Annex A Working Group, Review Group and Secretariat members

Working Group

The two Academies are extremely grateful to the Working Group for their hard work.

Prof Ann Dowling CBE FREng FRS (Chair)	Professor of Mechanical Engineering, University of Cambridge
Prof Roland Clift OBE FREng	Director of the Centre for Environmental Strategy, University of Surrey
Dr Nicole Grobert	Royal Society Dorothy Hodgkin Research Fellow, University of Oxford
Dame Deirdre Hutton CBE	Chair of the National Consumer Council
Dr Ray Oliver FREng	Senior Science and Technology Associate in the Strategic Technology Group, ICI plc
Baroness Onora O'Neill CBE FBA FMedSci	Newnham College, University of Cambridge
Prof John Pethica FRS	SFI Research Professor, Department of Physics, Trinity College Dublin and Visiting Professor, Department of Materials, University of Oxford
Prof Nick Pidgeon	Director of the Centre for Environmental Risk, University of East Anglia
Jonathon Porritt	Chair of the UK Sustainable Development Commission and Programme Director of Forum for the Future
Prof John Ryan	Director of the Interdisciplinary Research Collaboration on Bionanotechnology. Based at the University of Oxford
Prof Anthony Seaton CBE FMedSci	Emeritus Professor of Environmental and Occupational Medicine, University of Aberdeen and Honorary Senior Consultant, Institute of Occupational Medicine, Edinburgh
Prof Saul Tendler	Head of the School of Pharmacy and Professor of Biophysical Chemistry, University of Nottingham
Prof Mark Welland FREng FRS	Director of the Interdisciplinary Research Collaboration in Nanotechnology. Based at the University of Cambridge
Prof Roger Whatmore FREng	Head of the Advanced Materials Department, Cranfield University

Review Group

The two academies gratefully acknowledge the contribution of the reviewers. With the exception of Sir John Enderby and Mr Philip Ruffles, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release.

Sir John Enderby CBE FRS (Chair)	Physical Secretary and Vice-President of the Royal Society
Mr Philip Ruffles CBE FRS FREng (Vice-Chair)	Vice-President of the Royal Academy of Engineering and Chair of its Standing Committee on Engineering
Sir Richard Friend FRS FREng	Cavendish Professor of Physics, Cambridge University
Prof Nigel Gilbert FREng	Pro Vice-Chancellor and Professor of Sociology, University of Surrey
Dr James McQuaid CB FREng	Previously Chief Scientist, Health and Safety Executive
Prof Anthony Segal FRS	Department of Medicine, University College London

Secretariat

The core secretariat was: Sara Al-Bader, Dr Jofey Craig (June 2003 - September 2003), Dr Andrew Dunn (October 2003 – August 2004) and Dr Rachel Quinn at the Royal Society and Richard Ploszek at the Royal Academy of Engineering. Valuable administrative and web support was provided by Karen Scott-Jupp (Royal Society). The secretariat is grateful to the many other staff at the two Academies who contributed to the successful completion of this study.

Annex B Conduct of Study

Overview

The Working Group sought a wide range of views in the ways outlined below. Written evidence, and summary reports of workshops, meetings and other oral evidence sessions were posted on the dedicated website (www.nanotec.org.uk) as they became available, and comments on evidence was requested. The report has been prepared by the Working Group (listed in Annex A) on the basis of evidence collected and their own expertise. The report has undergone a rigorous peer review process by a review group comprising Fellows of both Academies (also listed in Annex A). It has been endorsed by the Council of the Royal Society and approved for publication by the Royal Academy of Engineering.

Evidence gathering elements

Initial call for views (June 2003)
The study was launched with an initial call for views that invited individuals and organisations to register their interest in this study and to identify the key issues that they thought should be considered by the Working Group. Over 90 responses were received.

Scientists/engineers workshop (30 September 2003)
The Working Group used this meeting to gather evidence from the scientific community (including industry) about the current state of research in nanotechnologies and both current and future applications of nanotechnologies.

Civil Societies workshop (30 October 2003 & 24 February 2004)
At this small workshop the Working Group consulted and discussed issues with a range of civil society organisations. The Working Group prepared questions or issues they wanted to discuss and participants had the opportunity to help set the meeting's agenda. The Working Group met with additional representatives on 24 February 2004.

Health and environmental impacts meeting (8 December 2003)
At this meeting the Working Group met with health and environment experts to consider the environmental applications of nanotechnologies as well as whether nanotechnologies might have a negative impact on human health or the environment.

Public consultation (December 2003 - March 2004)
To explore public attitudes to nanotechnology, the market research company BMRB International was commissioned to research public attitudes to nanotechnology. This involved two strands:
- Two in-depth workshops with members of the public were held in December 2003 to explore their ideas about nanotechnology, and to identify and discuss any potential concerns or questions that might arise.
- Three questions, designed to establish public awareness of nanotechnology were included in an Access omnibus survey in early January. The survey sought the views of 1,000 people in Great Britain aged 15+.

Workshop on regulation (11 February 2004)
The Working Group met with regulators and others with expertise in regulatory issues to discuss whether or not existing legislation is appropriate to nanosciences and nanotechnologies.

Industry meeting (3 March 2004)
This half-day meeting offered the Working Group an opportunity to further explore the issues covered in the terms of reference with industry representatives.

Dedicated website (www.nanotec.org.uk)
All interested parties (including the public) were able to comment via the website on any of the information posted on the website or raise issues relating to nanotechnologies in general or the about the study itself.

Independence

The study was conducted independently of Government, which was not involved in the selection of the Working Group members or its methods of working, and which did not view the report before it was printed.

Annex C List of those who submitted evidence

On 11 June 2003, the Royal Society and Royal Academy of Engineering issued a call for written evidence for the nanotechnology study. This was followed by a number of oral evidence sessions, meetings and workshops. Reports of these were posted on the website as they became available, and comments requested on them.

The following is a list of the individuals and organisations that gave evidence to the study in writing and/or orally. For ease of reference, evidence is listed according by individual and by organisation. The views of individuals do not necessarily represent those of their organisations.

The Royal Society and Royal Academy of Engineering are most grateful to those who assisted the study by providing evidence, and have made every endeavour to list them all here. If any individuals or organisations have been omitted we offer our apologies and will ensure that the web version of the evidence list is updated.

W = provided written evidence O = attended oral evidence session M = attended meeting or workshop

Individuals

A

Adams, Michael	Unilever (M)
Aeppli, Gabriel	London Centre for Nanotechnology (W &O)
Alakeson, Vidhya	Forum for the Future (W)
Albertario, Fabio (W)	
Aldrich, Tim	Forum for the Future (M)
Allen, Geoffrey	University of East Anglia (M)
Allen, Ray	University of Sheffield (M)
Alsop, Adrian	Economic and Social Research Council (W)
Altmann, Juergen	Experimentelle Physik II, Dortmund University (W)
Andrews, Arlan (W)	
Arnall, Alexander	Imperial College London (W)
Ayres, John	University of Aberdeen (W)

B

Bachmann, Gerd	Co-worker of a German Governmental nanotechnology funding agency (O)
Ball, Philip (W)	
Balmer, Richard	Association of Liberal Democrat Engineers and Scientists (W)
Barbur, Vicki	Eastman Kodak Company, USA (W)
Batchelor FREng, Keith (W)	
Besenbacher, Flemming	University of Aarhus, Denmark (O)
Biggs FREng, Simon	University of Leeds (W)
Binks, Peter	Nanotechnology Victoria (W)
Bosch, Wolfgang	Filtronic (M)
Bott, David	ICI (M)
Brazil, Rachel	Royal Society of Chemistry (W & M)
Briscoe, Brian	Imperial College London (M)
Broughton, Duncan (W)	
Brown, Mike	Boots (M)
Burgess, Doug	MOD (O)
Burgess, Jacquie	University College London (O)

C

Calladine FRS FREng, Chris	University of Cambridge (W)
Carroll, John	University of Cambridge (W)
Carson, Dave (W)	
Cass, Tony	Imperial College London (M)
Chadwick, Derek	The Novartis Foundation (W)
Chetwynd, Derek	University of Warwick (M)
Church, Colin	Department for environment food and rural affairs (DEFRA) (M)
Clarke, Andrew	Kodak (M)

Colbeck, Ian	University of Essex (M)
Collis, Amanda	The Biotechnolgy and Biological Sciences Research Council (W)
Cumpson, Peter	National Physical Laboratory (M)

D

Davey, Roger J (W)	
Davies, Graham J	University of Birmingham (M) (W)
Davies FREng, Stewart	CEO BT Exact (W)
Delic, Julian	Health and Safety Executive (M)
Dent, Benjamin	Department for environment food and rural affairs (DEFRA) (M)
Depledge, Mike	Environment Agency, Head of Science (M)
Devine, Steve (W)	
Dibb, Sue	National Consumer Council (W&O)
Dimmock, John	Media Services Sussex Ltd (W)
Dobson, Peter	University of Oxford, Begbrooke Science Park (W & M)
Donaldson, Ken	MRC Centre for Inflammation Research, University of Edinburgh (W &M)
Dowding, Peter	Infinaeum (M)
Downing, Steve	ICI (M)
Dransfield, Graham	Uniqema (M)
Drexler, Eric	Foresight Institute (W&O)
Duncan, Ruth	Welsh School of Pharmacy (W)

E

Eigler, Don	IBM (O)
Ellis, John	X-FAB UK Ltd (M)
Evans, Barry	University of Surrey (W)

F

Fenton, Gary (W)	
Festing, Michael	Animal Procedures Committee (M)
Fisher, Andrew	University College London (M)
Fitzmaurice, Donald	University College Dublin (M)
Fletcher, Amy L (W)	
Flodstrom, Anders	Royal Institute of Technology, Stockholm, Sweden (O)
Florence, Sandy	The London School of Pharmacy (M)
Foo, Joyce	FCO Singapore (W)
Fox-Male, Nick	Eric Potter Clarkson IP Services (W)
Fullam, Brian	HSE (M)

G

Gallop, John	National Physcial Laboratory (M)
Gann, David	Imperial College London (W)
Garnett, Martin	University of Nottingham (W)
Gimzewski FREng, James	Chemistry Dept, University of California, Los Angeles (W)
Gittins, David	Imerys (M)
Glover, Anne	University of Aberdeen (M)
Golunski, Stan	Johnson Matthey (W)
Grant, Malcolm	Agriculture and Environment Biotechnology Commission (O)
Greisch, Edward R	US Military (W)
Griffiths, Glynis	Food Standards Agency (M)
Grimshaw, David	ITDG (M)
Gubrud, Mark Avrum	Center for Superconductivity Research, Physics Dept, University of Maryland (W)

H

Hanson, Robin	George Mason University, Fairfax, USA (W)
Harper, Tim	Cientifica Ltd (W & O)
Harrison, Robert	Rouse Patents (O)
Hawksworth, Stuart	HSE (M)
Hayes, Emma	Environment Agency (M)

Healey, Peter	Science Technology and Governance in Europe (W)
Higgins, Rob	Medicines and Healthcare products Regulatory Agency (M)
Hilsum, Cyril	University of Cambridge (W)
Hinde, Julia	FCO, Canada (W)
Hitchcock, Julian	Eversheds LLP Solicitors (W)
Holister, Paul	Cientifica (M)
Holtum, Dave	Engineering and Physical Sciences Research Council (W)
Hook, David	Medicines and Healthcare products Regulatory Agency (M)
Hossain, Kamal	National Physical Laboratory (W)
Howard, Vyvyan	University of Liverpool (M)
Howorth, Dave (W)	
Howse, Mike (W)	
Humphreys, Colin (W)	
Hurley, Fintan	Institute of Occupational Medicine, Edinburgh (M)
Hyde, Vic	Cosmetics Toiletry and Perfumery Association (M)

I

Iden, Ruediger	BASF (M)
Illsley, Derek	Sun Chemical Co (M)
Ion, Sue	BNFL (W)
Irwin, Alan	Brunel University (O)

J

James FREng, Jim (W)	
Janzen, William	Amphora Discovery Corporation (O)
Jones, Richard	University of Sheffield (W & O)
Juniper, Tony	Friends of the Earth (W)

K

Karn, Barbara	US Environmental Protection Agency (W)
Kelly, Mike	University of Cambridge (M)
Khandelwal, Amit	Chemical Industries Association (M)
Knowland, John	University of Oxford (M)
Krauss, Thomas	University of St Andrews (M)
Kroto FRS, Harry (O)	
Kulinowski, Kristen M	Center for Biological and Environmental Nanotechnology USA (O)
Kumar, Dinesh	ION IT Ltd (W)

L

Leigh, Beatrice	GlaxoSmithKline (M)
Light, Richard	DAART Centre for Disability and Human Rights (W)
Loveridge, Denis	Honorary Visiting Professor – PREST (W)

M

Macaskie, Lynne	University of Birmingham (M) (W)
Martin, Philippe	EC Health and Consumer Protection (M)
Matthews, Kevin	Oxonica (M)
Maynard, Andrew	National Institute for Occupational Safety and Health (W)
McKeown FREng, PA (W)	
McLeod, Alistair	Imperial College London (M)
McQuaid, Jim (W)	
Mehta, Michael D.	University of Saskatchewan (W)
Meldrum, Maureen	HSE (M)
Merrifield, David	GSK (M)
Mesquida, Patrick	London Centre for Nanotechnology (M)
Miles, Glenn (W)	
Miles, Mervyn	University of Bristol (M)
Milner, Robin	UK Computing Research Committee (W)
Molyneaux, Andrea	Medicines and Healthcare products Regulatory Agency (M)
Mooney, Pat	Etc Group (O)

Moore, Julia	National Science Foundation (M)
Morris, Vic	Institute of Food Research (M)
Murray, Mike	ABPI (M)
Murrer, Barry	Johnson Matthey (M)

N

Northage, Christine	Health and Safety Executive (M)

O

Ozorio de Almeida	FCO, Brazil (W)

P

Pacholak, Anna	FCO, Poland (W)
Palmer, Richard E	University of Birmingham (W & M)
Palmer, SB	Warwick Nanosystems Group, UK (W)
Parkinson, Stuart	Scientists for Global Responsibility (W)
Parr, Douglas	Greenpeace (W&O)
Parry, Vivienne (O)	
Pethrick, RA	University of Strathclyde (W)
Pham FREng, DUC	University of Cardiff (W)
Phillips, Ian	ARM
Phoenix, Chris	Center for Responsible Nanotechnology (W)
Pick, Martin (W)	
Pilkington, Ian	Ilford (M)
Poirier, Natalie	FCO, The Netherlands (W)
Polak, Julia	Imperial College London (M)

Q

Quinn, Francis	L'Oreal (M)

R

Rajan, Bob	HSE (M)
Rayner, Steve	Saïd Business School, Oxford University (O)
Richards, David	Technopreneur limited (W)
Rickerby, David	Advisory Cell for Science and Technology, European Joint Commission Centre (W)
Reip, Paul	Qinetiq Nanomaterials Ltd. (O)
Rip, Arie	University of Twente, The Netherlands (O)
Rix, Sam	ex pupil of Hills Road Sixth Form College (W)
Roco, Mike	National Science Foundation, USA, Senior advisor for nanotechnology also Chair US Nanoscale Science and Engineering (W & O)
Roos, Ursula	FCO, Germany (W)

S

Santoli, Salvatore	International Nanobiological Testbed Ltd (W)
Savage, Nora	Environmental Protection Agency, USA (W)
Schneemilch, Matthew	Imperial College London (M)
Scott, Andrew	Intermediate Technology Development Group (W)
Semple, Sean	University of Aberdeen (M)
Sloan, Jeremy	University of Oxford (M)
Smalley, Richard	Rice University (O)
Smith, George	University of Oxford (M)
Snape, Julian (W)	
Snowdon, Ken	University of Newcastle (M)
Southerland, David	Department of trade and industry (M)
Stark FREng, Jim (W)	
Stepney, Susan UK	Computing Research Committee (W)
Stewart FREng, Will (W)	
Stone, Vicki	Napier University (M)
Sutherland Olsen, Dorothy (W)	
Sutton, David	ICI (M)

Swan, Harry	Thomas Swan & Co ltd (M)
Symons, Rex	Better Regulation Taskforce (M)
Syms, Richard	Imperial College London (M)

T

Tran, Lang	Institute of Occupational Medicine, Edinburgh (M)
Thomas, Jim	Action Group on Erosion, Technology and Concentration (W & M)
Tolfree, David	Technopreneur limited (W)
Tomlinson, Geoffrey (W)	
Treder, Mike	Center for Responsible Nanotechnology, USA (W)
Tsavalos, Alexander	Health and Safety Executive (W & M)
Tuppen, Chris	BT (M)

V

Vadgama, Pankaj	
Vaughan-Lee, David	Editor, Asia Pacific Coatings Journal (W)
Vest, Charles	Massachusetts Institute of Technology (O)
Visser, Germ W	DSM, The Netherlands (W)

W

Wadey, Rita	OST (M)
Wakeford, Tom	PEALS (M)
Wang, Brian	Owner of a software company, Silicon Valley (W)
Ward, Professor IM	University of Leeds (W)
Warheit, David B.	DuPont (W)
Weiss, Tilo	Sustech (M)
Wells FRS FREng, PNT	University of Bristol (W)
Whitby, Raymond	University of Sussex (W)
White, Ian	Chairman, scientific committee on cosmetic and non-food products (O)
Whitesides, George	Harvard University, Department of chemistry and chemical biology (O)
Wiggins, Jason	University of Oxford, Begbrooke Science Park (W)
Wilkinson, Chris	University of Glasgow (M)
Willett, Steve (W)	
Williams, Gary (W)	
Williams, Martin	Department for environment food and rural affairs (DEFRA) (M)
Williams FREng, Richard	Institute of Particle Science & Engineering (W)
Williams, Simon	The Patients Association (M)
Wilsdon, James	Demos (M)
Wilson, Neil	University of Warwick (M)
Windle, Alan	University of Cambridge (M)
Winkler, Stefan	FCO, USA (W)
Wood, Stephen	University of Sheffield (W & O)

Y

Yeates, Steve (W)	
Young, Anthony R	St Johns Institute of Dermatology, Kings College London

Organisations

A

Action Group on Erosion, Technology and Concentration (W & M)	
Advisory Cell for Science and Technology, European Joint Commission Centre	David Rickerby (W)
Agriculture and Environment Biotechnology Commission	Malcolm Grant (O)
Amphora Discovery Corporation	William Janzen (O)
Animal Procedures Committee	Michael Festing (M)
Asia Pacific Coatings Journal	David Vaughan-Lee (W)
Association of Liberal Democrat Engineers and Scientists	Richard Balmer, Hon Secretary (W)
Association of the British Pharmaceutical Industry	Mike Murray (M)

B

BASF group - Ruediger Iden (M)	
Begbroke Science Park	University of Oxford - Peter Dobson (W & M), Jason Wiggins (W)
Better Regulation Taskforce	Rex Symons (M)
Biotechnolgy and Biological Sciences Research Council	Amanda Collis (W)
Boots	Mike Brown (M)
British Nuclear Fuels	Sue Ion (W)
British Telecom	Chris Tuppen (M)
Brunel University	Alan Irwin (O)
BT Exact (W)	

C

Center for Biological and Environmental Nanotechnology, USA	Kristen M Kulinowski (O)
Center for Responsible Nanotechnology, USA	Mike Treder, Executive Director (W)
Chemical Industries Association	Amit Khandelwal (M)
Cientifica Ltd	Tim Harper (W & O), Paul Holister (M)
Computing Research Committee (W)	
Cosmetics, Toiletry and Perfumery Association	Vic Hyde (M)

D

DAART Centre for Disability and Human Rights	Richard Light
Department for the Environment, Food and Rural Affairs	Colin Church (M), Benjamin Dent (M), Martin Williams (M)
Department for Trade and Industry	David Southerland (M)
Demos	James Wilsdon (M)
DSM, The Netherlands	Germ Visser (W)
DuPont	David Warheit (W)

E

Eastman Kodak Company, USA	Vicki Barbur (W)
EC Health and Consumer Protection	Phillippe Martin (M)
Economic and Social Research Council	Adrian Alsop (W)
Engineering and Physical Sciences Research Council	Dave Holtum (W)
Environment Agency	Michael Depledge (M), Emma Hayes (M)
Environmental Protection Agency, USA	Nora Savage (W)
Eric Potter Clarkson IP Services	Nick Fox-Male (W)
ETC (Action Group on Erosion, Technology and Concentration)	Jim Thomas, Programme Manager and Pat Mooney (W, O & M)
Eversheds LLP Solicitors	Julian Hitchcock (W)

F

Filtronic	Wolfgang Bosch (M)
Food Standards Agency	Glynis Griffiths (M)
Foreign and Commonwealth Office (W)	

Foresight Institute	Eric Drexler (W & O)
Forum for the Future	Vidhya Alakeson, Principal Policy Advisor (W), Tim Aldrich (M)
Friends of the Earth	Tony Juniper (W)
G	
GeneWatch UK (W)	
George Mason University, Fairfax, USA	Robin Hanson (W)
GlaxoSmithKline	Beatrice Leigh (M), David Merrifield (M)
Greenpeace	Doug Parr (W & O)
H	
Harvard University	George Whitesides (O)
Health and Safety Executive	Julian Delic (M), Brian Fullam (M), Stuart Hawksworth (M), Maureen Meldrum (M), Christine Northage (M), Bob Rajan (M), Christine Northage (M), Alexander Tsavalos (W & M)
I	
IBM	Don Eigler (O)
ICI	Steve Downing (M), David Bott (M), David Sutton (M)
Ilford	Ian Pilkington (M)
Imerys	David Gittins (M)
Imperial College London	Brian Briscoe (M), Tony Cass (M), David Gann (W), Julia Polak (M), Matthew Schneemilch (M), Richard Syms (M), Alistair McLeod (M)
Imperial College, Business School and Department of Civil and Environmental Engineering	David Gann, Director Innovation Studies Centre (W)
Imperial College London Centre for Energy Policy and Technology	Alex Arnall (W)
Infinaeum	Peter Dowding (M)
Institute of Food Research	Vic Morris (M)
Institute of Food Science and Technology (W)	
Institute of Occupational Medicine, Edinburgh	Fintan Hurley (M), Lang Tran (M)
Institute of particle science and engineering (W)	
Institute of Physics (W)	
Intermediate Technology Development Group	David Grimshaw (M), Andrew Scott, Policy and Programmes Director (W)
International Nanobiological Testbed Ltd	Salvatore Santoli (W)
ION IT Ltd	Dinesh Kumar (W)
J	
Johnson Matthey	Dr Stan Golunski (W), Barry Murrer (M)
K	
Kodak	Andrew Clarke (M)
L	
L'Oreal	Francis Quinn (M)
London Centre for Nanotechnology	Gabriel Aeppli, Director (W), Patrick Mesquida (M)
London School of Pharmacy	Sandy Florence (M)
M	
Massachusetts Institute of Technology	Charles Vest (O)
Media Services Sussex Ltd	John Dimmock - Technical Director (W)
Medical Research Council (W)	
Medicines and Healthcare products Regulatory Agency	Andrea Molyneaux (M), Rob Higgins (M),

David Hook (M)	
Ministry of Defence	Doug Burgess (O)
MRC, Centre for Inflammation Research, University of Edinburgh	Ken Donaldson (W & M)

N

Nanotechnology Victoria	Peter Binks (W)
National Consumer Council	Sue Dibb, Senior Policy Officer (W)
National Institute for Occupational Safety and Health (W)	
National Physical Laboratory (W)	
National Physical Laboratory	Peter Cumpson (M), John Gallop (M), Kamal Hossain (W)
National Science Foundation US	Mike Roco, Senior Adviser NSF and Chair of US Nanoscale Science, Engineering and Technology (W & O), Julia Moore (M)
Natural Environment Research Council	Deborah Cosgrove (W)
Novartis Foundation	Derek Chadwick (W)
Ntera UK Ltd (W)	

O

Office of Science and Technology	Rita Wadey (M)
Oxonica	Kevin Matthews (M)

P

Patients Association	Simon Williams (M)
PEALS	Tom Wakeford (M)
Policy, Ethics And Life Sciences Research Institute	Tom Wakeford (M)
Policy Research in Engineering, Science and Technology	Denis Loveridge, Honorary Visiting Professor (W)

Q

Qinetiq Nanomaterials	Paul Reip (O)

R

Rice University	Richard Smalley (O)
Rolls Royce	Mike Howse (W)
Rouse Patents	Robert Harrison (O)
Royal Institute of Technology, Stockholm, Sweden	Anders Flodstrom (O)
Royal Society of Chemistry	Rachel Brazil, Manager, Materials Chemistry (W & M)

S

Saïd Business School, Oxford University	Steve Rayner (O)
Science Technology and Governance in Europe	Peter Healey, Coordinator (W)
Scientific committee on cosmetic and non-food product packaging (O)	
Scientists for Global Responsibility	Stuart Parkinson, Director (W)
St Johns Institute of Dermatology, Kings College London	Anthony R Young (M)
Sun Chemical Co	Derek Illsley (M)
Sustech	Tilo Weiss (M)

T

Technopreneur limited	David Tolfree (W)
Thomas Swan & Co ltd	Harry Swan (M)

U

UK Computing Research Committee	Robin Milner and Susan Stepney (W)
Unilever	Michael Adams (M)
Uniqema	Graham Dransfield (M)
Universitat Dortmund, Experimentelle Physik III	Juergen Altmann (W)
Université Louis Pasteur	Dorothy Sutherland Olsen (W)

University College Dublin	Donald Fitzmaurice (M)
University College London	Jacquie Burgess (O), Andrew Fisher (M)
University of Aarhus, Denmark	Flemming Besenbacher
University of Aberdeen	Anne Glover (M), Sean Semple (M)
University of Aston	Peter Brett & Xianghong Ma, Peter J Conley (W)
University of Birmingham	Richard E Palmer (W & M), Graham J Davies (M), Lynn Macaskie (M & W)
University of Bristol	Professor PNT Wells FRS FREng (W), Mervyn Miles (M)
University of California, Los Angeles, Chemistry Dept	James Gimzewski FREng (W)
University of Cambridge	Chris Calladine FRS FREng (W), John Carroll (W), Cyril Hilsum (W), Mike Kelly (M), Alan Windle (M)
University of Cardiff	Duc Pham FREng (W)
University of East Anglia	Geoffrey Allen (M)
University of Edinburgh	Ken Donaldson
University of Essex	Ian Colbeck (M)
University of Glasgow	Chris Wilkinson (M)
University of Leeds	Simon Biggs FREng (W), Professor I M Ward (W)
University of Liverpool	Vyvyan Howard (M)
University of Maryland, Dept of Physics	Mark Gubrud (W)
University of Napier	Vicki Stone (M)
University of Newcastle	Ken Snowdon (M)
University of Nottingham	Martin Garnett (W)
University of Oxford	Peter Dobson (M), John Knowland (M), Jeremy Sloan (M), George Smith (M)
University of Saskatchewan	Michael D Mehta (W)
University of Sheffield (W)	
University of Sheffield	Ray Allen (M), Richard Jones and Stephen Wood (W & O)
University of St Andrews	Thomas Krauss (M)
University of Strathclyde	RA Pethrick (W)
University of Surrey	Barry Evans (W)
University of Sussex	Raymond Whitby (W)
University of Twente	Arie Rip (O)
University of Warwick	Derek Chetwynd (M), Mr Neil Wilson (M)
US Environmental Protection Agency	Barbara Karn (W)
US Military	Edward R Greisch (W)

W

Warwick Nanosystems Group, UK	SB Palmer (W)
Welsh School of Pharmacy	Ruth Duncan (W)

X

X-FAB UK Ltd	John Ellis (M)

Annex D Mechanical self-replicating nano-robots and 'Grey Goo'

Media coverage of nanotechnologies has invariably raised the spectre of the 'grey goo': a doomsday scenario in which nanoscale robots self-replicate out of control, producing unlimited copies of themselves, consuming all available material and ultimately laying waste to the planet. Whereas most of the scientific community considers this to be science fiction, others have argued that it is a possible outcome of unregulated nanotechnology. The level of public and media interest in nanotechnology therefore justifies the following question: Is 'grey goo' a real concern, or is it a distraction from the important issues?

The original concept of molecular manufacturing described by Dr Eric Drexler, Chairman of the Foresight Institute, imagined the synthesis of materials and objects by a mechanical 'assembler'; that is, a machine with the ability make any object by selecting atoms from the environment and positioning them, one at a time, to assemble the object. This assembler can be programmed and is independently powered. As it can make any object, it can reproduce itself. If the process malfunctions or is corrupted, intentionally or not, the self-replication process could continue indefinitely. Over the past 20 years or so, Drexler and his colleagues have continued theoretical studies of the feasibility of such machines, but as far as we are aware there is no research in this field that has been supported by funding agencies, and there has been no practical experimental progress over this period. The reason is simple: there are many serious fundamental scientific difficulties and objections, to the extent that most of the scientific community believes the mechanical self-replicating nano-robot proposal to be impossible.

The scientific issues have been debated in open correspondence between Dr Drexler and Professor Rick Smalley, co-recipient of the Nobel Prize for Chemistry in 1996 for the discovery of carbon 60—so called buckyballs. In summary, there are two major difficulties: first, to lift and position atoms one needs very fine manipulators, of a similar size to the atoms being worked with; second, the atoms being manipulated must first attach – i.e. chemically bind – to the manipulator, and then unbind from the manipulator and bind to the object. Although scientists have used atomic force microscopes to manipulate a restricted group of individual atoms and molecules into simple structures on surfaces, the properties of matter on this lengthscale appear to be incompatible with the requirements for a mechanical self-replicating technology. These objections have been termed by Smalley as 'thick fingers' and 'sticky fingers'. Professor George Whitesides has questioned the feasibility of the energy management system that would be needed to handle the large energy input and release that occurs at the different stages of the construction process. Because the assembler is a nanomachine, its positioning accuracy is severely limited by the intense bombardment it receives from atoms in the environment – whether gaseous or liquid – which causes Brownian motion. It is quite clear: making a mechanical self-assembler is well beyond the current state of knowledge.

Our experience with chemistry and physics teaches us that we do not have any idea how to make an autonomous self-replicating mechanical machine at any scale, let alone nanoscale. Where we can find self-replicating machines is in the world of biology. The cell, thousands of nm in size, is the smallest unit we know that contains all the machinery essential for the process of reproduction, given a suitable environment. In fact, the planet we know today is quite different from its earliest form: biology evolved and turned a desert into the ecosystem of which we are now a part. At present however, the complete details of operation of even a simple cell are far beyond our understanding.

Given the above, we have heard no evidence to suggest that mechanical self-replicating nanomachines will be developed in the foreseeable future, and so would direct regulators at more pressing concerns outlined in chapter 8.

Quotations about mechanical self-replicating nano-robots and 'grey goo':

'I think there is no such thing as the assembler.' (Professor George Whitesides in evidence to the Working Group, with reference to the mechanical molecular assembler proposed by Dr Eric Drexler).

'My argument is that I believe that it is so implausible that I wouldn't worry about it…proving an impossibility is a very difficult thing to do and I've only done it in small parts.' (Professor Richard Smalley in evidence to the Working Group).

'… when people say "this isn't what we should be worrying about" I think they are right. I believe it's very much the wrong issue to focus on for a variety of practical and sensible reasons.' (Dr Eric Drexler in evidence to the Working Group).

Acronyms and abbreviations

AFM	atomic force microscope
AHRB	Arts and Humanities Research Board
BRTF	Better Regulation Task Force (UK)
BSE	bovine spongiform encephalopathy
CD	compact disk
CNT	carbon nanotube
CVD	chemical vapour deposition
DAMs	directed assembly of monolayers
DEFRA	Department for Environment Food and Rural Affairs
DfT	Department for Transport
DNA	deoxyribonucleic acid
DH	Department of Health
DTI	Department of Trade and Industry
DVD	digital versatile disk
EA	Environment Agency
EBL	electron beam lithography
EC	European Commission
EINECS	European Inventory of Existing Commercial Substances
ELID	electrolytic in-process dressing
ELV	End-of-Life Vehicles Directive
EPSRC	Engineering and Physical Sciences Research Council
EU	European Union
FDA	Food and Drug Administration (USA)
FIB	focused ion beam
GDP	gross domestic product
GM	genetically modified
HRTEM	high-resolution transmission electron microscopy
HSE	Health and Safety Executive (UK)
ICT	information and communication technology

IT	information technology
ITRS	International Technology Roadmap for Semiconductors
LCA	life cycle assessment
µm	micrometre
MBE	molecular beam epitaxy
MEMS	micro-electromechanical systems
mm	millimetre
MOD	Ministry of Defence
MOCVD	metal oxide chemical vapour deposition
MRI	magnetic resonance imaging
MWNT	multi-walled carbon nanotube
NEMS	nano-electromechanical systems
NGO	non-governmental organization
NIST	National Institute for Standards and Technology (USA)
NPL	National Physical Laboratory (UK)
nm	nanometre
NONS	Notification of New Substances
NSF	National Science Foundation (USA)
OEL	occupational exposure limit
OLED	organic light-emitting diode
OST	Office of Science and Technology
POST	Parliamentary Office of Science and Technology
PV	photovoltaic
R&D	research and development
RCUK	Research Councils UK
REACH	Registration, Evaluation, Authorisation of Chemicals
RFID	radio frequency identification
RIE	reactive ion etching
SAM	self-assembled monolayer
SCCNFP	Scientific Committee on Cosmetic Products and Non-food Products intended for Consumers

SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks
SEM	scanning electron microscopy
SPM	scanning probe microscopy
STM	scanning tunnelling microscope
SWNT	single-walled carbon nanotube
TBT	tributyl tin
TEM	Transmission electron microscopy
UV	ultraviolet
WEEE	Waste Electrical and Electronic Equipment Directive