First published 1999

ISSN 1328-4576

Published for the Australian Association of Professional and Applied Ethics by the Centre for Applied Philosophy and Public Ethics, Charles Sturt University

Printed by CSU Print, Charles Sturt University, 2010.

Australian Journal of Professional and Applied Ethics

Volume 11, Numbers 1 and 2, 2009

Contents

Setting the Nanotechnology Research Agenda: Medical Research versus Energy Research

John Weckert
Charles Sturt University

1. Introduction

The subject matter of applied ethics most commonly comes from problems raised by a particular technology or activity. Computer ethics has focussed on problems raised by computer technology while much of the subject matter of medical ethics is found in medical practices. Much of this is reactive, though not in a pejorative sense. Problems arise and applied ethicists attempt to find solutions; they react to those problems. Computer technology, for example, has enabled new levels of monitoring and surveillance, which raise problems of personal privacy which rightly, have been much discussed. But not all applied ethics is reactive, or *ethics last* (Moor and Weckert, 2004) and this is particularly true for the ethics of nanotechnology, or nanoethics. Nanotechnology is a new field, at least in its current form, and has not yet raised many problems apart from worries about the potential toxicity of various nanoparticles in products already on the market. Many concerns have been expressed however about potential problems of future developments and this has led to an emphasis on a proactive approach (van der Poel, 2008) or ethics first (Moor and Weckert, 2004). While this is not without its problems, it is a necessary approach to take to an important and powerful new technology such as nanotechnology, an enabling technology that can enhance many other technologies. A problem of course is that this approach involves making predictions and this is always problematic, but such predicting cannot be avoided.

Predicting possible technological futures, or more mundanely, consequences of certain research or technologies, generally involves examining the facts as they are currently known and then extrapolating or making inferences from them. This approach is similar to what has been called the inductive method in the philosophy of science. In this method, one makes inferences from the facts as they are known, often using analogy with other examples. A different approach, more akin to Popper's hypothetico-deductive method, is that of vision assessment. Visions about technological futures can come from a variety of sources: science fiction writers, scientists, developers of technology, policy makers, and so on. These visions are carefully assessed and outlined in three steps by Schmid *et al*: vision analysis, vision evaluation and vision management (Schmid *et al.*, 2006, p. 427). The details of these steps need not concern us here; what is important is that there are at least two ways of discussing the future that can give plausible, if uncertain, guidance for policy decisions.

One aspect of the proactive approach that has not yet received overly much attention in applied ethics is consideration of what the scientific agenda should be. With respect to nanotechnology this is consideration of what the focus of nanotechnology research should be. The focus will determine to a large extent what technologies and products will be developed. There are a number of good reasons for this reluctance. It is difficult to anticipate the consequences of research and the more basic the research the greater the

difficulty. A tradition of scientific freedom also exists (at least in principle), in which it is believed that scientists should be free to pursue their research wherever it may lead.

2. Goals of a research agenda

Despite the reluctance of applied ethicists to consider what research should be undertaken, research agendas are set by national governments and less formally by private organisations that fund research, for example chemical and drug companies. Given the competing and sometimes incompatible research goals, there is a need to examine, from an ethical and social perspective, what these goals should be. From a big picture point of view it can be asked what the purpose of scientific and technological research is. At the one extreme scientific research is seen as a search for knowledge; its goal is to better understand the world and that is justification enough. If there are more practical benefits, that is good but not the main purpose of science. At the other extreme research is aimed at developing products or techniques profitable for the organisation funding the research. Between these extremes is research to alleviate social, personal, economic or other problems. It is doubtful if much research today has only one of these goals, and while in any individual case the research will be closer to one end or the other, it will probably involve a mixture of profit, social and knowledge goals. Generally then, it can be said that scientific and technological research is designed to make life better in certain ways; more idealistically, to contribute to the good life by improving health, wealth, knowledge or some other aspect.

It must be noted that no sharp distinction is being drawn here between pure and applied science or between science and technology. While there are differences in degree they are not important for the argument of this paper and in any case the differences are not as easy to draw as it is often thought.

If research is aimed at improving life, whether it be better health, more knowledge of the world or greater profits, serious questions must be asked concerning the kind of research that should be done and who should make the decisions. A strongly held view has been that scientists are the best judges of what research should be pursued and that society benefits most when they are given free reign to follow the search for knowledge wherever it may lead. Given the abuses of science in Nazi Germany and Stalinist Russia such a view is not surprising. A strong advocate of this position was Michel Polanyi, who wrote:

> Any attempt at guiding scientific research towards a purpose other than its own is an attempt to deflect it from the advancement of science. … You can kill or mutilate the advance of science, you cannot shape it (Polanyi,1962).

Another enthusiastic supporter was Vannevar Bush who had a large influence on science policy in the USA. He wrote:

> Scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown. Freedom of inquiry must be preserved under any plan for Government support of science … (Bush, 1945).

This view still has currency, at least amongst many scientists, but seems out of favour with governments who attempt to set, or influence, the research agenda by funding policies supporting various types of applied research supposed to be in the national interest. These policies commonly do not favour basic research. In Australia for example, the current priority funding areas are:

> An environmentally sustainable Australia
> Promoting and maintaining good health
> Frontier technologies for building and transforming Australian industries
> Safeguarding Australia (Australian Research Council).

Governments of course might be wrong; perhaps they should not attempt to control the direction of scientific research. Philip Kitcher argues that governments are not the best bodies to decide what research should be done, but neither does he believe that, in a democracy, all decisions should be left to the scientists either. His suggestion is this:

> we need an institution that would offer a serious map of what scientific research has achieved and what possibilities it opens up for us. There's no reason why a group of senior scientists, perhaps scientists nearing the end of distinguished research careers, could not produce, in joint deliberation, a relatively accurate overall picture. They could then present that picture to representatives of different human constituencies in different human societies, representatives who would thus come to understand the lines along which future inquiry might be conducted. This *Scientific Forum* ... could then be set the task of trying to devise an appropriate research agenda that would take seriously the tutored preferences of all the represented groups. ... perhaps under the aegis of UNICEF (or UNESCO) or some similar group ... (Kitcher, 2007).

Kitcher's argument is a general one that applies to all sciences. The European Commission has recently published a 'Code of Conduct for Responsible Nanosciences and Nanotechnologies Research'. One of the clauses of this states:

> 4.1.13 Member States, N&N research funding bodies and organisations should encourage fields of N&N research with the broadest possible positive impact. A priority should be given to research aiming to protect the public and the environment, consumers or workers ... (Commission of European Communities, 2008).

This clause clearly advocates a research agenda that gives the greatest benefits to the greatest number of people. More importantly for our purposes, it advocates a research agenda that is not determined just by scientists' interests or by profits. It introduces a social element.

If Kitcher and the European Commission are correct about the desirability of research agendas being set with social goals in mind and not merely as a result of scientists following their own interests or of profits, then of course there must be consideration of those social goals.

3. How should the agenda be decided?

On the Polanyi or Bush model, insofar as there were an agenda, it would be set by individual scientists or groups of scientists with respect to their own work. They would go where their research led. In the current world, with serious and urgent problems to be solved, large profits to be made, national economies to be sustained and governments to be re-elected, competing and in some cases incompatible forces drive the decision making. Large profits, for example, might be made from developments desired by the affluent but those developments might not solve any serious social problem.

An obvious criterion for agenda setting is needs. Clearly needs of people are important but which needs and which people? For simplicity, initially we will limit the

discussion to just the setting of national research priorities. There are at least economic, health, environmental and security needs (as reflected in the Australian priorities). All are important but questions still arise of how they should be prioritised and what the priorities should be within each. For example, some particular research may lead to considerable health or economic benefits, but only for a few, so equity is an important factor. Should consideration be given to research that aims at enjoyment or quality of life but has little to do with health, the economy and so on? Perhaps Bhutan's Gross National Happiness should be taken just as seriously as the more commonly used GDP (Revkin, 2005).

Even this is only part of the story because it deals only with a *current* national population. To what extent should the interests of *future* generations be taken into account? And to what extent should national interests make way for global interests? Rather than answering these questions directly, we will consider an example in detail in order to better understand some of the considerations that must be taken into account.

4. Nanotechnology, health and energy

In the following argument we make four assumptions:

- Research funding is a limited resource
- There is climate change
- Climate change has a human cause
- It is not too late to remedy the situation

If any of these do not hold, obviously our argument will not work.

If reports of the dangers of climate change are to be believed, our environment is in serious danger unless carbon emissions can be reduced dramatically. High food prices are already causing riots, and concerns have been expressed that the situation is deteriorating. The high prices have been attributed to drought in various parts of the world, including Australia, and to land being taken out of food production and used for the production of biofuels. While the current droughts might or might not be a consequence of human-induced climate change, the growing of crops for energy production is a consequence of high oil prices and a concern to lower carbon emissions. A chief cause of the climate change problem is energy generation and use. Coal generation of electricity and the internal combustion engine are chief culprits but these are both essential components of current advanced societies. Australia has the highest per capita emissions of carbon, chiefly because most of its electricity is generated by coal. With a number of large countries developing rapidly, the demand for and use of energy, particularly from coal and petroleum, is continuing to increase (China, for example, is bringing online two new coal fired power stations each week) so the climate change problem will get worse. The 2006 *Stern Report* predicted, amongst other things, that on current trends, by the middle of this century '200 million people may be permanently displaced due to rising sea levels, heavier floods and droughts' (Stern, 2006). And Stern claimed in a recent speech that his initial report underestimated the problem (Stern, 2008).

Options for solving the problem seem to be few. The standard of living of those in advanced economies could be dramatically lowered and the developing economies stopped from developing. This is obviously neither viable nor fair. No government would stay in power if it intentionally lowered the standard of living of its citizens and to stop developing countries developing would be blatantly unfair. Lowering the world's population dramatically would lessen carbon emissions but that is hardly an option either and certainly not in the short term. It appears then that the only solution must be a technological one, or at least technology must play a significant role. Both clean energy technology and energy efficient products are vital. They alone will not solve the problem; they still must be used and distributed properly, but it is a necessary condition for a solution.

The potential of nanotechnology to help solve or at least allieviate the energy problem appears to be significant. Examples are solar energy for electricity generation and hydrogen production, better energy storage including hydrogen storage, reduced energy consumption using new materials and more efficient light bulbs and so on (Betzel, 2007; Mao and Chen, 2007; Naterer, 2007; Elter, 2009; Mulcahy, 2009; Saxl, 2009).

According to a recent report of the Australian Academy of Technological Sciences and Engineering, nanotechnology has potential in the following areas (ATSE, 2008, p. 6):

- energy conversion – solar cells, thermo-electric devices, catalysts for conversion, environmental management, fuel cells, hydrogen production, carbon dioxide capture;
- energy storage – supercapacitors, batteries, hydrogen storage;
- energy transmission – superconducting systems, hydrogen distribution; and
- energy use – conservation in industry and construction, materials for transport, fuel cells, catalysts for combustion.

Artificial photosynthesis too, a technology enabled by nanotechnology, seems to have potential. Pace gives this description:

> Artificial photosynthesis (AP) is an umbrella term, embracing totally novel approaches to research into and development of technologies for non-polluting electricity generation, fuel production and carbon sequestration, using solar energy (Pace, 2005).

While many researchers and developers are extremely optimistic about the potential of nanotechnology to play an important role in future energy creation, storage and saving, this optimism is not universally shared. At a recent conference strong reservations were expressed by one of the keynote speakers (Vogt, 2009). However, given the seriousness of the problem and the fact that many are optimistic there seems good reason to pursue this line of research.

Nanotechnologies' potential in the medical field seems equally great. Nanotechnology will almost certainly provide medical benefits through earlier, faster and more accurate diagnosis. Wilson *et al.*, (2002) talk of nanoreceptors to identify trace amounts of material that indicate the occurrence of some virus or body malfunction. Microelectromechanical (MEMS) lab-on-a-chip technologies (currently micro size) can be implanted in the body for continuous monitoring (ESRC, 2003; RS&RAE, 2004). More efficient drug delivery will also be enabled by nanotechnology. According to the Royal Society report, nanoparticles that target specific diseased cells and release therapeutic agents of just the right amount at the right time are being researched (RS&RAE, 2004). Drugs themselves could have better solubility and therefore greater absorption (ESRC, 2003). Faster diagnosis is also likely. Research indicates, for example, that the time to complete immunoassay could be slashed to minutes, and perhaps paramedics could 'test stroke victims for specific molecular markers on their way to hospital' (Schechter, 2003). Other research has the goal of using DNA to help design drugs that that can mesh not just with specific molecules, but with specific parts of the targeted molecules (Seeman, 2004).

Most funding of medical research is spent on diseases of the relatively affluent, for example on heart disease and cancer. A common statement is that around ninety percent of medical research is spent on diseases of ten percent of the world's population. The most likely reasons for this are that the affluent do the research and will want to focus on diseases that affect them and that it is more profitable to cure the wealthy than the poor.

In the remainder of this paper the argument will be that there should be less of a focus in nanotechnology on medical research aimed at the developed world and more of a focus on clean energy and other technologies for energy efficiency. This is not to argue that research into cancer and other diseases is not desirable but rather that research into energy is more urgent and will benefit many more people. Both areas receive considerable funding in the US. The estimate for 2008 for the US National Nanotechnology Initiative (NNI) was $251 million for energy and $226 for biomedical research, and the proposal for 2009 is $311 for energy and $226 for medical research NNI, 2007). These figures relate, in the energy case to Department of Energy spending and in the medical, Department of Health and Human Services spending, so they give an indication only. Obviously research in other areas also has a bearing on both energy and medical research, for example spending on materials and on the environment.

The argument for giving energy research priority over medical research may seem counter intuitive, but consider this example from Kitcher. A local African group were encouraged to have their children vaccinated but after some days of consideration their response was that 'what they really needed were vaccines for their goats' because 'if the goats die … all our lives are threatened' (Kitcher, 2007, p. 180). While children are undoubtedly more important than goats, it is not a choice between the children and the goats, it is a matter of the best way of sustaining all, including the children. The situation is analogous regarding energy and medical research.

It might be objected at the outset that we all have a right to the best medical treatment available and that therefore reducing research would be wrong. It is not quite true of course that we have a right to the best medical treatment available; the most to which we have a right is to the best treatment *other things being equal*. My right could be overridden by the rights of others who are in more need if there are not enough of the required resources for all. In any case, this argument applies to medical treatment, not medical research. The argument here is that there is no right to the best medical *research*. We accept that there is a right to the best medical treatment available. Medical research improves medical treatment so is obviously a good but it is not clear that there is any moral obligation to undertake it. The better swimmer that I am the more drowning people I will be able to save but nobody has the right to expect me to train to become a strong swimmer on the off chance that I will be better placed to save him or her if the need arises (unless I am a lifeguard or some equivalent). Similarly, nobody has a right to expect anyone, even the government, to undertake medical research in situations where there is already a high level.

Three arguments will be used here; a consequentialist argument, one based on duty and a third on ethics of care.

The consequentialist case

On utilitarian grounds a case can certainly be made for medical research, even if a rights-based case is more difficult to make. The utilitarian argument is stronger for research into diseases that afflict the developing world than for diseases of the developed world. Many more people will benefit and the benefits for each (in general) will be greater. In developed countries most people already have relatively long and healthy lives, and most life-threatening diseases afflict those already elderly, so there are diminishing returns from the research.

On purely utilitarian grounds an even stronger argument can be made for energy research at the expense of medical research on diseases of those in the developed world. Vastly more people will benefit; just about the whole world's population as opposed to a relatively small proportion of those in developed countries.

At first sight it might appear to be a matter of sacrificing a few, those who would have benefited from the medical research, for the sake of the many. On consequentialist grounds this kind of sacrificing can be justifiable. It could, for example, be justifiable to deny expensive treatment to one in order to provide less expensive treatment to many. But the situation is not quite like this. It is not simply the case that the person to miss out on medical treatment as a result of changed research priorities will suffer while others will benefit. *That* person will, or will potentially, benefit too by living in a cleaner environment. So it is not purely matter of choosing between a few or the many, because those few will also benefit from clean energy research (cf. Kitcher's goat example).

The duty case

The right thing to do cannot always be determined simply by the number of people who will benefit; individual rights and concomitant duties must also be taken into account. It is plausible to argue that there is a right to the best medical care available and therefore society has a duty to provide that care. Is there also a duty to do medical research? And is there a duty to provide the healthiest natural environment possible?
All of these duties are reasonable but our contention is that the duty for energy research is stronger than the duty for medical research. To defend this claim we need to look a little more closely at duties.

Positive duties, duties to do good, are commonly (though by no means universally) thought to be weaker than negative duties, duties not to do harm. The duty not to kill is stronger than the duty to save a life. Suppose that the only way to save the life of Tom is to kill Harry and transplant his heart into Tom. While saving the life of Tom is good, killing Harry to achieve it is not justifiable. Doing nothing will result in the death of Tom but Harry's death would be the result of an action. Letting Tom die is not good, but killing Harry is clearly worse.

The situation is not quite so clear because not all duties are straightforwardly either positive or negative. Some duties result from previous harmful actions, whether careless or intentional. I can have a duty to do good to someone who I have previously harmed in a way that I do not have a duty to do the same thing to someone I have not harmed. In these cases the situation is not like that of Tom and Harry. It is more like the case where Thomasina is injured by a careless action of Harriet. Harriet then does have a duty to do some good to Thomasina as a result of the action that caused the harm in the first place. These kinds of duties are what Pogge calls *intermediate* duties and while stronger than positive duties are weaker that negative duties (Pogge, 2005, p. 34). Now, many of the diseases that afflict those of us in developed countries are a result of our lifestyles and of the fact that we are living longer. Medical research to overcome or alleviate these diseases is undoubtedly a good, but if it is a duty at all it is a positive duty. Clean energy research is aimed at providing a better environment for future generations and this is an

environment that has been degraded by current and previous generations. Therefore if we, a generation that has caused much of the environmental damage, has a duty to provide a better one, it is an intermediate duty; a stronger duty than the positive one of undertaking more medical research.

The ethics of care case

While it is easy in the abstract to advocate spending more on clean energy and less on health, the argument does not seem so convincing when considered at a more personal level. If I or someone close to me has cancer or a heart problem, I will hope that the very best medical help is available and that as much research as possible is being done to help overcome the problem. After all, if I am dead, a cleaner environment will not help me much. Older people, including me, will probably benefit more from medical research than from energy research. Our problems are medical and we will not live long enough to see the worst consequences of climate change nor get the benefits of clean energy. From the point of view of future generations this looks particularly selfish but, it might be argued, future generations do not exist and we have no obligations to them. But that argument does not only appear selfish in the abstract where we talk of as yet unborn future generations. There is wide consensus amongst scientists that the climate change problems will most likely have serious consequences for humans this century. Life spans are increasing and many of those who are young now, say in their first ten years, will still be alive late this century when the problems will most likely be severe. Given the current state of medical knowledge and treatment, my grandchildren have a reasonable chance of living to around eighty and beyond. On many predictions, problems of climate change will be serious by the time that they are old and certainly will be by the time that their children are old. Therefore, without technological developments in clean energy their standard of living will most likely deteriorate and that of their children almost certainly will. If I care about my grandchildren I care not only about medical developments that could save or improve their lives but also about the environment in which they will have to live. I care too about the environment of my great-grandchildren, not because I have any great feeling for *them*; they do not exist, but my grandchildren will have feelings for their children so if that generation suffers, so will my grandchildren for whom I do care. So the choice between further medical research that might benefit my grandchildren and research on clean energy that will benefit the whole generation is not simply a matter of counting the numbers of those who will benefit but also a matter of weighing up benefits for some of those for whom I care, in this case, my grandchildren.

Viewed in this way, when we consider our grandchildren or other young people about whom we care, the argument that energy research is more important than medical research does not appear abstract. My grandchildren have individual rights just as I do. While I certainly want them to have the best medical care if they need it, I also want them to have an environment in which they can thrive. Personalised to little children who we love, the argument is not purely abstract.

5. Further considerations

Despite the arguments above, perhaps developing clean energy is not as important as it has been suggested. Many people in developing countries (and some in developed countries) live without much energy at all, relying on just fire and the sun. So developing clean energy technologies does not look so important. Two responses to this can be given. The first is that while living simply and relying on just fire and the sun is certainly possible, if people want to move beyond that the possibility for them to do so should be available, given that we in the developed world do have that option. This is a question of fairness. Second, many of those in developing countries currently not using much energy will not be immune to the consequences of climate change. A recent report shows that the populations of Bangladesh, Myanmar and Honduras are worst affected by climate change that has already occurred (Harmeling, 2009). While the consequences of climate change will, it seems, be variable, with some people being more adversely affected than others, and some, in fact, benefiting (by warmer climates, for example), the vast majority of the world's poor will be exposed to even more suffering.

A further consideration is that those worst affected by climate change might be better served by greater resources spent on health research than on energy research. This appears plausible if temperatures rise, as is predicted, and tropical diseases such as malaria, spread. First it should be noted that this paper does not argue that resources should be diverted from medical research on diseases affecting developing nations but rather should come from the 90% spent on the 10% of the more privileged section of the world's population. Still, perhaps it would be better to take the funding from the 10% and spend it on diseases likely to become worse with climate change. This may have more beneficial effects than clean energy research which may not improve the situation for many decades if at all. The first response to this is that an explicit assumption of this paper is that it is possible to beneficially affect climate change. If it turns out not to be possible, the argument fails. The consensus amongst climate scientists however, seems to be that it is possible to remedy the situation, hence attempts, such as the Copenhagen conference, are made to do so. A second response is that, if climate change will have serious, perhaps catastrophic, effects then increasing medical research funding for those likely to be worst affected by climate change, is a short term measure at best for current generations and will be of little benefit to future generations*.

6. Conclusion

Even if it is accepted that it would be better to focus research on clean energy rather than on the health of those in the developed world, one might still argue that it would be better still to bring some equity to medical research and spend more on diseases of the developing world. This is certainly a worthy goal deserving of much greater attention than it receives. The problem is that given the world's current population and current energy needs, this would exacerbate the problem. More people would live longer and desire a higher standard of living. This of course would be a good thing if there were ample resources to go around, but at least in the case of clean energy, there are not. What is necessary is that developments in clean energy are at least a little ahead of improvements in human health, otherwise those health improvements will be largely pointless.

More than clean energy is required to live a good life but it is a necessary prerequisite (for more than a basic, subsistence level of living) to other necessities such as adequate food, clean water, shelter and transport. Health is of course a necessity too and the argument here is not that medical research should stop and certainly not that medical treatment should stop, but rather that a greater focus should be on clean energy and a lesser focus on diseases of the developed world. With limitless financial resources no choices would need to be made but these resources are not limitless. Funding could of course be diverted from other sources, for example from weapons' research, and then perhaps we could have both: clean energy research and medical research. This would be the ideal situation but this does not alter the general argument. Even if this money did

become available the argument would be that it would be more important to spend it on clean energy research rather than on medical research.

* *I thank an anonymous referee for raising the issues discussed in this section.*

References

Australian Research Council (2009), www.gov.arc.au

Australian Academy of Technological Sciences and Engineering (2008). *Energy and Nanotechnologies: Strategy for Australia's Future*. Report of a Study by The Australian Academy of Technological Sciences and Engineering. www.atse.org.au/uploads/NanoRep.pdf

Betzel, Clemens (2007). 'Talking about nanogeneration', *Nano: The Magazine for Small Science*, vol. 4, December, pp. 44-45.

Bush, Vannevar (1945). *Science the Endless Frontier*. United States Government Printing Office.
Commission of European Communities (2008). 'Commission Recommendation on a Code of Conduct for Responsible Nanosciences and Nanotechnologies Research', Brussels, 07/02/2008, C(2008)424 final.

Elter, John F. (2009). 'Nanotechnology: the 21st century catalyst for sustainability', *Nano: The Magazine for Small Science*, vol. 13, August, pp. 39-41.

Economic & Social Research Council (2003). 'The Social and Economic Challenges of Nanotechnology' [Wood, S.J., Jones, R.A.L. and Geidart, A.]. UK.

Harmeling, Sven (2009). 'Global Climate Risk Index 2010', Briefing Paper, Germanwatch, www.germanwatch.org/klima/cri.htm

Kitcher, Philip (2007). 'Scientific research – who should govern?', *Nanoethics: Ethics for Technologies that Converge at the Nanoscale*, vol. 1, pp. 177-184.

Mao, Samuel S. and Chen, Xiaobo (2007). 'Selected nanotechnologies for renewable energy applications', *International Journal of Energy Research*, vol. 31, pp. 619-636.

Moor and Weckert (2004). 'Nanoethics: assessing the nanoscale from an ethical point of view'. In Joachim Schummer and Alfred Nordmann (eds.), *Discovering The Nanoscale*. IOS Press.

Mulcahy, Elaine (2009). 'Green energy: a revolution is needed to power the planet', *Nano: The Magazine for Small Science*, vol. 10, February, pp. 18-21.

National Nanotechnology Initiative, 'National Nanotechnology Initiative FY 2009 Budget and Highlights', www.nano.gov/NNI_FY09_budget_summary.pdf

Naterer, Greg F. (2007). 'Guest editorial: recent advances in micro and nano energy systems', *International Journal of Energy Research*, vol. 31, p. 547.

Pace, Ron J. (2005). 'An integrated artificial photosynthesis model'. In Anthony F. Collins and C. Critchley (eds.), *Artificial Photosynthesis: From Basic Biology to Industrial Application* (pp. 13-34). Wiley-VCH verlag GMBh & Co. KGaA, Weinheim.

Pogge, Thomas (2005). 'Real world justice', *The Journal of Ethics*, vol. 9, pp. 29-53.

Polanyi, M. (1962). 'The republic of science: its political and economic theory', *Minerva,* vol. 1, pp. 54-74.

Revkin, Andrew C. (2005, October 4). 'A new measure of well-being from a happy little kingdom', *The New York Times*,

Saxl, Ottilia (2009). 'Can nanotechnology save the planet?', *Nano: The Magazine for Small Science*, vol. 10, February, pp. 14-17.

Schechter, Bruce (2003). 'Bright new world', *New Scientist*, vol. 26, April, pp. 31-33.

Schmid, E., Ernst, H., Grunwald, A., Grüwald, W., Hofmann, H., Krug, H., Janich, P., Mayor, M., Rathgeber, W., Simon, U., Vogel, V. and Wyrwa, D. (2006). *Nanotechnology: Assessments and Perspectives* (in the series Wissenschaftsethik und Technikfolgenbeurteilung, Band 27). Springer: Berlin.

Seeman, Nadrian C. (2004). 'Nanotechnology and the Double Helix', *Scientific American*, vol. 290, 6 June, pp. 34-43.

Stern, Nicholas (2006). *The Stern Report*, http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm.

Stern, Nicholas (2008, April 17). 'Climate expert stern "underestimated problem"', *The Age*, (Australia),

The Royal Society and The Royal Academy of Engineering (2004). 'Nanoscience and Nanotechnologies', UK report, UK.

Van der Poel, Ibo (2008). 'How should we do nanoethics? A network approach to discerning ethical issues in nanotechnology', *Nanoethics: Ethics for Technologies that Converge at the Nanoscale*, vol. 2, pp. 25-38.

Vogt, Thomas (2009). 'Emerging technologies: catching up with utopia'. Presented at Society for the Study of Nanotechnology and Emerging Technologies Conference (S.Net), University of Washington, Seattle, 8-11 September.

Wilson, M., Kannangara, K., Smith, G., Simmons, M. and Raguse, B. (2002). *Nanotechnology: Basic Science and Emerging Technologies*. UNSW Press.

Neurotechnology: the need for neuroethicists

Laura Cabrera
Charles Sturt University

1. Introduction

Neurotechnology might not be as well-known as nanotechnology, but if Zack Lynch, executive director of the Neurosociety Institute is right, then it will certainly start gaining more and more attention, and could potentially become the next wave of techno-economic change (Lynch, 2004). In this paper I will argue that ethical discussion of neurotechnology is crucial as it deals with the organ that has been considered the core of ourselves, namely the brain. In the past a great deal of ethical reflection was dedicated to neurocognitive enhancers such as pharmaceuticals, or more recently to brain imaging techniques. However, these are only two of the different fields covered by neurotechnology. In this paper my aim is to expand the common understanding of neurotechnology and bring up different ethical issues that neurotechnology brings or could bring to the fore, arguing for the importance of ethicists working on these issues.

2. Defining Neurotechnology

During the latter part of the 20th century, the study of the brain moved from a minor position within the psychological and the biological sciences to become an interdisciplinary field that includes fields such as biology, medicine, psychology, chemistry, physics and mathematics. This interdisciplinary field has matured and made rapid progress thanks to advances in different emerging technologies, such as nanotechnology. Such rapid progress will likely continue enabling further investigation and clarification of functions and mechanisms of the brain (Lynch, 2005; Roco and Bainbridge, 2005; Teixido and Giralt, 2008; Highfield, 2008). Thus, it is plausible to say that as a result of current knowledge and techniques reached through other enabling technologies in modern neuroscience, neurotechnology emerged (Banks, 2003).

Definitions of neurotechnology vary, and no standard definition for it yet exists. In this paper, I will be using the term neurotechnology to refer to the science and technology, as well as the processes and devices, that enable us to understand, analyse, measure, monitor, treat and heal the nervous system and brain. The next section analyses the key features that make neurotechnology unique among other technologies in its potential to transform the human condition. This will allow us to understand why the ethical issues become crucial with neurotechnology.

3. State of Play in Neurotechnology

Neurotechnology is the most rapidly advancing area of medicine and biotechnology (Glannon, 2006; Science and Technology Options Assessment, 2009). Neurotechnology can be categorized into three main fields: (1) neuropharmacology or neuroceuticals[1], (2) neurodiagnostics (which includes neuroimaging, in vitro diagnostics and neuroinformatics), and (3) neurodevices (which includes neuromodulation, neuroprosthetics, neurofeedback and neurosurgical devices). Neuropharmacology and neuroimaging are the two fields that have received a large amount of attention in the literature, both the technical issues and the ethical ones. However, other fields, such as neurodevices, have not received much attention (Warwick and Cerqui, 2006). It is