

ARMIN GRUNWALD **RESPONSIBLE  
NANOBIOTECHNOLOGY**

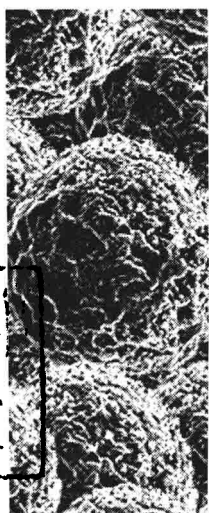
Philosophy and Ethics



ARMIN GRUNWALD **RESPONSIBLE  
NANOBIOTECHNOLOGY**

Philosophy and Ethics

常州大学图书馆  
藏书章



*Published by*

Pan Stanford Publishing Pte. Ltd.  
Penthouse Level, Suntec Tower 3  
8 Temasek Boulevard  
Singapore 038988

Email: [editorial@panstanford.com](mailto:editorial@panstanford.com)

Web: [www.panstanford.com](http://www.panstanford.com)

### **British Library Cataloguing-in-Publication Data**

A catalogue record for this book is available from the British Library.

### **Responsible Nanobiotechnology: Philosophy and Ethics**

Copyright © 2012 Pan Stanford Publishing Pte. Ltd.

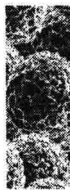
*All rights reserved. This book, or parts thereof, may not be reproduced in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system now known or to be invented, without written permission from the publisher.*

For photocopying of material in this volume, please pay a copying fee through the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, USA. In this case permission to photocopy is not required from the publisher.

ISBN 978-981-4316-80-4 (Hardcover)

ISBN 978-981-4363-33-1 (eBook)

Printed and bound in Great Britain by TJ International Ltd, Padstow



# **RESPONSIBLE NANOBIOTECHNOLOGY**

## Preface

Nanotechnology is one of the most prominent emerging technologies. It has been heralded as a key technology for the twenty-first century that — according to the expectations of a broad alliance of policymakers, scientists, and industry representatives — will contribute to economic prosperity and sustainable development. Via its enabling role in nanobiotechnology and in concert with “converging technologies,” nanotechnology could also influence the future of human nature and play a role in creating artificial life. The development of nanotechnology is thus also related to new debates about the *human condition* and the future of society as well as to man’s relationship with nature and technology.

In view of the revolutionary potential frequently attributed to the nanosciences and nanotechnology with respect to nearly all fields of society and individual life, it is not surprising that research and reflection on their presumed societal consequences started early. Technology assessment (TA) and studies of the ethical, legal, and social implications (ELSI) began analyzing issues related to nanotechnology and society about 10 years ago. The analysis, deliberation, and assessment of the expected impact of nanotechnology on future society are now regarded as necessary contributions to the present and further development of nanotechnology and its enculturation into society. Ethical reflection on nanotechnology, in particular on its relationship with living systems in nanobiotechnology, has emerged quickly and led to the new term “nanoethics,” which has been elaborated on and debated at workshops, conferences, and summer schools as well as in books and scientific journals.

In the present book, I review the considerations of nanotechnology elaborated in philosophy, ethics, and the social sciences and systematize and develop them further. The focus is on issues

of ethical responsibility regarding chances and risks of nanotechnology and its possible applications. From this analysis of the normative challenges posed by nanotechnology, my goal is to derive orientation for further, responsible work in research and development. I thus put the book in the context of the keywords “responsible innovation” and “reflective sciences” which have been central concepts in the debates about the relationship between science and society for the last few years.

To a not unsubstantial extent, the analyses presented in this book are based on my own previous studies. Nearly 10 years ago I began to concern myself with the societal and ethical aspects of nanotechnology. This research has led to a number of publications that I have been able to use as a starting point for the present work. I would like, above all, to mention the book *Auf dem Weg in eine nanotechnologische Zukunft. Philosophisch-ethische Fragen* (The Path to a Nanotechnological Future: Philosophical and Ethical Issues), published in German by Verlag Karl Alber in 2008. The major developments versus that book are the introduction to the historical development of the field, the mapping of the ethical issues posed by nanotechnology, the addition of the field of animal enhancement, the programmatic focus on the explorative role of ethics and philosophy, as it has been formed in the debates on speculative nanoeconomics, and the concentration on aspects of responsibility.

My thanks go to my many colleagues in Germany, Europe, and around the world with whom I have had the opportunity in the last few years to discuss the philosophical and ethical aspects of nanotechnology. This has taken place both within these disciplines as well as within the framework of interdisciplinary dialogue, for example in the fields of technology assessment and of STS studies (i.e., on science, technology, and society). To represent these many people, I would here like to name just a few: Alfred Nordmann, Arie Rip, and Tsjalling Swierstra. My special thanks for long and ongoing cooperation on questions related to nanotechnology and for a number of valuable substantive suggestions go to my colleagues in Karlsruhe Christopher Coenen, Michael Decker, Torsten Fleischer, and Peter Hocke-Bergler as well as to Hans-Jürgen Link.

My thanks also go to Alison Hepper and Michael Wilson for ensuring the quality of the language and for their professional translation. I heartily thank Monika Zimmer for preparing the layout rapidly and carefully.

**Armin Grunwald**

Karlsruhe, January 2012

# Contents

*Preface*

xiii

<b>1 Agenda and Overview</b>	<b>1</b>
1.1 The Motivation	1
1.2 Objectives, Conceptual Framework, and Premises	5
1.3 Quick Guide Through the Book	8
1.3.1 Chapter 2: Nanotechnology in Context	8
1.3.2 Chapter 3: Ethics, Technology, and Risk	9
1.3.3 Chapter 4: Ethics of Nano(bio)technology: The Program	9
1.3.4 Chapter 5: Ethics of Nano(bio)technology: An Overview	10
1.3.5 Chapter 6: Synthetic Nanoparticles	10
1.3.6 Chapter 7: Toward Creating Artificial Life	11
1.3.7 Chapter 8: Animal Enhancement	11
1.3.8 Chapter 9: Human Enhancement	11
1.3.9 Chapter 10: From Applied Ethics to an Explorative Philosophy of Nanotechnology	12
1.3.10 Chapter 11: Conclusions and Perspectives	13
<b>2 Nanotechnology in Context</b>	<b>15</b>
2.1 History of Nanotechnology	15
2.2 The World of Nanotechnology in a Nutshell	18
2.2.1 Nanometer-Scale Analysis and Manipulation	19
2.2.2 Characteristics of Nanomaterials	21
2.2.3 Areas of Activity and Applications	23
2.2.3.1 Synthetic Nanomaterials	23
2.2.3.2 Nanoelectronics	25
2.2.3.3 Nanobiotechnology	26
2.2.3.4 Nanomedicine	26

2.3	Defining Nanotechnology	27
2.4	The Interdisciplinary Nature of the Nanocommunity	33
2.5	Philosophical Interpretations	35
2.5.1	Triumph of Homo Faber	36
2.5.2	Huge Increase on Uncertainty	37
2.5.3	Nanotechnology as a Symbol of the Future	39
2.6	Public Perception	41
2.6.1	The "Grey Goo" Scenario	42
2.6.2	The "Prey" Scenario	42
2.6.3	The "Cyborg" Scenario	43
<b>3</b>	<b>Ethics, Technology, and Risk</b>	<b>49</b>
3.1	Problem-Oriented Ethics	49
3.1.1	Ethics for Resolving Moral Conflicts	50
3.1.2	Standard Situations in a Moral Respect	55
3.1.2.1	Pragmatic Completeness	56
3.1.2.2	Local Consistency	56
3.1.2.3	Sufficient Lack of Ambiguity	56
3.1.2.4	Acceptance	57
3.1.2.5	Compliance	57
3.1.3	Beyond Standard Situations in a Moral Respect	60
3.1.4	Ethical Expertise as Conditionally Normative Advice	63
3.2	Ethics of Technology	67
3.2.1	Normative Uncertainties Emerging from Technological Progress	67
3.2.2	Cross-Cutting Issues	70
3.2.2.1	Human Autonomy vs. Technicalization	71
3.2.2.2	Distributive Justice	71
3.2.2.3	Technology and the Environment	72
3.2.2.4	Technology and Life	73
3.2.2.5	Uncertainty of Our Knowledge of the Consequences	73
3.2.3	Ethics of Technology as Part of Technology Governance	74
3.2.3.1	Political Decisions	75

3.2.3.2	Entrepreneurial Decisions	76
3.2.3.3	Engineering	76
3.2.3.4	Consumer Behavior	77
3.2.3.5	Public Debate	77
3.2.4	Technology, Science, and Responsibility	78
3.3	Ethics and (Unclear) Risk	81
3.3.1	Classical Risk Management and Its Limitations	81
3.3.2	Ethical Issues in Dealing with Unclear Risk	84
3.3.2.1	Acceptability of Unclear Risk	85
3.3.2.2	Weighing Benefits against Unclear Risks	85
3.3.2.3	Normalizing the Situation under Consideration	86
3.3.2.4	Comparisons of Man-Made Situations of Unclear Risk with Natural Situations	87
3.3.2.5	Learning from Historic Cases	87
<b>4</b>	<b>Ethics of Nano(bio)technology: The Program</b>	<b>89</b>
4.1	Motivations of Nanoethics	89
4.1.1	Avoiding to Endanger Innovation	90
4.1.2	Taking Care of Unintended Side Effects as Early as Possible	92
4.1.3	Reacting to Apocalyptic Fears	93
4.2	Nanoethics as a New Field of Applied Ethics?	95
4.3	Problem-Oriented Ethics of Nanotechnology	102
<b>5</b>	<b>Ethics of Nano(bio)technology: An Overview</b>	<b>107</b>
5.1	Literature Overview	108
5.1.1	Interdisciplinary Expert Studies	108
5.1.2	Position Papers from Nongovernmental Organizations	111
5.1.3	Selected Edited Books	114
5.1.4	The Journal Nanoethics	118
5.2	Ethical Questions Related to Nano(bio)technology Applications	119
5.2.1	Nanomedicine: Risks and Benefits	120
5.2.2	Nanoelectronics: Surveillance and Privacy Issues	124

5.2.3	Using Processes of Life for Technological Purposes	126
5.2.4	Human Enhancement	128
5.2.5	Animal Enhancement	129
5.2.6	Military Applications	132
5.3	Cross-Cutting Ethical Issues	134
5.3.1	EHS: Environment, Health, and Safety	134
5.3.2	Distributive Justice: Nanotechnology and Developing Countries	137
5.3.3	Responsibility for Future Generations	140
5.4	Selection of Issues for In-Depth Studies	143
<b>6</b>	<b>Synthetic Nanoparticles</b>	<b>147</b>
6.1	Synthetic Nanoparticles: Fields of Application and Expectations	148
6.1.1	Surface Treatment	149
6.1.2	Food	150
6.1.3	Cosmetics	152
6.2	Possible Risks and Types of Risk	152
6.2.1	Health Risks	154
6.2.2	Environmental Risks	156
6.2.3	Nanoparticle Risks as "Unclear Risks"	157
6.3	Approaches to Dealing with Unclear Risk	159
6.3.1	Philosophical Approaches	159
6.3.1.1	The Consequentialist Approach	159
6.3.1.2	The Imperative of Responsibility	160
6.3.1.3	The Principle of Pragmatic Consistency	162
6.3.1.4	Deontological Advice	163
6.3.1.5	Projected Time	164
6.3.2	Operational Approaches	165
6.3.2.1	The Precautionary Principle	165
6.3.2.2	The Prudent Avoidance Approach	168
6.3.3	Interim Conclusions	170
6.4	Dealing Responsibly with Nanomaterials	171
6.4.1	Conditionally Normative Reflection	171
6.4.2	Informed Consent and Consumer Freedom	174

6.4.3	Regulation, Code of Conduct, and the Common Good	175
6.4.4	Operative Approach: Remarks on the Next Steps	181
6.4.5	Epilogue and Reflection: Risk Ethics and Nanoparticles	187
<b>7</b>	<b>Toward Creating Artificial Life</b>	<b>191</b>
7.1	Nanobiotechnology and Synthetic Biology	191
7.1.1	Nanobiotechnology	192
7.1.2	Synthetic Biology: Engineering Life	193
7.2	Chances and Risks	197
7.2.1	Chances	197
7.2.2	Risks	199
7.3	Ethical Issues	203
7.3.1	Dealing with Risks Responsibly	204
7.3.2	The Moral Status of Created Organisms	207
7.3.3	Quasi-ethical Concerns: Humans "Playing God"?	209
7.4	Hermeneutic Dimensions	213
7.4.1	Technicalization of the Natural or a More Natural Technology	213
7.4.2	The Relationship Between Technology and Life	217
7.5	Responsible Governance of Synthetic Biology	219
<b>8</b>	<b>Animal Enhancement</b>	<b>227</b>
8.1	(Nano)Technology for Intervening in Animals	228
8.2	The Semantics of Animal Enhancement	232
8.2.1	The Semantics of Enhancement	232
8.2.2	Animal Enhancement	234
8.3	Relevant Ethical Challenges and Normative Frameworks	237
8.3.1	Animal Experiments	238
8.3.2	Elimination of Animals' Capacity for Suffering	240
8.3.3	Transgressing the Boundary Between Humans and Animals	243
8.4	Changing Human-Animal Relationship	244
8.5	Summary and Conclusions	247

<b>9 Human Enhancement</b>	<b>251</b>
9.1 Improving Human Performance of Converging Technologies	251
9.1.1 The Vision of Converging Technologies	252
9.1.2 Improving Human Performance: The Cultural Background	255
9.1.3 Enhancement Utopia 1: Neuroenhancement	258
9.1.4 Enhancement Utopia 2: Antiaging and Immortality	261
9.2 Semantics of Technical Enhancement	263
9.2.1 Enhancement Beyond Healing	263
9.2.2 Healing, Doping, Enhancement, and Alteration	265
9.2.3 Technical Enhancement	269
9.3 Human Enhancement: Ethical Analysis	272
9.3.1 Normative Uncertainties	272
9.3.2 Patterns of Ethical Argumentation	275
9.3.2.1 Ethical Consideration of the Consequences	275
9.3.2.2 The Naturalness of Man	278
9.3.2.3 The Question as to Ought	280
9.3.3 Assessment of the Current Status of the Ethical Debate	281
9.4 Changing Relations Between Humans and Technology	284
9.4.1 Neuroelectric Interfaces	284
9.4.2 Technicalization of Man by Nanotechnology?	290
9.5 Conclusions for Responsible Action	293
9.5.1 Need for Orientation on Human Enhancement	293
9.5.2 Responsible Action	297
9.5.3 Approaching an "Enhancement Society?"	300
<b>10 Explorative Nanophilosophy: More Than Applied Ethics</b>	<b>303</b>
10.1 The Debate on "Speculative Nanoethics"	304
10.1.1 The Main Diagnosis: "Most Nanoethics Is Too Futuristic"	305
10.1.2 How Speculative Is "Speculative Nanoethics"?	306
10.1.3 The Anxiety that Unjustified and Artificial Concerns Might Emerge	308

10.1.4	The Opportunity–Costs Argument	310
10.1.5	Resume	311
10.2	Searching for Orientation by Investigating Futures	312
10.3	Futures as Social Constructs	314
10.4	Explorative Philosophy of Nanotechnology	317
10.4.1	Explorative Philosophy Beyond Applied Nanoethics	318
10.4.2	Elements of an Explorative Philosophy of Nanotechnology	321
10.4.2.1	Nano Epistemology	321
10.4.2.2	Nano Anthropology: The Relationship Between Humans and Technology	322
10.4.2.3	Nanotechnology Hermeneutics: Philosophical Interpretations of Nanotechnology	323
10.4.3	Epistemological Grounding	323
<b>11</b>	<b>Conclusions and Perspectives</b>	<b>327</b>
11.1	Ten Years of Nanoethics: What Has Been Achieved?	327
11.2	Moral Arguments Feeding a Broad Antinano Movement?	331
11.3	The Future of Nanoethics	335
11.3.1	Nanoethics as Concomitant Reflection on Nanotechnologies	335
11.3.2	Nanoethics as Interdisciplinary Research	337
11.3.3	Disentanglement of Nanoethics	339
	<i>Bibliography</i>	343
	<i>Index</i>	369

# Chapter 1

## Agenda and Overview

High expectations are placed on nanotechnology, for example, regarding health care, economic growth, and sustainable development. Parallel to them, however, there are also concerns about side effects and possible risks it poses. Commissions and expert groups have been dealing with the ethical, legal, and social implications (ELSI) of nanotechnology since an early stage of its development. The quest to achieve an ethical understanding in and for nanotechnology is an element of both public debate and scientific self-reflection. After having researched and debated the societal and ethical issues of nanotechnology for some ten years, the time is ripe for me to attempt to summarize, systematize, and assess the status of these issues as well as to think about the further perspectives of the field.

### 1.1 The Motivation

Since its beginning, nanotechnology has been viewed as something special, unlike any other technology, such as the technology of microsystems, propulsion technology, or catalytic technology. Starting with the controversial visions of Eric Drexler (1986), nanotechnology has contained a utopian and visionary element. After many in society were disillusioned with technical progress, especially as a result of the unintended consequences for the environment and society (Grunwald, 2009a), nanotechnology brought back hopes that technology might be a positively

---

*Responsible Nanobiotechnology: Philosophy and Ethics*

Armin Grunwald

Copyright © 2012 Pan Stanford Publishing Pte. Ltd.

ISBN 978-981-4316-80-4 (Hardcover), 978-981-4363-33-1 (eBook)

[www.panstanford.com](http://www.panstanford.com)

redeeming force. Yet it also triggered anxieties about just the opposite, namely about dystopian developments. This coincidence of new technical opportunities and extremely far-reaching expectations — but also anxieties — provided from the beginning the central motivation for systematically studying the social and ethical issues of nanotechnology (for a comprehensive overview see Guston, 2010).

Viewed against this backdrop, the social discussion about nanotechnology does not revolve solely around the future of a specific line of technology or around the resulting consequences for society. It also revolves around such grand topics as the future of human nature, the future of the relationship between man and technology or between man and nature, and the sustainability of human development. Far-reaching questions arise precisely there where nanotechnology encounters living systems, such as in nanobiotechnology and in nanomedicine. This was the reason for me to speak of “nano(bio)technology” in this book. The boom in visions of the future and the clustering of reflective scientific studies in this field (e.g., Baird *et al.*, 2004; Nordmann, 2005; Dupuy, 2005; Selin, 2005a,b; Brown *et al.*, 2000; Grunwald, 2007; Fiedeler *et al.*, 2010) are an expression of this particular manifestation of the debate about nanotechnology, which makes it especially appealing to philosophical analyses. It should not be surprising when in the process methodological issues sometimes move to the focus of attention, in particular whether and how it is possible to make statements with regard to visions of the future or to derive orientation without slipping off into ideas that are purely speculative and arbitrary (Nordmann and Rip, 2009; Grunwald, 2010). In the meantime, the debate has differentiated into two branches, a practically oriented one and a futuristic one:

- (a) Of interest among the practically oriented issues of nanotechnology are those that are already politically relevant, such as risks to our environment and health or issues of equity. Questions have been and are still being asked about the toxicity of nanoparticles, and debates have begun about the regulation of nanomaterials. The public debate about nanotechnology has been spurred on by position papers published by nongovernmental organizations (e.g., ETC, 2003), while ministries and other government bodies hold workshops and public discussions on the possible risks of nanomaterials. Researchers and nongovernmental organizations are dealing

with issues of equity, in particular concerning the access of developing countries to the expected benefits of nanotechnology. The UNESCO has commissioned an expert group to prepare the field for action (ten Have, 2007).

- (b) In a rather futuristic respect, the grand issues mentioned above — such as about the future of human nature and about man's relationship to nature and technology — continue to be discussed. This takes place above all in the field of “converging technologies” (Roco and Bainbridge, 2002), which builds on nanotechnology, especially on nanobiotechnology. Currently, the two great topics are human enhancement and synthetic biology.

The focus in both branches is on implementing the concepts of “responsible innovation,” “responsible development,” and “reflective science” (Siune *et al.*, 2009). Instead of there being a division of labor between science and innovation on the one hand and attempts to cope with their societal consequences on the other, as was frequently the case in earlier times, research and reflection on the possible consequences of science and innovation are now supposed to be pursued *as part of* research and development. Their results shall be taken into consideration in the further shaping of the scientific agenda and technical progress (Kaiser *et al.*, 2010).

In the last few years, ethical reflection on nanotechnology has developed quickly and identified many ethically relevant issues (e.g., Kushf, 2004; Grunwald, 2005). The early ethical studies on nanotechnology (about 2003) focused above all on the need to have ethics in and for nanotechnology. The ethically relevant aspects of nanotechnology that were named in those studies are an indication of a grouping and a very tentative (or positively phrased, of an open) approach to this relatively new field of reflection on science and technology. The concept “nanoethics” was quickly coined in this connection. Since then, a number of anthologies have been published about the social issues raised by nanotechnology in general and about ethical issues in particular (e.g., Schummer and Baird, 2006; Allhoff *et al.*, 2007; Banse *et al.*, 2008; Fiedeler *et al.*, 2010). The international journal *Nanoethics* was also founded during this period.

There are problems of definition, however, with the *object* of ethical reflection about nanotechnology, namely the field of nanotechnology itself (Schmid and Decker, 2003; Schmid *et al.*, 2006; Chapter 2). Nanotechnology has so far been less technology