NANO

meets

MACRO

Social Perspectives on Nanoscale Sciences and Technologies

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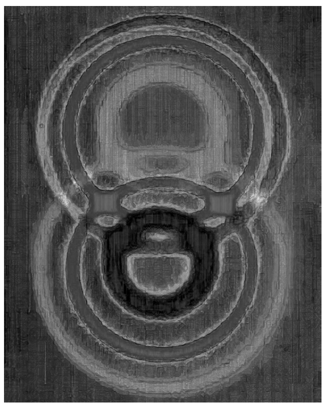

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PAN STANFORD PUBLISHING

Published by

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

Email: editorial@panstanford.com
Web: www.panstanford.com

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

NANO MEETS MACRO
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ISBN 978-981-4267-05-2 (Hardcover)
ISBN 978-981-4267-69-4 (eBook)

Printed in Singapore.

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Foreword

The Difficult Transition

The new emerging techno-sciences present huge perplexities. Their promise is great, even if it is not always predictable in detail. Perhaps their peril is even greater, but this is much more difficult to define. The idea of a world reduced to *grey goo* by nano-bots now seems far-fetched, but the dangers of nanoparticles passing the blood-brain barrier cannot be dismissed. We are now in a situation where it is impossible to hive off the downside of new developments as something extraneous or accidental, to be managed by some other less interesting sort of practice. All this is very confusing to the researchers participating in the enterprise because their training, equipping them to solve puzzles with very strict boundaries, has left them unprepared for this new sort of science.

For the emerging techno-sciences, it is important to recognize that the context of research impinges on the content in many ways. First there are the priorities that determine which sorts of issues will be investigated and which not. In this way, external forces influence not merely what we will know, but (equally important) that of which we will remain ignorant. Then there are the hazards of the work, which can run through a whole life-cycle, including the research and the materials (affecting research workers and the environment), going on to the manufacturing phase, eventually on to diffusion in the social and environmental contexts, and finally in becoming 'waste'. The sciences of these contextual aspects have traditionally come second, in prestige, rewards and influence, to those which created the problems along with the promise. But now they need high quality and equality with the mainstream sciences, lest we risk quite serious damage from unanticipated consequences. Also, there are now publics and pressure-groups that, with all their appreciation of the benefits of science-based technology, no longer trust researchers and authorities to guarantee their safety. They have power, through protest, politics and the market-place. Scientists who despise or dismiss them are in danger of finding themselves isolated and scorned.

In this context, Post-Normal Science (PNS) can make an important contribution. When scientists try to imagine all this complexity, as a new and urgent part of their job, PNS can be a guide to reflective practice. We say that PNS comes into play when “facts are uncertain, values in dispute, stakes high and decisions urgent”. Those scientists who still live in world where they can be secure in their valueless facts do not need PNS – yet. But for the others, it can offer some security in a new and threatening situation. We imagine two axes, one of Systems Uncertainties and the other of Decision Stakes. When both are low, we have traditional Applied Science where safe routine is effective and appropriate. When either is medium, we have Professional Consultancy, as when the surgeon or consulting engineer faces an unpredictable nature and has the client’s welfare in her hands. When either is high, as in the case of the new emergent techno-sciences, we are in a different realm. The most important difference is that the peer community who assess problems and solutions must be ‘extended’ beyond those with formal expertise. This is not only necessary for policies that are good in themselves and for policies that are legitimate in the eyes of the public, but also to ensure the quality of the scientific processes and products.

The transition from Normal to Post-Normal Science now takes place through a set of leading examples. Gene techno-science suddenly discovered that it was no longer normal, and was totally confused. With Nano techno-science, those who manage the development know full well that it’s not normal although they are still not fully aware of the significance and the consequences. They are formally determined to avoid the backlash that was so destructive for gene technology but the ideology, attitudes and folkways of science that were so totally dominant for so long cannot be transformed in the space of a few years. Bringing a post-normal perspective to techno-science will require radical changes in the mindset of scientists and of those who sponsor or direct their work. The learning of the necessary lessons may not be totally free of pain.

With Nano techno-science, the severe Systems Uncertainties are known to all and denied by few. The great power of manipulating matter at the nano scale lies in its properties being unpredictably different from those at the meso and macro scales. But, as is universally acknowledged, this unpredictability creates enormous problems for the control of the operations, be they in the lab, in the factory or in the environment. As the pace of technological advance has quickened, it has become increasingly difficult for regulation, on behalf of Safety, Health and the Environment, to keep up or even to catch up. Although there have been some important voluntary initiatives (as between the Environmental Defense Fund and Du Pont[1]) and regulatory agencies all over the world are gearing up for their tasks, the activities of R&D and innovation gallop ahead, into the unknown and the unknowable.

The Decision Stakes are correspondingly high, and ill defined. Certainly, nano methods can transform technologies of all sorts, and can prove to be of immeasurable benefit in a great variety of fields. But the particles, once released into the natural and human environments, will have effects that are indeterminate and possibly undetectable, or at least undetected, in the short run. We do have a few experiments indicating that nanoscale particles can interfere with some physiological processes. While these can serve as general warnings, they give only limited guidance for strategic governance interventions.

We can imagine a ‘too late’ scenario, when it is retrospectively discovered that some widespread ailments or environmental pathologies can be attributed to particular nano-products. It is inevitable that in retrospect specific early warnings can be discovered, and hence blame can be assigned to scientists, managers and regulators. Depending on how serious the crisis is, there could arise a reaction against the whole

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[1] See http://www.edf.org/article.cfm?contentID=4821

enterprise. If the social class of 'banksters' were joined by 'scriensters' in public opprobrium, then that core enterprise of our civilisation would enter a new phase in its evolution.

None of that need happen, of course; and it is possible that the huge benefits of nano techno-science will be realised with only minor damages as their price. But we will not know, and cannot know, until such a time as the technology has settled down and the regulators caught up. That moment itself may never arrive, especially if nano techno-science quickly yields its leading position to other, more powerful and exotic technologies, such as synthetic life.

The futurist Ray Kurzweil has a vision of the convergence of all the exciting technologies, when we will have powers exceeding those ever dreamed of by magicians or even science-fiction writers[2]. That vision would seem to be a highly optimistic extrapolation from normal science, when all the puzzles come together in a creative synthesis. We could equally well imagine a convergence of the Systems Uncertainties and Decision Stakes of PNS, when the powers and perils of the sciences that come to constitute our civilisation are inextricably mingled. Citizens will need just to hope for the best, and a constructive opposition to particular innovations may come to be seen by some as fruitless.

Judging by previous history, including nuclear weapons up to now, there is a chance that we will be able to muddle through. As a result of many initiatives like this admirable volume, we may arrive at a situation where scientists, managers and society will have learned to proceed with some genuine caution, and come to understand that it's alright to say no, when there is a danger that the attractions of progress might prove fatal.

Silvio Funtowicz & Jerry Ravetz

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[2] See, for example Ray Kurzweil (2005) The Singularity Is Near: When Humans Transcend Biology, Viking Penguin

PREFACE

This book is a fortunate spin-off of our own process of trying to come to terms with the rich field of research on social and ethical aspects of nanoscale sciences and technologies. At various times, and in a range of different settings, we have both been asked to teach, present or give an overview of this multifaceted body of work. This book results from our various attempts to find good ways of doing this.

While we come from very different backgrounds (e.g. one of us was raised on a farm in Australia while the other grew up in Norway's largest city), we share a range of academic interests. Both of us took degrees to support an interest in environmental problems and decision-making (Kamilla in Environmental Management and Fern in Political Science and Ecology). Both of us also went on to separately conduct research on genetically modified crops and how they should be governed in the face of uncertainty. We have brought these shared interests in issues of environment, governance and uncertainty, to our research on nanoscale sciences and technologies (nanoST), and they remain important to us.

We were brought together in 2006 at the Centre for the Study of the Sciences and the Humanities (SVT), University of Bergen, to work on a new project entitled "Interdisciplinary Studies of Ethical and Societal Implications of Nanotechnology". This project had a specific emphasis on fostering interaction, dialogue and research across social and natural sciences, and included project partners from a range of different disciplines and countries. Along with most of the project partners, we were new to the field of nanoST. At the initial project meeting, however, we were asked to provide the group with an overview of research conducted on social and ethical aspects of nanoST.

Although we were quite overwhelmed by the richness of the literature in this field, it was still at an early enough stage of development for us to be able to conduct, what was at the time, a relatively comprehensive literature review. This review involved reading all the works that we saw as part of the emerging field of research on social and ethical aspects of nanoST and finding a way to understand and present their diversity to those new to the topic. Through this process, we began to see the works clustering around some common themes and began to categorise them accordingly. This lead us to see value in presenting the field of social and ethical research on nanoST in four categories – Perception, Governance, Philosophy and Science.

After having presented our conceptual map of the field to our project partners, we also presented and discussed it with colleagues and researchers at a small conference and another workshop. We received valuable feedback during these exchanges and were encouraged to publish the work as an academic paper. Our review was published in the journal *NanoEthics* in 2007[1]. In early 2008, we were approached by Pan Stanford Publishing to turn our article into a book. We saw this as a wonderful opportunity to revisit and improve our ideas from the early phase of the project, and took little time to agree to the proposal.

Of course (and fortunately!), after three years of research, the way we understand the field and approach the presentation of it have changed somewhat. During this time, the field itself has also further developed and expanded rather dramatically. The change in our own thinking is perhaps most evident in the way in which we have chosen to rename the different nodes in this book (and indeed in the fact that we now use the more flexible concept of 'nodes', rather than the more rigid notion of 'categories' that we originally used in the article). In this book, the different nodes of social research on nanoST are presented as: *Nano meets Macro*: *In the Making* (formerly Science); *In the Public Eye* (formerly Perception); *In the Big Questions* (formerly Philosophy); and *In the Tough Decisions* (formerly Governance).

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[1] The article is published as Kjølberg, K. and Wickson, F. (2007) Social and ethical interactions with nano: Mapping the early literature, *NanoEthics*, 1, pp. 89-104.

For *Nano meets Macro*, we have not performed a new review of the field. Instead we have invited authors working on topics across the nodes to contribute with chapters. We specifically aimed for diversity among chapter authors in the sense that they come from different disciplines, different parts of the world and are at different stages of their research careers. In addition to these chapters, the book also contains ten artworks, three short science fiction stories and some poetry, as examples of non-academic commentary and social perspectives on nanoST. Three of the artworks were commissioned, while the others were selected from among the rich flora of existing 'nanoart'. The short stories were successful submissions in a call put out specifically for the book and the poetry was commissioned. While *Nano meets Macro* provides a varied selection of what we believe are important themes and perspectives in the field, it should not be seen as a comprehensive presentation of social aspects of nanoST. Our aim has rather been to show some of the existing diversity in this rich field, and to perhaps provide a useful conceptual apparatus for understanding the field as a whole.

The process of creating this book would not have been possible without help from a number of people and organisations. Firstly, we would like to thank all our authors and artists for agreeing to be involved in this project. We also thank the Norwegian Research Council and the University of Bergen for providing the necessary supporting funding. We thank all our project partners, and the participants at the NANOMAT ELSA conference in 2007 for feedback on our early ideas and the encouragement to develop them further. For detailed commentary on our original article, we thank the anonymous reviewers of *NanoEthics*. To all the staff at SVT, particularly Roger Strand, we extend our gratitude for regular stimulating academic conversation and an enjoyable working environment. We are also of course particularly grateful to Pan Stanford Publishing for their interest in our work and assistance in bringing this book into existence. Finally, we would like to thank our families, friends (and pets) for helping to maintain our sanity when we started to lose ourselves in the sometimes painful, sometimes all absorbing, but always rewarding, process of creating this book.

Kamilla Lein Kjølberg & Fern Wickson

Author Biographies

Lachlan Atcliffe is an Australian-born, currently England-based lawyer. A part-qualified barrister, he recently completed postgraduate study at Bristol University on the legal implications of radio-frequency identification tags. He suspects that no matter how advanced or widespread nanotechnology becomes, it will still have to carry safety labels saying ‘Caution: Do not attempt to eat’.

Tore Birkeland is a PhD student in nanoscience at the Department of Mathematics, University of Bergen (Norway). His research interests are numerical methods for atomic physics, and software development issues in computational science. He is the main developer of the atomic physics software package pyprop, which is an attempt to create a common framework for solving many different problems in atomic physics.

Diana Bowman is a Senior Research Fellow in the Monash Centre for Regulatory Studies, Faculty of Law, Monash University (Australia), and a Visiting Fellow in the Institute for Energy and Environmental Law, Faculty of Law, KU Leuven (Belgium). She has undergraduate degrees in both science and law, and has recently completed a PhD. Dr Bowman’s research focuses primarily on regulatory and policy issues related to nanotechnology and other new technologies. She was a co-editor of *New Global Frontiers in Regulation: The Age of Nanotechnology*. Recent projects have included assisting the Australian Government with their *Review on the Possible Impacts of Nanotechnology on Australia’s Regulatory Frameworks,* and the Food and Agricultural Organisation with their issues paper on *Nanotechnology applications in food and agriculture sectors: Principles and guidance for food safety regulation*.

Sarah Davies is a Research Associate at Durham University. Her research interests focus around 'public engagement' with science. Dr Davies' previous research has examined scientists' talk about publics and the practice of dialogue events. Her current research, on the EU-funded project DEEPEN (Deepening Ethical Engagement and Participation with Emerging Nanotechnologies) involves the analysis of lay ethics of nanotechnologies. She has a BSc in Biochemistry (2001), a MSc in Science Communication (2003), and a PhD (2007) on public dialogue on science, all from Imperial College, London. Dr Davies has also worked in exhibition development at the Science Museum, London, and taught undergraduate science students about communicating science.

Gian Carlo Delgado is a researcher specialized in societal, ethical, legal and environmental aspects of nanotechnology at the Interdisciplinary Research Centre on Sciences and Humanities, National Autonomous University of Mexico (UNAM). Dr Delgado is a member of the National Research System of the Mexican Science and Technology Council (CONACYT), and the editor of the journal "Mundo Nano", published by a group of research entities of the UNAM. He lectures at the Political and Social Sciences Faculty and at the Postgraduate Programme on Latin American Studies; both at the UNAM. Some of his work can be seen at www.giandelgado.net.

Susan Dodds is Professor of Philosophy and Dean of the Faculty of Arts at the University of Tasmania. She is a chief investigator on the Australian Centre for Excellence in Electromaterials Science (ACES), funded by the Australian Research Council. Professor Dodds leads the Ethics program within the ACES.

Robert Doubleday is a Lecturer in Environmental Policy at the Department of Geography, University of Cambridge (UK). His research is concerned with relations between science, citizenship and the governance of emerging technologies. Previously Dr Doubleday was based at the University of Cambridge's Nanoscience Centre, where he worked collaboratively with nanoscientists to explore the social dimensions of their work. He is currently working on a Wellcome Trust funded project that investigates how scientists working in the field of nanobiotechnology make strategic choices about their research careers.

Arianna Ferrari studied Philosophy in Milan (MA 2000) and completed her PhD with a double affiliation at the University of Tübingen (Germany) and the University of Torino (Italy). The topic of her dissertation was ethical and epistemological aspects of genetic modification of animals in biomedical research. Since 2006 Dr Ferrari has been working in the EU project DEEPEN (Deepening Ethical Engagement and Participation in Emerging Nanotechnologies). Her areas of interest include: animal and environmental ethics, bioethics, philosophy of technology, STS, nanoethics.

Arnout R. H. Fischer is Assistant Professor with the Marketing and Consumer Behaviour Group at Wageningen University (the Netherlands). He aims to understand public behaviour through social psychological approaches. Dr Fischer has published on consumer behaviour in relation to food safety and food technologies in academic books and peer reviewed journals. He is involved in several projects and committees in relation to public acceptance of nanotechnology in the Netherlands and internationally.

Hans Fogelberg is a researcher at the STS section of the Department of Sociology at the University of Gothenburg (Sweden). He has a Ms.Sci.Eng. in mechanical engineering and a Tekn.Lic. in History of Technology from Chalmers University of Technology. He completed a PhD in sociology of technology at University of Gothenburg (2000). Dr Fogelberg's main research areas are the sociology of innovation and the history of technology. These research interests include the analysis of innovation in relation to the knowledge economy and risk society. His main empirical fields are sustainable technologies, advanced road transportation technologies, and nanotechnology.

Lynn J. Frewer is Professor of food safety and consumer behaviour in the MCB group in the Social Sciences Department at Wageningen University (the Netherlands). Previously, Professor Frewer was Head of Consumer Science at the IFR in Norwich (UK). She has a background in psychology and has published extensively in the area of risk perception and communication.

Frøydis Gillund holds a Master's degree in Ecology and Natural Resource Management from the University of Life Sciences (Norway). She is currently a PhD student at 'GenØk – Centre for Biosafety'. Her PhD project: 'Genetic Engineering in Aquaculture: Perspectives on Management and Sustainability' focuses on how scientists and policymakers acknowledge and deal with scientific uncertainty related to the introduction of novel technologies in complex ecosystems. Her field of interest is natural resource management, philosophy of science and ethical and social implications of science and technology.

Mercy W. Kamara is a researcher at the Department of Communication, Business, and Information Technology, Roskilde University (Denmark). Her research focuses on 1) the relationship between policy, media representations and public perceptions with regard to controversial technologies; 2) the relationship between science funding policies, scientists' virtues and motivations, and scientific developments; and 3) the nature of public controversies involving sustainable development.

Matthew Kearnes is a RCUK Fellow at the Institute of Hazard and Risk Research (IHRR) and the Department of Geography at Durham University (UK). Since gaining his PhD in Human Geography from the University of Newcastle (Australia), Dr Kearnes has held positions at the Open University and Lancaster University before commencing his current position at Durham in 2006. His research work has focused on understanding the governance of contemporary scientific and ecological practices – particularly the co-production of science and society. Drawing on a background in science and technology studies and social and cultural geography, his recent research has focused particularly on the societal and ethical dimensions of nanotechnology and synthetic biology. He is currently coordinating an ESRC Project entitled: *Strategic Science: Research Intermediaries and the Governance of Innovation*. He is also a co-investigator on the European project DEEPEN (Deepening Ethical Engagement and Participation in Emerging Nanotechnologies) and the ESRC Seminar Series: *Critical Public Engagement*.

Kamilla Lein Kjølberg has a broad research interest in responsible environmental governance. She holds a Master's degree in Natural Resource Management from the University of Life Sciences (Norway), with a double specialisation in Tropical Ecology and Ecological Economics. Her master's thesis was called "When Experts Disagree", and dealt with expert advice on the deliberate release of genetically modified (GM) crops. She has worked with issues related to scientific uncertainty of GM aquaculture as a researcher at 'GenØk - Centre for Biosafety'. For a year she held the position as editor of Gennytt, an online newsletter about GM agriculture. She now works for the Centre for the Study of the Sciences and the Humanities, University of Bergen (Norway), with a PhD dissertation on Nanotechnology and Responsibility.

Renée Kyle is a researcher for the Office of Women (Australian Commonwealth Department of Families, Housing, Community Services and Indigenous Affairs). She was previously a post-doctoral Research Associate at the Australian Centre for Electromaterials Science, funded by the Australian Research Council.

Hildegard Lee is a pseudonym, employed to shield a scientist dabbling in amateur poetry from harsh critique and ridicule. Hildegard finds that expressing herself in poetry poses substantial challenges equal to, and sometimes exceeding, those she faces when expressing herself scientifically. She does, however, enjoy the way this alternative medium opens spaces for her to reflect on the nature of her work. She sometimes questions her choice of pursuing a career in scientific research and occasionally feels that her work is not allowed to benefit enough from her creativity. She would, for example, be very grateful if she could attend conferences and present her work in song, dance or theatre, rather than in powerpoint slides.

Phil Macnaghten is Professor of Geography at Durham University (UK). From a background in social psychology, his research focuses on the cultural dimensions of environmental and innovation policy and their intersection with everyday practice. Professor Macnaghten's current research addresses questions of public participation and the governance of emerging technologies. He is presently leading the European Commission FP6 project DEEPEN (Deepening Ethical Engagement and Participation in Emerging Nanotechnologies).

Colin Milburn is Associate Professor of English and a member of the Science & Technology Studies Program at the University of California, Davis (USA). His research focuses on intersections between science, literature, and media technologies. Associate Professor Milburn is the author of *Nanovision: Engineering the Future* (Durham: Duke University Press, 2008), and he is currently completing a new book about the convergence of video games and the molecular sciences, entitled *Mondo Nano: Fun and Games in the World of Digital Matter*.

Georgia Miller has been the national coordinator of the Friends of the Earth Australia Nanotechnology Project since 2005. She has been engaged in environment and social change campaigns since the mid-1990s, including in relation to GMOs. Georgia is particularly interested in supporting greater public involvement in science policy and decision making, and in making technology development more responsive to social and environmental needs. She has an Honours degree in Environmental Science.

Anne Ingeborg Myhr is employed as a scientist at ‘Genøk - Centre for Biosafety’ in Tromsø (Norway). She holds a Master’s degree in Biotechnology from NTNU (Norway), and a PhD from the University of Tromsø. The title of her PhD thesis is “Precaution, Context and Sustainability. A Study of How Ethical Values may be Involved in Risk Governance of GMOs”. Dr Myhr’s present research engagements are within the use of genetic engineering and nanotechnology. She is especially interested in governance of risk and uncertainty and how emerging technologies can contribute to sustainability. She is also involved in GenØk’s capacity building in risk assessment and management of GMO use and release in the Third World.

Alfred Nordmann received his Ph.D. in Hamburg (1986) and served on the faculty of the Philosophy Department at the University of South Carolina (1988-2002). Following this he became Professor of Philosophy and History of Science at Darmstadt Technical University (Germany) where he founded the nanoOffice. Professor Nordmann’s historical interests concern the negotiation of contested fields of scientific knowledge, such as theories of electricity and chemistry in the 18th century, mechanics, evolutionary biology and sociology in the 19th century, nursing science and nanoscale research in the 20th century. Since 2000, Professor Nordmann has been studying philosophical and societal dimensions of nanoscience and converging technologies. His focus, in particular, is on changes in the culture of science and the changing relationship of science, technology, nature and society. From October 2006 to September 2007 he was one of the coordinators of the research group ‘Science in the Context of Application’ at the ZiF of Bielefeld University (Germany). He remains closely associated as visiting adjunct professor with the Philosophy Department and NanoCenter of the University of South Carolina (USA). In the spring of 2009, he holds the Alcatel-Lucent Fellowship at the IZKT of the University of Stuttgart (Germany).

Rye Senjen has been an active campaigner for social justice for the last 30 years. She has been involved in campaigns on women's issues (including against the trafficking of women) and in the peace movement. Recently she has become very concerned about the potentially devastating effect of nanotechnology on society, the environment and all beings. She has been a member of the Friends of the Earth (FoE) Australia Nanotechnology project, since its inception in early 2005. In late 2006 Dr Senjen was invited to be an expert member on the UNESCO panel for nanotechnology and ethics. In 2008 she co-authored, together with Georgia Miller, the groundbreaking FoE report on nanotechnology and food. She has a life long interest in technology and its effect on society and has worked extensively in the telecommunications industry. She has published numerous scientific articles and a book about the Internet. She holds an Honours degree in Entomology and Horticultural Science, and a PhD in Artificial Intelligence.

Hope Shand is former Research Director of the Canadian-based ETC Group. Hope has conducted research, writing and advocacy work related to agricultural genetic resources and the social and economic impacts of new technologies for the past three decades. With ETC Group (and formerly with RAFI), she has monitored corporate concentration in the life sciences, especially the global seed industry. She lives in Chapel Hill, North Carolina (USA).

Lesley L. Smith lives and writes in Boulder, Colorado (USA). She specialises in hard science fiction and her short fiction has appeared in a variety of venues including 'Analog Science Fiction and Fact'. She is currently hard at work on her third novel, tentatively entitled 'Time Dream'. For more information please visit www.lesleylsmith.com.

Robert Sparrow is a Senior Lecturer in the School of Philosophy and Bioethics at Monash University (Australia). His current research interests include the ethics of nanotechnology, military robotics, human enhancement, and ethical issues surrounding cochlear implants. He has a BA (Hons) from Melbourne University (Australia) and a PhD from the Australian National University.

Roger Strand is Professor and Director of the Centre for the Study of the Sciences and the Humanities, University of Bergen (Norway). He holds a PhD in biochemistry. Professor Strand's research mainly falls within the philosophy of natural science and biomedicine, including research on the ethical and social aspects of bio- and nanotechnology. The focus of his research is on the nature and significance of scientific uncertainty and complexity for environmental and health-related decision-making processes. He is a member of the National Committee of Research Ethics of Natural Science and Technology in Norway.

Geert van Calster co-directs the Institute of Environmental and Energy Law at KU Leuven (Belgium), where he teaches and researches environmental law, energy law, European economic law, and international trade law. Professor van Calster is a former visiting professor at Erasmus University, Rotterdam (the Netherlands), where he held the chair of international economic law, and in EU law at Monash University (Australia). He was called to the Brussels Bar in February 1999. He is now of counsel (practising) in the DLA Piper Brussels office. He is cited in the Legal 500 as being "well regarded for the interface between economic and regulatory law", and as having an "excellent academic background aligned to pragmatic experience in both public and private sectors." Professor van Calster's current research interests include the regulation of new technologies (nanotechno logies in particular, heading a 5 year research project), and climate change law. His editorial works includes Carbon & Climate Law Review; Nano technology, Law and Business; and Law, Probability and Risk. He directs the Master programme on Energy and Environmental Law at the KU Leuven and is a tenured chair of the Research Fund , KU Leuven, and was a visiting lecturer at Oxford University (September 2006 – September 2008).

Ana Viseu is Assistant Professor in Communications & Culture, and Science and Technology Studies at York University (Canada). Anchoring her work on feminist technoscience and cyborg anthropology, she is interested in ethnographies of the practices of development and use of emergent (and contested) technologies, from both theoretical and material perspectives. Her goal is to understand how particular notions of embodiment, agency, science and technology are reified, created and enacted in emergent technologies. Assisstant Professor Viseu has addressed these issues in two complementary lines of research: wearable computers and nanotechnology. She has published in a number of venues, including the journals of *Ethics & Information Technology* and *Information, Communication and Society.* She is currently engaged in a project that seeks to conduct a discourse analysis of the field of nanomedicine so as to examine the figures of the body that are emerging and being reified within it.

Fern Wickson is a cross-disciplinary scholar with research interests in environmental philosophy and decision-making, the politics of risk and uncertainty, and the governance of emerging technologies. She completed her PhD across the Schools of Biological Sciences and Science, Technology and Society at the University of Wollongong (Australia). Her dissertation was entitled “From Risk to Uncertainty: Australia’s Environmental Regulation of Genetically Modified Crops”. Prior to this, Dr Wickson undertook a Bachelor of Arts/Bachelor of Science double degree at the Australian National University and an Honours degree in Environmental Politics at the University of Tasmania (Australia). She has lectured across the disciplines of history, politics, philosophy, science and technology studies, biology and engineering.

Lupin Willis is a citizen of the earth’s biotic community. When she is not busy growing organic vegetables, campaigning for the protection of oldgrowth forests, and contemplating deep ecology, she likes to write fiction as a way to stimulate reflection on the pace and direction of technological development. She prefers books to television, hand written letters to txts and fruit to fast food.

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Contents

Introduction

Nano science and technology is often said to be a ‘revolutionary’ new field of development with the potential to radically change our lives. But what does this actually mean? What is nano science and technology exactly? Where did it come from? Where is it going? Who’s leading this so-called ‘revolution’? How could it impact our lives? Do we want it? Do we need it? And; who decides these things? This book is about all these questions, and more. In other words, it is a book about the places and interfaces where *nano* science and technology meets *macro* social phenomena. All the perspectives offered in this book represent different narratives or stories, about what nano is, and what it means in a social context.

Our primary motivation in assembling this collection has been to showcase a diverse range of social views on nano in a way that might help stimulate and facilitate dialogue between those who do nano science and technology and those who study it as a social, political and cultural phenomenon. An additional motivation has been to illustrate how social perspectives on nano science and technology are expressed not just in academia but also in fields such as literature and art, and to try to present all these different perspectives in a way that makes them accessible for a broad audience.

In trying to juggle these multiple motivations, we have structured the book around four general nodes of interest. These are: *Nano meets Macro – In the Making; In the Public Eye; In the Big Questions*; and *In the Tough Decisions*. We believe that this framework helps to organise the wonderful richness and diversity of commentary in this field. Hopefully, the various perspectives offered, can inspire, encourage and assist readers in reflections on the questions posed above, and thereby make the book an interesting, informative and enjoyable read for all!

1. Nanoscale Sciences and Technologies

To attempt a short introduction to ‘nano’ science and technology is a daunting task. The field in question is incredibly broad and diverse, and both its definition and scope are hotly contested. The breadth of the field begins with the fact that the term ‘nano’ is used to refer to both ‘science’ and ‘technology’; where ‘nanoscience’ appears across a wide range of scientific disciplines (physics, chemistry, biology, materials science, computer science, etc.) and ‘nanotechnology’ has potential application in a range of different sectors (energy, transport, medicine, textiles, communications, etc). To add to this complexity, both present and potential future applications are commonly entangled in the same conversations. Present applications of ‘nano’ science and technology include things like transparent sunscreens, antibacterial kitchen utensils and stain resistant clothing. More far reaching future visions include the ability to construct absolutely anything through the precise placement of individual atoms; a scenario that thrills the optimists as much as it frightens the pessimists.

In the simplest sense, ‘nano’ comes from the Greek word for dwarf and refers to the scale length of one billionth (10^{-9}), e.g. one nanometre (nm) equals a billionth of a metre. Common popularisations to help imagine this size include: a nanometre is how much your fingernail grows in a second, or a sheet of paper is around 100 000 nm thick. Contestation begins when one tries to define the boundaries of what constitutes ‘the nanoscale’. For many people, the term ‘nanoscale’ refers to a range between 1 – 100 nm. However, both the beginning and the end of this range remain subject to ongoing debate. Some claim that it should extend as low as 0.1 nm (because atoms and some molecules are smaller than 1 nm) and as high as 300 nm (because the unique properties of the nanoscale can also be observed above 100 nm). The boundaries of ‘the nanoscale’ are highly significant in both scientific and political terms because they have the possibility to affect everything from funding, to risk assessment and product labelling. The high stakes involved here are an important reason why the definition of the nanoscale continues to be contested. As editors of this book, we use the term ‘nanoscale’ in a broad and inclusive sense, with a specific aim not to exclude relevant objects of study by referring to a particular range of numbers rather than to pertinent characteristics. Readers are, however, encouraged to keep the ongoing debate about the exact meaning and range of 'the nanoscale' in mind as they go on and read the various contributions in this book.

To capture and acknowledge the diversity that exists in the breadth of work occurring at the 'nanoscale', it is often referred to in the plural as either *nanosciences and nanotechnologies* or *nanoscale sciences and technologies*. In this book, you will find that the authors of different chapters use various terms. While we have encouraged them to explain their choices, as editors we have left this plurality because we feel it accurately represents the diversity that remains in the field. In the title of this book, as well as in the introductions, we have chosen to use the term 'nanoscale sciences and technologies' (nanoST). We do this so as to emphasise that the book deals with a range of different sciences and technologies and to not exclude any of the definitions and foci adopted by our authors.

The fact that 'nano' effectively only refers to a unit of measure is an important reason why a number of extremely different projects and products are collected under the label of nanoST. Just think about the diversity that a concept like 'metre' science and technology would include – all the science and technology that takes place in the size range of 1-100 metres! That would be a very diverse and broad field indeed. Given the incredible diversity in nanoST then, what is it that we are actually talking about? What is it that binds all of these different things together? The reason for talking about 'nano' sciences and technologies as something distinct and unique is that objects at the nanoscale may express different properties from those expressed by larger objects of the same material. Properties, such as colour, conductivity, reactivity and melting point, can all change at the nanoscale. A classic example of this is the way in which nano sized particles of gold appear red and are reactive rather than inert. This expression of novel properties is typically explained by both the presence of quantum effects at this scale (the peculiar phenomena of the subatomic level that are not adequately explained by classical physics), and the increase in surface area to volume ratio that occurs (when an object is divided into smaller pieces, the volume stays the same but more surfaces are created, which often enhances reactivity). Properties of larger objects are also related to nanoscale atomic configuration. For example, both graphite and diamond are made of carbon atoms, but these materials have very different physical properties because of the way in which the atoms are arranged (in sheet form for graphite and in a tetrahedral shape for diamond). One of the early areas of significant development in nanoST was the discovery of, and ability to fabricate, a different atomic structure for carbon, including soccer ball like shapes (fullerenes) and cylindrical tubes (carbon nanotubes). Carbon nanotubes are a 100 times stronger and six times lighter than steel, and can have very high conductivity. They are therefore a good example of the way in which restructuring atoms at the nanoscale can create materials with novel properties. In most definitions, it is the ability to employ, engage, and/or manipulate the novel properties of the nanoscale that is crucial for something to count as nanoST. This means that for many people, nanoST are seen as not just working on the nanoscale, but actively investigating and utilising the novel properties that are in effect there.

This book has a particular focus on *social perspectives* on nanoST. To explain what this means for us and why we think these types of perspectives are important, we will first take a step back and talk more generally about different visions of the relationship between science and society. Here we will indicate some of the ways in which different visions of the relationship between science and society have been dominant in public understandings and political orientations at different points in time, as well as indicate what visions we see rising to prominence around the time that nanoST are emerging. It is important to make clear that although we highlight historical shifts in dominant visions, we certainly do not wish to argue that only one vision has been active at any one time. We believe that different visions of the relationship between science and society very often co-exist (sometimes across different arenas) and tend to compete with each other for prominence and political support. Following our description of different visions of the relationship between science and society, we will discuss the emergence of the concept of 'ELSA research' (research on Ethical, Legal and Social Aspects of science and technology) and we present this as another key element in our story of the importance of social perspectives on nanoST. In our description of how this concept became prominent, we also sketch how our notion of ‘social perspectives’ both incorporates and expands that of ELSA.

While we have chosen to tell this particular story as a way to describe the context and broad framing of this edited collection, this story is of course informed by our own backgrounds and interests. It may therefore not be the same story that others would tell in an introduction to social perspectives on nanoST. As an introduction to this book, however, our version serves to provide an account of the framework within which we as editors have approached the topic.

2. Visions of the Relationship between Science and Society

That science has always interacted with society seems obvious, and yet, the two spheres are often conceptually separated. This separation is supported by powerful ideas of what science is and how society (particularly politics) should relate to it. According to a traditional view, science is seen as an activity that is objective and uninfluenced by beliefs, interests or biases. As a generator and provider of ‘objective facts’, science is seen as most efficient if largely left alone by society (and particularly politics) to pursue its course towards truth. Many scholars have, however, argued that this conceptual separation between science and society is no longer useful or applicable. Bruno Latour[1] is someone who has been particularly concerned with the conceptual separation between nature (the object of science) on one side and society (the object of politics) on the other. He suggests that this separation (that has been so efficient in bringing about our modern way of living), has now created problems that are not possible to classify as simply one or the other (i.e. as scientific or political). Latour argues that in order to approach these types of problems, we have to admit that ‘pure nature’ and ‘pure society’ never really existed, or in his words, that ‘we have never been modern’.

[1] Latour, B. (1993). *We Have Never Been Modern*. New York: Harvester Wheatsheaf.

We support the position that to overcome many of the social and environmental challenges society is faced with today, it is crucial to recognise the ways that science and society interact and co-create each other. To point to some of the historical shifts and theoretical work informing this position, we will now present a brief (and therefore inevitably rather superficial) overview of varying visions on the science/society relationship. In presenting this overview, we try to show why there is now a trend moving away from the dominance of a story that sees science and society as separate, independent spheres, to one where they are seen as entangled in a mutual process of co-production. We encourage those interested in more detailed descriptions of these visions to refer to the cited literature, as well as to the host of other works that can be found commenting on this topic.

2.1 Science: From a gentleman's activity to the way to win a war

Science,[2] in its early history (particularly in 18th and 19th century England), has been characterized as an activity predominantly carried out by 'gentlemen' – independent, wealthy men (or men supported by wealthy benefactors), who had the time and money available to engage in research activities. Science was therefore seen as a predominantly curiosity driven quest for knowledge undertaken by privileged individuals. Although some individuals engaged in early scientific research already saw its potential for application and social benefit,[3] they usually did not have the required resources and/or extensive theoretical grounding to see this social benefit realized (e.g. in the way that industry was later able to do with such incredible success). 'Technologies'

[2] We will not provide a precise definition of science here, as the definition itself will vary in the visions we are about to describe. In a very general sense, however, it can be thought of as referring to systematic processes of rational inquiry into the nature and behaviour of the physical world that result in knowledge capable of predictive explanation.

[3] For example Francis Bacon (1561-1626) was a particularly early example of someone who intellectually anticipated the application of science for social benefit while Isaac Newton (1643-1727) was a rare example of someone able to apply their scientific knowledge to technological development (e.g. in his telescope).

(interpreted broadly as tools) were certainly in use during this period. They were, however, primarily products of craftsmanship and tended to be used as instruments to help create scientific knowledge rather than being products created by it.

It is common in stories about the relationship between science and society to point to the importance of World War II (WWII) for creating a significant shift in the previously dominant vision. While the development of technologies based on scientific knowledge arguably occurred in fields such as chemistry and physics from at least the mid 19th century (e.g. in the development of dyes and electric power), this shift was given an enormous boost after WWII. During the war, science was actively mobilised by the nations involved to solve technical problems paramount in war (such as the development of superior weaponry, communications, medical treatment etc.) The active use of science and the development of science-based technologies in WWII are seen to have created a significant shift in the understanding of the relationship between science and society. This shift is often specifically linked to a series of letters exchanged between the US President Roosevelt, and the director of the US Office of Science and Development, Dr Vannevar Bush.

The key question posed by President Roosevelt to Dr Bush was: After science had been so successfully employed in advancing the war effort, how might it contribute to the betterment of society in times of peace? In other words, how could the government assist the advancement of science so that it might continue to offer benefits to society? Vannevar Bush's response was documented in a report entitled "Science – The Endless Frontier".[4] In this report, Bush recommended that the President invest in "basic scientific research", arguing that the generation of new knowledge was the crucial first step towards science-based technologies, and the subsequent social benefits that were assumed to follow. Basic research was described by Bush in this report as essential "scientific capital".

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[4] Bush, V. (1945). Science: The Endless Frontier http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm (last accessed 26.05.09).

The post WWII conception of the relationship between science and society is often referred to as "the linear model"[5] or as the "traditional social contract of science", where social contract refers to an unwritten set of mutual expectations. In this model, science and society (often understood as politics) are still perceived as distinct and separate spheres. There is, however, a unidirectional or linear exchange between these spheres: society puts money into science and science gives society the resulting knowledge and innovation. Between these stages of exchange, society allows science to conduct unhampered research, with the idea that the serendipitous nature of scientific investigation requires freedom from social/political control and constraints. It is important to emphasise that according to this model, science is seen as existing in two distinct forms: 'Academic Science', where public money is invested in basic research, and 'Industrial Science' where the 'scientific capital' of basic research is combined with the financial capital of industry and business to generate products and applications. According to this model, the primary role of politicians and the state is not to directly invest in the development of technological applications and innovations (seen as the preserve of industry and the market), but in the development of the necessary scientific capital for this, i.e. basic research. Importantly, within this concept of the science/society relationship, the scientific community is seen to have the responsibility, and ability, for self-regulation. This means that quality assurance and control over both the direction of investigation and the application of new knowledge can be largely left to the scientific community.

2.2 The paradoxes of modern science and technology

The dominance of this understanding of the science/society relationship in the post WWII years created a high level of public investment in basic scientific research and fed a hugely successful industrial application of science in new technologies. As human health, safety and personal

[5] Guston, D. (2000). *Between Politics and Science: Assuring the Integrity and Productivity of Research*, Cambridge University Press.

comfort have improved through this scientific and technological progress, however, it has been increasingly common to point out that as a society we now find ourselves facing a paradoxical situation: the same progress that we have benefitted so enormously from has also created new threats to both human health and safety, and to the environment. This paradox is closely linked with another: as the application of science-based technologies has generated new risks (e.g. those from pesticides, cars, heavy metal contamination etc.), humans remain reliant on what Ulrich Beck[6] calls the "sensory organs of science" to see, understand and control these risks. Within this situation, science becomes an important player within the political sphere - its expertise is sought to help inform decision-making, very often around remediation of the very problems that it has in part created!

The majority of the negative impacts generated by science-based technologies have of course been unexpected. Spectacular examples of this (such as ozone holes and climate change) have led to not only an increasing awareness of the potential for new technologies to have unintended negative consequences, but also of the limitations of science's ability to predict all potential impacts. In other words, there is now a greater sensitivity to the limitations of scientific knowledge and the way in which these limitations constrain the ability to understand and predict what will happen when new technologies are introduced into complex, interacting, and evolving social and biological systems.

Due to increasing awareness of these paradoxes, it is now becoming common to suggest that while science remains an important informant for political decision-making, the level of confidence in scientific expertise has been eroding among the public (particularly in certain sectors such as food and nations such as the UK). One therefore sees the story of the relationship between science and society shifting. This is particularly occurring through the development of an enhanced academic critique of the position and power of science in political decision-making.

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[6] Beck, U. (1992). *Risk Society: Towards a New Modernity*, London: SAGE.

In the early 1990s, Silvio Funtowicz and Jerome Ravetz[7] put forward the argument that different circumstances require different types of relationships between science and policy. In what is often referred to as the theory "post-normal science"[8] (PNS), they differentiated three types of science /society relationships based on the 'level of uncertainty' and the 'decision stakes' involved. Through this, they created a useful way of thinking about different roles that science can play in political decision-making, and particularly, the circumstances that may warrant broader involvement in judgments of its quality. Their approach specifically challenges the view of the traditional social contract, where quality control of science was always seen as best managed within the scientific community without involvement from society in the form of either politicians or citizens.

Funtowicz and Ravetz argue that when uncertainty and decision stakes are low,[9] the form of science Rayner[10] terms 'consensual science' is appropriate. The quality of this science is seen as aptly managed by traditional peer review processes. When decision stakes and uncertainties increase to a medium level,[11] however, the mode of scientific problem solving becomes more like professional consultancy. In this situation, different individuals can make different judgements on the appropriate scientific methods and the recipient of the scientific advice therefore becomes an important contributor in the evaluation of quality. Finally, when decision stakes and uncertainties are high,[12] Funtowicz and Ravetz

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[7] Funtowicz, S. O. and Ravetz, J. R. (1993). Science for the post-normal age, *Futures* 25, pp. 739-755. Funtowicz, S. and Ravetz, J. R. (1994). Uncertainty, complexity and post-normal science, *Env. Tox. and Chem*, 13, pp. 1881-1885.

[8] The term post-normal draws on the term 'normal science' famously coined by the philosopher of science Thomas Kuhn, who described science as a type of puzzle solving that occurred through steady advance but which was punctuated by conceptual revolutions or paradigm shifts.

[9] *Low* here refers to a situation where uncertainty is largely technical and the research is 'mission oriented' with a straightforward end use.

[10] Ravner, S. (1992). Cultural Theory and Risk Analysis. *Social Theories of Risk*. S. Krimsky and D. Golding (eds). Westport, Praeger: 83-115.

[11] *Medium* refers to a situation where uncertainty is methodological and includes questions about the reliability of particular theories/research approaches, and research has become 'client serving' rather than mission oriented.

[12] *High* refers to situations where uncertainties are of an epistemological or an ethical variety and the research is 'issue driven' and involves conflicting values and purposes.

argued that a new type of science for policy is required, a post-normal science. In this situation, quality assurance requires extension to a broader community (involving a wide range of stakeholders, including interested citizens) into what the two scholars call "extended peer review". Given the enormous potential and impact envisaged for nanoST, this field can certainly be seen to have high decision stakes. NanoST also arguably involve a high level of uncertainty relating not only to how to characterise, detect and measure nanoscale particles, their toxicological behaviour, and the levels and routes of potential exposures, but also related to social and ethical questions around the manipulation of matter on this scale. For nanoST, it can therefore be argued that it is meaningful to apply the model of PNS, which implies that any interaction between science and policy should be exposed to a process of extended peer review.

Other scholars have also advocated a shift away from the linear model as a way to understand and structure the science/society relationship, but have done so by arguing that the process or 'mode' of knowledge production itself has shifted. Where before it may be argued that there was a clear sense of distinction between 'Academic Science' and 'Industrial Science' (or between basic and applied science, science and technology), there is now said to be a range of more hybrid forms. Now, for example, governments fund applied research, university researchers seek industry funding, industry conducts basic research, basic knowledge is generated through technology creation, technology creation proceeds without the fundamental science being fully understood, and so on. Given the description of nanoST we have provided, one can certainly imagine how drawing a clear line between academic and industrial research, or basic science and applied technology is difficult in this case. The shift into more hybrid forms of knowledge production has been referred to by John Ziman as 'post-academic science'[13] and by Michael Gibbons *et al.*[14] as 'mode 2' science. Whether this represents a shift in

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[13] Ziman, J. (1998). Why must scientists become more ethically sensitive than they used to be? *Science*, 282: pp.1813-1814.
[14] Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. and Trow, M. (1994). The New Production of Knowledge: *The Dynamics of Science and Research in Contemporary Societies*. London: SAGE.

actual relations and practices or just a shift in dominant stories about relations and practices remains open to debate, as does the extent to which the hybridity of a 'mode 2' style science is a normative proposal or a descriptive account.

2.3 Towards scientific quality as social robustness

For Gibbons and colleagues, one important element in their vision of the relationship between science and society is the way in which public funding agencies have shifted from institutions primarily responsible for maintaining basic research at universities, to instruments for attaining national social and economic goals. The linear model suggests that funding basic research will always, in the end, lead to societal benefits. In a mode 2 model, however, researchers are asked to explicitly justify their projects in terms of their usefulness for society to achieve funding. This situation creates pressure for research to orient itself towards 'realworld' practical problems and economic growth creation, rather than to curiosity driven conundrums as in the previously dominant vision (even if this may sometimes only be manifest in applications for funding rather than in actual research work). From the point of view of public funding, this shift could be seen as driven by a realization of just how large an impact science and technology have on the social and biological world. As the mentioned paradoxes of science and technology become more apparent, society has arguably begun to increasingly demand opportunities to 'speak back' to science, to request specific types of knowledge and applications, and particularly, to request help in solving pressing practical problems.

In this situation, where science and society are seen as closely intertwined, ethics has received more attention in the narratives. While the vision of industrial science, with its intention to generate and release products into society, could be seen as always having had a direct connection to ethical questions (e.g. is this right/good/desirable?), basic academic research was traditionally considered largely free from entanglement in social and ethical dilemmas (except perhaps those around how research is carried out). As long as basic research was seen as a process of uncovering truth, it did not have to deal with social and ethical questions to the same extent, because truth was seen by definition as desirable and good. According to the understanding of 'mode 2' or 'post-academic' styles of knowledge production, however, where boundaries between basic and applied research are blurred and science is seen as a tool to be directed towards social priorities, the position of a science free from social, ethical and political scrutiny, critique and curtailment, disappears.

What appears then is a corresponding shift in the notion of what constitutes 'good' science. While 'good' science was seen as that which revealed truth; this has gradually shifted to that of 'good' science as reliable knowledge – knowledge that works and can be used and applied with success. Now, according to Gibbons and colleagues, however, one starts to see 'good' science as 'socially robust' knowledge - that which society wants, accepts, and deems valuable. This is not to suggest that truth becomes what society wants, accepts and deems valuable, but rather that social criteria for deciding the types of questions, problems and products publicly funded science should be occupied with, is given enhanced importance.

The concept of 'socially robust' science essentially implies a new social contract between science and society where the expectations on science take a new form. According to this model, knowledge generation should be more transparent and participatory. The public needs to be more informed about how science works and what research is under development, as well as have a say in how public money is spent. Furthermore, science should be more ethically sensitive and reflective about both its role in society and its potential implications, recognizing that some of these will be unanticipated and possibly negative. The new social contract also entails that one should be prepared to accept the inclusion of voices other than those of scientific experts in political decision-making, specifically acknowledging that the more experiential knowledge of other stakeholders and laypeople can also count as a form of expertise in certain circumstances. In many ways, the 'post-normal science' concept advocates similar changes to that of 'socially robust science'. Both concepts make the case for a new form of science that is more sensitive to its role in society and its ethical dimensions, more reflexive about its potential impacts and limitations, more prepared to engage in direct interactions with members of society and more open to broader notions of what constitutes quality.

Currently the situation is that a range of these different visions of the relationship between science and society can be seen to co-exist and compete in different spheres. However, over the last decade or so (and certainly since controversies such as those around genetically modified organisms and mad cow disease), there has arguably been a general tendency to request a more socially embedded and ethically sensitive science. It is within this context, in which a new social contract vision of the relationship between science and society has gained increasing currency and political support, that nanoST have entered the scene. From the very beginning of their becoming a political priority in most countries, nanoST have had to relate to visions of a new social contract for science. In many ways, nanoST are presented as one of the first 'new' fields of science that is being actively advanced through a 'mode 2' style of knowledge production, being asked to develop in a socially robust way, and being recognized at an early stage as involving both high levels of uncertainty and high decision stakes. This context is seeing social perspectives on nanoST become not only a widespread subject of research, but also a factor of increasing political importance. The relevance of research on social dimensions of nanoST is in line with, and supported by, a commitment to fund ELSA (Ethical, Legal and Social Aspects) research on emerging fields of science and technology.

3. ELSA: Research on Ethical, Legal and Social Aspects

The concept of ELSA[15] research as a field in its own right was brought into being with the human genome project (HGP). When the HGP was launched in 1990, a dedicated program specifically for research on ethical, legal and social aspects (ELSA) was created as an integral part of the project. Thereafter, ELSA research received 3-5% of the annual HGP budget. Since the development of this program, the inclusion of funding for ELSA research has developed into something of a norm for large-

[15] While the term ELSA has been that widely adopted in Europe, in the USA this field of research is often referred to as ELSI (Ethical, Legal, and Social Implications/Issues).

scale science and technology research projects, particularly those that are given national priority status and those considered to be pushing boundaries at the 'frontier' of knowledge.

ELSA forms of research became particularly prominent around the development of biotechnology in both medicine and agriculture; a field that has been both highly promising and subject to widespread social critique and concern. As politicians struggled with decision-making on biotechnology development, they began to increasingly seek out, fund and employ research looking into social, ethical and legal aspects. For cynics, this type of research might be seen as being supported simply to facilitate the smooth introduction of products into the consumer market. For others, however, this support represents a genuine recognition that broader issues and concerns (often initially raised in debates in the public sphere) are important and require careful research and political attention. There is now also an increasing tendency to see support for ELSA research as based on a belief in its ability to help steer new fields of science and technology in a socially robust direction; both directly through altering technology trajectories and more indirectly through working to enhance the reflexivity and ethical sensitivity of the scientists involved.

While ELSA research rose to prominence around biotechnology, it was argued that the research in this case often came too late and with too little influence on political and scientific processes. In other words, that it came when most of the important decisions were already taken and scientific and technological trajectories had already been set (for example through extensive financial investment and product development). When nanoST emerged as a political and economic priority at the beginning of the new millennium, there was therefore a sense in which this represented an opportunity for ELSA research to 'get it right'. It now had the chance to be initiated early in innovation processes and incorporated into both scientific processes and political institutions 'upstream' before important decisions had been taken. For nanoST, there has been a remarkable emphasis on the importance of early attention to ethical and social aspects (e.g. in important policy documents such as the US NSF (2001) and in the UK RS/RAE (2004)) .[16] Substantial funding has therefore been allocated to ELSA research on nanoST and ELSA researchers have become increasingly involved in important political initiatives as well as in a range of 'experimental' collaborative efforts with nanoST researchers

When we reviewed the field of ELSA and related research on nanoST in 2006,[17] we found a collection of highly self-reflective scholars, struggling to take advantage of their new opportunities and the heavy weight of the chance to 'get it right' this time. As described above, with nanoST, ELSA has in some ways gone from being a strand of research that has been in opposition to/functioned as a critical voice within the research establishment, to one that is now invited and included (and to some extent institutionalised) in various scientific and political arenas. This new situation is also something that ELSA researchers are struggling to come to terms with: How to seize the opportunities that are being offered, without losing their critical distance and potential?

In this book we document some of these struggles through showcasing some of the diverse research taking place on ethical, legal and social aspects of nanoST. However, we also try and stretch the concept of ELSA so as to capture broader social commentary taking place on nanoST. ELSA research has often been dominated by social science approaches and we wish to extend the notion of social perspectives to include more humanities based perspectives but also to specifically include perspectives being expressed on social, ethical and legal aspects from outside academia. With this in mind, we would now like to outline the book's overall structure, style, motivation and goals.

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[16] Roco, M. and Bainbridge, W. (eds). (2001). *Societal Implications of Nanoscience and Nanotechnology*. Final Report from the Workshop held at the National Science Foundation in Sept. 28-29, 2000. Arlington, VA: NSF. .http://www.wtec.org/loyola/nano/NSET.Societal.Implications/nanosi.pdf (last accessed 26.05.09). Royal Society & The Royal Academy of Engineering (RS/RAE). (2004). *Nanoscience and nanotechnologies: Opportunities and uncertainties*, London: Royal Society http://www.nanotec.org.uk/finalReport.htm (last accessed 26.05.09).

[17] Kjølberg, K. and Wickson, F. (2007). Social and Ethical Interactions with Nanotechnology: Mapping the early literature, *NanoEthics* 1, pp. 89-104.

4. Nano meets Macro: Social Perspectives on Nanoscale Sciences and Technologies

4.1 What do we mean by 'social perspectives'?

In ELSA research, 'the social' appears as just one of three perspectives, in addition to 'the ethical' and 'the legal'. It may therefore be natural to assume that this book is limited to a certain selection of what takes place under the label of ELSA research. We, however, think exactly the opposite and use the term 'social perspectives' in a broad way to include all research offering commentary on interactions between science and society. For us, 'social perspectives on nanoST' *includes* ethical and legal perspectives, as well as historical, anthropological, sociological, philosophical, etc - in other words, work from any discipline that relates to and explores interactions between nanoST and society.

Interesting and relevant commentary on nanoST in a social context does, however, also take place outside scientific institutions, research organisations and universities. In our broad understanding of 'social perspectives', we also include non-academic perspectives. This is demonstrated through the inclusion in this book of science fiction stories, poetry and visual artworks. These contributions should be seen as perspectives that engage many of the same questions and issues that are raised through the academic chapters. However, perhaps some readers find that they can engage with these contributions in a different way, or that these contributions provoke alternative responses and reflections. We think that this is what makes them particularly valuable and relevant for inclusion in a book dealing with nanoST in a social context. Other forms of social commentary on nanoST (e.g. those expressed in the media, policy and industry) as well as other forms of artistic contributions (such as movies and music), would also potentially represent relevant examples of social perspectives on nanoST for us, although they are not as easy to include in an anthology.

4.2 Outline of the book

The rich diversity of social perspectives is partly brought about by the way in which traditional disciplinary boundaries are often crossed in research on nanoST in a social context. To show the value of the way the field asks cross-disciplinary questions, we found it best to avoid using terms traditionally associated with particular disciplines when describing its overall shape. In our own efforts to understand and conceptually organise the richness and diversity in social perspectives on nanoST, we therefore began to view the different individual efforts as relating to a select number of overarching themes and interests.[18] In this book we call these themes or attractors of interest: 'nodes', in the sense that they form centering points of component parts, and link together otherwise quite different perspectives and commentaries. While it has been fruitful for the purpose of this book to not think within disciplinary boundaries, we should be clear that we are not at all questioning the value of traditional disciplinary research. Rather, we are seeking to show how people from different disciplines can meaningfully approach a shared topic of interest from very different perspectives. In this book we conceptualize and present social perspectives on nanoST as clustered around four different nodes of interest in the interface between science and society. These nodes are described as the places where *Nano meets Macro*: *In the Making; In the Public Eye; In the Big Questions;* and *In the Tough Decisions*. The idea and content of these nodes developed in our thinking through a process of mapping the themes, issues and questions people are interested in when they study nanoST in a social context. The table below shows the type of questions and topics we have identified, and how they have crystallized into our four nodes.

This book is organized into four sections, each presenting a range of academic and artistic works that can be seen as relating to a particular node. We have not aimed to give a comprehensive account of the various perspectives possible on each of the nodes. Our aim has rather been to showcase some of the existing diversity, and to hopefully provide a

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[18] Kjølberg, K. and Wickson, F. (2007). Social and ethical interactions with nanotechnology: Mapping the early literature, *NanoEthics* 1, pp. 89-104.

useful conceptual structure for understanding the shape and dimensions of the field as a whole.

As indicated in the table below, the first node and section links together interests somehow related to social perspectives on nanoST *In the Making*. These perspectives are interested in the process of creating nanoST and/or the history of their development; in other words, concerned with how nanoST are made or brought into being. The second node links together different perspectives and research interests related to nanoST *In the Public Eye*. Here we find a particular interest in how nanoST is represented, understood and perceived in the public sphere. Thirdly, there is the node that attracts those interested *In the Big Questions*. These are those deep questions, about how we do/should relate to technology, nature and each other and specifically how nanoST developments, concepts and visions engage with these (or in Douglas Adams' words, the big questions about 'life, the universe and everything'). The last node is the one that deals with nanoST *In the Tough Decisions*. Here we find perspectives on the politics and governance of nanoST and debate about how these processes of decision-making and control may best be approached.

CENTRAL CONCEPTS:	**INTERESTED IN nanoST AS:**	**FIELD OF CONCERN:**	**NANO MEETS MACRO:**
Laboratory practice, historical context, driving forces, instrumentation, images, cross-disciplinarity, scientific education…	A (new) field of research and development that spans various scientific disciplines	How nanoST are constructed and developed through scientific practices and social policies	***In the Making***
Perceptions and opinions, rhetoric, metaphors, hype, fear, visions, science fiction, media representations…	A development represented in a range of mediums and understood differently by various members of society	How nanoST are understood, presented, talked about and represented in the public sphere	***In the Public Eye***
Personhood, human/machine relations, human/nature relations, the natural vs the artificial, morality, ethical norms…	A complex phenomenon raising or engaging fundamental philosophical questions	How nanoST interact with questions of metaphysics, epistemology and ethics	***In the Big Questions***
Institutions, expertise, risk, uncertainty, public participation, engagement, responsibility, power, values, decision-making, trust, law…	A political/decision-making problem requiring new approaches to governance, regulation and decision-making	How nanoST are approached in the processes and institutions for decision-making, regulation and governance	***In the Tough Decisions***

To complicate this lovely clean picture just a little, it needs to be said that not all social perspectives on nanoST deal with issues and questions from just one node. Although we find it conceptually useful to separate the work into these four nodes, there are certainly instances where perspectives are given on topics of interest across them. We view this cross-nodal work as extremely valuable. For example, in addressing the question of how to achieve socially robust nanoST, it may be necessary to think about how nanoST is represented 'in the Public Eye', how it relates to 'the Big Questions' as well as how to approach 'the Tough Decisions'. For us, this does not diminish the value of the concept of the different nodes, it simply highlights the way in which all models are necessary simplifications of a complex and intertwined reality. The value of the concept of different nodes around which social perspectives on nanoST cluster, is that it helps us see higher level themes and issues of interest and how these can be approached by people from different backgrounds and from different perspectives. The contributions in this book are organised according to the node that we see them as primarily concerned with. However, some of the occasions where we see engagement with questions of interest across nodes will be highlighted in the section introductions. The introductions to each of the four sections will also provide more detail on both the node of attraction and on the content of the different academic and non-academic contributions presented within them.

4.3 Book style

The style of this book reflects our motivation to try to provide an approach to understanding and structuring the richness and diversity seen in social perspectives on nanoST. We have specifically attempted to design the book so that it may be used as a tool for interdisciplinary discussion and specifically asked all our authors to keep this in mind when writing their contributions. In our own experiences with trying to teach social perspectives on nanoST in a number of different settings, we have struggled to find texts that could be used as a starting point for discussion, primarily because they are so often written in dense disciplinary language. While the chapters in this book could be seen to have overcome the many challenges in addressing a multidisciplinary audience with varying degrees of success, we hope that at least the range of different perspectives offered and the way they have been positioned around common themes or nodes may help with the task of cross-disciplinary communication. Certainly our use of the concept of different nodes was an attempt to conceptually organise the field in a way that makes its richness apparent and accessible to people working outside it. Additionally, we have included suggested "Questions for Reflection" at the end of each contribution, in the hope that this may also facilitate interdisciplinary teaching and learning. In the situation that nanoST finds itself in, where actors from all sides are calling for enhanced interdisciplinarity (both between the natural sciences and between the natural and social sciences), there is a growing need to develop tools and skills for interdisciplinary communication and understanding. Our hope is that this book may help stimulate reflection and communication between people from different backgrounds and with varying entry points to their interest in nanoST. We therefore hope that our approach to this book has resulted in an interesting and enjoyable read for people interested in nanoST from the social sciences, the natural sciences and beyond!