

Contents

Foreword XIII

List of Contributors XV

Volume 1

1	Biopolymers: State of the Art, New Challenges, and Opportunities	1
	<i>Christophe Chassenieux, Dominique Durand, Parameswaranpillai Jyotishkumar, and Sabu Thomas</i>	
1.1	Introduction	1
1.2	Biopolymers: A Niche For Fundamental Research in Soft Matter Physics	3
1.3	Biopolymers: An Endless Source of Applications	4
1.4	Topics Covered by the Book	5
1.5	Conclusions	5
	References	6
2	General Overview of Biopolymers: Structure, Properties, and Applications	7
	<i>Charles Winkworth-Smith and Tim J. Foster</i>	
2.1	Introduction	7
2.2	Plant Cell Wall Polysaccharides	11
2.2.1	Cellulose	11
2.2.1.1	Cellulose Extraction	12
2.2.1.2	Nanocellulose	13
2.2.1.3	Microfibrillated Cellulose	14
2.2.1.4	Cellulose Nanowhiskers	14
2.2.2	Hemicelluloses	15
2.2.2.1	Galactomannans	15
2.2.2.2	Konjac Glucomannan	19
2.2.2.3	Xylan	19
2.2.2.4	Xyloglucan	20
2.2.3	Pectins	21
2.3	Biocomposites	23
2.3.1	Natural Fiber Composites	23

2.3.2	Cellulose Composites	25
2.3.3	Cellulose–Polymer Interactions	26
2.3.4	Semi-Solid Composites	27
2.4	Future Outlook	28
	References	29
3	Biopolymers from Plants	37
	<i>Maria J. Sabater, Tania Ródenas, and Antonio Heredia</i>	
3.1	Introduction	37
3.2	Lipid and Phenolic Biopolymers	38
3.2.1	The Biopolymer Cutin	38
3.2.1.1	Cutin Monomers: Biosynthesis and Physicochemical Characteristics	39
3.2.1.2	Molecular Architecture of Cutin	40
3.2.1.3	Cutin Biosynthesis	41
3.2.2	Lignin	42
3.2.2.1	Monomer Precursors and Chemical Reactivity	42
3.2.2.2	Lignin Biosynthesis	43
3.2.3	Suberin	45
3.2.3.1	Chemical Composition	45
3.2.3.2	Biosynthesis and Fine Structure	47
3.3	Carbohydrate Biopolymers: Polysaccharides	48
3.3.1	Structural Polysaccharides	49
3.3.1.1	Cellulose	49
3.3.1.2	Hemicellulose	54
3.3.1.3	Pectin	57
3.3.2	Storage Polysaccharides	59
3.3.2.1	Starch	59
3.3.2.2	Fructans: Inulin	63
3.3.3	Other: Gums (Guar Gum, Gum Arabic, Gum Karaya, Gum Tragacanth, and Locust Bean Gum)	66
3.4	Isoprene Biopolymers: Natural Rubber	67
3.4.1	<i>cis</i> -Polyisoprene	67
3.4.1.1	Occurrence	67
3.4.1.2	Composition, Structure, and Properties	67
3.4.1.3	<i>cis</i> -1,4-Polyisoprene Biosynthesis	68
3.4.1.4	Applications	73
3.4.2	<i>trans</i> -Polyisoprene	73
3.5	Concluding Remarks	74
	References	75
4	Bacterial Biopolymers and Genetically Engineered Biopolymers for Gel Systems Application	87
	<i>Deepti Singh and Ashok Kumar</i>	
4.1	Introduction	87
4.1.1	Nucleic Acid Biopolymers: Central Dogma	89

4.2	Microbial Polysaccharides as Biopolymers	90
4.2.1	Synthesis and Applications	90
4.3	Microbial Biopolymers as Drug Delivery Vehicle	92
4.3.1	ϵ -Poly-L-Lysine (ϵ -PL) and Its Applications	92
4.3.2	Polyhydroxyalkanoates and Its Applications	92
4.4	Polyanhydrides	93
4.5	Recombinant Protein Polymer Production	94
4.6	Recombinant Genetically Engineered Biopolymer: Elastin	95
4.7	Collagen as an Ideal Biopolymer	97
4.7.1	Microbial Recombinant Collagens: Production in <i>Pichia Pastoris</i>	97
4.8	Biopolymers for Gel System	99
4.9	Hydrogels of Biopolymers for Regenerative Medicine	99
4.9.1	Polysaccharide Hydrogels	99
4.9.2	Cellulose-Derived Biopolymers-Based Hydrogels	100
4.9.3	Protein-Biopolymers-Based Hydrogels	100
4.10	Supermacroporous Cryogel Matrix from Biopolymers	100
4.10.1	Protein Cryogel	101
4.11	Biopolymers Impact on Environment	102
4.12	Conclusion	103
	References	104

5 Biopolymers from Animals 109

Khaleelulla Saheb Shaik and Bernard Moussian

5.1	Introduction	109
5.2	Chitin and Hyaluronic Acid in the Living World	110
5.3	Milestones in Chitin History	110
5.4	From Trehalose to Chitin	112
5.5	Chitin Synthase	115
5.6	Regulation of Chitin Synthesis in Fungi	117
5.7	Organization of Chitin in the Fungal Cell Wall	118
5.8	Organization of Chitin in the Arthropod Cuticle	119
5.9	Chitin-Organizing Factors	123
5.10	Secretion and Cuticle Formation	126
5.11	Transcriptional Regulation of Cuticle Production	128
5.12	Chitin Synthesis Inhibitors	130
5.13	Noncuticular Chitin in Insects	131
5.14	Chitin as a Structural Element	133
5.15	Application of Chitin	134
5.16	Conclusion	135
	References	135

6 Polymeric Blends with Biopolymers 143

Hero Jan Heeres, Frank van Maastrikt, and Francesco Picchioni

6.1	Introduction	143
6.2	Starch-Based Blends	146

6.2.1	Polymer Selection for Starch Blending	147
6.2.2	Starch Structure	150
6.2.3	Uncompatibilized Blends	152
6.2.4	Compatibilization	155
6.2.5	Composites	157
6.3	Blends with Chitosan (One Amino Group Too Much . . .)	158
6.4	Future Perspectives	161
6.4.1	Biopolymer Plasticization	161
6.4.2	Blend Morphology and Compatibilization	162
6.4.3	Blend Processing: Technological Aspects	163
	References	164

7 Macro-, Micro-, and Nanocomposites Based on Biodegradable Polymers 173

Luc Avérous and Eric Pollet

7.1	Introduction	173
7.2	Biodegradable Polymers	174
7.2.1	Classification	174
7.2.2	Agro-Polymers: The Case of Starch	175
7.2.2.1	Native Starch Structure	175
7.2.2.2	Plasticized Starch	176
7.2.3	Biodegradable Polyesters	177
7.2.3.1	Polyesters Based on Agro-Resources	177
7.2.3.2	Petroleum-Based Polyesters	179
7.3	Biocomposites	181
7.3.1	Generalities	181
7.3.2	The Case of Biocomposites Based on Agro-Polymers	181
7.3.2.1	Cellulose Fiber Reinforcement	181
7.3.2.2	Lignin and Mineral Fillers	182
7.3.3	The Case of Biocomposites Based on Biopolyesters	182
7.3.3.1	Generalities	182
7.3.3.2	The Case of Biocomposites Based on Aromatic Copolyesters	183
7.4	Nanobiocomposites	186
7.4.1	Generalities	186
7.4.2	Nanobiocomposites Based on Agro-Polymers (Starch)	187
7.4.2.1	Whisker-Based Nanobiocomposites	190
7.4.2.2	Starch Nanocrystal-Based Nanobiocomposites	190
7.4.2.3	Nanoclay-Based Nanobiocomposites	190
7.4.3	Nanobiocomposites Based on Biopolyesters	193
7.4.3.1	Poly(lactic acid)-Based Nanobiocomposites	193
7.4.3.2	Polyhydroxyalkanoate-Based Nanobiocomposites	194
7.4.3.3	Polycaprolactone-Based Nanobiocomposites	195
7.4.3.4	Biodegradable Aliphatic Copolyester-Based Nanobiocomposites	197
7.4.3.5	Aromatic Copolyester-Based Nanobiocomposites	199
	References	200

8	IPNs Derived from Biopolymers	211
	<i>Fernando G. Torres, Omar Paul Troncoso, and Carlos Torres</i>	
8.1	Introduction	211
8.2	Types of IPNs	212
8.3	IPNs Derived from Biopolymers	214
8.3.1	Alginate	215
8.3.2	Agarose	215
8.3.3	Chitosan	215
8.3.4	Starch	216
8.3.5	Dextran	217
8.3.6	Gum Arabic	217
8.3.7	Fibrinogen	217
8.3.8	Collagen and Gelatin	217
8.3.9	Cellulose and Cellulose Derivatives	218
8.3.10	Polyhydroxyalkanoates	218
8.3.11	Lactide-Derived Polymers	219
8.4	Manufacture of IPNs	220
8.4.1	Casting–Evaporation Processing	220
8.4.2	Emulsification Cross-Linking Technique	220
8.4.3	Miniemulsion/Inverse Miniemulsion Technique	221
8.4.4	Freeze Drying Technique	222
8.5	Characterization of IPNs	222
8.5.1	Morphological and Structural Characterization	222
8.5.2	FTIR Spectroscopy	223
8.5.3	Mechanical Characterization	224
8.5.4	Rheological Characterization	225
8.5.5	Swelling Behavior Characterization	225
8.5.6	Thermal Characterization	226
8.6	Applications of IPNs	226
8.6.1	Drug Delivery Applications	226
8.6.2	Scaffolds for Tissue Engineering	227
8.6.3	Other Biomedical Applications	227
8.6.4	Antibacterial Applications	228
8.6.5	Sensor, Actuators, and Artificial Muscle Applications	228
8.7	Conclusions	229
	References	229
9	Associating Biopolymer Systems and Hyaluronate Biomaterials	235
	<i>Deborah Blanchard and Rachel Auzély-Velty</i>	
9.1	Introduction	235
9.2	Synthesis and Self-Association of Hydrophobically Modified Derivatives of Chitosan and Hyaluronic Acid in Aqueous Solution	237
9.2.1	General Aspects of Association in Amphiphilic Polyelectrolytes	237
9.2.2	Synthesis and Behavior in Aqueous Solution of Hydrophobically Modified Water-Soluble Derivatives of Chitosan	239

9.2.3	Synthesis and Behavior in Aqueous Solution of Hydrophobically Modified Water-Soluble Derivatives of Hyaluronic Acid	242
9.3	Design of Novel Biomaterials Based on Chemically Modified Derivatives of Hyaluronic Acid	248
9.3.1	Nanoassemblies Based on Amphiphilic Hyaluronic Acid	249
9.3.2	Hydrogels for Cell Biology and Tissue Engineering	254
9.3.2.1	Strategies for the Cross-Linking of HA to Obtain Scaffolds for Cells	254
9.3.2.2	Engineering Biological Functionality in Hyaluronic Acid-Based Scaffolds	260
9.3.2.3	Patterning of Hyaluronic Acid	261
9.4	Conclusions	271
	References	271
10	Polymer Gels from Biopolymers	279
	<i>Esra Alveroglu, Ali Gelir, and Yasar Yilmaz</i>	
10.1	Introduction	279
10.2	Experimental Methods	279
10.3	Polymerization and Gelation Kinetics	281
10.3.1	Fluoroprobe–Polymer Interactions	283
10.3.2	Real-Time Monitoring of Monomer Conversion	286
10.4	Sol–Gel Transition and Universality Discussion	287
10.5	Imprinting the Gels	292
10.6	Heterogeneity of Hydrogels	301
10.6.1	Effect of Ion Doping on Swelling Properties and Network Structure of Hydrogels	301
10.6.2	Current Measurements for Searching the Internal Morphology of the Gels	302
10.7	Ionic p-Type and n-Type Semiconducting Gels	303
10.7.1	Electrical Properties of Ionic p-Type and n-Type Semiconducting Gels	304
10.7.2	Polymeric Gel Diodes with Ionic Charge Carriers	305
10.8	Conclusions	307
	References	308
11	Conformation and Rheology of Microbial Exopolysaccharides	317
	<i>Jacques Desbrieres</i>	
11.1	Introduction	317
11.2	Conformation of Polysaccharides	318
11.3	Secondary Solid-State Structures for Microbial Polysaccharides	318
11.3.1	No Secondary Solid-State Structure	319
11.3.2	Single-Chain Conformation	319
11.3.3	Simple or/and Double Helices	321
11.3.4	Double Helix	323
11.3.5	Triple Helix	323

11.4	Conformation in Solution: Solution Properties and Applications	325
11.4.1	Dextran and Pullulan	325
11.4.2	Hyaluronan	326
11.4.3	Xanthan	331
11.4.4	Succinoglycan	334
11.5	Gelling Properties in the Presence of Salts	336
11.5.1	$\beta(1\rightarrow4)$ -D-Glucuronan	336
11.5.2	Polysaccharide 1644	337
11.5.3	Gellan and Similar Polysaccharides	337
11.5.4	$\beta(1\rightarrow3)$ -D-Glucans	341
11.5.5	YAS 34	342
11.6	Conclusions	345
	References	345
12	Sulfated Polysaccharides in the Cell Wall of Red Microalgae	351
	<i>Shoshana (Malis) Arad and Oshrat Levy-Ontman</i>	
12.1	Introduction	351
12.2	Sulfated Polysaccharides from Red Microalgae – General Overview	352
12.3	Sulfated Polysaccharides of Red Microalgal Cell Walls: Chemical Aspects	354
12.4	Proteins in the Cell Wall of Red Microalgae	355
12.5	Rheology of Red Microalgal Polysaccharide Solutions	356
12.6	Modifications of the Sulfated Polysaccharides	359
12.7	Red Microalgal Sulfated Polysaccharide Bioactivities	362
	References	365

Volume 2

13	Dielectric Spectroscopy and Thermally Stimulated Current Analysis of Biopolymer Systems	371
	<i>Valérie Samouillan, Jany Dandurand, and Colette Lacabanne</i>	
14	Solid-State NMR Spectroscopy of Biopolymers	403
	<i>Garrick F. Taylor, Phedra Marius, Chris Ford, and Philip T.F. Williamson</i>	
15	EPR Spectroscopy of Biopolymers	443
	<i>Janez Štrancar and Vanja Kokol</i>	
16	X-Ray Photoelectron Spectroscopy: A Tool for Studying Biopolymers	473
	<i>Ana Maria Botelho do Rego, Ana Maria Ferraria, Manuel Rei Vilar, and Sami Boufi</i>	
17	Light-Scattering Studies of Biopolymer Systems	533
	<i>Taco Nicolai and Dominique Durand</i>	

18	X-Ray Scattering and Diffraction of Biopolymers 567 <i>Yoshiharu Nishiyama and Marli Miriam de Souza Lima</i>
19	Large-Scale Structural Characterization of Biopolymer Systems by Small-Angle Neutron Scattering 583 <i>Ferenc Horkay</i>
20	Microscopy of Biopolymer Systems 611 <i>Changmin Hu and Wenguo Cui</i>
21	Rheo-optical Characterization of Biopolymer Systems 645 <i>Dagang Liu, Rakesh Kumar, Donglin Tian, Fei Lu, and Mindong Chen</i>
22	Rheological Behavior of Biopolymer Systems 673 <i>Tao Feng and Ran Ye</i>
23	Physical Gels of Biopolymers: Structure, Rheological and Gelation Properties 699 <i>Camille Michon</i>
24	Interfacial Properties of Biopolymers, Emulsions, and Emulsifiers 717 <i>Adamantini Paraskevopoulou and Vassilis Kiosseoglou</i>
25	Modeling and Simulation of Biopolymer Systems 741 <i>Denis Bouyer</i>
26	Aging and Biodegradation of Biocomposites 777 <i>Siji K. Mary, Prasanth Kumar Sasidharan Pillai, Deepa Bhanumathy Amma, Laly A. Pothen, and Sabu Thomas</i>
27	Biopolymers for Health, Food, and Cosmetic Applications 801 <i>Robin Augustine, Rajakumari Rajendran, Uroš Cvelbar, Miran Mozetič, and Anne George</i>
	Index 851