textbook of BIOCHEMISTRY for Medical Students

## A Clinically Integrated Approach

### Highlights

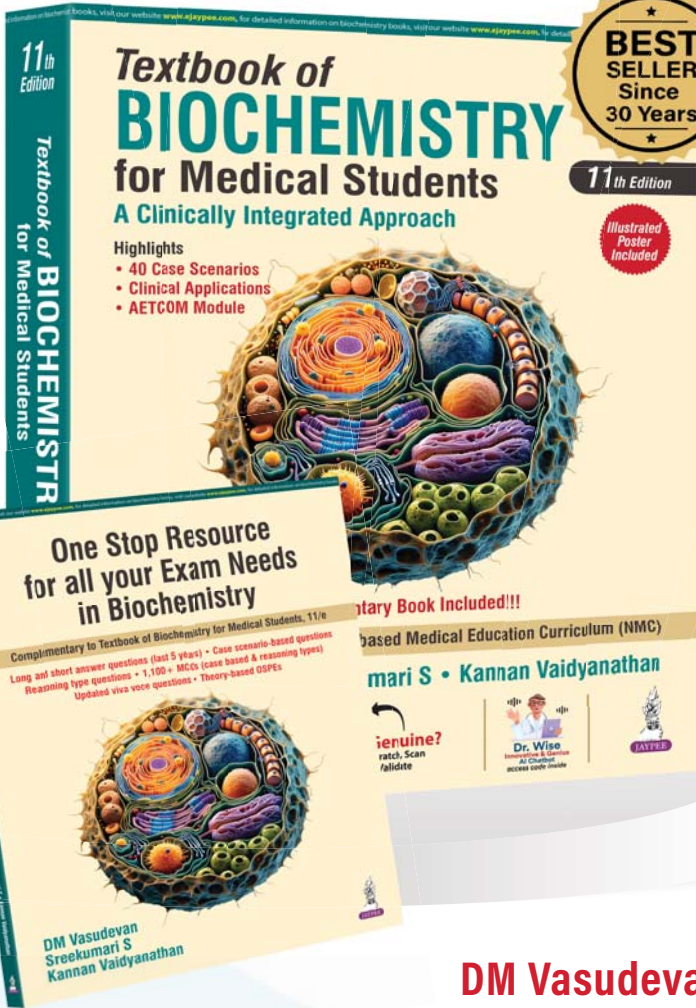
- 40 Case Scenarios
- Clinical Applications
- AETCOM Module



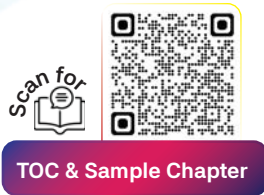
# 11<sup>th</sup> Edition

## Complimentary Book Included!!!

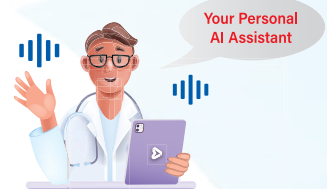
As per the Revised Competency-based Medical Education Curriculum (NMC)



## DM Vasudevan | Sreekumari S | Kannan Vaidyanathan



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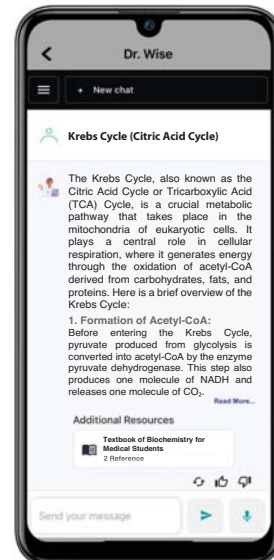
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### Why to Buy this Book ?

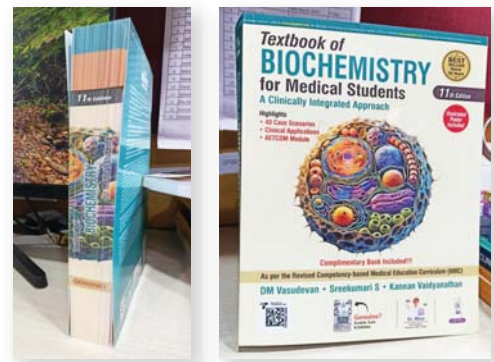
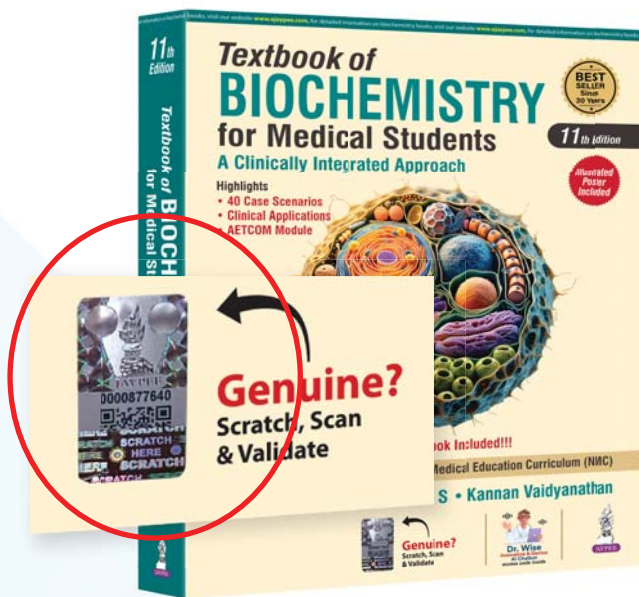
- The content has been thoroughly revised and updated to align with **Latest Competencies as per CBME Curriculum** ensuring that students are well prepared for the evolving medical education.
- Newer topics like **alcohol metabolism, Artificial intelligence in clinical laboratory and AETCOM module 1.1** are added as per new guidelines.
- The presentation and content have been designed to be **student-friendly, more accessible, and easier to understand**, making complex biochemical concepts simpler for students.
- The edition contains **new, high-quality visuals** such as figures, images, and flowcharts offering a clearer, visual approach to learning.
- **Additional tables and boxes, along with clinical application boxes**, are added for last-minute revision and quick reference.
- More than **40 case studies along with theory-based questions and answers** have been designed to reinforce clinical applications of biochemistry and developing problem-solving skills.
- **A complimentary booklet is provided, containing a variety of new theory pattern-based questions. These include long/short answer questions, reasoning-based questions, 1,000 MCQs, and scenario-based questions, along with viva voce questions to aid comprehensive preparation.**
- This edition includes complimentary access to **Dr. Wise, an AI-powered chatbot** that answers all your biochemistry-related queries to get answers anytime, anywhere, making it a convenient and interactive learning tool.



- MCQs
- Clinical Cases
- Short Notes
- Long Notes
- Images
- Flashcards
- Comparison Tables
- Flowcharts

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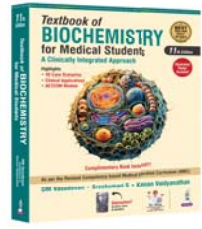


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# SAMPLE PAGES — MAIN BOOK

Each chapter begins with clear and Specific Learning Objectives that highlight key takeaways.

### SPECIFIC LEARNING OBJECTIVES

**The learner will be able to:**

- Outline the digestion of carbohydrates
- Describe the absorption of glucose and glucose transporters
- Trace the glycolysis pathway and explain its regulation
- Calculate the energy yield from glycolysis
- Define the Cori cycle and BPG shunt and state their clinical relevance
- Mention the role of pyruvate as a metabolic junction
- Describe gluconeogenesis and malate shuttle
- Explain the significance of gluconeogenesis and glucose alanine cycle
- Enumerate the substrates for gluconeogenesis
- Describe the synthesis and degradation of glycogen
- Explain the regulation of glycogen metabolism and the role of cyclic AMP
- Tabulate major glycogen storage diseases and their salient features
- Trace the hexose monophosphate shunt pathway
- State the metabolic and clinical significance of the shunt pathway
- Outline the gluconic acid pathway and essential pentosuria
- Enumerate the steps and significance of the polyol pathway
- Outline the metabolism of fructose

Scan me for Chapter's NMC Competencies or, for detailed competencies, please refer Prelims page xxxvii

### Metabolic Path

**SPECIFIC LEARNING OBJECTIVES**

**The learner will be able to:**

- Outline the digestion of carbohydrates
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- Trace the glycolysis pathway and explain its regulation
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- Outline the metabolism of fructose

### Table 8.1: Dietary carbohydrates and their digestion.

Name of CHO	Dietary source	Digestive enzyme	Location	Products
Starch	Cereals – Rice, wheat	Alpha amylase	Salivary amylase Pancreatic amylase	Dextrins Maltose Isomaltose
Glycogen	Meat	Alpha amylase	Pancreatic amylase	Maltose and isomaltose
Lactose	Milk sugar	Lactase	Intestinal brush border	Glucose and galactose
Sucrose	Cane sugar	Sucrase	Intestinal brush border	Glucose and fructose
Maltose and Isomaltose	Hydrolysis of starch	Sucrase-maltase complex and maltase-isomaltase complex	Intestinal brush border of jejunum	Glucose
Monosaccharides	Fructose, pentoses Fruits and honey	—	—	Fructose, pentoses
Fiber	Plant polysaccharides Cellulose and hemicelluloses, pectin, etc.	—	—	Needed for bowel movements Fermented by intestinal bacteria

Additional tables and boxes, are added for last-minute revision and quick reference.

### BOX 8.1 Clinical Application of Lactose Intolerance.

**Lactose Intolerance**  
Lactase hydrolyses lactose to glucose and galactose. Lactase is present in the brush border of enterocytes of the jejunum and the activity is highest around 1 month after birth. **Deficiency of lactase** leads to lactose intolerance. In this condition, lactose accumulates in the gut. Irritant diarrhea and flatulence are seen. Stool analysis is useful for diagnosis where Benedict's and stool acidity tests are positive.

**Congenital lactase deficiency** leads to lactose intolerance that is seen at birth, where symptoms start with the first breast feed. The condition should be recognized and treated immediately in newborns by giving lactose free formula diet instead of milk. Chronic diarrhea and malnutrition can also cause lactase deficiency in children.

Another reason for acquired lactose intolerance may be a sudden change into a milk-based diet. Lactase is an **inducible** enzyme. If milk is withdrawn temporarily, diarrhea will be limited. Curd is also an effective treatment, because the lactobacilli present in curd contains the enzyme lactase. Lactase is abundantly seen in **yeast** which can also be used in treatment.

In senior citizens, lactase enzyme may be absent. Normally the adult lactase levels are reached by 6–7 years of age. Adult hypolactasia occurs when lactase expression decreases to 10% of that present in infants. **Secondary lactase deficiency** may result from intestinal diseases that injure the absorptive cells of intestinal villi and decrease lactase activity. The undigested disaccharides, oligosaccharides and dextrins may be hydrolyzed by bacteria and used for their energy needs by converting them to short chain fatty acids (C2–C4) and lactate. Along with this process, gases such as hydrogen, methane and CO<sub>2</sub> are also produced which leads to flatulence. If undigested carbohydrates are left in the intestine, osmotic diarrhea, cramps and flatulence occur.

### BOX 8.2 Clinical Application of Absorption of Carbohydrates.

- Common treatment for diarrhea is the intake of oral **rehydration fluid**. It contains glucose and sodium. The presence of glucose in oral rehydration fluid allows the uptake of sodium to replenish body sodium chloride.
- Inhibiting absorption of glucose from intestinal lumen is a therapeutic measure to reduce hyperglycemia (Chapter 9).



Fig. 24.7: Glossitis, magenta colored tongue and chelosis (black arrow).



Fig. 24.9: Irregular ridges in the nails in riboflavin deficiency.

### Chemistry of Nicotinamide

Nicotinamide is a pyridine ring with a carboxamide group at the 3-position. It is a derivative of the heterocyclic ring pyridine. The nitrogen atom of the pyridine ring is bonded to a hydrogen atom. The nitrogen atom of the pyridine ring is bonded to a hydrogen atom. The nitrogen atom of the pyridine ring is bonded to a hydrogen atom.

**Dietary Sources of Riboflavin**  
Rich sources of riboflavin are liver, whole milk, egg and whole milk. Good sources are fish, whole cereals, legumes and green leafy vegetables.

**Daily Requirement**  
Riboflavin is converted mainly with the formation of isoflavin and as the requirement of riboflavin is

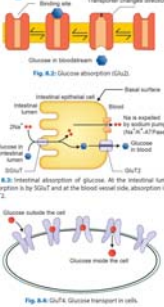
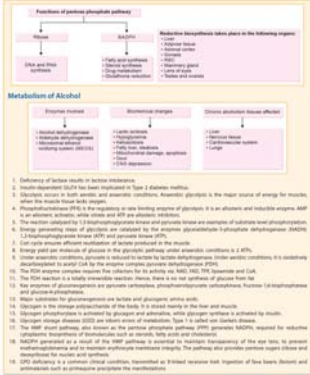
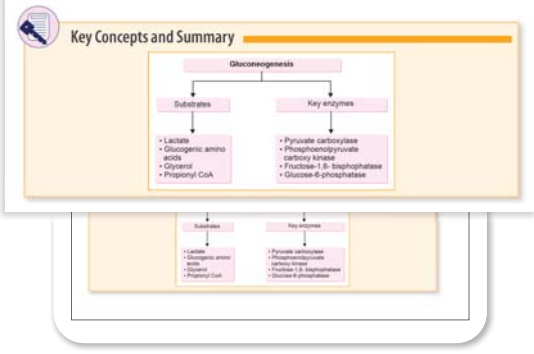


Fig. 8.5: Absorption of monosaccharides.

The edition contains new, high-quality visuals such as figures, images, and flowcharts offering a clearer, visual approach to learning.

Provides key Concepts and Summaries for effective revision at the end of each chapter.



Includes a comprehensive list of 40 clinical case scenarios for applied learning.

### Early Clinical Exposure

**Case 8.1 Lactose Intolerance**

A 2-month-old infant developed abdominal distension, watery diarrhea, and flatulence after every breastfeeding session. The mother reports no such problems prior to initiating full breastfeeding. On laboratory examination, stool tested positive for reducing sugars and was acidic in pH.

**Questions**

1. What is the probable diagnosis?
2. Explain the biochemical basis of this disorder.
3. What are the characteristic clinical features of this condition?
4. What biochemical tests are used for diagnosis?
5. What treatment strategies should be advised?

**Answers**

1. The most probable diagnosis is Congenital Lactase Deficiency, a form of lactose intolerance due to deficient lactase enzyme activity in the jejunal brush border.
2. Lactase ( $\beta$ -galactosidase), located in the brush border of enterocytes in the jejunum, hydrolyses lactose into glucose and galactose. In its absence:
  - Lactose remains unabsorbed in the intestinal lumen.
  - This undigested lactose increases osmotic load, drawing water into the lumen leading to osmotic diarrhea.
  - It also becomes a substrate for bacterial fermentation, producing short-chain fatty acids and gases ( $H_2$ ,  $CH_4$ ,  $CO_2$ ), resulting in flatulence and abdominal discomfort.

### Early Clinical Exposure

List of Clinical Case Scenario-Based Q/A's in this Book

These cases are based on ECG guidelines by NMC, 2024 and are covered so that students can get the idea about the clinical integration of the subject and get the idea of how clinical questions can be asked in exams. For more case base questions refer to Free Booklet.

S. No.	Case number	Topic	Chapter number	Page number
1.	Case 2.1	Zellweger syndrome	2	16
2.	Case 2.2	Cystic fibrosis	2	21
3.	Case 2.3	Renal glycosuria	2	24
4.	Case 3.1	Disengagement of liver enzymes (obstructive jaundice)	3	49
5.	Case 3.2	Organophosphate poisoning	3	50
6.	Case 3.3	Glucose-6-phosphate dehydrogenase deficiency	3	50
7.	Case 3.4	Lactic acidosis	7	110
8.	Case 6.1	Lactose intolerance	6	127
9.	Case 8.2	Von Gierke disease	8	149
10.	Case 8.3	Glucose-6-phosphate dehydrogenase deficiency (hemolytic anemia)	8	153
11.	Case 8.4	Fructose intolerance	8	156
12.	Case 8.5	Galactosemia	8	158
13.	Case 8.6	Methanol poisoning	8	161
14.	Case 8.7	Hurler's syndrome	8	165
15.	Case 9.1	Renal glycosuria	9	174
16.	Case 9.2	Diabetes mellitus 2	9	180
17.	Case 9.3	Diabetic acidosis	9	184
18.	Case 10.1	Steatorrhea	10	195
19.	Case 10.2	Fatty liver	10	208
20.	Case 10.3	Say-Sachs disease	10	219
21.	Case 11.1	Cholestasis	11	237
22.	Case 12.1	Atherosclerosis and myocardial infarction	12	242
23.	Case 12.2	Primary biliary hypercholesterolemia (PBC)	12	251
24.	Case 13.1	Hyperammonemia	13	269
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26.	Case 13.3	Phenylketonuria	13	294
27.	Case 16.1	Prothrombin	16	314
28.	Case 16.2	Methemoglobinemia	16	347
29.	Case 16.3	Sickle cell anemia	16	351
30.	Case 15.1	Jaundice	15	363
31.	Case 18.1	Renal failure	18	382
32.	Case 18.2	Nephrotic syndrome	18	383
33.	Case 20.1	Metabolic acidosis and ABG analysis	20	410
34.	Case 21.1	Vitamin D deficiency	21	436
35.	Case 24.1	Thiamine deficiency	24	462
36.	Case 25.1	Hypocalcaemia	25	493
37.	Case 25.2	Microcytic anemia	25	502
38.	Case 28.1	Hyperviscosity	28	530
39.	Case 31.1	Inheritance pattern and mutations	31	592
40.	Case 38.1	Hypertension	38	717

The book also includes the Attitude, Ethics, and Communication (AETCOM) modules.

### Appendices

**APPENDIX I: ATTITUDE, ETHICS, AND COMMUNICATION (AETCOM)**

**MODULE 1.1: What does it mean to be a doctor?**

**SPECIFIC LEARNING OBJECTIVES**

**The personal attitude to be:**

- Develop and identify professional qualities and roles of a physician.
- Describe and discuss the role of a physician in healthcare system.
- Identify and discuss the commitment to lifelong learning and the continuing care for the patient.

**PROFESSIONAL QUALITIES AND ROLES OF A PHYSICIAN**

A physician has a unique position to work in, not just a doctor but also an educator of the public, an ally, and a leader. To meet the expectations of the public and the healthcare system, physicians must have certain professional qualities and perform multiple roles.

**Key Professional Qualities**

**Integrity and Honesty**  
The ability to not seek reward (profit) and not willing to reward or punish. It is a responsibility (duty) to be honest, fair, and to report any unethical or illegal activities.

**Integrity**  
Physicians are responsible to their patients, peers, institutions, and society. They have a responsibility for their decisions and actions.

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**Rachel Paul**

★★★★★ **Must have to learn first year medicine (MBBS)**

Reviewed in India on 20 June 2024

**Verified Purchase**

It's the only book that I need to learn biochemistry. It has all the needful points with diagrams and flowcharts to remember and understand. Would definitely recommend!

**amazon**

**REVIEWS**

**SR**

★★★★★ **Good book**

Reviewed in India on 18 May 2023

Format: Paperback | **Verified Purchase**

Explained in a detailed way. Like it.

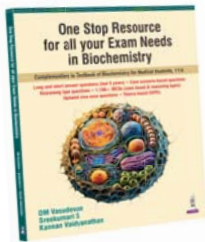
**Avid music listener**

★★★★☆ **Good for theory exams.**

Reviewed in India on 2 November 2023

**Verified Purchase**

Content is good for Indian theory exams.



# SAMPLE PAGES

Complimentary Free Book

## FREQUENTLY ASKED THEORY QUESTIONS

### Long Answer Questions (8–10 Marks)

- Describe the regulation of blood glucose levels in postprandial and fasting states. What are the roles of insulin and counter-regulatory hormones? (Page 168)
- Explain the biosynthesis, secretion, receptor action, and signal transduction pathway of insulin. (Page 174)
- Describe the biochemical basis and laboratory diagnosis of diabetes mellitus. What are the diagnostic criteria and classification of diabetes? (Page 179)
- Discuss the acute and chronic metabolic complications of diabetes mellitus. (Page 183)
- What are the indications for the oral glucose tolerance test? What precautions are to be taken before doing an OGTT? Explain the abnormal curves obtained? What is impaired glucose tolerance? (Page 170)

### Short Answer Questions (3–5 Marks)

- Define hypoglycemia with a note on insulin overdose? (Page 189)
- Differentiate between renal glycosuria and alimentary glycosuria. (Page 172)
- What is GOD-POD method? (Page 170)
- Describe the role of C-peptide estimation in diagnosing insulin secretion status. (Page 174)
- Write a note on insulin resistance. (Page 181)
- Write a note on metabolic syndrome. (Page 188)
- Define and differentiate IGT and IFG. (Page 172)
- Write a note on glycated hemoglobin (HbA1c). (Page 185)
- What are the effects of insulin on gene expression? (Page 172)
- What is the biochemical basis of Somogyi effect and Dawn phenomenon? (Page 189)
- Explain the genesis of advanced glycation end products. (Page 187)
- Write a note on renal threshold. (Page 172)
- What is gestational diabetes? How is it diagnosed? (Page 170)
- Discuss the role of incretin hormones in glucose homeostasis. (Page 178)

Frequently asked questions, including Long and Short answer types Questions, are given at the beginning of the chapters.

Scenarios-based Questions/Problem-Solving Exercises

## Scenario-based Questions/Problem-Solving Exercises (5–8 Marks)

- A 1-month-old infant presents with bloating, excessive flatulence, and watery diarrhea shortly after feeding. The symptoms worsen when given formula milk. A stool test reveals the presence of reducing sugars, and the pH is found to be acidic. (Page 127)
  - What is the most likely diagnosis?
  - What enzyme deficiency causes this condition?
  - What test can be used to confirm the diagnosis in older children or adults?
  - What is the treatment and dietary management?
- A 14-year-old girl presents with nausea, abdominal pain, rapid breathing, and confusion. Blood gas analysis reveals metabolic acidosis with a high anion gap. Blood lactate level is 7.5 mmol/L (normal <2.0 mmol/L). She has a history of mitochondrial disorder in the family. (Page 142)
  - What is the most likely diagnosis?
  - What is the biochemical cause of lactic acidosis?
  - How do mitochondrial defects contribute to this condition?
  - What are the main principles in treating lactic acidosis?
- A 9-month-old child is brought with complaints of frequent hypoglycemia, irritability, and a protuberant abdomen. Investigations reveal hepatomegaly, hyperuricemia, hyperlipidemia, lactic acidosis, and hypoglycemia. (Page 148)
  - What is the most likely diagnosis?
  - What enzyme is deficient?
  - Explain the biochemical basis for hyperuricemia and lactic acidosis.
  - What dietary modifications are recommended?
- A 3-month-old infant presents with severe muscle weakness, cardiomegaly, and respiratory distress. Enzyme analysis reveals a deficiency of acid alpha-glucosidase. (Page 148)
  - What is the most likely diagnosis?
  - What is the biochemical defect involved?
  - Why is cardiac involvement seen in this condition?
  - What is the difference between infantile and late-onset forms?

## Reasoning Type Questions

### REASONING TYPE QUESTIONS

- Hypoglycemia is more dangerous than hyperglycemia in acute settings. (Page 170)
- Adrenaline increases blood glucose during stress or exercise. (Page 175)
- Cortisol and growth hormone cause hyperglycemia in long-term stress. (Page 173)
- Excess alcohol consumption causes hypoglycemia in fasting individuals. (Page 181)
- C-peptide measurement help differentiate between Type 1 and Type 2 diabetes. (Page 187)
- Sulfonylurea is not effective in Type 1 diabetes. (Page 187)
- OGTT is not routinely used for Type 1 diabetes diagnosis. (Page 171)
- Insulin is injected and not given orally. (Page 187)
- Diabetic ketoacidosis is more common in Type 1 diabetes than Type 2. (Page 183)
- Frequent small meals are advised in patients with reactive hypoglycemia. (Page 189)
- Lactose excreted in urine in a pregnant woman. (Page 173)
- HbA1c is a reliable indicator of long-term glycemic control. (Page 185)

### MULTIPLE CHOICE QUESTIONS

- The main intracellular second messenger for glucagon is:
  - cAMP
  - cGMP
  - IP<sub>3</sub>
  - DAG
- Which of the following insulin actions is mediated by dephosphorylation of enzymes?
  - Inhibition of glycogen phosphorylase
  - Activation of PFK-1
  - Activation of glucose-6-phosphatase
  - Suppression of HMG-CoA reductase
- C-peptide is useful in diagnosing:
  - Starvation ketosis
  - Type 2 DM
  - Insulinoma
  - Type 1 DM
- Which hormone is secreted in response to food and increases insulin secretion?
  - Cortisol
  - Epinephrine
  - GLP-1
  - Glucagon
- Mechanism of action of sulfonylureas involves:
  - Blocking DPP-4
  - Activating GLP-1 receptors
  - Stimulating insulin secretion via SUR
  - Blocking alpha-glucosidase
- Which enzyme does insulin inhibit via gene repression?
  - Glucokinase
  - Glucose-6-phosphatase
  - Pyruvate kinase
  - Acetyl-CoA carboxylase
- Which of the following is a ketone body detectable by Rother's test?
  - Acetyl-CoA
  - Acetone
  - β-Hydroxybutyrate
  - Acetoacetate
- HbA1c reflects the average glucose level over the past:
  - 1–2 days
  - 10–12 weeks
  - 6 months
  - 24 hours
- Increased methylglyoxal formation in diabetes promotes:
  - Insulin secretion
  - Glucagon release
  - AGE formation
  - SGPT activity
- Which hormone contributes to dawn phenomenon in diabetic patients?
  - Insulin
  - GLP-1
  - Cortisol
  - Somatostatin

## Multiple Choice Questions

## Objective Structure Practical Examinations (OSPES)

## Viva-Voce Questions

### VIVA-VOCE QUESTIONS

- How is glucose absorbed from the intestine? Via sodium-dependent glucose transporter (SGLT) on luminal side.
- Which transporter releases glucose from intestinal cells into blood? GLUT2.
- What is the role of GLUT4? Insulin-sensitive glucose transporter in muscle and adipose tissue.
- How is glucose uptake affected in diabetes mellitus? Reduced GLUT4 leads to impaired glucose entry into muscle cells.
- What is glycolysis? Conversion of glucose to pyruvate/lactate with ATP generation.
- When is lactate produced instead of pyruvate? Under anaerobic conditions.
- What is the significance of glycolysis in RBCs and muscles? It is the only energy source in RBCs; predominant during exercise.
- Which enzymes catalyse substrate-level phosphorylation in glycolysis? Phosphoglycerate kinase and pyruvate kinase.

## Section B Objective Structure Practical Examinations (OSPES)

1. A 22-year-old diabetic male presented to emergency with vomiting, abdominal pain, fruity breath, and altered consciousness. ABG analysis report is given below:

Parameter	Value	Normal Range
pH	7.38	7.35–7.45
PO <sub>2</sub>	95 mmHg	85–100 mmHg
PCO <sub>2</sub> (20)	12 mmHg	35–45 mmHg
Anion Gap (AG)	28 mEq/L	8–12 mEq/L
Sodium (Na <sup>+</sup> )	143 mEq/L	130–145 mEq/L
Chloride (Cl <sup>-</sup> )	104 mEq/L	98–106 mEq/L

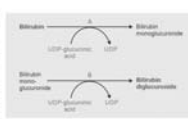
- What acid-base disorder is evident in the ABG? Metabolic acidosis with an increased anion gap.
- What is primarily responsible for the fruity breath? Ketones.
- Which enzyme is responsible for this agent synthesis causing fruity breath? HMG-CoA synthase.

2. A 3-year-old child with fatigue, pallor, and history of blood transfusion undergoes hemoglobin electrophoresis.



- What is the likely diagnosis based on the electrophoresis pattern? Sickle cell anemia.
- What is the defect in this disorder? Defect in hemoglobin.
- Name one conventional genetic test. PCR for β-globin gene mutation.

3. A 3-year-old female was brought to pediatric OPD with vomiting and diarrhoea. Based on blood examination, the attending physician diagnosed metabolic acidosis. The cationic gap for your student using department for ECE class asked about the reason for this.



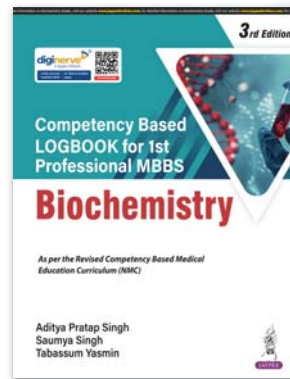
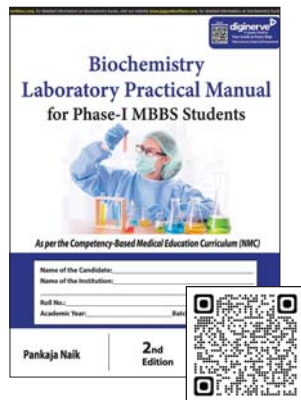
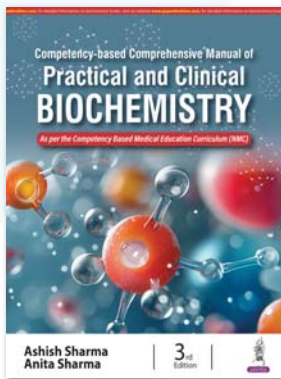
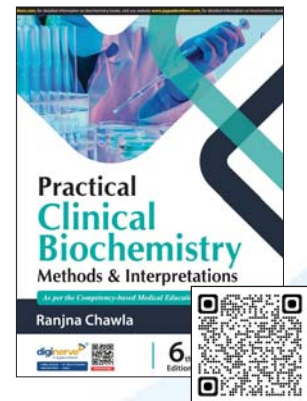
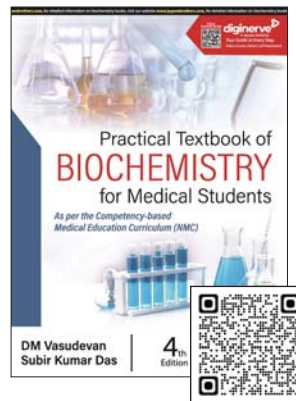
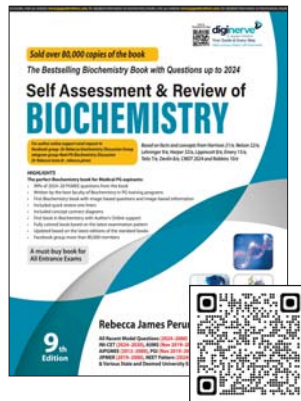
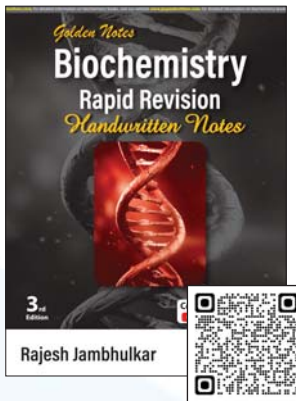
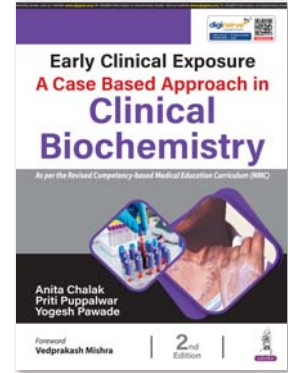
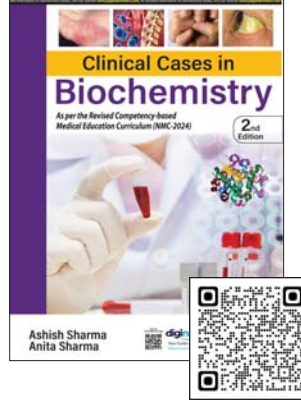
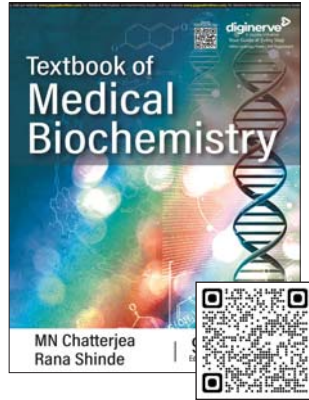
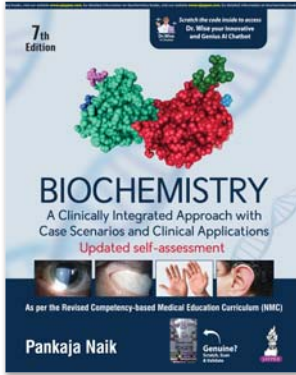
- What is the probable diagnosis? Lactic acidosis.
- Of A and B, which is responsible for the excess unglycogenated lactates levels? B.
- What is the risk of very high lactates levels? Coma.

4. A 3-year-old boy reported to OPD with following clinical and laboratory findings. Blood investigations revealed low calcium levels.



- What is the reason for the presenting features? Vitamin D deficiency.
- What enzyme activates this vitamin in the kidney? 1-α,25-dihydroxyvitamin D<sub>3</sub> synthase.
- What is the active form of this vitamin in body? 1,25-dihydroxyvitamin D<sub>3</sub>.

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