

Contents

List of Abbreviations XXXIII

1 Introduction to Marine Biotechnology

<i>Se-Kwon Kim, Jayachandran Venkatesan</i>	1
1.1 Marine Biotechnology – Definition	1
1.2 Marine Biotechnology – Tools	2
1.3 Marine Sources and Research Areas	4
1.4 Applications of Marine Biotechnology	4
1.5 Research Scope	6
1.6 Organization of the Handbook	7
References	8

Part A Marine Flora and Fauna

2 Marine Fungal Diversity and Bioprospecting

<i>Kalaiselvam Murugaiyan</i>	13
2.1 Preamble	13
2.2 Diversity of Fungi	14
2.3 Habitats of Fungi in the Marine Ecosystem	16
2.4 Habitat Characteristics and Their Effect on Fungal Diversity	17
2.5 Collection, Isolation, and Identification of Fungi	19
2.6 Bioprospecting of Marine Fungi	22
2.7 Conclusions	22
References	23

3 Diversity of Marine Phototrophs

<i>Hideaki Miyashita</i>	27
3.1 Traditional Understanding of Primary Producers (≈1970s)	27
3.2 Recognition of Picocyanobacteria Dominance (1970s–2000s)	28
3.3 Discovery of Ubiquitous Photoheterotrophs (2000–Current Times) .	29
3.4 Oxygenic Photosynthesis Using Far-Red Light (1990s–2011)	30
3.5 Discovery of Picoeukaryotic Phytoplankton (1990s–2011)	30
3.6 Strange Phototrophic(?) Microorganisms (1990–2011)	31
3.7 Diversity of Light Energy Transformation Systems and Reconsideration of <i>Photosynthesis</i>	31
3.8 Conclusion	33
References	33

4 Marine Viruses

<i>Jeeva Subbiah</i>	35
4.1 Viruses	35
4.2 General Characteristic Features of Viruses	36
4.3 Host Specificity	36

4.4	Viral Families in Marine Ecosystems	36
4.5	Marine Phages	37
4.6	Impact of Marine Viruses on Mollusks	40
4.7	Marine Viruses and Shrimp Aquaculture	40
4.8	Conclusion	46
	References	47
5	Marine Microalgae	
	<i>Tsuyoshi Tanaka, Masaki Muto, Yue Liang, Tomoko Yoshino,</i>	
	<i>Tadashi Matsunaga</i>	51
5.1	Overview	51
5.2	Marine Microalgae	52
5.3	Microalgal Genomes	53
5.4	Genetic Engineering of Microalgae	54
5.5	Photobioreactors for Marine Microalgae	57
	References	58
6	Seaweed Flora of the European North Atlantic and Mediterranean	
	<i>Leonel Pereira</i>	65
6.1	Marine Macroalgae (Seaweeds)	65
6.2	The Marine Algae and Their Biotechnological Potential	67
6.3	Taxonomy and Description of Marine Algae with Biotechnological Potential	67
	References	141
7	Corals	
	<i>Mohammad Kazem Khalesi</i>	179
7.1	Background	179
7.2	Potential Pharmaceuticals from Soft Corals	180
7.3	Potential Pharmaceuticals from Hard Corals	196
7.4	Mycosporine-Like Amino Acids (MAAs)	197
7.5	Conclusion	197
	References	204
8	Marine Sponges – Molecular Biology and Biotechnology	
	<i>Stephen A. Jackson, Jonathan Kennedy, Lekha Menon Margassery,</i>	
	<i>Burkhardt Flemer, Niall O'Leary, John P. Morrissey, Fergal O'Gara,</i>	
	<i>Alan D. W. Dobson</i>	219
8.1	Marine Sponges	219
8.2	Sponge-Associated Microorganisms	222
8.3	Symbiotic Functions of Sponge-Associated Microorganisms	227
8.4	Biotechnological Potential of Marine Sponges – Pharmacological Potential	229
8.5	Exploiting the Pharmacological Potential of Marine Sponges	229
8.6	Metagenomic Strategies for Natural Product Discovery	230
8.7	Conclusions	243
	References	243

Part B Tools and Methods in Marine Biotechnology

9 Bioprocess Engineering of Phototrophic Marine Organisms

<i>Gregory L. Rorrer</i>	257
9.1 Introduction to Marine Process Engineering	257
9.2 Growth Characteristics of Phototrophic Suspension Cultures	261
9.3 Basic Elements of Photobioreactor Design and Operation	267
9.4 Limiting Factors in Photobioreactor Design and Operation	277
9.5 Future Directions for Process Scale Enclosed Photobioreactors	290
9.6 Notation.....	291
References	293

10 Bioinformatic Techniques on Marine Genomics

<i>A. Mir Bilal, H. Mir Sajjad, Inho Choi, Yoon-Bo Shim</i>	295
10.1 Background	295
10.2 Marine and Bacterial Fluorescence Shining Light on Biological Questions	297
10.3 Recent Advances in Imaging Techniques for Marine Biotechnology	297
10.4 Chemical Analysis of Volatile Microbial Metabolites	297
10.5 Bioinformatics Resources	298
10.6 Large-Scale Sequence Analysis	299
10.7 Integrating Sequence and Contextual Data	300
10.8 Proteomics as Potential Tool for Survey in Marine Biotechnology...	301
10.9 Proteomics and Seafood	301
10.10 Present Status and Future Trends of Proteomics in Marine Biotechnology.....	302
10.11 Pharmacophore Model Hypo1, Virtual Screening for Identification of Novel Tubulin Inhibitors with Potent Anticancer Activity	302
10.12 The Polymerase Chain Reaction: A Marine Perspective	303
10.13 Conclusions and New Frontiers.....	303
References	304

11 Microbial Bioprospecting in Marine Environments

<i>Mariana Lozada, Hebe M. Dionisi</i>	307
11.1 Bioprospecting.....	307
11.2 Marine Microbial Habitats and Their Biotechnologically-Relevant Microorganisms.....	308
11.3 Methods for Microbial Bioprospecting in Marine Environments.....	309
11.4 Conclusions	319
References	319

12 Novel Bioreactors for Culturing Marine Organisms

<i>Debashis Roy</i>	327
12.1 Biofilm Reactors (BFR).....	327
12.2 Photobioreactors (PBR)-Tubular, Plate/Panel and Stirred Tank Configurations.....	331
12.3 Airlift Bioreactors (ALBR) and Bubble Column Bioreactors (BCBR) ...	337
12.4 Membrane Bioreactors (MBR).....	349

12.5	Immobilized-Cell Bioreactors	353
12.6	Hollow Fiber Bioreactors (HFBR)	359
12.7	Fluidized Bed and Moving Bed Bioreactors (FBBR and MBBR)	363
12.8	High-Temperature and/or High-Pressure Bioreactors (HP-/HTBR) ...	368
	References	382
13	Transgenic Technology in Marine Organisms	
	<i>Thomas T. Chen, Chun-Mean Lin, Maria J. Chen, Jay H. Lo, Pinwen P. Chiou, Hong-Yi Gong, Jen-Leih Wu, Mark H.-C. Chen, Charles Yarish</i>	387
13.1	Synopsis	387
13.2	Production of Transgenic Marine Organisms	388
13.3	Characterization of Transgenic Marine Organisms	396
13.4	Biotechnological Application of Transgenic Marine Organisms	398
13.5	Concerns and Future Perspectives.....	405
	References	406
14	Marine Enzymes – Production and Applications	
	<i>Kai Muffler, Barindra Sana, Joydeep Mukherjee, Roland Ulber</i>	413
14.1	Overview	413
14.2	Cultivation Techniques of Marine Bacteria	414
14.3	Examples of Marine Enzymes.....	417
14.4	Molecular Biology	422
14.5	Downstream Processing of Marine Enzymes	422
14.6	Conclusion	424
	References	425
15	Biofouling Control by Quorum Quenching	
	<i>Vipin C. Kalia, Prasun Kumar, Shunmugiah K. T. Pandian, Prince Sharma</i>	431
15.1	Overview	431
15.2	Bacterial Biosensors.....	432
15.3	Quorum Quenching (QQ)	432
15.4	Applications.....	436
	References	438
16	Detection of Invasive Species	
	<i>Nathan J. Bott</i>	441
16.1	Background	441
16.2	Traditional Techniques	442
16.3	Sample Collection	442
16.4	Molecular Approach to the Identification of Marine Invasive Species.....	443
16.5	PCR-Based Methods Utilized for Routine Identification and/or Surveillance	445
16.6	Ecogenomic Techniques.....	447
16.7	Future Approaches	448
16.8	Concluding Remarks	449
	References	450

Part C Marine Genomics

17 Marine Sponge Metagenomics

<i>Valliappan Karuppiyah, Zhiyong Li</i>	457
17.1 Background and Problems of Sponge Research	457
17.2 The Principle of Metagenomics and Related Techniques.....	460
17.3 Application and Latest Progress in Sponge Metagenomics.....	465
17.4 Future Perspectives.....	469
References	470

18 Proteomics: Applications and Advances

<i>Vernon E. Coyne</i>	475
18.1 Omics	475
18.2 Overview of Proteomics Techniques	476
18.3 Proteomics and Marine Biotechnology	477
18.4 Aquaculture	478
18.5 Environment.....	482
18.6 Natural Products.....	486
18.7 Algal Toxins	488
18.8 Conclusion	490
References	491

19 Marine Metagenome and Supporting Technology

<i>Tetsushi Mori, Haruko Takeyama</i>	497
19.1 Bacteria and Marine Ecosystems	497
19.2 Technologies Supporting Metagenomic Research	502
19.3 Summary	505
References	505

20 Microfluidic Systems for Marine Biotechnology

<i>Morgan Hamon, Jing Dai, Sachin Jambovane, Jong W. Hong</i>	509
20.1 Basic Principal of Microfluidics	510
20.2 Microfluidic Devices for Marine Biology and Ecosystem Studies	511
20.3 Microfluidic Devices for Sea-Related Health and Safety	517
20.4 Microfluidic Systems for Other Marine Biotechnology Applications .	521
20.5 Conclusion	524
References	524

21 Genome Mining for Bioactive Compounds

<i>Soumya Haldar, Kalpana H. Mody</i>	531
21.1 Overview	531
21.2 Temporary Halt in the Discovery of Bioactive Compounds	533
21.3 Future Directions	533
21.4 The Hurdles of Drug Discovery	536
21.5 Marine Pharmaceuticals Under Clinical Trials	536
References	538

Part D Marine Algal Biotechnology

22 Cell Wall Polysaccharides of Marine Algae	
<i>Andriy Synytsya, Jana Čopíková, Woo J. Kim, Yong Il Park</i>	543
22.1 Overview	544
22.2 Structural Diversity of Algal Polysaccharides	545
22.3 Isolation from Algal Raw Material.....	555
22.4 Algal Polysaccharides such as Phycocolloids	558
22.5 Biological Activities and Medicinal Applications.....	562
References	571
23 Iodine in Seaweed: Two Centuries of Research	
<i>Frithjof C. Küpper</i>	591
References	594
24 Marine Macrophytes: Biosorbents	
<i>Chiara Pennesi, Fabio Rindi, Cecilia Totti, Francesca Beolchini</i>	597
24.1 Marine Macrophytes.....	597
24.2 Heavy Metals: Definition and Toxicity	601
24.3 Biosorption	601
24.4 Biosorption Experiments: Procedure	606
24.5 Conclusions	606
References	607
25 Marine Algae Biomass for Removal of Heavy Metal Ions	
<i>Laura Bulgariu, Dumitru Bulgariu, Constantin Rusu</i>	611
25.1 General Remarks	611
25.2 Chemical Characteristics of Marine Algae Biomass.....	613
25.3 Experimental Methodology.....	615
25.4 Influence of Experimental Parameters	618
25.5 Modeling of Biosorption Process in Batch Conditions:	
Isotherm and Kinetic Models.....	628
25.6 Modeling of Biosorption Process in Dynamic Continuous-Flow	
Conditions	637
25.7 Mechanism of Biosorption.....	639
25.8 Final Remarks.....	642
References	642

Part E Marine Microbiology and Biotechnology

26 Biotechnological Potential of Marine Microbes	
<i>Gian M. Luna</i>	651
26.1 Microbial Diversity in the World's Oceans and Biotechnological	
Applications of Marine Microbes	651
26.2 Why Do Marine Microbes Matter in Biotechnology?	652
26.3 Biotechnology of Marine Microbes, from Viruses	
to Microbial Eukaryotes	654
26.4 Conclusions and Future Perspectives	657
References	658

27 Marine Actinomycetes in Biodiscovery	
<i>D. Ipek Kurtböke, Tanja Grkovic, Ronald J. Quinn</i>	663
27.1 Overview	663
27.2 Advances in the Field of Biodiscovery: Genomics and Genome Mining for Discovery of New Antibiotics	665
27.3 Ecological and Physiological Perspectives	666
27.4 An Australian Example: Exploring the Biosynthetic Potential of a Marine-Derived Streptomyces	668
27.5 Future Prospects	671
References	672
28 Biotransformation of Nitriles by Marine Fungi	
<i>Julietta Rangel de Oliveira, Mirna H. Reagli Seleglim, André L. Meleiro Porto</i>	677
28.1 Overview	678
28.2 Experimental Methods	691
28.3 Results and Discussion	696
28.4 Conclusion	705
References	706
Part F Marine Derived Metabolites	
29 Drugs and Leads from the Ocean Through Biotechnology	
<i>José de Jesús Paniagua-Michel, Jorge Olmos-Soto, Eduardo Morales-Guerrero</i>	711
29.1 Overview and Current Status	712
29.2 Approved Marine Drugs as Pharmaceuticals	713
29.3 Marine Natural Products – Overcoming Hurdles	718
29.4 <i>Quo Vadis?</i> Marine Natural Products and Clinical Trials	718
29.5 Marine Natural Products: New and Recurrent Challenges	720
References	724
30 Biocatalysts from <i>Aplysia</i>: Sweet Spot in Enzymatic Carbohydrate Synthesis	
<i>Antonio Trincone</i>	731
30.1 Biocatalysis, Glycosylation and Marine Enzymes	731
30.2 Biocatalytic Methodologies to Access Glycosides and Oligosaccharides	732
30.3 The Marine Ecosystem as a Source for New Glycoside Hydrolases ...	734
30.4 Glycoside Hydrolases Present in the Genus <i>Aplysia</i>	735
30.5 Other Enzymatic Activities of Interest Present in <i>Aplysia</i> sp.	741
30.6 Conclusion	742
References	742
31 Antimicrobial Peptides from Marine Organisms	
<i>Venugopal Rajanbabu, Jyh-Yih Chen, Jen-Leih Wu</i>	747
31.1 Marine Antimicrobial Peptides	747
31.2 Isolation of Antimicrobial Peptides	748

31.3	Characterization and Functions of AMP.....	748
31.4	Future Directions in Marine AMP Applications	753
	References	755
32	Marine-Derived Fungal Metabolites	
	<i>Sherif S. Ebada, Peter Proksch</i>	759
32.1	Overview	759
32.2	Drug Screening from Marine Organisms	760
32.3	Marine Organic Compounds	765
32.4	Conclusions	782
	References	782
33	Marine Dinoflagellate-Associated Human Poisoning	
	<i>Samanta S. Khora</i>	789
33.1	Preface	789
33.2	Historical Perspective	791
33.3	Marine Dinoflagellates	792
33.4	Algal Blooms and Red Tide Dinoflagellates	793
33.5	Toxigenic Dinoflagellate-Associated Human Poisoning	794
33.6	Biotechnological Significance of Toxic Marine Dinoflagellates	805
33.7	Control and Prevention	806
33.8	Discussion and Conclusion	807
	References	808
34	Carotenoids, Bioactive Metabolites Derived from Seaweeds	
	<i>Ratih Pangestuti, Se-Kwon Kim</i>	815
34.1	Seaweeds	815
34.2	Biological Activities of Carotenoids and Health Benefit Effects	816
34.3	Concluding Remarks	819
	References	819
35	Marine Bioactive Compounds from Cnidarians	
	<i>Joana Rocha, Miguel Leal, Ricardo Calado</i>	823
35.1	Cnidarians.....	823
35.2	The Most Promising Marine Natural Products from Cnidaria	828
35.3	Concluding Remarks and Future Challenges	838
	References	840
36	Fatty Acids of Marine Sponges	
	<i>Pravat Manjari Mishra, Ayinampudi Sree, Prasanna K. Panda</i>	851
36.1	Fatty Acids – Pharmaceutical and Biomedical Importance	851
36.2	Sponge Fatty Acids	854
36.3	Bioactive Lipids/FAs from Marine Sponges	862
36.4	Summary	863
	References	863
37	Marine Biotoxins	
	<i>Aníbal Martínez, Alejandro Garrido-Maestu, Begoña Ben-Gigirey,</i> <i>María José Chapela, Virginia González, Juan M. Vieites, Ana G. Cabado</i> ...	869
37.1	Marine Toxins	870

37.2	Lipophilic Toxins.....	871
37.3	Hydrophilic Toxins.....	872
37.4	Other Toxins.....	873
37.5	Biotechnological Techniques Used to Study Toxic Microalgae and Marine Biotoxins	875
37.6	Biotechnology Application for Phytoplankton Detection, Monitoring, and Toxins Production	879
37.7	Potential Pharmacological Uses of Phycotoxins.....	884
	References	892
38	Marine Microbial Enzymes: Current Status and Future Prospects	
	<i>Barindra Sana</i>	905
38.1	Overview	905
38.2	Marine Extremozymes and Their Significance.....	906
38.3	Current Use of Marine Microbial Enzymes	909
38.4	Current Research Status of Marine Microbial Enzymes.....	909
38.5	Future Prospects	913
38.6	Conclusion	914
	References	914
39	Marine-Derived Exopolysaccharides	
	<i>Christine Delabarre-Ladrat, Vincent Boursicot, Sylvia Collicec-Jouault</i>	919
39.1	In Search of New Polysaccharides	919
39.2	Marine Biodiversity.....	920
39.3	Bacterial Polysaccharides	925
39.4	Applications of EPSs	928
39.5	Marine EPSs as Glycosaminoglycans (GAGs)	930
39.6	Conclusion	933
	References	933
40	Sulfated Polysaccharides from Green Seaweeds	
	<i>MyoungLae Cho, SangGuan You</i>	941
40.1	Overview	941
40.2	Extraction and Chemical Composition of Sulfated Polysaccharides.....	942
40.3	Structural Characteristics of Sulfated Polysaccharides	942
40.4	Biological Activities of Sulfated Polysaccharide from Green Seaweeds	945
40.5	Conclusion	949
	References	949
Part G Application of Marine Biotechnology		
41	Marine-Derived Pharmaceuticals and Future Prospects	
	<i>Kalpa W. Samarakoon, Don A. S. Elvitigala, You-Jin Jeon</i>	957
41.1	Marine Bioresources.....	957
41.2	Marine Secondary Metabolites	958
41.3	Marine Proteins.....	961

41.4	Marine Lipids	963
41.5	Molecular Biology Approaches	963
41.6	Future Trends in Marine Pharmaceuticals	964
	References	965
42	Marine Functional Foods	
	<i>Ana C. Freitas, Dina Rodrigues, Ana P. Carvalho, Leonel Pereira, Teresa Panteleitchouk, Ana M. Gomes, Armando C. Duarte</i>	969
42.1	General Overview	969
42.2	Marine Sources as Healthy Foods or Reservoirs of Functional Ingredients	971
42.3	Food Marine-Derived Ingredients with Biological Properties	974
42.4	Functional Foods Incorporating Marine-Derived Ingredients	979
42.5	Current Understanding and Future Trends	987
	References	988
43	Marine Nutraceuticals	
	<i>S.W.A. Himaya and Se-Kwon Kim</i>	995
43.1	Marine Bioactives as Potential Nutraceuticals	995
43.2	Functional Carbohydrates	996
43.3	Polyunsaturated Fatty Acids	1002
43.4	Carotenoids	1003
43.5	Soluble Calcium	1005
43.6	Fish Collagen and Gelatin	1006
43.7	Marine Probiotics	1007
43.8	Nutraceutical Market Trends and Quality Control	1008
43.9	R&D for Facing the Challenges and Supply for the Demand	1008
	References	1009
44	Cosmetics from Marine Sources	
	<i>Elena M. Balboa, Enma Conde, M. Luisa Soto, Lorena Pérez-Armada, Herminia Domínguez</i>	1015
44.1	Scenario of Marine Sources in the Cosmetic Industry	1015
44.2	Cosmetics: Definition and Regulations	1016
44.3	Cosmeceuticals	1017
44.4	Target Organs and Cosmetics Delivery Systems	1018
44.5	Components of Cosmetics	1019
44.6	Major Functions of Some Marine Components in Cosmetics and Cosmeceuticals	1020
44.7	Treatments Based on Marine Resources	1029
44.8	Products Based on Marine Resources	1032
44.9	Conclusions	1033
	References	1033
45	Omega-3 Fatty Acids Produced from Microalgae	
	<i>Munish Puri, Tamilselvi Thyagarajan, Adarsha Gupta, Colin J. Barrow</i>	1043
45.1	Importance of Unsaturated Fatty Acids	1043
45.2	Potential Alternative Sources for PUFA Production	1045

45.3	Marine Microalgae.....	1045
45.4	Biosynthesis of Omega-3 Fatty Acids in Marine Algae	1048
45.5	Microalgae Fermentation for the Production of PUFAs	1049
45.6	Thraustochytrid Fermentation	1051
45.7	Conclusions	1052
	References	1053
46	Selenoneine in Marine Organisms	
	<i>Michiaki Yamashita, Yumiko Yamashita</i>	1059
46.1	Biochemistry of Selenium	1059
46.2	Selenium and Selenoneine Determination	1060
46.3	Biochemical Characterization of Selenoneine.....	1062
46.4	Nutritional and Functional Properties of Dietary Organic Selenium.....	1063
46.5	MeHg Detoxification.....	1065
46.6	Conclusion	1067
	References	1068
47	Biological Activities of Marine-Derived Oligosaccharides	
	<i>Tatsuya Oda</i>	1071
47.1	Overview	1071
47.2	Preparation of Alginate Oligosaccharide Mixture	1072
47.3	Antioxidant Activities of Alginate Oligosaccharides.....	1073
47.4	Cytokine-Inducing Activities of Alginate Oligosaccharides.....	1076
47.5	Induction of Cytokines in Mice	1080
47.6	Growth-Promoting Effect of Alginate Oligosaccharides	1083
	References	1085
48	Vector and Agricultural Pest Control	
	<i>Venkateswara Rao Janapala</i>	1089
48.1	Preamble	1090
48.2	Current Status of Research and Development in the Subject	1090
48.3	Research in India	1092
48.4	Preparation of Crude Extracts.....	1094
48.5	Active Extracts of Marine Origin	1094
48.6	Pesticidal Properties of Alkyl Xanthates	1099
48.7	Antifeedant and IGR Activities of Xanthates	1101
48.8	Conclusions	1108
	References	1108
Part H Bioenergy and Biofuels		
49	Nanotechnology – from a Marine Discovery Perspective	
	<i>Ramachandran S. Santhosh, Visamsetti Amarendra</i>	1113
49.1	Marine Nanotechnology	1113
49.2	The Ocean as Source for Nanomaterials and Nanodevices	1114
49.3	Ocean in Climate Control.....	1123
49.4	Detoxification of Nanomaterials	1123

49.5	Biomimetics.....	1124
49.6	Conclusions	1125
	References	1125
50	Algal Photosynthesis, Biosorption, Biotechnology, and Biofuels	
	<i>Ozcan Konur</i>	1131
50.1	Overview	1131
50.2	Algal Photosynthesis	1132
50.3	Algal Biofuels	1136
50.4	Algal Biotechnology	1145
50.5	Algal Biosorption	1150
50.6	Conclusion	1157
	References	1158
51	Biofuel Innovation by Microbial Diversity	
	<i>Thiago Bruce, Astria D. Ferrão-Gonzales, Yutaka Nakashimada, Yuta Matsumura, Fabiano Thompson, Tomoo Sawabe</i>	1163
51.1	Bioprospecting of Marine Microbial Diversity	1163
51.2	Marine Microbial Diversity Applied to Biofuel Innovation	1166
51.3	Conclusions	1176
	References	1176
52	Maraine Biomaterials as Antifouling Agent	
	<i>Parappurath Narayanan Sudha, Thandapani Gomathi, Jayachandran Venkatsan, Se-Kwon Kim</i>	1181
52.1	Pollution	1181
52.2	Use of Marine Biomaterials for Water Treatment	1182
52.3	Modification of Marine Biomaterials	1183
52.4	Antifouling Marine Biomaterials for Water Treatment.....	1185
52.5	Conclusion	1189
	References	1189
Part I Biomedical Applications		
53	Marine Biomaterials	
	<i>Jayachandran Venkatesan, Se-Kwon Kim</i>	1195
53.1	Examples of Marine Biomaterials	1195
53.2	Marine Polysaccharides	1197
53.3	Marine Ceramics	1207
53.4	Current Understanding and Future Needs.....	1209
53.5	Conclusions	1209
	References	1209
54	Marine Materials: Gene Delivery	
	<i>Bijay Singh, Sushila Maharjan, Yun-Jaie Choi, Toshihiro Akaike, Chong-Su Cho</i>	1217
54.1	Nonviral Vectors for Gene Delivery	1217
54.2	Chitosan	1218

54.3	Alginate	1221
	References	1224
55	Marine Organisms in Nanoparticle Synthesis	
	<i>Pallavi Mohite, Mugdha Apte, Ameeta R. Kumar, Smita Zinjarde</i>	1229
55.1	Basic Concepts in Nanotechnology.....	1229
55.2	Marine Ecosystems	1231
55.3	Nanostructures Inherently Produced by Marine Organisms.....	1231
55.4	Metal Interactions in Marine Biological Forms.....	1231
55.5	Bacteria in Nanoparticle Synthesis.....	1232
55.6	Fungi in the Synthesis of Nanomaterials	1236
55.7	Algae in the Synthesis of Nanoparticles	1239
55.8	Marine Plants in Nanoparticle Synthesis	1240
55.9	Nanoparticle Synthesis by Sponges	1241
55.10	Mechanistic Aspects	1241
55.11	Current Understanding and Future Needs.....	1242
	References	1242
56	Marine Biomaterials in Therapeutics and Diagnostics	
	<i>Ashutosh Srivastava, Arti Srivastava, Ananya Srivastava, Pranjal Chandra</i>	1247
56.1	Biomaterials	1247
56.2	Classification of Biomaterials.....	1248
56.3	Marine Biodiversity.....	1249
56.4	Biomaterials from Marine Origin	1249
56.5	Status of Marine Natural Product as Therapeutic Agents	1252
56.6	Marine Resources for Medical Diagnostic Devices.....	1255
	References	1260
57	Enzymatically Synthesized Biosilica	
	<i>Xiaohong Wang, Heinz C. Schröder, Werner E.G. Müller</i>	1265
57.1	The Sponges: The Earliest Ancestor of the Metazoa	1265
57.2	Silicatein-Based Siliceous Spicule Formation	1266
57.3	Spiculogenesis	1268
57.4	Bio-Silica: The Enzymatically Formed Scaffold of Siliceous Sponge Spicules.....	1270
57.5		1271
57.6	Bio-Silica: The Osteogenic Bioinorganic Polymer	1272
57.7	Future Design of Novel Bioinspired, Silica-Based Materials	1273
	References	1274
58	Biom mineralization in Marine Organisms	
	<i>Ille C. Gebeshuber</i>	1279
58.1	Overview	1279
58.2	Materials – Biom minerals	1281
58.3	Materials – Proteins Controlling Biom mineralization	1290
58.4	Organisms and Structures That They Biom mineralize.....	1290

58.5	Functions	1294
58.6	Applications.....	1294
	References	1298

Part J Industrial Applications

59 Functional Feeds in Aquaculture

<i>Jorge Olmos Soto, José de Jesús Paniagua-Michel, Lus Lopez, Leonel Ochoa.....</i>		1303
59.1	Overview	1304
59.2	Food Formulation Ingredients	1304
59.3	Conventional Feeds Versus Functional Feeds	1309
59.4	Aquaculture Regulations.....	1310
59.5	Functional Feeds in Aquaculture	1311
59.6	Results Obtained in Crustaceans and Fish Using Functional Feeds..	1312
59.7	Conclusions	1317
	References	1317

60 Mussel-Derived Bioadhesives

<i>Bong-Hyuk Choi, Bum J. Kim, Chang S. Kim, Seonghye Lim, Byeongseon Yang, Jeong H. Seo, Hogyun Cheong, Hyung J. Cha</i>		1321
60.1	Marine Mussel Adhesion	1322
60.2	Application of MAPs to Tissue Engineering	1323
60.3	Application of MAP to Tissue Engineering Scaffolds	1326
60.4	Application of MAP Using Complex Coacervation	1328
60.5	MAP-Based Biosensors for Industrial Applications	1330
	References	1332

61 Marine Silicon Biotechnology

<i>Katsuhiko Shimizu</i>		1337
61.1	Overview	1337
61.2	Silicateins: Structure and Molecular Mechanisms	1338
61.3	Silicatein-Mediated Synthesis of Inorganic Materials	1344
61.4	Genetically Engineered Silicateins	1350
61.5	Prospectives.....	1351
	References	1351

62 Microalgal Biotechnology: Biofuels and Bioproducts

<i>José de Jesús Paniagua-Michel, Jorge Olmos-Soto, Eduardo Morales-Guerrero</i>		1355
62.1	Sustainable Biofuels from Marine Microalgae: Closer to Reality than Fiction	1356
62.2	Why Microalgae is Promissory for Biofuel Production	1356
62.3	Biodiesel Production by Microalgal Lipid Transesterification	1358
62.4	Bioethanol from Microalgae: A Simpler Procedure	1359
62.5	Microalgal Biohydrogen Production Through Sunlight and Seawater	1360

62.6	Genomics and Metabolic Engineering of Microalgae for Biofuels Production	1361
62.7	Microalgal Culture Systems: A Contribution to the Sustainability of Biofuels	1363
62.8	Products of Industrial Interest from Microalgae	1365
62.9	Future Needs: Making Sustainable the Unsustainable Lightness of Biofuels	1368
	References	1368
63	Marine Actinobacterial Metabolites and Their Pharmaceutical Potential	
	<i>Panchanathan Manivasagan, Jayachandran Venkatesan, Kannan Sivakumar, Se-Kwon Kim</i>	1371
63.1	Marine Actinobacteria	1371
63.2	Research on Marine Actinobacteria	1372
63.3	Novel Metabolites from Marine Actinobacteria	1373
63.4	Conclusion	1381
	References	1382
64	Marine Microbial Biosurfactins	
	<i>Jen-Leih Wu, Jenn-Kan Lu</i>	1387
64.1	Overview	1387
64.2	Methodology of Production of Marine Biosurfactants	1388
64.3	Applications of Marine Bioactive Biosurfactants	1392
64.4	Conclusions	1399
	References	1400
65	Nutraceuticals and Bioactive Compounds from Seafood Processing Waste	
	<i>V. Venugopal Menon, Smita S. Lele</i>	1405
65.1	Seafood as a Source of Nutraceuticals	1406
65.2	Bio-Waste from Processing of Seafood	1406
65.3	Seafood Waste and Discards as Sources of Nutraceuticals	1407
65.4	Nitrogen-Derived Compounds	1407
65.5	Lipid-Based Nutraceuticals	1412
65.6	Polysaccharide-Derived Nutraceuticals	1415
65.7	Mineral-Based Nutraceuticals	1419
65.8	Novel Marine Organisms and Compounds	1419
65.9	Commercial Aspects	1420
	References	1421
	Acknowledgements	1427
	About the Authors	1431
	Detailed Contents	1461
	Index	1491

ACP	acyl carrier protein	ACM	alginate oligosaccharide mixture
ACP	acyl-acyl carrier protein	ACM	anaerobic oxidation of methane
ADPAC	alkyltrimethylbenzylammonium chloride	APTT	activated partial thromboplastin time
ADHD	attention deficit hyperactivity disorder	APTT	activated partial thromboplastin time