Contents

	Preface	<i>page</i> xiii
1	Nanomaterials: Principles and Properties	1
11	Bionanotechnology: Concept and History	i
12	Nanomaterials in Bionanotechnology	2
13	Nanosized vs Bulk Materials	2
1.0	In Numbers 1.1. How Many Atoms Are There in a Nanonarticle?	4
	Back to Basics 1.1. Density of States of a Solid	7
	In Numbers 1.2. At What Diameter Does a Gold Nanoparticle Achieve	
	Quantum Confinement at 25 °C2	0
	Back to Basics 1.2 Surface Plasmon	10
14	The Batic of Surface Atoms to Volume	10
1.4	Surface Epergy	15
1.0	Back to Basics 1.3 Crystal Facets and Their Surface Energy	10
16	Strategies to Reduce Surface Energy	10
1.0	Back to Basics 1.4. Laws of Thermodynamics and the Cibbo Energy	10
17	Principles of Nanomatorial Synthesis	10
1.7	Principles of Nationaterial Synthesis	20
	Back to Basics 1.5 Colloids	22
1.8	Nano(crystal) Growth	23
1.0	Ostwald Pipening and Caslessanas	20
1.9	People to Design 1.7. Van der Waste and Coulomb Interactions	28
10	Back to Basics 1.7 van der waals and Coulomb Interactions	30
.10	Rock to Regiss 1.8. Clusters and Magic Numbers, Case of Nable Metals	31
	Back to Basics 1.6 Clusters and Magic Numbers: Case of Noble Metals	33
	Rey Concepts	35
	Problems	37
	Poteronace	38
	Rejerences	38
0	Nonematorials, Dreneration Strategies	10
2	Nanomaterials: Preparation Strategies	40
2.1	Bottom-Up and Top-Down Strategies	43
0.0	Back to Basics 2.1 Top-Down Method: Lithography	44
2.2	Preparation of Metallic Nanostructures	45
	2.2.1 Use of Strong Reducing Agents: A Case of Gold Nanoparticles	47
	2.2.2 Use of Mild Reducing Agents: A Case of Platinum Nanoparticles	48
	2.2.3 Micelle-Guided Reduction	49

	2.2.4 Polyols and Surface Capping Agents for Shape Control	50
	2.2.5 Metallic Nanoparticles: A Brief Overview of Other Methods	53
2.3	Preparation of Metal Oxide Nanomaterials	55
	Back to Basics 2.2 Sol-Gel Processing	55
	2.3.1 Hydrolysis of Alkoxide Precursors	56
	2.3.2 Hydrolysis of Inorganic or Organic Metal Salts	58
	Back to Basics 2.3 Types of Magnetism	59
	2.3.3 High-Temperature Non-Hydrolytic Methods	60
2.4	Synthesis of Quantum Dots	61
	Research Report 2.1 Quantum Dots for Improved Antibiotic Activity	63
2.5	Preparation of Carbon Nanomaterials	64
	2.5.1 Synthesis of Fullerene	65
	2.5.2 Carbon Nanotubes and Graphene	66
	Research Report 2.2 Activity of Neurons Restored by Carbon Nanotubes	69
	2.5.3 Preparation of Carbon Nanodiamonds	71
	Research Report 2.3 Carbon Nanodiamonds As Cell Thermometers	73
2.6	Preparation of Polymeric Nanoparticles	74
	Back to Basics 2.4 Polymer Synthesis	74
	Research Report 2.4 Biocompatible Polymer for Drug Formulation	76
2.7	Preparation of Porous Nanomaterials	77
	Research Report 2.5 Mesoporous Silica for Bone Regeneration	78
	Back to Basics 2.5 Hydrogels	80
2.8	Biosynthesis of Nanomaterials	81
	Key Concepts	84
	Problems	85
	Further Reading	86
	References	87
3	Biomolecules and Scales of Biological Systems	91
3.1	Cell Compartments	92
	Back to Basics 3.1 Prokaryotic vs Eukaryotic Cells	94
3.2	Carbohydrates	97
	Back to Basics 3.2 Isomers and Molecular Mirror Images	97
	Back to Basics 3.3 It Is an ATP World	99
	Back to Basics 3.4 Nanocellulose	101
3.3	Lipids	102
3.4	Nucleic Acids	104
	Back to Basics 3.5 Nucleic Acid Glossary	105
	3.4.1 Deoxyribonucleic Acid	107
	3.4.2 Ribonucleic Acid	109

	• •	
1/11	Conton	to
VII	COLLET	15
	Conton	-

35	From DNA to Protain: Control Dogmo of Malagular Biology	110
0.0	Rock to Replice 2.6. Bibecomest True Biological Machines	110
36	Protoine	112
0.0	Rack to Rasics 2.7. Secondary Protein Structure Motifs	112
	Back to Basics 3.7 Secondary Protein Structure Motilis	110
37	Proteins in Riepenstechnology, Interfacing Proteins	110
0.7	3.7.1. Strentavidin	110
	3.7.2 Antibodies and Nanohodies	110
	Research Report 3.1 Antibodies in Cancer Therapy	120
38	Proteins in Bionanotechnology: Labelling Proteins/Protein Tags	120
0.0	Back to Basics 3.9. Recombinant DNA and Fusion Proteins	122
	3.8.1. Fluorescent Proteins	122
	3.8.2 Protein Tags	120
3.9	Proteins in Bionanotechnology: Enzymes	127
	Back to Basics 3.10. Six Enzyme Families	127
	Research Report 3.2 Cofactor Exchange and Reconstitution	131
	Research Report 3.3 An Enzyme Degrades Graphene	133
3.10	Proteins in Bionanotechnology: Structural Proteins	133
	Key Concepts	137
	Problems	138
	Further Reading	139
	References	140
4	(Bio)functionalisation of Nanomaterials	143
4.1	Self-Assembly	144
	Back to Basics 4.1 Concept of Self-Assembly throughout History	144
	Back to Basics 4.2 Stochastic Processes	145
	Research Report 4.1 Enzyme-Instructed Self-Assembly	149
4.2	Modification of the Nanomaterial Surface	152
	4.2.1 Self-Assembled Monolayers	152
	Research Report 4.2 Gold–Thiol Self-Assembled Monolayers	153
	4.2.2 Surface-Binding Groups	155
	Research Report 4.3 Catechol-Titanium Dioxide Charge Transfer Complex	157
	4.2.3 The Space Between: The Spacer	159
	Back to Basics 4.3 Kupffer Cells	160
	4.2.4 Functional Groups	162
4.3	Non-Covalent Biofunctionalisation Strategies	163
	4.3.1 Physical Adsorption	163
	Research Report 4.4 Improving Stability of Lipase Enzyme	165
	4.3.2 DNA-Directed Functionalisation	166

	Research Report 4.5 DNA-Directed Assembly of Nanoparticles	167
	4.3.3 DNA Aptamers	168
	Back to Basics 4.4 Systematic Evolution of Ligands by Exponential	
	Enrichment	168
4.4	(Bio)functionalisation Using Proteins and Protein Tags	170
	4.4.1 Streptavidin–Biotin Interaction	170
	Research Report 4.6 STV–Gold Nanoparticles to Study Cell Receptor	
	Geometry	170
	4.4.2 Antibody-Antigen Interactions	172
	Research Report 4.7 Carbon Nanotube Biosensor for Lyme Disease	172
	4.4.3 Protein Tags	173
	Back to Basics 4.5 SNAP, CLIP and Halo Tags for Protein Conjugation	175
4.5	Covalent Biofunctionalisation Strategies	176
	Back to Basics 4.6 Click Chemistry	176
	Key Concepts	181
	Problems	182
	Further Reading	183
	References	184
5	Analytical Methods in Bionanotechnology	187
5.1	Assessing the Morphology of Nanostructures	189
	Back to Basics 5.1 A Short History of Electron Microscopy	190
	5.1.1 Electron Beam	191
	5.1.2 Transmission Electron Microscopy	192
	In Numbers 5.1 Electronvolts	193
	Back to Basics 5.2 Cryogenic Electron Microscopy	194
	5.1.3 Scanning Electron Microscopy	195
	5.1.4 X-ray Diffraction	197
	5.1.5 Small Angle X-ray Scattering	198
5.2	Composition and Surface Properties of Nanostructures	199
	5.2.1 Energy Dispersive X-ray Analysis	200
	5.2.2 X-ray Photoelectron Spectroscopy	200
	5.2.3 Auger Electron Spectroscopy	202
	5.2.4 Time of Flight Secondary Ion Mass Spectrometry	203
	5.2.5 Scanning Tunnelling Microscopy	204
	5.2.6 Atomic Force Microscopy	206
	Research Report 5.1 Chemical Bond Formation Explored by AFM	207
5.3	Exploring Physiochemical Properties on the Nanoscale	209
	5.3.1 Molecular Spectroscopy	210
	Back to Basics 5.3 The Jablonski Diagram Explained	211

	5.3.2 Ultraviolet–Visible Spectroscopy	212
	In Numbers 5.2 Determining the Concentration of Functionalised Silver	
	Nanoparticles	214
	5.3.3 Fluorescence: Spectroscopy and Microscopy	214
	Back to Basics 5.4 Lasers	217
	Back to Basics 5.5 Types of Fluorescence Microscopy	220
	5.3.4 Vibrational Spectroscopy: Infrared Spectroscopy	223
	Back to Basics 5.6 Fourier Transform IR	225
	5.3.5 Raman Spectroscopy and Surface-Enhanced Raman Scattering	226
	Back to Basics 5.7 Tip-Enhanced Raman Spectroscopy	229
	5.3.6 Dynamic Light Scattering	230
	5.3.7 Zeta Potential	232
	Back to Basics 5.8 Zeta Potential ζ	234
5.4	Exploring (Bio)Molecular Interactions on the Nanoscale	235
	5.4.1 Fluorescence (Förster) Resonance Energy Transfer	235
	Research Report 5.2 Protein Folding Studied by FRET	237
	5.4.2 Surface Plasmon Resonance	238
	5.4.3 Quartz Crystal Microbalance	240
	Back to Basics 5.9 Piezoelectric Materials	241
	Research Report 5.3 Detection of Cancer Biomarker Using SPR and QCM	243
	Key Concepts	244
	Problems	245
	Further Reading	247
	References	248
6	DNA Nanotechnology	252
6.1	Chemical Synthesis of DNA	253
	Back to Basics 6.1 A Short History of the Chemical Synthesis of DNA	253
	Back to Basics 6.2 A Single Cycle of the Phosphoramidite Coupling	256
6.2	DNA As an Immobilisation Tool	258
	Research Report 6.1 DNA-Directed Immobilisation to Study Signalling in a	259
6.3	DNA-Nanoparticle Conjugates	261
6.4	DNA for Material Design: DNA Hydrogels	267
	Research Report 6.2 DNA Hydrogels	267
6.5	DNA Nanostructuring	269
6.6	DNA Origami	273
	Back to Basics 6.3 Rolling Circle Amplification	275
6.7	DNA Origami: Applications	277
	6.7.1 Origami-Guided Assembly	277

8	Bionanotechnology in Biosensor Design	344
8.1	Biosensors and Nanosensors	345
8.2	Nano-Enhanced Electrochemical Biosensors	346
	Research Report 8.1 Carbon Nanotube-Based Electrochemical Glucose	
	Biosensor	349
	Research Report 8.2 Silicon Nanowire FET Biosensors	351
8.3	Optical Bionanosensors	352
	8.3.1 Plasmonic Nanosensors	352
	Research Report 8.3 Colorimetric Detection of Influenza A Virus	353
	8.3.2 FRET Biosensors	355
	8.3.3 Surface-Enhanced Raman Scattering Biosensors	357
	Research Report 8.4 SERS Nanosensor for Detection of Multiple	
	Antibiotic-Resistant Pathogens	357
8.4	Mechanical Nanosensors	358
	Research Report 8.5 Hybrid Mechanical and Plasmonic Nanobiosensor	360
8.5	In Vivo Nanosensors	361
	Research Report 8.6 Photoacoustic Imaging of the Distribution of an	
	Injected Drug	362
	Key Concepts	364
	Problems	364
	Further Reading	366
	References	367
9	Bionanotechnology Meets Medicine	370
9.1	Nano-Based Therapeutics	371
	Back to Basics 9.1 The Blood-Brain Barrier	372
	Back to Basics 9.2 Two- and Three-Dimensional Cell Cultures	374
9.2	Drug Nanocarriers and Therapeutic Nanomaterials	376
	Back to Basics 9.3 Types of Drug Nanocarriers	377
	Research Report 9.1 Nanomaterials As Potent Antibacterial Agents	379
	Back to Basics 9.4 Cancer	381
	9.2.1 Passive Targeting and EPR Effect for Delivery of Nanotherapeutics	382
	Back to Basics 9.5 Fenestration of Tumour Blood Vessels	382
	9.2.2 Active Targeting of Nanocarriers	384
	9.2.3 Cell Uptake Mechanisms	385
	Research Report 9.2 Mesoporous Nanoparticles Coated with a Protein	
	Corona Shield	387
9.3	Tracking Nanomaterials in Biological Systems	388
	Back to Basics 9.6 Medical Imaging Techniques	389

	Research Report 6.3 DNA Origami for Studying Chemical Reactions	
	at the Single Molecule Level	279
	6.7.2 DNA Origami for Drug Delivery	280
	Back to Basics 6.4 Battling Cancer: Doxorubicin	281
	6.7.3 Biosensors and Movable Devices	284
	Key Concepts	285
	Problems	286
	Further Reading	287
	References	287
	Becken water to First of Galactic Bidden and Becken Spectra 2 and the second	
7	Bioinspired Nanotechnology	291
7.1	Self-Assembled Peptide Nanostructures	293
	Research Report 7.1 Peptides for Drug Delivery	296
7.2	Biomineralisation Peptides and Proteins in Nanodesign	297
	7.2.1 Nanostructures in Biomineralisation	297
	Back to Basics 7.1 Common Biominerals	297
	7.2.2 Designer Peptides for Growth of Nanostructures	302
	Research Report 7.2 Virus-Templated Lithium-Oxygen Battery	304
	7.2.3 Nanostructuring Using Biomineralisation Proteins	305
7.3	Biotemplate-Assisted Nanodesign	309
	7.3.1 Protein Templates for Nanostructuring	310
	Research Report 7.3 Silk Fibroin for Preparation of Nanoparticles	311
	7.3.2 Nanostructure Design Using Microbial and Viral Templates	313
	Back to Basics 7.2 Structural Diversity of Viruses	315
	Research Report 7.4 Plasmonic Metamaterials from Cowpea Mosaic Virus	317
7.4	Biomimetic Nanodesign	318
	7.4.1 Biomimetic Catalysts: Enzyme-Like Nanostructures	319
	Research Report 7.5 Peptide–Quantum Dot Hybrid As a Powerful Nanozyme	322
	7.4.2 Nanostructured Superhydrophobic Materials and Adhesive Surfaces	323
	Back to Basics 7.3 Superhydrophobicity and Surface Wetting	323
	Research Report 7.6 Frog's Toe Pad Structure As Inspiration for	
	Surgical Graspers	327
	7.4.3 Nanostructured Colour	328
	Back to Basics 7.4 Photonic Crystals	329
	Research Report 7.7 Bioinspired Structural Colours As Actuators	333
	Key Concepts	335
	Problems	336
	Further Reading	337
	References	338

8	Bionanotechnology in Biosensor Design	344
8.1	Biosensors and Nanosensors	345
8.2	Nano-Enhanced Electrochemical Biosensors	346
	Research Report 8.1 Carbon Nanotube-Based Electrochemical Glucose	
	Biosensor	349
	Research Report 8.2 Silicon Nanowire FET Biosensors	351
8.3	Optical Bionanosensors	352
	8.3.1 Plasmonic Nanosensors	352
	Research Report 8.3 Colorimetric Detection of Influenza A Virus	353
	8.3.2 FRET Biosensors	355
	8.3.3 Surface-Enhanced Raman Scattering Biosensors	357
	Research Report 8.4 SERS Nanosensor for Detection of Multiple	
	Antibiotic-Resistant Pathogens	357
8.4	Mechanical Nanosensors	358
	Research Report 8.5 Hybrid Mechanical and Plasmonic Nanobiosensor	360
8.5	In Vivo Nanosensors	361
	Research Report 8.6 Photoacoustic Imaging of the Distribution of an	
	Injected Drug	362
	Key Concepts	364
	Problems	364
	Further Reading	366
	References	367
9	Bionanotechnology Meets Medicine	370
9.1	Nano-Based Therapeutics	371
	Back to Basics 9.1 The Blood-Brain Barrier	372
	Back to Basics 9.2 Two- and Three-Dimensional Cell Cultures	374
9.2	Drug Nanocarriers and Therapeutic Nanomaterials	376
	Back to Basics 9.3 Types of Drug Nanocarriers	377
	Research Report 9.1 Nanomaterials As Potent Antibacterial Agents	379
	Back to Basics 9.4 Cancer	381
	9.2.1 Passive Targeting and EPR Effect for Delivery of Nanotherapeutics	382
	Back to Basics 9.5 Fenestration of Tumour Blood Vessels	382
	9.2.2 Active Targeting of Nanocarriers	384
	9.2.3 Cell Uptake Mechanisms	385
	Research Report 9.2 Mesoporous Nanoparticles Coated with a Protein	
	Corona Shield	387
9.3	Tracking Nanomaterials in Biological Systems	388
	Back to Basics 9.6 Medical Imaging Techniques	389

	Research Report 9.3 Magnetic Nanoparticles As Contrast Agents for	
	MRI of Cancer Tissue	391
9.4	Theranostic Nanomaterials	392
	Back to Basics 9.7 Light-Induced Hyperthermia	394
9.5	Nanomaterials in Tissue Engineering	395
	9.5.1 The Extracellular Matrix	397
	Back to Basics 9.8 Composition of the Extracellular Matrix	397
	9.5.2 Nanomaterials for Tissue Scaffold Engineering	400
	Research Report 9.4 Nanopatterns Influence the Differentiation of	
	Stem Cells	400
	Back to Basics 9.9 Bone Engineering	402
	9.5.3 Nanocomposite Hydrogels in Tissue Engineering	404
	Back to Basics 9.10 Peptide Hydrogels	404
	Research Report 9.5 Magnetically Responsive Hydrogels for Tissue	
	Engineering and Soft Robot Design	407
9.6	Nanotoxicity and Environmental Impact of Nanomaterials	408
	Research Report 9.6 Exploration of the Cellular Toxicity of Nanomaterials	410
	Key Concepts	413
	Problems	414
	Further Reading	417
	References	418
	Appendix	421
	Index	423

10

Back to Basket S.C. Maded Imported Technicities