

Contents

Preface to the Fourteenth Edition

v

Preface to the First Edition

vi

Index of Competencies

xix

Section I General Physiology

1. Cell Physiology: Structure and Functions of Cell Organelle 2

Introduction	2
Cell Structure	2
Cell Membrane	2
Cytoplasm and its Organelles	4
Nucleus	6
Chromatin	7
Chromosomes	7
Applied Physiology	7
Intercellular Communication and Mode of Communication	7
Special Structural Features of Cell and Intercellular Communication	7
Molecular Motors	9
Apoptosis	9
Applied Physiology	9
Methods used to Demonstrate the Functions of the Cells and its Product	10
Exam-oriented Questions	13

2. Homeostasis 14

Introduction	14
Role of Various Systems of Body in Homeostasis	14
Role of Neuroendocrine Reflex in Homeostasis	14
Feedback Homeostasis Regulations	15
Examples of Negative Feedback Mechanism	15
Examples of Positive Feedback Mechanism	16
Internal Factors Influencing Homeostasis	17
External Factors Influencing Homeostasis	17
Exam-oriented Questions	17

3. Transport Across Cell Membrane 18

Introduction	18
Introducing to Key Terms and Concepts	18
Important Concepts in Transport Mechanism	18
Ion Channels	18
Types of Transport Mechanism	19
Characteristic Features	21
Osmosis	21
Membrane Transport: Active Transport	22
Primary Active Transport	22
Secondary Active Transport	23
Vesicular Transport Mechanisms	25
Transport through Cellular Sheets	26
Applied Physiology	26
Exam-oriented Questions	26

4. Membrane Potential 27

Introduction	27
Role of Ion in Generating Membrane Potential	27
Ionic Mechanisms of Resting Potentials	27
Physico-chemical Principles Involved in Generating RMP	27
Nernst Potential	27
Goldman-Hodgkin and Katz (GHK) Equation	27
Gibbs-Donnan Membrane Equilibrium	27
Recording of Membrane Potential	28
Graded Potential and Action Potential	28
Introduction	28
Terms Associated with Membrane Potential	29
Graded Potential	29
Local Response of Graded Potential	29
Types of Graded Potential	29
Summation of Graded Potential	29
Action Potential	29
Characteristics of Action Potential	30
Nerve Stimulation and Phases of Action Potential	30
Ionic Basis of Action Potential	31
Cardiac Action Potentials	31
Property of Action Potential	32
Ion Channel Studies	33
Procedures	33
Exam-oriented Questions	33

5. Body Fluids and Blood Volume 34

Introduction	34
Total Body Water and its Distribution	34
Extracellular Fluid Compartment	34
Blood Volume	35
Methods of Determination of Blood Volume	35
Blood Volume	35
Measurement of Plasma Volume	35
Measurement of Interstitial Fluid Volume	35
Interstitial Fluid (IF)	35
Intracellular Fluid Compartment (ICF)	35
Measurement of Body Fluid Compartments	36
Total Body Water	36
Extracellular Fluid Volume	36
Intracellular Fluid Measurement	36
Hydrogen Ion Concentration of the Body Fluids	37
Regulation of Body Fluid Volume	37
Exogenous and Endogenous Water Input	37
Water Excretion and its Daily Output	37
Maintenance of Electrolyte Balance	37
Potassium Conc and its Balance	37
Disorders of Fluid Volume	38
Exam-oriented Questions	38
Clinical Case Scenario	39
General Physiology	39

Section II Blood

6. Composition and Functions of Blood	42		
Introduction	42		
Properties of Blood	42		
Composition of Blood	42		
Functions of Blood	42		
Relative Volume of Corpuscles and Plasma	43		
Exam-oriented Questions	44		
7. Specific Gravity of Blood	45		
Introduction	45		
Rise in Specific Gravity	45		
Fall in Specific Gravity	45		
Method of Determination	45		
Exam-oriented Questions	45		
8. Plasma Proteins	46		
Introduction	46		
Plasma Proteins Varieties	46		
Origin of Plasma Proteins	46		
Rate of Regeneration of Plasma Proteins: Whipple's Experiment	46		
Whipple's Experiment	46		
Relation of Diet to Plasma Proteins	46		
Functions of Plasma Protein	47		
Exam-oriented Questions	47		
9. Viscosity and Erythrocyte Sedimentation Rate (ESR)	48		
Introduction	48		
Viscosity: Characteristics	48		
Suspension Stability of Blood (Erythrocyte Sedimentation Rate or ESR)	48		
ESR Increased and Decreased	49		
Significance of ESR	49		
Physiological Variations in ESR	49		
Exam-oriented Questions	49		
10. Coagulation of Blood	50		
Introduction	50		
Importance of Coagulation of Blood	50		
General Characteristics of Coagulation	50		
Blood Coagulation Factors	51		
Factor I or Fibrinogen	51		
Factor II or Prothrombins	51		
Factor III or Thromboplastin	51		
Factor IV or Calcium	51		
Factor V or Labile Factor Accelerator Globulin or Proaccelerin	51		
Factor VII or Stable Factor or Proconvertin	51		
Factor VIII or Antihæmophilic Factor (AHF) or Antihæmophilic Globulin (AHG) or Platelet Cofactor I	51		
Factor IX or Christmas Factor or Plasma Thromboplastin Component (PTC) or Platelet Cofactor II	52		
Factor X or Stuart Factor	52		
Factor XI or Plasma Thromboplastin Antecedent (PTA)	52		
Factor XII or Hageman or Surface Factor	52		
Factor XIII or Fibrin-stabilising or Laki-Lorand Factor (LLF)	52		
Fitzgerald Factor also known as High Molecular Weight Kininogen	52		
Fletcher Factor also known as Prekallikrein	52		
Other Important Factors Participating in Coagulation Mechanism	52		
Thrombomodulin	52		
Protein C	52		
Protein S	52		
Anti-thrombin III	52		
Tissue Factor Pathway Inhibitor	52		
Extrinsic and Intrinsic Mechanisms of Coagulation of Blood	52		
Clot Retraction	53		
Fibrinolysis	54		
Plasminogen	54		
Natural Inhibitors of Coagulation	55		
Antithrombin Activities Remove Thrombin from Blood	55		
Intravascular Clotting or Thrombosis	55		
Thrombus	55		
Heparin as an anticoagulant	55		
Characteristics	55		
Applied Physiology	55		
Coagulation Disorders	55		
Bleeding Disorders	56		
Exam-oriented Questions	58		
11. Bone Marrow	59		
Introduction	59		
Key Points	59		
Red Bone Marrow	59		
Yellow Bone Marrow	59		
Vascular Arrangement in the Bone Marrow	59		
Functions of Bone Marrow	59		
Formed Elements of Blood	59		
Precursors of Blood Cells	60		
Applied Physiology: Bone Marrow Biopsy	62		
Exam-oriented Questions	62		
12. Red Blood Corpuscles (Erythrocytes)	63		
Introduction	63		
Size, Volume, Thickness, etc. of Red Blood Corpuscles	63		
Cytoplasm of the Red Cells	63		
Normal Red Cell Count	63		
Variations of Red Cell Count under Various Physiological Conditions	63		
Abnormal Forms of Erythrocytes	63		
Stages of Blood Formation in the Embryo and Foetus	64		
Site of Development	64		
Important Factors Controlling Erythropoiesis	64		
Maturation of Red Blood Cells	64		
Stages of Development	64		
Factors Regulating Erythropoiesis	66		
Energy Metabolism of RBC	66		
Key Points	66		
Functions of Red Blood Corpuscles	68		
Exam-oriented Questions	68		
13. Haemoglobin	69		
Introduction	69		
Chemistry	69		
Structure of Haemoglobin	69		
Properties	70		
Haemoglobin Varieties	70		
Haemoglobin and its Variant	70		
Synthesis of Haemoglobin	70		
Amount of Haemoglobin in Normal Blood	70		
Variations of Hb under Different Physiological Conditions	71		
Derivatives of Haemoglobin	71		
Exam-oriented Questions	72		

14. Iron Absorption, Transport, Storage and Excretion	73	17. Blood Groups and Blood Transfusion	90
Introduction 73		Blood Groups 90	
Daily Requirement 73		A, B and O Groups 90	
Distribution of Iron 73		Rh Antibodies and Rh Incompatibility 91	
Absorption and Transport 73		Erythroblastosis Foetalis 91	
Key Points 73		M and N Factors: Medicolegal Significance 91	
Iron in Blood 73		H Blood Group System and Bombay Phenotype 92	
Storage of Iron 73		Blood Transfusion: Blood Groups 92	
Excretion 74		Indications for Blood Transfusion 92	
Functions of Iron 74		Autologous Transfusion 92	
Applied: Iron Deficiency Anaemia 75		Mismatched Blood Transfusion 93	
Exam-oriented Questions 75		Blood Bank 93	
		Blood Storage 93	
		Exam-oriented Questions 93	
15. Anaemia, Polycythemia, Osmotic Fragility and Blood Indices	76	18. Formation of Tissue Fluids	94
Introduction 76		Introduction 94	
Other Causes 76		Composition of Tissue Fluid 94	
Sickle Cell Anaemia 76		Functions of Tissue Fluid 94	
Thalassemia 76		Oedema and its Causes 95	
Alpha Thalassemia 78		Aggregation of Tissue Fluid 95	
Beta Thalassemia 78		Lymph and Lymphatics 95	
Glucose-6-Phosphate Dehydrogenase Deficiency 78		Characteristic Features 95	
Congenital Spherocytosis 78		Properties of Lymph 95	
Blood Indices and Morphological Classification of Anemia 78		Composition of Lymph 95	
Determination of Osmotic Fragility of Red Blood Cells 79		Solids 95	
Principle 79		Rate of Flow 95	
Procedure 79		Factors Responsible for Formation of Lymph 97	
Precautions 79		Functions of Lymph 98	
Applied Physiology: Haemolysis and Osmotic Fragility 79		Lymph Node 98	
Polycythemia 80		Structure of Lymph Node 98	
Exam-oriented Questions 80		Functions of Lymph Node 99	
		Structure of Spleen 99	
		Splenic Pulp 99	
		Marginal Zone 100	
16. White Blood Cells and Platelets	81	Functions of Spleen 101	
White Blood Cells 81		Classification, Varieties and Distribution of RE Cells 102	
Variations in Normal Count of White Blood Corpuscles 81		Functions of the Reticuloendothelial System 103	
Classification and Differential Count of White Blood Corpuscles or Leucocytes 81		Exam-oriented Questions 103	
Granular Leucocytes or Granulocytes 82			
Neutrophil 82		19. Immunity	104
Arneth Count or Arneth Index (Modified by von Bonsdorff and Later by Cooke) 82		Introduction 104	
Eosinophil (1–4%) 83		Innate Defenses 104	
Basophil (0–1%) 83		Complement 105	
Lymphocytes (20–40%) 83		Adaptive Defenses 106	
Small Lymphocyte 83		Development of the Acquired Immune System 106	
Large Lymphocyte 83		Humoral Immunity 107	
Monocytes (Large Mononuclear Cell, Transitional Cell, etc.) (2–8%) 84		Acquired Humoral Response: Formation of Primary and Secondary Antibodies 107	
Characteristic Features 84		Types of Acquired Immunity 107	
Development of Leucocytes 84		Antibody Mediated Humoral Response 108	
Development of Granular Leucocytes or Granulocytes 84		Cell-mediated Immune Response 108	
Development of Lymphocytes 85		T Cell Activation 109	
Role of Lymphocyte in Immunology 86		Function of T Helper Cells, Cytotoxic T Cells and Suppressor T Cells 109	
Development of Monocytes 86		Organ Transplant 110	
Life and Fate of Leucocytes 86		Severe Combined Immunodeficiency (SCID) Syndrome 110	
Functions of WBC 86		Acquired Immune Deficiency Syndrome (AIDS) 110	
Applied Physiology: WBC Disorders 86		Hypersensitivity 110	
Platelets 87		Exam-oriented Questions 111	
Properties 87		Clinical Case Scenario 112	
Total Number and its Variations 87		Blood 112	
Methods of Counting of Platelets 88		Recent Advances: Innate Immunity 113	
Development of Platelets 88			
Functions of Platelets 88			
Exam-oriented Questions 89			

- 2008 Nobel Prize for Physiology and Medicine: HIV Virus 114
 Notable Contributions: Diseases, Drugs, Immunity and Recovery 114

Section III Nerve and Muscle

- 20. Structure and Functions of Neuron** 118
- Introduction 118
 - Histological Structure 118
 - Neuron 118
 - Structure of Nerve Fibres 118
 - Neuroglia 120
 - Functions of Neuroglia 120
 - Axonal Transport and Nourishment of Neurons 121
 - Role of Neurotrophins in Neuronal Development 121
 - Exam-oriented Questions 121
- 21. Properties, Classification of Nerve Fibres and Nerve Action Potential** 122
- Introduction: Properties of Nerve Fibres 122
 - Excitability 122
 - Generation of Action Potential and Excitability of the Nerve 122
 - Ionic Basis of Excitability of Nerve 122
 - Excitability Depends upon Following Factors 124
 - Compound Action Potential 124
 - Conductivity 124
 - Factors Affecting Conductivity and Excitability 125
 - All-or-none Law 126
 - Refractory Period 126
 - Summation 126
 - Adaptation 126
 - Accommodation 126
 - Unfatigability 126
 - Heat Production in Nerve Fibre 126
 - Classification of Nerve Fibres 127
 - Mechanism of Conduction of the Nerve Impulse 127
 - Saltatory Conduction in the Myelinated Nerve Fibre 128
 - Physiological Properties of the Nerve Fibres 129
 - Degeneration and Regeneration of Nerve 129
 - Sunderland Classification of Nerve Injury 129
 - Regeneration 130
 - Degeneration and Regeneration of Nerve 130
 - Transneuronal Degeneration 130
 - Applied Physiology 130
 - Cathode Ray Oscilloscope (CRO) 130
 - Exam-oriented Questions 131
- 22. Neuromuscular Junction** 132
- Introduction 132
 - Anatomical Considerations 132
 - Neuromuscular Junction 132
 - Presynaptic Terminal 132
 - Synaptic Cleft 133
 - Post-synaptic Membrane 133
 - Synthesis of Acetylcholine in Motor Neuron 133
 - Sequence of Events in Neuromuscular Transmission 133
 - Neuromuscular Blockers 134
 - Applied Physiology 134
 - Exam-oriented Questions 135
- 23. Classification of Muscular Tissue** 136
- Introduction 136
 - Muscle Classification 136
 - Exam-oriented Question 137
- 24. Structure of Skeletal Muscle** 138
- Introduction 138
 - Distribution 138
 - Origin and Development 138
 - General Features 138
 - Histological Structure of Muscle Fibres 138
 - Myofibrils: Characteristic Features 138
 - Myosin Filaments 139
 - Actin Filament 140
 - Sarcotubular System 141
 - Blood Vessels, Lymphatics and Nerves of Skeletal Muscle 141
 - Ending of Muscle in Tendon 141
 - Exam-oriented Questions 142
- 25. Muscle Contraction** 143
- Introduction 143
 - Mechanism of Contraction 143
 - Molecular Mechanism of Muscle Contraction (Sliding Filament Theory of AF Huxley and HE Huxley) 143
 - Changes during Muscular Contraction 146
 - Role of Creatine Phosphate or Phosphagen and Adenosine Triphosphate (ATP) 146
 - Muscular Contraction and its Relationship with the Breakdown of ATP 147
 - Oxygen Utilization and CO₂ Production 147
 - Cori Cycle 147
 - Thermal Changes 148
 - Electrical Changes 148
 - Strength–Duration Relationship—Chronaxie and Rheobase 148
 - Muscular Disorders 149
 - Exam-oriented Questions 149
- 26. Properties of Skeletal Muscle** 150
- Introduction 150
 - Excitability and Contractility 150
 - Refractory Period 154
 - Tonicity 154
 - Conductivity 154
 - Extensibility and Elasticity 154
 - Contraction of Skeletal Muscle 154
 - Exam-oriented Questions 155
- 27. Cardiac Muscle** 156
- Introduction 156
 - Blood Vessels, Lymphatics and Nerves of Cardiac Muscle 158
 - Exam-oriented Questions 159
- 28. Smooth Muscles** 160
- Introduction 160
 - Histology 160
 - Contractile Mechanism 161
 - Properties of Plain (Smooth) Muscles 161
 - Excitability and Contractility 161
 - Functions of the Muscular Tissue 163
 - Rigor Mortis 163
 - Exam-oriented Questions 163
 - Clinical Case Scenario 165
 - Nerve Muscle 165
 - Recent Update: A Newly Discovered Muscle: The Tensor of the Vastus Intermedius 166

Section IV Cardiovascular System

- 29. Introduction to Cardiovascular System** 170
- Introduction 170
 - Anatomical Considerations of the Heart 171
 - Key Points 171
 - Valves of the Heart 172
 - Action of the Valves 173
 - Histology of the Cardiac Muscle 174
 - Valves of the Veins 176
 - Blood Vessels (Vasa Vasorum) 176
 - Factors that Maintain Circulation 176
 - Special Junctional Tissues 176
 - Sino-atrial Node (Keith and Flack, 1907) 177
 - Atrioventricular Node (Tawara, 1906) 177
 - Bundle of His 178
 - Bundle Branch 178
 - Purkinje Fibres 179
 - Exam-oriented Questions 179
- 30. Initiation and Spread of Cardiac Impulse** 180
- Origin of the Heartbeat 180
 - Initiation of Impulse and Localisation of Pacemaker 180
 - Conduction Over Atrial Muscle 180
 - Conduction Over AV Node 180
 - Conduction Over Bundle of His and the Right and Left Bundle Branches 181
 - Conduction through Purkinje Systems 181
 - Conduction through Ventricular Muscle 181
 - Heart Block 181
 - Exam-oriented Questions 182
- 31. Properties of Cardiac Muscle** 183
- Introduction 183
 - Rhythmicity 183
 - Excitability 183
 - Conduction 184
 - Contraction 185
 - All-or-none Response 185
 - Staircase Phenomenon 185
 - Refractory Period 185
 - Tone 185
 - Functional Syncytium 186
 - Exam-oriented Questions 186
- 32. Cardiac Cycle** 187
- Introduction 187
 - Cardiac Cycle Time 187
 - Summary of the Sequence of Events in Cardiac Cycle 190
 - Time Relations of the Various Events 191
 - Summary of the Time Relations 191
 - Exam-oriented Questions 192
- 33. Haemodynamics of Circulatory System and Pressure and Volume Changes during Cardiac Cycle** 193
- Haemodynamics of Circulatory System 193
 - Blood Flow through Vessel 193
 - Structural Overview 193
 - Overall Blood Flow in Circulation 193
 - Pattern of Blood Flow 193
 - Blood Flow Resistance (Peripheral Resistance) 194
 - Velocity of Blood Flow 194
 - Lumen of the Blood Vessel 194
 - Effect of Gravity on Mean Blood Pressure 194
 - Regulation of Blood Flow 195
 - Acute Control of Local Blood Flow 195
 - Long-term Control of Local Blood Flow 195
 - Role of Humoral Vasoconstrictors and Vasodilators 195
 - Pressure Volume Changes 196
 - Methods of Study 196
 - Pressure Changes 196
 - Intraventricular Pressure Changes and Assessment 196
 - Ventricular Systole 196
 - Ventricular Diastole 196
 - Intra-atrial Pressure Changes 197
 - Jugular Pressure Tracing (Venous Pulse) 197
 - Ventricular Volume Changes 198
 - Composite Representation of the Sequential Changes in the Pressure and Volume events in the Heart and Blood Vessels during the Cardiac Cycle Correlating with Phonocardiogram and Electrocardiogram 198
 - Heart Sounds 199
 - Exam-oriented Questions 201
- 34. Electrocardiogram** 202
- Introduction 202
 - Methods of Recording Electrocardiogram 202
 - Electrocardiographic Leads Used both Clinically and Experimentally 203
 - Unipolar Limb Leads 205
 - Augmented Unipolar Limb Leads 206
 - Normal ECG Recorded in Chest Leads 207
 - Significance of Various Leads and their Limitations 207
 - Electrocardiographic Appearances under Certain Cardiac Disorders 208
 - ECG Changes in Atrial Tachycardia, Atrial Flutter and Atrial Fibrillation 208
 - Ventricular Premature Beat or Extra Systole 209
 - Ventricular Paroxysmal Tachycardia 209
 - Ventricular Fibrillation 209
 - Wolff-Parkinson-White Syndrome 209
 - Myocardial Infarction 210
 - Myocardial Infarction: Coronary Ischaemia and Current Injury 210
 - Mean Electrical Axis of the Heart 210
 - Determination of Electrical Axis 210
 - Ventricular Conditions that may Cause Axis Deviation 211
 - Exam-oriented Questions 212
- 35. Innervations of Heart and Heart Rate** 213
- Introduction 213
 - Nerves of the Heart and their Action 213
 - Vagus Nerves 213
 - Tonic Action of the Vagus Nerves 214
 - Sympathetic Nerves 214
 - Cardiac Centres 214
 - Heart Rate 214
 - Factors Affecting Heart Rate 214
 - Regulation of Heart Rate 215
 - Applied Physiology 217
 - Exam-oriented Questions 217
- 36. Cardiac Output** 218
- Introduction 218
 - Normal Values: 5–6 Litres/Minute 218
 - Important Terminology and Definitions 218
 - Distribution of Cardiac Output 218
 - Cardiac Reserve 218
 - Factors Affecting Cardiac Output 219
 - Control of Cardiac Output 219
 - Preload Depends on Ventricular Filling and Venous Return 219

Cardiac Contractility	219
Afterload	220
Methods of Measuring Cardiac Output	221
Dye Method: Stewart and Hamilton's Dye Dilution Method	221
Employing for Measuring Cardiac Output	
Fick Principle Using O ₂ and CO ₂	221
Physical Method: Ballistocardiography	222
Thermo-dilution Method (Cold Saline Method)	222
Applied Physiology	222
Doppler Echocardiography	222
Calculation	222
Exam-oriented Questions	222

37. Blood Pressure 223

Introduction	223
Basal Blood Pressure	223
Physiological Variations	223
Significance of Blood Pressure	224
Systolic Pressure	224
Diastolic Pressure	224
Pulse Pressure	224
Physiological Significance of Blood Pressure	224
Measurement and Recording of Blood Pressure	224
Arterial Blood Pressure	224
Venous Pressure	226
Determinants of Blood Pressure	226
Adjustment of Blood Pressure	226
Efferent Pathways of this Self-adjustment or Homoeostasis of Blood Pressure	227
Vasomotor System	227
Afferent Pathways	228
Role of Sino-aortic Mechanism in the Regulation of Normal Blood Pressure	228
Sino-aortic Mechanism	228
Chemoreceptors Location	229
Aortic Bodies	230
Vascular Receptors other than Sino-Aortic for the Control of Blood Pressure and Flow	230
As Chemoreceptors	231
Mechanism of Regulation of Blood Pressure	231
Short-term Regulating Mechanisms	231
Intermediate Mechanism of Regulation of Blood Pressure	232
Long-term Regulation of Blood Pressure	232
Role of other Hormone in Regulation of Blood Pressure	232
Role of Humoral Vasoconstrictors and Vasodilators	232
Humoral Vasoconstrictors	232
Humoral Vasodilators	233
Chemical Control of Blood Pressure Influenced by Vasomotor Mechanism	233
Exam-oriented Questions	233

38. Velocity of Blood Flow and Radial Pulse 234

Introduction	234
Velocity of Blood	234
Methods of Measurement of Velocity of Blood	234
Radial Pulse	234
Pressure Pulse	235
Recording of Radial Pulse	235
Clinical Features of Radial Pulse	235
Special Varieties of Pulse	235
Applied Physiology	236
Exam-oriented Questions	236

39. Regional Circulation 237

Introduction	237
Coronary Circulation	237

Anatomical Considerations	237
Venous Drainage	238
Methods of Study	238
Normal Values	238
Variations of Coronary Inflow during Different Phases of Cardiac Cycle	239
Coronary Inflow	239
Factors Influencing Coronary Circulation	240
Circulatory Status of the Cardiac Muscle under Certain Diseased Conditions	241
Aortic Stenosis	241
Pulmonary Hypertension	241
Aortic Insufficiency	241
Mitral Stenosis	241
Aortic Coarctation	241
Hypertensive Cardiovascular Disease	241
Ischaemic Heart Disease	241
Coronary Spasms and Intercoronary Reflexes	241
Pathological Physiology of Angina Pectoris and Acute Myocardial Infarction	241
Cerebral Circulation	241
Anatomical Considerations	241
Method of Study: Nitrous Oxide Method: Fick Principle	242
Vasomotor Supply	242
Normal Values of Cerebral Circulation	242
Regulation of Cerebral Circulation	243
Existence of Auto-regulation of Cerebral Blood Flow	243
Key Points	243
Factors Controlling Cerebral Circulation	243
Cerebrovascular Resistance	243
Pulmonary Circulation	244
Anatomy of Circulation	244
Method of Recording Pulmonary Arterial Pressure	244
Vasomotor Supply	244
Normal Values of Pulmonary Circulation	244
Functions of Pulmonary Circulation	245
Control of Pulmonary Circulation	245
Peculiarities of Pulmonary Circulation	246
Pulmonary Vascular Reflex	246
Circulatory Status in Different Cardiopulmonary Diseases	246
Mitral Stenosis	246
Emphysema	246
Pulmonary Embolism	246
Atelectasis	246
Removal of Lung	247
Diffuse Sclerosis of Lung Vessels	247
Pulmonary Fibrosis	247
Hepatic Circulation	247
Vascular Arrangement	247
Vasomotor Supply	247
Normal Values of Hepatic Circulation	247
Factors Modifying Hepatic Circulation	248
Peculiarities of Hepatic Circulation	248
Splenic Circulation	249
Control of Blood Flow	249
Renal Circulation	249
Capillary Circulation	249
Histology	249
Methods of Study of Capillary Circulation	249
Vasomotor Supply	249
Control of Capillary Circulation	250
Interchange in the Capillary Area	251
Cutaneous Circulation	251
Anatomy of Cutaneous Circulation	251
Rate of Blood Flow	251

Regulation of Blood Flow: Nervous Control	251
Vascular Response of Skin	252
Auto-regulation of Skin Blood Flow	252
Normal Colour of the Skin	252
Skeletal Muscle Circulation	253
Vascular Arrangement in Skeletal Muscle	253
Rate of Blood Flow Through Muscle	253
Basal Tone of Arterioles	253
Control of Skeletal Muscle Blood Flow	253
Exam-oriented Questions	254

40. Physiology of Exercise **255**

Introduction	255
Muscular Exercise	255
Changes in Cardiovascular System	256
Heart Rate Changes during Exercise	256
Circulatory Status during Exercise	257
Changes in Respiration	258
Blood Cell Changes during Exercise	258
Body Temperature	258
Body Fluid Changes during Exercise	259
Kidney Function in Exercise	259
Digestive System	259
Endocrine Status	260
Aerobic Training	260
Isometric and Isotonic Exercises	260
Cardiovascular and Cardiorespiratory Response to Isometric Exercise	260
Sedentary Lifestyle and Health Implication	261
Introduction	261
Health Implication in Sedentary Lifestyle	261
Role of Nutrition in Exercise	262
Over-exercising and Ill Effects on Health	262
Cardiorespiratory Changes under Different Environmental Conditions (Heat and Cold)	262
Exam-oriented Questions	262

41. Applied Cardiovascular Physiology: Haemorrhage, Heart Failure, Hypotension, Hypertension and Shock **263**

Haemorrhage	263
Compensatory Changes after Haemorrhage	263
Heart Failure	264
Types of Heart Failure	264
Role of Compensatory Mechanisms in Heart Failure	265
Management and Prevention	265
Hypotension	265
Orthostatic Hypotension	265
Hypertension	265
Signs and Symptoms	265
Pathophysiology of Hypertension	266
Shock	267
Types of Shock	267
Clinical Features of Shock	267
Stages of Shock	267
Physiology of Treatment in Shock	270
Applied Physiology: Cardiovascular System	270
Cardiac Disorders	270
Exam-oriented Questions	271
Clinical Case Scenario	272
Cardiovascular System	272
Important Cardiovascular Research Study: Framingham Heart Study	273
First Cardiac Catheterization and Future Development of Technique	273
Open-heart Surgery	273
Recent Advances in Cardiovascular Research	273

Section V Respiratory System

42. Functional Organization of Respiratory System **276**

Structure of the Respiratory Tract	276
Trachea	276
Functions of Respiratory Tract	276
Reflexes Help in Clearing Irritating agents from Respiratory Passage	277
Respiratory Units	277
Broncho-pulmonary Anastomosis	277
Pulmonary Alveoli	277
Respiratory Functions of Lung	278
Pleural Cavity and Intra-pleural Pressure	279
Intra-pleural Pressure	279
Surface Tension at the Fluid–Air Interface within the Alveoli and the Role of Surfactant	279
Pressure Changes in the Pleural Cavity and its Relation to Volume Changes in the Lungs	280
Exam-oriented Questions	280

43. Mechanics of Breathing **281**

Introduction	281
Diaphragm	281
Intercostal Muscles	282
Motion of the Ribs during Inspiration and Expiration	282
Accessory Muscles of Respiration	283
Resistance to Breathing	283
Elastic Resistance	283
Lung Compliance	283
Measurement of Lung Compliance and Pressure–Volume Curve	283
Viscous or Non-elastic Resistance	284
Elastic Forces and Characteristics of Compliance Pressure–Volume Curve	284
Elastic Forces of Lung Tissue	284
Alveolar Radius and its Relation to Surface tension	284
Energy Utilization for Respiration	285
Applied Physiology	285
Exam-oriented Questions	286

44. Pulmonary Volumes and Capacities (Spirometry) **287**

Introduction	287
Lung Volumes	288
Tidal Volume (TV = 500 ml)	288
Respiratory Minute Volume (RMV)	288
Inspiratory Reserve Volume (IRV)	288
Expiratory Reserve Volume (ERV)	288
Residual Volume (RV)	288
Lung Capacities	288
Inspiratory Capacity (IC)	288
Functional Residual Capacity (FRC)	288
Total Lung Capacity (TLC)	288
Vital Capacity (VC)	288
Forced Expiratory Volume (FEV)	289
Functional Residual Capacity (FRC)	290
Forced Vital Capacity (FVC)	291
Forced Expiratory Volume in 1 (FEV ₁) Second	291
FEV ₁ /FVC Ratio (FEV ₁ %)	291
Forced Expiratory Flow (FEF)	291
Peak Expiratory Flow (PEF)	291
Breathing Reserve (BR)	292
Applied Physiology: Obstructive and Restrictive Lung Disease	292
Exam-oriented Questions	292

- 45. Alveolar Ventilation and Gases Exchange in Lungs** **293**
- Alveolar Ventilation 293
 - Respiratory 'Dead Space' 293
 - Definition 293
 - Measurement of Dead Space Volume 293
 - Nitrogen Meter Method 293
 - Intrapulmonary Gas-mixing or Even Distribution of Inspired Air 294
 - Methods of Detection of Uneven Ventilation 294
 - Alveolar Air 294
 - Composition of Alveolar Air 294
 - Partial Pressure of Gases in Inspired Air, Expired Air and Alveolar Air 295
 - Effect of Voluntary Hyperpnoea on Alveolar Air 295
 - Breath-holding Time 295
 - Effects of High Altitude on Alveolar Oxygen 296
 - Factors Controlling Alveolar $p\text{CO}_2$ 296
 - Anatomical Shunt 296
 - Physiological Shunt 297
 - Applied Physiology 297
 - Hyperventilation and Hypoventilation 297
 - Exam-oriented Questions 297
- 46. Ventilation and Perfusion in Lungs** **298**
- Diffusion 298
 - Factors Controlling Diffusion 299
 - Summary of Factors Affecting Diffusion through Fluids and Respiratory Membrane 299
 - Diffusion through Respiratory Membrane 299
 - Pulmonary Diffusing Capacity for O_2 (DO_2) 299
 - Diffusion of CO_2 300
 - Perfusion 300
 - Applied Physiology 300
 - Exam-oriented Questions 300
- 47. Transport of Oxygen and Carbon Dioxide in Blood** **301**
- Introduction 301
 - Oxygen Transport 301
 - Percentage Saturation of Haemoglobin 302
 - Dissociation Curve for Haemoglobin 302
 - Nature of the Curve 303
 - Explanation of the Sigmoid Shape of the Curve 303
 - Oxygen Exchange in the Lungs 304
 - Oxygen Transport in the Tissues 304
 - Applied Physiology 305
 - Carbon Dioxide Transport 305
 - CO_2 Content and Tension of Blood 305
 - Transport 305
 - Carbon Dioxide Dissociation Curves 306
 - Summary: Transport of Oxygen and Carbon Dioxide in Blood 308
 - Exam-oriented Questions 308
- 48. Regulation of Respiration** **309**
- Introduction 309
 - Respiratory Centre 309
 - Dorsal Respiratory Group (DRG) of Neurons and Inspiratory Ramp Signals 310
 - Ventral Respiratory Group of Neurons 310
 - Mechanism of Rhythmic Respiration 310
 - Role of Abdominal Muscles in Respiration 310
 - Role of Reflex in Respiration 310
 - Voluntary Control of Respiration 313
 - Chemical Control of Respiration 313
 - CO_2 and Respiration 313
 - Nervous Factors Influencing Respiration in Exercise 315
 - Periodic Breathing 315
 - Cheyne-Stokes Breathing 315
 - Factors Involved in Development of Cheyne-Stokes Breathing Pattern 315
 - Mechanism of Cheyne-Stokes Breathing 317
 - Kussmaul's Breathing 317
 - Exam-oriented Questions 317
- 49. Hypoxia** **318**
- Definition 318
 - Classification of Hypoxia 318
 - Anoxic Hypoxia or Arterial Hypoxia 318
 - Causes of Arterial Hypoxia 318
 - Anaemic Hypoxia 319
 - Stagnant Hypoxia or Hypokinetic Hypoxia 319
 - Histotoxic Hypoxia 319
 - Altitude Hypoxia 319
 - Oxygen Therapy in Hypoxia 320
 - Dyspnoea 321
 - Dyspnoea due to Alteration in Chemical Composition of Blood 321
 - Factors Affecting Diffusion of Gases Across the Alveolo-capillary Membrane (Alveolo-capillary Block Syndrome) 321
 - Excessive Work of the Respiratory Muscles 322
 - Applied Physiology 322
 - Psychogenic or Emotional Dyspnoea 322
 - Exam-oriented Questions 322
- 50. Compressed Air Sickness and Deep Sea Diving** **323**
- Dysbarism (Caisson Disease) 323
 - Exam-oriented Question 323
- 51. Respiration in Abnormal Conditions** **324**
- Asphyxia 324
 - Definition 324
 - Classification 324
 - Essential Conditions of Asphyxia 324
 - Hyperpnoea 324
 - Causes 324
 - Effects of Voluntary Hyperpnoea 324
 - Orthopnoea 326
 - Cyanosis 326
 - Factors Causing Cyanosis 326
 - Applied Physiology 326
 - Exam-oriented Questions 327
- 52. Artificial Respiration or Resuscitation** **328**
- Methods of Artificial Respiration 328
 - Manual Methods 328
 - Sylvester's Method 329
 - Holger-Nielsen Method 329
 - Mouth-to-mouth Method 329
 - Eve's Rocking Method 329
 - Instrumental Method 329
 - Drinker's Method 329
 - Resuscitator 329
 - In the Newborn Baby 329
 - Exam-oriented Questions 331
- 53. Acclimatisation** **332**
- Compensatory Changes at Moderately High Altitude 332
 - Changes in Acclimatisation 332
 - Natural Acclimatisation of Natives Residing at High Altitude 332
 - Acute Mountain Sickness 333

Mountaineering	333
Atmosphere High Altitude Physiology	334
Hypoxia	334
Problem Faced by Aviators	334
Radiation Hazards	335
Dysbarism at High Altitude (Decompression Sickness)	335
Explosive Decompression	335
Effect of Centrifugal Acceleratory Forces	336
Protection of Body against Centrifugal Acceleratory Forces	336
Parachute Jump	337
Weightlessness in Space (Zero-G State)	338
Exam-oriented Questions	338

54. Underwater Physiology **339**

Introduction	339
Nitrogen	339
Oxygen	339
Mechanism of Oxygen Poisoning	340
Carbon Dioxide	340
Helium	340
Underwater Respiration	340
SCUBA Diving	341
Exam-oriented Question	341

55. Vocalisation and Basic Life Support (BLS) **342**

Vocalisation	342
Articulation and Resonance	343
Basic Life Support (BLS)	343
Basic Life Support Sequence	343
Collapsed Victim	343
CAB	344
Compressions	344
Automated External Defibrillators (AEDs)	344
Airway and Ventilations	345
Opening the Airway	345
Ventilations	345
Choking	346
Adult Choking Sequence	347
Unresponsive Victim	347
Chain of Survival	347
Exam-oriented Questions	347
Clinical Case Scenario	348
Respiratory System	348
Recent Advances	348

Section VI Gastro-intestinal Tract

56. General Outline of Digestive System **350**

Introduction	350
Anatomical Consideration	350
Histological Structure	351
Innervation of the Digestive Tract	351
Functions of the Digestive System	352
Histology of Tongue	352
Glands	355
Nerve Supply	355
Functions	355
Salivary Glands	355
Histology of Salivary Glands	355
Pharynx or Throat Cavity	357
Oesophagus	357
Histology	357
Stomach	358
Histology of Stomach	359
Functions of Stomach	360
Small Intestine	360
Vermiform Appendix	362

Large Intestine	362
Rectum	362
Anal Canal	362
Brief Summary of the Chief Identifying Features of Different Parts of the Digestive Tract	362
Exam-oriented Questions	362

57. Digestive Juices **363**

Introduction	363
Saliva	363
Characteristics	363
Composition	363
Functions	363
Gastric Juice	364
Composition	364
Characteristics	364
Functions	364
Pancreatic Juice	364
Characteristics	364
Succus Entericus	365
Characteristics	365
Composition	365
Intestinal Juice Enzymes	365
Carbohydrate Splitting	365
Functions	365
Biles	365
Introduction	365
Composition of Bile	366
Functions of Bile	366
Bile Salts	367
Variety and Chemistry	367
Synthesis of Bile Salts	367
Enterohepatic Circulation and Fate of Bile Salts	367
Functions of Bile Salts	367
Bile Pigments	368
Chemistry and Varieties	368
Origin and Formation	368
Site of Formation, Circulation and Fate	368
Exam-oriented Questions	370

58. Mechanism of Secretion of Various Digestive Juices **371**

Introduction	371
Saliva	371
Nerve Supply of Salivary Glands	371
Significance of Double Nerve Supply	372
Salivary Secretion and Reflexes	372
Reflex Control of Rate of Flow and Composition of Saliva	373
Disturbances of Salivary Secretion	373
Gastric Secretions	373
Cephalic Phase	374
Gastric Phase	375
Gastric Phase Characteristic Features	375
Intestinal Phase	375
Action of Other Hormones on Gastric Secretion	376
Interrelation between the Different Phases	377
Gastric Function Test	377
Investigation of Gastric Secretion in Man	377
Other Functional Tests	378
Origin and Character of the Important Constituents of Gastric Juice	379
Hydrochloric Acid	379
Applied Physiology: Peptic Ulcer	379
Pepsin	380
Mucin	380
Intrinsic Factor	380

Neurotrophic Factor	380
Pancreas	380
Development	381
Mechanism of Pancreatic Secretions	381
Nervous Phase	381
Chemical Phase	382
Influence of Various Foodstuffs on Pancreatic Secretion	383
Applied Physiology	383
Liver	383
Anatomy	383
Gall Bladder: Structure and Functions	383
Mechanism of Bile Secretion	384
Mechanism of Secretion	384
Mechanism of Expulsion of Bile	385
Factors Controlling Movements of Gall Bladder	385
Functions of Gall Bladder	386
Applied Physiology	386
Mechanism of Secretion of Succus Entericus (Intestinal Juice)	386
Mechanism	387
Applied Physiology	387
Summary of Secretions of the Various Digestive Juices	387
Exam-oriented Questions	388
59. Movements of Alimentary Canal	389
Introduction	389
Facts about Movement	389
Cause of Movements	389
Relation with Degree of Activity	389
Deglutition (Swallowing)	389
Common Disturbances in the Swallowing	391
Movements of Stomach	391
Applied Physiology	393
Vomiting (Emesis)	393
Movements of Small Intestine	395
Frequency	395
Movements of Villi	397
Applied Physiology	397
Movements of Large Intestine	397
Functions of Large Intestine	398
Rate of Progress of Barium Meal	398
Applied Physiology—Large Intestine	400
Defaecation	400
Mechanism	400
Exam-oriented Questions	400
60. Digestion and Absorption of Foodstuffs	401
Introduction	401
Digestion of Carbohydrates	401
Introduction	401
Different forms of Carbohydrates	401
Digestion of Proteins	402
Introduction	402
Different Forms of Protein	403
Digestion of Nucleoprotein	403
Digestion of Casein	403
Digestion of Milk	404
Digestion of Collagen and Gelatin	404
Digestion of Mucin	404
Digestion of Lipids	404
Digestion in the Pancreatic Juice	404
Absorption	405
Definition	405
Absorption of Carbohydrates	405
Absorption of Proteins	405

Fats Absorption	406
Process of Absorption	406
Water Absorption	406
Absorption of Electrolytes	406
Faeces	407
Contents and Characteristics	407
Exam-oriented Questions	407
61. Gastro-intestinal Hormones	408
Introduction	408
Gastrin	408
Cholecystokinin (CCK) or Pancreozymin	409
Regulation of Secretion of Cholecystokinin	409
Glucagon-like Peptide-1	409
Gastric Inhibitory Polypeptide (GIP)	409
Vasoactive Intestinal Peptide (VIP)	409
Urogastrone	409
Villikinin	409
Enterocrinin	410
Motilin	410
Neurotensin	410
Somatostatin	410
Gastrin Releasing Peptide	410
Ghrelin	410
Peptide YY	410
Substance P	410
Bombesin	410
Exam-oriented Questions	410
Clinical Case Scenario	411
Gastrointestinal Tract	411
Recent Advances: Treatment of Peptic Ulcer	411
Recent Advances: Capsule Endoscopy	412

Section VII Renal Physiology

62. Functional Anatomy of Excretory System	414
Introduction	414
Kidneys	414
Characteristic Features	414
Nephron	415
Uriferous Tubules	416
Types of Nephrons	416
Renal Tubules	419
Proximal Convoluted Tubule (PCT)	419
Henle's Loop	419
Distal Convoluted Tubule (DCT)	420
Collecting Tubule	421
Juxtaglomerular Apparatus	421
Regulation of Renin Secretion	422
Renal Circulation	423
Peculiarities	423
Peculiarities of Renal Circulation	425
Exam-oriented Questions	426
63. Urine Formation by Kidneys: Renal Blood Flow and their Control	427
Introduction	427
Autoregulation of Renal Blood Flow	427
Nervous Control	428
Other Factors	429
Blood Glucose Level	429
Hormones Influencing Renal Functions	429
Measurement of Renal Blood Flow	429
Functions of Kidney and Glomerulus	430
Functions of Kidney	430
Exam-oriented Questions	430

64. Urine Formation by the Kidney: Glomerular Filtration Rate and their Control	431		
Introduction	431		
Key Points	431		
Glomeruli as Ultrafilter	433		
Functions of Glomerulus	433		
Applied physiology: Chronic Kidney Disease and Glomerular Filtration Rate	435		
65. Tubular Reabsorption and Tubular Secretion (Urine Formation): Water and Electrolytes Balance and Counter-current Mechanism	436		
Introduction	436		
Methods of Study of Tubular Functions	436		
Selective Reabsorption	436		
Glucose	436		
Water	437		
Sodium and Chloride	439		
Potassium	439		
Bicarbonate	441		
Phosphate	442		
Reabsorption of other Substances	442		
Tubular Secretion	442		
Formation of Some New Substances	442		
Exam-oriented Questions	444		
66. Renal Function Test, Urine, Urinary Characteristic and its Mechanism of Formation	445		
Introduction	445		
Assuming	445		
I. Test for measurement of GFR	446		
Inulin Clearance (A Measure of Glomerular Filtration Rate)	446		
Creatinine Clearance Test	446		
II. Test to Measure Excretory Function	446		
Urea Clearance Test (Van Slyke)	446		
III. Test to Estimate Tubular Secretion Capacity	447		
IV. Test to Measure Renal Blood Flow	447		
Urine, Urinary Characteristic and its Mechanism of Formation	447		
Introduction	447		
Other Characteristics	448		
Colour	448		
Reaction	448		
Specific Gravity	448		
Turbidity	448		
Odour	448		
Osmotic Pressure	448		
Composition of Urine	448		
Normal Constituents of Urine	448		
Abnormal Constituent of Urine	449		
Protein	449		
Glucose	450		
Ketone Bodies	450		
Presence of Blood in Urine	450		
Pigments	450		
Calculi and Casts	450		
Pus	450		
Hormones	450		
Factors Affecting Formation of Urine	451		
Reaction of Urine	451		
Mechanism of Regulation of Blood Reaction by the Kidneys	451		
Bicarbonate Mechanism	451		
Phosphate Mechanism	452		
Ammonia Mechanism	453		
Elimination of Acids	453		
Elimination of Alkalis	454		
Glycosuria	454		
Glycosuria due to Hyperglycaemia	454		
Glycosuria due to Less Tubular Reabsorption	455		
Factors Controlling Volume of Urine	455		
Abnormal Volume of Urine	456		
Applied Physiology	456		
Exam-oriented Questions	457		
67. Micturition	458		
Introduction	458		
Structure of Urinary Bladder	458		
Mechanism of Filling of Bladder	459		
Mechanism of Micturition	459		
Key Features	459		
Micturition Reflex	460		
Centres of Micturition	461		
Effect of Lesion of Autonomic Nerves	461		
Applied: Pathological Conditions involving Bladder Control Physiology	462		
Artificial Kidney	463		
Exam-oriented Questions	463		
68. Skin, Body Temperature and its Regulation	464		
Introduction	464		
Structure	464		
Epidermis	464		
Dermis (Cutis Vera or True Skin)	465		
Functions of Skin	465		
Glands in the Skin	466		
Mechanism of Secretion of Sweat	466		
Composition of Sweat	467		
Sebaceous Glands	467		
Composition of Sebum	467		
Control	467		
Special Structures of Skin	469		
Nails (Ungues)	469		
Hair (Pili)	469		
Body Temperature and its Regulation	470		
Introduction	470		
Factors Affecting Body Temperature	470		
Regulation of Body Temperature	471		
Mechanisms of Heat Production (Thermogenesis)	471		
Mechanisms of Heat Loss (Thermolysis)	472		
Nervous System and Thermotaxis	472		
Interaction of Central and Peripheral Factors	473		
Role of Endocrines	474		
Temperature Regulation in the Newborn Infant	474		
Mechanism of Regulation of Body Temperature	474		
Decreased Body Temperature and Responses	474		
Other Factors	474		
Effects of Exposure to High and Low Atmospheric Temperature	474		
Physiological Alterations of Body Mechanisms on Exposure to Hot Atmosphere	474		
Life in Deserts	475		
Physiological Alterations of Body Mechanisms on Exposure to Cold Atmosphere	476		
Effect of Sudden Change of Atmospheric Temperature	476		
Pyrexia	476		
Physiological Responses due to Pyrexia (Fever)	476		
Hypothermia	476		
Physiological Responses to (Deliberate) Hypothermia	476		

Applied Physiology 477
Exam-oriented Questions 478

69. Regulation of Reaction of Blood and Disturbances in Acid–Base Regulation 479

Introduction 479
Respiratory H⁺ 479
Metabolic H⁺ 479
Acid–base, Hydrogen Ion Concentration and pH 479
Acid and Base 479
Hydrogen Ion Concentration 480
pH 480
Calculation of pH 480
Calculation of [H⁺] Ion Concentration 480
The pH Scale 480
Physiological Importance of Maintenance of pH 481
Buffers, Lungs and Kidney 482
Buffer Action 482
Bicarbonate Buffer System 482
Bicarbonate Buffer System and its importance as Extracellular Buffer 482
Role of Kidney and Lung 482
Role of Respiration in Acid–Base Balance 484
Role of Kidneys in Acid–Base Balance 484
Disturbances in Acid–Base Regulation 485
Respiratory Acidosis 485
Definition 485
Pathophysiology 485
Compensatory Mechanism 485
Metabolic Alkalosis 485
Definition 485

Respiratory Compensation 486
Renal Compensation 486
Metabolic Acidosis 486
Definition 486
Compensation 486
Respiratory Alkalosis 486
Definition 486
Renal Compensation 487
Assessment of the Acid–Base Status 487
Exam-oriented Questions 487
Clinical Case Scenario 488
Kidney 488
Applied Physiology 489
Peritoneal Dialysis 489
Renal Transplantation 489

Multiple Choice Questions

General Physiology 492
Blood 496
Nerve and Muscle 500
Cardiovascular System 504
Respiratory System 508
Gastro-intestinal Tract 511
Renal System 515
References 519

Appendix A1–A5

Index I1–I6