

# NANOTECHNOLOGY

RISK, ETHICS AND LAW

EDITED BY  
GEOFFREY HUNT & MICHAEL MEHTA

# Nanotechnology Risk, Ethics and Law

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*Edited by*  
Geoffrey Hunt  
and  
Michael D. Mehta



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**John Balbus** MD MPH directs the Health programme at the non-profit Environmental Defense in Washington DC. Prior to joining Environmental Defense in 2002, he spent seven years at George Washington University, where he was founding director of the Center for Risk Science and Public Health and served as acting chairman of the Department of Environmental and Occupational Health. Dr Balbus' background combines training and experience in clinical medicine with expertise in epidemiology, toxicology and risk sciences; he is Board-certified in both internal medicine and in occupational and environmental medicine. He currently serves as a member of the US National Academy of Sciences Board on Environmental Studies and Toxicology; the US Environmental Protection Agency (EPA) Children's Health Protection Advisory Committee; and the US National Academy of Sciences panel on 'Applications of Toxicogenomic Technologies to Predictive Toxicology'.

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**Anna Carr** is an inter-disciplinary scholar whose research interests lie in the relationship between local places, knowledge practices and scientific truth claims. Her intellectual agenda is to increase community engagement with (professional) environmental science. She is currently based in Sydney, Australia working for the Department of Infrastructure, Planning and Natural Resources and holds a visiting fellowship at the University of Surrey, UK.

**Timothy Caulfield** is a professor in the Faculty of Law and the Faculty of Medicine and Dentistry, and is the research director of the Health Law Institute at the University of Alberta. In 2002, he received a Canada research chair in Health Law and Policy. His research has focused on two general areas: (1) genetics, ethics and the law and (2) the legal implications of health care reform in Canada.

**Roland Clift** CBE FREng FICChemE HonFCIWEM is distinguished professor of Environmental Technology and founding director of the Centre for Environmental Strategy, University of Surrey, UK. He is a member of the Royal Commission on Environmental Pollution, of the International Expert Group on application of Life Cycle Assessment to waste management, and has been awarded the Sir Frank Whittle medal by the Royal Academy of Engineering for his leading role in developing the holistic life cycle assessment of products. He was a member of the 2004 Working Group on Nanotechnology of the Royal Society and Royal Academy of Engineering.

**Richard Denison** PhD is a senior scientist at Environmental Defense in Washington DC. Prior to joining Environmental Defense in 1987, he served as analyst and assistant project director for the US Office of Technology Assessment. He specializes in nanotechnology and chemical hazard assessment, and serves on the National Pollution Prevention and Toxics Advisory Committee to the US EPA and is on the Steering Group for Nanotechnology of the Organisation for Economic Co-operation and Development (OECD).

**K. Eric Drexler** presented the basic concepts of molecular manufacturing in a scientific article (*Proceedings of the National Academy of Sciences*, 1981), and wrote *Engines of Creation* (1986) to introduce a broad audience to the prospect of advanced nanotechnologies, and *Nanosystems* (AAP, 1992, Most Outstanding Computer Science Book) to provide a graduate-level introduction to the field. His research in nanotechnology ranges from computational modelling of molecular machines to engineering analysis of molecular manufacturing systems and their potential products. In support of US federal policy development, he has provided presentations and briefings to (among others) the Senate Subcommittee on Science, Technology and Space; the White House Office of Science and Technology Policy; and the vice chairman of the Joint Chiefs of

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**Karen Florini** JD is a senior attorney at Environmental Defense in Washington DC. She focuses on nanotechnology, toxic chemicals, antibiotic resistance and other environmental health issues, and has participated in numerous federal advisory committees on topics such as lead poisoning, hazardous waste management and children's environmental health.

**Linda Goldenberg** is completing her PhD at the University of Calgary, Faculty of Communication and Culture, where she is applying her expertise in science, nanotechnology and ethics to the area of national security, critical infrastructure protection and emergency management. Her current research focus is intelligent technologies, such as public warning systems, in the national security context. Linda's expertise includes research in broadband technology, scientific imaging and complex systems analysis. She is a contributor to the recent US National Science Foundation report 'Nanotechnology: Societal Implications – Maximizing Benefits for Humanity'.

**Alan Hannah** is a solicitor advocate and is an employment law partner in Brachers solicitors, Maidstone and London. Additionally he used to practise in the field of medical negligence and was a member of the Maidstone Health Authority Ethics Committee for many years. He is currently a member of the Ethics Committee of the British Association of Paediatric Surgeons. He is a former part-time Employment Tribunal chairman. His work now includes corporate advice and general strategy in employment related business matters. He advises and acts for a number of NHS Trusts and commercial concerns. Alan retains an interest in the law relating to liability for tortious acts and omissions.



**C. Vyvyan Howard** MB ChB PhD FRCPath is a medically qualified toxicopathologist who has specialized in low dose developmental toxicology. He is currently professor of bioimaging at the University of Ulster, Northern Ireland and editor in chief of *Nanotoxicology*, a new peer reviewed journal in the field of nanotechnology. He is a past president of the Royal Microscopical Society and has served on two European Union (EU) expert groups addressing the toxicity of nanoparticles. He co-edited the book *Particulate Matter: Properties and Effects Upon Health*, Springer-Verlag Telos, 1999.

**Geoffrey Hunt** BSc(Hons) MLitt PhD is full professor of ethics and global policies at the University of Surrey (European Institute of Health and Medical Sciences), and a member of the university's Nanotechnology Forum. As an ethics specialist he has published books and papers on public accountability, professional and healthcare ethics, and public interest disclosure. He has been a consultant to various professional bodies. As a philosopher he has published in philosophy of medicine and healthcare, and political philosophy. He lectured in Africa for 12 years, and in 2001 he was British Visiting Professor in healthcare ethics at the Medical School of Kagawa University, Japan. He has lectured on 'nanotechnology and society' in several universities and research institutes in Japan and the UK. He is the founder of the public accountability non-governmental organization (NGO) 'Freedom to Care'.

**Decemba S. K. Ikah** MB BS is in the Developmental Toxicology-Pathology Group, Department of Human Anatomy and Cell Biology, University of Liverpool, UK. Dr Ikah trained in medicine in Nigeria. Currently he is researching the toxicology of nano-particles at the University of Liverpool. He is specializing, in particular, in the effects of particle size and surface chemistry on the developing nervous system.

**Karan V. I. S. Kaler**, professor of electrical and computer engineering at the University of Calgary, has more than 70 refereed publications and 3 patents. He is the director of the BioMEMS and the Bioelectronics Laboratories at the University of Calgary. He developed the first automated instrument capable of non-invasive interrogation and quantification of the electrical properties of individual cells and the first micromachined dielectrophoresis filter for the separation of viable from non-viable mammalian cells in commercial scale bioreactors.

**Kristen Kulinowski** is a faculty fellow in the Department of Chemistry and executive director for education and public policy of the Center for Biological and Environmental Nanotechnology at Rice University in Houston, Texas. Her research interests include policy of emerging technologies and science education.

**Matsuda Masami** is a professor in the Graduate division of the Faculty of Nursing, University of Shizuoka, Japan. His interests are in health care

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**Michael Mehta** is professor of sociology and chair, Sociology of Biotechnology Program, University of Saskatchewan, Canada. He specializes in science, technology and society. Interests include risk perception and communication on biotechnology, nuclear safety, blood safety, endocrine modulators and nanotechnology. His academic background includes a BA in psychology, a Masters in environmental studies, a PhD in sociology and post-doctoral training in policy studies. He has held academic appointments at York University (Faculty of Environmental Studies) and Queen's University (School of Policy Studies and School of Environmental Studies), and has taught graduate and undergraduate students for more than 15 years. He is a co-founder of the Environmental Studies Association of Canada (ESAC).

**Kirsty Mills** received her BSc in electrical engineering in 1974, and her PhD in 1979, both from the University of Nottingham in the UK. She developed III–V devices and integrated circuits at Plessey Research (UK) from 1979 to 1980, Thomson CSF (France) from 1980 to 1986 and General Electric (Syracuse) from 1986 to 1991. A professor in the Electrical and Computer Engineering Department at the University of New Mexico, she is professor and the associate director of the Center for High Technology Materials. In response to the increasing need for interdisciplinary function, she initiated and leads the University of New Mexico's 'Science and Society Dialogue' project, embraced by a wide range of university departments, schools and institutes. As well as teaching engineering ethics, Dr Mills offers seminars and workshops to a range of stakeholder groups.

**Obayashi Masayuki** is professor of bioethics, Kyoto Institute of Technology, Japan. His specialty is history and philosophy of science, especially history and methodology of molecular biology. He has taught bioethics and Science, Technology and Society (STS) at some universities and medical schools. He is now interested in ethical problems of genetics and the professional ethics of physicians, scientists and engineers.

**Linda M. Pilarski**, professor of oncology at the University of Alberta and senior scientist of the Alberta Cancer Board, has more than 150 articles and 3 patents. Her research focuses on blood cancers, molecular biology and cancer profiling on microfluidics platforms. She is on the board of the Microsystems Technology Research Institute and on the scientific advisory boards for the Multiple Myeloma Research Foundation (US), the International

Myeloma Foundation (US) and the Research Fund for macroglobulinaemia Waldenstrom's (US).

**Árpád Pusztai** MSc PhD FRSE is a consultant to the Norwegian Institute of Gene Ecology (GenOk), Tromsø, Norway; formerly Rowett Research Institute, Aberdeen, UK. He was born in Budapest (Hungary) in 1930 and qualified in Chemistry. He received his PhD in biochemistry and physiology from the University of London; did postdoctoral studies at the Lister Institute of Preventive Medicine in London, and then joined the protein chemistry department at the Rowett Research Institute, Aberdeen, Scotland in 1963. He worked at the Rowett until his 'official' retirement as a senior scientist in 1990. From 1990 to end of 1998 he was engaged in research as a senior research fellow of the Rowett at the request of the Institute's director and coordinated six major research programmes, and several national and European research programmes until, as a result of his disclosures on our GM-potato work, his contract was prematurely terminated and not renewed for 1999. From 2001 he has been collaborating in a Norwegian Research Council-funded GM food research programme at the Norwegian Institute of Gene Ecology, University of Tromsø.

**Lori Sheremeta** is a lawyer and research associate at the Health Law Institute at the Faculty of Law at the University of Alberta, and is cross-appointed to the National Institute for Nanotechnology. Lori's academic interests focus on the legal, ethical and social issues implicated in new technologies including genetics, genomics, regenerative medicine and nanotechnology. She is particularly interested in the commercialization of research, the translation of research findings to society and the role of intellectual property in this process. Lori is a member of the Genome Prairie GE<sup>3</sup>LS research team, the Stem Cell Network, the Advanced Food and Materials Network and the Canadian Biotechnology Secretariat International Public Opinion Research Team. She has written numerous scoping papers for various federal government departments and agencies, including Health Canada (intellectual property, nanotechnology), the Canadian Biotechnology Advisory Committee (biobanking), the Inter-agency Panel on Research Ethics (nanotechnology and human subject research) and Genome Canada (Canada's GE<sup>3</sup>LS research capacity). Through the Office of the National Science Advisor, Lori was recently appointed to a Canadian Expert Panel on nanotechnology.

**Siva Vaidhyanathan** is a cultural historian and media scholar, is the author of *Copyrights and Copywrongs: The Rise of Intellectual Property and How it Threatens Creativity* (New York University Press, 2001) and *The Anarchist in the Library* (Basic Books, 2004). Vaidhyanathan has written for many periodicals, including *The Chronicle of Higher Education*, *The New York Times Magazine*, MSNBC.COM, Salon.com, openDemocracy.net, and *The Nation*. After five years as a professional journalist, Siva earned a PhD in American Studies from the University of Texas at Austin. He has taught at

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**Scott Walsh** MBA is a project manager at Environmental Defense in Washington, DC. He manages partnerships with leading companies to create environmental improvements that make business sense, and is currently leading corporate partnership efforts to ensure the safe development of nanotechnology. He is also participating in projects addressing sustainable seafood, antibiotic resistance and vehicle-fleet management. Prior to joining Environmental Defense, he served as a business strategy consultant with Boston Consulting Group and as an environmental policy consultant with Jellinek, Schwartz and Connolly.

**Celia Wells** is professor and deputy head of the Law School, Cardiff University. She is involved in the university's Economic and Social Research Council Centre for Business Relationships, Accountability, Sustainability and Society. Her research is mainly in criminal law and corporate criminal liability. She is author of *Corporations and Criminal Responsibility* (2nd edition OUP, 2001) and *Reconstructing Criminal Law* (with Nicola Lacey and Oliver Quick, 3rd edition, Cambridge University Press, 2003). Recent work includes 'The Impact of Feminist Thinking on Criminal Law' (2004 *Criminal Law Review*) and an essay on corporate complicity in human rights violations in Alston (ed) *Non State Actors in International Law* (OUP, 2005).

# Preface and Acknowledgements

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Until very recently most people associated nanotechnology with science fiction-based accounts that tended to focus on fantastical devices and applications. With recent developments in nanoscience (for example greater control over atomic structure due in part to the atomic force microscope), nanotechnology has entered the commercial realm, and has simultaneously begun the journey of finding its space within the social imaginary. This book represents a leg of this journey. By exploring the risks and benefits of nano-derived processes and products, *Nanotechnology: Risk, Ethics and Law* considers the shifting social space that this technology currently occupies. By examining how nanotechnology has been introduced to a range of actors, this book explores how different governments in Europe, Japan, the US and Canada have responded to the nanotechnology revolution. Additionally, this book considers how experience with other technologies (for example biotechnology) may influence how the general public, non-governmental organizations, scientists, regulators and legal communities around the world are likely to frame nanotechnology. Lastly, this book provides readers with a unique opportunity to think about the ethical and conceptual issues raised by the introduction and dissemination of this nanotechnology. In short, it provides a platform for readers to conceptualize the multifaceted impacts of nanotechnology by pointing out several of the gaps in our collective understanding of how this transformative technology is shaping the topography of the 21st century.

Geoffrey Hunt first developed an interest in nanotechnology in late 2002 when planning a visit to Japan to discuss the ethical implications of technological futures, and he put forward a tentative overview of nanotechnological possibilities in a presentation at the Seizon Institute, Tokyo in 2003. Hunt reciprocated with an invitation to Japanese colleagues and others the following year to a small international workshop that he organized on the subject at St Mary's College (a college of the University of Surrey), in Twickenham, UK. It was on that occasion in April 2004 that Hunt and Mehta first met, and they formed the idea of this collection while taking a break along the river Thames at Teddington Lock. Dr Arthur Naylor, Principal of St Mary's was most generous in his support for this workshop. Rev. Michael Hayes and Dr David Jones of the college are to be warmly thanked for possessing the boldness and curiosity to support what at the time might have seemed to

many others a rather peculiar and unlikely interest. The Wellcome Trust made the meeting financially possible, and we are deeply thankful for that. Taking what we thought might be the risk of a multidisciplinary Tower of Babel we were not only relieved but heartened by the efforts that contributors made to understand each other's disciplinary perspectives on and questions about a new field.

At the Twickenham meeting we were fortunate to have contributions from Professor John Joe McFadden (cell biology), Professor John Hay (chemistry), Dr Michael Hughes (biomechanics), and Dr Anna Carr (psychology), all from the University of Surrey. Professor Matsuda Masami (public health), Professor Morishita Naoki (philosophy) and Professor Obayashi Masayuki (history of science) provided insights from Japanese technological, public health and cultural perspectives. Other contributors were Professor Richard Strohman (molecular biology), Dr Árpád Pusztai (gut biology), Mr Alan Hannah (legal practice), Dr Harold Hillman (cell biology), Dr Susan Bardocz (biology), Mr Roger Higman (environmental protection), Hunt (philosophy) and Mehta (sociology), and there were theological and ethical perspectives from Rev. Hayes and Dr Jones. Although only some of the original workshop participants appear in this volume all of them provided novel ideas and insights.

Thanks to a travel grant from the Daiwa Anglo-Japanese Foundation, Hunt had visited Japan in October 2004 and spoke on the subject at the Kyoto Institute of Technology, at Tokyo University and at the National Institute of Advanced Industrial Science and Technology (AIST), in the Ministry of Economy, Trade and Industry, Tokyo at the invitation of Dr Ata Masafumi, senior researcher in nanotechnology strategy. This meeting, one in an ongoing series, attracted over 50 representatives from government, industry and business, and was reported in *Nikkei Nanotechnology*. Such was the interest in the social and ethical dimension of nanotechnology that Hunt returned to Japan in March 2005, with a travel grant from the University of Surrey, and spoke on the subject at two more universities and at the Tsukuba branch of AIST at the invitation of Dr Abe Shuji, deputy director of the Nanotechnology Research Institute. The unswerving support and kindness of Professor Matsuda Masami has made these busy itineraries in Japan run smoothly, with a little help from the speed and precision of the *shinkansen* (bullet train). Subsequent brief joint articles by Matsuda and Hunt in three Japanese journals introduced some specific questions regarding the social implications and risks of nanotechnology to the scientific and professional community in Japan. (Note that in this book, for Japanese names we have followed the Japanese convention of placing the family name first.)

Hunt also wishes to record the support of his colleagues in the Nanotechnology Forum at the University of Surrey, especially Professor Gary Stevens (polymer science), Professor Ugur Tüzün (process engineering), and Professor Roland Clift CBE, pioneer of the life cycle approach to environmental management. Professor Robin Attfield (environmental philosophy) and Professor Steven Norris (cultural studies) provided opportunities for challenging questions at a Cardiff University seminar led by Hunt in November 2003.

Michael Mehta's interest in nanotechnology began in 2001 upon being approached by an undergraduate student at the University of Saskatchewan named Crystal Wallin. Wallin encouraged Mehta to consider the links between nanotechnology and biotechnology and to eventually put together a grant application to fund research on how developments in nanotechnology were unfolding within Canada. This grant application was rejected by social science peer reviewers from one of Canada's major federal granting agencies with the observation that one cannot study nanotechnology since it is nothing more than 'science fiction'. This spurred Mehta to develop an active programme of research on the social impacts of nanotechnology.

Mehta is one of the few academics in Canada to explore the social and ethical dimensions of nanotechnology. He has presented his work in this area in many parts of the world: Canada, the US, the UK, Germany, Spain, Iceland and Singapore. His presentations have been on a wide array of topics including expanding the research base on risk perception and risk communication to incorporate nanotechnology, the impact of nanotechnology on the enterprise of science, the role of technological convergence as a driver of regulatory reform, nanoethics, nanomedicine and its ethical and social challenges, nanotechnology and surveillance, nanotechnology and its anticipated economic impacts, and the lessons that can be learned from biotechnology and nuclear technology to assist in predicting the challenges posed by nanotechnology.

With Dr Linda Pilarski from the University of Alberta and others, Mehta shares a CAD\$1.5 million grant (2003–2008) from the Canadian Institutes of Health Research (CIHR) to explore the social, ethical and legal issues related to the development and use of microfluidic devices for genetic analysis. The objective of this project is to develop microfluidics-based platforms having photolithographically defined networks of microchannels whose versatility has led to terms such as 'lab on a chip'. These platforms are able to sort cells and analyse their genomic profiles, individual genes, chromosomes and mitochondrial DNA, thereby bringing the benefits of the genomics and proteomics revolutions to the clinic. These novel, integrated microfluidic platforms will implement microsystems and nanoscience to develop automated, real time multiplex cell manipulation and genetic analysis. Mehta's role in this project is to: (1) assess how Canadians understand issues related to health information, genetic testing and privacy; (2) assess how medical practitioners (oncologists) in Canada perceive the use of microfluidic platform technologies for clinical applications; and (3) to hold consensus conferences on the risks and benefits associated with the use of microfluidic platform technologies for non-clinical purposes. In all likelihood this innovation will be the first available consumer application of a medical device that incorporates nanotechnology.

Mehta wishes to thank Zaheer Baber, Timothy Caulfield, Abdallah Daar, Edna Einsiedel, Linda Goldenberg, Jose Lopez, Chris MacDonald, Lori Sheremeta, Peter Singer, Crystal Wallin and Gregor Wolbring for the intellectual stimulation and debate over the years. Together we are the nanotechnology and society cohort that has helped make Canada a significant player in this field of inquiry. Mehta also wishes to thank his spouse Kathy Edwards for

her assistance with this book. Kathy did much of the original formatting to get the manuscript ready for peer review.

Chapters 2, 3, 4, 10 and 17 come from a special issue on nanotechnology of the *Bulletin of Science, Technology and Society* (February 2004). That issue of the journal, co-edited by Michael Mehta and Zaheer Baber, included several other contributions that add to a slowly accumulating literature in nanotechnology within the Science, Technology and Society field. Chapter 20 by Lori Sheremeta is drawn from a special issue on nanotechnology of the *Health Law Review* (autumn 2004). Chapter 11, John Balbus et al, 'Getting Nanotechnology Right the First Time', is reprinted with permission from *Issues in Science and Technology*, summer 2005, pp65–71, copyright 2005 by the University of Texas at Dallas, Richardson, US. All remaining contributions in this volume have been originally commissioned for this book.

Responsibility for the views expressed in this volume lies only with the co-editors and the individual contributors.

*Geoffrey Hunt, Guildford, UK*

*Michael Mehta, Saskatoon, Canada*

*28th November 2005*



# List of Acronyms and Abbreviations

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|                 |  |
|-----------------|--|
| AIST            | National Institute of Advanced Industrial Science and Technology, Japan                    |
| ANSI            | American National Standards Institute  |
| ANSI-NSP        | ANSI Nanotechnology Standards Panel  |
| ATP             | adenosine triphosphate   |
| BANJAN          | Ban Asbestos Network Japan   |
| BSE             | bovine spongiform encephalopathy   |
| C4I             | collective command, control, communications, coordination and information                  |
| CAD\$           | Canadian dollars   |
| CBAC            | Canadian Biotechnology Advisory Committee  |
| CBEN            | Center for Biological and Environmental Nanotechnology                                     |
| CBRN            | Chemical, Biological, Radiological and Nuclear   |
| CFCs            | chlorofluorocarbons  |
| CFI             | Canada Foundation for Innovation   |
| CFIA            | Canadian Food Inspection Agency  |
| CGIAR           | Consultative Group in Agricultural Research  |
| CHN             | Center for High-Rate Nanomanufacturing, Northeastern University                            |
| CIHR            | Canadian Institutes of Health Research   |
| CHISEL          | criticality, holism, interaction, self-organization, emergence and long-termism            |
| CJD             | Creutzfeldt-Jakob Disease  |
| CO <sub>2</sub> | carbon dioxide   |
| CRN             | Centre for Responsible Nanotechnology, US  |
| CRTI            | Chemical, Biological, Radiological and Nuclear Research and Technology Initiative (Canada) |
| CSR             | Corporate social responsibility  |
| DHS             | Department of Homeland Security, US  |
| DJSI            | Dow Jones Sustainability Index   |
| DNA             | deoxyribonucleic acid  |
| DOD             | Department of Defence, US  |
| DOE             | Department of Energy, US   |
| DOJ             | Department of Justice, US  |