

Contents

Preface *xi*

List of Contributors *xiii*

1	Shape- and Size-Dependent Antibacterial Activity of Nanomaterials	1
	<i>Senthilguru Kulanthaivel and Prashant Mishra</i>	
1.1	Introduction	1
1.2	Synthesis of Nanomaterials	3
1.3	Classification of NMs	4
1.3.1	Classification Based on Dimensions	5
1.3.1.1	Zero-Dimensional NMs	5
1.3.1.2	One-Dimensional NMs	6
1.3.1.3	Two-Dimensional NMs	6
1.3.1.4	Three-Dimensional NMs	6
1.3.2	Classification Based on Chemical Compositions	7
1.3.2.1	Carbon-Based NMs	7
1.3.2.2	Organic-Based NMs	7
1.3.2.3	Inorganic-Based NMs	8
1.3.3	Classification Based on Origin	9
1.4	Application of NMs	9
1.4.1	Advanced Application of NMs as Antimicrobial Agents	9
1.5	Bacterial Resistance to Antibiotics	10
1.5.1	Mechanism of Antibiotic Resistance	10
1.5.1.1	Antibiotics Modification	11
1.5.1.2	Antibiotic Efflux	12
1.5.1.3	Target Modification or Bypass or Protection	12
1.6	Microbial Resistance: Role of NMs	12
1.6.1	Overcoming the Existing Antibiotic Resistance Mechanisms	13
1.6.1.1	Combating Microbes Using Multiple Mechanisms Simultaneously	13
1.6.1.2	Acting as Good Carriers of Antibiotics	13

1.7	Antibacterial Application of NMs	15
1.7.1	Nanometals	16
1.7.2	Metal Oxides	17
1.7.3	Carbonaceous NMs	18
1.7.4	Cationic Polymer NMs	19
1.8	Interaction of NMs with Bacteria	19
1.9	Antibacterial Mechanism of NMs	20
1.10	Factors Affecting the Antibacterial Activity of NMs	22
1.10.1	Size	22
1.10.2	Shape	23
1.10.3	Zeta Potential	24
1.10.4	Roughness	24
1.10.5	Synthesis Methods and Stabilizing Agents	25
1.10.6	Environmental Conditions	26
1.11	Influence of Size on the Antibacterial Activity and Mechanism of Action of Nanomaterials	27
1.12	Influence of Shape on the Antibacterial Activity and Mechanism of Action of Nanomaterials	30
1.13	Effects of Functionalization on the Antimicrobial Property of Nanomaterials	34
1.14	Conclusion and Future Perspectives	35
	Questions and Answers	36
	References	38
2	Size- and Shape-Selective Synthesis of DNA-Based Nanomaterials and Their Application in Surface-Enhanced Raman Scattering	53
	<i>K. Karthick and Subrata Kundu</i>	
2.1	Introduction	53
2.2	Mechanism of Surface-Enhanced Raman Scattering (SERS)	55
2.2.1	Significance of Nano-Bio Interfaces and Role of DNA in Enhancing SERS Activity	56
2.3	Size- and Shape-Selective Synthesis of Metal NPs with DNA for SERS Studies	57
2.3.1	Metal NP Assemblies on DNA Using Photochemical Route for SERS Studies	58
2.3.2	Metal NP Assemblies on DNA Using Chemical Reduction Process as Aquasol for SERS Studies	69
2.3.3	Metal NP Assemblies on DNA Using Chemical Reduction as Organosol for SERS Studies	77
2.3.4	Metal NP Assemblies on DNA Prepared Using Microwave Heating for SERS Studies	79

2.3.5	Conclusions and Outcomes of DNA-Based Metal Nanostructures for SERS Studies	83
	Take Home Message	85
	Questions and Answers	85
	References	86
	Academic Profile	90
3	Surface Modification Strategies to Control the Nanomaterial–Microbe Interplay	93
	<i>T. K. Vasudha, R. Akhil, W. Aadinath, and Vignesh Muthuvijayan</i>	
3.1	Introduction	93
3.2	Factors Influencing NM–Microbe Cross talk	96
3.2.1	Surface Features of Microbes	96
3.2.2	Physicochemical Properties of NMs	97
3.3	Surface Functionalization	100
3.3.1	Techniques Used for Surface Functionalization	101
3.3.1.1	Self-Assembled Monolayers	102
3.3.1.2	Layer-by-Layer Technique	102
3.3.2	Surface Functionalization Strategies	103
3.3.2.1	Physicochemical Modifications	103
3.3.2.2	Biofunctionalization	105
3.4	Characterization of NM–Microbe Interactions	106
3.4.1	Microbe Parameters	107
3.4.2	NM Parameters	108
3.5	Toxicity of the Surface-Modified NMs	109
3.6	Challenges and Future Perspectives	110
	Questions and Answers	111
	Take Home Message	112
	References	112
4	Surface Functionalization of Nanoparticles for Stability in Biological Systems	129
	<i>Srishti Agarwal and D. Sakthi Kumar</i>	
4.1	Introduction	129
4.2	Major Processes Affecting NP Stability in Biological Media	130
4.2.1	Aggregation	130
4.2.2	Nanoparticle Design and Properties	131
4.2.3	Hydrophobicity/Hydrophilicity Effects	133
4.2.4	Effect of Protein Corona	134
4.2.4.1	Effect of Protein Corona on Active Targeting	134
4.2.5	External Factors	135

4.3	Measures to Enhance NP Stability in Biological Systems	135
4.3.1	Stabilization Against Aggregation	135
4.3.2	Ligand Exchange	136
4.3.3	Coating with Additional Layers	136
4.3.3.1	Silica Coating	137
4.3.3.2	PEG Coating	138
4.3.3.3	Lipid Bilayer Coating	141
4.3.3.4	Zwitterionic Coating	141
4.3.3.5	Protein Coating	143
4.3.3.6	Aptamer Coating	144
4.3.4	Subsiding the Nonspecific Protein Interaction	146
4.3.5	Nanoparticle Design	146
4.3.5.1	Particle Functionalization	147
4.3.6	Influence of NM Physicochemical Properties on Microbe–NM Interaction	149
4.4	Conclusion and Future Perspectives	151
4.5	Summary	152
	Questions and Answers	152
	References	153

5 Molecular Mechanisms Behind Nano-Cancer Therapeutics 167

Surya Prakash Singh and Aravind Kumar Rengan

5.1	Nanotechnology at Nano–Bio Interfaces	167
5.2	Armory of Nanomedicine at Nano–Bio Interfaces	168
5.3	Nanoparticle Edge in Modulating Biological Process	170
5.4	Intracellular Uptake and Trafficking of Nanoparticle	173
5.5	Challenges in Clinical Applications	176
5.6	Conclusion	177
	Take Home Message	177
	Questions and Answers	178
	References	179

6 Protein Nanoparticle Interactions and Factors Influencing These Interactions 187

R. Mala and R. Keerthana

6.1	Introduction	187
6.2	Types and Biomedical Application of Nanoparticles	188
6.3	Methods and Mechanisms of Nanomaterials Synthesis	189
6.4	Routes of Entry of Nanoparticles into Biological System	190
6.5	Rationale for Studying Nanoparticles–Protein Interactions	191
6.6	Formation of Protein Corona	191
6.6.1	Structure and Composition of Corona	191

6.6.2	Kinetics of Formation of Nanoparticles–Corona	193
6.7	Nanoparticles-Induced Structural Changes in Proteins	195
6.7.1	Reversible	195
6.7.2	Irreversible	195
6.8	Factors Influencing Corona Formation	196
6.8.1	Properties of Nanoparticles	196
6.8.1.1	Size	196
6.8.1.2	Shape	198
6.8.1.3	Charge	198
6.8.1.4	Surface Functionalization	198
6.8.1.5	Surface Reactivity	199
6.8.1.6	Solubility	199
6.8.2	Properties of Protein	199
6.8.3	Effect of Surrounding Environment	201
6.8.3.1	Effect of Media Composition on Corona Formation	201
6.8.3.2	Effect of Temperature	201
6.8.3.3	Static In Vitro Model Vs. Dynamic In Vivo System	201
6.9	Interaction of Nanoparticles with Cells and Their Uptake	202
6.10	Pleiotrophic Effect of Nanoparticles	204
6.11	Analytical Methods to Study Nanoparticles–Protein Interaction	204
6.11.1	Spectral Properties	204
6.11.1.1	UV–Vis Spectroscopy	204
6.11.1.2	FTIR	205
6.11.1.3	Raman Spectroscopy	205
6.11.1.4	Fluorescence Spectroscopy	206
6.11.2	Surface Plasmon Resonance	208
6.11.3	Cellular Uptake of Nanoparticles–Protein	208
6.11.3.1	Flow Cytometry	208
6.11.3.2	Confocal Microscopy	208
6.11.4	Binding Affinity	209
6.11.4.1	Differential Scanning Calorimetry and Isothermal Calorimetry	209
6.11.4.2	Isothermal Titration Calorimetry	209
	Questions and Answers	209
	References	210
7	Interaction Effects of Nanoparticles with Microorganisms Employed in the Remediation of Nitrogen-Rich Wastewater	225
	<i>Parmita Chawley and Sheeja Jagadevan</i>	
7.1	Introduction	225
7.2	Bacterial Nitrification Process	227

- 7.2.1 Effect of NPs on Functional Gene Abundance and Transcriptional Response 227
- 7.2.2 Effect of NPs on Enzyme Activity 229
- 7.2.3 Effect on Cellular Morphology 230
- 7.3 Effect of NPs on Denitrifying Bacteria 231
- 7.3.1 Effect on Functional Gene Abundance and Transcriptional Response 232
- 7.3.2 Enzymatic Response 234
- 7.4 Impact of Nanoparticles on Nitrogen Removal 236
- 7.5 Conclusion 236
 - Take Home Message 236
 - Questions and Answers 237
 - References 238

8 Silver-Based Nanoparticles for Antibacterial Activity: Recent Development and Mechanistic Approaches 245

Arpita Roy, Papia Basuthakur, Shagufta Haque, and Chitta Ranjan Patra

- 8.1 Introduction 245
- 8.2 Historical Background of Silver 246
- 8.3 Synthesis Procedures of Silver Nanoparticles 247
 - 8.3.1 Chemical Synthesis 247
 - 8.3.2 Physical Methods 249
 - 8.3.3 Biological Methods 249
- 8.4 Biological Application of Silver Nanoparticles 251
- 8.5 Bacterial Infection and Antibiotic Resistance 251
- 8.6 Nanosilver for Antibacterial Therapy 254
 - 8.6.1 Metallic Silver Nanoparticles 254
 - 8.6.2 Biosynthesized Silver Nanoparticles 254
 - 8.6.3 Silver Nanocomposites 257
 - 8.6.4 Silver Nanoscaffolds 260
- 8.7 Influence of Size and Shape of Silver Nanoparticles as Antibacterial Agents 260
- 8.8 Nanosilver and Its Mechanism of Action for Antibacterial Therapy 261
- 8.9 Application of Silver Nanoparticle in Commercial Products 266
 - 8.9.1 Silver Nanoparticles in Wound Dressing Materials and Devices 266
 - 8.9.2 Silver Nanoparticles in Soaps and Detergents 268
 - 8.9.3 Silver Nanoparticles in Fabrics 269
 - 8.9.4 Silver Nanoparticles in Cosmetics 271
 - 8.9.5 Silver Nanoparticles in Food Packaging 271
 - 8.9.6 Silver Nanoparticles in Paints 273

8.10	Toxicity of Silver Nanoparticles	273
8.11	Future Prospective and Challenges	275
8.12	Conclusion	276
	Take Home Message	276
	Questions and Answers	277
	Abbreviation	278
	References	280
9	Microbial Gold Nanoparticles and Their Biomedical Applications	303
	<i>Dindyal Mandal, Rohit Kumar Singh, Uday Suryakant Maharana, Bijayananda Panigrahi, and Sourav Mishra</i>	
9.1	Introduction	303
9.2	Microbial Gold Nanoparticles Synthesis	304
9.2.1	Bacteria-Mediated Gold Nanoparticles	306
9.2.2	Algae-Mediated Gold Nanoparticles	308
9.2.3	Fungi-Mediated Gold Nanoparticles	311
9.2.4	Yeast-Mediated Gold Nanoparticles	315
9.2.5	Mechanism Involved in Microbial Nanoparticles Synthesis	315
9.3	Applications of Microbial Gold Nanoparticles	317
9.3.1	Biosensing	317
9.3.2	Antibacterial Activity of Au NPs	318
9.3.3	Anticancer Activity of Microbial Gold Nanoparticles	321
9.4	Conclusion	322
	Take Home Message	323
	Questions and Answers	323
	References	325
10	Nano-Bio Interactions and Their Practical Implications in Agriculture	337
	<i>Achintya N. Bezbaruah and Ann-Marie Fortuna</i>	
10.1	Introduction	337
10.1.1	Agriculturally Beneficial Soil Microorganisms	339
10.2	Engineered Nanomaterials and Agriculture	340
10.2.1	Pathways for ENM to Soil	340
10.2.2	Fate of ENMs in Soil	340
10.2.3	Chemical Interactions of ENM in Soil	343
10.2.4	Mechanisms Controlling Heteroaggregation	344
10.2.5	Mobility of Colloids and ENMs in Soil	344
10.2.6	Nanoagriculture	345
10.2.7	Nanopesticides	348

10.2.8	ENMs and Agriculturally Beneficial Microorganisms	349
10.3	Summary	352
	References	353
11	Biogeochemical Interactions of Bioreduced Uranium Nanoparticles	359
	<i>S. Sevinç Şengör and Rajesh K. Sani</i>	
11.1	Introduction	359
11.2	Coupled Biogeochemical Mechanisms and Interactions of U in the Subsurface	361
11.3	Biogenic Uraninite Precipitation and Its Nanoparticulate Forms	367
11.4	Re-oxidation and Stability of Bioreduced Uranium	371
11.5	Summary and Conclusions	373
	Questions and Answers	374
	References	376
12	Characterization and Quantification of Mobile Bioreduced Uranium Phases	383
	<i>S. Sevinç Şengör and Rajesh K. Sani</i>	
12.1	Introduction	383
12.2	Characterization of Biogenic U(IV)	384
12.3	Quantification of Mobile Bioreduced U(IV) Nanoparticles	386
12.4	Summary and Conclusions	388
	Questions and Answers	389
	References	391
	Index	395