

# Contents

## Preface *xiii*

<b>1</b>	<b>Biotechnology and Various Environmental Concerns: An Introduction</b>	<b>1</b>
	<i>Ravi K. Gangwar, Rajesh Bajpai, and Jaspal Singh</i>	
1.1	Introduction	1
	References	7
<b>2</b>	<b>Plant Biotechnology: Its Importance, Contribution to Agriculture and Environment, and Its Future Prospects</b>	<b>9</b>
	<i>Jeny Jose and Csaba Éva</i>	
2.1	Where do Environment and Biotechnology Meet?	9
2.1.1	Introduction	9
2.1.2	Chief Applications	10
2.2	Understanding Agricultural Biotechnology	11
2.2.1	Introduction	11
2.2.2	Main Components of Agricultural Biotechnology	12
2.2.3	Applications of Agricultural Biotechnology	12
2.3	Animal and Plant Biotechnology	13
2.3.1	Animal Biotechnology	13
2.3.2	Plant Biotechnology	14
2.3.2.1	Introduction	14
2.3.2.2	Traditional Breeding and Genetic Modification	14
2.3.2.3	Creating GMOs	15
2.3.2.4	Applications of GM Plants	22
2.3.2.5	GMO Controversy	23
2.3.2.6	Conclusion	24
	References	25

### **3 Recent Advances in the Remediation of Petroleum Hydrocarbon Contamination with Microbes 31**

*Parvaze A. Wani and Salami O. Rahman*

- 3.1 Introduction 31
- 3.2 Sources of Petroleum Hydrocarbons 32
- 3.3 Composition of Petroleum Pollutants 32
- 3.4 Toxic Effects of Petroleum Hydrocarbons 33
  - 3.4.1 Hydrocarbon Toxicity to Microorganisms 33
  - 3.4.2 Petroleum Toxicity to Soil 34
  - 3.4.3 Petroleum Toxicity and Plant Growth 34
  - 3.4.4 Petroleum Toxicity and Human Health 34
- 3.5 Hydrocarbon-Degrading Microorganisms 34
- 3.6 Mechanism of Petroleum Hydrocarbon Degradation 36
  - 3.6.1 Enzymatic Degradation of Hydrocarbons 37
  - 3.6.2 Degradation of Hydrocarbons by Biosurfactants 37
  - 3.6.3 Petroleum Hydrocarbon Degradation by Immobilized Cells 37
- 3.7 Types of Hydrocarbon Degradation 38
  - 3.7.1 Degradation of Hydrocarbons Under Aerobic Condition 38
  - 3.7.2 Hydrocarbon Degradation Under Anaerobic Condition 38
- 3.8 Factors Affecting Hydrocarbon Degradation by Microorganisms 39
  - 3.8.1 Hydrocarbon Biodegradation and Temperature 39
  - 3.8.2 Hydrocarbon Biodegradation and pH 40
  - 3.8.3 Microbial Population, Microbial Efficiency, and Catabolism 40
  - 3.8.4 Hydrocarbon Biodegradation and Consortium of Microbes 40
  - 3.8.5 Hydrocarbon Content and Soil 40
  - 3.8.6 Salinity and Hydrocarbon Biodegradation 41
  - 3.8.7 Presence of Dissolved Oxygen in Soil 41
  - 3.8.8 Nutrient Status of Soil 41
- 3.9 Conclusion 41
- References 42

### **4 Remediation of Heavy Metals: Tools and Techniques 47**

*Ankita Singh and Amit Kumar Tripathi*

- 4.1 Introduction 47
- 4.2 Bioremediation 48
- 4.3 Organism of Bioremediation 49
  - 4.3.1 Factors Affecting Microbial Bioremediation 50
  - 4.3.2 Biotic Factors 50
  - 4.3.3 Abiotic Factors 50
- 4.4 Techniques of Bioremediation 51
  - 4.4.1 Solid-Phase Bioremediation 51
  - 4.4.2 Slurry-Phase Bioremediation 51
- 4.5 Types of Bioremediation 52
  - 4.5.1 Biopile 52
  - 4.5.2 Windrows 52

4.5.3	Land Farming	53
4.5.4	Bioreactor	53
4.5.4.1	Techniques for <i>In Situ</i> Bioremediation	54
4.5.4.2	Types of <i>In Situ</i> Bioremediation	54
4.5.5	Bioventing	54
4.5.6	Bioslurping	54
4.5.7	Biosparging	55
4.5.8	Phytoremediation	55
4.5.9	Permeable Reactive Barrier (PRB)	55
4.6	Prospects of Bioremediation	56
4.7	Advantages and Disadvantages of Bioremediation	57
4.7.1	Bioremediation's Drawbacks	59
4.8	Conclusion	59
	Acknowledgment	60
	References	60

## **5 Soil Biodiversity and Environmental Sustainability 69**

*Tsedekch G. Weldmichael*

5.1	Introduction	69
5.1.1	Biodiversity in the Soil	69
5.1.2	Environmental Sustainability	70
5.2	Importance of Soil Biodiversity in Supporting Terrestrial Life and Diversity	71
5.2.1	Nutrient Acquisition and Retention	71
5.2.2	Pest and Disease Control	73
5.3	Soil Biodiversity and Climate Change	75
5.4	Soil Biodiversity and Hydrological Cycle	77
5.5	Soil Biodiversity and Environmental Remediation	79
5.6	Conclusion	80
	References	81

## **6 Plant Growth-Promoting Rhizobacteria: Role, Applications, and Biotechnology 89**

*Induja Mishra, Pashupati Nath, Namita Joshi, and Bishwambhar D. Joshi*

6.1	Introduction	89
6.2	Functions and Role of PGPR	90
6.3	Range and Different Diversity of PGPR	91
6.3.1	Rhizosphere: Focal Point of PGPR	91
6.3.2	Characteristics of an Ideal PGPR	92
6.3.3	Growth-Enhancing Activities	93
6.3.4	PGPR Over the Period of Time	93
6.4	Mechanisms of Plant Growth Promotion by PGPR	94
6.5	Biotechnological Effects of PGPR	95
6.5.1	Biological Fixation of Nitrogen	95
6.5.2	Solubilization of Phosphorus	95

6.5.3	Antagonistic Activity and Biocontrol Agents	96
6.5.4	Synthesis of Hydrolytic Enzymes	97
6.5.5	Production of Siderophores	97
6.5.6	Production of Antibiotics	98
6.5.7	Production of Ethylene	98
6.5.8	Production of Gibberellins and Cytokinin (Stimulators of Plant Growth)	99
6.5.9	Production of Bacteriocins	99
6.5.10	Induced Systemic and Systemic Acquired Resistance (ISR and SAR)	100
6.6	PGPR Cometabolism	100
6.7	Classification and Assortment of PGPR Strains	101
6.8	Commercial Significance of PGPR	101
6.8.1	Restrains with PGPR	102
6.9	Future Prospects of PGPR	102
6.10	Concluding Remarks of PGPR	103
	References	103

## **7 A Green Approach for CO<sub>2</sub> Fixation Using Microalgae Adsorption: Biotechnological Approach 115**

*Priyanka Raviraj and Syed Atif Ali*

7.1	Introduction	115
7.2	Effect of CO <sub>2</sub> Emissions on Environment	116
7.3	Advanced CO <sub>2</sub> -Capturing Methods	117
7.3.1	Absorption	117
7.3.2	Adsorption	118
7.3.3	Membrane Separation	118
7.4	Biological Methods for CO <sub>2</sub> Capturing	118
7.5	Earlier Technologies of Carbon Dioxide Capturing	119
7.6	Natural Carbon Capture Technology: Photosynthesis	120
7.7	Microalgae as the Modern Tool to Capture CO <sub>2</sub>	121
7.8	Biology of Microalgae as Photosynthetic Organisms and CO <sub>2</sub> Absorbers	122
7.9	Conclusion	123
	References	123

## **8 Assessment of *In-Vitro* Culture as a Sustainable and Eco-friendly Approach of Propagating Lichens and Their Constituent Organisms for Bioprospecting Applications 129**

*Amrita Kumari, Himani Joshi, Ankita H. Tripathi, Garima Chand, Penny Joshi, Lalit M. Tewari, Yogesh Joshi, Dalip K. Upreti, Rajesh Bajpai, and Santosh K. Upadhyay*

8.1	Lichens and Their Structural Organization	129
8.1.1	Structural Organization	129
8.1.2	Role of Mycobionts and Phycobionts in the Symbiotic Association	130
8.2	Lichens and Bioprospection	131
8.3	Lichens as Sources of Unique Metabolites	132

8.4	Need of <i>In Vitro</i> Culture of Lichen and Lichen Components and Its Utility in Environment Conservation	134
8.5	<i>In Vitro</i> Culture of Lichens/Constituent Organisms	135
8.5.1	Efforts Carried Out on Lichen Culture	135
8.5.2	Mycobiont Culture	136
8.5.3	Endolichenic Fungal Culture	138
8.6	Use of <i>In Vitro</i> Lichen Culture for Bioprospecting	139
8.6.1	lichen Symbiont/Mycobiont Culture	139
8.6.2	Endolichenic Fungal Culture	141
8.7	Challenges Associated	145
8.8	Conclusion	145
	Acknowledgment	145
	References	146

## 9 **Bioprospection Potential of Indian Cladoniaceae Together with Its Distribution, Habitat Preference, and Biotechnological Prospects** 155

*Rajesh Bajpai, Upasana Pandey, Brahma N. Singh, Veena Pande, Chandra P. Singh, and Dalip K. Upreti*

9.1	Introduction	155
9.2	Materials and Methods	159
9.3	Results and Discussion	160
9.4	Conclusions	182
	Acknowledgments	183
	References	183

## 10 **Biotechnological Approach for the Wastewater Management** 193

*Anamika Agrawal, Sameer Chandra, Anand K. Gupta, Rajendra Singh, and Jaspal Singh*

10.1	Introduction	193
10.1.1	Sources of Water Pollution	194
10.1.2	Water Pollutants	194
10.1.2.1	Sewage Pollutants	194
10.1.2.2	Industrial Pollutants	194
10.1.2.3	Agriculture Pollutant	194
10.1.3	Physical Pollutants	195
10.1.3.1	Radioactive Waste	195
10.1.3.2	Thermal Sources	195
10.1.3.3	River Streams and Mountain Springs Sediments	195
10.1.3.4	Petroleum Products	195
10.2	Effects of Water Pollution	195
10.3	Role of Biotechnology to Control Water Pollution	196
10.3.1	Genetically Engineered Microorganisms (GEMs) in Remediation of Pollution	196

10.3.1.1	Biotechnological Approaches for Water Pollution Remediation	198
10.3.1.2	Aerobic Biological Treatment	198
10.3.1.3	Activated Sludge Process	198
10.3.1.4	Constructed Wetlands	199
10.3.1.5	Biological Filters-Fixed Film Systems	199
10.3.1.6	Rotating Biological Contactors	199
10.3.1.7	Fluidized Bed Reactor	200
10.3.1.8	Expanded Bed Reactor (EBR)	200
10.3.2	Anaerobic Biological Treatment	200
10.3.2.1	Membrane Bioreactors (MBRs)	201
10.3.2.2	Bioremediation	201
10.3.2.3	Bioremediation of Industrial Effluent Using Biotechnology	202
10.3.2.4	Bioremediation of Pulp and Paper Mill Effluent	202
10.3.2.5	Bioremediation of Spilled Oil and Grease Deposits	202
10.3.2.6	Bioremediation of Textile Industry Effluent Through Biotechnology	203
10.3.2.7	Bioremediation of Distillery Effluent Using Biotechnology	203
10.3.2.8	Phytoremediation	204
10.4	Role of Biotechnology in Phytoremediation	205
10.4.1	Bioaugmentation	205
10.4.2	Biosorption	206
10.4.3	Advantages	207
10.5	Conclusion	207
	References	207

## **11 The Application of Biotechnology in the Realm of Bioenergy and Biofuels 209**

*Manvi Singh, Namira Arif, and Anil Bhatia*

11.1	Introduction	209
11.2	Bioenergy (Biomass Energy)	210
11.2.1	Biomass and Its Sources	211
11.2.2	Biomass to Energy	211
11.2.2.1	Biomass to Biogas	212
11.2.2.2	Biomass to Biofuels	214
11.2.3	Agri-biomass (Biochar) to Energy	217
11.3	Conclusions	217
	References	218

## **12 Nanotechnological Approach for the Abatement of Environmental Pollution: A Way Forward Toward a Clean Environment 221**

*Manzari Kushwaha, Anuradha Mishra, Divya Goel, and Shiv Shankar*

12.1	Introduction	221
12.2	Nanoparticles: Properties, Types, and Route of Synthesis	222
12.2.1	Properties of Nanoparticles	223

12.2.2	Classification of Nanoparticles	223
12.2.3	Synthesis of Nanoparticles	225
12.2.3.1	Top-Down Approach	225
12.2.3.2	Bottom-Up Approach	226
12.2.4	Environmental Applications of nanoparticles	226
12.3	Nanoremediation for Environment Cleanup	227
12.3.1	Nanoremediation of Air	228
12.3.1.1	Nanoadsorption	229
12.3.1.2	Degradation by Nanocatalysis	229
12.3.1.3	Nanofiltration	230
12.3.2	Nanoremediation of Water	231
12.3.2.1	Adsorption	231
12.3.2.2	Membrane Process	231
12.3.2.3	Photocatalysis	232
12.3.3	Nanoremediation of Soil	233
12.3.4	Nanomaterial for Control of Environmental Pathogens	233
12.4	Challenges in Nanoremediation of the Environment and Solution	236
12.5	Conclusion and Future Prospects	238
	Acknowledgments	238
	References	239
<b>13</b>	<b>Role of Fatty Acids and Proteins in Alteration of Microbial Cell Surface Hydrophobicity: A Regulatory Factor of Environmental Biodegradation</b>	<b>249</b>
	<i>Babita Kumari, Kriti Kriti, and Gayatri Singh</i>	
13.1	Introduction	249
13.2	Cell Surface Fatty Acids and Alteration in CSH	250
13.2.1	Saturated and Unsaturated Fatty Acid	251
13.3	Proteins/Genes Responsible in CSH Modulation	253
13.3.1	Flo Mannoprotein	253
13.3.2	CyoC	255
13.3.3	LapF	255
13.3.4	CSH1	255
13.3.5	A-protein	255
13.3.6	BslA	256
13.3.7	Foam-Forming Gene	256
13.3.8	Cpx-Signaling Pathway	256
13.4	Eicosapentaenoic Acid (EPA)	256
13.5	Factors that Influence Cell Surface Hydrophobicity	257
13.5.1	Chemicals	257
13.5.1.1	Hydrocarbons	257
13.5.1.2	Surfactants	258
13.5.1.3	Antimicrobial Chemicals	258
13.5.2	Environmental Condition	259

13.6	Conclusion	260
	Acknowledgment	260
	References	260
<b>14</b>	<b>Chemical Sustainability for a Nontoxic Environment – A Healthy Future</b>	<b>269</b>
	<i>Puneet Khare, Shashi K. Tiwari, and Lakshmi Bala</i>	
14.1	Introduction	269
14.2	Basis of Sustainable Chemistry	271
14.3	Challenges in Front of Sustainable Chemistry	272
14.4	Green Chemistry: A Sustainable Approach at a Minor Level	273
14.5	Research and Education in Green and Sustainable Chemistry	274
14.6	Scope of the Concerned Field	274
14.7	Role of OECD Toward Sustainable Chemistry	275
14.8	Difference Between Green and Sustainable Chemistry	275
14.9	The 12 Principles of Green Chemistry (EPA)	276
14.10	Applications and Innovations of Sustainable Chemistry	277
14.11	In the Pharmaceutical Industry	277
14.12	Intense Use of Renewable Resources	278
14.13	Improvement in Catalytic Methods	278
14.14	Encouragement of the Use of Biomass	278
14.15	Improvement of Lignocellulose Extraction Technology	278
14.16	Improvement in Solvents	278
14.17	Biocatalyst Advancement	279
14.18	Improvement in Plastic Technology	279
14.19	Techniques for Assessing Environmentally Friendly Chemical Processes and Products	280
14.20	R&D in Sustainable Chemical Fields	280
14.21	Benefits of Sustainable Chemistry	280
14.22	Conclusion	281
	Acknowledgment	281
	References	281
	<b>Index</b>	<b>285</b>