

TABLE OF CONTENTS

0. Executive Summary	19
1. Basics of Nanobiotechnology	21
Introduction	21
Classification of nanobiotechnologies	22
Top-down and bottom-up approaches.....	23
Landmarks in the evolution of nanobiotechnology.....	23
Relation of nanobiotechnology to healthcare.....	24
2. Technologies.....	27
Introduction	27
Micro- and nano-electromechanical systems	27
BioMEMS.....	27
Microarrays and nanoarrays	28
Dip Pen Nanolithography for nanoarrays	28
Protein nanoarrays.....	29
Microfluidics and nanofluidics.....	30
Nanotechnology on a chip	30
Microfluidic chips for nanoliter volumes.....	31
Nanogen's NanoChip	32
Use of nanotechnology in microfluidics	33
<i>Construction of nanofluidic channels.....</i>	<i>33</i>
<i>Nanoscale flow visualization</i>	<i>34</i>
<i>Moving (levitation) of nanofluidic drops with physical forces</i>	<i>34</i>
<i>Electrochemical nanofluid injection.....</i>	<i>34</i>
<i>Nanofluidics on nanopatterned surfaces</i>	<i>35</i>
<i>Nano-interface in a microfluidic chip.....</i>	<i>35</i>
<i>Nanofluidic channels for study of DNA</i>	<i>35</i>
Visualization and manipulation on nanoscale	36
4Pi microscope	36
Atomic force microscopy	36
<i>Basic AFM operation</i>	<i>36</i>
<i>Advantages of AFM.....</i>	<i>36</i>
<i>Force sensing Integrated Readout and Active Tip</i>	<i>37</i>
Cantilever technology	37
CytoViva® Microscope System	39
Fluorescence Resonance Energy Transfer	39
Magnetic resonance force microscopy and nanoscale MRI.....	39
Multiple single-molecule fluorescence microscopy	40
Near-field scanning optical microscopy	40
Nano-sized light source for single cell endoscopy	40
Nanoparticle characterization by Halo™ LM10 technology	41
Nanoscale scanning electron microscopy	42
<i>Use of SEM to reconstruct 3D tissue nanostructure.....</i>	<i>42</i>
Optical Imaging with a Silver Superlens.....	42
Photoactivated localization microscopy	43
Scanning probe microscopy.....	43
Partial wave spectroscopy	44
Ultra-nanocrystalline diamond	44
Visualizing atoms with high-resolution transmission electron microscopy	45
Companies that provide microscopes for nanobiotechnology.....	45
Surface plasmon resonance	46
Nanoparticles.....	46
Types of nanoparticles.....	47
<i>Fluorescent nanoparticles.....</i>	<i>47</i>
<i>Gold nanoparticles</i>	<i>47</i>
<i>Lipoparticles.....</i>	<i>47</i>
<i>Paramagnetic and superparamagnetic nanoparticles.....</i>	<i>48</i>
<i>Quantum dots</i>	<i>48</i>
<i>Silica nanoparticles</i>	<i>50</i>
Assembly of nanoparticles into micelles	50
<i>Biomedical applications of self-assembly of nanoparticles.....</i>	<i>50</i>
Production techniques for nanoparticles	51
Nanostructures	52
Bacterial structures relevant to nanobiotechnology.....	52
<i>Bacterial spores.....</i>	<i>52</i>
<i>Nanostructures based on bacterial cell surface layers</i>	<i>53</i>

<i>Bacterial magnetic particles</i>	53
Cubosomes	54
Dendrimers	54
<i>Properties</i>	55
<i>Applications</i>	55
DNA-nanoparticle conjugates	56
DNA octahedron	56
<i>Potential applications</i>	57
Fullerenes	57
Nanoshells	57
Nanotubes	58
<i>Carbon nanotubes</i>	58
<i>Carbon nanotubes and DNA</i>	59
<i>Applications of nanotubes</i>	59
NanoBuds	60
Nanowires.....	60
Nanostamping	61
Nanoneedles	61
Nanopores	61
Nanoporous silica aerogel	62
Nanostructured silicon	63
Networks of gold nanoparticles and bacteriophage	63
Polymer nanofibers	63
Protein-nanoparticle combination	64
Nanomaterials for biolabeling	64
DNA Nanotags	66
Fluorescent lanthanide nanorods.....	66
Magnetic nanotags	66
Molecular computational identification	67
Nanophosphor labels	67
Organic nanoparticles as biolabels.....	68
Quantum dots as labels	68
SERS nanotags.....	69
Silica nanoparticles for labeling antibodies	69
Silver nanoparticle labels	69
Companies providing services and products for nanobiotechnology	70
3. Applications in Life Sciences	71
Introduction	71
Nanotechnology and biology	71
NanoSystems Biology	71
Nanobiology and the cell	72
<i>Biosensing of cellular responses</i>	73
<i>Control of T cell signaling activity</i>	73
<i>Measuring mass of single cells</i>	74
<i>Nanostructures involved in endocytosis</i>	74
<i>Nanotechnology-based live-cell single molecule assays</i>	74
<i>Quantum dots for cell labeling</i>	75
<i>Quantum dots for study of apoptosis</i>	75
<i>Single cell injection by nanolasers</i>	75
<i>Study of complex biological systems</i>	76
Molecular motors	76
<i>Nanomotor made of nucleic acids</i>	78
<i>phi29 DNA packaging nanomotor</i>	78
<i>Light-activated ion channel molecular machines</i>	79
Application of AFM for biomolecular imaging	79
<i>Future insights into biomolecular processes by AFM</i>	80
4Pi microscopy to study DNA double-strand breaks	80
Multi-isotope imaging mass spectrometry	81
Applications of biomolecular computing in life sciences	81
Molecular electronics	82
Microbial nanomaterials	82
<i>Use of bacteria to construct nanomachines</i>	82
<i>Bacteriophage nanoshells</i>	83
Natural nanocomposites.....	83
Nanotechnology in biological research	83
<i>Nanoparticles for biological research</i>	84
<i>Disguising quantum dots as proteins for cell entry</i>	84
Molecular biology and nanotechnology	85
<i>Structural DNA nanotechnology</i>	85
<i>Reversibly binding of gold nanospheres to DNA strands</i>	86

<i>RNA nanotechnology</i>	87
<i>Genetically engineered proteins for nanobiotechnology</i>	87
Single molecule studies	88
<i>Optical trapping and single-molecule fluorescence</i>	88
<i>3D single-molecular imaging by coherent X-ray diffraction imaging</i>	88
<i>Studying the molecular mechanisms of enzymes</i>	88
Nanochemistry	89
Nanoscale pH Meter	89
Application of nanolasers in life sciences	89
Nanomanipulation	90
Nanomanipulation by combination of AFM and other devices	90
Surgery on living cells using AFM with nanoneedles.....	91
Optoelectronic tweezers.....	91
Optical manipulation of nanoparticles	92
Manipulation of DNA sequence by use of nanoparticles as laser light antennas.....	92
Nanomanipulation of single molecule.....	92
Fluorescence-force spectroscopy.....	93
Nanomanipulation for study of mechanism of anticancer drugs	93
Nanotechnology in genomic research	93
Nanotechnology for separation of DNA fragments	93
Nanostructured devices for controlled gene expression	94
Nanotechnology-based DNA sequencing.....	94
Single-molecule detection of DNA hybridization	94
Role of nanobiotechnology in identifying single nucleotide polymorphisms.....	95
Nanobiotechnology for study of mitochondria	95
Nanomaterials for the study of mitochondria	95
Study of mitochondria with nanolaser spectroscopy.....	96
Role of nanotechnology in proteomics research	96
Study of proteins by atomic force microscopy.....	96
Single cell nanoprobe for studying gene expression of individual cells.....	97
Nanoproteomics.....	97
<i>Dynamic reassembly of peptides</i>	97
<i>High-field asymmetric waveform ion mobility mass spectrometry</i>	98
<i>Multi Photon Detection</i>	98
<i>Nanoflow liquid chromatography</i>	98
<i>Nanoproteomics for study of misfolded proteins</i>	99
<i>Nanotube electronic biosensor for proteomics</i>	99
<i>Nanometer photomasks from bacterial protein</i>	99
<i>Protein nanocrystallography</i>	100
<i>QD-protein bioconjugate nanoassembly</i>	100
Proteomics at single molecule level	101
<i>Study of protein synthesis and single-molecule processes</i>	101
<i>Protein expression in individual cells at the single molecule level</i>	102
<i>Single-molecule mass spectrometry using nanotechnology</i>	102
Biochips for nanoscale proteomics.....	103
<i>Protein biochips based on fluorescence planar wave guide technology</i>	103
<i>Nanofilter array chip</i>	103
Role of nanotechnology in study of membrane proteins	104
<i>Nanoparticles for study of membrane proteins</i>	104
<i>Study of single protein interaction with cell membrane</i>	104
<i>Quantum dots to label cell surface proteins</i>	104
<i>Study of single membrane proteins at subnanometer resolution</i>	105
Nanoparticle-protein interactions	105
Protein engineering on nanoscale.....	105
<i>Nanowires for protein engineering</i>	105
<i>A nanoscale mechanism for protein engineering</i>	106
<i>Role of nanoparticles in self-assembly of proteins</i>	106
<i>Role of nanotechnology in peptide engineering</i>	106
Manipulating redox systems for nanotechnology.	107
Self-assembling peptide scaffold technology for 3-D cell culture.....	107
Nanobiotechnology and ion channels	108
Aquaporin water channels	108
Role of nanobiotechnology in engineering ion channels	109
Application of nanobiotechnology in molecular electronics	110
Nanotechnology and bioinformatics	110
3D nano-map of synapse	111
Companies providing nanotechnology for life sciences research	111

4. Nanomolecular Diagnostics	113
Introduction	113
Nanodiagnosics	113

Rationale of nanotechnology for molecular diagnostics.....	114
Nanoarrays for molecular diagnostics.....	115
NanoPro™ System	115
Nanofluidic/nanoarray devices to detect a single molecule of DNA.....	115
Self-assembling protein nanoarrays.....	116
Fullerene photodetectors for chemiluminescence detection on microfluidic chip.....	116
Nanofountain AFM probe	116
AFM for immobilization of biomolecules in high-density microarrays	117
Protein microarray for detection of molecules with nanoparticles.....	117
Protein nanobiochip.....	117
Nanoparticles for molecular diagnostics	118
Gold nanoparticles	118
Quantum dots for molecular diagnostics	118
<i>Quantum dots for detection of pathogenic microorganisms.....</i>	<i>119</i>
<i>Bioconjugated QDs for multiplexed profiling of biomarkers</i>	<i>119</i>
<i>Imaging of living tissue with QDs.....</i>	<i>120</i>
Use of nanocrystals in immunohistochemistry.....	120
Magnetic nanoparticles	121
<i>Ferrofluids.....</i>	<i>121</i>
<i>Magnetic nanoparticles for bioscreening</i>	<i>121</i>
<i>Monitoring of implanted NSCs labeled with nanoparticles</i>	<i>121</i>
<i>Perfluorocarbon nanoparticles to track therapeutic cells in vivo.....</i>	<i>121</i>
<i>Superparamagnetic nanoparticles for cell tracking.....</i>	<i>122</i>
<i>Superparamagnetic iron oxide nanoparticles for calcium sensing.....</i>	<i>122</i>
<i>Magnetic nanoparticles for labeling molecules.....</i>	<i>122</i>
<i>Superconducting quantum interference device.....</i>	<i>123</i>
<i>Study of living cells by superparamagnetic nanoparticles</i>	<i>123</i>
Imaging applications of nanoparticles	123
<i>Dendritic nanopores for imaging of angiogenesis.....</i>	<i>124</i>
<i>Gadolinium-loaded dendrimer nanoparticles for tumor-specific MRI</i>	<i>124</i>
<i>Gadonanotubes for MRI</i>	<i>125</i>
<i>Gold nanorods and nanoparticles as imaging agents.....</i>	<i>125</i>
<i>In vivo imaging using nanoparticles.....</i>	<i>125</i>
<i>Manganese oxide nanoparticles as contrast agent for brain MRI.....</i>	<i>126</i>
<i>Nanoparticles vs microparticles for cellular imaging.....</i>	<i>126</i>
<i>Nanoparticles as contrast agent for MRI.....</i>	<i>126</i>
<i>Optical molecular imaging using targeted magnetic nanopores.....</i>	<i>127</i>
<i>QDs for biological imaging.....</i>	<i>127</i>
<i>Superparamagnetic iron nanoparticles combined with MRI</i>	<i>128</i>
<i>Concluding remarks and future prospects of nanoparticles for imaging</i>	<i>128</i>
Study of chromosomes by atomic force microscopy.....	128
Applications of nanopore technology for molecular diagnostics.....	129
Nanopore technology for detection of single DNA molecules	129
Nanocytometry	130
Simultaneous detection of DNA and proteins	130
DNA-protein and -nanoparticle conjugates	130
Resonance Light Scattering technology	131
DNA nanomachines for molecular diagnostics	132
Nanobarcodes technology.....	132
Nanobarcode particle technology for SNP genotyping	132
Qdot nanobarcode for multiplexed gene expression profiling	133
Biobarcode assay for proteins.....	133
Single-molecule barcoding system for DNA analysis	135
Nanoparticle-based colorimetric DNA detection method.....	135
SNP genotyping with gold nanoparticle probes.....	136
Nanoparticle-based Up-converting Phosphor Technology	136
Surface-Enhanced Resonant Raman Spectroscopy.....	136
Near-infrared (NIR)-emissive polymersomes	137
Nanobiotechnology for detection of proteins	138
Captamers with proximity extension assay for proteins.....	138
Nanobiosensors	138
Cantilevers as biosensors for molecular diagnostics	138
<i>Advantages of cantilever technology for molecular recognition.....</i>	<i>139</i>
<i>Antibody-coated nanocantilevers for detection of microorganisms</i>	<i>140</i>
<i>Cantilevers for direct detection of active genes</i>	<i>140</i>
<i>Portable nanocantilever system for diagnosis.....</i>	<i>141</i>
Carbon nanotube biosensors	141
<i>Carbon nanotube sensors coated with ssDNA and electronic readout</i>	<i>141</i>
<i>Carbon nanotubes sensors wrapped with DNA and optical detection</i>	<i>142</i>
FRET-based DNA nanosensor.....	142
Ion Channel Switch biosensor technology.....	143

Electronic nanobiosensors	143
Electrochemical nanobiosensor	144
Metallic nanobiosensors	144
Quartz nanobalance biosensor	144
Viral nanosensor	145
PEBBLE nanosensors	145
Detection of cocaine molecules by nanoparticle-labeled aptasensors.....	145
Nanosensors for glucose monitoring	145
Microneedle-mounted biosensor.....	146
Optical biosensors.....	146
<i>Laser nanosensors</i>	146
<i>Nanoshell biosensors</i>	147
<i>Plasmonics and SERS nanoprobe</i>	147
<i>Novel optical mRNA biosensor</i>	148
<i>Optonanogen biosensor</i>	148
<i>Surface plasmon resonance technology</i>	149
<i>Surface Enhanced Micro-optical Fluidic Systems</i>	150
<i>Nanoparticle-enhanced sensitivity of fluorescence-based biosensors</i>	150
Nanowire biosensors	150
<i>Nanowire biosensors for detection of single viruses</i>	151
<i>Nanowires for detection of genetic disorders</i>	151
<i>Nanowires biosensor for detecting biowarfare agents</i>	152
<i>Concluding remarks and future prospects of nanowire biosensors</i>	152
Nanoscale erasable biodetectors	152
Future issues in the development of nanobiosensors	153
Applications of nanodiagnosics.....	154
Nanotechnology for detection of biomarkers	154
Nanotechnology for genotyping of single-nucleotide polymorphisms	155
<i>Nanoparticles for detecting SNPs</i>	155
<i>Nanopores for detecting SNPs</i>	155
Nanobiotechnologies for single molecule detection	156
Protease-activated quantum dot probes.....	157
Labeling of MSCs with QDs.....	157
Nanotechnology for detection of cancer	157
<i>Dendrimers for sensing cancer cell apoptosis</i>	158
<i>Detection of circulating cancer cells</i>	158
<i>Differentiation between normal and cancer cells by nanosensors</i>	158
<i>Gold nanoparticles for cancer diagnosis</i>	158
<i>Gold nanorods for detection of metastatic tumor cells</i>	159
<i>Implanted magnetic sensing for cancer</i>	159
<i>Nanoatomic tubes for detection of cancer proteins</i>	160
<i>Nanobiochip sensor technique for analysis of oral cancer biomarkers</i>	160
<i>Nanodots for tracking apoptosis in cancer</i>	161
<i>Nanolaser spectroscopy for detection of cancer in single cells</i>	161
<i>Nanoparticles designed for dual-mode imaging of cancer</i>	161
<i>Nanotechnology-based single molecule assays for cancer</i>	162
<i>QDs for detection of tumors</i>	162
<i>QD-based test for DNA methylation</i>	163
Nanotechnology for point-of-care diagnostics	163
<i>Nanotechnology-based biochips for POC diagnosis</i>	164
<i>Nanoprobes for POC diagnosis</i>	164
<i>Carbon nanotube transistors for genetic screening</i>	164
<i>POC monitoring of vital signs with nanobiosensors</i>	165
Detection of viruses	165
<i>Cantilever beams for detection of single virus particles</i>	165
<i>Carbon nanotubes as biosensors for viruses</i>	166
<i>Electric fields for accelerating detection of viruses</i>	166
<i>QD fluorescent probes for detection of respiratory viral infections</i>	166
<i>Verigene SP Respiratory Virus Assay</i>	167
<i>Surface enhanced Raman scattering for detection of viruses</i>	168
Detection of bacteria	168
<i>QDs for detection of bacterial infections</i>	169
<i>Sensing of Phage-Triggered Ion Cascade for detection of bacteria</i>	169
Nanodiagnosics for the battle field and biodefense	169
<i>An integrated nanobiosensor</i>	170
Nanodiagnosics for integrating diagnostics with therapeutics	170
Companies involved in nanomolecular diagnostics	171
Concluding remarks about nanodiagnosics.....	173
Future prospects of nanodiagnosics	174

5. Nanobiotechnology in Drug Discovery & Development 177

Introduction	177
Nanobiotechnology for drug discovery	177
Nanofluidic devices for drug discovery	178
Gold nanoparticles for drug discovery	179
<i>Tracking drug molecules in cells.....</i>	<i>179</i>
<i>SPR with colloidal gold particles.....</i>	<i>179</i>
Use of quantum dots for drug discovery	179
<i>Advantages of the use of QDs for drug discovery</i>	<i>179</i>
<i>Drawbacks of the use of QDs for drug discovery</i>	<i>180</i>
<i>Quantum dot for imaging drug receptors in the brain</i>	<i>181</i>
Ligand-conjugated nanocrystals.....	181
Lipoparticles for drug discovery	181
<i>Biosensor for drug discovery with Lipoparticles</i>	<i>181</i>
Magnetic nanoparticles assays	182
Micelles for drug discovery	182
Nanolasers for drug discovery	182
Analysis of small molecule-protein interactions by nanowire biosensors	183
Cells targeting by nanoparticles with attached small molecules	183
Role of AFM for study of biomolecular interactions for drug discovery	183
Nanoscale devices for drug discovery	184
Nanotechnology enables drug design at cellular level.....	185
Nanobiotechnology-based drug development	185
Dendrimers as drugs	185
Fullerenes as drug candidates.....	186
Nanobodies	187
Role of nanobiotechnology in the future of drug discovery	188
Companies using nanobiotechnology for drug discovery	188
6. Nanobiotechnology in Drug Delivery.....	191
Introduction	191
Micronization versus nanonization for drug delivery.....	191
Nanoscale devices delivery of therapeutics	191
Nanobiotechnology solutions to the problems of drug delivery	191
Nanosuspension formulations	192
Nanotechnology for solubilization of water-insoluble drugs	193
Improved absorption of drugs in nanoparticulate form	193
Interaction of nanoparticles with human blood.....	193
Ideal properties of material for drug delivery	193
Nanomaterials and nanobiotechnologies used for drug delivery	194
Viruses as nanomaterials for drug delivery.....	195
Bacteria-mediated delivery of nanoparticles and drugs into cells	195
Nanoparticle-based drug delivery	196
Calcium phosphate nanoparticles	196
Cationic nanoparticles.....	197
Ceramic nanoparticles	197
Cyclodextrin nanoparticles for drug delivery	197
Dendrimers for drug delivery.....	198
<i>DNA-assembled dendrimers for drug delivery</i>	<i>198</i>
Fullerenes for drug delivery	199
<i>Amphiphilic fullerene derivatives.....</i>	<i>199</i>
<i>Fullerene conjugate for intracellular delivery of peptides</i>	<i>199</i>
Gold nanoparticles as drug carriers	199
Layered double hydroxide nanoparticles	199
Nanocomposite membranes for magnetically triggered drug delivery	200
Nanocrystals	200
<i>Nanocrystalline silver</i>	<i>200</i>
<i>Elan's NanoCrystal technology.....</i>	<i>201</i>
<i>Eurand's Biorise system.....</i>	<i>201</i>
Nanodiamonds.....	202
Polymer nanoparticles	203
<i>Biodegradable PEG nanoparticles for penetrating the mucus barrier</i>	<i>203</i>
<i>PLGA-based nanodelivery technologies</i>	<i>203</i>
<i>Polymeric micelles.....</i>	<i>204</i>
<i>Chitosan nanoparticles.....</i>	<i>204</i>
QDs for drug delivery	205
Special procedures in nanoparticle-based drug delivery	205
<i>Coated nanoparticles for penetrating cell membranes without damage</i>	<i>205</i>
<i>Drug delivery using "Particle Replication in Nonwetting Templates"</i>	<i>206</i>
<i>Encapsulating water-insoluble drugs in nanoparticles.....</i>	<i>206</i>
<i>Filomicelles vs spherical nanoparticles for drug delivery</i>	<i>207</i>
<i>Flash NanoPrecipitation.....</i>	<i>207</i>

<i>Magnetic nanoparticles for drug delivery</i>	208
<i>Nanoparticles bound together in spherical shapes</i>	208
<i>Perfluorocarbon nanoparticles for imaging and targeted drug-delivery</i>	209
<i>Prolonging circulation of nanoparticles by attachment to RBCs</i>	209
<i>Self-assembling nanoparticles for intracellular drug delivery</i>	210
<i>Trojan nanoparticles</i>	210
<i>Therapeutic protein delivery from nanoparticle-protein complexes</i>	210
Liposomes	211
Basics of liposomes	211
Stabilization of phospholipid liposomes using nanoparticles	211
Lipid nanoparticles	212
<i>Polymerized Liposomal Nanoparticle</i>	212
<i>Applications of lipid nanoparticles</i>	213
<i>Limitations of liposomes for drug delivery</i>	213
Lipid nanocapsules	213
Lipid emulsions with nanoparticles	214
Nanostructured organogels	215
Liposomes incorporating fullerenes.....	215
Arsonoliposomes.....	215
Liposome-nanoparticle hybrids	215
Nanogels	216
Nanogel-liposome combination	216
Nanospheres	217
Nanosphere protein cages.....	217
Nanovesicle technology for delivery of peptides	217
Nanotubes	217
Carbon nanotubes for drug delivery	218
Lipid-protein nanotubes for drug delivery	218
Haloysite nanotubes for drug delivery	219
Nanocochleates	220
Nanobiotechnology and drug delivery devices	221
Coating of implants by ultrafine layers of polymers	221
Nano-encapsulation.....	221
<i>Polymer nanocontainers</i>	222
Nanotechnology-based device for insulin delivery.....	222
Mirocontainer delivery systems for cell therapy.....	223
Nanoporous materials for drug delivery devices	223
<i>Nanopore membrane in implantable titanium drug delivery device</i>	223
<i>Measuring the permeability of nanomembranes</i>	224
Nanovalves for drug delivery	224
Nanochips for drug delivery.....	224
Nanobiotechnology for vaccine delivery	225
Bacterial spores for delivery of vaccines.....	225
Nanoparticles for DNA vaccines.....	225
Nanospheres for controlled release of viral antigens	225
Proteosomes™ as vaccine delivery vehicles	226
Targeted Synthetic Vaccine Particle (tSVP™) technology	226
Nanobiotechnology for antisense drug delivery	226
Antisense nanoparticles	226
Dendrimers for antisense drug delivery.....	227
Polymer nanoparticles for antisense delivery system	227
Nanoparticle-mediated siRNA delivery	228
Chitosan-coated nanoparticles for siRNA delivery	228
Delivery of gold nanorod-siRNA nanoplex to dopaminergic neurons	228
Polymer-based nanoparticles for siRNA delivery.....	228
<i>Polyethylenimine nanoparticles for siRNA delivery</i>	228
<i>siRNA-PEG nanoparticle-based delivery</i>	229
<i>Polycation-based nanoparticles for siRNA delivery</i>	229
<i>Calando's technology for targeted delivery of anticancer siRNA</i>	230
Quantum dots to monitor RNAi delivery	230
Nanobiotechnology for gene therapy	231
Nanoparticle-mediated gene therapy	231
<i>Calcium phosphate nanoparticles as nonviral vectors</i>	232
<i>Carbonate apatite nanoparticles for gene delivery</i>	232
<i>Gelatin nanoparticles for gene delivery</i>	233
<i>Immunolipoplex for delivery of p53 gene</i>	233
<i>Lipid nanoparticles for targeted delivery of nucleic acids</i>	234
<i>Nanoparticles for imaging and intracellular delivery of nucleic acids</i>	234
<i>Nanoparticles as nonviral vectors for CNS gene therapy</i>	234
<i>Nanoparticles linked to viral vectors for photothermal therapy</i>	235
<i>Nanoparticles for p53 gene therapy of cancer</i>	235

<i>Nanoparticles with virus-like function as gene therapy vectors</i>	236
<i>Silica nanoparticles for gene delivery</i>	236
<i>Targeted nanoparticle-DNA delivery to the cardiovascular system</i>	236
Dendrimers for gene transfer	237
DNA-PEG complexes as nanoparticles.....	238
Compacted DNA nanoparticles.....	238
Cochleate-mediated DNA delivery	238
Nanorod gene therapy	239
Nanodel™ gene vector	239
Nanomagnets for targeted cell-based cancer gene therapy.....	240
NanoNeedles for delivery of genetic material into cells.....	240
Nanomachines for gene delivery	240
Application of pulsed magnetic field and superparamagnetic nanoparticles.....	240
Nanocomposites for gene therapy	241
Nonionic polymeric micelles for oral gene delivery.....	241
Nanocarriers for simultaneous delivery of anticancer drugs and DNA	241
Delivery of siRNA by nanosize liposomes.....	242
Nanobiotechnology-based drug delivery in cancer.....	242
Nanoparticle formulations for drug delivery in cancer	244
<i>Anticancer drug particles incorporated in liposomes</i>	244
<i>Encapsulating drugs in hydrogel nanoparticles</i>	245
<i>Exosomes</i>	246
<i>Folate-linked nanoparticles</i>	246
<i>Iron oxide nanoparticles</i>	247
<i>Lipid based nanocarriers</i>	247
<i>Micelles for drug delivery in cancer</i>	247
<i>Minicells for targeted delivery of nanoscale anticancer therapeutics</i>	249
<i>Nanomaterials for delivery of poorly soluble anticancer drugs</i>	249
<i>Nanoparticle formulation for enhancing anticancer efficacy of cisplatin</i>	249
<i>Nanoparticle formulations of paclitaxel</i>	250
<i>Nanoparticles containing albumin and antisense oligonucleotides</i>	251
<i>Non-aggregating nanoparticles</i>	251
<i>Pegylated nanoliposomal formulation</i>	251
<i>Poly-2-hydroxyethyl methacrylate nanoparticles</i>	252
<i>Polypeptide-doxorubicin conjugated nanoparticles</i>	252
<i>Protosphere nanoparticle technology</i>	252
<i>Zinc oxide nanoparticles for drug delivery in cancer</i>	253
Nanoparticles for targeted delivery of anticancer therapeutics	253
<i>Antiangiogenic therapy using nanoparticles</i>	254
<i>Canine parvovirus as a nanocontainer for targeted drug delivery</i>	254
<i>Carbon magnetic nanoparticles for targeted drug delivery in cancer</i>	255
<i>Carbon nanotubes for targeted drug delivery to cancer cells</i>	255
<i>Cycloset system for targeted delivery of anticancer therapeutics</i>	256
<i>DNA aptamer-micelle for targeted drug delivery in cancer</i>	256
<i>DNA aptamer-micelle for targeted drug delivery in cancer</i>	256
<i>Fullerenes for enhancing tumor targeting by antibodies</i>	257
<i>Gold nanoparticles for targeted drug delivery in cancer</i>	257
<i>Lipoprotein nanoparticles targeted to cancer-associated receptors</i>	259
<i>Magnetic nanoparticles for remote-controlled drug delivery to tumors</i>	259
<i>Nanobees for targeted delivery of cytolytic peptide melittin</i>	259
<i>Nanocell for targeted drug delivery to tumor</i>	260
<i>Nanodiamonds for local delivery of chemotherapy at site of cancer</i>	261
<i>Nanoimmunoliposome-based system for targeted delivery of siRNA</i>	261
<i>Nanoparticle-mediated targeting of MAPK signaling pathway</i>	262
<i>Nanoparticles for targeted antisense therapy of cancer</i>	262
<i>Nanoparticles for delivery of suicide DNA to prostate tumors</i>	262
<i>Nanostructured hyaluronic acid for targeted drug delivery in cancer</i>	262
<i>Polymer nanoparticles for targeted drug delivery in cancer</i>	263
<i>Polymersomes for targeted cancer drug delivery</i>	264
<i>Quantum dots and quantum rods for targeted drug delivery in cancer</i>	264
<i>Remote controlled drug delivery from magnetic nanocrystals</i>	265
<i>Targeted delivery of nanoparticulate drugs into lymphatic system</i>	265
<i>Targeted drug delivery with nanoparticle-aptamer bioconjugates</i>	265
Dendrimers for anticancer drug delivery	266
<i>Application of dendrimers in boron neutron capture therapy</i>	267
<i>Application of dendrimers in photodynamic therapy</i>	267
<i>Dendrimer-based synthetic vector for targeted cancer gene therapy</i>	268
<i>Poly-L-lysine dendrimer as antiangiogenetic agent</i>	268
Devices for nanotechnology-based cancer therapy	269
<i>Convection-enhanced delivery with nanoliposomal CPT-11</i>	269
<i>Nanocomposite devices</i>	269

<i>Nanoengineered silicon for brachytherapy</i>	269
Nanoparticles combined with physical agents for tumor ablation	270
<i>Boron neutron capture therapy using nanoparticles</i>	270
<i>Laser-induced cancer destruction using nanoparticles</i>	270
<i>Photodynamic therapy of cancer using nanoparticles</i>	271
<i>Thermal ablation using nanoparticles</i>	272
<i>Thermosensitive affibody-conjugated liposomes</i>	273
<i>Ultrasound radiation of tumors combined with nanoparticles</i>	273
RNA nanotechnology for delivery of cancer therapeutics	273
<i>Delivery of siRNAs for cancer</i>	274
Nanocarriers for simultaneous delivery of multiple anticancer agents	274
Nanotechnology-based drug delivery to the CNS	274
Nanoencapsulation for delivery of vitamin E for CNS disorders	274
Nanoparticle technology for drug delivery across BBB	275
<i>Delivery across BBB using NanoDel™ technology</i>	276
<i>NanoMed technology to mask BBB-limiting characteristics of drugs</i>	276
<i>Nanovesicles for transport across BBB</i>	276
Nanotechnology-based drug delivery to brain tumors	277
<i>Multifunctional nanoparticles for treating brain tumors</i>	277
<i>Nanoparticles for delivery of drugs to brain tumors across BBB</i>	277
Nanoparticle delivery across the BBB for imaging and therapy of brain tumors	278
<i>Intravenous gene delivery with nanoparticles into brain tumors</i>	279
<i>PLA nanoparticles for controlled delivery of BCNU to brain tumors</i>	279
Nanotechnology-based devices and implants for CNS	279
Nanoparticle-based drug delivery to the inner ear	280
Nanobiotechnology in cardiovascular drug delivery	280
Liposomal nanodevices for targeted cardiovascular drug delivery	280
<i>Drugs encapsulated in biodegradable nanoparticles</i>	280
<i>Controlled delivery of nanoparticles to injured vasculature</i>	281
Nanotechnology-based drug-eluting stents	281
<i>Drugs encapsulated in biodegradable nanoparticles</i>	281
<i>Magnetic nanoparticle-coated DES</i>	282
<i>Nanopores to enhance compatibility of drug-eluting stents</i>	282
Low molecular weight heparin-loaded polymeric nanoparticles	282
Injectable peptide nanofibers for myocardial ischemia	283
Nanotechnology approach to the vulnerable plaque as cause of cardiac arrest	283
Nanobiotechnology-based transdermal drug delivery	283
Delivery of nanostructured drugs from transdermal patches	284
Ethosomes for transdermal drug delivery	284
NanoCyte transdermal drug delivery system	285
Nanoparticles for targeted therapeutic delivery to the liver	286
Nanoparticles for pulmonary drug delivery	286
Systemic drug delivery via pulmonary route	286
Nanoparticle drug delivery for effects on the respiratory system	286
Fate and toxicology of nanoparticles delivered to the lungs	287
Nanoparticle drug formulations for spray inhalation	287
Inhalation of glucose-sensitive nanoparticle for regulated release of insulin	287
Pulmonary drug delivery by surface acoustic wave technology	288
In vivo lung gene transfer using compacted DNA nanoparticles	288
Nasal drug delivery using nanoparticles	288
Mucosal drug delivery with nanoparticles	289
Companies involved in nanobiotechnology-based drug delivery	289
Future prospects of nanotechnology-based drug delivery	293
Nanomolecular valves for controlled drug release	294
Nanosponge for drug delivery	294
Nanomotors for drug delivery	294

7. Clinical Applications of Nanobiotechnology

Introduction	295
Nanomedicine	295
Clinical nanodiagnostics	296
Nano-endoscopy	296
Application of nanotechnology in radiology	297
High-resolution ultrasound imaging using nanoparticles	297
Nanobiotechnology combined with stem cell-based therapies	298
Nanobiotechnology in tissue engineering	299
3D nanofilament-based scaffolds	299
Electrospinning technology for bionanofabrication	300
Nanomaterials for tissue engineering	300
<i>Carbon nanotubes for artificial muscles</i>	301
<i>Nanofibers for tissue engineering of skeletal muscle</i>	301

Nanomaterials for combining tissue engineering and drug delivery	301
Nanobiotechnology for organ replacement and assisted function	302
Exosomes for drug-free organ transplants.....	302
Nanobiotechnology and organ-assisting devices.....	303
Nanotechnology-based human nephron filter for renal failure	303
Blood-compatible membranes for renal dialysis	304
Nanosurgery	304
Miniaturization in surgery.....	304
<i>Nanotechnology for hemostasis during surgery.....</i>	<i>304</i>
Minimally invasive surgery using catheters.....	305
Nanorobotics	305
Nanoscale laser surgery	306
Nanooncology	307
Nanobiotechnology for early detection of cancer to improve treatment	307
Impact of nanotechnology-based imaging in management of cancer	307
<i>Nanoparticle-MRI for tracking dendritic cells in cancer therapy</i>	<i>308</i>
<i>Nanoparticle-CT scan.....</i>	<i>308</i>
<i>QDs aid lymph node mapping in cancer</i>	<i>308</i>
<i>Nanosensor device as an aid to cancer surgery.....</i>	<i>309</i>
<i>Role of nanoparticle-based imaging in oncology clinical trials.....</i>	<i>309</i>
Nanoparticle-based anticancer drug delivery to overcome MDR.....	309
Nanoparticle-based management of cancer metastases	310
Nanoshells for thermal ablation in cancer	310
Nanobody-based cancer therapy	311
Nanoparticles for targeting tumors.....	312
Nanocarriers with TGF- β inhibitors for targeting cancer.....	312
Nanoshell-based cancer therapy	313
Nanobomb for cancer	313
Combination of diagnostics and therapeutics for cancer	314
<i>Biomimetic nanoparticles targeted to tumors.....</i>	<i>314</i>
<i>Dendrimer nanoparticles for targeting and imaging tumors</i>	<i>314</i>
<i>Gold nanoparticle plus bombesin for imaging and therapy of cancer</i>	<i>314</i>
<i>Gold nanorods for diagnosis plus photothermal therapy of cancer</i>	<i>315</i>
<i>Magnetic nanoparticles for imaging as well as therapy of cancer</i>	<i>315</i>
<i>Nanobialys for combining MRI with delivery of anticancer agents</i>	<i>316</i>
<i>Nanoparticles, MRI and thermal ablation of tumors</i>	<i>316</i>
<i>pHLIP nanotechnology for detection and targeted therapy of cancer</i>	<i>316</i>
<i>QD conjugates combine cancer imaging, therapy and sensing</i>	<i>317</i>
<i>Radiolabeled carbon nanotubes for tumor imaging and targeting</i>	<i>317</i>
<i>Self-assembling nanoparticles for imaging and therapy of cancer.....</i>	<i>317</i>
<i>Targeted therapy with magnetic nanomaterials guided by antibodies.....</i>	<i>318</i>
<i>Ultrasonic tumor imaging and targeted chemotherapy by nanobubbles.....</i>	<i>318</i>
A cancer killing device based on nanotechnology	318
Nanoparticles for protection against adverse effects of radiation therapy	319
Fullerenes for protection against chemotherapy-induced cardiotoxicity	319
Role of nanobiotechnology in personalized management of cancer	319
Concluding remarks on nanooncology.....	320
Nanoneurology	320
Nanobiotechnology for study of the nervous system	321
<i>Nanowires for monitoring brain activity.....</i>	<i>321</i>
<i>Nanoparticles and MRI for macrophage tracking in the CNS.....</i>	<i>321</i>
<i>Nanoparticles for tracking stem cells for therapy of CNS disorders</i>	<i>322</i>
Nanobiotechnology for neurotherapeutics.....	322
<i>Nanowire neuroprosthetics with functional membrane proteins</i>	<i>323</i>
<i>Nanoparticles for neuroprotection</i>	<i>323</i>
<i>Nanotube-neuron electronic interface</i>	<i>323</i>
<i>Nanofibers as an aid to CNS regeneration by neural progenitor cells.....</i>	<i>324</i>
<i>Nanoparticles for repair of spinal cord injury.....</i>	<i>324</i>
<i>Peptide nanostructures for repair of the CNS</i>	<i>325</i>
<i>Repair of SCI by nanoscale micelles</i>	<i>325</i>
Nanobiotechnology-based devices for restoration of neural function	326
<i>Nanobiotechnology-based artificial retina</i>	<i>326</i>
Nanoneurosurgery	326
<i>Femtolaser neurosurgery</i>	<i>326</i>
<i>Nanofiber brain implants.....</i>	<i>327</i>
<i>Nanoparticles as an aid to neurosurgery</i>	<i>327</i>
<i>Nanoscaffold for CNS repair.....</i>	<i>328</i>
<i>Electrospun nanofiber tubes for regeneration of peripheral nerves.....</i>	<i>328</i>
<i>PEBBLEs for brain tumor therapy</i>	<i>328</i>
<i>Bucky balls for brain cancer</i>	<i>329</i>
Application of nanotechnology to pain therapeutics	329

Nanotechnology-based management of diabetes.....	330
Nanocardiology.....	330
Nanotechnology-based diagnosis and treatment	330
<i>Cardiac monitoring in sleep apnea.....</i>	<i>330</i>
<i>Use of perfluorocarbon nanoparticles in cardiovascular disorders.....</i>	<i>331</i>
Nanolipoblockers for atherosclerotic arterial plaques.....	331
IGF-1 delivery by nanofibers to improve cell therapy for myocardial infarction.....	331
Tissue engineering and regeneration of the cardiovascular system	332
Restenosis after percutaneous coronary angioplasty.....	332
Nanotechnology-based personalized medicine for cardiovascular disorders.....	333
Monitoring for disorders of blood coagulation.....	334
Nanoorthopedics.....	334
Application of nanotechnology for bone research.....	334
Reducing reaction to orthopedic implants.....	334
Enhancing the activity of bone cells on the surface of orthopedic implants	335
Nanobone implants	335
Synthetic nanomaterials as bone implants.....	336
Carbon nanotubes as scaffolds for bone growth	336
Aligning nanotubes to improve artificial joints.....	337
Cartilage disorders of knee joint	338
<i>Role of nanotechnology in engineering of a replacement for cartilage</i>	<i>338</i>
<i>Nanotechnology as an aid to arthroscopy.....</i>	<i>338</i>
<i>Scanning force arthroscope.....</i>	<i>339</i>
Nanodentistry	339
Bonding materials	339
Dental caries	340
Nanospheres for dental hypersensitivity.....	340
Nanomaterials for dental filling	341
Nanomaterials for dental implants.....	341
Nanoophthalmology.....	341
Nanocarriers for ocular drug delivery	341
<i>Nanoparticle-based topical drug application to the eye.....</i>	<i>342</i>
<i>Chitosan nanoparticles for topical drug application to the eye</i>	<i>342</i>
<i>Poly lactide nanoparticles for topical drug application to the eye</i>	<i>343</i>
<i>Ophthalmic drug delivery through nanoparticles in contact lenses</i>	<i>343</i>
<i>Nanoparticles for intraocular drug delivery</i>	<i>343</i>
<i>DNA nanoparticles for nonviral gene transfer to the eye.....</i>	<i>344</i>
<i>Nanotechnology for treatment for age-related macular degeneration.....</i>	<i>344</i>
Nanotechnology-based therapeutics for eye disorders.....	345
<i>Nano-engineered cornea.....</i>	<i>345</i>
<i>Use of dendrimers in ophthalmology.....</i>	<i>345</i>
<i>Nanotechnology for prevention of neovascularization.....</i>	<i>345</i>
<i>Regeneration of the optic nerve</i>	<i>346</i>
<i>DNA nanoparticles for gene therapy of retinal degenerative disorders.....</i>	<i>346</i>
<i>Nanobiotechnology for treatment of glaucoma.....</i>	<i>346</i>
Nanomicrobiology.....	347
Nanobiotechnology and virology	347
<i>Study of interaction of nanoparticles with viruses.....</i>	<i>347</i>
<i>Study of pathomechanism of viral diseases</i>	<i>347</i>
<i>Transdermal nanoparticles for immune enhancement in HIV.....</i>	<i>348</i>
<i>Nanofiltration to remove viruses from plasma transfusion products</i>	<i>348</i>
Role of nanobacteria in human diseases.....	349
<i>Nature of nanobacteria</i>	<i>349</i>
<i>Nanobacteria and kidney stone formation</i>	<i>349</i>
<i>Nanobacteria in cardiovascular disease</i>	<i>350</i>
Nanotechnology-based microbicidal agents	350
<i>Nanoscale bactericidal powders.....</i>	<i>350</i>
<i>Nanotubes for detection and destruction of bacteria</i>	<i>351</i>
<i>Carbon nanotubes as antimicrobial agents</i>	<i>352</i>
<i>Nanoemulsions as microbicidal agents</i>	<i>352</i>
<i>Silver nanoparticle coating as prophylaxis against infection</i>	<i>352</i>
Nanotechnology-based antiviral agents.....	353
Silver nanoparticles as antiviral agents	353
<i>Fullerenes as antiviral agents</i>	<i>353</i>
<i>Gold nanorod-based delivery of RNA antiviral therapeutics.....</i>	<i>354</i>
<i>Nanocoating for antiviral effect.....</i>	<i>354</i>
<i>Nanoviricides.....</i>	<i>354</i>
Nanotechnology-based vaccines.....	356
Nanoparticles to combat biological warfare agents	356
Companies developing antiinfective agents	357
Nanoimmunology.....	358

Nanomedical aspects of oxidative stress	358
Nanoparticle antioxidants.....	358
<i>Fullerene-based antioxidants</i>	358
<i>Ceria nanoparticles as neuroprotective antioxidants</i>	359
Antioxidant nanoparticles for treating diseases due to oxidative stress	359
Nanotechnology for wound healing	359
Nanotechnology-based products for skin disorders	360
Cubosomes for treating skin disorders of premature infants.	360
Nanoparticles for improving targeted topical therapy of skin.....	360
Nanoparticle-based sun screens.....	360
Nanoengineered bionic skin.....	361
Topical nanocreams for inflammatory disorders of the skin.....	361
Nanobiotechnology for disorders of aging	362
Personal care products based on nanotechnology	362
Nanotechnology for hair care.....	363
Nanoparticles for chemo-radioprotection	363
Role of nanobiotechnology in biodefense.....	364
Nanosuspension formulations for treating bioweapon-mediated diseases	364
Use of antidotes as nanoparticulate formulations	364
Removal of toxins from blood	364
Blood substitutes	365
<i>Artificial red cells</i>	365
Companies using nanotechnology for healthcare.....	365
Nanobiotechnology for public health	367
Nanobiotechnology and nutrition.....	367
Nanobiotechnology and food industry	368
Role of nanobiotechnology in personalized nutrition	368
Nanobiotechnology research in the academic centers	368
Future potential of nanomedicine	371
US Federal funding for nanobiotechnology.....	371
Nanomedicine initiative of NIH.....	372
<i>NIH Nanomedicine Center for Nucleoprotein Machines</i>	372
NCI Alliance for Nanotechnology in Cancer	373
Research in cancer nanotechnology sponsored by the NCI	373
Global Enterprise for Micro-Mechanics and Molecular Medicine	376
8. Ethical, Safety and Regulatory issues	377
Introduction	377
Ethical and social implications of nanobiotechnology	377
Nanoethics.....	377
Nanotechnology patents	378
Quantum dot patents relevant to healthcare applications	379
Challenges and future prospects of nanobiotechnology patents	379
Legal aspects of nanobiotechnology	380
Nanotechnology standards	380
Preclinical testing of nanomaterials for biological applications.....	381
Safety concerns about nanobiotechnology.....	381
Environmental safety of aerosols released from nanoparticle manufacture	382
Toxicity of nanoparticles	382
Testing for toxicity of nanoparticles	382
<i>In vitro testing of nanoparticle toxicity</i>	383
Variations in safety issues of different nanoparticles.....	383
<i>Carbon nanotube safety</i>	383
<i>Fullerene toxicity</i>	384
<i>Gold nanoparticle toxicity</i>	384
<i>Quantum dot safety issues</i>	385
Fate of nanoparticles in the human body.....	386
Pulmonary effects of nanoparticles	386
Blood compatibility of nanoparticles	387
<i>Carbon nanoparticle-induced platelet aggregation</i>	387
<i>Compatibility of lipid-based nanoparticles with blood and blood cells</i>	388
Transfer of nanoparticles from mother to fetus	388
Cytotoxicity of nanoparticles	388
<i>Indirect DNA damage caused by nanoparticles across cellular barriers</i>	389
Neuronanotoxicology	389
<i>Nanoparticle deposits in the brain</i>	389
<i>Nanoparticles and neurodegeneration</i>	389
Measures to reduce toxicity of nanoparticles.....	390
<i>Reducing toxicity of carbon nanotubes</i>	390
A screening strategy for the hazard identification of nanomaterials	391
Concluding remarks on safety issues of nanoparticles.....	391

Research into environmental effects of nanoparticles	391
Role of US government agencies in research on safety of nanoparticles	391
Work at NanoSafety Laboratories Inc UCLA	392
Center for Biological and Environmental Nanotechnology	393
European NEST project for risk assessment of exposure to nanoparticles	394
Efforts by nanotechnology companies to establish safety of nanoparticles	394
Public perceptions of the safety of nanotechnology	395
Evaluation of consumer exposure to nanoscale materials	395
Safety of nanoparticle-based cosmetics.....	396
Regulations in the European Union	396
Nanotechnology-based sunscreens.....	396
Cosmetic industry's white paper on nanoparticles in personal care	397
Skin penetration of nanoparticles used in sunscreens	397
EPA safety requirements for silver nanoparticles	398
FDA regulation of nanobiotechnology products	398
FDA and nanotechnology-based medical devices	400
FDA's Nanotechnology Task Force	400
FDA collaboration with agencies/organizations relevant to nanotechnology.....	402
Regulation of nanotechnology in the European Union.....	402
UK government policy on safety of nanoparticles	403
Safety recommendations of the Royal Society of UK	404
European Commission and safety of nanocosmetics	404
9. Nanobiotechnology Markets	407
Introduction	407
Markets according to areas of applications	408
Markets for nanomedicine	409
Markets for nanodiagnostics	409
Imaging agents	410
Pharmaceuticals.....	410
<i>Role of nanobiotechnology in drug delivery market.....</i>	<i>410</i>
Nanobiotechnology in life sciences research market.....	411
Markets according to technologies	411
Markets for nanomaterials.....	411
Markets for biomedical nanodevices	411
<i>Markets for nanosensors.....</i>	<i>411</i>
Markets for nanotools	412
Geographical distribution of markets.....	412
Nanobiotechnology in the US	413
Nanobiotechnology in the European Union	413
Nano2Life	414
European Technology Platform on NanoMedicine	415
Nanobiotechnology in Australia	415
Nanobiotechnology in Asia.....	416
Japan	416
South Korea	417
China	417
Taiwan	418
India	419
Nanobiotechnology in Russia	420
Nanobiotechnology in the developing world	420
Venture capital investment in nanotechnology	420
Big pharma and nanotechnology.....	421
Impact of nanobiotechnology on markets for current pharmaceuticals	421
Unmet needs in nanobiotechnology	421
Drivers for the development of nanobiotechnology markets.....	422
Strategies for developing markets for nanobiotechnology	422
Collaborations of industry with academic research centers	423
Collaborations of pharmaceutical and nanotechnology companies	423
Collaboration of chemical industry and the government	424
Cost-benefit of nanotechnology-based drug delivery.....	424
Education of healthcare professionals	424
Education of the public	424
10. References.....	427

Tables

Table 1-1: Dimensions of various objects in nanoscale	21
---	----

Table 1-2: Classification of basic nanobiotechnologies	22
Table 1-3: Historical landmarks in the evolution of nanotechnology.....	24
Table 2-1: Companies with nanoarray and nanofluidic technologies	32
Table 2-2: Applications of cantilever technology	38
Table 2-3: Applications of optical nanoscopy	41
Table 2-4: Companies that provide microscopes for nanobiotechnology	45
Table 2-5: Nanobiotechnological applications of S-layers	53
Table 2-6: Potential applications of dendrimers in nanobiotechnology.....	55
Table 2-7: Nanomaterials for biolabeling.....	65
Table 2-8: Companies providing services and products for nanobiotechnology industry	70
Table 3-1: Nanomaterials for the study of mitochondria.....	96
Table 3-2: Companies that provide nanotechnologies for life sciences research	111
Table 4-1: Nanotechnologies with potential applications in molecular diagnostics.....	114
Table 4-2: Nanobiotechnologies for single molecule detection.....	156
Table 4-3: Companies developing nanomolecular diagnostics	171
Table 5-1: Basic nanobiotechnologies relevant to drug discovery	178
Table 5-2: Companies involved in nanobiotechnology-based drug discovery and development.....	188
Table 6-1: Comparison of features of drug delivery by micronization vs nanonization	191
Table 6-2: Nanomaterials used for drug delivery.....	194
Table 6-3: Liposome-nanoparticle hybrid systems.....	216
Table 6-4: Examples of application of nanoparticles for gene therapy	231
Table 6-5: Classification of nanobiotechnology approaches to drug delivery in cancer.....	242
Table 6-6: Approved anticancer drugs using nanocarriers	243
Table 6-7: Clinical trials of anticancer drugs using nanocarriers	244
Table 6-8: Companies involved in nanobiotechnology-based drug delivery	289
Table 7-1: Nanomedicine in the 21st century	296
Table 7-2: Applications of nanobiotechnology for neurological disorders	320
Table 7-3: Nanoparticles used for drug delivery in ophthalmology.....	342
Table 7-4: Companies using nanotechnology-based anti-infective agents.....	357
Table 7-5: Companies using nanotechnology for healthcare and therapeutics.....	365
Table 7-6: Applications of nanotechnologies in food and nutrition sciences.....	367
Table 7-7: Non-commercial institutes/laboratories involved in nanobiotechnology.....	368
Table 8-1: FDA-approved nanotechnology based drugs	398
Table 9-1: Nanobiotechnology markets according to areas of application 2009-2019.....	408
Table 9-2: Markets for nanobiotechnology according to technologies 2009-2019	411
Table 9-3: Geographical distribution of nanobiotechnology markets 2009-2019	412
Table 9-4: Drivers for the development of nanobiotechnology markets.....	422
Table 9-5: Strategies for developing markets for nanobiotechnology	423
Table 9-6: Cost-benefit of nanotechnology-based drug delivery	424

Figures

Figure 1-1: Top-down and bottom-up approaches.....	23
Figure 1-2: Relationship of nanobiotechnology to healthcare and related technologies.....	25
Figure 2-1: Schematic representation of Dip Pen Nanolithography (DPN)	29
Figure 2-2: The core, branching and surface molecules of dendrimers	54
Figure 4-1: Scheme of bio-barcode assay	134
Figure 4-2: Scheme of a novel optical mRNA biosensor	148
Figure 4-3: Surface plasmon resonance (SPR) technology.....	149
Figure 4-4: Concept of nanopore-based sequencing	156
Figure 5-1: Application of nanobiotechnology at various stages of drug discovery	177
Figure 6-1: Bacteria plus nanoparticles for drug delivery into cells	195
Figure 6-2: A lipid nanoparticle.....	212
Figure 6-3: Lipid-protein nanotubes for drug delivery	219
Figure 6-4: Nanocochleate-mediated drug delivery	239
Figure 6-5: Nanodel™ gene vector	239
Figure 6-6: Use of micelles for drug delivery	247
Figure 7-1: Role of nanobiotechnology in personalized management of cancer	320
Figure 9-1: Components of the \$1 trillion market for nanotechnologies in the year 2015	407
Figure 9-2: Nanobiotechnology markets according to applications 2009-2019	409
Figure 9-3: Geographical distribution of nanobiotechnology markets 2009-2019.....	413
Figure 9-4: Unmet needs in nanobiotechnology applications.....	422