

Contents

Preface to the Second Edition IX

From the Preface to the First Edition X

Contributors XI

1 Introduction and General Aspects 1

Gerhard Michal and Dietmar Schomburg

- 1.1 Organization of This Book 1
 - 1.1.1 Conventions Used in This Book 3
 - 1.1.2 Common Abbreviations 3
- 1.2 Carbohydrate Chemistry and Structure 4
 - 1.2.1 Structure and Classification 4
 - 1.2.2 Glycosidic Bonds 5
- 1.3 Amino Acid Chemistry and Structure 5
 - 1.3.1 Structure and Classification 6
 - 1.3.2 Peptide Bonds 6
- 1.4 Lipid Chemistry and Structure 6
 - 1.4.1 Fatty acids 6
 - 1.4.2 Acylglycerols and Derivatives 7
 - 1.4.3 Waxes 7
 - 1.4.4 Glycerophospholipids 7
 - 1.4.5 Plasmalogens 7
 - 1.4.6 Sphingolipids 7
 - 1.4.7 Steroids 8
 - 1.4.8 Lipoproteins 8
- 1.5 Physico-Chemical Aspects of Biochemical Processes 8
 - 1.5.1 Energetics of Chemical Reactions 8
 - 1.5.2 Redox Reactions 9
 - 1.5.3 Transport Through Membranes 9
 - 1.5.4 Enzyme Kinetics 10

2 The Cell and Its Contents 14

Gerhard Michal and Dietmar Schomburg

- 2.1 Classification of Living Organisms 14
- 2.2 Structure of Cells 14
 - 2.2.1 Prokaryotic Cells 14
 - 2.2.2 General Characteristics of Eukaryotic Cells 15
 - 2.2.3 Special Structures of Plant Cells 17
 - 2.2.4 Special Structures of Animal Cells 18
- 2.3 Protein Structure and Function 18
 - 2.3.1 Levels of Organization 19
 - 2.3.2 Protein Function 21
- 2.4 Enzymes 21
 - 2.4.1 Catalytic Mechanism 21
 - 2.4.2 Isoenzymes 23
 - 2.4.3 Multienzyme Complexes 23
 - 2.4.4 Reaction Rate 23
 - 2.4.5 Classification of Enzymes 23
- 2.5 Regulation of the Enzyme Activity 24
 - 2.5.1 Regulation of the Quantity of Enzymes 24
 - 2.5.2 Regulation of the Activity of Enzymes 24
 - 2.5.3 Site of Regulation 26
- 2.6 Nucleic Acid Structure 26
 - 2.6.1 Components of Nucleic Acids 26
 - 2.6.2 Properties of RNA Chains 27
 - 2.6.3 Properties of DNA Chains 27
 - 2.6.4 Compaction Levels of DNA Chains 28
- 2.7 Genetic Code and the Flow of Information 30
 - 2.7.1 From DNA to RNA 30
 - 2.7.2 From Nucleic Acids to Proteins – The Genetic Code 30
 - 2.7.3 Influence of Errors 31

- 2.8 Polymeric Carbohydrates 31
 - 2.8.1 Polymeric Carbohydrates in Energy Storage 31
 - 2.8.2 Polymeric Carbohydrates as Structural Elements 32

2.9 Glycosylated Proteins and Peptides 32

- 2.9.1 Glycoproteins 33
- 2.9.2 Proteoglycans 33
- 2.9.3 Peptidoglycans 35

2.10 Lipid Aggregates and Membranes 35

3 Metabolism 37

3.1 Carbohydrate Metabolism and Citrate Cycle 37

Röbke Wünschiers

- 3.1.1 Glycolysis and Gluconeogenesis 37
- 3.1.2 Polysaccharide Metabolism 42
- 3.1.3 Pyruvate Turnover and Acetyl-Coenzyme A 46
- 3.1.4 Di- and Oligosaccharides 48
- 3.1.5 Metabolism of Hexose Derivatives 48
- 3.1.6 Pentose Metabolism 51
- 3.1.7 Amino Sugars 54
- 3.1.8 Citrate Cycle 55
- 3.1.9 Glyoxylate Metabolism 57

3.2 Amino Acids and Derivatives 58

Röbke Wünschiers

- 3.2.1 Nitrogen Fixation and Metabolism 58
- 3.2.2 Glutamate, Glutamine, Alanine, Aspartate, Asparagine and Ammonia Turnover 59
- 3.2.3 Proline and Hydroxyproline 62
- 3.2.4 Serine and Glycine 62
- 3.2.5 Lysine, Threonine, Methionine, Cysteine and Sulfur Metabolism 65
- 3.2.6 Leucine, Isoleucine and Valine 72
- 3.2.7 Phenylalanine, Tyrosine, Tryptophan and Derivatives 74
- 3.2.8 Histidine 79
- 3.2.9 Urea Cycle, Arginine and Associated Reactions 80

3.3 Tetrapyrroles 82

Martina Jahn and Dieter Jahn

- 3.3.1 Pathways for the Biosynthesis of Tetrapyrroles 82
- 3.3.2 Heme and Cytochrome Biosynthesis 86
- 3.3.3 Linear Tetrapyrroles 87
- 3.3.4 Biosynthesis of Chlorophylls 90
- 3.3.5 Biosynthesis of Cobalamins 91
- 3.3.6 Siroheme Biosynthesis 91

3.4 Lipids and Glycolipids 93

Röbke Wünschiers

- 3.4.1 Fatty Acids and Acyl-CoA 93
- 3.4.2 Triacylglycerols (Triglycerides) 98
- 3.4.3 Phospholipids 100
- 3.4.4 Glycolipids 104

3.5 Steroids and Isoprenoids 107

Röbke Wünschiers

- 3.5.1 Cholesterol 107
- 3.5.2 Hopanoids, Steroids of Plants and Insects 110
- 3.5.3 Isoprenoids 111
- 3.5.4 Steroid Hormones 114
- 3.5.5 Gestagen 115
- 3.5.6 Androgens 116
- 3.5.7 Estrogens 117
- 3.5.8 Corticosteroids 119
- 3.5.9 Bile Acids 121

3.6	Nucleotides and Nucleosides	124	4.1.3	Bacterial Protein Synthesis	214
	<i>Röbke Wünschiers</i>		4.1.4	Degradation of Nucleic Acids	217
3.6.1	Purine Nucleotides and Nucleosides	124	4.2	Protein Biosynthesis in Eukarya	219
3.6.2	Pyrimidine Nucleotides and Nucleosides	130		<i>Röbke Wünschiers</i>	
3.7	Cofactors and Vitamins	133	4.2.1	Eukaryotic Transcription	219
	<i>Ida Schomburg</i>		4.2.2	Regulation of Eukaryotic Transcription	226
3.7.1	Retinol (Vitamin A)	133	4.2.3	Eukaryotic Translation	228
3.7.2	Thiamin (Vitamin B ₁)	134	4.2.4	Translational Regulation	231
3.7.3	Riboflavin (Vitamin B ₂), FMN and FAD	135	4.2.5	mRNA Degradation	231
3.7.4	Pyridoxine (Vitamin B ₆)	136	4.3	Cell Cycle in Eukarya	232
3.7.5	Cobalamin (Coenzyme B ₁₂), Vitamin B ₁₂	137		<i>Stefan Ries</i>	
3.7.6	Folate and Pterines	138	4.3.1	Core Components of the Cell Cycle Machinery	232
3.7.7	Pantothenate, Coenzyme A and Acyl Carrier Protein (ACP)	141	4.3.2	Cell Cycle Regulation in Yeast	234
3.7.8	Biotin	141	4.3.3	G ₁ to S Transition in Mammalian Cells	234
3.7.9	Nicotinate, NAD ⁺ and NADP ⁺	143	4.3.4	G ₂ to M Transition in Mammalian Cells	235
3.7.10	Ascorbate (Vitamin C)	145	4.3.5	Mitosis in Mammalian Cells	235
3.7.11	Calciferol (Vitamin D)	146	4.3.6	Cell Cycle Checkpoints	236
3.7.12	Tocopherol (Vitamin E)	148	4.4	Posttranslational Modification of Proteins	238
3.7.13	Phylloquinone and Menaquinone (Vitamin K)	148		<i>Röbke Wünschiers</i>	
3.7.14	Other Compounds	149	4.4.1	Protein Processing in the Endoplasmic Reticulum	238
3.8	Nucleic Acid Metabolism in Bacteria	149	4.4.2	Glycosylation Reactions in the Golgi Apparatus	241
	<i>Susanne Peifer and Elmar Heinzle</i>		4.4.3	Terminal Carbohydrate Structures of Glycoconjugates	243
3.8.1	Bacterial DNA Replication	149	4.5	Protein Folding, Transport/Targeting and Degradation	244
3.8.2	Bacterial DNA Repair	151		<i>Petra Dersch</i>	
3.8.3	Degradation of Nucleic Acids	156	4.5.1	Folding of Proteins	244
3.9	Nucleic Acid Metabolism in Eukarya	157	4.5.2	Vesicular Transport and Secretion of Proteins	248
	<i>Helmut Burtscher</i>		4.5.3	Protein Transport into the Nucleus	249
3.9.1	Eukaryotic DNA Replication	157	4.5.4	Protein Transport into Mitochondria	252
3.9.2	Eukaryotic DNA Repair	162	4.5.5	Protein Transport into Chloroplasts	254
3.10	Special Bacterial Metabolism and Biosynthesis of Antimicrobials	164	4.5.6	Protein Degradation	256
	<i>Julia Garbe, Annika Steen and Max Schobert</i>		4.5.7	Protein Degradation by the Ubiquitin-Proteasome System	258
3.10.1	Bacterial Envelope	164	5	Viruses	261
3.10.2	Bacterial Protein Export across the Cytoplasmic Membrane	166		<i>Klaus Klumpp</i>	
3.10.3	Protein Transport across the Outer Membrane of Gram-Negative Bacteria	167	5.1	General Characteristics of Viruses	261
3.10.4	Bacterial Transport Systems	168	5.1.1	Genomic Characteristics of Viruses	261
3.10.5	Bacterial Fermentations	169	5.1.2	Structure	263
3.10.6	Anaerobic Respiration	173	5.2	DNA Viruses	264
3.10.7	Chemolithotrophy	175	5.2.1	Papillomavirus	264
3.10.8	Quinoenzymes, Alkane and Methane Oxidation	178	5.3	RNA Viruses	267
3.10.9	Antibiotics	179	5.3.1	Hepatitis C Virus	267
3.11	Electron Transfer Reactions and Oxidative Phosphorylation	183	5.4	Retroviruses	268
	<i>Martina Jahn and Dieter Jahn</i>		5.4.1	Human Immunodeficiency Virus (HIV)	268
3.11.1	General Principles	183	6	Transport	272
3.11.2	Different types of electron transport chains	183			
3.11.3	The Energetic Basis of the Oxidative Phosphorylation	183	6.1	Transport Through Membranes	272
3.11.4	Electron Transport System in Mitochondria and Bacteria	184		<i>Wilhelm Just</i>	
3.12	Photosynthesis	188	6.1.1	Systems of Eukaryotic Membrane Passage	272
	<i>Dieter Oesterhelt and Josef Wachtveitl</i>		6.1.2	Channels/Pores	272
3.12.1	Light Reaction	188	6.1.3	Solute Carriers	276
3.12.2	Dark Reactions	192	6.1.4	Primary Active Transport Systems	277
3.13	Plant Secondary Metabolism	193	6.1.5	Import by Endocytosis and Pinocytosis	278
	<i>Antje Chang</i>		6.1.6	The Cytoskeleton as Means for Intracellular Transport and Cellular Movements in Eukarya	278
3.13.1	Phenolics	194	6.2	Transport of Lipids in Plasma	279
3.13.2	Terpenoids	198		<i>Horst Klima</i>	
3.13.3	Nitrogen-containing Secondary Metabolites	201	6.2.1	Apolipoproteins (Apo)	279
4	Protein Biosynthesis, Modifications and Degradation	210	6.2.2	Plasma Lipoprotein Metabolism	279
			6.2.3	Lipid Transport Proteins	281
4.1	Protein Synthesis in Bacteria	210	6.2.4	Lipoprotein Receptors	281
	<i>Martina Jahn and Dieter Jahn</i>		6.2.5	Lipid Metabolic Disorders	282
4.1.1	Bacterial Transcription	210			
4.1.2	Regulation of Bacterial Gene Expression	212			

6.3	Oxygen Transport by Hemoglobin 282	8.1.3	Development and Maturation of the Cellular Components 328
	<i>Gerhard Michal</i>	8.1.4	Antigen Receptor of B Lymphocytes, Antibodies 330
6.3.1	Biosynthesis and Properties of Hemoglobin and Myoglobin 282	8.1.5	Complement System 334
6.3.2	Oxygen Binding to Hemo- and Myoglobin 283	8.1.6	Antigen Receptor of T Lymphocytes 336
6.3.3	Hemoglobin Diseases in Humans 285	8.1.7	Antigen Presentation by MHC Molecules 337
		8.1.8	Cytokines, Chemokines and Receptors 338
7	Signal Transduction and Cellular Communication 286	8.2	Generation of a Specific Immune Response 343
	<i>Gerhard Niederfellner</i>	8.2.1	Activation of T Cells 343
7.1	Intercellular Signal Transmission by Hormones 286	8.2.2	CD4 ⁺ T Effector Cells, Regulation of the Immune Response 344
7.1.1	General Characteristics of Hormones 286	8.2.3	Activation of B Cells 345
7.1.2	General Characteristics of Receptors 286	8.2.4	Lymphocyte Circulation and Generation of Cellular and Humoral Immune Responses in Lymphoid Tissue 345
7.1.3	Insulin and Glucagon 287	8.2.5	Cellular Cytotoxicity and Apoptosis 347
7.1.4	Epinephrine and Norepinephrine (Catecholamines) 287	8.2.6	Interactions between the Immune System and the Neuroendocrine System 350
7.1.5	Hypothalamus-Anterior Pituitary Hormone System 287	8.2.7	Immunological Tolerance 350
7.1.6	Placental Hormones 291	8.2.8	Induction of Specific Immune Responses against Pathogens 351
7.1.7	Hormones Regulating the Extracellular Ca ⁺⁺ , Mg ⁺⁺ and Phosphate Concentrations 292	8.3	Pathologic Immune responses 352
7.1.8	Hormones Regulating the Na ⁺ Concentration and the Water Balance 292	8.3.1	IgE-Mediated Hypersensitivity of the Immediate Type 352
7.1.9	Hormones of the Gastrointestinal Tract 293	8.3.2	Autoimmunity 353
7.2	Nerve Conduction and Synaptic Transmission 294	8.4	Adhesion of Leukocytes 354
7.2.1	Membrane Potential 294		<i>Anton Haselbeck</i>
7.2.2	Conduction of the Action Potential along the Axon 294	9	Blood Coagulation and Fibrinolysis 357
7.2.3	Transmitter Gated Signalling at the Synapse 294		<i>Peter Müller</i>
7.2.4	Voltage Gated Signalling at the Synapse 296	9.1	Hemostasis 357
7.2.5	Postsynaptic Receptors 296	9.2	Initial Reactions 358
7.2.6	Axonal Transport 296	9.2.1	Reactions Initiated by the Tissue Factor 358
7.3	Principles of Intracellular Communication 296	9.2.2	Contact Activation 358
7.4	Receptors Coupled to Heterotrimeric G-Proteins 299	9.2.3	Generation of Binding Surfaces 358
7.4.1	Mechanism of Heterotrimeric G-Protein Action 300	9.3	Coagulation Propagation and Control 359
7.4.2	cAMP Metabolism, Activation of Adenylate Cyclase and Protein Kinase A 302	9.3.1	Requirements for Protease Activity 359
7.4.3	Activation of Phospholipase C and Protein Kinase C 302	9.3.2	Pathways Leading to Thrombin 359
7.4.4	Metabolic Role of Inositol Phosphates and Ca ⁺⁺ 303	9.3.3	Key Events 359
7.4.5	Muscle Contraction 305	9.3.4	Controlled Propagation 360
7.4.6	Visual Process 307	9.3.5	Generation of Fibrin 361
7.4.7	Olfactory and Gustatory Processes 308	9.4	Platelets (Thrombocytes) 362
7.4.8	Arachidonate Metabolism and Eicosanoids 309	9.5	Fibrinolysis 364
7.5	Receptors Acting Through Tyrosine Kinases 311	9.5.1	Pathways of Plasminogen Activation 364
7.5.1	Regulatory Factors for Cell Growth and Function 311	9.5.2	Control of Fibrinolysis 365
7.5.2	Components of the Signal Cascades 311	10	Biochemical Networks, Bioinformatics and Systems Biology 366
7.5.3	Receptor Tyrosine Kinases 312		<i>Dietmar Schomburg</i>
7.5.4	Tyrosine Kinase-Associated Receptors (TKaR) 315	10.1	Systems Biology and Networks 366
7.6	Programmed Cell Death (Apoptosis) 319	10.2	Modeling of Metabolic Fluxes 366
7.7	Receptors for Steroid and Thyroid Hormones, for Retinoids and Vitamin D 321	10.3	Biochemical Pathways Information Resources 366
7.8	Cyclic GMP Dependent Pathways and Effects of Nitric Oxide (NO) 322	10.3.1	Overview 366
7.8.1	Membrane Bound Guanylate Cyclases 323	10.3.2	Detailed Description of Some Databases 367
7.8.2	Soluble Guanylate Cyclases and Their Activation by Nitric Oxide (NO) 323	Index 374	
7.8.3	Protein Kinase G 323		
8	Immune System 325		
	<i>Ernst Peter Rieber</i>		
8.1	Components of the Immune System 325		
8.1.1	Innate, Non Adaptive Immune System 325		
8.1.2	Specific, Adaptive Immune System 328		