

Competency-Based

Textbook of **Biochemistry**

with Clinical Approach and Case Studies for MBBS Students

has been specially written and presented keeping in mind the requirements of undergraduate medical students studying biochemistry as per the CBME Guidelines | Competency Based Curriculum for the Indian Medical Graduate.

The main emphasis of the latest CBME based curriculum is on developing the clinical correlation of biochemistry in medical student's mind in such a fashion that this complex subject becomes relevant in understanding and approaching the patients afflicted with various metabolic and genetic disorders.

The author's extensive experience of teaching biochemistry to medical students in an easy and focussed manner is well reflected in writing the chapters of this textbook.

A number of case scenarios are presented in an easy and interesting way and their biochemical basis is explained in a lucid manner. This approach not only makes the subject relevant and easier for student to learn, but also enhances the retention of the subject in the learner's mind.

Salient features of the book

- Covers all the competencies prescribed for biochemistry in CBME curriculum
- Clinical scenarios related to various topics are incorporated
- Exhaustive question bank includes LAQs, SAQs and MCQs with detailed explanations
- Keypoints at the end of the chapter for revising the primary concepts

Poonam Agrawal MBBS, MD, FIMSA, ACME

is currently Professor and Head, Department of Biochemistry, and MEU Coordinator, Dr Baba Saheb Ambedkar Medical College and Hospital, New Delhi. She has been actively involved in teaching biochemistry to medical undergraduate and postgraduate students for the past 17 years. Teaching is her passion and she is popular among her students for simplified and fascinating approach towards the subject with strong clinical connections. Other popular books which she has authored are *Concepts in Biochemistry based on CBME*; *Practical Biochemistry based on CBME* and *Review of Biochemistry for PGME*, all brought out by CBSPD.



She has completed Advance Course in Medical Education (ACME) conducted by MCI in 2017 and has completed and published many innovative projects in the field of medical education.

She is actively involved in research and patient care and her areas of interest are diabetic complication, thyroid dysfunction, novel biomarkers and medical education. She has won a number of awards for her research work presentations at various national and international events.



CBS Publishers & Distributors Pvt Ltd

4819/XI, Prahlad Street, 24 Ansari Road, Daryaganj, New Delhi 110 002, India
E-mail: delhi@cbspd.com, customercare@cbspd.com; Website: www.cbspd.com
New Delhi | Bengaluru | Chennai | Kochi | Kolkata | Lucknow | Mumbai
Hyderabad | Jharkhand | Nagpur | Patna | Pune | Uttarakhand



Scan for price of this book and catalogue

ISBN: 978-93-5466-464-9



Textbook of **Biochemistry**

with Clinical Approach and Case Studies
Agrawal



Additional study material available on CBSiCentral App

Competency-Based

Textbook of **Biochemistry**

with Clinical Approach and Case Studies for MBBS Students

As per the latest CBME Guidelines | Competency Based Undergraduate Curriculum for the Indian Medical Graduate

- Covers all the competencies prescribed for biochemistry in CBME Curriculum
- Clinical scenarios related to important topics
- Exhaustive question bank includes LAQs, SAQs and MCQs with detailed explanations
- Keypoints for revising the primary concepts

Poonam Agrawal



Dedicated to Education

CBS Publishers & Distributors Pvt Ltd



Contents

<i>Preface</i>	<i>vii</i>	
<i>Index of Competencies</i>	<i>xiii</i>	
<i>Some Commonly Used Abbreviations in Biochemistry</i>	<i>xv</i>	
Section 1		
Cell, its Organelles and Enzymes		
1. Biochemical and Clinical Significance of Cell and its Various Organelles	3	
Description of individual organelles in the eukaryotic cell 4		
Various compartments in the cell and pathways which occur in cell 12		
Plasma membrane 13		
2. Enzymes: Various Aspects	15	
Classification of enzymes 15		
Mode of action of enzyme 17		
Enzyme kinetics 18		
Cofactor and coenzyme 23		
Metalloenzymes 23		
Regulation of enzyme activity 25		
Isoenzymes 28		
Serine protease 29		
Ribozyme 30		
Functional vs nonfunctional enzymes 30		
3. Clinical Enzymology	32	
Enzyme as a marker of the disease 32		
Enzyme as a marker in myocardial infarction 32		
Enzyme as a marker in liver disease 35		
Enzyme as a marker in pancreatic disease 35		
Enzyme as a marker in prostatic cancer 37		
Enzymes used in various analytical techniques 37		
Enzyme-linked immunosorbent assay (ELISA) 37		
Enzymes used in bioassay 38		
Enzymes used in therapeutics 40		
Section 2		
Chemistry of Carbohydrates, Amino Acids and Lipids		
4. Carbohydrates: General Characteristics and Role in Health and Disease	51	
Classification of carbohydrates 51		
Isomers 67		
5. Amino Acids: General Characteristics and Clinical Importance	71	
Classification of amino acids 74		
Properties of amino acids 77		
6. Lipids: General Characteristics and Clinical Importance	84	
What are lipids? 84		
Lipids and their diverse role 84		
Classification of lipids 84		
Description of an individual lipid compound 85		
Fat or triacylglycerol (TAG) 88		
Phospholipids 90		
Glycolipid (glycosphingolipid) 92		
Sphingolipids 93		
Lipoproteins 94		
7. Eicosanoids and their Metabolism	99	
COX and LOX pathways of arachidonic acid 101		
Important characteristics and biological role of various eicosanoids 102		
Section 3		
Proteins, Plasma Membrane, and Extracellular Matrix		
8. Protein: Structure, Properties and Clinical Importance	111	
Structural organization of the protein 111		
Separation, purification and identification of proteins 116		
Sequencing of protein 116		
General characteristics of proteins 116		
Classification of proteins 117		
9. Components of Plasma Membrane and their Role in Homeostasis	122	
Lipids of membrane 123		
Proteins of membrane 123		
Carbohydrate found in plasma membrane 124		
10. Plasma Proteins: Role in Health and Diseases	128	
Description of important plasma proteins 128		
Albumin 128		
Globulin 130		
Acute phase proteins 131		
Amyloidosis 131		
11. Components and Characteristics of Extracellular Matrix	133	
Structural proteins 133		
Synthesis of collagen and its post-translational modification 134		

Elastin 141			
Fibrillin 142			
Specialized proteins 144			
Fibronectin 144			
Laminin 144			
Proteoglycans 144			
12. Protein Targetting	146		
Sorting of protein synthesized on rough endoplasmic reticulum 146			
Protein degradation in eukaryotes 147			
Sorting of proteins synthesized on free ribosomes in cytosol 148			
Section 4			
Metabolism of Carbohydrates			
13. Digestion and Absorption of Carbohydrate in Human	157		
14. Metabolism of Carbohydrate I: Glucose and its Various Metabolic Pathways	163		
Glycolysis 163			
Steps of glycolysis 163			
Purpose of glycolysis 164			
Inhibitors of glycolysis 165			
Fates of pyruvate 168			
PDH complex 168			
Citric acid cycle (Krebs cycle or TCA cycle) 172			
Gluconeogenesis 172			
Glycogen metabolism 175			
Glycogenesis 176			
Glycogenolysis 177			
Glycogen storage diseases 177			
Hexose monophosphate shunt 181			
Functions of HMP shunt pathway 181			
Uronic acid pathway 185			
15. Metabolism of Carbohydrate II: Fructose and Galactose	189		
Metabolism of fructose 189			
Digestion of lactose 190			
Galactose metabolism 190			
Section 5			
Metabolism of Lipids			
16. Lipids: Digestion and Absorption	207		
17. Synthesis of Fatty Acid	211		
Fatty acid synthase complex (FAS complex) 212			
Fatty acid elongase and desaturase 214			
18. Fatty Acid: Oxidation and Clinical Significance	216		
Beta-oxidation of fatty acid 216			
Fatty acid activation 216			
Transport across the mitochondrial membrane 216			
Steps of β -oxidation of fatty acid in mitochondrial matrix 218			
Peroxisomal beta-oxidation 222			
Minor pathway of fatty acid oxidation 224			
19. Ketone Body: Synthesis and Utilization	228		
Ketogenesis 228			
Ketone body utilization 229			
20. Cholesterol: Synthesis and its Further Fate	232		
Biosynthesis of cholesterol 232			
Regulation of cholesterol biogenesis 232			
21. Lipoprotein Metabolism	237		
Lipoprotein 237			
Chylomicron metabolism 237			
VLDL metabolism 239			
LDL metabolism 241			
HDL metabolism 243			
Lipoproteia [Lp(a)] 244			
22. Lipoprotein Disorders	246		
Hyperlipoproteinemia 246			
Hypolipoproteinemia 251			
Section 6			
Proteins and Amino Acid Metabolism			
23. Protein: Digestion and Absorption	269		
24. Amino Acid Metabolism I: Urea Cycle	272		
Biosynthesis and catabolism of amino acids (an overview) 272			
Urea cycle (Krebs-Henseleit cycle or ornithine cycle) 273			
Ammonia: Its diverse sources and fate in human 277			
25. Amino Acid Metabolism II: Aliphatic Amino Acids	281		
Simple amino acids 281			
Glycine 281			
Alanine 282			
Hydroxyl group containing amino acids 283			
Serine 283			
Serine and ethanolamine 284			
Branched-chain amino acids 285			
Acidic amino acids 288			
Glutamic acid 288			
Aspartic acid 289			
Basic amino acids 289			
Arginine 289			
Lysine 291			
Histidine 291			
Sulphur containing amino acids 292			
Methionine 292			
Cysteine 294			
One-carbon pool 294			
Source of one-carbon compound in one-carbon pool 294			
Utilization of one-carbon group 294			
Biogenic amines 296			
Polyamines 296			
26. Amino Acid Metabolism III: Aromatic Amino Acids	298		
Phenylalanine 298			
Tyrosine 300			
Tryptophan 309			
Description of NAD ⁺ /kynurenine pathway 309			
Description of serotonin/melatonin pathway 311			

Section 7			
TCA Cycle, Oxidative Phosphorylation and Metabolic Integration			
27. TCA Cycle	325		
Citric acid cycle/Krebs cycle or TCA (tricarboxylic acid) cycle 325			
28. Electron Transport Chain and Oxidative Phosphorylation	330		
Electron transport chain (ETC) 330			
ETC components 331			
Redox couple and redox potential (reduction potential) 331			
Factors adversely affecting the process of biological oxidation 334			
Shuttle to transport reducing equivalent of cytosolic NADH to the coenzyme inside the mitochondrial matrix 335			
29. Metabolic Integration in Various Physiological and Pathological States	338		
Starve-feed cycle 338			
Mechanism responsible for metabolic control in well-fed and starved state in liver 341			
Adipose tissue in starve-feed cycle 343			
Skeletal muscle in starve-feed cycle 344			
Obesity 344			
Section 8			
Nutrition and Micronutrients			
30. Nutrition and Balanced Diet	351		
Dietary reference intake (DRI) 352			
Basal metabolic rate (BMR) 352			
Respiratory quotient (RQ) 352			
Specific dynamic action (SDA) or diet-induced thermogenesis 353			
Glycemic index 353			
Dietary fiber 354			
Protein energy malnutrition (PEM) 355			
31. Water-Soluble Vitamins	357		
Fat soluble 357			
Water soluble 357			
Vitamin B ₁ 357			
Vitamin B ₂ (riboflavin) 362			
Vitamin B ₃ (niacin) 364			
Vitamin B ₅ (pantothenic acid) 367			
Vitamin B ₆ 369			
Vitamin B ₇ (biotin) 372			
Folic acid (vitamin B ₉) 374			
Vitamin B ₁₂ 376			
Vitamin C (ascorbic acid) 379			
Vitamin-like compounds 381			
Hematological and neurological changes in alcoholics due to micronutrient deficiencies 382			
32. Fat-Soluble Vitamins	385		
Vitamin D 385			
Vitamin A 390			
Vitamin E (tocopherol) 393			
Vitamin K 394			
33. Minerals and their Metabolism	397		
Macrominerals 398			
Calcium and its metabolism 398			
Phosphorus (P) 404			
Magnesium (Mg) 405			
Sodium (Na) and Chloride (Cl ⁻) 406			
Potassium 406			
Microminerals 406			
Copper 406			
Zinc (Zn) 410			
Iron (Fe) 410			
Fluorine 414			
Chromium (Cr) 415			
Manganese (Mn) 415			
Ultratrace elements 416			
Iodine (I) 416			
Selenium (Se) 416			
Molybdenum (Mo) 417			
Section 9			
Organ Function Tests			
34. Liver Function Tests (LFTs)	433		
Urine investigations 434			
35. Kidney Function Tests (KFTs)	438		
36. Thyroid Function Tests (TFTs)	444		
Hypothyroidism 444			
Pancreatic function test 447			
Gastric function test 448			
Section 10			
Nucleotides and Polynucleotides			
37. Nucleotides: Chemistry and their Metabolism	453		
Nucleotide and its metabolism 453			
Purine nucleotide 454			
Salvage pathway 454			
Pyrimidine nucleotide 458			
38. Nucleic Acid I: Structural Organization of DNA and RNA	462		
Types of nucleic acids 462			
39. Nucleic Acid II: DNA Replication (Prokaryotes and Eukaryotes)	470		
DNA replication in prokaryotes 470			
Replication fork 470			
Termination 472			
Topoisomerase 472			
DNA replication in eukaryotes 472			
Meselson-Stahl experiment to prove semiconservative DNA replication 473			
Telomerase and telomere 474			
Mutation 476			
40. Nucleic Acid III: Transcription and Post-Transcriptional Modifications	479		
Transcription (RNA synthesis) 479			
Prokaryotic transcription 479			

Eukaryotic transcription 481			
Post-transcriptional modification of primary transcript to mRNA 483			
Genetic code 485			
Wobble hypothesis 486			
41. Nucleic Acid IV: Translation and Post-Translational Modifications	488		
Description of translation 488			
P bodies 490			
42. Gene Expression and Regulation	492		
Prokaryotic gene expression 492			
LAC operon model 492			
Tryptophan operon model 493			
Eukaryotic gene expression 493			
Section 11			
Genetic Techniques			
43. Technologies in Genetics	499		
Recombinant DNA technology (genetic engineering)/DNA cloning 499			
Gene therapy 502			
DNA library (gene library) 502			
Nucleotide probes 503			
Blotting technique 503			
Fluorescence <i>in situ</i> hybridization (FISH) 505			
DNA sequencing 505			
Polymerase chain reaction (PCR) 506			
Restriction fragment length polymorphism (RFLP) 508			
Section 12			
Heme and Hemoglobin			
44. Heme Metabolism	535		
Heme proteins 535			
Metabolism of heme 536			
45. Hemoglobin and Myoglobin	540		
Section 13			
Free Radicals and Malignancy			
46. Free Radicals	547		
Reactive oxygen species (ROS) 547			
Cellular defence against free radical (detoxification of free radical) 549			
47. Xenobiotics and Biotransformation	552		
Xenobiotics and their biotransformation 552			
Phase 1 Reactions 552			
Phase 2 Reactions 555			
Phase 3 Reactions 556			
48. Cancer Biochemistry, Proto-oncogene, Oncogene	557		
Introduction 557			
Nongenetic associations of cancer 557			
Factors-mediating carcinogenesis 559			
49. Tumor Markers	569		
50. Radioisotopes and their Applications in Diagnostics and Therapeutics	572		
Introduction 572			
Section 14			
Metabolic and Lifestyle Disorders			
51. Acid–Base Disorder	587		
Acid–base disorder: A general overview 587			
Lab report interpretation 588			
52. Diabetes Mellitus	590		
53. Oral Glucose Tolerance Test	593		
Oral glucose tolerance test 593			
Renal glycosuria 595			
Alimentary glycosuria (LAG curve) 595			
54. Obesity	597		
Causes and risk factors 597			
Effects and health risks 598			
Obesity and diabetes mellitus 598			
Obesity and hypertension 599			
Metabolic syndrome 599			
Section 15			
Laboratory Instruments and Biomedical Waste Management			
55. Laboratory Instruments	605		
Commonly used laboratory apparatus and equipment 605			
56. Biomedical Waste Management	615		
Difference between hospital waste and biomedical waste 615			
<i>MCQs for Revision and Practice</i>	619		
<i>Sample Question Paper 1</i>	663		
<i>Sample Question Paper 2</i>	665		
<i>Sample Question Paper 3</i>	667		
<i>Sample Question Paper 4</i>	669		
<i>Glossary</i>	671		
<i>Index</i>	687		

Index of Competencies

Competency based Undergraduate Curriculum for the Indian Medical Graduate

1.	BI1.1	Explain molecular and functional organization of a cell and its subcellular components.	1, 9	3, 122
2.	BI2.1	Explain fundamental concepts of enzyme, isoenzyme, alloenzyme, coenzyme and cofactors. Enumerate the main classes of IUBMB nomenclature.	2	15
3.	BI2.3	Describe and explain the basic principles of enzyme activity.	2	15
4.	BI2.4	Explain enzyme inhibitors as poisons and drugs and as therapeutic enzymes.	2	15
5.	BI2.5	Explain clinical utility of various serum enzymes as markers of pathological conditions.	2	15
6.	BI2.6	Use of enzymes in laboratory investigations (enzyme-based assays).	2	15
7.	BI3.4	Explain pathways of carbohydrate metabolism, (glycolysis, gluconeogenesis, glycogen metabolism, HMP shunt).	14	163
8.	BI3.5	Explain regulation, functions and integration of carbohydrate along with associated diseases/disorders.	14	163
9.	BI3.6	Explain concept of TCA cycle as an amphibolic pathway and its regulation.	27	325
10.	BI3.7	Explain common poisons that inhibit crucial enzymes of carbohydrate metabolism (e.g. fluoride, arsenate).	14	163
11.	BI3.10	Interpret the results of blood glucose levels and other laboratory investigations related to disorders of carbohydrate metabolism.	53	593
12.	BI4.1	Explain monosaccharides, disaccharides and polysaccharides giving examples of main carbohydrates as energy fuel, structural element and storage in the human body.	4	51
13.	BI4.3	Describe regulation of lipoprotein metabolism and associated disorders.	21	237
14.	BI4.4	Explain structure and functions of lipoproteins, their functions, interrelations and relations with atherosclerosis.	21	237
15.	BI4.6	Describe the therapeutic uses of prostaglandins and inhibitors of eicosanoid synthesis.	7	99
16.	BI5.1	Describe and discuss structural organization of proteins.	8	111
17.	BI5.2	Explain functions of proteins and structure–function relationships in relevant areas, e.g. hemoglobin and selected hemoglobinopathies.	8	111
18.	BI6.1	Explain main classes of lipids (essential/nonessential fatty acids, cholesterol and hormonal steroids, triglycerides, major phospholipids and sphingolipids) relevant to human system and their major functions.	6	84
19.	BI6.1	Explain metabolic processes that take place in specific organs in the body in the fed and fasting states.	29	338
20.	BI6.2	Explain metabolic processes in which nucleotides are involved.	37	453
21.	BI6.3	Explain common disorders associated with nucleotide metabolism.	37	453
22.	BI8.2	Explain types and causes of protein energy malnutrition and its effects.	30	351

23.	BI6.5	Biochemical role of vitamins in the body and explain the manifestations of their deficiency.	31	357
24.	BI6.5	Explain biochemical role of vitamins in the body and explain the manifestations of their deficiency.	32	385
25.	BI6.9	Explain functions of various minerals in the body, their metabolism and homeostasis.	33	397
26.	BI6.10	Enumerate and describe the disorders associated with mineral metabolism.	33	397
27.	BI6.11	Explain functions of heme in the body and describe the processes involved in its metabolism and describe porphyrin metabolism.	44	535
28.	BI6.12	Explain hemoglobin and its derivatives found in the body and their physiological/pathological relevance.	45	540
29.	BI6.13	Explain functions of the kidney, liver, thyroid and adrenal glands.	35	438
30.	BI6.14	Perform tests that are commonly done in clinical practice to assess the functions of these organs (kidney, liver, thyroid and adrenal glands).	35	438
31.	BI7.1	Explain structure and functions of DNA and RNA and outline the cell cycle.	38	462
32.	BI7.2	Explain processes involved in replication and repair of DNA and the transcription and translation mechanisms.	39, 40, 41	470 479 488
33.	BI7.3	Gene mutations and basic mechanism of regulation of gene expression.	42	492
34.	BI7.4	Explain applications of molecular technologies like recombinant DNA technology, PCR in the diagnosis and treatment of diseases with genetic basis.	43	499
35.	BI7.5	Explain the role of xenobiotics in disease.	47	552
36.	BI7.6	Explain antioxidant defence systems in the body.	46	547
37.	BI7.7	Explain the role of oxidative stress in the pathogenesis of conditions such as cancer, complications of diabetes mellitus and atherosclerosis.	46	547
38.	BI8.2	Explain types and causes of protein energy malnutrition and its effects.	30	351
39.	BI8.3	Provide dietary advice for optimal health in childhood and adult, in disease conditions like diabetes mellitus, coronary artery disease and in pregnancy.	30	351
40.	BI8.4	Describe the causes (including dietary habits), effects and health risks.	54	597
41.	BI8.5	Summarize the nutritional importance of commonly used items of food including fruits and vegetables (macromolecules and their importance).	30	351
42.	BI9.1	Explain the functions and components of the extracellular matrix (ECM).	11	133
43.	BI9.2	Explain involvement of ECM components in health and disease.	11	133
44.	BI9.3	Explain protein targeting and sorting along with its associated disorders.	12	146
45.	BI10.1	Describe the cancer initiation, promotion oncogenes and oncogene activation. Also focus on p53 and apoptosis.	48	557
46.	BI10.2	Describe various biochemical tumor markers and the biochemical basis of cancer therapy.	49, 51	569, 587
47.	BI11.1	Describe commonly used laboratory apparatus and equipment.	55	605
48.	BI11.19	Outline the basic principles involved in the functioning of instruments commonly used in a biochemistry laboratory and their applications.	55	605
49.	BI11.16	Observe use of commonly used equipment/techniques in biochemistry.	55	605

Some Commonly Used Abbreviations in Biochemistry

ABG	Arterial blood gas	EDTA	Ethylene diamine tetra-acetate
Ab	Antibody	EFAs	Essential fatty acids
ACP	Acyl carrier protein	eIFs	Eukaryotic initiation factors
ACTH	Adrenocorticotrophic hormone	EGF	Epidermal growth factor
Acyl-CoA	Fatty acid derivative of coenzyme A	ELISA	Enzyme-linked immunosorbent assay
ADA	Adenosine deaminase	ER	Endoplasmic reticulum
ADH	Alcohol dehydrogenase	ETC	Electron transport chain
ADP	Adenosine diphosphate	FA	Fatty acid
AFP	α -fetoprotein	Fab	Antigen-binding fragment
Ag	Antigen	FAD	Flavin adenine dinucleotide
A/G	Albumin/globulin (ratio)	FADH ₂	Reduced FAD
AIDS	Acquired immunodeficiency syndrome	FAS	Fatty acid synthase
ALA	δ -aminolevulinic acid	F-1,6-BP	Fructose-1,6-bisphosphate
ALP	Alkaline phosphatase	F-2,6-BP	Fructose-2,6-bisphosphate
ALT	Alanine transaminase	FDNB	1-fluoro-2,4-dinitrobenzene
AMP	Adenosine monophosphate	FFA	Free fatty acid
ANF	Atrial natriuretic factor	FH ₄	Tetrahydrofolate
APC	Antigen presenting cell	FIGLU	Formiminoglutamic acid
ApoA	Apoprotein A	FMN	Flavin mononucleotide
AP sites	Apurinic sites	FMNH ₂	Reduced FMN
AST	Aspartate transaminase	F-1-P	Fructose-1-phosphate
ATP	Adenosine triphosphate	F-6-P	Fructose-6-phosphate
BAL	British antilewisite	ΔG	Free energy change
BMR	Basal metabolic rate	GGT (GT)	γ -glutamyl transpeptidase
BNP	Brain natriuretic peptide	GH	Growth hormone
BP	Blood pressure	GHRH	Growth hormone-releasing hormone
BPG	Bisphosphoglycerate (2,3-BPG, 1,3-BPG)	GIP	Gastric inhibitory peptide
BUN	Blood urea nitrogen	GIT	Gastrointestinal tract
BV	Biological value	Gly	Glycine
Cal	Calorie	GLUT	Glucose transporter
cAMP	3',5'-cyclic adenosine monophosphate (cyclic AMP)	GnRH	Gonadotropin-releasing hormone
CAP	Catabolite activator protein	G-6-P	Glucose-6-phosphate
CCK	Cholecystokinin	G-6-PD	Glucose-6-phosphate dehydrogenase
cDNA	Complementary DNA	GSD	Glycogen storage disease
CEA	Carcinoembryonic antigen	GSH	Glutathione (reduced form)
CFTR	Cystic fibrosis transmembrane regulator	GSSG	Glutathione (oxidized form)
cGMP	3',5'-cyclic guanosine monophosphate	GTP	Guanosine triphosphate
CoA or CoASH	Coenzyme A	GTT	Glucose tolerance test
COHb	Carboxyhemoglobin	Hb	Hemoglobin
COMT	Catechol-o-methyltransferase	HbA ₁	Adult hemoglobin
COPD	Chronic obstructive pulmonary disease	HbA _{1c}	Glycosylated hemoglobin
CPK (CK)	Creatine phosphokinase (creatin kinase)	HbF	Fetal hemoglobin
CPS	Carbamoyl phosphate synthase	HbO ₂	Oxyhemoglobin
CSF	Cerebrospinal fluid	HBsAg	Hepatitis B surface antigen
DAM	Diacetyl monoxime	HDL	High-density lipoprotein
dAMP	Deoxyadenosine monophosphate	HGPRT	Hypoxanthine guanine phosphoribosyl-transferase
DHA	Docosahexaenoic acid	HIAA	Hydroxy indole acetic acid
DHCC	Dihydroxycholecalciferol (1,25-DHCC: 24,25-DHCC)	HIF	Hypoxia inducible transcription factor
DHEA	Dehydroepiandrosterone	HIV	Human immunodeficiency virus
DIT	Diiodotyrosine	HLA	Human leukocyte antigen
DNA	Deoxyribonucleic acid	HMG-CoA	β -hydroxy- β -methylglutaryl-CoA
DNase	Deoxyribonuclease	HNPCC	Hereditary nonpolyposis colon cancer
DOPA	Dihydroxy phenylalanine	hnRNA	Heterogeneous nuclear RNA
DPG	Diphosphoglycerate	Hp	Haptoglobin
ECF	Extracellular fluid	HPLC	High performance liquid chromatography
EDRF	Endothelium-derived-releasing factor	hs-CRP	High sensitive C-reactive protein

5HT	5-hydroxytryptamine	PI	Phosphatidyl inositol
ICD	Isocitrate dehydrogenase	PIP ₂	Inositol-4,5-bisphosphate
IDDM	Insulin-dependent diabetes mellitus	pK _a	Negative log K _a
IF	Initiation factor	pO ₂	Partial pressure of O ₂
Ig	Immunoglobulin	POMC	Pro-opiomelanocortin
IgG	Immunoglobulin G	PRL	Prolactin
IGF	Insulin-like growth factor	PRPP	5-phosphoribosyl-1-pyrophosphate
IL	Interleukin	PTH	Parathyroid hormone
INH	Isonicotinic acid hydrazide (isoniazid)	PTH	Phenyl thiohydantoin
LATS	Long-acting thyroid stimulator	PUFAs	Polyunsaturated fatty acids
LCAT	Lecithin cholesterol acyltransferase	QPRT	quinolate phosphoribosyltransferase
LDH	Lacate dehydrogenase	RBC	Red blood cells
LDL	Low-density lipoproteins	RBP	Retinol-binding protein
LFT	Liver function test	RDA	Recommended dietary (daily) allowance
LH	Luteinizing hormone	RDI	Recommended daily intake
LINEs	Long interspersed elements	RE	Retinol equivalents
LT	Leukotrienes	RER	Rough endoplasmic reticulum
Lp(a)	Lipoprotein-a	RF	Releasing factor
MAO	Maximal acid output	RFLP	Restriction fragment length polymorphsim
Mb	Myoglobin	RIA	Radioimmunoassay
MCAD	Medium chain acyl-CoA dehydrogenase	RNA	Ribonucleic acid
MELAS	Mitochondrial encephalopathy, lactic acidosis and stroke	RNase	Ribonuclease
mg	Milligram	rRNA	Ribosomal RNA
MHC	Major histocompatibility complex	RT	Reverse transcriptase
MI	Myocardial infarction	SAM	S-adenosylmethionine
MIT	Moniodotyrosine	SCID	Severe combined immunodeficiency
mol	mole	SDA	Specific dynamic action
mM	Millimolar	SGOT	Serum glutamate oxaloacetate transaminase
mol. wt.	Molecular weight	SGPT	Serum glutamate pyruvate transaminase
mRNA	Messenger RNA	SIDS	Sudden infant death syndrome
mtDNA	Mitochondrial DNA	SINEs	Short interspersed elements
MW	Molecular weight	SNPs	Single nucleotide polymorphisms
NAD ⁺	Nicotinamide adenine dinucleotide	T ₃	3,5,3'- triiodothyronine
NADH	Reduced NAD ⁺	T ₄	3,5,3'5'- tetraiodothyronine (thyroxine)
NADP ⁺	Nicotinamide adenine dinucleotide phosphate	TBG	Thyroxine-binding globulin
NADPH	Reduced NADP ⁺	TBPA	Thyroxine-binding prealbumin
NAG	N-acetylglutamate	TCA	Tricarboxylic acid
NANA	N-acetylneuraminic acid	TFA	Trans fatty acid
ncRNAs	Nonprotein coding RNAs	T form	Taut or tense form
NEFA	Nonesterified fatty acid	Tgb	Thyroglobulin
ng	Nanogram (10 ⁻⁹ g)	THF	Tetrahydrofolate
NIDDM	Noninsulin-dependent diabetes mellitus	TIBC	Total iron-binding capacity
NMP	Nucleoside monophosphate	TLC	Thin layer chromatography
NMR	Nuclear magnetic resonance	TLS	Tumor lysis syndrome
NPN	Nonprotein nitrogen	tPA	Tissue plasminogen activator
NPU	Net-protein utilization	TPP	Thiamine pyrophosphate
OAA	Oxaloacetate	TRH	Thyrotropin-releasing hormone
Ob	Obese	tRNA	Transfer RNA
PABA	Para amino benzoic acid	TSH	Thyroid-stimulating hormone
PAF	Platelet-activating factor	μm	Micrometer (10 ⁻⁶ m)
PAGE	Polyacrylamide gel electrophoresis	UBG	Urobilinogen
PAH	Para-amino hippurate	UCP	Uncoupling protein
PAPS	Phosphoadenosine phosphosulfate	UDP	Uridine diphosphate
pCO ₂	Partial presence of CO ₂	μl	Microliter (10 ⁻⁶ m)
PCR	Polymerase chain reaction	μM	Micromoles (10 ⁻⁶ M)
PCT	Proximal convoluted tubule	UMP	Uridine monophosphate
PDGF	Platelet-derived growth factor	UTP	Uridine triphosphate
PDH	Pyruvate dehydrogenase	UV	Ultraviolet
PEG	Polyethylene glycol	VLDL	Very-low-density lipoprotein
PEM	Protein-energy malnutrition	V _{max}	Velocity maximum
PEP	Phosphoenol pyruvate	VNTRs	Variable number tandem repeats
PEST	Proline, glutamine, serine, threonine	WBC	White blood cell
pH	Negative log of H ⁺	YAC	Yeast artificial chromosome

National Advisory Board

Dr Abhishek Sharma

Associate Professor and Head
Department of Biochemistry
Datia Medical College
Datia, Madhya Pradesh

Dr Abdul Kayyum Shaikh

Professor and Head
Department of Biochemistry
Ashwini Rural Medical College
Maharashtra
abkayyumsk@gmail.com

Dr Amit Kumar Sonkar

Assistant Professor
Department of Biochemistry
All India Institute of Medical Sciences
Guwahati, Assam

Dr Anita Verma

Professor and Head
Department of Biochemistry
Sardar Patel Medical College
Bikaner, Rajasthan

Dr Anuvaba Mishra

Head
Department of Biochemistry
Saheed Laxman Nayak
Medical College and Hospital
Koraput, Odisha

Dr Ashish Kumar Sharma

Assistant Professor
Department of Biochemistry
Madhav Prasad Tripathi Medical College
Siddharthnagar, Uttar Pradesh
ashishgrmcg@gmail.com

Dr Basant Joshi

Assistant Professor
Department of Biochemistry
Rohilkhand Medical College and Hospital
Bareilly, Uttar Pradesh
bjoshi86@gmail.com

Dr Brijendra Singh Hindoliya

Assistant Professor
Department of Biochemistry
Santinikatan Medical College and Hospital
West Bengal

Dr Bushra Fiza

Professor
Department of Biochemistry
Mahatma Gandhi Medical College
Jaipur, Rajasthan

Dr C Rekha

Professor and Head
Department of Biochemistry
Apollo Institute of Medical Science
Jubilee Hills, Hyderabad
Telangana

Dr C V Sarada

Professor and Head
Department of Biochemistry and Principal
Government Medical College
Suryapet, Telangana

Dr Debasmita Bandyopadhyay

Professor
Department of Biochemistry
Bankura Sanmalani Government Medical College
Bankura, West Bengal

Dr Dileep Singh Nirwan

Assistant Professor
Department of Biochemistry
Pandit Deendayal Upadhyay Medical College
Churu, Rajasthan

Dr Harjeet Singh

Senior Professor
Department of Biochemistry
Sawai Man Singh Medical College
Jaipur, Rajasthan

Dr H Kishan Reddy

Professor and Head
Department of Biochemistry
Pratima Institute of Medical Sciences
Nagnur, Karimnagar
Telangana

Dr Ishrat Kareem

Professor and Head
Department of Biochemistry
Dr Shankarrao Chavan Government Medical College
Nanded, Maharashtra
ishratkareem7686@gmail.com

Dr Jitendra Ahuja

Professor and Head
Department of Biochemistry
RUHS College of Medical Sciences
Jaipur, Rajasthan

Dr Juhi Aggarwal

Professor and Head
Department of Biochemistry
Santosh Medical College
Ghaziabad, Uttar Pradesh

Dr Jyotindra Kumar Sahu

Professor and Head
Department of Biochemistry
Government Medical College
Chittorgarh, Rajasthan

Dr Kalpana

Assistant Professor
Department of Biochemistry
Government Kallakurichi Medical College
Kallakurichi, Tamil Nadu
drdkalpana84@gmail.com

Dr Kavindra Borgaonkar

Associate Professor
Department of Biochemistry
Vilasrao Deshmukh Government Medical College
Latur, Maharashtra

Dr Kavitarati Dharwadkar

Professor and Head
Department of Biochemistry
Sri Aurobindo Institute of Medical Science
Indore, Madhya Pradesh

Dr K D Mekhala

Professor
Department of Biochemistry
Karpagam Faculty of Medical Sciences and Research
Coimbatore, Tamil Nadu
drmekhala@gmail.com

Dr K Satyanarayana Reddy

Assistant Professor
Department of Biochemistry
Government Medical College
Siddipet, Telangana
Ex Vice Dean and Associate Professor
Department of Biochemistry
Sakshi Medical College and Research Centre
Guna, MP

Dr K Sangeetha

Vice Principal
Department of Biochemistry
Government Villupuram Medical College
Villupuram, Tamil Nadu
sangeetha6482@gmail.com

Dr Madhuri Gupta

Professor and Head
Department of Biochemistry
Government Medical College
Dholpur, Rajasthan

Dr Malligai

Professor and Head
Department of Biochemistry
Tagore Medical College
Chennai
malli.murugesan@gmail.com

Dr Manish Singh

Associate Professor and Head
Department of Biochemistry
Government Medical College
Badaun, Uttar Pradesh

Dr MD Rafi

Professor and Head
Department of Biochemistry
Surabhi Institute of Medical Science
Siddipet, Telangana

Dr MD Siddique Ahmed Khan

Professor and Head
Department of Biochemistry
Shadan Institute of Medical Science
Hyderabad, Telangana

Dr MD Suleman

Principal and Head
Department of Biochemistry
Government Medical College
Mancheril, Telangana

Dr Milind Dudhane

Professor and Head
Department of Biochemistry
Ananta Institute of Medical Sciences
Udaipur, Rajasthan

Dr Minakshi

Associate Professor and Head
Department of Biochemistry
Pandit Deendayal Upadhyay Medical College
Churu, Rajasthan

Dr Mohit V Rojekar

Professor and Head
Department of Biochemistry
Rajiv Gandhi Medical College
Thane, Maharashtra
rgmcbiochemistry@gmail.com

Dr M R Mogarekar

Professor and Head
Department of Biochemistry
Swami Ramanand Teerth Rural
Government Medical College
Maharashtra
mimogrekr@gmail.com

Dr Mrinal Gupta

Assistant Professor
Department of Biochemistry
Government Medical College
Kathua, Jammu and Kashmir

Dr M Siddaiah Madupathi

Professor and Head
Department of Biochemistry
JIMS Homeopathic Medical College
Muchintal, Telangana

Dr M Uma Devi

Professor and Head
Department of Biochemistry
Bhaskar Medical College
Moinabad, Telangana

Dr Nabarun Mandal

Associate Professor
Department of Biochemistry
Raiganj Government Medical College
West Bengal
dr.nabarunmandal@gmail.com

Dr Neeru Bhaskar

Professor and Head
Department of Biochemistry
Adesh Medical College
Ambala

Dr Nirupama Devi

Head
Department of Biochemistry
Maharaja Krushna Chandra Gajapati
Medical College and Hospital
Brahmapur, Odisha

Dr Nita Sahi

Professor and Head
Department of Biochemistry
Pacific Medical College and Hospital
Bedla, Udaipur

Dr N Jaya

Professor and Head
Department of Biochemistry
Osmania Medical College
Hyderabad, Telangana

Dr Poonam Kachhawa

Associate Professor and Head
Department of Biochemistry
Autonomous State Medical College
Shahjahanpur, UP

Dr Pragna

Professor and Head
Department of Biochemistry
ACS Medical College
Chennai
drpragna.mohan@gmail.com

Dr Prashant Tripathi

Assistant Professor
Department of Biochemistry
Maharani Laxmi Bai Medical College
Jhansi, Uttar Pradesh

Dr Pratyusha Pavuluri

Professor
Department of Biochemistry
RVM Institute of Medical Science and Research Centre
Telangana

Dr Praveen Sablania

Professor and Head
Department of Biochemistry
Rama Medical College and Research Centre
Hapur, Uttar Pradesh

Dr Premkumar

Professor and Head
Department of Biochemistry
Government Thiruvallur Medical College
Tiruvallur, Tamil Nadu
gullu04112000@yahoo.com

Dr Rachna Sabharwal

Professor
Department of Biochemistry
Government Medical College
Jammu

Dr Rajul Lodha

Professor
Department of Biochemistry
Rabindranath Tagore Medical College
Udaipur, Rajasthan

Dr Rinchu Loomba

Professor and Head
Department of Biochemistry
Christian Medical College
Ludhiana, Punjab

Dr R M Zine

Associate Professor
Department of Biochemistry
Swami Ramanand Teerth Rural
Government Medical College
Maharashtra
rahulzine@rediffmail.com

Dr R Shivasubhramaniam

Professor and Head
Department of Biochemistry
JNU Medical College
Jaipur, Rajasthan

Dr Ruchir Khare

Associate Professor and Head
Department of Biochemistry
Netaji Subhash Chandra Bose Medical College
Jabalpur, Madhya Pradesh

Dr Sangeeta Kapoor

Professor and Head
Department of Biochemistry
Teerthankar Mahaveer Medical College and
Research Center
Moradabad, Uttar Pradesh

Dr Sarat Chandan T

Associate Professor
Department of Biochemistry
RVM Institute of Medical Science and Research Centre
Telangana

Dr Sarika Arora

Professor
Department of Biochemistry
ESI Medical College
Alwar, Rajasthan

Dr Sarla Mahawar

Senior Professor
Department of Biochemistry
Jawahar Lal Nehru Medical College
Ajmer, Rajasthan

Dr Seema Jawalekar

Professor and Head
Department of Biochemistry
Government Medical College
Pali, Rajasthan

Dr Shobha Mohammed

Professor
Department of Biochemistry
Mamata Academy of Medical Science
Bachupally, Hyderabad
Telangana

Dr Shweta Singh

Professor and Head
Department of Biochemistry
Maharshi Devraha Baba State
Autonomous Medical College
Deoria, Uttar Pradesh
shwetacm9@gmail.com

Dr Subhasree Ray

Head
Department of Biochemistry
Institute of Medical Sciences and SUM Hospital
Bhubaneswar, Odisha

Dr Sukhraj Kaur

Professor and Head
Department of Biochemistry
Government Medical College
Amritsar

Dr Sweta Kotkar

Assistant Professor
Department of Biochemistry
Vilasrao Deshmukh Government Medical College
Maharashtra
shwet23683@gmail.com

Dr Syyeda Anees

Professor and Head
Department of Biochemistry
Deccan Medical College
Hyderabad, Telangana

Dr Tapaswini Pradhan

Head
Department of Biochemistry
Kalinga Institute of Medical Science
Bhubaneswar, Odisha

Dr Uma Gujral

Associate Professor
Department of Biochemistry
Government Medical College
Amritsar, Punjab

Dr Utpal Kumar Biswas

Professor and Head
Department of Biochemistry
North Bengal Medical College
Siliguri, West Bengal
drutpalbiswas2010@gmail.com

Dr Vinodini

Professor and Head
Department of Biochemistry
SRM Medical College
Chennai
hod.biochemistry@svmist.edu.in

Dr V Sampath Kumar

Professor and Head
Department of Biochemistry
ESIC Medical College
Sanata Nagar, Hyderabad
Telangana

Dr V V Aghav

Assistant Professor
Department of Biochemistry
Maharashtra Institute of
Medical Sciences and Research
Latur, Maharashtra