

**Nanotechnology - Ethical and Social Issues:
Results from New Zealand focus groups**

**Andrew J Cook
John R Fairweather**

**Research Report No. 281
December 2005**

Research to improve decisions and outcomes in agribusiness, resource, environmental, and social issues.

The Agribusiness and Economics Research Unit (AERU) operates from Lincoln University providing research expertise for a wide range of organisations. AERU research focuses on agribusiness, resource, environment, and social issues.

Founded as the Agricultural Economics Research Unit in 1962 the AERU has evolved to become an independent, major source of business and economic research expertise.

The Agribusiness and Economics Research Unit (AERU) has five main areas of focus.

These areas are trade and environment; economic development; business and sustainability, non-market valuation, and social research.

Research clients include Government Departments, both within New Zealand and from other countries, international agencies, New Zealand companies and organisations, individuals and farmers.

Two publication series are supported from the AERU Research Reports and Discussion Papers.

DISCLAIMER

While every effort has been made to ensure that the information herein is accurate, the AERU does not accept any liability for error of fact or opinion which may be present, nor for the consequences of any decision based on this information.

A summary of AERU Research Reports, beginning with #242, are available at the AERU website www.lincoln.ac.nz/aeru/

Printed copies of AERU Research Reports are available from the Secretary.

Information contained in AERU Research Reports may be reproduced, providing credit is given and a copy of the reproduced text is sent to the AERU.

Nanotechnology - Ethical and Social Issues: Results from New Zealand focus groups

**Andrew J Cook
John R Fairweather**

December 2005

Research Report No. 281

**Agribusiness and Economics Research Unit
P O Box 84
Lincoln University
Canterbury
New Zealand**

**Ph: (64) (3) 325 2811
Fax: (64) (3) 325 3847
<http://www.lincoln.ac.nz/AERU/>**

**ISSN 1170-7682
ISBN 0-909042-65-9**

Contents

PREFACE.....	III
SUMMARY	V
ACKNOWLEDGEMENTS	IX
CHAPTER 1 RATIONALE, OBJECTIVES AND OVERVIEW OF NANOTECHNOLOGY.....	1
1.1 Background and rationale for the study	1
1.2 Overview of nanotechnology and its potential	3
1.3 Current examples of nanotechnology	4
1.4 Rationale, aims and objectives.....	9
1.5 Plan of the report.....	9
CHAPTER 2 METHOD.....	11
2.1 Introduction.....	11
2.2 The focus group method	11
2.3 Panel focus groups and nanotechnology.....	12
2.4 Recruitment.....	12
2.5 The groups.....	13
2.6 Plans for the sessions	13
CHAPTER 3 RESULTS.....	17
3.1 Introduction.....	17
3.2 Group one - Session one: Introductions.....	17
3.3 Group one - Session two: Introduction to nanotechnology.....	19
3.4 Group one - Session three: Nanotechnology examples	20
3.5 Group two - Session one: Introductions.....	24
3.6 Group two - Session two: Introduction to nanotechnology	26
3.7 Group two - Session three: Nanotechnology examples	29
3.8 Group three - Session one: Introductions.....	34
3.9 Group three - Session two: Introduction to nanotechnology	38
3.10 Group three - Session three: Nanotechnology examples	40
3.11 Group four - Session one: Introductions.....	42
3.12 Group four - Session two: Introduction to nanotechnology.....	44
3.13 Group four - Session three: Nanotechnology examples.....	46
CHAPTER 4 SUMMARY, IMPLICATIONS AND CONCLUSION.....	51
4.1 Introduction.....	51
4.2 Limitations	51
4.3 Summary and discussion of results.....	51
4.4 Implications.....	53
4.5 Recommendations	55
4.6 Conclusion	55
REFERENCES.....	57
APPENDIX.....	59

Preface

The technological advancements offered by nanotechnology will shape the lives of ordinary New Zealanders. It is therefore important to take account of what the public thinks so that science, industry, government and New Zealanders themselves can consider the social impacts of nanotechnology. The AERU has for some time been involved in researching public reactions to biotechnology. Our national focus groups and surveys have shown what New Zealanders think about various biotechnologies and have presented many important reasons for their views. This report presents the first New Zealand research on public reactions to nanotechnology and will be of value to those interested and involved in the ethical and social aspects of nanotechnology.

Professor Caroline Saunders
Director

Summary

Rationale

There is a need to gauge and understand public reactions to nanotechnology so as to usefully inform science and industry.

Aims and objectives

The overall aim was to inform the development and implementation of nanotechnology applications through developing an understanding of relevant public reactions.

Necessary objectives were as follows:

- Investigate and identify salient attitudes, beliefs, views and values arising from possible developments of nanotechnology.
- Identify and compare reactions to particular applications as well as an overall attitude towards nanotechnology.
- Understand ethical and social reactions to, and implications arising from, a range of nanotechnologies.
- Provide guidance for processes of interaction between scientists, policymakers and the public.

Method

Panel focus groups were used to investigate reactions to nanotechnology because of the novelty and diverse nature of the topic.

Adult participants were solicited using local primary schools that were selected to represent a range of levels of personal income for those living in the school zone.

Each group met three times during the months of June to November, 2005. Overall, there were a total of 40 participants with ages ranging from 25 to 72, of which nine were male.

The groups were facilitated with a general plan involving the introduction of topics and use of educational material. Apart from these forms of standardisation, the method encouraged the facilitation of discussion of emergent themes.

An introductory session involved consideration of examples of topical issues involving science and technology. The second session used an educational video to familiarise participants with nanotechnology followed by discussion of everyday actual commercial products that incorporated nanotechnology. The third session used six examples of examples of nanotechnology that may occur in the next 25 years to prompt discussion.

Key results from the first session

- Some public information campaigns were seen to be as biased and participants expressed a need for balanced information.
- There was evidence of a thoughtful process of weighing up advantages and disadvantages which included consideration of personal cost and social benefit.
- It was a concern that once the public accepted one particular use of a technology then further unacceptable use would occur without public consultation.

- In the face of conflicting information, decisions for some were based on feelings.
- It was considered that less controversial technologies could be used instead of techniques such as cloning.
- The possibility of unknown harmful outcomes was an important concern.

Key results from the second and third sessions

- The possibility of medical advances from nanotechnology was praised but these raised moral and ethical concern involving objections to eugenics.
- Scientists were perceived to focus on the science while disregarding social outcomes.
- There was concern that nano-particles could become pollutants.
- Nanotechnology was seen to be driven by money as opposed to serving social interests.
- It was considered unlikely that medical applications of nanotechnology would replace the human touch of a trusted health professional.
- The possibility of medical self diagnosis using nanotechnology was considered convenient and cost effective although the possibility of paranoia and hypochondria were also mentioned as negative consequences.
- Replacement body parts were talked about favourably but there was ethical concern over the improvement of human abilities.
- Nano-particles in food to add flavour were considered unusual and it was thought that consumers may not buy the products. In addition, the possibility of harmful consequences to the human body and the environment were raised in response to this example.
- The use of a direct interface between the human brain and a computer prompted concern that the human qualities of a person would be lost in the process of augmenting or transferring neural activity.
- The consideration of nano-particles with a single moving part in toothpaste was not considered particularly offensive or revolting, although concern was expressed about their effects on the human body and the environment.
- Sophisticated self-replicating nano-machines for cleaning up toxic waste and oil spills were considered in a ‘matter of fact’ way. The general view was that possible problems of uncontrolled replication and unexpected environmental damage would have to be addressed.

Implications

The following key implications derive from a number of concerns about the development and implication of nanotechnology.

- Concern that nanotechnology could become problematic in both foreseen and unforeseen ways suggests calls for a precautionary approach could be made against nanotechnology. Similar calls preceded the legislation that has made GM research difficult and expensive in New Zealand.
- The results suggest a public need for unbiased information and there is distrust of the media as a provider of impartial information. In addition, in response to conflicting information some tend to form their views based on their feelings rather than a consideration of views and viewpoints.
- There was apparent feeling of betrayal upon finding of the potential for harmful consequences after receiving a positive presentation about nanotechnology.
- The method of science was perceived by some respondents as involving the ‘value free’ pursuit of knowledge with a necessary exclusion of moral or ethical concerns.

- There was concern over the motives of scientists and concern that the commercialisation of the technology was primarily for the purpose of making money above other possible goals such as social well-being or, as some participants put it, the pursuit of ‘happiness’.
- There was a general appreciation of the benefits of various examples of nanotechnology, but some examples were seen to be unnecessary.
- There was an expectation that scientists and the government and its agencies will have to deal with the actual and potential risks associated with particular applications of nanotechnology.

Recommendations

It was recommended that a strategy for nanotechnology development and implementation include public consideration of both risks and benefits, and, to include New Zealanders in a responsive and deliberative process towards ensuring nanotechnology developments do not conflict with social attitudes and values.

Conclusion

There is a need to utilise social research to inform and guide the development of nanotechnology and its introduction to the New Zealand public and avoid nanotechnology becoming problematic by identifying challenges to the views and attitudes of the public. There is presently time and opportunity for science to offer knowledge and tools that are aligned to the needs and prospects of New Zealanders.

Acknowledgements

Acknowledgement is given to the focus group participants who provided their time for this research and the schools and fund raising committees who helped organise the focus groups.

This research was funded by the MacDiarmid Institute for Advanced materials and Nanotechnology.

Chapter 1

Rationale, Objectives and Overview of Nanotechnology

1.1 Background and rationale for the study

In recent years scientists from various disciplines have probed the molecules and atoms that make our world. This has led to the discovery of new structures and properties of matter at a very small scale. Using specialised microscopes individual atoms and molecules can be identified and tools and techniques have been developed to move atoms and molecules. At this scale, it has been found that materials can behave very differently from when they are in larger form. With such discoveries comes the prospect of making use of the new properties to make useful new products and processes. The resulting new technology is regarded by many as a key factor in a revolution that may lead to general improvements in the quality of life.

Science and engineering at an extremely small scale is called 'nanoscience' and 'nanotechnology'. The terminology is derived from the nanometre which is a measurement of a millionth of a millimetre or about one eighty thousandth the width of a human hair. In consequence, nanoscience is concerned with the study of extremely tiny objects. This has led to the development of new materials with some being stronger or lighter, or good conductors of heat or electricity, because of the way their molecules and atoms are assembled. For example, carbon nanotubes, made from carbon atoms, have strength characteristics similar to diamonds and, like graphite, are good conductors of electricity. Such a discovery shows that by controlling the way in which atoms and molecules form tiny structures, it is possible to design and develop new materials with specified properties.

The developing nanotechnology is expected to eventually join with, and further enhance information technology and biotechnology and create a new generation of products and services that will make a positive contribution to the way people live their lives (e.g., Anton, Silberglitt & Schneider, 2001; Dewick, Green & Miozzo, 2004). At this stage in the development of the new technology there have been few studies of public reactions to nanotechnology. Nevertheless, the few studies of public reactions have reported optimism, for example, an internet based survey conducted in 2001 found most respondents were very positive (Bainbridge, 2002). Similarly, a national phone survey conducted in the U.S. (N = 1,536) found that initial reactions to nanotechnology were positive and linked to a positive view of science (Cobb & Macoubrie, 2004). This survey also found that respondents tended to expect benefits to be more prevalent than risks and were particularly positive about the use of nanotechnology to detect human diseases. Negative outcomes were the use of nanotechnology in personal surveillance and concern that business leaders could not be trusted to minimise risks to public health.

Other relevant research on attitudes towards nanotechnology has been conducted by BMRB Social Research (2004) for the Royal Society and Royal Society of Engineers Working Group. This research employed two workshops (23 participants in London and 27 participants in Birmingham) and door to door interviews (N = 1,005). A shortcoming with the interviews was that they contained only three questions about nanotechnology. In addition, scientists were involved in the workshops in recommending the information provided to the participants and in interaction with the workshop participants. This meant that the participant responses may have been influenced tacitly or otherwise by the scientists. Nevertheless, the results show that while there was interest in the prospects for new medical treatments from

nanotechnology there also was concern over impacts that the technology could have on employment, social freedom and personal control. Also, long term unintended effects were of concern. The interview survey found that a reasonably high percentage (29 per cent) had heard of nanotechnology.

As the BMRB workshop results suggest, the new technology may well be associated positive benefits but the introduction of novel technologies to society can be problematic. This is because new technologies can challenge cultural norms and ethical practices, and raise public concern over foreseen and unforeseen risks. In this context nanotechnology is potentially looming as the next technology to incite controversy, given that they may be perceived to have impacts on, for example, public health and the environment. Nanotechnology has the potential to bring social benefits, yet some applications could become problematic. This means that it is possible that some nanotechnology applications could suffer problems related to public perception and acceptance that occurred with the development of biotechnology.

The history of public acceptance of genetic modification (GM) shows there has consistently been a good deal of concern over this novel biotechnology. A review by Cook, Fairweather and Campbell (2000) found that prior to 1995 studies of public reactions showed that New Zealanders were not predominantly averse to the use of GM in food production. However, a more recent review showed that over time the public had developed a predominantly negative attitude towards the use of GM in food production (Cook, Fairweather, Satterfield & Hunt, 2004). The Royal Commission on Genetic Modification (2001), for example, found most people that responded to a national survey had disapproved the use of gene technology in processed foods and agriculture. More recently, Cook and Fairweather (2005) showed that a small decline in negative attitudes had occurred but aversion still remained substantial. A similar trend had been observed in the U.S which Bonny (2003) linked to the rise of strong opposition in Europe with government debate and government moves to regulate biotechnology activity. Similarly, it could have been the investigations of the Royal Commission and the consequential increase in attention in the popular media that had contributed to increased aversion in New Zealand. Clearly GM failed to gain public acceptance and importantly, while the Royal Commission did not rely solely on public opinion, it recommended caution in the development and use of genetic modification. This was followed by the addition of further regulatory hurdles and constraints on GM from the perspective of those promoting the technology.

High levels of public aversion and restrictions on the use of GM can arguably serve as a lesson for nanotechnology. At this stage in its development the rough road that GM has ridden would be best avoided. The fate of nanotechnology then rests with the ability of various institutions to gauge and respond to public views and values. Essential to this proactive approach is the utilisation of detailed social research to usefully inform and guide the development of nanotechnology and its introduction to the New Zealand public.

To identify how the public is currently responding to nanotechnology the research presented in this report focused on identifying the relevant views and values that ordinary New Zealanders have regarding nanotechnology. Thus the project was intended to perform the primary functions of problem identification and problem definition necessary for informing research and development and giving direction to policies and processes to recognize, take account of, and ideally include human and societal issues.

1.2 Overview of nanotechnology and its potential

Nanotechnology is an area of technological innovation which will likely produce its own new developments, but is most immediately set to compliment and enhance information technology and biotechnology while enabling incremental improvements in industry with subsequent commercial benefits (Dewick, Green and Miozzo, 2004; Anton, Silbergliitt & Schneider, 2001). The expected timely enhancement by nanotechnology of computer capacity and processing power is readily envisaged at a time when the hardware that enables information technology is reaching its natural limitations. It is also readily foreseen that nanotechnology can be usefully applied to assist biotechnology in its quest to utilise organic material in the development of new processes and products. One aim is to study the molecules of living cells and to build nanoscale devices to help diagnose and cure diseases. More generally the new techniques and processes developed for nanotechnology are starting to assist in the investigation of biological processes at a molecular level. In addition, and more generally, nanotechnology is expected to enhance material processes for various industries and enterprises. Nanotechnology is therefore expected to have a large pervasive impact through enhancement of recent technological innovations and improvements to commercial activity through improvements in industrial processes.

The recent attention given nanotechnology has resulted from the development of specialised tools and techniques. A necessary initial development was the development and dissemination of tools and techniques for nanoscience. As Wood, Jones and Geldart (2003) pointed out, science has fuelled developments in technology and in turn technology has then enabled advancements in science. For example, Ratner and Ratner (2003) explained that by the year 2000 various tools became readily available and manufacturing techniques were mastered to enable observation, measurement and manipulation at the nanoscale. They also provided examples of tools and techniques which quickly diversified. Scanning probe techniques, for example, have provided information at the molecular scale using various methods for measuring adhesion, energy, friction, magnetic domains, and surface elasticity. In addition, the same tools and techniques have been used to manipulate and arrange individual atoms. Other enabling technologies include microlithography and micro engineering systems that enable the production and etching of nanoscale layers of material and have been used as templates for further replication at the nanoscale. The production of synthetic molecules from chemistry is mentioned as another technique that is concerned with composition and structure at the nanoscale. In addition, techniques involving rudimentary self assembly have involved making molecules that have the propensity to bond and form larger structures. This form of self assembly has been used for the purpose of forming complex structures with particular properties.

An associated factor in the development of the new science and technology has been the blending of a number of scientific disciplines. The necessary knowledge and skills have come principally from the modern physics and chemistry, with necessary contributions from materials science and molecular biology. Most of the work has been in the development stage, at the level of nanoscience, and is primarily undertaken by universities and research institutes. This research tends to be funded by government, and often involves long-term projects for the advancement of knowledge.

Initial investment has been substantial, for example, by 2004 US President Bush had authorised \$3.7 billion to be spent over four years on nanotechnology research initiatives and Japan had budgeted \$875m in government funds (Thuermer, 2004). Interest and funding from the private sector is also substantial fuelled by the prospects of commercial opportunity extending from a new development or discovery. Private funding of research is therefore

primarily directed at enabling the utilisation of nanotechnology in industry-scale production. When private funding does extend into the funding of the developmental stage, such funding is generally prudently targeted at the extension of existing techniques and knowledge where material results are more readily realised. Major corporates, such as Hewlett Packard and IBM, for example, have devoted approximately one third of their research budgets to nanotechnology (Dewick, Green & Miozzo, 2004). Nevertheless, nanotechnology is dependant upon nanoscience for innovative discoveries and developments which extend from scientific enquiry into the nature and properties of substances at the nanoscale.

In keeping with financial support there is a general expectation and enthusiasm that new and innovative products and processes will be created using nanotechnology that will have positive implications for people's lives. Yet there are a number of factors which make it difficult to predict what particular applications will emerge as well as the particular impacts these might have. One factor discussed by Arnall (2003) is that materials and processes that may be developed are the result of a technology push rather than being determined by the general needs of society. In other words, it is expected that nanoscience will make discoveries about the workings of things at the nanoscale that will lead to the development of useful technologies. As the US Committee for the Review of the National Nanotechnology Initiative (2002:4) stated in considering recent discoveries: "Nanoscale science and engineering seek to discover, describe, and manipulate those unique properties of matter at the nanoscale in order to develop new capabilities with potential applications across all fields of science, engineering, technology and medicine." However, while presumably benefiting society, research is not necessarily targeted at making a particular product or solving a particular social problem.

1.3 Current examples of nanotechnology

While there are a number of products and industrial processes that have been enhanced by nanotechnology, these are few compared to the number of innovations that are expected. At present there are a number of products available to consumers that incorporate nanotechnology. According to the International Nanotechnology Business Directory (www.nanovip.com; accessed 4/4/2005) and the Federal (US) Funded National Nanotechnology Initiative (<http://www.nano.gov> accessed 4/4/2005), the following commercially produced consumer products have been made using nanotechnology.

- Ski wax particles that are organised automatically on the ski surface.
- Glass that self cleans.
- Improved tennis rackets and tennis balls.
- Emulsion form of commercial disinfectant.
- Golf ball that reduces hooks and slices.
- Indoor air purifier powered by light.
- Shoe inserts with increased insulating properties.
- Golf driver with more resistance to bending and increased golf ball flight distance.
- Sunscreens and cosmetics, and skin care products to combat the effects of aging and skin disorders.
- Bumpers on cars, automobile catalytic converters and coatings on automotive glass that repel rain and dirt.

- Paints and coatings to protect against corrosion, scratches and radiation.
- Stain-resistant clothing.
- Display screens with brighter images, lighter weight, less power consumption and wider viewing angles for computers, cell phones media players and other uses.

These early products of nanotechnology have tended to use nanoparticles as composite materials in a production processes. Wood, Jones and Geldart (2003) explain that such applications are generally for the purpose of making materials stronger, lighter and more durable. For general use in the automotive industry, materials are being developed for packaging and the aerospace industry. Some nanoparticles have been found to be highly effective catalysts for improving the manufacture of plastics. In this manner the use of nanotechnology is expected to initially involve improvements in the performance of existing components, with the prospect of the new materials enabling new designs to further advance on existing technologies.

Nanotechnology is expected to make significant advances in medicines and health care and treatment. Two general areas of immediate advancement are techniques to aid in diagnosis and the delivery of drug treatment with further ready developments in the area of artificial implants developed using nanotechnology. The development of a 'lab on a chip' means that smaller samples can be processed more quickly which holds the prospect for self monitoring of personal health and other new sensor-type monitors are also envisaged. Drug delivery is also likely to benefit, particularly through controlling the release of a drug to a specific target area within the human body. In addition to these advances, new materials are also likely to become commonplace in implants with immediate benefits for orthopaedics (Salata, 2004).

Nanotechnology is also likely to be introduced into more commonplace areas of everyday life. For example, food is also likely to be enhanced initially through flavour enhancement and by making nutrients more readily available (Ross et al., 2004). In addition, the technology has been readily taken up by the cosmetics industry with shampoos and skin creams improved to increase absorption into the skin and sunscreens made to be more effective (Wood, Jones & Geldart, 2003). In addition, for identification pets have been implanted with nanoscale markers. This implant technology has been offered to people to use for recording payment and for verifying security clearance (Laurent & Petit, 2005).

In more general review Wood, Jones & Geldart, (2003) show the wide ranging possibilities for nanotechnology. For example, they relate that in the US a good deal of funding is being provided to the military to improve defence and security. Examples of applications under investigation include sensors for the detection of chemical and biological agents and lighter and stronger weapons. In addition, it is pointed out that improvements to the protection of the environment are like to come from improved filters to clean pollutants from air or water. Hydrogen fuel cells are also envisaged as a cleaner source of fuel and a way of reducing reliance on current energy sources. Similarly the use of solar energy is expected to become more efficient through enhancement of current technologies and the development of new techniques for utilisation of solar energy such as using solar energy to manufacture hydrogen. Ultimately these developments would lead to less reliance on fossil fuels and the use of a cleaner source of energy.

In order to provide more details about the future of nanotechnology the remainder of this section considers two of a number of possible paths for development.

Nanobots and grey goo

The possibility of automated machines operating at the nano scale was envisaged early in the history of nanotechnology, first by Feynman and later by Drexler. Feynman (1959) promoted the science of the small to both scientists and the public and Drexler (1986) provided further encouragement which included the prediction of nanoscale devices capable of complicated operations. Drexler (1986) predicted capabilities of nanotechnology machines which included repairing cells in the human body, self-replication and the manufacture of other nanodevices. Such devices termed 'nanorobots' and often termed 'nanobots' have been predicted to result from the sophisticated and precise control of individual atoms and molecules for the formation of complex functional structures.

This vision of purposeful self-replicating nanobots has caught the imagination of writers and the public. The vision gave rise to the term 'grey goo' which came from Drexler (1986) who described what could occur over the surface of the earth if self-replicating nanobots became rampant. In public media the idea has been popularised, for example, the Prince of Wales was accused of inappropriate public use of the term in 1994 when urging caution in developing nanotechnology (BBC News - <http://news.bbc.co.uk/1/hi/sci/tech/3883749.stm>: accessed May 23rd 2005).

Drexler (1986) had envisaged the less controversial prediction that new technology would reach the stage of making materials with new properties by arranging atoms and molecules. However, while not absolutely impossible, sophisticated self-replicating nanobots envisaged by Drexler (1986) are regarded by many as an improbable development. Indeed, Drexler has since pointed out that it would be inherently safer and more feasible to produce nanobots using specialised nano-size assemblers (Phenex & Drexler, 2004). The assemblers were envisaged as being under control as they could not be moved, would not be self replicating, would be unable to mutate and would have to be provided with raw material rather than drawing material from their environment. Under this scenario self replication is not necessary as making the assemblers would be like the more conventional tooling of a factory to assemble particular manufactured goods. Of importance, a key imperative for favouring factory type assemblers was the possibility of Drexler's (1986) scenario of the uncontrolled large scale use of resources by nanobots which would result in 'grey goo'. For Drexler and his associates who envisage nano-scale manufacturing systems the development of mobile self replicating nanobots that thrive in the natural environment would be undesirable and difficult though not impossible to produce. 'Grey goo' is then a scenario of devastating proportions which requires the specialised highly sophisticated nanobots that are presently neither feasible nor wanted.

Indeed, despite the grey goo scenario being extremely unlikely, popular fiction has capitalised on the idea of nanobots. In a modern story in the vein of Frankenstein, Michael Crichton's novel 'Prey' had self-replicating nanobots preying on their human makers with a collective will and intelligence comparable to that of their victims (Crichton, 2002). The novel can be criticised for capitalising on a most terrible and most unlikely outcome of nanotechnology, but it nevertheless also presented the form of manufacturing that Drexler envisaged.

Fictional scenarios involving nanobots were likely inspired by Drexler (1986) and suggest popular culture is being influenced by the idea of a nanotechnology involving tiny yet sophisticated machines. However, nanotechnology is somewhat divided on the possible realisation of the scenario for nanotechnology envisaged by Feynman (1959) and Drexler (1986). Professor of chemistry, physics, and astronomy, R. E. Smalley, for one, does not consider the Drexler (1986) vision possible because of seemingly insurmountable difficulties

in making and operating molecular assemblers (Smalley, 2001). In support of this opposition, contemporary accounts of possible near future developments often involve the use of nano-scale materials, sensors and electronic components (e.g., US Committee for the Review of the National Nanotechnology Initiative 2002:6). However, although molecular assembly was a possibility for Anton, Silbergliitt & Schneider (2001:36), it was envisaged to be realised only after intensive development with little social opposition. More recently, from a science perspective, Brown (2004) has explained that molecular assembly devices are a remote possibility given current difficulties in working on simple nano-scale objects. Arguably, concern about the potential dangers of nanotechnology is not warranted given current and foreseeable developments in nanotechnology. Nevertheless, the popularisation of the 'grey goo problem' suggests that the problem, even if lacking substantiation, may well have to be recognised as an actual public concern.

Linking people to computers

Another vision of seeming fantasy regarding nanotechnology is a belief that nanotechnology will eventually lead to the development of cybernetic humans. The term 'cyborg' has been used to describe the symbiotic relationship between a human being and a machine which has been used to describe a person's use of technology (e.g., Haraway, 1989). In modern context, the term has been commonly used to refer to a human whose body function incorporates internal electromechanical devices. An example from popular science fiction was the character played by Arnold Schwarzenegger in the Terminator movies that had a computer brain, mechanical skeleton with human flesh and person-like characteristics. An early example, from the 1970s, was the *The Six Million Dollar Man* TV series which was based on a novel titled 'Cyborg' (Caidin, 1972), in which a man had damaged body parts replaced by mechanical devices (<http://en.wikipedia.org/wiki/Cyborg> accessed 27 May 2005). Such examples, from popular media portray a cyborg as having strength and ability better than those of other human beings.

Some distance from the capabilities of fictional characters, Kevin Warwick a Professor of Cybernetics at the University of Reading has experimented with cybernetic implants. As explained on his website (<http://www.kevinwarwick.com>, accessed May, 30th, 2005), a silicon chip transponder was surgically implanted in the Professor's forearm. This meant by sensing the chip signal a computer could operate doors, lights and heaters. His website explains that this use of technology has the capacity to impact on the public as it could be used to carry information about a person, for example credit card details, blood type or medical records. A more recent project involving Professor Warwick begun in 2002 involves an implant designed to send signals back and forth between the nervous system and a computer. Communication between people via implants and computer is also planned to investigate how movement, thought or emotion signals could be transmitted and received.

Llinàs and Makarov (2002) have considered constructing a brain-machine interface using a known procedure for guiding catheters to the brain. They expect that this technique can be adapted using nanotechnology to establish an interface for the monitoring and observation of brain activity. It is expected that current computer hardware would be sufficient but the programming would initially be demanding. This advanced technology is merely designed to be a novel way of observing brain activity, though two-way communication is mentioned as a future possibility.

Discussions of the possibilities for improving human performance through human machine interaction are detailed by Nicoletis (2002). Given the development of techniques for establishing a brain-machine interface it is expected that movement of an artificial limb or

restoration of body paralysis such as paraplegia would be an immediate benefit. It is also considered reasonable to envisage super-human capabilities through instructions to robot controlled mechanisms. A number of examples of this capability were discussed by Asher (2002) who pointed out that military applications, such as fighter aircraft operation, could be advantaged by faster transmissions of commands from a pilot to the aircraft by not requiring body movement such as the pressing of a button. A third possibility presented by Nicoletis (2002) is simulated movement in a personally experienced virtual reality without the involvement of the normal senses. It is also envisaged that experience via virtual reality could function as a new medium for enhancing scientific enquiry, for example, to visualise and understand various scenarios envisaged in psychics.

The construction of a working brain-machine interface is also expected to enhance human potential. Based on the common expectation of improved computing power through nanotechnology Caulder and Penz (2002) envisaged a greater understanding of brain function. This understanding was expected to lead to the development of computational systems that would have human-like intellectual capabilities, such as consciousness and independent thought. While artificial neural networks and initial designs of quantum computers have been found to have limitations for supporting artificial intelligence, it is expected that through the use of nanotechnology new suitable adaptations or designs will emerge. Importantly, this is not expected to involve the development of a completely programmable system, but rather mentored development of an artificial intelligence that could be taught much like the teaching of a child is envisaged. In this way it is thought that an android or robot could be developed that resembles a person, at least in terms of having the ability to similarly think and reason, while not necessarily having the capacity for computer like computational tasks.

Problems and risks

Nanotechnology brings the prospect of new useful products and processes but radical departures from traditional technology can be unwelcome. As Hansen (1993) explained, on the one hand, as a new research speciality change tend to occur within traditional research institutions. For this scenario a new focus on materials within traditional disciplines such as chemistry and physics would result in change principally within an institution. A more fundamental change, with wider ramifications, would be the realisation of nanobots. Although less likely, according to Hansen (1993) this would bring a large, sudden and destabilising change with wider social ramifications. Nevertheless, in the less radical form of a new materials science, the benefits of nanotechnology are becoming better known, but there is also increasing consideration of potential negative effects. From a recent workshop on risk analysis for nanotechnology (European Commission on Community Health & Consumer Protection, 2004), for example, the following are negative effects that were put forward for discussion.

- Exacerbation of global inequalities.
- Heightened optimism and pessimism.
- Acute and chronic health effects.
- Adverse environmental effects.
- Increased government control.
- Threats to privacy.
- Increased militarization.

1.4 Rationale, aims and objectives

Nanotechnology is an emergent technology that appears set to enhance society and the lives of everyday people. Despite the prospect of benefits it cannot be entirely ruled out that its introduction to the public would be problematic, especially given recent public controversy over the use of GM. A problem for this biotechnology has been that public reactions are being understood only after developments had made considerable progress, somewhat ahead of public opinion. It would seem prudent to gauge and understand public reactions to nanotechnology, so as to usefully inform science and industry as well as resource policies, programmes and projects to inform the public.

The overall aim of this research was to inform the development and implementation of nanotechnology applications through developing an understanding of relevant public reactions.

Necessary objectives are as follows:

- Investigate and identify salient attitudes, beliefs, views and values arising from possible developments of nanotechnology.
- Identify and compare reactions to particular applications as well as an overall attitude towards nanotechnology.
- Predict ethical and social reactions to, and implications arising from, a range of nanotechnologies.
- Provide guidance for processes of interaction between scientists, policymakers and the public.

These aims and objectives will also be used to structure a national survey to be undertaken in 2006.

1.5 Plan of the report

The following is a brief overview of the remaining chapters of this report.

Chapter 2 describes the design of the quantitative enquiry using focus groups.

Chapter 3 presents the qualitative results and their interpretation.

Chapter 4 begins with a discussion of the results and practical implications are then identified. The chapter closes with conclusions and recommendations for further research.

Chapter 2

Method

2.1 Introduction

Focus groups were used to identify salient attitudes, beliefs, views and values arising from possible developments of nanotechnology. This chapter begins with a discussion of the merits of using focus groups recruitment is then explained and a general plan for the focus groups is provided.

2.2 The focus group method

The focus group method is one of a number of research methods for studying individuals or small groups of people in depth. As a method its principle purpose is to develop a comprehensive account of the understanding that people have about the topic under consideration. The method is also a useful preliminary tool to aid in the development of a quantitative questionnaire and is also a useful analytical tool for the preliminary investigation of an under-researched area (Babbie, 1998). Focus groups can also be used to test or develop hypotheses and provide the opportunity for the exploration of insights into attitudes towards a thing or person that may not have been previously considered by the researcher.

Focus groups are often preferred over other qualitative methods, such as participant observation or in-depth interviews, because they take less time and are less costly (Babbie, 1998). Focus groups are also conducive to the consideration of a new issue or topic, because participants can build on the ideas of other group members. In addition, the flexibility to explore topics and to generate ideas it is a particular strength of the method (Morgan, 1988).

Disadvantages of focus groups are that they can be difficult to control; responses to questions may be indirect and difficult to analyse; questions are often rephrased and a degree of ambiguity can be introduced that may lead to difficulties in interpreting responses (Greenbaum, 1998). An often cited criticism is that the results of focus group discussions are seldom representative of a wider population. However, using focus groups for the design and construction of a quantitative survey can address the problems of representativeness and external validity (Knap & Propst, 2001). Nevertheless, summarising large amounts of conversation data can be difficult and there is potential for a variety of different interpretations (Stewart & Shamdasani, 1990). Focus groups usually comprise six to 12 people and involve guided discussion. Groups of smaller numbers may not be large enough to encourage elaboration on the topic and larger numbers can cause some participants to be bored or frustrated if they do not have the opportunity to speak (Babbie, 1998). More than one focus group is usually undertaken, as a single group may provide a limited range of views on a topic.

For familiar topics, a precise set of questions can be used to shape the discussion. Alternatively, if the research is exploratory, or there is a lack of prior research in a given area, a general plan can be sketched out around which the discussion develops. This means that such exploratory research is never fully prescribed because it is expected that additional topics and lines of discussion may emerge. Using this approach the focus group is essentially a discussion group in which a moderator helps to focus the discussion on a research topic.

There is usually a general plan of inquiry, but generally no specific set of questions are asked in a particular order to suit the way a discussion evolves (Morgan, 1988).

If the purpose is to help develop material for constructing a questionnaire for which there is no previous research, flexibility is essential. Focus groups can be useful in adapting instructions and questions to the language of the recipients. For the purpose of questionnaire construction, focus groups facilitate examples of lay language expression with the opportunity of probing for the meanings of words. This enables the refined development of survey questions and serves to guide interpretation. Focus groups can also be used to enhance reliability by better matches of response scales to how respondents actually evaluate (Wade, 1998). In addition, for survey questionnaires that contain professional and technical terminology, focus groups can serve as a check for comprehension.

2.3 Panel focus groups and nanotechnology

Focus groups were selected as the preferred method for an initial study of reactions to nanotechnology largely because of the novelty of the topic. Given the expectation of unfamiliarity, focus groups can provide the opportunity for people to learn and jointly explore a topic through building on the insights and ideas of the other participants. The technique of using a general plan for the groups to facilitate the emergence of topics and themes of relevance to participants was also considered appropriate for the topic.

The possibility of quite different lines of discussion emerging in different groups led to the decision to use more than one group with the number constrained by the available budget. In addition, it was judged that there would be limited time for the discussion of a less than well known, diverse and technical topic if only one meeting was held. A remedy for this expected problem was the use of panel focus groups, that is, having the same people meet more than once was planned to ease participants into the topic. Therefore, the problem of novelty of the topic was addressed by the novel use of more than one meeting for each group. This enabled sufficient time for instruction regarding the science behind nanotechnology and time to become familiar with and discuss various recent examples and expected future developments.

It was decided that three meetings would best suit the situation. The first meeting served as a primer, involving the consideration of topical local issues involving science and technology generally. The second session was necessarily an introduction to nanotechnology in broad form. It involved more education than discussion with the showing of the 'Nano: The next dimension' educational video and discussion of a list of examples of products that incorporate nanotechnology. The third and final session was used to discuss various current and possible future applications of nanotechnology, in a manner much like the topical issues discussed in the first session, and to elicit concerns about nanotechnology.

2.4 Recruitment

Four Christchurch primary schools provided adult participants for four focus groups. This method was used primarily for convenience and has the advantage of encouraging group cohesion through bringing together participants who have a common interest or may be known to each other. The method could be criticised for introducing a bias of a common interest, but the method had the advantage of recruiting ordinary New Zealanders engaged in family life.

A payment of \$300 was provided to the schools for providing a venue and soliciting volunteers. To best use the available budget all four schools were located in Christchurch. The schools were selected to represent the range of decile ratings. Decile ratings are ratings based on the level of income for those living in school zone. The ratings do not accurately represent the income of families with children attending a school, but served to guide the selection of schools based on local measure of income. The participating schools generally conformed to the range of decile ratings. However, to preserve anonymity neither the decile ratings for the participating schools or the names of the schools are provided in this report.

Contact with prospective schools was first made by telephone and in each case contact was made with a school representative who was involved in school fundraising. After a brief explanation this person was sent a letter of explanation and information sheets for distribution to prospective participants. The school representative was directed to source prospective participants from people involved with the school or who lived in the local area. It was requested that a balance of gender was desirable as well as participants of various ages. It was also explained that it was not essential for participants to have children that attended the school. In all cases approval for school involvement was given by the school principal. The day and time of the meetings was chosen by each group.

2.5 The groups

The four groups had their meetings from the months of months of June to September, 2005. The facilitation of all the focus groups was conducted solely by the principle researcher. Each group met on their preferred evening once a week for three weeks. As planned each group had approximately 10 participants. Overall, there were a total of 40 participants of which nine were male. Age ranged from 25 to 72. Most respondents had children attending primary school and many were involved in fundraising for a primary school.

Overall, the highest qualification for most participants was a school qualification and most had a personal income of less than \$15,000, likely because many were females with young children and not in paid employment.

2.6 Plans for the sessions

The panel focus groups were facilitated with a general plan involving the introduction of topics and use of educational material. Apart from these forms of standardisation, the facilitator encouraged discussion of emergent themes and topics. This method was used to encourage joint exploration of personal reactions and sought to avoid prefiguring responses. Each session took between an hour and an hour and a half. Tea, coffee and fruit juice as well as chocolate and plain biscuits were provided for refreshment at the end of each session.

In addition to the materials provided in the sessions, all respondents were provided with a colour folder produced by the Agribusiness and Economic Research Unit which contained a pad and pen for taking notes. Other than the showing of the documentary, all information was provided to respondents in the form of a handout rather than using a data display or overhead projector. These materials were used to avoid a teaching or lecturing style of presentation.

With the consent of the participants all focus group meetings were tape recorded and, apart from the introduction by the facilitator prior to gaining the consent of the participants, all discussions were transcribed.

Plan for session one

The first session comprised an introduction to the focus groups followed by consideration of examples of topical issues involving science and technology. An A5 sized booklet was provided to participants. The booklet contained a summary of information about the purpose and aim of the meetings and briefly introduced the topic of nanotechnology. An explanation of how the groups would be conducted was provided as well as an outline plan of the three sessions. Details of payment were provided as well as notes that accompanied an explanation of the provision of consent.

Participants were asked to provide their consent in writing at this stage of the meeting and were then asked to introduce themselves and related how they came to be at the meeting.

The second and main part of the first session was the consideration of topical issues involving science and technology. The prompted debate and discussion of points of interest regarding topical issues was designed to serve as a primer for the later consideration of nanotechnology examples. Having participants grapple with familiar social issues involving science and technology was intended to instil confidence in the later consideration of scenarios involving nanotechnology, as if they were real issues.

The booklet following sixteen topical examples which have been the subject of continuing social research in New Zealand (Coyle, Maslin, Fairweather & Hunt, 2003; Cook, Fairweather, Satterfield & Hunt, 2004, Cook & Fairweather, 2005). The following list of examples was presented to participants.

- Using aerial sprays made from soil bacterium to control insect pests in urban areas.
- Developing a new virus that reduces fertility in possums.
- Genetically modifying a crop to produce a low pollution fuel for cars.
- Cloning a kakapo to ensure the survival of the species.
- Using bacteria from a human being in throat lozenges to prevent serious infections.
- Using human genes in a cow to produce milk for the treatment of multiple sclerosis.
- Using cells from a pig to treat a person suffering from diabetes.
- Using cells (stem cells) from a five day old human embryo to treat an Alzheimer sufferer.
- Using genetic screening to breed sheep that produce twins or triplets.
- Using a drug to raising hormone levels in farm animals to increase fertility.
- Genetically modifying pine trees to produce stronger timber.
- Genetically modifying an apple to make it more nutritious.

Participants were asked to first assess the acceptability of the examples and were then invited to talking about the examples they found most interesting. Opportunity was also provided for the discussion of other issues involving issues of the use of science and technology in society.

Plan for session two

The purpose of the second session was to familiarise participants with nanotechnology. This was done by the showing of the video 'Nano: The next dimension' and discussion of examples of nanotechnology. The 28 minute video was intended for the general public and was commissioned by the European Commission. The video has won a number of documentary TV awards. A transcription of the video is provided in the appendix.

The following is the list of examples of everyday commercial products that was provided to the participants.

- Glass that self cleans.
- Improved tennis rackets and tennis balls.
- Emulsion form of commercial disinfectant.
- Golf ball that reduces hooks and slices.
- Indoor air purifier powered by light.
- Shoe inserts with increased insulating properties.
- Golf driver with more resistance to bending.
- Sunscreens and cosmetics, and skin care products to combat the effects of aging and skin disorders.
- Bumpers on cars, automobile catalytic converters and coatings on automotive glass that repels rain and dirt.
- Paints and coatings to protect against corrosion, scratches and radiation.
- Stain-resistant clothing.
- Display screens for computers and cell phones that provide with brighter images, weight less, use less power and have wider viewing angles.

The following areas of current development and related examples were also provided to participants.

Information technology

- Faster communications.
- Faster and more powerful computers.

Medicines, health care and medical treatment

- Lab on a chip.
- Sensor type health monitors.
- Targeted drug release.
- Implants and prosthetics.

Military

- More extensive use of field sensors.
- Easier detection of chemical and biological agents.
- Lighter and stronger weapons.
- Protective uniforms.

Environment

- Improved filters to clean pollutants from air or water.
- Development of Hydrogen fuel cells.
- More efficient solar cells.

Plan for session three

The purpose of session three was to prompt discussion of examples of nanotechnology that may occur in the next 25 years. The following six examples were provided to respondents who were asked to consider their acceptability. The following examples were selected to represent different areas where nanotechnology applications could be used that would be of interest or relevance to the participants.

- Sensors, lab on a chip, self testing and remote diagnosis.

Tiny sensors have been made for diagnosis that sit under the skin and can be read from outside the body. 'Lab on a chip' is a small laboratory and makes medical tests simple and convenient. Using these things a treatment could be prescribed without a visit to the doctor.

- Replacement body parts.

Artificial parts can be used to restore hearing and eye sight. Artificial limbs can be made that are controlled using the nervous system. Brain functions could be restored using artificial implants.

- New types of food.

Nanotechnology particles can be used in food so that flavour and texture could be selected by the consumer. For example, different flavours of soup could be made from the same packet.

- Connecting the brain to a machine.

A direct connection between the brain and a computer would create a new way of interacting with machines.

To command a computer or machine a person would just have to think the command. Without moving a person could type a letter or turn on a light. People could also communicate by having their thoughts sent to each other and experience worlds generated by a machine.

- Simple nano-machines.

Simple nano-machines could be used in tooth paste to keep teeth clean and could be used in shampoo, soap or hand wash.

- Sophisticated nano-machines.

Sophisticated nano-machines that could manufacture more of themselves could be used to carry out tasks such as cleaning up toxic waste or combating viruses and the effects of disease in the human body.

Chapter 3

Results

3.1 Introduction

This results chapter is structured to provide consideration of each issues and themes from each panel focus group. The results of each focus group meeting follow chronologically the themes and issues discussed by each group. Further points arising from within and across each session are presented at the beginning of Chapter 4.

The analysis involved consideration of the transcribed data. To ensure validity the results are presented with relevant excerpts from the transcripts in the form of bullet points in italics. The transcribed excerpts are followed by a section of interpretation with comment on points of relevance to understanding how members of the focus groups make decisions about nanotechnology.

3.2 Group one - Session one: Introductions

(60 minutes)

Group one met in a school staff room on Sunday evenings. For the first session there were 12 participants of which three were male. There was a comment at the beginning of the meeting that it is usually the case that more females than males attended meetings associated with the school.

In the personal introductions it was found that only one of the 12 did not have children at the school. At least four were on the school fund raising committee and all participants seemed to know at least one other participant. One participant, as well as having children at the school, was the assistant principal of the school. Her attendance was associated with her being the local key holder for the school facilities. One participant expressed interest in nanotechnology and said he liked the idea of "...little motors and making little tools out of atoms" and another said she had been interested, but complained that none of her friends knew anything about it.

Consideration of examples

Respondents briefly considered the acceptability of the examples provided to them and were then asked to report their consideration of the first example of using bacterium in aerial sprays. The following are the key responses.

Arial spray using bacterium

- *More natural than pesticides but I'm not sure about use in urban areas.*
- *It is more natural but not when used in concentrated form.*
- *The media blows it up, spray drift over schools for example, coughs and sneezes ... it is then perceived as a chemical.*
- *Doesn't happen often ...not large scale – it's not a big issue.*
- *If it was in my area, I'd weigh the pest problem up with personal inconvenience.*

- *Once they spray for one thing they will be spraying permanently. Then it will be something else.*
- *There might also be a resistance issue. Like flu vaccines.*
- *Opens the door to more of the same kind of things.*

The comments regarding the use of the bt spray in urban areas show that naturalness was a consideration, although it was also recognised that its use in concentrated form was different from how the bacteria occurred naturally. Given that the example suggested naturalness, the comments are not surprising. A second point was that the media can disproportionately represent the effects of the spray. This media coverage, which was reported as involving coughs and sneezes, was thought to show the spray to be much like a chemical. The inference was that it was a representation that could affect the consideration of the spray but importantly the speaker demonstrated that a person could have the capacity to recognise the possibly biased influence of the media. The factor of frequency of occurrence was also mentioned as well as weighing up the costs and benefits. These could be used to support an assumption of decision making processes that involve evaluating and then summing various factors. An interesting comment was that once initiated in one form a technology could then more easily be applied elsewhere. This was further reinforced by the ‘opens the door to more of the same, comment. A further similar comment involved the development of resistance.

Meningococcal vaccinations

- *Analogous information is inadequate - I signed the form and my husband went mad.*
- *It has not been tested further than initial tests.*
- *They are using scare tactics at high school, which caused my son to object - he now has many reasons why not to have it.*
- *Kids can have reactions, so I don't have my daughter done.*
- *We are rushed into deciding and signing.*
- *The info was clear but too positive....not enough of the side effects and how it can affect the kids.*
- *We may not want to know the negative sidebut its not knowing the negative side that gets the media up.*
- *A lot of money is being spent and it kills children, but there are lots of things that do this.*
- *It's emotive.*

Some participants felt very strongly about the meningococcal vaccination of young people. In discussion, it was identified that there may be an issue about the effectiveness of the vaccine and the amount of testing that had been done. There was talk about pressure to agree to have the vaccination and one person considered the risk to their family was too great. There was agreement in being rushed to decide and it was apparent that the participants wanted to know more details about both the negative and positive aspects. The comment that it was emotive may have signified that the need for more information was a reaction to being uncomfortable with the feelings associated with the decision to vaccinate their children. Clearly at the time of the meeting many of the participants felt caught up in this issue and were unsure about it. While this talk could be seen as a window on the state of their decision making, it is very likely that the participants were keen to talk about this issue as a way of dealing with a decision that was relevant to them.

Cloning in general

- *...other things can be used instead of this.*
- *Given that they can already clone animals this (human cloning) will happen.*
- *We were not aware it could happen, then dolly was thrust upon us. Wow, I was unaware – because it had happened you had to deal with it – accept it was physical evidence, but it really made you think about what it could lead on to.*
- *It gives me the heebies. People trying to clone a child who is dying, but you can't recreate what you've lost. Its quite scary. And you have all these mad scientists being locked away doing these things and letting things loose in the world and we don't know (the group laughs).*
- *What about organ donors? I can see cloning being quite an issue - making organs for people. But if it was one of the family, your children, we would.*

An initial comment on cloning involved a comment that the technology was unnecessary as surely other things could be done instead. A further comment was the observation that once allow the use of the technology will escalate and be used in areas previously of concern. Perhaps unique to this technology was the surprise when it became public. Cloning also gave rise to an affective reaction. The difference that personal need made to consideration of cloning was a further point of importance.

Stem cells

- *A woman travelled to China for treatment, she had made a dramatic recovery, but it could last two days or two years.*
- *I find that acceptable.*
- *If its something about our health it's important.*
- *It's scary that you create embryos for that reason.*
- *In America women could become pregnant and use cells from their cord or a new child to treat their existing child.*
- *Does it harm ... no, but to have a child to save another is the issue.*
- *I think society says you should have better reasons to have a child.*
- *Surely there must be governments that put limitations on these things.*
- *Surely the government won't let people do just what they want.*
- *Well it's OK if society says it's OK.*

The use of embryonic stem cells was generally considered acceptable by the group as a treatment for a disabling medical condition. However, there was concern over the wider use of the technique which could involve the farming of babies or embryos. There was general agreement that this was seen as an issue for government intervention. Of interest, was the idea that social acceptance involving ethical issues could change over time. This seemed to take the edge off objections to the use of stem cells, as there was general agreement that ethical objection could abate over time.

3.3 Group one - Session two: Introduction to nanotechnology

(65 minutes)

Ten of the twelve participants attended. The video of nanotechnology was shown (28 minutes) and elaboration given of the list of examples that were provided. An explanation of the distant prospect of the type of nanotechnology proposed by Drexler was also provided.

Key responses

- *Tend to hear of the end product - not how it was made.*
- *If you saw the add on TV. It looks so wonderful - this nanotechnology.*
- *Are we going to talk about the problems?*
- *Does it kill the fish? How were the fish affected?*
- *Did the fish go nutty or something?*
- *Scientists are not telling the whole picture.*
- *Scientists want to get funding, so they present it as positive.*
- *When you tell me some of the problems then, no way, no way.*
- *Is this going to save a family member or just enhance my life? If your child is dying you look at this very differently.*

As prompted by the video, there was a realisation that, in the short term, nanotechnology would primarily produce materials for manufacturing. However, there was a realisation that there were also negative consequences. From an increasing number of studies on health effects of nanomaterials (e.g., see Hoet, Bruske-Hohlfeld & Salata, 2004) the straightforward example of nanoparticles concentrating in fish was related. A number of the respondents were very concerned about this consequence and were annoyed that only the positive side of the technology was being presented. Scientists were considered to be self-interested and responsible for a biased presentation of the technology. Nevertheless, it was pointed out that personal need could outweigh the possibility of wider risks.

3.4 Group one - Session three: Nanotechnology examples

(65 minutes)

Ten participants attended. In picking up from the previous sessions this session began with more comment on the issue of Meningococcal vaccinations that had been discussed in session one. There was also some talk about items raised in the second session. For the remainder of the session the group followed the planned consideration of six nanotechnology examples.

Meningococcal vaccinations

- *Was this a live virus, because people who are allergic to eggs didn't have it?*
- *If it's not a live virus should it matter?*
- *Can take a long time for an 11 year old to build up the courage for a shot.*
- *There was a problem with refusals, because some tough guys had refused.*
- *They know if they refuse they can't give it to them. There's a screen set up but its a problem for some getting the second and third shot.*
- *They complain about the soreness afterwards.*
- *A lot are away on the day after. The sports team was short because of it.*
- *If you cry at high school do you go back for a second shot... some have panic attacks.*

Of interest, comment on the vaccination programme showed that compliance was related to the social standing of being a 'tough guy'. The participants also mentioned effects, such as the level of soreness. The comments also suggest an awareness of the possibility that information about negative consequences was withheld to encourage compliance.

Sensors, lab on a chip, self testing and remote diagnosis

- *It would be good to replace self examination for breast cancer or for other cancers.*
- *Something like this being done in the UK – was a genetic type of test.*
- *Genetic screening can be done. I had a friend who was found to have 75 per cent chance of cancer. She's got a gene associated with developing cancer, but this doesn't mean she would get it.*
- *You talked before about people getting diabetes having their blood sugar tested – could also test for cholesterol perhaps.*
- *New sensors are like a substitute blood test. That would be great!*
- *Would need to look at the long term effects.*
- *Its \$25 to take the child to the doctor! But my friends from the states think this is just a gift.*
- *The internet use as a substitute would be OK. I just want to get my treatment.*
- *Loosing contact is not important – a specialist has no personality, so what do you lose.*

For this medical example there was agreement that the new techniques would benefit and there was interest in the possibilities for diagnosis using the techniques. Convenience was recognised as a positive factor, although the need for study of the long term consequences was mentioned. At the prospect of remote diagnosis, using the internet as an example, the main consideration was the savings made by avoiding medical fees. The enquiry which suggested there might be a difference without personal contact, found that compared to cost savings this was not a concern.

Replacement body parts

- *Not visible, hearing aids and eye things, that were would be good.*
- *They would be quite dear as opposed to the current ones.*
- *Artificial limbs were on TV last week. It looked very crude.*
- *They played it up, but he had a heck of a job using it.*
- *It's good to be independent.*
- *I guess there isn't a negative side effect.*
- *People can enhance the body as much as they can for sport and stuff and for brain functions.*
- *Could be used instead of stem cell... it would be better to have a mechanical fix.*
- *Still have to watch out for people using it for enhancement rather than for a medical cure.*
- *People would use it for advantage in anything in time.*

The prospect of replacement body parts was treated as a near future development and it was realised that some initial developments would be crude. However, it was not envisaged that there would be any immediate side effects. One possibility that was foreseen was the use of replacement body parts for personal enhancement, rather than their simply being for medical treatment. Initially this was brought up in the context of improvement for sport, possibly in response to recent controversies over drugs enhancing athletic performances. This talk then developed more broadly into recognition that advantage would occur more generally. Unintended use of the technology was a further secondary consideration though while considered a shortcoming its implications were not expressed.

New types of food

- *I don't know about this, it sounds strange.*
- *It's fast food to the extreme.*
- *It's a commercial interest. Make 2 cents a drink means making millions.*
- *I don't like the idea of ingesting the things.*
- *What about the nutritional value it might be low or lost.*
- *Oh OK why not? So you could dial up roast beef!*
- *It's not a natural kind of thing. You have no reason to do it.*
- *It's like dial a pizza.*
- *We would need more information if it's going to be in food or drink and that and it would have to be nutritious, but there are lots of things that aren't.*
- *Could be a commercial thing that's the reason.*
- *You need to be concerned about the environment. When you take a new thing it goes through your body and goes somewhere else. We need to think about where it goes - about the life cycle.*
- *You go to a restaurant you don't want this stuff. Just zapping something through and pushing a button isn't what you want.*
- *I'm sure the flavour could never be as good. I can see it happening in fizzy drinks but not in a chef's creation with mixes of herbs and spices.*
- *Years ago we never thought we would have what we have now.*
- *We do some quick things – use an instant packet for something – two minute noodles thrown in or something –the old chicken flavoured sachet.*
- *It sounds different when you say you are pressing a button to change a flavour. I don't think people would ever want it.*

For the food example initial reactions included the feeling that it was strange and felt unnatural. It was also quickly recognised as involving commercial considerations and concern over nutritional value. There was concern over harm to the environment which was likely prompted by discussion from the previous session on possible effects of nanoparticles in the environment. A class of commercial products was singled out for the technology and a similarity with contemporary convenience foods was also noted. Of importance to the group was the seeming sanctity of creative cooking, as well as a general view that it would not be realised because no one would want it.

Connecting the brain to a machine

- *I think this is like the car we plug in now to tune it up. Engine tuning is now very technical, a further step, kind of like the human body.*
- *Good for paraplegics but just a novelty for other people.*
- *They have light bulbs that only go for ten minutes and they fade out. What about thinking the lights down?*
- *My friend has some sensors in her home. She might go for something like this. A lot can happen and it can start with little things like this.*
- *Look at what's happened with cell phones. Putting cameras in them and spying problems.*
- *What about teenagers texting. They don't talk to each other they just text.*
- *Starts with a good idea, but how people use them can be a problem.*
- *Thought to thought could be bad - goodbye friends.*

- *If a pilot could fly a plane with it more error would happen. Would I do this or that, it would be a problem, indecision for quicker decisions.*

Copying the brain

- *It would be a bit disappointed with my brain (laughter).*
- *It would be OK to save a brilliant mind, maybe you could then examine it more.*
- *Einstein was amazing he was unique, could express himself.*
- *It would be revolting if you could live forever, if it happened to all people.*

This example was particularly foreign to the group and the initial use of everyday examples of car tuning and fading lights was likely useful as a tool to assist in conceptualising the new technology. The next point of interest was the unintended use of technology with the realisation that the expected use of technology may not equate with its actual use. The possibility of using commands directly from the brain was considered different from physical control. Apparently brain activity or thoughts were considered more random or undisciplined in comparison with control over the movements of the body. In the time available, the idea that brain activity could be copied so that a person could exist in a machine was not considered closely. The most meaningful response seemed to be an ethical objection involving revulsion.

Simple nano-machines

- *We have so much now in toothpaste – I don't see this as an important thing.*
- *We get used to this and then we get used to that - it might be put in our shampoo - so what.*
- *It's not like the throat lozenge, it depends if it has someone's saliva in it.*

The toothpaste example was intended to enable comparison with the use of bacteria in throat lozenges from the first session. In comparison, the example did not give rise to anything like the revulsion expressed for the lozenge. In contrast, the use of simple nanomachines in toothpaste was readily compared to the current use of various novel additions to toothpaste or shampoo.

Sophisticated nano-machines

- *More acceptable if it's helping, such as fighting cancer cells and things like that, and cleaning up toxic waste.*
- *More accepting when it fights diseases or heals the human body.*
- *Watch out for the harm when in the environment.*
- *We don't know what will really happen.*
- *We need to start thinking about how much we should change the world and ourselves. It's wrong to play god with nature.*
- *How would you control something that makes itself?*
- *After cleaning up the oil slick, where would it head afterwards?*
- *What about using these things for bad, using them to kill soldiers.*
- *Like using a cell phone to take spy photos, there is always the possibility that people would use these things in ways that was not intended.*

Sophisticated nanomachines were considered more acceptable if they were used for medical benefits or to do other good work such as cleaning up toxic waste. The possibility of environmental damage was raised again, as well as the obvious problem of control after release. The possibility of unintended use was also raised.

3.5 Group two - Session one: Introductions

65 minutes)

Group two met at the home of one of the participants. There were nine participants with one person having cancelled due to an unforeseen commitment. Three of the nine participants were male.

In the personal introductions it was found that two of the participants had a grandchild at the school, one was a teacher and the remaining six all had children at the school. Four had previously heard of nanotechnology. One of the four had read about it in the newspaper and in novels.

Consideration of examples

Respondents briefly considered the acceptability of the examples provided to them and were then asked to report their consideration of the first example of using bacterium in aerial sprays. However, the plan to base discussion around the provided examples was not adhered to closely by this group. In keeping with the research design relevant themes and issues salient to the participants and of relevance to the research were pursued. Also of note, compared to the other groups, there was less prompting from the facilitator, with more attention given to clarifying one or two points raised by respondents. Occasional prompts were used to ensure the focus of the conversation remained on science and technology issues.

Arial spray using bacterium

- *Whether you can spray in urban areas depends if it is about wrecking the economy or not.*
- *It also depends on whether it affects your area or not.*
- *In isolation it can be OK, but my concern is over where you draw the line in any of these sorts of things.*

Initially for the spray example, consideration was given to the relative benefit to the economy as well as the whether one was personally affected. There was also the issue of being unable to establish a margin for acceptability. In similar manner to group one, the question of initial acceptance leading to wider use was recognised.

GM crop

- *What sort of crop? Depends on what it is.*
- *The point is GM, it does not matter what the crop.*
- *I have strong feelings about GM, it also depends on the crop and how it is modified.*
- *It depends on the purpose.*
- *Yes, how easy it would go into the food chain.*
- *But if it could be planted in Africa in a drought, it would be good.*

- *Yes I am very concerned, suspicious of the companies and information they provide, such as Monsanto and others, producing GM in food. They have a track record of dishonesty and greed. They are out to make money and control international crops by being sole supplier. Crops have been contaminated by GM it's a worry for me and a lot of people.*
- *I don't know if GM is much different from traditional breeding.*
- *It's about isolating genes and swapping them usually unrelated species.*
- *People can object because the scientists don't necessarily know exactly what will come out of the process.*
- *But we need to experiment to progress.*
- *But on the large scale it can't be reversed if there is a problem.*
- *It's like the danger from radium. It's only found after the harm has been done.*
- *Suppliers in the UK don't supply GM products because the customers don't want it because of ethics. For the supplier it was done for market advantage but it's hard to get good information for quality control.*
- *Ordinary people don't know enough about it. It's a confusing issue and there's a variety of information out there.*
- *It's a problem that it's hard to identify GM free food.*
- *The government wants us to be confused, so it can get through in some products.*

For the GM example, the type of modification and purpose was important as was other benefits and the need to keep GM out of food. A concerned participant was suspicious of the motives and tactics of multinationals. There was discussion on similarity and differences to traditional breeding methods. The apparent need to experiment was raised as well as the possibility of irreversible consequences. Further comment included the potential for confusion given the amount of information.

Stem cell research and general comment

- *If you start here the moral code goes. Science is exciting but it affects us. Its gradual change and gradual familiarisation and as things change its accepted a bit more. Then we have the embryos and the lady going to China. Then all of a sudden there's a gradual shift, but things like GE is a big jump.*
- *I would do anything to me to fix my health but this is different.*
- *The GM issue has never gone away. We accept butts of it until something ugly happens.*
- *No - other issues we come to accept. If you see the word often enough it becomes OK. It's political, because it's about conditioning people.*
- *My personal views don't make an impact. We have lost control of what we eat. Its part of the way we live our lives now that we don't have control over where we source our everyday products, the things we surround ourselves with, not only our food but the things in our houses like paint. It is in your face every day and we accept these things, so we have lost control.*
- *Yes but you need money to make these choices, if you have no money you buy the cheapest.*
- *Now days it's just a half hour spare to do the shopping. If you had two hours you could look at every label and study every ingredient but we have no time.*
- *But new things haven't done us any harm in the last 30 to 40 years.*
- *But what about asthma and more sterile men! Were still functioning but not as well as we would; we are not a well population.*

- *There are poor areas of the city where nutrition is poor Their development must be affected.*
- *It all comes back to money and convenience. We are loosing skills to cook basic foods and these are being replaced by packets. The sauces have lots of numbers on the back. You can decode them for allergies. You would have to change your lifestyle, and it can be expensive, but you feel better.*

The brief comments on stem cell research led to a wider ranging conversation. This talk began with the idea of stem cell research introducing further change and an erosion of ethics. The idea of general familiarisation and eventual acceptance was also introduced and this was seen as involving the intentional conditioning of the public. GM was seen as a big jump, which would presumably explain adverse public reaction.

One participant gave emphasis to the feeling of loss of control and explained this as being a consequence of current lifestyles. Less abstract was the comment about money enabling choice and the problem of busy lives preventing detailed consideration of products. Also related was the view that things had improved over time which was countered by the assertion of illness associated with modern technology. There was also lament at the loss of traditional skills and the better feeling associated with a conscious return to a traditional way of life.

3.6 Group two - Session two: Introduction to nanotechnology

(75 minutes)

All nine participants attended the second meeting. The meeting began with the educational video and the remainder of the meeting involved general discussion stemming from the provided list of examples. Like the previous session, occasionally the discussion strayed but when prompted there was consideration of the current examples.

Clarifying nanoscience

- *Is this like an electron microscope or have they taken it a step further?*
- *I presume they are looking at very tiny things, but they are saying they can actually manipulate things?*
- *Because it's touching it, it can then manipulate what's happening.*
- *It's about changing, it can shift it, so it has two functions.*
- *With each of these benefits, say for stain resistance, do they look at the atom first, find the properties, and then differentiate and separate then put in to various applications? Is that what they are doing?*

As shown by these excerpts, having just viewed the nanotechnology video some participants found it necessary to check their understanding of the new technology. Clarification was provided in each instance. In comparison with the first group, this group appeared to need more clarification. However, the second group tended to be generally less inhibited and more talkative. While it would seem that the group may have had trouble understanding nanotechnology, it is more likely they were less inhibited in checking their understanding was correct.

Computing and Moore's Law

- *The first computer occupied a whole room.*
- *Yes, it took 20 years to get to that point and now they are very small and fast.*
- *It's called Moore's Law. Information now doubles in 12 months. It's a theory from the 1960s.*
- *There's the problem of limits, the limits of current technology, the physical limits. It's about shifting the limits.*

Having pointed out some of examples of nanotechnology a point was raised about computers and Moore's Law. This involved a reference to the size of the first computers and the time and the more powerful units that are produced today. It was interesting that Moore's Law was mentioned, as it is often mentioned in relation to the recent slowing of the pace of upgrades in computing and the potential for increased performance using nanotechnology.

Medical advances

- *Like Star Wars or Star Trek, they put it on your skin and it can read what's wrong with you.*
- *Talking about it seems like using your imagination.*
- *You'd amass an enormous amount of data. Seems like the new technology just recognises something, so it is more simple.*
- *It's just refining - making things cheaper, more efficient.*
- *Are they doing it now?*

The talk of medical advances began with the likening of the technology to science fiction. It was also commented that one had to use imagination in considering the technology. The comments suggest some distance between the new technology and current understanding. Further comment dealt briefly with the implication of presumably reduced costs. In addition, and of interest, was the enquiry regarding whether the new technology was actually being used.

Moral and ethical issues

- *It's wonderful these medical things, to restore sight to blind people, or to treat hearing loss, or correct debilitating diseases. But if you can do those things you have the power to do other things. There are ethical issues involved here.*
- *Yes, but everybody has the right to life and shouldn't people who are paralysed have access to the latest technology.*
- *I guess you can't see how we wouldn't use it on a paraplegic. But what about when the technology becomes so common that people use it to advance their physical and mental performance.*
- *Yes that was what I was getting at. I'm actually thinking of futuristic movies like Gattaca where there are all these perfect people. You know, if you are ever so slightly less than perfect then you were a nobody. Unless you're careful, in society, that sort of thing can happen.*
- *The philosophy of Hitler.*

- *Yes, that's right, that's right. The thing is that our humanity loses something. We actually gain something from knowing people who are less than perfect. We become more empathic, we learn new ways of relating to people, loving people and things like that. If we don't have that we lose something collectively that makes us human.*
- *I agree entirely but I don't think you should turn your back on something that's new.*

The movement to broader considerations was a characteristic of this group, as shown in further discussion of moral or ethical issues associated with medical uses for nanotechnology. Talk about the treatment of disabilities shifted to consideration of the ethics of wider use of the technology. On the one hand the view was that people had the right to treatment using available technology but when the possibility of enhancement was raised it became an issue of concern. This was further extended to an argument against eugenics whereby interventions in natural processes are used to alleviate suffering and improve human performance.

Changing social views

- *Gradually we readjust ourselves and our thinking as we move along. We are readjusting.*
- *We are basically just flexible characters and whilst what shocked us earlier, or knocked us out of our comfort zone, for one reason or another, something else comes along so we adjust to that and on we go again.*

Further discussion showed recognition of the changing nature of social views. In addition, it was related that the current view was continually being challenged and that challenge and adjustment was a continual process.

Concern and acceptance

- *It like when microwave ovens were very new. Some people thought they were great and some leapt in boots and all, fantastic!*
- *There was that whole thing about pregnant women not standing by them and what were they actually doing to the food and the molecules in the food and that sort of stuff and now 20 years on its all completely gone away and everybody has a microwave.*
- *You don't have to go far back to all the hoo-ha over the cell phone towers. After all the fuss they just appear now.*
- *What strikes me is that you get a technology for some good use and then you turn around and use the same technology for a negative side medically and then militarily, doing things that were contrary to what the original use. You can't stop people with the wherewithal from doing it. The scientists don't think about making something out of it, they don't think what it's for, they just get excited.*

The cycle of change and acceptance was illustrated by initial comments about reactions to microwave ovens and cell phone towers. A further emergent idea was that the end use of technology can be unforeseen and undesirable. It was suggested that scientists were often more interested and excited by a discovery than contemplation of the eventual technology and its use.

Risk of harm and labelling

- *It's like asbestos.*
- *Surely what happened with asbestos shouldn't happen today.*
- *It might kill the tumour but it might cause something else.*
- *But if you use it, it's like we don't know if particles are around like dead skin. When they touch something else, something might be left.*
- *What about labelling products so we can choose and really know what's in the cosmetics or sunscreen. Labelling is about making people aware about what's involved. By labelling we can choose.*
- *Now days we are more aware of these things. Now days health and safety is done in the workplace and is more common.*

In consideration of potential risks the parallel with asbestos was recognised. There was also mention of unforeseen harm as well as the possibility of particles becoming pervasive in the home and environment. Labelling of products was also mentioned. Choice was also an important point. There was also the comment that recently there was more awareness of the potential for problems and that workplace procedures had improved.

3.7 Group two - Session three: Nanotechnology examples

(70 minutes)

All of the nine participants attended. For this session the group followed the planned consideration of six nanotechnology examples. However, because this group enjoyed extending upon initial observations and developing new ideas it was decided not to deal with the second example.

Sensors, lab on a chip, self testing and remote diagnosis

- *It could be like some sort of kit for cancer.*
- *It is possible, like on Star Trek.*
- *But it assumes that you can have the knowledge. It needs knowledge to make it work. We've come a long way in self diagnosis and understanding but this would take too much.*
- *I am not sure, doctors could see it as a hindrance or a threat.*
- *They can't prescribe based on readings, there are some many types of pills and people misuse treatments.*
- *Can't be done independently, self diagnosis can cause trouble.*
- *But with this you could get an opinion on it but if you use your imagination doctors would have more to study and with all of that information you could just plug yourself in to have a diagnosis read out.*
- *If ordinary people had this technology they could panic and do all sorts of stupid things. It still takes a specialist. It still takes logical thinking.*
- *The other thing is someone might think I'm going to check out what's happening in my body today and it says you've got a rumbling appendix and your livers not too healthy and all of a sudden you have potentially serious things.*
- *Your body has this immune system - an army of antibodies. You might be off today but you might be perfectly alright tomorrow or the next day but you get yourself in a panic and self medicate, but if you left it a bit longer you wouldn't need to.*

- *So many things are around but they aren't a problem, we all carry them around.*
- *But when it comes to diagnosis of your little bug or various bugs, a lot of these have to be put under culture, for example, whooping cough. By the time that's diagnosed it's already an epidemic. It would be incredible to actually be able to ascertain whether they can get that bug in their bodies.*

Initial talk about this medical example quickly became caught up in whether this example was possible. It was considered that it could be sophisticated and useful but not to the extent that it could replace a doctor. There was an assertion that it would “cause trouble”. This was tempered by the concession that the technique would be used to assist a doctor. One participant voiced the idea of people becoming inappropriately concerned over their health. A further comment related that it was natural for the body to respond in its own time and that personal concern and intervention was unnecessary. It was also pointed out that ‘bugs’ are often present but should not be of concern. It was recognised that it would be a significant advance if the technology could reduce the time taken to identify a ‘bug’.

Comments on progress

- *We can't close our mind to something like this. The same thing happened when the telephone started and the same thing happened when electricity came in. I remember my mother talking about the first electrical oven she saw and thought it would explode.*
- *It's the fear of the new. There's a certain built in resistance in all of us to accept change.*
- *I remember my father in law saying when he was a boy they were still out in the fields cutting with scythes and things and then there was the combine harvester, the motor car and air travel. He just couldn't believe the change he had seen in his life. And its exponential growth, its carrying on and it just hasn't stopped.*

Talk about the problems of accepting new technology appeared to have been prompted by questioning the possibilities for nanotechnology. ‘Fear of the new’ was seen to be a long standing problem and it was recognised that this had to be overcome. There was also the problem of the quickening pace of change, suggesting that it would be difficult to accept change if change came at a continually faster pace.

New types of food

- *Wow.*
- *We used to see packets on TV, just add water.*
- *As things are changing, they are rebelling, going back to basic healthy foods, there is a lot of this.*
- *As a child we were never allowed other food. My mother was constantly saying no preservatives, nothing added. No Oxo cubes, no Maggi soups no nothing.*
- *Packets are high in sugars and salts and they put things in it that gets you addicted, it's a flavour thing.*
- *There's stuff about that we don't know about.*
- *That's the key thing. We talk about how many Es or whatever is in our food. But it could be that nanotechnology particles are just another carcinogenic.*
- *I think it's the health issues that could be a problem. If there were zero health implications we might be a lot more relaxed about it.*

- *I'm actually happier with a little chip in my arm than eat these things. I could diagnose a bad cough or the flu but why do I have to eat these things.*
- *I don't really mind the insertion of a sensor in my arm but eating these things is unnatural.*

This example was initially framed as being like existing convenience foods. A point was then made about a responsive return to more natural foods which was linked to a tradition of older generation. The conversation then moved to concern over the actions of food producers and the lack of knowledge about food content. This led to the comment that people have become concerned about certain beneficial elements while there could be as yet unknown harmful effects. Then an interesting remark was that an implant with particularly useful benefit would be more acceptable than eating nanoparticles. This could raise the issue of this application of nanotechnology having little consumer benefit with consumers questioning the need to introduce something foreign to their diet.

The pace of change

- *It is interesting that some of these things are already here. But nanotechnology is already here its going to change a lot quicker.*
- *Its concern about unknown things and its concern about moving on and what it does to us. Just like the meningitis debate, you have beliefs and have a debate inside yourself. Information is very important but at the end of the day but its not everything. It's how you take on that info as well as your basic belief system. Certain parents believe the meningitis injection is a drug and we don't know the result even when science has studied it.*
- *It was the same for Tb and polio.*
- *Yes and Fluoride, Thalidomide and the DDT poison were huge mistakes. We've had some catastrophes. Various medications have caused issues along the way, lots and lots of things. I'm not saying not to move forward, I'm just saying caution all the way along.*

The idea of the accelerating pace of change was raised again. In an apparent explanation the public response was thought to involve concern of the unknown, lifestyle change and its effect on the person. Of interest, one person spoke of a personal debate or weighing up the pros and cons of meningitis vaccinations while accounting for a deeper personal disposition. In addition, there was some suggestion of a framing or classifying of the vaccine as a 'drug'. Then the common association of new technology with past mistakes was raised. However, rather than questioning progress the more moderate suggestion of caution was made.

Identity chips

- *It could well be that a paraplegic or disabled person could open doors and operate appliances.*
- *Civil libertarians would be against it because people could keep track of you. Actually people like the police could use these things. I don't have a problem with it you only have a problem if you have something to hide.*
- *They wouldn't give a rats about ya.*
- *But it's very big brotherish and very much open to abuse.*
- *When you think about these things with best intentions it would be good to track terrorists but with time everyone gets monitored. Like home detention clamps. They use it for animals. Drivers licence and credit cards are a step towards it.*

- *The crims go along with technology and think how to outwit it or use it for themselves. Society has one idea and the bad people have another. What about a burglar alarm it goes or doesn't go depending on the chip you have. Then the police don't bother dusting for prints, they just plug into the computer to see who's been here.*
- *Ten or so years ago they talked about an ID card. It was strongly objected to. In Europe they have it in Italy and France you must have ID to show the police. Its escalating towards that. We are going that way because you need picture ID to get your ticket at the airport.*
- *Older people remember during the Second World War there were certain people in Europe who had to carry ID cards and that was because they were considered lesser people. That's why older people think it's a bad thing to do.*
- *They have been against it in the UK but now with terrorism people might see it differently.*

A discussion about the use of chips inserted under a person's skin as a form of identification arose from discussion of medical examples. A chip was considered a potentially useful tool for disabled people and was made more real with the mention of existing use of similar technology. It was generally recognised that this could be a 'big brother' issue involving the institution of uniform identification. However, while it was considered that older people had some ethical reason for concern this was not apparent for the participants. While the idea of big brother was mentioned the general need for security against crime or terrorism seemed important enough to forgo personal inconvenience.

Connecting the brain to a machine

- *You can get a computer that recognises your voice but they don't work too well. It will come. It's just about getting familiar with a new thing.*
- *Cell phones can operate by voice recognition, so what was a problem is now dealt with.*
- *More likely to go to sleep than do something and your computer will be doing a dream for you. You'll dose off because you don't have to do anything except think about what you are doing and then you're lying on the virtual beach and the computer does it all.*
- *One could also teach straight from the lecturers mind but another thought might intrude like needing to pee.*

Initial talk about improving the machine person interface was about voice to computer recognition. This talk of similar current technology may have been a way of assisting comprehension of the new technology and suggested the new technology would be useful. The idea of thought control operation of a machine via a computer prompted more humorous comment than serious consideration. Possibly the bizarre nature of the example meant it could only be dealt with in a joking manner.

Communicating thoughts

- *This is just like using a cell phone and texting instead of talking. Texting is disengaging, a way of not being there, disengaging from the present and getting wrapped up in the messaging.*
- *With multiple sclerosis this would be good, and we could use the computer to translate different languages.*
- *What about lie detecting. But you could do lie detecting better by understanding how the brain works.*

- *In the end people would have polite thoughts in their heads.*
- *The concept of a machine would be different; the computer could be the size of your finger nail. So you could be hooked up at home on a plane.*
- *It's really sci-fi stuff, but it's exciting to repair the eyes or hearing or re grow limbs or fix Alzheimers. We would all be perfect though is that a good thing.*
- *Are we heading to a utopia? Isn't that a good thing?*
- *I'm thinking of the Borg and everyone has access to the best info, but you're all living on the same level as each other. In Star Trek this was a frightening thing and maybe it would be in reality as well.*

Again the grasping of this example was done through the current use of something similar. The interesting aspect of texting was mentioned with users said to become disengaged as if in deeper thought. The inference was that this would similarly occur with preoccupation with virtual thought transference via a machine. The idea of the system enabling language translation and assistance for disabled people and better lie detection may have been ways of making the example less abstract. As one participant pointed out, it was 'really sci-fi stuff'. The eugenic idea threatened again but was countered by the positive suggestion of utopia. Somehow the tragedy of the hive like existence of the 'Borg' of Star Trek was associated with the advancement offered by nanotechnology. Perhaps the most common factor for the Borg and nanotechnology is a striving for perfection.

Simple nano-machines

- *Not really machines are they? It just has a moving part.*
- *What about after you've done your teeth what happens to them?*
- *They move down and then turn into little chimney sweeps and they would clean around the bend.*
- *What about people with stents in their heart? You could use these things to clean up the artery.*
- *Yes and clean up cholesterol problems.*
- *I don't like the idea of swallowing them.*
- *But toothpaste always has new things, foreign things for white teeth.*
- *I imagine that this kind of thing will get accepted and the advertising will persuade us to buy it.*
- *I think it would be important to make panty hose that don't run. They seem to be made to run and wear out after five wears.*
- *But they are supposed to wear out so you have to keep buying more of them.*
- *But I don't know weather I would want to wear the same panty hose all the time.*
- *Could you also change their colour to suit the occasion?*

The example of a molecule with one moving part in toothpaste did not elicit any particularly adverse response. Instead, initially there was humorous comment about the idea of these moving things continuing to do their job after helping clean someone's teeth. The potential for other health benefits was realised but the idea of swallowing the simple devices was not a pleasant thought. As toothpaste was often advertised with new additives it was thought that this would be accepted as more of the same. Perhaps in response to the lack of stimulation from this example the call for better pantyhose was made. The thought that the wear was intended by the manufacturer was voiced as well as the objection to having to wear the same pair. But in the vein of talking about the innovations of nanotechnology the idea of varied colours was offered.

Sophisticated nano-machines

- *Like antibodies to attack new viruses. They would be much like living things.*
- *The scary thing would be the lack of control.*
- *Once they have done their job - do they disassemble once they are finished? They could be dangerous, as well as decontaminating a site they could also be made to contaminate a site. So should we stifle it? It can do many good things. If we used it to clean up the duck itch in Wanaka Lake would it get into the farm land then get into our bodies and become like a poison how would you stop it?*
- *The solution is to make it so they can't reproduce.*
- *The environment can only handle so much meddling.*
- *But surely they can be used as a weapon.*
- *Yes, anything can be used for bad.*
- *But if you say don't go ahead, you miss out on something. The military has long driven technologies, radar and useful tools in everyday work, but you can understand the concern.*
- *But the military doesn't always have our best interests at heart.*

The idea of self-replicating nanomachines was treated seriously. The idea of them being like life forms because they could replicate was initially observed as well as the potential for them to be out of control. This was extended into a food chain type example to illustrate the possible invasive treat such a technology would pose. The practical solution of ensuring control by removing the ability to replicate was suggested, but again the technology was criticised for its potential to be used for military purposes.

3.8 Group three - Session one: Introductions

(65 minutes)

Group three met in a school staff room. There were ten participants and three of the ten were male.

The ten respondents in turn introduced themselves. All had children attending the school except for one participant who was a teacher at the school. Eight of the participants had more than one child in their family and six had involvement with the school PTA. Three were particularly interested in nanotechnology, which they had heard about in popular media and two indicated their partners were interested in the topic. It was apparent that most of the respondents knew one another.

Consideration of examples

Respondents spent a few minutes ranking the acceptability of the four environmental examples of biotechnology. Discussion began with discussion of the reasons for their scores for the use of bacterium in aerial sprays. Only the first three environmental examples were dealt with while other relevant lines of talk were pursued. In comparison with the two earlier groups, this group was less reticent than the first group, but was not as talkative or wide ranging in their discussion as the second group. Consequently the participants were occasionally prompted to consider alternative views of the topics for the purpose of extending and broadening the discussion.

Arial spray using bacterium

- *I think it's acceptable but I still have misgivings. But when it's explained as being natural I think it's OK.*
- *It seems a good solution and seems natural but it's different when it's in Auckland.*
- *The media makes this out to be really bad, I mean they tell you to stay inside before they spray and it had to be a calm day. So why was it made out to be something really bad. The media gave the impression it would affect us - like its toxic.*
- *It's probably some green people who went to the media and it started from there. I only heard it on the news.*
- *It may have been started by the Greens and brought to the press but why not go to the experts and really find out about it.*
- *I could have been conveyed in such a way that it was just tucked in and the other stuff stands out. Conveyed in such a way that you don't pick up on it. They like to make things sensational.*
- *The idea of planes flying over and spraying things does not give me a feeling of great joy.*
- *I was thinking about the health issues. I'm an asthmatic and I would not be happy with spray being about and not knowing if it was going to affect me and my asthma.*
- *Coughing and sneezing means it affects people but the scientists say it's OK and of low risk, but if you were an Asthmatic it would be a lot worse. Low risk is different from no risk.*

The use of a spray containing soil bacterium was acceptable to some participants when associated with the idea that it was natural, although one participant was less sure when considering the case of it occurring in Auckland. This suggests that the general idea of the use of naturally occurring bacteria is acceptable but its actual use in a familiar urban setting causes concern. Further discussion centred on the use of the spray in Auckland with comment provided on apparent distortion by the popular media. This negative media reporting was apparently not helped by the precaution given to householders to stay inside. A further element was the suggestion that the "greens" were responsible for initiating the apparent media bias. Of note, this presumption of "greens" as instigators had no substantiation. The comment that the spraying "does not give me a feeling of great joy" served to plainly point out that the inevitable lack of benefit for affected individuals. Further comment involved the possibility of health risk and the importance of access to information. A final interesting point was made regarding the possible disparity between the perspectives of scientists and affected individuals on risk

Possum fertility virus

- *I always think that a virus is going to mutate. Just because it affects one species, others close to it could also get affected.*
- *Public opinion makes the use of a virus difficult.*
- *Coalesce virus was used to reduce the rabbit population, but there's a resistance problem. Now, in parts of Canterbury rabbit numbers are on the rise again.*
- *The control of possums in NZ is desirable, but I think of the virus jumping across oceans and you don't want to inflict in on Australia. This is my biggest fear because a virus doesn't have any boundaries. I don't know enough about it but that's my fear.*
- *You have to weigh up the risk with what is trying to be achieved. What's the flip side, like spaying in Auckland for the painted apple moth might be a risk but there's a huge gain or huge benefit in wiping them out.*

The example of developing a new virus that reduces fertility in possums initially prompted worry over virus mutation. This was followed by the observation that public opinion would be against this use of a virus. The example was then discussed using the analogy of the Coalesce virus that had been introduced to cull rabbits, while pointing out that some rabbits were now resistant. The perceived problem of the virus spreading beyond national boundaries was then raised was a particular fear for one participant. Then it was claimed that the acceptability of this example, and the previous example, involved a weighing up of benefit and risk, as if such factors could be traded off.

GM crop

- *I just read GM and to me I don't like it. When will it stop, what are they going to do next. I think that with the ozone layer they need to do something but that modifying just freaks me out. How far are we going to let it go? We've got to be aware of what cars are doing and things and the damage that we're doing now. People are becoming more aware and perhaps something drastic is going to be done, but I'm just dead against genetic modification of anything.*
- *I'm the opposite, I think that so much good can come from genetic modification. A lot of really debilitating diseases and things could really benefit. A lot of good can come of it. Obviously a lot of bad can come from anything. Technology, or for any innovation that man can promote, there will be goods and bads. But I see a lot of good in genetic modification.*
- *There are places for it and everything has limits and boundaries and I think that if something like this can be produced to save our environment all well and good.*
- *Some think mutation is a problem, but mutations occur naturally all over the place and only one in a million increases the survival. A virus will mutate that's why there is resistance to antibiotics and it naturally occurs everything changes not just us. It will but is it bad? The better crop will proliferate, like possums better suited to living here.*
- *We have an impact every day. Global warming was inevitable. Its part of natural selection.*
- *The food issue, eating organic food, is different from something just getting infected. In history thalidomide, for example, caused birth defects. For my family I want to know what were eating and what's been done to it to make a conscious decision about it. I'm not against progress and I also think we have to move with the times and we do have to look at the good and bad things.*

Responses to the example of genetically modifying a crop to produce a low pollution fuel for cars began with one respondent having a particular aversion to GM. This involved recognition of the need for technology and a seemingly moral or ethical outright objection to GM. As pointed out by the next speaker this person's position was the opposite. Nevertheless, there was concession that bad things can happen but the suggestion that this always occurs seemed to obviate the singling out of GM as a being particularly bad. Some middle ground was offered for the opposing positions with the idea of limits or boundaries. This was followed by a sophisticated argument involving mention of a feature of natural selection in countering mutation as one of the main concerns over GM. Presumably unintended spread of GM plants should not be a concern because such spread is natural and merely means the survival of the fittest resulting in an optimal outcome. The next comment more favourably framed GM as being a part of other human modifications. The idea of global warming being part of natural selection is not unlike an extension of the view that because humans and their abilities have been 'selected for' then their use of technology is natural. Some blame was placed on the media and a local example of concern over pollen spread from GM plants was

raised. The issue of GM food and the often cited possibility of unforeseen risk were then raised. This was followed by concern over choice and an expression of the need to be informed about new technology.

Further comments and problems of technology

- *I think the problem with the media is that you get this kind of panic stuff and often there's not an opportunity to find the up side as well.*
- *It's not always just a media thing. I know that when I went to school I didn't know any children with a heart problem. All this asthma and all these things and then we start bringing in all this new stuff such as apples that always look red and we can do that all of a sudden it now nothing to say my kid has asthma and now my daughter is in a class with three or four kids with heart problems. And this is just accepted but it's just what happens now and we accept it. But where is this coming from, why is this happening now, and it's acceptable for people to now live with these kinds of things.*
- *It's like Celiac disease, intolerance to gluten and wheat, and now it's common, whole families have it and dad he's just developed it and now the kids have got it and it's because of the white bread. How far are we going to go and we are accepting it now that's another asthmatic kid and another person with cancer.*
- *Is it just that it's recognised a lot more. Now people are now less enclosed in their families. My family is full of cancer but it's not to do with what they're eating. I know what you mean but I have a family history of cancer. I think if you live long enough you'll die of cancer. It's just aging and melanoma is sun.*
- *Unlike my parents, now we have more time to interact with others. So asthma is not as prevalent, its just diagnosed more now. I'm worse in Canterbury. Use an inhaler a lot.*
- *Asthma is getting worse but Celiac is just now being diagnosed and that's why there's more of it.*
- *I was told intolerance to some foods happens naturally over time so if we eat lots of white bread we will build up intolerance to it. That's why some were not told about it.*
- *People use to die more quickly of things because it wasn't diagnosed. But my family has cancer from both sides and I really feel for my girls because I got it from them. But my doctor said by the time they're old enough to worry about it there'll be a test a genetic test and there'll be a vaccine, that's where medicine is heading.*
- *We used to have our children vaccinated and we didn't really know much about it. Sometimes it doesn't last but we say, yes, lets do it. It's interesting that when we were children and our parents were told the kid needs a vaccine there wasn't any discussion about it.*
- *It's interesting how our perception or risk tolerance has dropped to the point where everything worries us. We question a lot more now don't we? We go to the doctor and we have a conversation one on one about what they recommend and do you agree about it. Often when we were kids it was like, right you need this and off you go. Doctors were God like but now we're children's advocates. We make decisions for them and make sure we know. It's an accountable society.*
- *I think we get our education through the media as adults, but for me, because I know about GM I could see there was a real lack of understanding and a real lack of desire to sort it out. It was an emotional issue and they ran with it. People just wanted it to be sensationalised and seemed to just want an emotive report from the media.*
- *Information comes quicker and we tend to trust that box in the living room don't we. Its sort of entertainment as well and we get caught up in it.*

Moving to the final stages of the meeting there was initially a comment about the media failing to report adequately on the benefits of technology. This was followed by talk of a perceived problem that our technological society has led to new health problems which may not be openly recognised. This was then countered with the view that the apparent rise in some illnesses was due to their becoming more noticeable. However, another person was of the opinion that asthma was getting worse but the recent diagnosis of celiac disease was seen responsible for appearing more prevalent. In a further negative comment the idea of developed intolerance to food was raised with the suggestion that this information was being withheld from the public. Other reasons for more prevalence of some ailments were then offered, as well as an optimistic view of better technology and treatment in the future. Of interest this optimism was then countered by the observation of a growing questioning of medical decisions. It was pointed out that the source of information for public views on GM was different from the experts. In this person's opinion the media was responsible for the public lack of understanding and emotional response, but this was further qualified with the comment that people wanted sensationalised or emotive reports. Another participant agreed and related the way people want to be entertained resulting in a biased view of technology.

3.9 Group three - Session two: Introduction to nanotechnology

(75 minutes)

The second meeting was attended by all ten participants. The video of nanotechnology was shown and the remainder of the meeting centred on the list of examples that were provided. This group tended to be less talkative than the previous groups and tended to listen to the list of examples rather than offer comment. In consequence a good deal of the discussion reported below occurred after the examples had been related to the group.

Technology and society

- *We are pouring billions and billions into something and what about if it doesn't work.*
- *Commercially there are huge benefits. If you were the first person to make digital paint you would make millions. And there might be benefits to society as well.*
- *If it works.*
- *We didn't know we needed it till they made it.*
- *One of the things with research is that you never know where it's going to take you. All the things we got out of going to the moon. If you can make a car lighter, it does not use as much fuel.*
- *Technology is going to change our future rather than the choices that we make.*
- *In my parents' generation they say they saw the most change, stoves and fridges and things. But I think now things change so rapidly. It's like we do have the same amount of change as them but we don't notice it.*
- *I think our world changes rapidly. Perhaps with variations more than significant changes.*
- *The new medical thing from nanotechnology is great, the people with new prosthetic limbs, surely it is better for them, lighter and stronger.*
- *The ethical side needs to be included. Look at how cell phones changes teenager's lives.*

After comment on the cost and potential for making money from an innovation, attention was given to the way in which advances using nanotechnology cannot be predicted. The association with benefits from going to the moon illustrated the idea further. The comment that such change did not necessarily involve choice added a further dimension by suggesting

that where society was going was not set by a community agenda. The common observation about the accelerated pace of change was made, as well as an expression of welcome to medical advances. Of interest, ethics was mentioned but rather than for a new medical intervention this was linked to the effect of technology on everyday lives using the example of cell phones and changes in teenager behaviour.

Problems

- *Like the Painted Apple Moth example, it could cause breathing problems for asthmatics. The problem is they didn't know about it till it caused harm, like asbestos.*
- *What about the stuff in sun block, it penetrates like the L'Oreal product. If all the things we use get absorbed, think about all that stuff floating around in our bodies. God if we are absorbing these things, perhaps we should chuck them out.*
- *When they release these things can they collect them back up? Do they just wash them down the sink?*
- *The more technology the more change to the environment and more problems.*
- *Going back to last week's discussion about GM, I love the idea of progression and technology and things but we don't give it enough time to try it. We really need a life time, perhaps two generations, but scientists cannot wait.*
- *Like you can buy a kitchen drawer from the factory and the draw has been pulled ten hundred times by a robot, so you would think it would last a long time, but with human parts or whatever it's different.*
- *Yes, it's like laser surgery, I've always wondered about having my eyes done but I wonder because while they've only had it out for 20 years. I want to live for 60 more. I don't want to have a problem 40 years down the road.*

The discussion moved to consideration of possible problems. The problem of lack of information and the possibility of unknown adverse effects were raised. Concern was then related about the use of nanotechnology in skincare products as well as concern over precautions associated with use of nanotechnology particles. The idea of the introduction of technology ahead of tests for harmful effects was voiced as well as a practical precautionary approach to something new.

Technology and society

- *If it's already here from the scientists' point of view it's going to happen no matter what. Why are we having these discussions if they are doing it anyway?*
- *If you watch the video and talk about the cool things, you think, oh yea, cool, but when you talk about the problems such as health concerns it comes down to how it is presented.*
- *The products out at the moment are pretty feeble, it's still an emerging technology.*
- *For the sunscreen I want to know if it's in it and if it has been tested. It's about being informed I suppose. It's like having organic vegetables, some buy and some don't, it's about making a choice.*

In comment about the general effect of nanotechnology on society it was pointed out that talk about it seemed pointless because of the view that nanotechnology was going to be implemented regardless. A further comment reflected on the way the technology could seem fantastic which was quickly rebuffed by talk about problems that could eventuate. It was also noted that current examples of nanotechnology were somewhat benign and unimpressive

compared to potential developments. A further relevant point was access to information, as well as adequate tests and trials for nanotechnology developments. Informed choice was emphasised as being important.

3.10 Group three - Session three: Nanotechnology examples

(65 minutes)

For this session the ten participants followed the planned consideration of six nanotechnology examples.

Sensors, lab on a chip, self testing and remote diagnosis

- *Always room for stuffing up, computers go down all the time. It could tell you have some nasty thing that you didn't have.*
- *My mother's a diabetic and this would be fantastic, she wouldn't have to go to the doctor all the time, the test kit at home is horrible.*
- *We could limit it. Something serious, then the doctor would have you come in.*
- *I think of monitoring like diabetes, but to actually detect diseases you would have to go to the doctor to check that everything is OK.*
- *Might make you get onto things earlier, like if you used it as a maintenance thing. Especially if there is actually a trace in your blood, really early cancers and stuff, it would be nice to have pre-warning.*
- *Hypochondria would be a big thing.*
- *Some people could worry and test themselves all the time. Some people exist with medical dictionaries already it's the same thing. For people who know they might be disposed to get something like cancer it would be a good thing.*
- *There will always be people who want to be just perfect. People will always strive for beauty and perfection. I don't know if nanotechnology would make people more like that it's just another tool.*

The set of medical applications for personal testing were generally welcomed. However, the testing was considered to be best applied to the treatment of minor ailments, with more serious illnesses left to be dealt with in the usual manner by the medical profession. A further point was the possibility of hypochondria or becoming self centred. However, it was thought that the new technology would merely be another means for this behaviour to come apparent, rather than being a cause of this behaviour per se.

Replacement body parts

- *It's about keeping everybody perfect.*
- *If you wanted to have it done OK but it puts the heebie geebies up me.*
- *Imagine the independence if it happened to me, it would be OK.*
- *There are some people who have a lack of these functions and are happy with their life, but they should be given the opportunity of a better life to be independent and look after themselves.*
- *It's like being a machine, where will it stop? You can do the whole body, why stop at arms?*
- *The person is really their brain, or the processes in their brain, so as long as they don't interfere with that it wouldn't stop would it. To me, I think the only thing that makes me*

human is the thought processes in my brain. It's nothing to do with my hands or feet or anything biological, it's the reasoning.

- *Some still have a young family so to rejuvenate brain function would be fantastic.*
- *But where do you stop, young babies can be saved, but have poor quality of life in their later years.*
- *But all we do is an intervention. Everything we do affects the environment. The important thing for us is to be conscious of it and decide for the better and realise that some things we do aren't for the better.*

Continuing with the medical theme, the idea of striving for perfect people, as well as an expression of a feeling of revulsion, started the consideration of replacement body parts. The opportunity to treat disabilities was then mentioned, as well as problem of finding where to stop such treatment. Of interest, one participant expressed the view that the mind contained what was essentially human. Further comment emphasised the need for modern treatments that might be available through nanotechnology, but again the need to draw an ethical limit on the technology was raised.

New types of food

- *It would be good wouldn't it?*
- *I find that weird.*
- *I think the Star Trek thing is going to come someday where we can build the molecules to make food. When you look back at microwaves in the seventies it sounded really bad but now we can't live without them, even my kids nuke things now.*
- *I still find microwaves have something funny about them and don't cook in them very much.*

A few comments were made about incorporating particular nanoparticles in food. The food was regarded as both novel and strange, while being likened to initial reactions to microwave ovens but noting their eventual acceptance.

Connecting the brain to a machine

- *Oh no, this sends me over the edge.*
- *I think it would be fantastic for disabled people who are paralysed so they cannot speak. So you'd be doing less and less.*
- *You could have an argument with your partner without the kids hearing. Like texting people, you don't actually talk to each other but can have a relationship. Flirting on the phone without meeting.*
- *That's like the Darleks on Dr Who.*
- *This is the logical conclusion because the essence of a human being in is in their thoughts. If they can do something like that they can then help disabled people.*

One person reacted particularly adversely to consideration of the use of nanotechnology to enable a computer to brain interface. The technique was thought to be good for the disabled. In addition, as had occurred in previous groups, the use of cellphones by teenagers was used as an analogy for possible effects of this use of nanotechnology. The fictional cybernetic Darleks were suggested as one possible outcome. However, it was proposed that the human essence was found in the individual's thought processes. This suggests that the possibility of a cybernetic existence was not entirely unacceptable.

Simple nano-machines

- *If you don't know about them, you would be worried.*
- *Would be good to keep your teeth longer.*
- *Could be built into bubble gum, to clean teeth for kids.*
- *Yuk.*
- *What about a toilet cleaner. You wouldn't have to scrub.*

There were few comments about the use of simple nano-machines in toothpaste. While there was a remark mentioning revulsion, the example was generally accepted by the participants.

Sophisticated nano-machines

- *So they breed.*
- *Breeding could make a problem.*
- *Then we would need to bring in something to clean them up.*

Very few comments were offered regarding what were described as sophisticated nano-machines. It seemed enough to plainly state the necessary points and because the session was out of time no further prompting was made.

3.11 Group four - Session one: Introductions

(60 minutes)

Group four met in a private residence of one of the group participants. There were nine participants of which two were male. This group differed from the other three groups. This group had been arranged through a primary school but the group participants were existing members of a church support group that had regular weekly meetings. As a consequence the participants were very well known to each other. This group was comparable to the participants of the other groups in terms of their being parents of young children. Eight of the nine participants had children that either attended primary school or were about to attend primary school. The remaining participant was married with no children.

Consideration of examples

Respondents were asked to consider and discuss the acceptability of the examples provided to them, or to consider an issue or example that was of particular interest to the group. This group began by discussing their views on the recent meningococcal programme and vaccinations in general, before their consideration of the first example of using bacterium in aerial sprays. The following were the key responses.

Meningococcal vaccinations

- *Some of us certainly looked into it because it is definitely something that was pushed very quickly. It's something that you just don't go along and do. You need to make a decision for yourself.*
- *No, none of us got rock hard information.*

- *I think that in the end it came down to personal feeling about it. There was information either way. You could argue for or against. There was no one thing that said this was the right thing to do, so it came down to how you personally felt about it.*
- *I'll always be concerned about it. I don't have children yet so I haven't had to make the decision. I come from a family of 6 children and none of us were immunised in the 70s. So for my own influences I would always be against it and the reading that I have done and my family have done that strongly shows me there is another side to it.*
- *I also have not been vaccinated as a child. I felt that the diseases weren't life threatening enough. It might have been inconvenient and uncomfortable but they won't kill you.*

As mentioned in the first comment the issues surrounding meningococcal vaccinations had been discussed by the group at one of their social meetings. This comment also introduced two factors with lack of trust in the government and a need to personally consider the use of the vaccination on teenagers and children. The view that there was a lack of information was expressed as well as the view that due to this lack the decision to vaccinate was largely one based on feelings. A person related their objection to the vaccination was seated in their families' views and behaviour and another participant considered that vaccinations, in general, were not worthwhile.

Arial spray using bacterium

- *I don't agree with it because it takes away personal choice.*
- *It's interesting because when I heard about it I thought it can't be that bad but for my house it would be different.*
- *The media hypes this stuff up - terrible apple moth – terrible Painted Apple Moth.*
- *I don't know if I can trust the research put in front of us particularly with the meningococcal thing – one piece of paper says this and one says another thing like it will kill you but who do I trust – how do I know whose right. – It's the same with the spray.*
- *The problem with these things to control the environment is I don't know what it might cause like the amazing rise in child cancer. There's huge evidence of that kind of thing like the company where the employees have cancer and there's also asbestos.*
- *They don't actually, as part of the testing, exactly simulate what was going to happen. They say there's a low risk, but what are they basing it on. All sorts of poisons are natural. We just don't know the long term effects.*
- *Drug companies that put a positive spin on things, so we are led to believe we are making informed choices when actually we are poorly informed. The information is different depending on who is providing it. How can you tell which one is right? The pamphlet words the information differently and the way they pushed it. Pictures of babies around the schools pressure the children. They tried to railroad us.*
- *There's a lot more information out there for us now and we have to make more choices. Previously whatever was done was done and nobody questioned things like we do now.*
- *I think that the GP in the old style community was like an extended family member. But most of the time when you go to the GP they don't know what you've got.*
- *GPs are pressured by government, they aren't independent and their driven by Pharmac. It's good to have someone you know, it comes back to that trust thing. The average person doesn't have the time to dig into issues and find the source of information. Sometimes they just need it to be believable.*

- *It's like sunscreen, we had this debate because my niece only uses sunscreen that has no chemicals in it, but how much sunscreen do you have to use to get a bad effect? Everything is a risk and that's life. You have to weigh up the risk.*
- *We have to be gatekeepers for our children and be careful about food and fly spray.*
- *Yes it's different once you have kids.*

This group's consideration of the example of the aerial spray prompted diverse comment. The issue of personal choice was mentioned first, followed by the comment that the reaction was contingent on whether the participant was immediately affected. 'Media hype' was also mentioned but unlike comment in the other groups this was related to sanctioning the use of aerial sprays. There was then a mention of contradicting information and resulting reliance on trust in information sources. Trust in this case is not an immediately preferred influence on the participant but rather was seen to be a factor because of the consideration of conflicting information. Continuing with the diversity of contributions, risk and concern over the reliability of tests for harmful effects were also mentioned. Questioning was also made of reliance of the opinion of GPs, as well as comment on the weighing up of benefit and risk. Finally, comments were made of the concern of parents over possible effects on children.

3.12 Group four - Session two: Introduction to nanotechnology

(60 minutes)

All nine of the original participants attended. The video of nanotechnology was shown and elaboration given of the list of examples that were provided.

Nano-particles as pollutants

- *What concerns me is the amount of waste we have on the planet now and how bad the monitors and stuff are and they're just being dumped by the millions all over the place. My concern is whether these new improved things are going to be even more toxic to the environment than we've already had.*
- *The stuff going into the dump is being mess around with and is causing more damage to our waterways.*
- *Surely if they can come up with new technology, they can come up with technology that is more environmentally friendly.*
- *The thing I picked up from the video was that in making something by flicking away molecules, the molecules are not recycled. Obviously they are wearing masks or gloves for a reason.*
- *What I find really ironic that improved filters are used to clean water, but if they didn't do the stuff in the first place you wouldn't need them.*

There was concern about the possibility of nano-particles becoming pollutants. In addition, as well as considering the possible extent of a pollution problem, the possibility of residual modifications the process of making nano-particles was also a concern. A further comment pointed to the irony of using nanotechnology to clean up pollution made by nanotechnology.

Military issues

- *This thing worries me this military one you can imagine the US government being involved in this as much as the corporates. They spend millions and millions of dollars on creating these fantastic weapons. Using this kind of thing they can immunise their soldiers and release an agent to kill an enemy.*

Military uses of nanotechnology were not an important topic, probably because of the small size of New Zealand's armed forces. However, it was recognised that the US military would very likely use nanotechnology as a means of improvement for their armed forces.

It's about money

- *The things we want improved are probably boring to scientists. Everything is about money and competition – it's a roller coaster and then everyone gets excited till its boring and they go on to something else.*
- *If you use this technology to prevent bad stuff happening you don't get paid as much as for making something new.*
- *Say for example a disease, if they eradicate it there's no money in it.*
- *They have independent research through the Child Cancer Foundation which does research not driven by drug companies and government departments loose stacks of money on medical treatments.*
- *I think there is good technology like fuel because oil is such a huge thing that people have invented other technologies. But it's about money, so the corporations have bought out these inventions.*
- *A lot of the recent products are commercial.*
- *If they put the same amount of resources and money into finding out what it could do then they should do this before they go ahead. Just to avoid getting sued.*
- *But a lot of money is being poured into this. What was wrong with living in a little community and growing vegetables and killing our own animals and living in caves?*

In this group it was considered the making of money was the impetus behind nanotechnology. It was thought that nanotechnology would be developed primarily in areas where there was prospect of making money. In addition, corporates were seen to be strategic and active in promoting their products, at the expense of benefits to society.

Further comment

- *There's always something in human nature that wants to advance, but we could be happier with a bow and arrow.*
- *They will be saying in 30 yrs time – how did we live without this floppy screen that I carry around rolled up in my bag. If you get stain proof clothing, dry cleaners will go out of business. A lot of people will go out of business with nanotechnology, like the wiring – the copper wire being replaced.*
- *I think they have got some good things but what about long term ramifications.*
- *Humans are dumb sometimes.*

In further comment the idea that nanotechnology may not lead to happiness was voiced as well as the idea of new technology becoming accepted as commonplace. The possibility of

long term ramifications was considered and a comment that humans were 'dumb' likely referred to unforeseen difficulties arising after a technology has been implemented.

3.13 Group four - Session three: Nanotechnology examples

(65 minutes)

All nine participants attended. For this session the group followed the planned consideration of six nanotechnology examples.

Sensors, lab on a chip, self testing and remote diagnosis

- *I worked in a medical centre and people were frustrated with paying big fees just for advice.*
- *Some people don't trust the medical system because they don't have a good relationship with a GP.*
- *But the doctor may know about a longer- term negative effect.*
- *You have more than one scenario for each diagnosis, you have to trust someone who knows more about it than you for what to take.*
- *Surely it would be advantage enough to have a diagnosis and recommend a treatment and side effects and risks.*
- *But there's always more than one option.*
- *But how are you going to tell the lab chip you're getting depressed.*
- *Think how brilliant it would be for a hormone it could test for when you get pregnant and things like that.*
- *Imagine the neurotic people like me, we would always be diagnosing ourselves and our kids.*
- *There would be a lot more paranoid people.*
- *You would probably end up spending more money on stuff you wouldn't necessarily need because you'd find out about something you wouldn't necessarily know about and you would treat it.*
- *There's a lot of stuff you decide based on your own choice and your own feelings... but how do you get philosophy into fact.*
- *It can only be applied so far.*
- *It's not going to replace doctors.*

Nanotechnology applications for personal testing were generally considered acceptable although some problems were envisaged. While presumed to be less costly, the disadvantage of a lack of contact with the expertise of medicinal professional was thought a negative outcome. The possibility of paranoia or hypochondria was also mentioned. A number of further limitations suggested the group considered the implementation of this type of nanotechnology would be problematic.

Replacement body parts

- *Some people choose not have their children given implants because it will change their identity.*
- *This is like the question of immortality. You will replace all of the bits eventually.*
- *We are not meant to live in a perfect world.*

- *Well that's part of your identity to have eyes that don't work properly. But this would radically transform someone's life. But it would be the best thing ever.*
- *Some people would say that they were not missing anything.*
- *These things would happen over a long time period. It would be like someone looking at us a thousand years ago and saying things like oh my goodness they can see through these devices that they put on their faces. Things we take for granted now - a thousand years ago they would have thought no way it would be radical.*
- *Just think of life in terms of fifty years ago ... 1950s New Zealand was completely unrecognisable to what we have now - all the bits of technology. Fifty years from now we might all still be alive but a lot of tiny steps would happen in fifty years.*
- *We already have huge problems with consumer acceptance - are we making it worse?*
- *Very rich people can say I've got little kids and I can plug in some nanotechnology and make them brighter.*
- *It's like the plastic surgery thing because it helps people who are hurt, but potentially it can be used on the other side of the coin, to combat the effects of old age.*
- *If it was my kid that was dying from a horrific disease I wouldn't care how many trees would die to save her.*

The ideas of a loss of personal identity and aversion to extending the length of a person's life began discussion about replacement body parts. Also there was comment that this aspect of nanotechnology becoming acceptable over time. The technology was also likened to the use of cosmetic surgery by the wealthy.

New types of food

- *The kids would think it's great.*
- *You could make everything taste just like chocolate.*
- *I think that people are prepared to embrace it - like we embrace what we already have.*
- *Society as a whole is in such a hurry, they just get what's easy and convenient.*
- *What's to stop them putting it in food?*
- *If nanotechnology in food is better for you, then where's the harm in that?*

The consideration of using nanotechnology to enable flavour choice in food and drink was thought appealing to younger people and was something that society would eventually embrace. It was seen to fit in with modern lifestyle of convenience and possibly of health benefit.

Connecting the brain to a machine

- *If you want to tell a computer what to do, the actual thought processes would be more than just this and that.*
- *Is there that potential to plug people in and give them wonderful holidays when actually they're not going anywhere.*
- *Total recall – wow! Except it wouldn't be reality.*
- *But it would imprint on your memory, so how would you know if it was real or not.*
- *It could be very dangerous. Paedophiles could plug themselves in to look at pornography.*
- *People could do things in their fantasy world and not realise what was real and what was not.*
- *You could have a game of golf – but you wouldn't get fit.*

- *I grew up thinking that humans would eventually destroy themselves by nuclear explosions. Now I'm thinking we are going to destroy ourselves in a completely different way.*

A creative implication from this example was the idea of dreaming a version of reality in a computer. A concern was voiced about the difficulty of discerning reality and it was thought the technology could be used for undesirable purposes. The final comment of the above set shows concern over eventually destroying or eroding natural human experience.

Downloading the brain

- *You couldn't download your soul*
- *The whole thing sounds like you are trying to play God. You're not supposed to play God, you're supposed to be people.*
- *It's like cloning, they are soon going to clone people, but what happens to your personality. You can't exactly duplicate a personality.*
- *God gives a person a spirit so you can't create a spirit as well.*

There was concern over downloading the contents of a person's brain into a computer which likely stemmed from the religious nature of the group. It was thought that the spirit or soul could not be transferred, suggesting the person when transferred would be incomplete.

Simple nano-machines

- *Not as weird as plugging your brain into a computer.*
- *Is it any different than the technology we use already? We've got that 24 hour Colgate - brushes your teeth while you're not even brushing.*
- *They would carry on right through your system - they might never stop.*
- *You could have a body one so you don't have to have a shower any more. All the dirt and sweat would slide right off.*
- *Imagine having clothing that you could just zap it and it changes colour.*
- *But we might need to all wear special suits to stop nano-particles being absorbed into your skin.*

Initially there was little exception taken to the example of using simple nano-machines in toothpaste and it was thought similar to novel additions presently advertised in toothpaste. The possible problem of these nano-particles existing beyond their intended purpose was noted and then a few imaginative possibilities were voiced. A final comment returned the discussion to the possibility of harmful outcomes.

Sophisticated nano-machines

- *That's really scary.*
- *And how do you stop them.*
- *Humans think were so smart, but actually were just really stupid.*
- *Aren't we perfectly happy just living the way we are now.*
- *What by product do you end up with though?*
- *This nanotechnology could help reduce some of our waste.*

A participant thought the use of sophisticated nano-machines to be scary and comment was made about the possible difficulty of controlling them. The seeming stupidity of making something potentially dangerous was voiced, as well as comments suggesting progress was pointless. More positively, it was thought this form of nanotechnology could be useful in reducing waste.

Chapter 4

Summary, implications and conclusion

4.1 Introduction

This concluding chapter begins with the limitations of the research and then a summary and discussion is provided of the results. Implications from the research for nanotechnology development and implementation are provided as well as recommendations for a strategy of further research before concluding the report.

4.2 Limitations

This research has involved the gathering and analysis the talk of groups of New Zealanders. While small in terms of the number of participants the research has involved extensive discussion with its participants enabling an in-depth analysis. Such research is not intended to represent the views of all New Zealanders. The findings are offered as examples of the kind of things lay New Zealanders might discuss regarding nanotechnology given the context of the focus groups.

4.3 Summary and discussion of results

To summarise across the groups for the first session, the example of aerial spraying of bt based insecticide was not unfamiliar to the groups. The consideration that the bt spray was natural was an initial comment made in two of the groups and is an understandable comment given the description of this example. Such comments are therefore understandable and can not readily be considered evidence of respondents considering a technology in terms of it being natural or unnatural particularly in the more abstract sense of being associated with nature as identified in focus group work on biotechnology (Coyle et al., 2003). A more common consideration was that popular media tends to dramatise this issue and give emphasis to public concerns. Such comment could be made about the media treatment of many social issues. A further consideration of similar prominence was the need to weigh up personal cost against social benefit. This suggests people could be reasonable and personally consider the costs imposed upon them in light of wider social benefit. Exactly how reasonable a person could be in actual circumstances is not evident, but, of interest, comments of this type suggest a thoughtful process of weighing up advantages and disadvantages without the perhaps more common simple one-line objections against the use of a technology. In further review, in one of the groups, concern was mentioned over the eventual escalation of the use of such methods with the view that when accepted in some form license is assumed for wider use of the method. Like the comment about reporting bias in popular media, this point could be applied to many uses of science and technology in society. The suggestion that pest resistance or immunity would develop was also made in two of the groups. Again, this comment could be attributed to other issues.

Concerns over vaccinating against meningitis were discussed by two of the groups. Key points were the need for unbiased information and that the issue was more salient for parents. The decision for parents was emotive and it was evident that some might decide based on how they felt about it. One group discussed cloning and the point was raised that other things should be considered instead of this technique, and that the issue was sudden and thrust upon

the public. One group thought stem cell treatment acceptable when it did not involve cloning and thought the government should decide on the issue. A comment from another group was that there was a loss of personal control over such issues. Group two and three discussed issues associated with GM crops at some length. While some considered their objections depended on the crop, a few rejected the technology outright and had strong feelings against GM. The possibility of unknown harmful outcomes was mentioned in both groups and in group three one person was dead against GM while another was very positive about it.

In summary, while the first session served as a primer there were a number of comments that could be considered relevant for considering reactions to nanotechnology. The perception of the media as being biased and a need for information beyond what advocates might provide could be relevant to nanotechnology. Also, while there were a number of one line objections to particular applications of science and technology, a number of participants considered their decisions were the result of weighing up the risk or costs and benefits. In addition, once condoned it was felt licence was given to wider use of a technology. Some issues such as the immediate issues surrounding vaccinations were emotive and, in the face of conflicting information, decisions for some were based on feelings. In this regard, promoters and objectors to a technology might consider factors such as whether the information comes from a trusted source or whether the information is delivered in an attractive manner, so as to influence those with less considered decisions. The lesson from GM is that reactions can be polarised and outright rejection of any application involving this technology can be the result.

The second session for the four groups involved approximately half an hour for discussion. In general the video served the purpose of informing the group but a few still required some discussion to adequately understand the science behind the technology. One problem was that the participants realised that the scientists gave a positive presentation of the technology. In one group one person seemed well informed by their explanation of Moore's law. The possibility of medical advances was also praised and one group went on to discuss moral and ethical issues involving objections to eugenics. The idea of changing social views was also mentioned. Possible problems were enlarged upon by one group, while linking to issues that were raised in their first session to consideration of problems for nanotechnology. One group also talked about the problems of scientists focussing on the science while disregarding social outcomes. The fourth group chose to discuss nano-particles as pollutants and gave emphasis to the technology being driven by money. A further point is the array of varied lines of talk arising after the showing of the video and introduction of further information. This can serve to highlight the multi faceted nature of reactions and show that a planned introduction to the technology may result in unforeseen public reactions.

The third and final session for the four groups involved the introduction and explanation of a number of fictitious scenarios that were introduced with the invitation to the respondents to use their imagination for their discussion. This session generally worked as intended, although there was some disbelief at the possibility of replacing a doctor with self examination and remote diagnosis. The human touch of a trusted health professional was considered necessary for many, but not all, of the group participants. Saving money and convenience were common positive factors mentioned in most of the groups, although the possibility of paranoia and hypochondria were also mentioned as a negative consequence. Replacement body parts were talked about favourably, but the possibility of eugenic-like improvement was raised. In two groups, attempts were made to articulate the benefits of being an ordinary person with flaws. The idea of nano-particles in food to add flavour was seen as unusual and it was expressed that consumers may not buy the products. However, it was noted that young people may be attracted to this as a novelty. For this example, the possibility of harmful consequences to the human body and the environment were raised. The

progression from connecting the brain to a computer to aid first in typing was made by the facilitator in steps. This example culminated in the seemingly fantastic downloading of a human beings neural activity into a computer. While seemingly incredulous, the taking of steps in developing this example made it seem possible. A number of participants thought this more fictional than the other examples and concern was expressed that the human qualities of a person and their personality would be lost in the process of transferring neural activity. It was thought fantastic and, while considered somewhat impossible, it was not a desirable outcome.

For the second to last example the consideration of simple nano-machines, or molecules with a single moving part, in toothpaste was not considered particularly offensive or revolting. In addition, this new toothpaste was likened to the many variations that are commonly advertised for toothpaste at present. In two of the groups, without prompting, the question of what happens to the particles after cleaning teeth was raised. Also, without prompting, two of the groups gave imaginative consideration to the possibilities for nanotechnology including colour changing clothing. The final scenario involved the use of sophisticated self-replicating nano-machines. These were described to each of the groups as potentially useful for cleaning up toxic waste and oil spills. In addition, two of the groups, of their own initiative, discussed the value of self-replicating nano-machines as possible artificial antibodies in a human being. Unlike reported reactions to this scenario from overseas (e.g., BBC News - <http://news.bbc.co.uk/1/hi/sci/tech/3883749.stm>: accessed May 23rd 2005), the example of using self-replicating nano-machines was treated in a very 'matter of fact' way by the groups. This was possible because each group had already discussed the possibility of harmful consequences for other examples, so that it was little revelation to them that harmful consequences could occur for subsequent examples. The general view was that possible problems would have to be addressed in the development and use of this example of nanotechnology.

In summary, the third session worked well in terms of encouraging consideration and discussion of a range of nanotechnology scenarios. In general the participants were interested in the examples used in the scenarios and had little trouble in imagining and discussing the implications of the scenarios. Although at least one participant appeared to be very concerned, the others showed little sign of distress or worry possibly because their consideration of general possible harmful consequences in session two meant they could thoughtfully consider harmful consequences. This meant that possible harmful consequences were considered using the stance that such consequences would have to be addressed and were as apparent to the scientists and authorities as they were to the participants. However, it can not be wholly discounted that the participants tended to calmly discuss the examples and scenarios because they were hypothetical.

4.4 Implications

A key finding likely to have implications for nanotechnology is that participants thought it important to talk about unforeseen risks that could lead to serious negative consequences. In addition, during the talk about various nanotechnology examples there was a tendency to refer to possible negative consequences. There was concern that nanotechnology could become problematic in both foreseen and unforeseen ways. In the case of the possibility of unforeseen harmful consequences, much use was made of this possibility by those opposed to GM at the New Zealand Royal Commission on Genetic Modification 2001. The possibility of unforeseen risk was used to support a call for a precautionary approach by those opposed to GM. Subsequently the commission recommended caution in the use and introduction of GM

with resulting legislation making GM research difficult and expensive. Reference to the historic problems of asbestos, for example, and the reasonably common comments about potential problems for some nanotechnology examples, suggests calls for a precautionary approach could be made against nanotechnology research and its implementation in New Zealand.

A further implication from the research involves a recognised need for unbiased information and distrust of the media as a provider of impartial information. Despite a seemingly well planned information campaign in support of the immunization of children and teenagers against the meningococcal virus in New Zealand, it would seem that the vaccination programme was somewhat thwarted because this campaign was perceived to be biased. Other sources of information questioned the need and value of the vaccination, which resulted in disquiet for many participants. In addition, some insisted that information regardless of source be made available so that everyday individuals could decide. Others, however, found such a situation confusing and admitted reverting to a decision based more on feelings than a rational consideration of views and viewpoints. This means that while it would seem that public engagement between those in favour and those opposed would be useful, such a forum could well result in confusion for the individual. This could simply result in many reverting to consideration of the credibility of the messenger, for example, without serious consideration of the issue and its implications. A further conundrum could well occur given participant suspicions of bias in reports from the popular media. While possibly aware of such bias many participants are nevertheless introduced to an issue and primarily informed about it through this medium. Logically, a biased view would result, even with an awareness of the possibility of media bias. Of further relevance, although the Hunt, Fairweather and Coyle (2003) study of reactions to GM found many concerns particular to GM, it found lack of information and media hype were important concerns of its participants.

A key finding of relevance was the apparent feeling of betrayal upon finding of the potential for harmful consequences after receiving a positive presentation about nanotechnology. In the groups it seemed that all the good work done by the video in explaining and promoting nanotechnology was quickly undone at the mention of possible harmful consequences. Worse than merely raising questions about the technology, this situation likely resulted in distrust and suspicion of the promotion of the new technology. Given that concern has been identified regarding the possibility of unforeseen harmful consequences, the belief that proponents of the technology hid of the possibility of predictable or expected harmful consequences was particularly damaging. In addition to a failure to be clearly open about possible adverse consequences, other impressions of proponents of nanotechnology can be found in remarks about the motives of scientists and the commercialisation of the technology for the purpose of making money. The method of science was perceived by some respondents as involving the 'value free' pursuit of knowledge with a necessary exclusion of moral or ethical concerns. This was perceived to result in science that did not necessarily serve the interests of society and the creation of technology that also ignored social ethics and morals. Further, the commercialisation of science was seen to involve the pursuit of money above other possible goals such as social well-being or, as some participants put it, the pursuit of 'happiness'. While it was clear that participants welcomed the benefits of nanotechnology, particularly for medical treatment, the development of nanotechnology for items such as golf clubs or car bumpers could have seemed trivial, unnecessary, and more about commercialisation than being important for social well-being.

An encouraging implication from the study was that, while there were misgivings associated with each example, there was a general appreciation of the benefits most of the examples. While some examples were seen to be unnecessary or of less benefit such as the example of

using of nanotechnology in food. Nevertheless, the medical examples, for example, elicited a particularly favourable reaction with expressions of appreciation for immediate benefits from the treatment of known medical problems such as diabetes as well as concern over eugenic like enhancement. Another example was the introduction of identity chips in the form of implanted sensors for personal convenience and to combat crime and terrorism but with the caveat that this use of technology would raise issues of personal privacy. A third example shows it to be clearly evident to the participants that the use of self-replicating nano-machines had potential for disaster, however, this example of nanotechnology was considered useful in medical treatment and for the amelioration of environmental damage. This suggests an expectation or assumption that scientists and the government and its agencies will have to deal with the actual and potential risks associated with particular applications of nanotechnology. It was recognised that there were benefits from nanotechnology; however, there was an expectation that the risks had to be dealt with in the development and implementation of the new technology. Of interest there was a similar finding in focus group research on GM (Hunt, Fairweather & Coyle, 2003). While apparently very concerned about risk from GM these groups also indicated the risks would have to be dealt with before the technology was developed and implemented.

4.5 Recommendations

The implications of the research suggest a number of potentially useful steps towards a strategy for recognising and including public views and potential reactions in the consideration, development and implementation of nanotechnology. It is recommended that the strategy include the open discussion of both risks and benefits and that the public be consulted using a responsive and deliberative process towards ensuring nanotechnology developments do not conflict with social attitudes and values. This consultation should be meaningful, in the sense that the public views and interests would have the opportunity to affect the form and type of nanotechnology developed in New Zealand.

One necessary aim would be identify and research various areas that could be, or could become, problematic for nanotechnology. To meet this aim research projects could be targeted to deal with emergent reactions and track their development into public responses and reactions to examples or aspects of nanotechnology. As the findings of this research has indicated, this initiative might include targeted research on concerns about privacy, human enhancement, environmental risk and health risk, attitudes towards science and scientists, perceptions of media bias and risk communication. Ideally proponents of nanotechnology need to be informed and form an understanding of public reactions for the purpose of informing and involving the public. Integral to this strategy would be a commitment to align nanotechnology research and development to the needs and aspirations of New Zealanders.

4.6 Conclusion

The impetus for this research was the rationale that the difficulties associated with GM technology in New Zealand are best avoided in the introduction of nanotechnology. The simple rule being that a new technology is more easily introduced when the needs and concerns of the public are incorporated in the development of the technology. Clearly there is a need to utilise social research to inform and guide the development of nanotechnology and its introduction to the New Zealand public and avoid nanotechnology becoming problematic by identifying the relevant views and attitudes of the public.

The research reported in this paper is a beginning for social research on nanotechnology in New Zealand and suggests various areas where nanotechnology is acceptable while flagging concerns that ordinary New Zealanders have about the new technology. Some of these concerns may well be resolved through the provision of information; however, for others, because nanotechnology could intersect with current problematical social issues such as cloning or human rights, prospects for resolution might seem difficult. Nevertheless, there is presently time and opportunity for science to offer knowledge and tools that are aligned to the needs and prospects of New Zealanders. Given the willingness of science and its institutions to work with the public, there is still time to do good work in smoothing the path for nanotechnology in New Zealand.

References

- Arnall, A. H. (2003). *Future technologies, today's choices. Nanotechnology artificial intelligence and robotics: A technical, political and institutional map of emerging technologies*. Report for the Greenpeace Trust.
- Asher, R. (2002). Brain-machine interface. In M. C. Roco & W. S. Bainbridge (Eds.) *Converging technologies for improving human performance*. (pp. 357-359) NSF/DOC sponsored report.
- Brown, S. (2004). *Demystifying nanotechnology*. Canterbury, 1, 2, 28 – 29.
- Caulder, L. & Penz, A. (2002). Artificial brains and natural intelligence. In M. C. Roco & W. S. Bainbridge (Eds.) *Converging technologies for improving human performance*. (pp. 256-259) NSF/DOC sponsored report.
- Cook, A. J., Kerr, G.N. & Moore, K. (2002). Attitudes and intentions towards purchasing GM food. *Journal of Economic Psychology*, 23, 557-572.
- Cook, A. J., Fairweather, J. R., Satterfield, T. & Hunt, L. M. (2004). *New Zealand public acceptance of biotechnology*. Research Report No. 269, Agribusiness and Economics Research Unit, Lincoln University.
- Cook, A. J. & Fairweather, J. R. (2004). Change in New Zealand farmer and grower attitudes towards gene technology: Results from a follow up survey. *Agbioforum*, 6, 3, 9-16.
- Couchman, P. K. & Fink-Jensen, K. (1990). *Public attitudes to genetic engineering in New Zealand*. DSIR Crop Research Report No 138.
- Coyle, F. J., Maslin, C., Fairweather, J. R. & Hunt, L. M. (2003). *Public understandings of biotechnology in New Zealand: Nature, clean green image and spirituality*. Research Report No. 265, Agribusiness and Economics Research Unit, Lincoln University.
- Crichton, M. (2002). *Prey*. New York: Harper Collins.
- Dewick, P. Green, K and Miozzo, M. (2004). Technological change, industry structure and the environment. *Futures*, 36, 267-293.
- European Commission on Community Health & Consumer Protection (2004). *Nanotechnologies: A preliminary risk analysis on the basis of a workshop organised by the health and consumer protection directorate general of the European Commission*. European Communities, 2004.
- Fitzgerald, G., Saunders, L. & Wilkinson, R. (1996). *Public attitudes to the biological control of rabbits in New Zealand*. MAF Policy Technical Paper no. 96/3. Wellington New Zealand.
- Gamble, J. & Gunsen, T. (2002). *The New Zealand public's attitudes regarding genetically modified food: May and October 2001*. Mount Albert research centre. Horticulture and Food Research Institute of New Zealand Limited.

- Gamble, J., Mugglestone, S., Hedderly, D., Parminter, T. & Richardson-Harman, N. (2000). *Genetic engineering - the public's point of view*. Mount Albert Research Centre. Horticulture and Food Research Institute of New Zealand Limited.
- Haraway, D. (1991). *Simians, cyborgs, and women: The reinvention of nature*. New York: Routledge.
- Hunt, L. M. Fairweather, J. R. & Coyle, F. J. (2003). *Public understandings of biotechnology in New Zealand: Factors affecting acceptability rankings of five selected biotechnologies*. Research Report No. 266, Agribusiness and Economics Research Unit, Lincoln University.
- Laurent, L. & Petit, J. (2005). Nanotechnology and its convergence with other technologies. *International Journal for Philosophy of Chemistry*, 11, 1, 45-76.
- Llinàs & Makarov (2002). Brain-machine interface via a neurovascular approach. In M. C. Roco & W. S. Bainbridge (Eds.) *Converging technologies for improving human performance* (pp. 244-250) NSF/DOC sponsored report.
- Macer, D. (1994). *Bioethics for the people by the people*. Christchurch: Eubios Ethics Institute.
- Nicolelis, M. A. L. (2002). Human-machine interaction: Potential impact of nanotechnology in the design of neuroprosthetic devices aimed at restoring or augmenting human performance. In M. C. Roco & W. S. Bainbridge (Eds.) *Converging technologies for improving human performance*. (pp. 251-255) NSF/DOC sponsored report.
- Phoenix, C & Drexler, M. (2004). Safe exponential manufacturing. *Nanotechnology*, 15, 869-874.
- Ross, S.A., Srinivas, P.R., Clifford, A.J., Lee, S.C., Philbert, M.A. & Hettich RL (2004). New technologies for nutrition research. *Journal of Nutrition*, 134, 3, 681- 685
- Salata, O. V. (2004). Applications of nanoparticles in biology and medicine. *Journal of Nanobiotechnology*, 2, 3.
- Smalley, R. E. (2001). Of chemistry, love and nanobots. *Scientific American*, September 16th, 95-99.
- Thuermer, K. E. (2004). Small wars: Nanotechnology is on the verge of creating a global revolution. *Foreign Direct Investment*, August 9th 2004.
- US Committee for the Review of the National Nanotechnology Initiative (2002). *Small wonders, endless frontier: A review of the national nanotechnology initiative*. National Academies Press, Washington.
- Wood, S., Jones, R. & Geldart, A. (2003). *The social and economic challenges of nanotechnology*. Report for the Economic and Social research Council (www.esrc.ac.uk).

Appendix

Transcription of 'Nano: the Next Dimension'. A television documentary commissioned by the European Commission. Produced by Ex-Nihilo, France

Sourced from: http://europa.eu.int/comm/research/conferences/2002/pdf/presspacks/1-3-nano-new-dimension-script_en.pdf

Commentaire:

The earth. Let's take a look at our planet on a new scale: a billionth of a metre, a nanometre. Suddenly, it seems to have grown immensely. An equally radical revolution has been brought about by nanosciences and technologies.

Jean-Marie Lehn

What actually is "nanotechnology"? Doing things on a small scale. That's very vast. Nanotechnology is technology on a very small scale. It can be chemistry, physics or biology. It can be materials, or medicine, and so forth. The concept is extremely vast. It doesn't hurt to push on further. So let's do that!

Commentaire:

The distance between the Moon and the Earth: on the order of a billion metres, a day's travel. The distance between a metre and a billionth of a meter: roughly the same gulf, but taking just a few seconds. Now we're heading deep into the world of nanoscience, down to the dimension of an atom. To understand today's scientific nanorevolution, we must first take this plunge into a sea of atoms. New landscapes, new sensations... This hidden world surrounds us at all times on every side... Each white ball is a cloud of electrons concealing an atomic nucleus. You are about to discover how scientists have reached this frontier: the land of the atom..... and opened up an infinite new field of research and practical applications.

Jean-Marie Lehn:

First of all, we can see increasing miniaturisation of components in the electronic or nanoelectronic industry...

Jean-Marie Lehn (off):

storing, in tiny volumes of space, far more processing power than is currently possible, but also making use of biomedical applications : an artificial retina, replacing an ear which no longer works, being able to make molecular wires like a nerve which could store all sorts of impulses that the brain would decode. That would be quite something.

Jean-Marie Lehn:

The economic and social consequences would doubtlessly be very great.

Commentaire:

Work on the nanoscale has already revolutionised research in Europe.

Helmut Schmidt :

The new concept which was developed there isn't limited to research and fundamental research. It endeavours to lead all disciplines to the finished product and to take part in the whole engineering process.

Commentaire:

Like others, this research institute is already producing applications based on assembled molecules barely 10 nanometres long: nanoparticles. Here are a few little experiments, demonstrating product efficiency before and after, just like the old hair-restorer ads! On the right of the picture: a normal paint job; on the left: a coating containing new, improved nanoparticles! Now, this car door can't be scratched... Neither can these glasses, which grow darker as light gets stronger... A music CD can be engraved on this flexible plastic sheet. The nanoparticles on this surface repel water... and make this surface hydrophobic too. Spraying graffiti here is a waste of time. No need to scrub, the paint just slides off. Straw and wood no longer burn. Fire-fighters can rest easy.

Commentaire:

The reason for these phenomena - almost magical on our scale - is the shared property of all these objects: nanoparticles at the surface or inside. To understand how industry can manipulate these molecules on the nanoscale, we'll begin at the beginning... For the observation of particles no bigger than a few billionths of a metre, researchers invented a new microscope, only to discover that it could manipulate atoms too! With this tool, seeing is touching. Like a blind man's probing stick, the tip of the microscope "feels" the atoms to display their contours.

Christian Joachim :

This represents a tip with, ideally, a tiny atom at the end. I'm going to bring the tip near the surface of an atom. You can see that this tiny probe must be about the same size as the objects we're observing. We're going to move the tip very close to the surface and record the interactions between the tip and the surface.

Commentaire:

In this animated sequence, the tip - made up of atoms - is bathed in a blue glow linking it to the surface observed. This glow represents an exchange of electrons between the surface atoms and those forming the tip. On this scale, the atoms can swap electrons. This is what happens as the tip of the microscope moves. With a scanning microscope such as this, pictures on the screen do not represent light, but rather computation. They are actually a measurement of electron flow voltage and intensity, changing with every movement across the measured atoms. This provides a sort of relief map of the surface examined, atom by atom.

Enrique Ortega:

When the distance between the tip and the sample is about a nanometre, you get a current of electrons between them, which can't be explained by classical Newtonian physics, but only by quantum mechanics.

Angel Rubio:

Basically, it's a principle of quantum physics that doesn't exist. So if you apply a potential to an empty space, in theory, there is no current. Except that when the tip approaches the sample, there's an overlap between the function of the sample and that of the tip, You get a tunnelling current that depends on the distance between them. This is a purely quantum mechanical effect.

Commentaire:

To sum up, we think of atoms as spheres, but in fact, they're made up of a nucleus surrounded by a number of electrons in orbit - no surprises there. However - brace yourself for a shock! - no scientist can say with certainty where an electron will be at any given moment. In fact, an electron doesn't revolve around a nucleus on a fixed orbit like a satellite around a planet. Instead, it may be any point around the nucleus at any given time, it's as if it were everywhere at once, forming a sort of electronic cloud... a sphere, in fact. This is one of the basic consequences of quantum physics. From time to time, an electron may happen to move a little further from its nucleus than usual. Since there's necessarily another atom close by on this scale, the electron sometimes find itself in the cloud of electrons of this other atom, having broken through the "barrier" that held it around its own nucleus. This electron transfer is that we call the "tunnel effect". It explains a large number of physical phenomena, finds an important application in the scanning tunnelling microscope. For example it can move them or tear them away.

Commentaire :

By generating a stronger electron flow through the tip of the microscope, a given atom can be attracted. This tool that can "feel" matter – and thus give us an image - it can also sculpt it. By gouging out atoms, it can etch lines... or more complex patterns, to build electronic circuits, for instance.

Enrique Ortega:

We're trying to create the shapes that we want, the atomic configuration that we want on an industrial scale, and to design circuits or electronic systems, on this ultimate, tiny scale.

Commentaire :

In Europe and elsewhere, a lot of research is done to improve computer memory capacity... In this miniaturisation race, engineers at Seagate have produced a read-write head just a few atoms thick. On this scale, the magnetic-pole variations in each atom can be used to store encoded data. This has enabled hard-disk capacity to be increased tenfold. Even so, research is moving so fast that other, competing systems are already being developed.

Commentaire :

Elsewhere in Europe, researchers are exploring a completely different method in which molecular robots convert matter using matter itself. In Toulouse, the process begins with ordinary chemical reactions, presented more than succinctly by one of the project team...

Gwenaël Rapenne :

Here's the molecule we've synthesised in seven steps. It has four legs. We're about to look at it through the microscope. We've inserted billions of molecules, although theoretically just one would do.

Commentaire :

These 4 white marks are an electron microscope image of the molecule. And here is a more detailed representation... Pushed by the tip of the tunnel effect microscope, it moves, rubbing against the surface. Successive images are needed to check that it has really been displaced. Mission accomplished! To make this movement more precise, researchers are trying to modify the initial structure of the molecule by adding "paddle-wheel" extensions.

Gwenaël Rapenne :

It works like a cogwheel, it bumps into an atom and turns.

Commentaire:

Throughout Europe, scientists are working on many other types of nanorobot, which may be able to move hundreds of thousands of molecules at once where the tip of the tunnel effect microscope can only handle one at a time... Although, other avenues are also being explored.

Jean-Marie Lehn :

Instead of having to build these objects, which is becoming increasingly hard and expensive, there might be a way of exploiting a property of matter, which is, not mysterious -there are no mysteries in Science, only the unknown-, but a property which is certainly there, and which leads matter to selfassemble.

Commentaire :

In quite another field of research, Harold Kroto's team have stumbled on a new, spontaneously-formed structure of matter. While studying the origin of the universe and trying to reproduce deep-space chemical reactions in the laboratory, they came across a molecule that is frankly amazing.

Harold Kroto :

We found the carbon chains and we explained how these chains came to be in space. But there was a big surprise. At the same time, we discovered this beautiful cage of carbon, of 60 carbon atoms. Which is this one, here. It has 60 carbon atoms.

Commentaire :

This discovery, named fullerene, is a new structure of carbon, an element that takes the form of charcoal, pencil lead or diamonds. A Japanese team completed the picture with a structure very similar to fullerene: the carbon nanotube.

Sumio Iijima :

The mechanical property is determined by how these two atoms are connected to each other, how strongly they are connected. So, in the diamond case, this connection is very strong, in this carbon nanotube the connection is even stronger than in a diamond.

Harold Kroto :

It has basically half of C60 at this end, and half of C60 at that end and then is a tube of graphite, flat sheet, which is rolled into a tube.

Commentaire :

To obtain nanotubes, take two pure-carbon graphite electrodes connected to a DC generator in an atmosphere of helium. An inert gas that does not react with carbon. At 4000° C, the graphite fuses and matter torn from the electrode on the left is deposited on the right-hand one, forming nanotubes. After cooling, they can be collected from the freshly-produced tip. There are hundreds of thousands of nanotubes here, so small that the knife doesn't damage them. Forming 90% of this powder, they are only visible through a microscope. This long structure spanning the screen measures about 5 to 10 microns in length for 10 to 40 nanometres in diameter.

Harold Kroto :

Now the amazing thing about this material is that it is perhaps the strongest object that has ever been made. This tube. And now you have a material that, if you could put in bundles of maybe a million, or maybe much more than that, million, million, million of these, you would have a material which is a100 times stronger than steel and 1/6 the weight.

Commentaire :

As you can imagine, nanotubes look set to take over from superannuated steel. But that's not all: since they're perfect electrical conductors too, they'll certainly provide a major boost for the informatics revolution.

Harold Kroto :

Certain of these tubes are what we call ballistic conductors. They conduct without loss. Not superconductors. But that means that whatever you put in this end gets to the other end. And that means these incredibly thin, sort of light wires could replace the copper wires, aluminium wires, that we use today in transmitting electricity, and with zero loss.

Angel Rubio :

The simplest model is this : imagine a one-dimensional system, and that each of these balls is an electron. So we have two electrodes. We want to carry current from the right one to the left one. What normally happens is what's called transport by diffusion. An electron is injected into the sample, so all the atoms start to vibrate. Since there are impurities, the electron follows a zigzag path, bumping into obstacles, sometimes moving backward. So there's a diffusion, it doesn't go there directly. What happens with ballistic transport? "Ballistic" means that when we inject an electron, another one comes out at the end. We have conduction with zero energy loss in the conductor.

Commentaire :

It is precisely these perfect conduction properties that have led researchers at Delft University in the Netherlands to use nanotubes to make microprocessors.

Cees Dekker:

If you take a nanotube, you have a row of atoms, with all these hexagons of carbon atoms. Looking closely, you see a series of atoms at an angle to the tube. This is essential to the electronic properties of the nanotube.

Commentaire:

To make use of these properties, accurately positioning millions of nanotubes on silicon-chip components would be too time-consuming and tricky. So paradoxically, Cees Dekker's team are trying to accomplish this precision task using the benefits of pure chance.

Cees Dekker:

We are going to place the nanotubes on the chips. The nanotube material itself looks a bit granular, fairly black. We dip it into a liquid and place a drop of it on the surface. Keith Williams from our team will show you.

Keith Williams :

To make a sample it's quite simple just use the pipette. Take the nanotubes out. Like so. And just put them on the surface. And then the next step is just to rinse off the excess solution. It looks like everything is gone but in fact there are a lot of nanotubes left on the surface. And then finally just dry off the water. .

Cees Dekker:

What we do with the drop, which has nanotubes moving about in it, is place it on the surface of the chip. It falls onto the surface, lots of nanotubes fall next to it, and some nanotubes fall right across the two electrodes. So we can get a current to flow from here to here.

Commentaire:

We can see the electrical contacts through the microscope, linking our dimension to the scale of the nanotube. Here, one of the nanotubes is in contact with the electrodes and carries electrical current almost instantaneously. Throughout Europe, researchers are working on electronic components for use in increasingly tiny and ever more powerful circuits. Jean-Marie Lehn, for instance, aims to use matter's ability to organise itself for this purpose.

Jean-Marie Lehn :

Some architectures look more nanoelectronic than others. I can show you some examples which look like electronic circuits, such as this one. Seeing this pattern, without a caption here that seems rather chemical, you might think : this is electronics, these are circuits, this is a rod with contacts on it, these are perpendicular circuits. There are contacts everywhere, that sort of thing. And yet it's chemistry. The little round shapes here are metal ions. And here's the rod. There are 3 notches here, here and here, and these three notches can interact with silver ions. Silver is a salt, so it's a solid, which we dissolve in a solvent. The other thing, the molecule, is a solid that we dissolve. You mix them and it happens. Instantly, in a millisecond, by spontaneous self-assembly.

Commentaire:

Each of these circuits could spontaneously connect to similar circuits, increasing memory capacity.

Jean-Marie Lehn:

After all, if matter self-assembles, then we should try to understand the mechanisms of self-assembly. From there we can try to improve our understanding of the origins of life but also use self-assembly and its underlying principles and concepts to produce structures of a certain kind, spontaneously, yet in a completely controlled way.

Commentaire:

Elsewhere in Europe, researchers are convinced that biology will play a key role in the future of nanotechnology...

Carlo Taliani:

At a fundamental research level, we are studying how to improve the efficiency of electronic circuits based on organic materials. European industry is taking a great deal of interest in this. Improving this property means that it will be possible to have electronics that are inexpensive and widely available. That would be a revolution in our daily life.

Commentaire:

Nanotechnologies reflect the rhythm and dimension of nature itself.

Angel Rubio :

I think that with miniaturisation, we're trying to imitate what nature has been doing throughout the course of evolution. What happens in human eyesight ? All this takes place in 200 femtoseconds, a scale you need to bear in mind. A femtosecond equals 10^{-15} seconds : a thousand or a hundred times faster than the normal vibrations of molecules. These are very fast processes which we can use to make high-speed devices.

Commentaire:

At this point in the story, prospective nanoscience applications are appearing before your very eyes. Now we can dream of imminent and more long-term applications, and note that nanotechnologies are already used today. Let's look at a last concrete example beginning with a standard industrial-scale

chemical reaction controlled on the nanoscale. Take iron chloride and mix it with water to give this orange colour. Add caustic soda. Leave the combination to react for a few minutes until it turns black, showing that iron oxide crystals have formed. Above all, don't let the sauce go lumpy! Particles must be kept down to a scale of a billionth of a metre. Of course, the exact recipe is a closely-guarded industrial secret. To simplify, let's just say that each particle is positively charged so that they repel each other. Here's the low-down... On the left is the magnetisable particle, on the right, an AIDS virus antibody. They bind together because of their positive and negative charges. If the virus is present, the antibody recognises and sticks to it. Then the magnetisable nanoparticle is extracted, still bound to the virus. This early AIDS screening method is still in its development phase. But the example shows what a wide variety of roles nanoparticles can play, particularly in the biomedical field.

Jean-Marie Lehn:

Small also means small amounts of matter and energy. So it's extremely ecological, as it were. As science moves forward, it will generate smaller, more complex objects. It will consume less energy and matter.

Jean-Marie Lehn:

Our most powerful computer is the brain. It's obviously self-assembled, it wasn't made, it made itself. This object which assembles itself in such a complex way, nonetheless follows a specific pre-established plan of complexification. I'm talking to you, I'm connected, the brain is controlling my voice. At the same time, I see and hear you, so it's self-connected. Matter has managed to make something which is the most powerful computer in existence, a computer that selfassembles and self-connects. It's possible, since it exists.

Commentaire :

Especially since this nanoworld seems to offer an unending stream of potential applications, from brighter light-bulbs that use less electricity and high-capacity batteries that charge a hundred times faster to nanocapsule-enclosed drugs that go straight to their target in the body. However far these nanotechnologies must travel to reach us, they will soon be as common - and vital - in our lives as sliced bread.

Carlo Taliani:

Europe has played a leading role in the development of nanosciences and nanotechnologies. You can see this from the number of papers written these past few years. Europe has always been ahead of other developed countries. But other countries are now moving into the arena and investing heavily. If Europe wishes to keep its leading role, at any rate, it must invest more, both in human and material resources.

End.

