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Nanotechnology

Report of Toi Te Taiao: the Bioethics Council to the Minister for the Environment

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Foreword

Toi Te Taiao: the Bioethics Council was established in 2002. Its role is to:

1. provide independent advice to government on biotechnological issues involving significant cultural, ethical and spiritual dimensions
2. promote and participate in public dialogue on cultural, ethical and spiritual aspects of biotechnology, and enable public participation in the Council's activities
3. provide information on the cultural, ethical and spiritual aspects of biotechnology.

Our terms of reference also require us, "through a 'future watch' function to monitor emerging issues and developments in biotechnology".

In recent months the Council has noticed an emerging international conversation about the likely impact of a rapidly expanding technology – nanotechnology.

Not all applications of nanotechnology have any direct or immediate application in biotechnology, the arena of our concern. But many applications do offer promise in such areas as the better delivery of drugs in medical care, or dealing with environmental pollutants. In addition, some enthusiastic supporters are looking forward to this technology interfacing with advances in biotechnology, information science and neurology to produce new ways of enhancing human capabilities, or to create wearable sensors and computers.

For some, these possibilities are exciting and positive. Others are conscious of the lack of information on the safety of nano-particles, or see potential for risky choices or inappropriate and undesirable developments.

It is not yet clear what developments will be realised, or within what timeframe. In the meantime, a range of interested parties are recognising the need for communities, regulators and governments to be prepared for possible developments. These preparations will need to include attention to the appropriateness and readiness of the regulatory institutions, but also public dialogue about the appropriate use of a technology that offers great promise, and radical possibilities for intervention in human life.

This report to the Minister for the Environment is our initial contribution to the conversations about such issues. We are mindful that the technology is at a very early stage of development, and we make no claims to being able to predict the directions it will take. We do, however, hope that this report will contribute to discerning the most appropriate ways for this country to benefit from nanotechnology.

We record out thanks to those who have provided us with information, and to the confidential peer reviewers who provided us with helpful comment on earlier drafts of the paper.

Sir Paul Reeves
Chair
Toi Te Taiao: the Bioethics Council

Executive summary

Nanotechnology is the science of the very small, involving manipulation of atoms and molecules, with applications in the areas of material sciences and biology, and with the potential for convergence in the areas of biotechnology, and the information and cognitive sciences. There is an increasing investment in this research internationally, and some strong research initiatives in New Zealand.

It is a technology that has considerable potential, but one that may also have associated risks. The nature of these risks will be dependent on the trajectory of the development of the research, which is still unclear.

There is also the potential for this technology to be socially contentious, on the basis of both the assessment of physical and biological risks, and the cultural and ethical dimensions of some developments. There are a number of calls internationally for better regulation of the technology and for public debate on the developments of the technology.

The Bioethics Council thinks it is important that New Zealand be well prepared for the expansion of this technology.

Recommendations

The Bioethics Council recommends that the Government:

- **notes the emergence of nanotechnology as a potentially socially contentious technology, as well as one with potential benefits**
- **notes the government initiatives in the UK, and in particular the current independent review of nanotechnology commissioned from the UK Royal Society and the Royal Academy of Engineering**
- **notes that the Bioethics Council will continue to investigate the cultural, ethical and spiritual implications of nanotechnology**
- **encourages those government agencies such as MoRST and FRST who have an interest in, and involvement with, nanotechnology to ensure that they are fully aware of the social research work being undertaken internationally on the ethical, spiritual and cultural implications of nanotechnology**
- **maintains a watching brief on developments in nanotechnology with an eye to reviewing the current regulatory requirements in all areas that are likely to be affected by nanotechnology.**

Introduction

The Bioethics Council is charged to "enhance New Zealand's understanding of the cultural, ethical and spiritual aspects of biotechnology and ensure that the use of biotechnology has regard for the values held by New Zealanders". Our terms of reference include an expectation that we will fulfil a "future watch" function to monitor emerging issues and developments in biotechnology.

This paper was produced as part of fulfilling that function. We wish to alert the Government to an emerging technology with biotechnological applications – nanotechnology.

This paper briefly describes the science and the emerging debates, and concludes with a list of recommendations.

The science

'Nanotechnology' is a collective term for a set of technologies, techniques and processes involving manipulation and characterisation of matter on the scale of atoms and molecules. The materials are worked with on the nanoscale (a nanometre is a billionth of a metre, or about 10 times the diameter of a hydrogen atom), with dimensions and tolerances in the range of 0.1 to 100 nanometres.

Although this technology has been around for some time, there has been a rapid increase in the past few years in the funding made available, both in New Zealand and overseas, and in the hopes and aspirations for the technology.

The applications of nanotechnology range across the computer, material and biological sciences. Examples of actual and potential uses include:

- improved treatment of disease through 'targeted drug delivery' (precision delivery of medicine to affected cells)
- technologies for environmental remediation
- faster computers with greater data storage
- new materials that are lighter, stronger, more energy-efficient and/or cheaper to produce.

Enthusiastic proponents of the technology are promoting the potential for nanotechnology to converge with biotechnology, information technology and cognitive science, based on "material unity at the nanoscale, and on technology integration from that scale"[1]. This means that the traditional divisions between different areas of work will break down as it becomes possible to manipulate matter at the molecular level, regardless of the area of work. The enthusiasts propose that nanotechnology will contribute to such developments as:

- fast broadband interfaces directly between the human brain and machines
- comfortable wearable sensors and computers, making the human body more durable, healthy, energetic, easier to repair and resistant to many kinds of stress, biological threats and ageing processes
- enhancement of national security through military developments and improved surveillance
- further ability to control genetics.

Broad themes identified from the discussions include the potential to expand human cognition and communication, improve human health and physical capabilities, and enhance group and societal outcomes.

[1] Roco M C, Bainbridge W S (eds) *Converging Technologies for Improving Human Performance* NSF/DOC- sponsored report, June 2002.

Other proponents of the technology regard some of these proposals as belonging in the area of science fiction, and would expect nanotechnology products to be more mundane – such as paint additives, sunscreens, cosmetics, computers and optical devices.

Considerable financial benefits are expected. For instance, the Report of the Department of Trade and Industry in the UK, *New Dimensions in Manufacturing: A UK strategy for nanotechnology*, quotes predictions that range up to a $1 trillion global market for nanotechnology by 2011 - 2015.

Current research investment

In New Zealand the Government is already investing in nanotechnology in the following areas.

- The MacDiarmid Institute, one of the Centres of Research Excellence, involves researchers from five New Zealand universities and two Crown Research Institutes. Their work focuses on four major research themes: nano-engineering materials and devices; novel electronic, electro-optic and superconducting materials; functional materials; and soft materials.The Institute has operational funds of $13,400,000 over three years, and capital funds of $9,800,000.
- The New Economy Research Funds (NERF) and Marsden Funding have invested in nanotechnology. For instance, Industrial Research Limited, in collaboration with Otago University and the Cawthron Institute, has received $5.9 million dollars over five years from the NERF. The researchers hope to make nanometre-sized particles that can be used to target drugs to specific sites, resulting in better performance and fewer side-effects. Advanced drug-delivery technologies are forecast to reach half the value of the worldwide pharmaceutical market. It is regarded as high-risk research in terms of return on investment, but if successful may produce some extremely high-value, low-volume products.

  Another NERF programme involving the Universities of Canterbury, Victoria and Otago, Industrial Research Limited, and the Institute of Geological and Nuclear Sciences is looking at nano-engineered materials for optics and electronics, with funding of approximately $1.5 million over four years (2000-2004). This has given rise to New Zealand's first nanotechnology start-up company, Nanocluster Devices Limited.
- FRST is preparing a request for proposals for "impacts of new technologies: manufacturing and services". It is anticipated that this will be funded at around $200,000 to $300,000 per year from July 2004. This funding is to address social, cultural and environmental aspects in manufacturing and services, which may include nanotechnology.

Internationally there has been a rapid increase in funding for this technology, from both private and public sources. For instance, in recent months the UK government has announced further injections of research money for nanotechnology, with an announcement on 2 July 2003 of £90 million over the next six years. Existing government investment in nanotechnology totals £94 million. In the USA the House of Representatives in May this year approved a $2.4 billion bill to continue the United States National Nanotechnology Initiative over the next three years.

Nanotechnology will be the largest government-funded science programme since the Space Race, exceeding even the Human Genome Project. It is estimated that there are more than 500 nanotech companies active throughout Europe, North America and Asia, including leading transnationals such as BASF, L'Oreal, Bayer, Exxon, IBM and Hewlett Packard. Their nanotech particles are already used within cosmetics, clothing, windows, sports goods and ammunitions.

The debates

In recent months there has been a surge of public and government interest in this technology. There are debates about the likely trajectory of the technology (covering what areas will be developed and the likely timeframe), calls for more regulation, and for greater involvement of the public in understanding and shaping its application.

Potential trajectory of the technology

Some proponents of nanotechnology make radical claims for its likely success and impact on every dimension of our lives. For instance, Eric Drexler, author of an early and influential book, *Engines of Creation* (1986), introduced a broad audience to the promise and dangers of advanced nanotechnologies. The Foresight Institute he founded and directs continues to argue for the possibility of molecular manufacturing that will be able to control the structure of matter based on molecule-by-molecule control. This will lead to such things as new materials and capacities, enhanced health, and the potential to remove environmental wastes and heal damaged environments.

This radical view of the technology can also be detected in some US governmental reports. For instance, the National Science Foundation report on a 2002 conference, *Converging Technologies for Improving Performance*, also offers the vision of:

- expanding human cognition and communication (through enhancement of the human mind)
- improving health and physical capacities (via nanobio processes, nanotechnology-based implants and regenerative biosystems, nano-scale tools and brain-to-brain and brain-to-machine interfaces)
- enhancing group and societal outcomes (via various new technologies)
- strengthening national defence (through such developments as uninhabited combat vehicles and non-drug treatments to enhance human performances).

Some scientists are less inclined to see such a radical development of the technology, and see exaggerated claims for the technology as unhelpful. There are nanotechnology researchers who are skeptical that scientists can overcome the constraints of scale and adequately manipulate the interactions that happen at molecular levels in the way that Drexler and his colleagues suggest. There is also skepticism that nano-scale machines can be made by scaling down macro-machines. While the goals of radical nanotechnology may be possible, this may be better achieved by looking at the design principles developed in nature rather than by the scaling down of mechanical engineering approaches. It may be that the time to develop some possibilities is longer than some would hope.

People's responses to the technology are in part shaped by their expectations of the trajectory it is likely to take – both the nature of the applications of the technology and the timeframes involved. Some accept the radical trajectory, see significant risks associated with the technology, and are reluctant to pursue a line of research that has too many potential dangers, whether this be physical and biological risk, or potential social impact. For instance, Bill Joy, co-founder and Chief Scientist of Sun Microsystems has pointed out:

…as with nuclear technology, it is far easier to create destructive uses for nanotechnology than constructive ones. Nanotechnology has clear military and terrorist uses, and you need not be suicidal to release a massively destructive nanotechnological device … We are being propelled into this new century with no plan, no control, no brakes. Have we already gone too far down the path to alter course? I don't believe so, but we aren't trying yet, and the last chance to assert control – the fail-safe point – is rapidly approaching. We have our first pet robots, as well as commercially available genetic engineering techniques, and our nano-scale techniques are advancing rapidly. While the development of these technologies proceeds through a number of steps, it isn't necessarily the case as happened in the Manhattan Project and the Trinity test that the last step in proving a technology is large and hard. The breakthrough to wild self-replication in robotics, genetic engineering, or nanotechnology could come suddenly, reprising the surprise we felt when we learned of the cloning of a mammal.

For others, perhaps expecting a less radical and rapid development of nanotechnology, the issues can be managed through appropriate engagement by scientists with the public, and more research into the environmental and health impacts of the technology, leading to appropriate regulation.

Calls of regulation

There have been a number of calls for more regulation of nanotechnology.

- **The Pacific Research Institute's** report in November 2002, *Forward to the Future: Nanotechnology and regulatory policy*, discusses three possible regulatory futures for nanotechnology: prohibition; limitation to military applications; or modest regulation with an emphasis on civilian research. The report argues that the last option provides the "greatest prospects for reaping nanotechnology's benefits while minimising any risks".
- **The UK Better Regulation Taskforce**, an advisory body, produced a report in January 2003, *Scientific Research: Innovation with controls*, which recommended the government should:
  - enable, through an informed debate, the public to consider the risks for themselves, and help them to make their own decisions by providing suitable information
  - be open about how it makes decisions, and acknowledge where there are uncertainties
  - communicate with, and involve as far as possible, the public in the decision-making process
  - ensure it develops two-way communication channels
  - take a strong lead over the handling of any risk issues, particularly information provision and policy implementation.

  The UK Government also received a report in June 2002, *New Dimensions for Manufacturing: A UK strategy for nanotechnology*, a report of the UK Advisory Group on Nanotechnology Applications.

  The UK government has now commissioned the Royal Society and the Royal Academy of Engineering to investigate the potential benefits and possible problems associated with nanotechnology and nanoscience, and the first meeting was held in July 2003.
- **ETC** is a group dedicated to the conservation and sustainable advancement of cultural and ecological diversity and human rights. It supports socially responsible developments of technologies useful to the poor and marginalised, and it addresses international governance issues and corporate power.

  In April 2003 ETC released an occasional paper *No Small Matter II: The case for a global moratorium – size matters!* This paper argues that in the absence of testing for health, safety and environmental impacts, governments should adopt a moratorium on synthetic nanomaterials that are being manufactured in the lab and in some cases commercialised.
- The May 2003 issue of ***The Ecologist*** journal has a number of articles highlighting the possibilities and challenges of nanotechnology. One article places nanotechnology in the context of the public debate about technologies, and proposes the steps to regulation that would follow any moratorium (safety protocols, international conventions, labelling, liability, patenting, arms control and clean production).

Public involvement in public discussions

There is wide recognition and some concern that the development of nanotechnology has the potential to reproduce some of the dimensions of the public debates on genetic modification. The UK Better Regulation Taskforce and ETC both place an emphasis on involving the public at an early stage of this technology.

Two recent reports add to this call.

- The UK's Economic and Social Research Council released a report in July 2003 (prepared by a team from the University of Sheffield) on *the Social and Economic Challenges of Nanotechnology.* This report identifies two tensions running through the debates: the extent to which nanotechnology, which is assumed to have a radical impact on society, will be utopian or have a more destructive potential; and whether the technology will have a positive economic benefit, or whether, on the grounds of environmentalism and social equity, there should be efforts to slow down or halt the development of nanotechnology.
- In July 2003 Greenpeace released a commissioned report, *Future Technology, Today's Choices*, written by Alexander Huw Arnall of Imperial College, University of London. This report aims to provide background information on nanotechnology, and the related areas of artificial intelligence and robotics. Greenpeace foresees valuable innovation, but also cause for concern. This report is their contribution to increasing public understanding of the technologies.

There are also calls for more research into the ethics of nanotechnology. For instance, Toronto researchers Mnyusiwalla et al[2] argue that if the ethical, legal and social implications of nanotechnology do not catch up with the speed of scientific development, nanotechnology may be derailed, and that there is a need to learn from the lessons of the debates about genomics and biotechnology. Their concerns include issues of equity (the distribution of benefits from the technology), privacy and security, environmental impact, and the acceptability of technologies that modify living systems in new ways.

The call for more discussion and regulation is welcomed by some, but there are also observations that some in the business community seem to feel that the less talk the better, and that researchers should exert more effort into putting the risks posed by their work in the proper perspective. Still others are inclined to characterise the debate as "between academic scientists on one end, and the fringe on the other, which is not productive[3]. There is some anxiety expressed that the popular imagination, fed by publications such as Michael Crichton's novel *Prey*[4], will shape public opinion.

[2] Mnyusiwalla, A., Daar, A. & Singer, P. 'Mind the Gap': science and ethics in nanotechnology. *Nanotechnology* 2003, 14: R9-R13.

[3] C. Batt. Nanotechnology Center, Cornell University, as reported in press report from *Small Times,* 20 March 2003. URL: http://www.smalltimes.com/document_display.cfm?document_id=5693.

[4] M. Crichton. *Prey: A novel.* HarperCollins, 2002.

Discussion

Nanotechnology is a rapidly developing technology, with features that parallel developments in genetic technology. These include:

- developing New Zealand expertise and research investment
- expanding and high levels of international investment in both public and commercial research
- concerns over the safety of the technology, and little research on safety having been published
- the likelihood of considerable public concern about safety, and about the cultural and ethical dimensions of the technology. This is particularly so given the move towards the convergence of nanotechnology with biotechnology, neurological science, and information technology.

The technology has considerable potential. There is also uncertainty about the trajectory of its development, the possibility of environmental and safety issues, and the cultural challenges of a technology that may enable human enhancement and the merging of the human/machine interface.

It is important that New Zealand prepares well for this technology, and is positioned to capture its benefits, manage the risks, and address the cultural, ethical and spiritual dimensions of the technology. Among other things, this requires proactive attention to the regulatory environment in New Zealand to ensure it is robust and appropriate for dealing with both safety and ethical issues.

To that end, the Bioethics Council recommends that the Government:

- **notes the emergence of nanotechnology as a potentially socially contentious technology, as well as one with potential benefits**
- **notes the government initiatives in the UK, and in particular the current independent review of nanotechnology commissioned from the UK Royal Society and the Royal Academy of Engineering**
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