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 PGMEE*, 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.

Dedicated to Education

CBSPD

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

CBSPD

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

CBSPD *Dedicated to Education*

CBS Publishers & Distributors Pvt Ltd

50 Years in Publishing — Dedicated to Education

Contents

Section 7
TCA Cycle, Oxidative Phosphorylation and Metabolic Integration

Section 8
Nutrition and Micronutrients

Section 9
Organ Function Tests

Section 10
Nucleotides and Polynucleotides

Index of Competencies

Competency based Undergraduate Curriculum for the Indian Medical Graduate

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.	BI 10.1	Describe the cancer initiation, promotion oncogenes and oncogene activation. Also focus on p53 and apoptosis.	48	557
46.	BI 10.2	Describe various biochemical tumor markers and the biochemical basis of cancer therapy.	49, 51	569, 587
47.	BI 11.1	Describe commonly used laboratory apparatus and equipment.	55	605
48.	BI 11.19	Outline the basic principles involved in the functioning of instruments commonly used in a biochemistry laboratory and their applications.	55	605
49.	BI 11.16	Observe use of commonly used equipment/techniques in biochemistry.	55	605

Some Commonly Used Abbreviations in Biochemistry

ABG	Arterial blood gas
Ab	Antibody
ACP	Acyl carrier protein
ACTH	Adrenocorticotropic hormone
Acyl-CoA	Fatty acid derivative of coenzyme A
ADA	Adenosine deaminase
ADH	Alcohol dehydrogenase
ADP	Adenosine diphosphate
AFP	α-fetoprotein
Ag	Antigen
A/G	Albumin/globulin (ratio)
AIDS	Acquired immunodeficiency syndrome
ALA	δ-aminolevulinic acid
ALP	Alkaline phosphatase
ALT	Alanine transaminase
AMP	Adenosine monophosphate
ANF	Atrial natriuretic factor
APC	Antigen presenting cell
ApoA	Apoprotein A
AP sites	Apurinic sites
AST	Aspartate transaminase
ATP	Adenosine triphosphate
BAL	British antilewisite
BMR	Basal metabolic rate
BNP	Brain natriuretic peptide
BP	Blood pressure
BPG	Bisphosphoglycerate (2,3-BPG, 1,3-BPG)
BUN	Blood urea nitrogen
BV	Biological value
Cal	Calorie
cAMP	3′,5′-cyclic adenosine monophosphate (cyclic AMP)
CAP	Catabolite activator protein
CCK	Cholecystokinin
cDNA	Complementary DNA
CEA	Carcinoembryonic antigen
CFTR	Cystic fibrosis transmembrane regulator
cGMP	3′,5′-cyclic guanosine monophosphate
CoA or CoASH	Coenzyme A
COHb	Carboxyhemoglobin
COMT	Catechol-o-methyltransferase
COPD	Chronic obstructive pulmonary disease
CPK (CK)	Creatine phosphokinase (creatine kinase)
CPS	Carbamoyl phosphate synthase
CSF	Cerebrospinal fluid
DAM	Diacetyl monoxime
dAMP	Deoxyadenosine monophosphate
DHA	Docosahexaenoic acid
DHCC	Dihydroxycholecalciferol (1,25-DHCC: 24,25-DHCC)
DHEA	Dehydroepiandrosterone
DIT	Diiodotyrosine
DNA	Deoxyribonucleic acid
DNase	Deoxyribonuclease
DOPA	Dihydroxy phenylalanine
DPG	Diphosphoglycerate
ECF	Extracellular fluid
EDRF	Endothelium-derived-releasing factor
EDTA	Ethylene diamine tetra-acetate
EFAs	Essential fatty acids
eIFs	Eukaryotic initiation factors
EGF	Epidermal growth factor
ELISA	Enzyme-linked immunosorbent assay
ER	Endoplasmic reliculum
ETC	Electron transport chain
FA	Fatty acid
Fab	Antigen-binding fragment
FAD	Flavin adenine dinucleotide
$FADH_2$	Reduced FAD
FAS	Fatty acid synthase
F-1,6-BP	Fructose-1,6-bisphosphate
F-2,6-BP	Fructose-2,6-bisphosphate
FDNB	1-fluoro-2,4-dinitrobenzene
FFA	Free fatty acid
FH_4	Tetrahydrofolate
FIGLU	Formininoglutamic acid
FMN	Flavin mononucleotide
$FMNH_2$	Reduced FMN
F-1-P	Fructose-1-phosphate
F-6-P	Fructose-6-phosphate
ΔG	Free energy change
GGT (GT)	γ-glutamyl transpeptidase
GH	Growth hormone
GHRH	Growth hormone-releasing hormone
GIP	Gastric inhibitory peptide
GIT	Gastrointestinal tract
Gly	Glycine
GLUT	Glucose transporter
GnRH	Gonadotropin-releasing hormone
G-6-P	Glucose-6-phosphate
G-6-PD	Glucose-6-phosphate dehydrogenase
GSD	Glycogen storage disease
GSH	Glutathione (reduced form)
GSSG	Glutathione (oxidized form)
GTP	Guanosine triphosphate
GTT	Glucose tolerance test
Hb	Hemoglobin
HbA_1	Adult hemoglobin
HbA_{1C}	Glycosylated hemoglobin
HbF	Fetal hemoglobin
HbO_2	Oxyhemoglobin
HBsAg	Hepatitis B surface antigen
HDL	High-density lipoprotein
HGPRT	Hypoxanthine guanine phosphoribosyl-transferase
HIAA	Hydroxy indole acetic acid
HIF	Hypoxia inducible transcription factor
HIV	Human immunodeficiency virus
HLA	Human leukocyte antigen
HMG-CoA	β-hydroxy-β-methylglutaryl-CoA
HNPCC	Hereditary nonpolyposis colon cancer
hnRNA	Heterogeneous nuclear RNA
Hp	Haptoglobin
HPLC	High performance liquid chromatography
hs-CRP	High sensitive C-reactive protein

5HT	5-hydroxytryptamine
ICD	Isocitrate dehydrogenase
IDDM	Insulin-dependent diabetes mellitus
IF	Initiation factor
Ig	Immunoglobulin
IgG	Immunoglobulin G
IGF	Insulin-like growth factor
IL	Interleukin
INH	Isonicotinic acid hydrazide (isoniazid)
LATS	Long-acting thyroid stimulator
LCAT	Lecithin cholesterol acyltransferase
LDH	Lacate dehydrogenase
LDL	Low-density lipoproteins
LFT	Liver function test
LH	Luteinizing hormone
LINEs	Long interspersed elements
LT	Leukotrienes
Lp(a)	Lipoprotein-a
MAO	Maximal acid output
Mb	Myoglobin
MCAD	Medium chain acyl-CoA dehydrogenase
MELAS	Mitochondrial encephalopathy, lactic acidosis and stroke
mg	Milligram
MHC	Major histocompatibility complex
MI	Myocardial infarction
MIT	Monoiodotyrosine
mol	mole
mM	Millimolar
mol. wt.	Molecular weight
mRNA	Messenger RNA
mtDNA	Mitochondrial DNA
MW	Molecular weight
NAD^+	Nicotinamide adenine dinucleotide
NADH	Reduced NAD^+
$NADP^+$	Nicotinamide adenine dinucleotide phosphate
NADPH	Reduced $NADP^+$
NAG	N-acetylglutamate
NANA	N-acetylneuraminic acid
ncRNAs	Nonprotein coding RNAs
NEFA	Nonesterified fatty acid
ng	Nanogram (10^{-9} g)
NIDDM	Noninsulin-dependent diabetes mellitus
NMP	Nucleoside monophosphate
NMR	Nuclear magnetic resonance
NPN	Nonprotein nitrogen
NPU	Net-protein utilization
OAA	Oxaloacetate
Ob	Obese
PABA	Para amino benzoic acid
PAF	Platelet-activating factor
PAGE	Polyacrylamide gel electrophoresis
PAH	*Para*-amino hippurate
PAPS	Phosphoadenosine phosphosulfate
pCO_2	Partial presence of CO_2
PCR	Polymerase chain reaction
PCT	Proximal convoluted tubule
PDGF	Platelet-derived growth factor
PDH	Pyruvate dehydrogenase
PEG	Polyethylene glycol
PEM	Protein-energy malnutrition
PEP	Phosphoenol pyruvate
PEST	Proline, glutamine, serine, threonine
pH	Negative log of H^+
PI	Phosphatidyl inositol
PIP_2	Inositol-4,5-bisphosphate
pK_a	Negative log K_a
pO_2	Partial pressure of O_2
POMC	Pro-opiomelanocortin
PRL	Prolactin
PRPP	5-phosphoribosyl-1-pyrophosphate
PTH	Parathyroid hormone
PTH	Phenyl thiohydantoin
PUFAs	Polyunsaturated fatty acids
QPRT	quinolinate phosphoribosyltransferase
RBC	Red blood cells
RBP	Retinol-binding protein
RDA	Recommended dietary (daily) allowance
RDI	Recommended daily intake
RE	Retinol equivalents
RER	Rough endoplasmic reticulum
RF	Releasing factor
RFLP	Restriction fragment length polymorphsim
RIA	Radioimmunoassay
RNA	Ribonucleic acid
RNase	Ribonuclease
rRNA	Ribosomal RNA
RT	Reverse transcriptase
SAM	S-adenosylmethionine
SCID	Severe combined immunodeficiency
SDA	Specific dynamic action
SGOT	Serum glutamate oxaloacetate transaminase
SGPT	Serum glutamate pyruvate transaminase
SIDS	Sudden infant death syndrome
SINEs	Short interspersed elements
SNPs	Single nucleotide polymorphisms
T_3	3,5,3′- triiodothyronine
T_4	3,5,3′5′- tetraiodothyronine (thyroxine)
TBG	Thyroxine-binding globulin
TBPA	Thyroxine-binding prealbumin
TCA	Tricarboxylic acid
TFA	Trans fatty acid
T form	Taut or tense form
Tgb	Thyroglobulin
THF	Tetrahydrofolate
TIBC	Total iron-binding capacity
TLC	Thin layer chromatography
TLS	Tumor lysis syndrome
tPA	Tissue plasminogen activator
TPP	Thiamine pyrophosphate
TRH	Thyrotropin-releasing hormone
tRNA	Transfer RNA
TSH	Thyroid-stimulating hormone
µm	Micrometer (10^{-6} m)
UBG	Urobilinogen
UCP	Uncoupling protein
UDP	Uridine diphosphate
µl	Microliter (10^{-6} m)
µM	Micromoles (10^{-6} M)
UMP	Uridine monophosphate
UTP	Uridine triphosphate
UV	Ultraviolet
VLDL	Very-low-density lipoprotein
V_{max}	Velocity maximum
VNTRs	Variable number tandem repeats
WBC	White blood cell
YAC	Yeast artificial chromosome

National Advisory Board

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 Prinicpal
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
Mancherial, 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 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
Researh 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 Swete 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