

## Contents

Preface *XI*

Acknowledgement *XV*

### Part I What You Know (or Don't Know) about Nanoinnovation 1

- 1 Quick – Name Something “Nano” 3
  - Your Nano I.Q. 13
- 2 A Quick-Start Guide: 10 Things You Should Know About Nanoinnovation 17
  - 2.1 10 Things You Should Know about Nanoinnovation 17
    - 2.1.1 What is Nanoinnovation? 18
    - 2.1.2 Five Categories of Nanoinnovation 20
    - 2.1.3 Learning the Jargon of Nanoinnovation 23
    - 2.1.4 How Small Is Nanoscale? 26
    - 2.1.5 What Are the Unique (Quantum) Properties of Nanotechnology? 28
    - 2.1.6 The Metrics of Nanoinnovation 30
    - 2.1.7 The Need to Become Nanodextrous 36
    - 2.1.8 Where Are We Now in the Evolution of Nanoinnovation? 37
    - 2.1.9 A Short History of Modern – and Ancient – Nanoinnovation 40
    - 2.1.10 Critical Issues for Nanoinnovation 51
      - References 52

### Part II The Science of Nanoinnovation 55

- 3 What Nanoscientists Are Working On 57
  - 3.1 Using Nanoscience to Solve Puzzles and Unlock Innovations 58
  - 3.2 Solid Smoke: Catching the Comet's Tail 60
  - 3.3 Turning DNA into Boxes, Lattices, and Pyramids 62
  - 3.4 How Nanoinnovation Is Extending Moore's Law 67
  - 3.5 Invisibility Cloaks, Optical Tweezers, and Nanophotonics 72

3.6	Nanoscience Wild Cards: Will Tree Lights Replace Streetlights?	77
3.7	Science Genius versus Commercial Challenge	84
3.8	Nanoscience Pioneers Are Mapping the Future	87
	References	89
<b>4</b>	<b>Imaging the Unseen: Viewing Structures Smaller than Light Waves</b>	<b>91</b>
4.1	What Nano Images Reveal	91
4.2	Using Electrons Instead of Light to View Nanoscale Structures	97
4.3	A Short History of Nanoscale Imaging	97
4.4	Different Types of Nanoscale Microscopes	99
4.5	Bringing Biological Nanostructures into Focus	102
4.6	Using Optical Imaging Systems to View Nanoscale Structures	104
4.7	Probing the Future	106
4.8	Nanosopes on Mars	109
4.9	The Future of Nanoscale Imaging	111
	References	112
<b>5</b>	<b>Where Nanoscience Becomes Nanoart</b>	<b>113</b>
5.1	Holistic Nano at the Convergence of Nanobliss, Nanoform, and Nanofunction	116
5.2	Innovating at the Convergence of Biomimetics, Nanoart, and Nanoscience	119
5.3	Using Art to Conceptualize the Future	123
	Reference	125
<b>Part III</b>	<b>The Business of Nanoinnovation</b>	<b>127</b>
<b>6</b>	<b>Lessons from the First Wave of Nanoventures</b>	<b>129</b>
6.1	The First Wave of Nanoventures	130
6.2	Zyvox: Divide and Conquer	131
6.3	Zyvox Piranha: The First Carbon Nanotube Boat	139
6.4	Nantero: Patent, Fabricate, Outsource	143
6.5	QuantumSphere: Competitive Catalysts	147
6.6	InsituTec: From Grad Students to Commercial Venture	153
6.7	Nanocomp: Taking Nanotubes to Jupiter and Beyond	155
6.8	Nanosys: Resurrection and Redemption	159
6.9	Graphene Frontiers: Commercializing Graphene	162
6.10	Carbon Nanotechnologies: Early Promise, Not Fulfilled	165
	References	165
<b>7</b>	<b>Implementing Your Nanoinnovation Strategy</b>	<b>167</b>
7.1	A Sense-Making Framework for Nanoinnovators	167
7.2	10 Strategic Questions that Nanoinnovators Need to Ask	168
7.2.1	What's the Value Proposition?	169

7.2.2	Where Do We Fit in the Supply Chain?	170
7.2.3	Can This Be Funded with “Patient Money?”	171
7.2.4	Can the “Lab Solution” Be Translated into a “Commercial Solution?”	172
7.2.5	Is the Intellectual Property Secured?	173
7.2.6	Do We Have the Right Partners?	174
7.2.7	Is This the Best Team for This Project?	174
7.2.8	Is Our Strategy Flexible?	176
7.2.9	What Are the Obstacles?	176
7.2.10	Is It Safe?	177
7.3	Where to Learn About Nanoinnovation	178
	Reference	180
<b>8</b>	<b>International Perspectives</b>	<b>181</b>
8.1	The Critical Role of Nanoinnovation Ecosystems	183
8.2	Nanoinnovation in the Asia–Pacific Region	188
8.3	Nanoinnovation in Latin America	191
8.4	Nanoinnovation in the European Community	194
8.5	Insights from Selected Nanoinnovation Ecosystems	199
8.6	Critical Issues for International Nanoinnovation	206
8.7	Nanoinnovation for the Bottom of the Pyramid	210
	References	212
<b>Part IV</b>	<b>Where Bio Meets Nano</b>	<b>215</b>
<b>9</b>	<b>Innovation at the Frontiers of Nanomedicine</b>	<b>217</b>
9.1	Medical Miracles and the Nanomedicine Landscape	218
	References	226
<b>10</b>	<b>Areas Where Nanoinnovations Are Creating Medical Miracles</b>	<b>227</b>
10.1	Smart Pills and Wearable Sensors = Digital Medicine	228
10.2	Organs-on-a-Chip	232
10.3	Growing Your Own Replacement Organs	236
10.4	Tumor-Seeking Nanoparticles	248
10.5	Nanosizing Drugs	257
10.6	Gene Therapy: The First Breakthroughs (At Last)	258
10.7	DRACO: Designing a “Kill Switch” for Viral Diseases	277
10.8	Nanoinnovation in the Decade of Diagnostics	286
10.9	In Search of the Star Trek Tricorder	290
10.10	Nanobacteria: The Smallest Life-Form?	292
	References	294
<b>11</b>	<b>Nanomimicry: Cool Things We Can Do with Nanobiology</b>	<b>297</b>
11.1	Turning DNA into Nanocomputers	298

11.2	Turning DNA into “Walking” Nanorobots	299
11.3	Nanomimicry: Learning from Nature at the Nanoscale	300
11.4	Mimicking Geckos to Create Glue	300
11.5	Biomimicking the Waterproofing Properties of Butterfly Wings	306
	References	309
12	<b>Nanotechnology: Is It Safe?</b>	311
12.1	Early Experience with Nano Safety	313
12.2	What We Know about Nanoparticle Risks	316
12.3	The Regulatory Climate and Safety Knowledge Gaps	321
12.4	Perspectives of Nano-Insiders	326
	References	328
13	<b>Prologue to the Future What's Next?: Predictions and Possibilities</b>	329
13.1	Keeping Nanoinnovation on Your Radar Screen	340
	References	340
	<b>Appendix A: Answers to the Nano I.Q. Quiz</b>	341
	<b>Appendix B: Carbon Nanotubes: Company List</b>	349
	<b>Appendix C: University Nanotechnology Research and Educational Centers</b>	353
	<b>Index</b>	359