APPENDICES

Answers to Self-assessment Exercises

CHAPTER 2

Answers to III and IV

1. Sucrose,
2. Glyceraldehyde,
3. Epimers,
4. Anomers,
5. Aglycone,
6. Streptomycin,
7. α-1,6-Glycosidic bond,
8. Inulin,
9. Hyaluronic acid,
10. N-Acetylneuraminic acid,
11. b,
12. d,
13. a,
14. d,
15. a.

CHAPTER 3

Answers to III and IV

1. Triacylglycerolds,
2. Geometric isomerism (*cis-trans* isomerism),
3. Chaulmoogric acid,
4. Triacylglycerols,
5. Stereospecific number,
6. Saponification number,
7. Dipalmitoyl lecithin,
8. Phosphatidylinositol,
9. Gangliosides,
10. Cyclopentanoperhydrophenanthrene,
11. a,
12. d,
13. d,
14. c,
15. b.

CHAPTER 4

Answers to III and IV

1. 16%,
2. L-α-Amino acids,
3. Methionine,
4. Zwitterion,
5. β-Alanine,
6. Peptide bonds,
7. Tryptophan,
8. 9,
9. 1-Fluro 2,4-dinitrobenzene (FDNB),
10. Denaturation,
11. b,
12. d,
13. b,
14. d,
15. a.

CHAPTER 5

Answers to III and IV

1. Gene,
2. RNA,
3. Nucleotides,
4. Thymine,
5. 2,
6. Base + sugar + phosphate,
7. Erwin Chargaff,
8. 3 Hydrogen bonds (in place of 2 in A-T),
9. β-Form,
10. CCA(5′ to 3′),
11. d,
12. b,
13. c,
14. d,
15. d.

CHAPTER 6

Answers to III and IV

1. In yeast,
2. Ligases,
3. Coenzyme,
4. Denaturation,
5. Alcohol dehydrogenase, carbonic anhydrase,
6. Active site,
7. $NADP^+$,
8. E.C. 1.1.1.1,
9. AMP/ADP,
10. Creatine phosphokinase (CPK),
11. c,
12. d,
13. b,
14. d,
15. b.

CHAPTER 7

Answers to III and IV

1. Acetylation,
2. Riboflavin,
3. Vitamin E (tocopherol),
4. Pyridoxine (B_6),
5. Avidin,
6. Pantothenic acid,
7. Cobalamin (B_{12}),
8. Dermatitis, diarrhea and dementia,
9. Vitamin K,
10. Folic acid,
11. b,
12. d,
13. a,
14. d,
15. a.

CHAPTER 8

Answers to III and IV

1. β-Glycosidic bonds,
2. Raffinose,
3. Lactase (β-galactosidase),
4. Fiber,
5. Parietal (oxyntic) cells,
6. Glutathione,
7. Hartnup's disease,
8. Arginine, lysine,
9. Colipase
10. Mixed micelles,
11. a,
12. d,
13. c,
14. b,
15. a.

CHAPTER 9

Answers to III and IV

1. Fibrinogen,
2. Electrophoresis,
3. Hemoglobin,
4. *B-Lymphocytes*,
5. IgG,
6. IgE,
7. 40–50°C,
8. C-reactive protein,
9. Staurt factor (Xa),
10. Plasmin,
11. c,
12. d,
13. a,
14. b,
15. b.

CHAPTER 10

Answers to III and IV

1. 574,
2. Methemoglobin,
3. Carbonic anhydrase,
4. 2,3-Bisphosphoglycerate,
5. *Deoxyhemoglobin*,
6. Thalassemias,
7. Succinyl CoA,
8. Uroporphyrinogen synthase I,
9. δ -Aminolevulinate synthase,
10. Biliverdin,
11. a,
12. a,
13. b,
14. d,
15. c.

CHAPTER 11

Answers to III and IV

1. $\Delta G = \Delta H - T\Delta S$ (T = Absolute temperature),
2. Exergonic or spontaneous,
3. Phosphoanhydride bonds,
4. Phosphoarginine,
5. Electrons,
6. Inner mitochondrial membrane,
7. Heme (porphyrin with iron),
8. Cytochrome oxidase (cyt a + a_3),
9. Cytochrome a + a_3,
10. Superoxide dismutase,
11. d,
12. a,
13. b,
14. d,
15. a.

CHAPTER 13

Answers to III and IV

1. Thiamine, riboflavin, lipoic acid, niacin, pantothenic acid,
2. Absence of glucose 6-phosphatase,
3. L-Gulonolactone oxidase,
4. Sorbitol,
5. Galactose 1-phosphate uridyltransferase,
6. Leucine and lysine,
7. Succinate thiokinase,
8. Uronic acid pathway,
9. Glycogenin,
10. Oxaloacetate,
11. d,
12. c,
13. b,
14. a,
15. b.

CHAPTER 14

Answers to III and IV

1. Triacylglycerols,
2. HMG CoA reductase,
3. Ampipathic,
4. Sphingomyelinase,
5. HDL,
6. 129 ATP,
7. Zellweger syndrome,
8. Citrate,
9. HDL,
10. Unsaturated fatty acid,
11. d,
12. a,
13. d,
14. c,
15. b.

CHAPTER 15

Answers to III and IV

1. Pyridoxal phosphate,
2. Glutamate dehydrogenase,
3. Carbamoyl phosphate synthase I,
4. Glycine transaminase,
5. Tetrahydrobiopterin,
6. Dopamine,
7. Homogentisate,
8. Malignant carcinoid syndrome,
9. Ornithine decarboxylase,
10. Leucine,
11. b,
12. d,
13. a,
14. c,
15. a.

CHAPTER 17

Answers to III and IV

1. Glutamine and aspartate,
2. Allopurinol,
3. Sodium urate,
4. Xanthine oxidase,
5. Lesch-Nyhan syndrome,
6. Thioredoxin,
7. Inosine monophosphate,
8. Alloxanthine,
9. Aspartate,
10. Carbamoyl phosphate synthetase II,
11. d,
12. a,
13. c,
14. b,
15. d.

CHAPTER 18

Answers to III and IV

1. 9–11 mg/dl. (4.5–5.5 mEq./l.),
2. Calcitriol,
3. Phosphorus,
4. Magnesium,
5. Sodium,
6. 3.5–5.0 mEq/l,
7. Transferrin,
8. Ceruloplasmin,
9. Gusten,
10. Selenium,
11. d,
12. a,
13. b,
14. c,
15. a.

CHAPTER 19

Answers to III and IV

1. Adenylate cyclase,
2. Ca^{2+},
3. Anterior pituitary,
4. Endorphins and enkephalins,
5. Thyroperoxidase,
6. Aldosterone,
7. Vanillyl mandelic acid (VMA),

8. Dihydrotestosterone (DHT),
9. Cholesterol,
10. Cholecystokinin (CCK),
11. a,
12. d,
13. b,
14. c,
15. a.

CHAPTER 20

Answers to III and IV

1. Heme,
2. van den Bergh reaction,
3. Alanine transaminase,
4. Alkaline phosphatase,
5. Bromosulphthalein (BSP),
6. 180 mg/dl,
7. Inulin,
8. 2ml/min,
9. Ryle's tube,
10. Pentagastrin,
11. a,
12. d,
13. c,
14. b,
15. b.

CHAPTER 21

Answers to III and IV

1. Antidiuretic hormone (ADH),
2. Na^+,
3. 285–295 milliosmoles /kg,
4. Aldosterone,
5. Carbonic acid (H_2CO_3),
6. Bicarbonate buffer,
7. 20 : 1,
8. Ammonium ion (NH_4^+),
9. Bicarbonate (HCO_3^-),
10. Carbonic acid (H_2CO_3) or CO_2,
11. d,
12. a,
13. c,
14. b,
15. d.

CHAPTER 22

Answers to III and IV

1. Collagen,
2. Glycine,
3. β-oxalyl aminoalamine,
4. Fibrillin,
5. Glycosaminoglycans,
6. Sarcomere,
7. Actin,
8. Calcium caseinate,
9. Lecithin/Sphingomyelin,
10. Vitamin C,
11. c,
12. d,
13. a,
14. c,
15. b.

CHAPTER 23

Answers to III and IV

1. 4.128,
2. Thyroid gland,
3. Fiber,
4. Carbohydrates,
5. Chemical score,
6. 1g/kg body weight/day,
7. Biological value (BV) of protein,
8. Sulfur containing amino acids,
9. Iron,
10. Plasma albumin,
11. a,
12. d,
13. c,
14. d,
15. a.

CHAPTER 24

Answers to III and IV

1. DNA helicase,
2. Okazaki pieces,
3. DNA polymerase III,
4. DNA topoisomerases,
5. Cyclins,
6. Telomere,
7. Transposons or transposable elements,
8. Mutation,
9. Missense,
10. Hereditary nonpolyposis colon cancer,
11. c,
12. a,
13. b,
14. a,
15. b.

CHAPTER 25

Answers to III and IV

1. Genome,
2. hnRNA,
3. Introns,
4. Reverse transcriptase,
5. Wobble hypothesis,
6. Ribosomes,
7. rRNA,
8. Chaperones,
9. Prion diseases,
10. Protein targeting,
11. d,
12. c,
13. a,
14. b,
15. a.

CHAPTER 26

Answers to III and IV

1. 30,000–40,000,
2. Constitutive genes,
3. One cistron-one subunit concept,
4. Protein-DNA complex,
5. a,
6. b,
7. a,
8. d.

CHAPTER 27

Answers to III and IV

1. *Escherichia coli*,
2. RNA,
3. Dot-blotting,
4. *Thermus aquaticus*,
5. Genomic library/DNA library,
6. Site-directed mutagenesis,
7. Humulin,
8. Hepatitis B vaccine,
9. Mouse,
10. Sheep (Dolly),
11. c,
12. d,
13. d,
14. a,
15. c.

Appendix I : Abbreviations used in this Book

A	*adenine, adenosine*
Ab	antibody
ACP	acyl carrier protein
ACTH	adrenocorticotropic hormone
Acyl CoA	*fatty acid derivative of coenzyme A*
ADA	adenosine deaminase
ADH	*alcohol dehydrogenase*
ADH	*antidiuretic hormone*
ADP	*adenosine diphosphate*
AFP	α-fetoprotein
AFLP	amplified fragment length polymorphism
Ag	antigen
A/G	albumin/globulin (ratio)
AIDS	acquired immunodeficiency syndrome
ALA	*δ-aminolevulinic acid*
ALP	alkaline phosphatase
ALT	alanine transaminase
AMP	adenosine monophosphate
APC	antigen presenting cell
Apo-A	apoprotein-A
AP sites	*apurinic sites*
AST	*aspartate transaminase*
AT	α_1-antitrypsin
ATCase	aspartate transcarbamoylase
ATP	adenosine triphosphate
BAL	*British antilewisite*
BAO	basal acid output
BHA	butylated hydroxyanisole
BHT	butylated hydroxy toluene
BMR	basal metabolic rate
BOAA	*β-oxalylaminoalanine*
bp	base pair
BP	blood pressure
BPG	bisphosphoglycerate (2,3-BPG, 1,3-BPG)
BSP	bromosulphthalein
BUN	blood urea nitrogen
BV	*biological value*
C	cytosine, cytidine
CA	carbonic anhydrase
Cal	calorie
Cam	calmodulin
cAMP	3′,5′-cyclic adenosine monophosphate (cyclic AMP)
CAP	catabolite activator protein
CBG	corticosteroid binding globulin
CCK	cholecystokinin
cDNA	complementary DNA
CD_4	cluster determinant antigen 4
CDP	cytidine diphosphate
CEA	carcinoembryonic antigen
CF	*cystic fibrosis*
CFTR	*cystic fibrosis transmembrane* regulator
cGMP	3′,5′-cyclic guanosine monophosphate
C_H	*constant heavy chain*
CHD	coronary heart disease
ChE	cholinesterase
Chl	chlorophyll
C_L	*constant light chain*
CLIP	*corticotropin like intermediate lobe* peptide
CMP	cytidine monophosphate
CNS	central nervous system
CoA or CoASH	coenzyme A
COHb	carboxyhemoglobin

COMT	catechol-o-methyltransferase
CoQ	coenzyme Q (ubiquinone)
CPK (CK)	creatine phosphokinase (creatine kinase)
CPPP	cyclopentanoperhydrophenanthrene
CPS	carbamoyl phosphate synthase
CRH	corticotropin releasing hormone
CS	chorionic somatomammotropin
CSF	cerebrospinal fluid
CT	calcitonin
CTP	cytidine triphosphate
dA	deoxyadenosine
dADP	deoxyadenosine diphosphate
DG	diacylglycerol
DAM	diacetyl monoxime
dAMP	deoxyadenosine monophosphate
dATP	deoxyadenosine triphosphate
dCMP	deoxycytidine monophosphate
DCT	distal convoluted tubule
DEAE	diethyl aminoethylamine
DFP or DIFP	diidopropyl fluorophosphate
dGMP	deoxyguanosine monophosphate
DHAP	dihydroxyacetone phosphate
DHCC	dihydroxycholecalciferol (1, 25-DHCC; 24, 25-DHCC)
DHEA	dehydroepiandrosterone
DHF	dihydrofolate
DHT	dihydrotestosterone
DIT	diiodotyrosine
dl	deciliter
DMB	dimethyl benzimidazole
DMS	dimethyl sulfate
DNA	deoxyribonucleic acid
DNase	deoxyribonuclease
DNP	2, 4-dinitrophenol
DOPA	dihydroxy phenylalanine
DPG	diphosphoglycerate
DPP	dimethyl allyl pyrophosphate
dTMP	deoxythymidine monophosphate
E_O	redox potential
EC	enzyme commission
ECF	extracellular fluid
EDRF	endothelium-derived releasing factor
EDTA	ethylene diamine tetraacetate
EF	elongation factor
EFA	essential fatty acids
eIFs	eukaryotic initiation factors
EGF	epidermal growth factor
ELISA	enzyme-linked immunosorbent assay
EM	Embden-Meyerhof
ER	endoplasmic reticulum
ES	enzyme-substrate complex
ES cells	embryonic stem cells
E-site	exist site
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
Fc	crystalline fragment
FDNB	1-fluoro 2, 4-dinitrobenzene
FFA	free fatty acid
FGF	fibroblast growth factor
FH_4	tetrahydrofolate
FIGLU	formiminoglutamic acid
fMet	N-formylmethionine
FMN	flavin mononucleotide
$FMNH_2$	reduced FMN
F 1-P	fructose 1-phosphate
F 6-P	fructose 6-phosphate
Fp	flavoprotein
FSH	follicle stimulating hormone
FTM	fractional test meal
G	guanine, guanosine
g	gram
ΔG	free energy change
GABA	γ-aminobutyric acid
GAG	glycosaminoglycans
Gal-Cer	galactocerebroside
GAR	glycinamide ribotide
GDH	glutamate dehydrogenase
GDP	guanosine diphosphate
GFR	glomerular filtration rate
GGT (GT)	γ-glutamyl transpeptidase
GH	growth hormone
GHRH	growth hormone releasing hormone
GIP	gastric inhibitory peptide
GIT	gastrointestinal tract
Gla	γ-carboxy glutamate
GLC	gas liquid chromatography
Glu-Cer	glucocerebroside
Gly	glycine
GLUT	glucose transporters

GN	glucose-nitrogen (ratio)
GMP	guanosine monophosphate
GnRH	gonadotropin releasing hormone
GRH	growth hormone releasing hormone
GRIH	growth hormone release-inhibiting hormone
G 6-P	glucose 6-phosphate
G 6-PD	glucose 6-phosphate dehydrogenase
GPP	geranyl pyrophosphate
GSH	glutathione (reduced form)
GSSG	glutathione (oxidized form)
GTP	guanosine triphosphate
GTT	glucose tolerance test
ΔH	change in enthalpy
HAC	human artificial chromosome
Hb	hemoglobin
HbA_1	adult hemoglobin
HbA_{1C}	glycosylated hemoglobin
HbF	fetal hemoglobin
HbO_2	oxyhemoglobin
HBsAg	hepatitis B surface antigen
HbS	sickle-cell hemoglobin
hCG	human chorionic gonadotropin
HDL	high density lipoproteins
HGPRT	hypoxanthine guanine phosphoribosyltransferase
HIAA	hydroxy indole acetic acid
HIF	Hypoxia inducible transcription factor
HIV	human immunodeficiency virus
HLA	human leukocyte antigen
HLH	helix-loop-helix
HMG CoA	β-hydroxy β-methylglutaryl CoA
HMP	hexose monophosphate
HNPCC	hereditary nonpolyposis colon cancer
hnRNA	heterogeneous nuclear RNA
Hp	haptoglobin
HPLC	high performance liquid chromatography
HRE	hormone responsive element
Hsp	heat shock protein
5HT	5-hydroxytryptamine
HTH	helix-turn-helix
ICD	isocitrate dehydrogenase
IDDM	insulin dependent diabetes mellitus
IDL	intermediate density lipoproteins
IDP	inosine diphosphate
IF	initiation factor
Ig	immunoglobulin
IgG	immunoglobulin G
IGF	insulin-like growth factor
IL	interleukins
IMP	inosine monophosphate
INH	isonicotinic acid hydrazide (isoniazid)
$InsP_2$ (IP_2)	inositol 1, 4-bisphosphate
$InsP_3$ (IP_3)	inositol 1, 4, 5-triphosphate
IPP	isopentenyl pyrophosphate
IR	infrared
ITP	inosine triphosphate
IU	international unit
IV	intravenous
K	dissociation constant
KA	King Armstrong
K_a	dissociation constant of acid
Kbp	kilo base pair
KD	kilodalton
Keq	equilibrium constant
α-KG	α-ketoglutarate
Ki	inhibition constant
K_m	Michaelis constant
KJ	kilojoule
LATS	long acting thyroid stimulator
LCAT	lecithin cholesterol acyltransferase
LDH	lactate dehydrogenase
LDL	low density lipoproteins
LFT	liver function tests
LH	luteinizing hormone
LINES	Long interspesed elements
LPH	lipotrophic hormone (lipotropin)
LT	leukotrienes
Lp-a	lipoprotein-a
LSD	lysergic acid diethylamide
M	molar
MAO	maximal acid output
MAO	monoamine oxidase
Mb	myoglobin
MbO_2	oxymyoglobin
MCAD	medium chain acyl CoA dehydrogenase
MDH	malate dehydrogenase
mEq	milliequivalents
mg	milligram
MHC	major histocompatibility complex
MI	myocardial infarction
MIT	monoiodotyrosine
mol	mole(s)

mM	millimolar
mol. wt.	molecular weight
mRNA	messenger RNA
MSH	melanocyte stimulating hormone
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
NDP	nucleoside diphosphate
NE	niacin equivalents
NEFA	non esterified fatty acid
ng	nanogram (10^{-9} g)
NGF	nerve growth factor
NIDDM	non-insulin dependent diabetes mellitus
NMP	nucleoside monophsphate
NMR	nuclear magnetic resonance
NPN	non-protein nitrogen
NPU	net protein utilization
OAA	oxaloacetate
Ob	obese
OD	optical density
OMP	orotidine monophosphate
Osm	osmoles
PABA	para amino benzoic acid
PAF	platelet-activating factor
PAGE	polyacrylamide gel electrophoresis
PAH	para amino hippurate
PAPS	phosphoadenosine phosphosulfate
PBG	porphobilinogen
PBI	protein bound iodine
PCM	protein-calorie malnutrition
PCNA	proliferating cell nuclear antigen
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
PER	protein efficiency ratio
PEST	proline, glutamine, serine, threonine
PFK	phosphofructokinase
PG	prostaglandins
PGA	pteroyl glutamic acid
pH	negative log of (H^+)
PI	phosphatidyl inositol
Pi	inorganic phosphate
p^I	isoelectric pH
PIF	prolactin inhibitory factor
PIP_2	inositol 4, 5-bisphosphate
p^{Ka}	negative log of Ka
PKU	phenylketonuria
PL	phospholipid
PLP	pyridoxal phosphate
pO_2	partial pressure of O_2
POMC	pro-opiomelanocortin
PPi	inorganic pyrophosphate
ppm	parts per million
PRIH	prolactin release-inhibiting hormone
PRL	prolactin
PRPP	5-phosphoribosyl 1-pyrophosphate
PT	prothrombin time
PTH	parathyroid hormone
PTH	phenyl thiohydantoin
PUFA	polyunsaturated fatty acids
QPRT	quinolinate phosphoribosyltransferase
RACE	rapid amplification of cDNA ends
RAIU	radioactive iodine uptake
RAPD	random amplified polymorphic DNA
ras	rat sarcoma
RBC	red blood cells
RBP	retinol binding protein
RDA	recommended dietary (daily) allowance
rDNA	recombinant DNA
RE	retinol equivalents
RER	rough endoplasmic reticulum
RF	releasing factor
Rf	ratio of fronts
RFC	replication factor C
RFLP	restriction fragment length polymorphism
R-form	relaxed form
RIA	radioimmunoassay
RMR	resting metabolic rate
RNA	ribonucleic acid
RNAP	RNA polymerase
RNase	ribonuclease

R 5-P	ribose 5-phosphate
RPA	replication protein A
RQ	respiratory quotient
rRNA	ribosomal RNA
RSV	rouse sarcoma virus
RT	reverse transcriptase
rT_3	reverse T_3
SAM	S-adenosylmethionine
SCID	severe combined immunodeficiency
SDA	specific dynamic action
Sf	Svedberg floatation
SGOT	serum glutamate oxaloacetate transaminase
SGPT	serum glutamate pyruvate transaminase
SHBG	sex hormone binding globulin
SIDS	sudden infant death syndrome
SINEs	short interspersed elements
sn	stereospecific number
SNPs	single nucleotide polymorphisms
snRNA	small nuclear RNA
snRNP	small nuclear ribonucleoprotein
sRNA	soluble RNA
SRS	slow reacting substance
STRs	simple tandem repeats
T	thymine, thymidine
T	thymus (T-lymphocyte)
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
TF	tissue factor
T-form	taut or tense form
TG	triacylglycerol
Tgb	thyroglobulin
TGF	transforming growth factor
THF	tetrahydrofolate
TIBC	total iron binding capacity
TLC	thin layer chromatography
Tm	tubular maximum
TMP	thymidine monophosphate
TNF	tumor necrosis factor
tPA	tissue plasminogen activator
TPP	thiamine pyrophosphate
TRH	thyrotropin releasing hormone
tRNA	transfer RNA
TSH	thyroid stimulating hormone
TX	thromboxane
µm	micrometer (10^{-6} m)
UBG	urobilinogen
UCP	uncoupling protein
UDP	uridine diphosphate
UDPG	uridine diphosphate glucose
µl	microliter (10^{-6} l)
µM	micromoles (10^{-6} M)
UMP	uridine monophosphate
UTP	uridine triphosphate
UV	ultraviolet
V_H	variable heavy chain
VIP	vasoactive intestinal peptide
V_L	variable light chain
VLDL	very low density lipoproteins
VMA	vanillyl mandelic acid
V_{max}	velocity maximum
VNTRs	variable number tandem repeats
WBC	white blood cells
XMP	xanthosine monophosphate
XP	xeroderma pigmentosum
Xyl	xylose
YAC	yeast artificial chromosome

Appendix II : Greek Alphabets
(Commonly used as symbols)

Alphabet	Symbol
Alpha	α
Beta	β
Gamma	γ
Delta	δ
Epsilon	ε
Zeta	ζ
Eta	η
Theta	θ
Kappa	κ
Lambda	λ
Mu	μ
Xi	ξ
Pi	π
Rho	ρ
Sigma	σ
Phi	ϕ
Chi	χ
Psi	ψ
Omega	ω

Appendix III : Origins of Important Biochemical Words

Acid *(Latin)* acidus–sour

Acidosis *(Latin)* acidus–sour; osis–condition

Albinism *(Greek)* albino–white

Alkali *(Arabic)* al-qite–ashes of saltwort

Allergy *(Greek)* allos–other; ergon–work

Alloseric *(Greek)* allo–the other

Amentia *(Latin)* amentis–mental deficiency

Amnesia *(Greek)* a–not; mnesis–memory

Amphipathic *(Greek)* amphi–both; pathos–feeling

Amphiphilic *(Greek)* amphi–both; philic–love

Anaerobe *(Greek)* a–not; aer–air; bios–life

Anaplerotic *(Greek)* ana–up; plerotikos–to fill

Androgen *(Greek)* aner–man; genesis–production

Anemia *(Greek)* a–not; haima–blood

Anorexia *(Greek)* a–not; orexis–appetite

Anticoagulant anti *(Greek)*–against; coagulare *(Latin)*–to curdle

Antimetabolite *(Greek)* anti-against; metabole-change

Arteriosclerosis arteria *(Latin)*–artery; sclerosis *(Greek)* hardening.

Arthritis *(Greek)* arthron–joint; itis–inflammation

Atherosclerosis *(Greek)* athere–porridge; sclerosis–hardening

Beri-beri *(Singhalese)*–I cannot (said twice)

Biochemistry *(Greek)* bios–life; chymos–juice

Biology *(Greek)* bios–life; logos–discourse

Bovine *(Latin)* bovinus–pertaining to cow or ox

Calorie *(Latin)* calor–heat

Cancer *(Latin)* crab

Carbohydrate carbo *(Latin)*–coal; hydor *(Greek)*–water

Caries *(Latin)*–decay

Casein *(Latin)* caseus–cheese

Catabolism *(Greek)* kata–down; ballein–to throw

Catalysis *(Greek)* kata–down; lysis–degradation

Cathepsin *(Greek)* to digest

Cephalins *(Greek)* kephale–head

Cheilitis *(Greek)* cheilos–lip; itis–inflammation

Cheilosis *(Greek)* cheilos–lip; osis–condition

Chirality *(Greek)* cheir–hand

Chlorophyll *(Greek)* chloros–pale green; phyllon–leaf

Cholelithiasis *(Greek)* chole–bile; lithos–stone; asis–condition

Cholesterol *(Greek)* chole–bile; sterol–solid alcohol

Chromatography *(Greek)* chroma–colour; graphein –to write

Chromosome *(Greek)* chroma–colour; soma–body

Chyle *(Greek)* chylos–juice

Chyluria *(Greek)* chylos–juice; auron–urine

Chyme *(Greek)* chymos–juice

Cirrhosis *(Greek)* kirrhos–orange-tawny; osis–condition

Cis *(Latin)* same side

Coagulation *(Greek)* coagulare–to curdle

Collagen *(Greek)* kolla–glue; genesthai–to be produced

Colloid *(Greek)* kolla–glue; eidos–form

Consanguinity *(Latin)* con-with; sanguis–blood

Creatine *(Greek)* kreas–flesh

Cristae *(Latin)* crests

Cutaneous *(Latin)* cutis–skin

Cytology *(Greek)* kytos–cell; logos–discourse

Cytoplasm *(Greek)* kytos–cell; plassein–to mould

Dermatitis *(Greek)* derma–skin; itis–inflammation

Diabetes mellitus *(Greek)* diabetes–running through (or a siphon); mellitus–sweet

Eicosanoids *(Greek)* eikosi–twenty

Embolism *(Greek)* embolos–to plug

Emphysema *(Greek)* emphysan–to inflate

Enkephalin *(Greek)* in the brain

Enthalpy *(Greek)* to warm within

Entropy *(Greek)* in turning

Enzyme *(Greek)* in yeast

Erythrocyte *(Greek)* erythros–red; kytos–cell

Eukaryotes *(Greek)* eu-true; karyon–nucleus

Ferrous *(Latin)* ferrum–iron

Folate *(Latin)* folium–leaf

Galactose *(Greek)* gala–milk

Gastritis *(Greek)* gaster–belly; itis–inflammation

Gene *(Greek)* genesis–descent

Genome *(Greek)* genos–birth

Globin *(Latin)* globus–ball

Globulin *(Latin)* globulus—little ball

Glossitis *(Greek)* glossa–tongue; itis–inflammation

Glycolysis *(Greek)* glycos–sweet; lysis–dissolution

Goitre *(Latin)* gultur–throat

Gonadotrophin *(Greek)* gona–generation; trophe–nourishment

Hemoglobin haima *(Greek)*–blood; globus *(Latin)*–ball

Hepatitis *(Greek)* hepar–liver; itis–inflammation

Hormone *(Greek)* hormain–to excite

Hydrophilic *(Greek)* hydro–water; philic–living

Hydrophobic *(Greek)* hydro–water; phobic–hating

Hyperglycemia *(Greek)* hyper–above; glycos-sweet; haima–blood

Hypertonic *(Greek)* hyper-above; tonos–tension

Hypoglycemia *(Greek)* hypo-below; glycos-sweet; haima–blood

Hypotonic *(Greek)* hypo–below; tonos–tension

Icterus *(Greek)* ikteros–jaundice

Immunity *(Latin)* immunis–exempt from public burden

Inflammation *(Latin)* inflammare–to set on fire

In situ *(Latin)* in the correct position

In vitro *(Latin)* in a test tube

In vivo *(Latin)* in the living tissue

Isomerism *(Greek)* iso-equal; mesos–part

Isotonic *(Greek)* iso–equal; tonos–tension

Isotope *(Greek)* iso–equal; topos–place

Jaundice (French) jaune–yellow

Keratin *(Greek)* keras–horn

Kwashiorkor *(Ga-African)* sickness of the deposed child

Lactalbumin *(Greek)* lac-milk; albumin–white

Lecithin *(Greek)* lekithos–egg yolk

Lipids *(Greek)* lipos–fat

Lactosuria lac *(Latin)*–milk; ovron *(Greek)*–urine

Leukocytes (Geek) leukos–white; kytos–cell

Leukoderma *(Greek)* leukos–white; derma–skin

Ligase *(Greek)* ligate–to bind

Malaria *(Italian)* bad air

Malnutrition *(Latin)* malus–bad; nutrire–nourishment

Marasmus *(Greek)* to waste

Melanin *(Greek)* melan–black

Menopause *(Greek)* men–month; pausis–stopping

Metabolism *(Greek)* metabole–change

Mitochondria *(Greek)* mitos–thread; chondros–granule

Mitosis *(Greek)* mitos–thread; osis–condition

Monosaccharide *(Greek)*–mono–one; saccharin–sugar

Myeloma *(Greek)* myelos–marrow; oma–tumor

Nephritis *(Greek)* nephros–kidney; itis–inflammation

Neurosis *(Greek)* neuron–nerve; osis–condition

Oedema or edema *(Greek)* oidema–swelling

Oligosaccharides *(Greek)* oligo–few; saccharon–sugar

Osmosis *(Greek)*–push

Osteomalacia *(Greek)* osteon–bone; malakia–softness

Oxyntic *(Greek)* oxynein–to make acid

Oxytocin *(Greek)*–rapid birth

Palindrome *(Greek)*–to run back again

Pantothenic acid *(Greek)* pantos–everywhere

Pathogenesis *(Greek)* pathos–disease; genesis–producing

Pellagra *(Italian)*–rough skin

Pepsin *(Greek)* pepsis–digestion

Phagocytosis *(Greek)* phagein–to eat; kytos–cell; osis–condition

Phobia *(Greek)* phobos–fear

Polysaccharide *(Greek)* poly–many; saccharin–sugar

Porphyrin *(Greek)* porphyra–purple colour

Post-prandial *(Latin)*–after food

Prokaryotes *(Greek)* pro–before; karyon–nucleus

Proteins *(Greek)* proteios–holding first place

Rickets *(Old English)* wrickken–to twist

Serum *(Latin)*–whey

Sphingosine *(Greek)* sphingein–to bind tight

Steatorrhea *(Greek)* stear–fat; rheein–to flow

Stereoisomerism *(Greek)* stero-space

Sterol *(Greek)* steros–solid; ol- alcohol

Thalassemia *(Greek)* thalassa–sea

Thermodynamics *(Greek)* therme–heat; dynamics–power

Thermogenesis *(Greek)* therme–heat; genesis–production

Thrombosis *(Greek)* thrombos–clot; osis–condition

Thylakoid *(Greek)* thylakos–a sac or pouch

Tocopherol *(Greek)* tokos–child birth; pheros–to bear; ol–alcohol

Trans *(Latin)* across

Tumor *(Latin)* swelling

Vitamin (coined inappropriately in 1906) *(Latin)* vita–life; amine

Xanthoma *(Greek)* xanthos–yellow

Xenobiotics *(Greek)* xenos–strange

Zwitterion *(German)* zwitter–hybrid.

Appendix IV : Common Confusables in Biochemistry

Acetone; acetate – Acetone is a ketone; acetate is a carboxylic acid.

Acetyl CoA; acyl CoA – Acetyl CoA is a specific compound containing acetate bound to coenzyme A; acyl CoA is a general term used to refer to any fatty acid (acyl group) bound to coenzyme A.

Albumin; albinism – Albumin is a serum protein; albinism is a genetic disease in tysosine metabolism.

Amino; imino – Amino group ($-NH_2$) is found in majority of amino acids; imino group (=NH) is present in a few amino acids like proline and hydroxyproline.

Anabolism; catabolism – Anabolism refers to the biosynthetic reactions involving the formation of complex molecules from simpler ones; catabolism is concerned with the degradation of complex molecules to simpler ones with a concomitant release of energy.

Anomers; epimers – Anomers refer to two stereoisomers of a sugar that differ in configuration around a single carbonyl atom; epimers are two stereoisomers that differ in configuration around one asymmetric carbon of a sugar possessing two or more asymmetric carbon atoms.

Apoenzyme; coenzyme – Apoenzyme is the protein part of the functional enzyme (holoenzyme); coenzyme is the non-protein organic part associated with enzyme activity.

Bile pigments; bile salts – Bile pigments (biliverdin, bilirubin) are the breakdown products of heme; bile salts are the sodium and potassium salts of bile acids (glycocholate, taurocholate) produced by cholesterol.

Biliverdin; bilirubin – Both are bile pigments. Biliverdin is produced from heme in the reticuloendothelial cells; bilirubin is formed by reduction of biliverdin.

Biotin; biocytin – Biotin is a B-complex vitamin; biocytin refers to the covalently bound biotin to enzymes (through ε-amino group of lysine).

B-Lymphocytes; T-lymphocytes – B-lymphocytes produce immunoglobulins (antibodies) and are involved in humoral immunity; T-lymphocytes are responsible for cellular immunity.

Bisphosphate; diphosphate – Bisphosphate has two phosphates held separately e.g. 2,3-BPG; diphosphate has two phosphates linked together e.g. ADP.

Calcitriol; calcitonin – Calcitriol (1,25-DHCC) is the physiologically active form of vitamin D; calcitonin is a peptide hormone, synthesized by thyroid gland.

Calorimetry; colorimetry – Calorimetry deals with the measurement of heat production by organism; colorimetry is concerned with the measurement of colour compounds.

Carboxyl; carbonyl – These two are functional groups found in organic substances; carboxyl group $-COOH$; carbonyl $-\overset{\|}{C}-$.

Carnitine; creatine; creatinine – Carnitine transports activated fatty acids (acyl CoA) from

cytosol to mitochondria; creatine is mostly found in the muscle as creatine phosphate, a high energy compound; creatinine is the anhydride of creatine.

Choline; cholic acid – Choline is a trimethyl quaternary base and is a constituent of acetylcholine; cholic acid is an important bile acid.

Chyle; chyme – Chyle refers to lymph with milky appearance due to chylomicrons; chyme is the partially digested food in the stomach that passes to deodenum.

Configuration; conformation – Configuration is the geometric relationship between a given set of atoms (e.g. L- and D-amino acids). Conformation is the special relationship of every atom in a molecule (e.g. secondary structure of protein).

Cysteine; cystine – Both are sulfur containing non-essential amino acids. Cysteine contains sulfhydryl (−SH) group; cystine is formed by condensation of two cysteine residues and contains a disulfide (−S−S−) group.

Dextrins; dextrans; dextrose – The first two are polysaccharides composed of glucose. Dextrins are the breakdown products of starch; dextrans are gels produced by bacteria from glucose. Dextrose is glucose in solution (dextrorotatory) used in medical practice.

Diabetes mellitus; diabetes insipidus – Diabetes mellitus is primarily an impairment in glucose metabolism due to the deficiency of, or inefficient insulin; diabetes insipidus is characterized by excretion of large volumes of urine (polyuria), caused by the deficiency of antidiuretic hormone (ADH).

Endocytosis; exocytosis – Endocytosis is the intake of macromolecules by the cells; exocytosis refers to the release of macromolecules from the cells to the outside.

Epinephrine; norepinephrine – Both are catecholamines synthesized from tyrosine. Epinephrine is methylated while norepinephrine does not contain a methyl group.

Exons; introns – Exons are the DNA sequences coding for proteins; introns are the intervening DNA sequences that do not code for proteins.

GABA; PABA – γ-Aminobutyric acid (GABA) is a neurotransmitter; p-aminobenzoic acid (PABA) is a vitamin.

Gene; genome – A gene refers to the DNA fragment of a chromosome that codes for a single polypeptide; all the genes of a cell or an organism are collectively known as genome.

Glu; Gla – Glu is the code for glutamic acid; Gla is the code for γ-carboxy glutamic acid.

Glucuronic acid; gluconic acid – Both are derived from glucose; oxidation of C_6 results in glucuronic acid while oxidation of C_1 yields gluconic acid. Glucuronic acid is produced in uronic acid pathway; gluconic acid is formed in hexose monophosphate shunt.

Glutaric acid; glutamic acid – Glutaric acid is a dicarboxylic acid; glutamic acid (α-amino glutaric acid) is an amino acid.

Glycogen; glycogenin – Glycogen is a storage form of carbohydrate (polysaccharide) in the animal body; glycogenin is a protein which serves as a primer for the initiation of glycogen synthesis.

Glycoproteins; mucoproteins – Both are conjugated proteins containing carbohydrate as the prosthetic group. The term glycoprotein is used if the carbohydrate content is <4%; mucoprotein contains >4% carbohydrate.

Hydrophilic; hydrophobic – Hydrophilic refers to affinity to water; hydrphobic means hatred towards water.

Insulin; inulin – Insulin is a peptide hormone; inulin is a polysaccharide composed of fructose.

In vivo; in vitro – In vivo refers to within the cell or organism; in vitro means in the test tube.

Isoniazid; iproniazid – Isoniazid is an anti-tuberculosis drug; iproniazid is an anti-depressant drug.

Lactam; lactim – These terms are used to represent tautomerism. Lactam indicates the existence of a molecule in keto form; lactim represents a molecule in enol form.

Lactose; lactase – Lactose is a disaccharide; lactase is an enzyme that cleaves lactose to glucose and gulactose.

Linoleic acid; linolenic acid – Both are 18 carbon unsaturated fatty acids. Linoleic acid has two double bonds; linolenic acid has three double bonds.

Lipoproteins; lipotropic factors – Lipoproteins are molecular complexes composed of lipids and proteins; lipotropic factors are the substances (e.g. choline, betaine), the deficiency of which causes accumulation of fat in liver.

β-Lipoprotein; β-lipotropin – β-Lipoprotein refers to the low density lipoproteins; β-lipotropin is a peptide hormone derived from pro-opiomelanocortin (POMC) peptide.

Lyases; ligases – Lyases are the enzymes that catalyse the addition or removal of water, ammonia, CO_2 etc.; ligases catalyse the synthetic reactions where two molecules are joined together.

Malate; malonate; mevalonate – Malate is an intermediate in the citric acid cycle; malonate is a competitive inhibitor of the enzyme succinate dehydrogenase; mevalonate is an intermediate in cholesterol biosynthesis.

Melanin; melatonin – Melanin is the pigment of skin and hair; melatonin is a hormone synthesized by pineal gland.

Maltose; maltase – Maltose is a disaccharide; maltase is an enzyme that cleaves maltose to two molecules of glucose.

Methyl, methenyl; methylene – All the three are one-carbon fragments as shown in brackets, methyl ($-CH_3$); methenyl ($-CH=$); methylene ($-CH_2-$).

Molarity; molality – Molarity is defined as the number of moles of a solute per liter solution; molality represents the number of moles of a solute per 1,000 g of solvent.

Nicotinic acid; nicotine – Nicotinic acid is a B-complex vitamin; nicotine is an alkaloid present in tobacco leaves.

Nucleoside; nucleotide – A nucleoside is composed of a nitrogen base and a sugar; nucleotide contains one or more phosphate groups bound to nucleoside.

Osmolarity; osmolality – Osmolarity represents osmotic pressure exerted by the number of moles (milli moles) per liter solution; osmolality refers to the osmotic pressure exerted by the number of moles (milli moles) per kg solvent.

Palmitate; palmitoleate – Both are even chain (16-carbon) fatty acids. Palmitate is a saturated fatty acid; palmitoleate is a monounsaturated fatty acid.

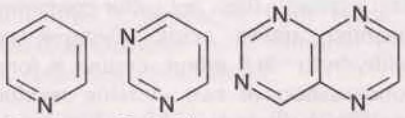
Phosphatidyl ethanolamine; phosphatidal ethanolamine – Both are phospholipids. In phosphatidyl ethanolamine, the fatty acid is bound by an ester linkage. The fatty acid is held by an ether linkage in phosphatidal ethanolamine.

Phytic acid; phytanic acid – Phytic acid is formed by the addition of six phosphate molecules to inositol, it is an inhibitor of the intestinal absorption of calcium and iron; phytanic acid is an unusal fatty acid derived from phytol, a constituent of chlorophyll.

Prokaryotes; eukaryotes – Prokaryotes are the cells that lack a well defined nucleus; eukaryotes possess a well-defined nucleus.

Prolamines; protamines – Both are simple proteins. Prolamines are soluble in alcohol; protamines are basic protein soluble in NH_4OH.

Pyridine; pyrimidine; pteridine – All the three are heterocyclic rings containing nitrogen, as depicted below.



Pyridine ring is found in niacin and pyridoxine; pyrimidine is present in thiamine (vitamin B_1), thymine, cytosine and uracil; folic acid contains pteridine ring.

Pyridoxine; pyridoxal – Pyridoxine is the primary alcohol form of vitamin B_6; pyridoxal is the aldehyde form of B_6.

RDA; SDA – RDA (recommended dietary/daily allowance) represents the quantities of nutrients to be provided in the diet daily for maintenance of good health and physical efficiency; specific dynamic action (SDA) is the extra heat produced by the body over and above the caloric value of foodstuffs.

Renin; Rennin – Renin is synthesized by the kidneys and is involved in vasoconstriction causing hypertension; rennin is an enzyme found in gastric juice responsible for coagulation of milk.

Ribosomes; ribozymes – Ribosomes are the sites of protein biosynthesis; ribozymes refer to the RNA molecules which function as enzymes.

Retinol; retinal – Retinol is the alcohol form of vitamin A; retinal is the aldehyde form obtained by the oxidation of retinol.

Scleroproteins; selenoproteins – Scleroproteins are a group of fibrous proteins; selenoproteins contain the amino acid selenocysteine.

Serotonin; melatonin – Serotonin is a neurotransmitter synthesized from tryptophan; melatonin is a hormone derived from serotonin in the pineal gland.

Somatotropin; somatostatin; somatomedin – Somatotropin is the other name for growth hormone (GH); growth hormone release inhibiting hormone (GRIH) is also called somatostatin; somatomedin refers to the insulin-like growth factor -I (IGF-I), produced by liver in response to GH action.

Sucrose; sucrase – Sucrose is a disaccharide; sucrase is an enzyme that cleaves sucrose to glucose and fructose.

Synthase; synthetase – Both the enzymes are concerned with biosynthetic reactions. Synthase does not require ATP; synthetase is dependent on ATP for energy supply. (***Note :*** This distinction between synthase and synthetase however, is not maintained strictly by most authors).

Thiamine; thymine – Thiamine is a vitamin (B_1); thymine is a pyrimidine base found in DNA structure.

Thiokinase; thiolase – Thiokinase activates fatty acids to acyl CoA; Thiolase catalyses the final reaction in β-oxidation to liberate acetyl CoA from acyl CoA.

Transcription; translation – Transcription refers to the synthesis of RNA from DNA; translation involves the protein synthesis from the RNA.

Uric acid; uronic acid – Uric acid is the end product of purine metabolism; uronic acids are formed by the oxidation of aldehyde group of monosaccharides (e.g. glucuronic acid).

Ureotelic; uricotelic – Ureotelic organisms (e.g. mammals) convert NH_3 to urea; uricotelic organisms (e.g. reptiles) convert NH_3 to uric acid.

Vitamin A; coenzyme A – Vitamin A is fat soluble vitamin; coenzyme A is derived from water soluble vitamin, pantothenic acid.

Appendix V : Practical Biochemistry—Principles

QUALITATIVE EXPERIMENTS

Several laboratory qualitative experiments are performed to indentify the compounds of biochemical importance (carbohydrates, proteins/amino acids, non-protein nitrogenous substances) and to detect the abnormal constituents of urine. The principles of the reactions pertaining to the most widely employed qualitative tests are described here.

I. REACTIONS OF CARBOHYDRATES

The carbohydrates used in the laboratory for the qualitative tests include glucose and fructose (monosaccharides), sucrose, lactose and maltose (disaccharides) and starch (polysaccharide). The principles of the reactions of carbohydrates are given :

1. **Molisch test :** It is a general test for the detection of ***carbohydrates***. The strong H_2SO_4 hydrolyses carbohydrates (poly- and disaccharides) to liberate monosaccharides. The monosaccharides get dehydrated to form furfural (from pentoses) or hydroxy methylfurfural (from hexoses) which condense with α-naphthol to form a violet coloured complex.

2. **Iodine test :** Polysaccharides combine with iodine to form a coloured complex. Thus, ***starch*** gives blue colour while dextrins give red colour with iodine.

3. **Benedict's test :** This is a test for the identification of ***reducing sugars***, which form enediols (predominantly under alkaline conditions). The enediol forms of sugars reduce cupric ions (Cu^{2+}) of copper sulfate to cuprous ions (Cu^{+}) which form a yellow precipitate of cuprous hydroxide or a red precipitate of cuprous oxide.

4. **Barfoed's test :** The principle of this test is the same as that of Benedict's test except that the reduction is carried out in mild acidic medium. Since acidic medium is not favourable for reduction, only strong reducing sugars (monosaccharides) give this test positive. Thus, Barfoed's test serves as a key reaction to distinguish ***monosaccharides*** form disaccharides.

5. **Seliwanoff's test :** This is a specific test for ***ketohexoses***. Concentrated hydrochloric acid dehydrates ketohexoses to form furfural derivatives which condense with resorcinol to give a cherry red complex.

6. **Foulger's test :** This is also a test for ***ketohexoses***. The furfural derivatives formed from ketohexoses condense with urea in the presence of stannous chloride to give a blue colour.

7. **Rapid furfural test :** ***Ketohexoses*** are converted to furfural derivatives by HCl which form a purple colour complex with α-naphthol.

8. **Osazone test :** Phenylhydrazine in acetic acid, when boiled with reducing sugars forms osazones. The first two carbons (C_1 and C_2) are involved in this reaction. The sugars that differ in their configuration on these two carbons give the same type of osazones, since the difference is marked by binding with phenylhydrazine. Thus, glucose, fructose and mannose give the same type (needle shaped) of osazones. However, the osazones of reducing disaccharides differ — maltose gives sunflower-shaped while lactose powder-puff shaped.

9. **Sucrose hydrolysis test :** Sucrose is a non-reducing sugar, hence it does not give Benedict's and Barfoed's tests. Sucrose can be hydrolysed by concentrated HCl, to be converted to glucose and fructose (reducing monosaccharides) which answer the reducing reactions. However, after sucrose hydrolysis, the medium has to be made alkaline (by adding Na_2CO_3) for effective reduction process.

II. REACTIONS OF PROTEINS

The proteins employed in the laboratory for the qualitative tests include albumin, globulins, casein, gelatin and peptones. The principle of the most common reactions of proteins / amino acids performed in the laboratory are given hereunder.

A. PRECIPITATION REACTIONS

Proteins exist in colloidal solution due to hydration of polar groups (—COO^-, —NH_3^+, —OH). They can be precipitated by dehydration or neutralization of polar groups. Several methods are in use to achieve protein precipitation.

1. **Precipitation by neutral salts :** The process of protein precipitation by the addition of neutral salts such as ammonium sulfate or sodium sulfate is referred to as salting out. This phenomenon is explained on the basis of dehydration of protein molecules by salts. This causes increased protein-protein interaction, resulting in molecular aggregation and precipitation.

The amount of salt required for protein precipitation depends on the size (molecular weight) of the protein molecule. In general, the higher is the protein molecular weight, the lower is the salt required for precipitation. Thus, serum globulins are precipitated by half saturation with ammonium sulfate while albumin is precipitated by full saturation.

2. **Precipitation by salts of heavy metals :** Heavy metal ions like Pb^{2+}, Hg^{2+}, Fe^{2+}, Zn^{2+}, Cd^{2+} cause precipitation of proteins. These metals being positively charged, when added to protein solution (negatively charged) in alkaline medium result in precipitate formation.

3. **Precipitation by anionic or alkaloid reagents :** Proteins can be precipitated by trichloroacetic acid, sulphosalicylic acid, phosphotungstic acid, picric acid, tannic acid, phosphomolybdic acid etc. By the addition of these acids, the proteins existing as cations are precipitated by the anionic form of acids to produce protein-sulphosalicylate, protein-tungstate, protein-picrate etc.

The anionic reagents such as phosphotungstic acid and trichloroacetic acid are used to prepare protein-free filtrate of blood needed for several estimations (e.g., urea, sugar) in the laboratory.

4. **Precipitation by organic solvents :** Organic solvents such as alcohol are good protein precipitating agents. They dehydrate the protein molecule by removing that water envelope and cause precipitation.

B. COLOUR REACTIONS

The proteins give several colour reactions which are often useful to identify the nature of the amino acids present in them as shown in the table.

Colour reactions of proteins/amino acids

	Reaction	*Specific group or amino acid*
1.	Biuret reaction	Two peptide linkages
2.	Ninhydrin reaction	α-Amino acids
3.	Xanthoproteic reaction	Benzene ring of aromatic amino acids (Phe, Tyr, Trp)
4.	Millons reaction	Phenolic group (Tyr)
5.	Hopkins-Cole reaction	Indole ring (Trp)
6.	Sakaguchi reaction	Guanidino group (Arg)
7.	Nitroprusside reaction	Sulfhydryl groups (Cys)
8.	Sulfur test	Sulfhydryl groups (Cys)
9.	Pauly's test	Imidazole ring (His)
10.	Folin–Coicalteau's test	Phenolic groups (Tyr)

1. **Biuret reactions :** Biuret is a compound formed by heating urea to 180°C. When biuret is treated with dilute copper sulfate in alkaline medium, a purple colour is obtained. This is the basis of biuret test used for identification of proteins and peptides.

Biuret test is answered by compounds containing two or more CO—NH groups i.e., ***peptide bonds.*** All proteins and peptides possessing atleast two peptide linkages i.e., tripeptides (with 3 amino acids) give positive biuret test. The principle of biuret test is conveniently used to detect the presence of proteins in biological fluids. The mechanism of biuret test is not clearly known. It is believed that the colour is due to the formation of a copper co-ordinated complex.

2. **Ninhydrin reaction :** The α-amino acids react with ninhydrin to form a purple, blue or pink colour complex (Ruhemann's purple).

Amino acid + Ninhydrin ⟶
Keto acid + NH_3 + CO_2 + Hydrindantin

Hydrindantin + NH_3 + Ninhydrin ⟶
Ruhemann's purple

3. **Xanthoproteic reaction :** Xanthoproteic reaction is due to nitration of ***aromatic amino acids*** (tryptophan, tyrosine and phenylalanine) on treatment with strong nitric acid at high temperature.

4. **Millon's test :** This test is given by the amino acid ***tyrosine***, or any other compound containing hydroxyphenyl ring. A red colour or precipitate is obtained in this reaction due to the formation of mercury complex of nitrophenol derivative.

5. **Hopkins-Cole reaction :** This reaction is specific for the indole ring of ***tryptophan***. It combines with formaldehyde in the presence of the oxidizing agent (sulfuric acid with mercuric sulfate) to form a violet or purple coloured compound.

6. **Sakaguchi reaction :** Arginine, containing guanidino group, reacts with α-naphthol and alkaline hypobromite to form a red colour complex.

7. **Sulfur test :** This is a test specific for sulfur containing amino acids namely ***cysteine*** and ***cystine***, but not methionine. When cysteine and cystine are boiled with sodium hydroxide, organic sulfur is converted to inorganic sodium sulfide. This reacts with lead acetate to form a black precipitate of lead sulfide. Methionine does not give this test, since sulfur of methionine is not split by alkali.

8. **Pauly's test :** This reaction is specific for ***histidine*** (imidazole ring). Diazotised sulfanilic acid reacts with imidazole ring in alkaline medium to form a red coloured complex.

9. **Molisch test :** This is a specific test for the detection of ***carbohydrates***. The proteins containing carbohydrates (e.g., glycoproteins) give this test positive. Albumin contains carbohydrate bound to it, hence answers Molisch test.

III. REACTIONS OF NON-PROTEIN NITROGENOUS SUBSTANCES

The non-protein nitrogenous (NPN) substances of biochemical importance include urea, uric acid and creatinine.

1. **Sodium hypobromite test :** This is a test for the detection of ***urea***. Sodium hypobromite decomposes urea to liberate nitrogen. The latter can be identified by brisk effervescence.

2. **Specific urease test :** The enzyme urease (source-horse gram) specifically acts on ***urea*** to liberate ammonium carbonate (alkali). The latter can be identified by a colour change in phenophthalein indicator (pink colour in alkaline medium).

3. **Benedict's uric acid test :** ***Uric acid***, being a strong reducing agent, reduces phosphotungstate to tungsten blue in alkaline medium.

4. **Murexide test :** ***Uric acid*** is oxidized by nitric acid to give purpuric acid (reddish yellow). This in turn combines with ammonia to form purple red colour ammonium purpurate (murexide).

5. **Jaffe's test :** Creatinine reacts with picric acid in alkaline medium to form orange red colour complex.

IV. ABNORMAL CONSTITUENTS OF URINE

Urine is the most important excretory fluid from the body. Some of the diseases are associated with an excretion of abnormal constituents in urine. The identification of such compounds in urine is of great diagnostic importance.

Urine abnormal constituent	*Associated disorder(s)*
Albumin	Kidney damage (glomerulonephritis)
Hemoglobin	Damage to kidneys or urinary tract.
Glucose	Diabetes mellitus, renal glycosuria.
Ketone bodies	Diabetes mellitus, starvation.
Bile salts	Obstructive jaundice
Bile pigments	Obstructive jaundice and hepatic jaundice.

1. **Sulfosalicylic acid test :** ***Proteins*** get precipitated by sulfosalicylic acid by forming protein-sulfosalicylate.

2. **Heat coagulation test :** This is a test for the detection of ***albumin*** and/or ***globulins*** in urine. Heat coagulation test is based on the principle of denaturation of proteins, followed by coagulation.

(**Note :** Small amounts of dilute acetic acid are added to dissolve the phosphates and sulfates that get precipitated on heating.)

3. **Benzidine test :** This test detects the presence of ***blood***. Hemoglobin (acts like peroxidase) decomposes hydrogen peroxide to liberate nascent oxygen (O–) which oxidises benzidine to a green or blue coloured complex.

(**Note :** Pus cells of urine possess peroxidase activity which interferes in benzidine test. This can be eliminated by boiling the urine prior to the test to inactivate the enzyme).

4. **Benedict's test :** This is a semiquantitative test for the detection of urine reducing sugars (primarily glucose). Benedict's test is based on the principle of reducing property of sugars (described in detail under reactions of carbohydrates). Colour of the precipitate formed indicates the approximate amount of ***glucose*** present in urine. Thus, green turbidity = traces; green precipitate = 0.5%; yellow precipitate = 1%; orange precipitate = 1.5% brick red precipitate = 2%. (Note : Benedict's test is not specific to glucose, since it can be answered by any reducing substance).

5. **Glucose oxidase test :** This is a strip test for the ***specific detection of glucose***. The enzyme glucose oxidase oxidizes glucose to liberate hydrogen peroxide which in turn is converted to nascent oxygen (O–) by peroxidase enzyme. The compound O-diansidine combines with nascent oxygen to form a coloured (yellow to red) complex.

6. **Rothera's test :** Nitroprusside in alkaline medium reacts with keto group of ***ketone bodies*** (acetone and acetoacetate) to form a purple ring. This test is not given by β-hydroxybutyrate.

7. **Hay's test :** This test is based on the surface tension lowering property of ***bile salts*** (sodium glycocholate and sodium taurocholate). Sulfur powder sprinkled on the surface of urine containing bile salts sinks to the bottom.

8. **Petternkofer's test :** This test is employed for the detection of ***bile salts***. The furfural derivatives (by reacting sugar with concentrated H_2SO_4) condense with bile salts to form a purple ring.

9. **Gmelin's test :** Nitric acid oxidizes the bile pigment bilirubin to biliverdin (green) or bilicyanin (blue). Gmelin's test gives a play of colours and is used for the identification of ***bile pigments***.

10. **Fouchet's test :** This test is also employed for the detection of ***bile pigments***. Bile pigments are adsorbed on barium sulfate. Fouchet's reagents (containing ferric chloride in trichloroacetic acid) oxidizes bilirubin to biliverdin (green) and bilicyanin (blue).

QUANTITATIVE EXPERIMENTS

Quantitative experiments, dealing with the determination of concentrations of several biologically important compounds and the assay of many enzymes, are of great significance in the laboratory practice. Very often, the ultimate diagnosis and prognosis of a large number of diseases are guided by the quantitative biochemical investigations.

The principles involved in some of the quantitative experiments, commonly employed in the biochemistry laboratory by an undergraduate student, are briefly described here.

1. Blood glucose estimation

The quantitative determination of blood (plasma/serum) glucose is of great importance in the diagnosis and monitoring of diabetes mellitus.

(i) ***Folin Wu method*** : Alkaline copper (cupric ions) is reduced by glucose when boiled with protein free blood filtrate to cuprous oxide. The cuprous oxide in turn reacts with phosphomolybdic acid to form blue coloured oxides of molybdenum. The intensity of the colour can be measured in a colorimeter at a wavelength 680 nm. [Folin Wu method is rather old and is not specific for glucose determination, since other substances (e.g., fructose, lactose, glutathione) also bring about reduction. Consequently the blood glucose level when estimated by Folin Wu method is higher i.e., normal fasting is 80-120 mg/dl against true glucose 60-100 mg/dl]

(ii) ***O-Toluidine method*** : Glucose combines with O-toluidine when boiled in acid medium to form a green coloured complex which can be measured in a colorimeter at a wavelength 630 nm. (This method determines glucose alone).

(iii) ***Glucose oxidase-peroxidase (GOD—POD) method*** : This is an enzymatic determination of blood glucose. Glucose gets oxidized by glucose oxidase to

gluconic acid and hydrogen peroxide. The enzyme peroxidase converts hydrogen peroxide to water and oxygen. The oxygen in turn reacts with 4-aminophenzone in the presence of phenol to form a pink coloured complex, the intensity of which can be measured at 530 nm.

2. Blood urea estimation

Determination of blood urea (reference range 10-40 mg/dl) is important for the evaluation of kidney (renal) function. Elevation of blood urea is associated with pre-renal (diabetic coma, thyrotoxicosis), renal (acute glomerulonephritis, polycystic kidney) and post-renal (obstruction in the urinary tract, due to tumors, stones) conditions.

Diacetyl monoxime (DAM) method : Urea when heated with diacetyl monoxime forms a yellow coloured complex of dioxime derivatives which can be measured at 520 nm.

3. Serum creatinine estimation

Estimation of serum creatinine (reference range 0.5-1.5 mg/dl) is used as a diagnostic test to assess kidney function. Serum creatinine is not influenced by endogenous and exogenous factors, as is the case with urea. Hence, some workers consider serum creatinine as a more reliable indicator of renal function.

Alkaline picrate method : This method is based on Jaffe's reaction. Creatinine reacts with alkaline picrate to form creatinine picrate, an orange red coloured complex, which can be measured in a colorimeter at 530 nm.

(**Note** : Urinary creatinine can also be determined by employing the same principle given above).

4. Determination of serum proteins

The normal concentration of total serum proteins is in the range 6-8 g/dl (albumin 3.5-5.0 g/dl; globulins 2.5-3.5 g/dl; A/G ratio is 1.2 to 1.5 : 1). The A/G ratio is lowered either due to a decrease in albumin or an increase in globulins.

Serum albumin concentration is decreased in liver diseases, severe protein malnutrition, and excretion of albumin in urine (due to renal damage). Serum globulin concentration is elevated in chronic infections and multiple myeloma.

Biuret method : Peptide bonds (—CO—NH) of proteins react with cupric ions in alkaline medium to form a violet colour complex which is measured at a wavelength 530 nm. This method is suitable for total serum proteins with estimation.

Bromocresol green (BCG) dye method : This technique is employed for the estimation of serum albumin. BCG dye reacts with albumin to form an intense blue-green coloured complex which can be measured at 628 nm.

5. Estimation of serum bilirubin

The total bilirubin concentration in serum is 0.2-1 mg/dl (conjugated ~ 0.6 mg/dl; unconjugated ~ 0.4 mg/dl). Elevation in serum bilirubin concentration is observed in jaundice. Unconjugated bilirubin is increased in hemolytic jaundice, conjugated bilirubin in obstructive jaundice, while both of them are increased in hepatic jaundice.

van den Bergh reaction : Serum bilirubin estimation is based on van den Bergh reaction. The principle of the reaction is that diazotised sulfanilic acid (formed by mixing equal volumes of sulfanilic acid in HCl and sodium nitrite) reacts with bilirubin to form a purple coloured azobilirubin which can be measured at 540 nm.

6. Estimation of serum cholesterol

Serum cholesterol concentration (reference range 150-225 mg/dl) is elevated in atherosclerosis, diabetes mellitus, obstructive jaundice and hypothyroidism. Decreased levels are observed in hyperthyroidism.

Acetic anhydride method : Serum cholesterol reacts with acetic anhydride in the presence of glacial acetic acid and concentrated H_2SO_4 to form a green coloured complex. Intensity of this colour is measured at 560 nm.

7. Estimation of serum uric acid

Uric acid is the end product of purine metabolism. Its concentration in serum is increased (reference range - men 4-8 mg/dl; women 3-6 mg/dl) in gout.

Henry-Caraway's method : Uric acid in the protein-free filtrate when treated with phosphotungstic acid in the presence of sodium carbonate (alkaline solution) gives a blue coloured complex which can be measured at 660 nm.

8. Estimation of serum calcium

Serum calcium level is elevated (reference range 9-11 mg/dl) in hyperparathyroidism and decreased in hypothyroidism.

O-Cresolphthalein complexone method : Calcium reacts with the dye, O-cresolphthalein complexone (CPC) in alkaline solution to form a complex which can be measured at a wavelength 660 nm.

9. Estimation of serum phosphorus (inorganic)

Serum phosphate (reference range 3-4.5 mg/dl) is increased in hypoparathyroidism, and decreased in hyperparathyroidism and renal rickets.

For the determination of serum phosphate, serum proteins are precipitated by trichloroacetic acid. The protein-free filtrate containing inorganic phosphate is reacted with molybdic acid reagent to form phosphomolybdate. The latter in turn is reduced to molybdenum blue by treatment with 1-amino 2-naphthol-4 sulfonic acid (ANSA). The intensity of the blue colour is measured at 689 nm.

10. Determination of SGPT and SGOT

Serum glutamate pyruvate transaminase (SGPT; alanine transaminase) and serum glutamate oxaloacetate transaminase (SGOT; aspartate transaminase) are two important diagnostic enzymes. SGPT activity (reference range 5-40 IU/L) is more specifically increased in liver diseases (hepatic jaundice). SGOT activity is elevated (reference range 5-45 IU/L) in heart diseases (myocardial infarction).

Principle of assay : SGPT catalyses the following reaction

L-Alanine + α-ketoglutarate ⟶ L-glutamate + pyruvate

SGOT brings about the following reaction

L-Aspartic acid + α-ketoglutarate ⟶ L-glutamate + oxaloacetate

The keto acid (pyruvate or oxaloacetate), formed in the above reaction, when treated with 2, 4-dinitrophenyl hydrazine forms dinitrophenyl hydroazone (brown colour) in alkaline medium which can be measured at 505 nm.

11. Determination of serum alkaline phosphatase

The activity of the enzyme serum alkaline phosphatase (normal range 3-13 KA Units/dl) is elevated in rickets and obstructive jaundice.

Principle of assay : Alkaline phosphatase hydrolyses disodium phenylphosphate liberating phenol. On treatment with 4-amino antipyrine in alkaline medium, phenol gives ferricyanide (reddish colour) which can be measured at 520 nm.

12. Determination of serum amylase

Serum amylase activity is increased (reference range 80-180 Somogyi Units/dl) in acute pancreatitis.

Principle of assay : Amylase acts on starch and hydrolyses to dextrins and maltose. Starch forms blue coloured complex with iodine, a decrease in the colour (measured at 670 nm) is proportional to the activity of amylase.

13. Analysis of cerebrospinal fluid

Cerebrospinal fluid (CSF) is the aqueous medium surrounding the brain and spinal cord. From the biochemical perspective, estimation of proteins and glucose in CSF is important. Increase in protein (reference range 15-40 mg/dl) and decrease in glucose (reference range 50-75 mg/dl) in the cerebrospinal fluid are observed in tuberculosis meningitis.

CSF protein estimation : Sulfosalicylic acid (in sodium sulfate solution) precipitates CSF proteins and the turbidity is measured at 680 nm.

CSF glucose estimation : Any one of the standard methods employed for the determination of blood glucose (already described) can be used for CSF glucose estimation.

Appendix VI : Clinical Biochemistry Laboratory

The ultimate application of the biochemistry subject is for the health and welfare of mankind. Clinical biochemistry (also known as ***clinical chemistry*** or ***chemical pathology***) is the laboratory service absolutely essential for medical practice. The results of the biochemical investigations carried out in a clinical chemistry laboratory will help the clinicians to determine the diseases (diagnosis) and for follow-up of the treatment/recovery from the illness (prognosis). Biochemical investigations hold the key for the diagnosis and prognosis of diabetes mellitus, jaundice, myocardial infarction, gout, pancreatitis, rickets, cancers, acid-base imbalance etc. Successful medical practice is unimaginable without the service of clinical biochemistry laboratory.

The ***biological fluids*** employed in the clinical biochemistry laboratory include ***blood***, ***urine***, ***cerebrospinal fluid*** and pleural fluid. Among these, blood (directly or in the form of plasma or serum) is frequently used for the investigations in the clinical biochemistry laboratory.

COLLECTION OF BLOOD

Venous ***blood*** is most commonly used for a majority of biochemical investigations. It can be drawn from any prominent vein (usually from a vein on the front of the elbow). ***Capillary blood*** (<0.2 ml) obtained from a finger or thumb, is less frequently employed. ***Arterial blood*** (usually drawn under local anesthesia) is used for blood gas determinations.

Precautions for blood collection : Use of sterile (preferably disposable) needles and syringes, cleaning of patients skin, blood collection in clean and dry vials/tubes are some of the important precautions.

CHOICE OF BLOOD SPECIMENS

Biochemical investigations can be performed on 4 types of blood specimens-whole blood, plasma, serum and red blood cells. The selection of the specimen depends on the parameter to be estimated. ***Whole blood*** (usually mixed with an anticoagulant) is used for the estimation of hemoglobin, carboxyhemoglobin, pH, glucose, urea, non-protein nitrogen, pyruvate, lactate, ammonia etc. (Note : for glucose determination, plasma is prefered in recent years).

Plasma, obtained by centrifuging the whole blood collected with an anticoagulant, is employed for the parameters—fibrinogen, glucose, bicarbonate, chloride, ascorbic acid etc.

Serum is the supernatant fluid that can be collected after centrifuging the clotted blood. It is the most frequently used specimen in the clinical biochemistry laboratory. The parameters estimated in serum include proteins (albumin/globulins), creatinine, bilirubin, cholesterol, uric acid, electroylets (Na^+, K^+, Cl^-), enzymes (ALT, AST, LDH, CK, ALP, ACP, amylase, lipase) and vitamins.

Red blood cells are employed for the determination of abnormal hemoglobins, glucose 6-phosphate dehydrogenase, pyruvate kinase etc.

ANTICOAGULANTS

Certain biochemical tests require unclotted blood. Anticoagulants are employed for collecting such specimens.

Heparin : Heparin (inhibits the conversion of prothrombin to thrombin) is an ideal anticoagulant, since it does not cause any change in blood composition. However, other anticoagulants are prefered to heparin, due to the cost factor.

Potassium or sodium oxalate : These compounds precipitate calcium and inhibit blood coagulation. Being more soluble, potassium oxalate (5-10 mg per 5 ml blood) is prefered.

Potasium oxalate and sodium fluoride : These anticoagulants are employed for collecting blood to estimate glucose. Further sodium fluoride inhibits glycolysis and preserves blood glucose concentration.

Ammonium oxalate and potassium oxalate : A mixture of these two compounds in the ratio 3 : 2 is used for blood collection to carry out certain hematological tests.

Enthylene diaminetetracetic acid (EDTA) : It chelates with calcium and blocks coagulation. EDTA is employed to collect blood for hematological examinations.

HEMOLYSIS

The rupture or lysis of RBC, releasing the cellular constituents interferes with the laboratory investigations. Therefore, utmost care should be taken to avoid hemolysis when plasma or serum are used for biochemical tests. Use of dry syringes, needles and containers, allowing slow flow of blood into syringe are among the important precautions to avoid hemolysis.

PRESERVATION OF BLOOD SPECIMENS

Plasma or serum should be separated within 2 hours after blood collection. It is ideal and advisable to analyse blood, plasma or serum, immediately after the specimen collection. This however, may not be always possible. In such a case, the samples (usually plasma/serum) can be stored at 4°C until analysed. For enzyme analysis, the sample are preserved at –20°C.

TYPES OF LABORATORY TESTS

The biochemical investigations (on blood/plasma/serum) carried out in the clinical biochemistry laboratory may be grouped into different types.

1. **Discretionary or on-off tests :** Most common clinical biochemistry tests that are designed to answer specific questions. e.g., does the patient have increased blood urea/glucose concentration? Normally, these tests are useful to support the diagnosis.

2. **Biochemical profiles :** These tests are based on the fact that more useful information on the patients disease status can be obtained by analysing more constituents rather than one e.g., ***plasma electrolytes*** (Na^+, K^+, Cl^-, bicarbonate, urea); ***liven function tests*** (serum bilirubin, ALT, AST).

3. **Dynamic function tests :** These tests are designed to measure the body's response to external stimulus e.g., oral glucose tolerance test (to assess glucose homeostasis) : bromosulphthalein test (to assess liver function).

4. **Screening tests :** These tests are commonly employed to identify the inborn errors of metabolism, and to check the entry of toxic agents (pesticides, lead, mercury) into the body.

5. **Metabolic work-up tests :** The programmed intensive investigations carried out to identify the endocrinological disorders come under this category.

The term ***emergency tests*** is frequently used in the clinical laboratory. It refers to the tests to be performed immediately to help the clinician for proper treatment of the patient e.g., blood glucose, urea, serum electrolytes.

COLLECTION OF URINE

Urine, containing the metabolic waste products of the body in water is the most important excretory fluid. For biochemical investigations, urine can be collected as a single specimen or for 24 hours. Single specimens of urine, normally collected in the morning, are useful for qualitative tests e.g., sugar, proteins. Twenty four hour urine collections (done between 8 AM to 8 AM) are employed for quantitative estimation of certain urinary constituents e.g., proteins, hormones, metabolites.

Preservatives for urine : For the collection of 24 hr urine samples, preservatives have to be used or else urine undergoes changes due to bacterial action. Hydrochloric acid, toluene, light petroleum, thymol, formalin etc., are among the common preservatives used.

CEREBROSPINAL FLUID (CSF)

CSF is a fluid of the nervous system. It is formed by a process of selective dialysis of plasma by the choroid plexuses of the ventricles of the brain. The total volume CSF is 100-200 ml.

Collection of CSF : CSF is collected by puncturing the interspace between the 3rd and the 5th lumbar vertebrae, under aseptic conditions and local anesthesia.

Biochemical investigations on CSF : Protein, glucose and chloride estimations are usually performed in the clinical biochemistry laboratory.

QUALITY CONTROL

Quality control in clinical biochemistry laboratory refers to the reliability of investigative service. Any error in the laboratory will jeopardize the lives of patients. It is therefore utmost important that the laboratory errors are identified and rectified.

Quality control comprises of four interrelated factors namely precision, accuracy, specificity and sensitivity.

Precision refers to the reproducibility of the result when the same sample is analysed on different occasions (replicate measurements) by the same person. For instance, the precision is good, if the blood glucose level is 78, 80 and 82 mg/dl on replicates.

Accuracy means the closeness of the estimated result to the true value e.g., if true blood urea level is 50 mg/dl, the laboratory reporting 45 mg/dl is more accurate than the one reporting 35 mg/dl.

Specificity refers to the ability of the analytical method to specifically determine a particular parameter e.g., glucose can be specifically estimated by enzymatic glucose oxidase method.

Sensitivity deals with the ability of a particular method to detect small amounts of the measured constituent.

METHODS OF QUALITY CONTROL

Internal quality control refers to the analysis of the same pooled sample on different days in a laboratory, the results should vary within a narrow range.

External quality control deals with the analysis of a sample received from outside, usually from a national or regional quality control centre. The results obtained are then compared.

AUTOANALYSERS IN CLINICAL CHEMISTRY

The heavy work load in the clinical biochemistry laboratory has lead to the discovery of autoanalysers. These modern equipment are useful to analyse hundreds of samples in a short time. Single channel and multi-channel machines (autoanalysers) based on the principles of either continuous or discrete analysis are available on the market.

ANALYSIS IN CLINICAL BIOCHEMISTRY LABORATORY AND REFERENCE VALUES

As already stated, clinical biochemistry laboratory is a service-oriented establishment for the benefit of patient health care. The reader may refer tools of biochemistry (***Chapter 41***) and principles of practical biochemistry (***Appendix-V***) for a brief knowledge on the principles of some of the equipment used and the laboratory investigations employed.

The details on the biochemistry of health and disease states in relation to the normal and abnormal biochemical data are described in the text of this book. For ready reference, the most common reference biochemical values are given on the inside of back cover.

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This book, **BIOCHEMISTRY (Third Edition)**,

- offers an integration of medical and pure sciences, and is comprehensively written, revised and updated to meet the curriculum requirements of Medical, Pharmacy, Dental, Veterinary, Biotechnology, Biomedical Engineering, Agricultural Sciences, Life Sciences, and others studying Biochemistry as one of the subjects.
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Dr. U. SATYANARAYANA, Ph.D., posseses over 30 years (20 years as Professor) of experience in teaching the subject of Biochemistry to Medical, Dental, and Science students. He has authored three other popular books *Essentials of Biochemistry*, *Biochemistry Review*, and *Biotechnology*—besides publishing about 50 research papers in national and international journals. A gold medalist of Nagpur University and a recipient of the Dr. Krishnaswamy Best Teacher Award (of Siddhartha Medical College), Dr. Satyanarayana has been honoured twice (Hong Kong 1989, Japan 1991) with the Regional Service Award by the Asian-Pacific Congress of Clinical Biochemistry. He is a Fellow of both the National Academy of Clinical Biochemistry, USA, and the Institution of Chemists, India. Besides, he is also Advisor, Research Board, American Biographical Institute, USA.

Dr. U. CHAKRAPANI, M.B.B.S., M.S., the first student to learn Biochemistry from the original manuscript of this book, significantly contributed at every stage of its preparation with creative ideas and constant feedback. Now, after obtaining his post-graduate degree in Medical Faculty, he is a full-fledged co-author of the third edition of this book. Dr. Chakrapani is largely responsible for the comprehensive coverage of the clinical and biomedical aspects related to human biochemistry in health and disease.

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ISBN 81-87134-80-1

9 788187 134800