Science fiction or the wave of the future?

Nanotechnology is seen by some as a dehumanising threat and by others as promising almost limitless benefits. Stephen Wood, Richard Jones and Alison Geldart argue that we need urgently to get to grips with its real implications.

Nanotechnology is provoking extreme visions of the future of humankind. As one commentator (Dinkelacker) has put it, it offers the"possibilities of either wondrous prosperity and freedom or a wretched, hard-scrabble existence under cruel oppression".

For the optimists, new forms of manufacturing could bring about material abundance the world over, undermining power based on the control of scarce resources. Institutions would need to restructure to accommodate these changes. The contexts that determine our identities, such as the work place and the family, may have to be redefined and the nature of work itself would be transformed. The most radical change to society, however, could be our increasing longevity. Nanotechnology's supporters envisage the end to disease and suffering.

These utopian scenarios are mirrored by equally strong predictions. Those opposed to nanotechnology fear a dystopian future, in which it not only fails to bring about a perfect world, but positively hastens humanity's demise. The "grey goo" scenario envisages nanosized, self-replicating robots getting out of control and reproducing themselves with such speed and in such quantities that they obliterate the biosphere.

This may all be an interesting and fertile debate for social science, but there are more imminent and important issues surrounding nanotechnology that are currently in danger of being ignored.

First, it is necessary to define what nanotechnology is. It is a generic term to describe a range of emerging by Stephen Wood, Richard Jones and Alison Geldart

technologies. Its domain is defined in terms of a length scale – from about 1 to 100 nanometers. Its importance derives from the appearance of different physical properties at these length-scales.

There is the risk of over-hype

The underlying science – nanoscience – is a convergence of physics, chemistry, materials science and biology, which investigates and controls matter at the molecular level. Nanoscience is here and flourishing, with the capacity to observe and manipulate matter at the nano level well developed.

In contrast, nanotechnology is an emerging engineering discipline, which applies methods from nanoscience to create usable, marketable and economically viable products. It is still very much in its infancy. In fact, the most developed domain of nanotechnology is the making of the tools that enable the science. The basic tool of nanoscience is the scanning probe microscope that allows individual atoms to be observed and manipulated. Its development has been, perhaps, the single most important step in the crystallisation of nano-scale science and technology as a discipline.

Advances in the broad field that is labelled nanotechnology are incremental and the development of new techniques has been a progression from such disciplines as materials and colloid science. The research here is not a radical or conceptual break from investigations over the last 20 years. Even those products that are heavily publicised as relying on nanotechnology, such as stronger materials and sunscreens, are the results of an evolutionary progress. In the short term, the majority of nanotechnology products will be fairly prosaic.

Nanotechnology's diversity – and its core theme of molecular manipulation – makes it applicable in many areas. Its promoters predict that it will have an impact on the vast majority of industries, from cosmetics and food, to new materials, electronics and defence. However, there are three major areas where nanotechnology is expected to make the greatest difference: sustainable energy, medicine and information.

Environmentalists are often suspicious of new technology and its potential impact on the world; yet, developed responsibly, nanotechnology could signal the end of our reliance on fossil fuels. It promises advances in several alternative sources of power, such as solar and hydrogen fuel cells. Research being undertaken into new materials for photovoltaics, such as carbon nanotubes and semiconducting polymers, could soon lead to cheaper and more efficient solar cells. If significant improvements can be made in this area, nanotechnology could potentially lower the cost of energy generated by solar cells towards that from non-renewable energy sources, such as gas and oil.

In medicine, nanotechnology could transform drug delivery, diagnostics and monitoring systems, and artificial implants. Drug particles would be encased in nanoparticles, either to protect the active element from the body's defences until it reached its desired target, or to protect the body from their unwanted side effects. In diagnostics, "laboratory-on-a-chip" technology could eliminate the need to take large fluid samples and could even respond to biochemical changes within the body. Diabetics, for instance, could benefit from the development of a chip that monitors insulin levels and secretes the required hormone into the bloodstream as needed.
Artificial implants continue to be developed and artificial skin is now used commonly in treatment. Nanotechnology could contribute to this field through advances in scaffolds that encourage cells to grow in a pre-designed shape. Biocompatible coatings are also in development, which will make artificial implants, such as bone replacements, less likely to be rejected by the host's immune system.

Its basic tool is the scanning probe microscope

Nanotechnology is also likely to contribute to vast increases in the availability of computing power and information. The development of ever faster, better, smaller and cheaper computers will allow them to be incorporated into even the cheapest and smallest artefacts. Electronic tags for product packaging are very close to being marketed and will improve supply chain management. Similarly, surveillance will become cheaper and easier and, therefore, more prevalent.

These advances raise important social and economic issues, which have little to do with either the utopian or the dystopian scenarios for the future of nanotechnology. The ease and cheapness of storing information will cause a growing lack of privacy. Fast and cheap DNA sequencing could lead to requirements for screening by insurance companies and affect how life insurance policies are calculated. More efficient surveillance may lead to less crime, but will also inhibit the privacy of individuals.

Medical uses of nanotechnology will further increase the intimate association between the human body and artificial implants. Other uses, such as the development of display screens that are projected directly onto the retina, promise to further reduce the differences between humans and machines. We have been taking structures from living things to use in artificial contexts throughout history, but further developments in bionanotechnology could see the radical modification of bacteria to make new functional devices. This raises questions of whether such a radical remodelling of a living organism is ethically acceptable.

Economic issues also need to be considered. As investors latch onto nanotechnology as a buzzword and

Surveillance will become cheaper and more prevalent

national governments race to become the world leaders in research and development, there is the risk of over-hype, leading to a stock market bubble and the collapse of the emergent industry. Technological development is driven by market opportunities, generating questions about inequity and economic divides. Will nanotechnology lead to the eradication of poverty through material abundance and beneficial applications, as the utopians predict; or will most products be those that are highly profitable and aimed at a richer market, such as cosmetics and life extension?

These are some of the real issues which social science needs to investigate as nanotechnology develops. The danger is that they will be lost in either futuristic enthusiasm or indiscriminate pessimism. The opportunity is here now to prepare society for the technological changes that are coming.

Involving social science in the debates about technological development will help to guide it in a more socially useful way. Nanotechnology is a unique opportunity for scientists and social scientists to work together. There are currently three generic questions fertile for research:

- how technological change is governed, including an understanding of the drivers and decision processes at the various key points of choice;
- how social learning occurs, including how conflicts of interest can be identified and clarified in a way that fosters informed debate; and
- how evaluation of risk and opportunities under uncertainty is accomplished, particularly looking at how scientists, technologists and firms can best be regulated and at the limits of the nation state's ability to act as a regulator in an increasingly international world.

Stephen Wood is research chair and deputy director, Institute of Work Psychology, University of Sheffield and co-director of the ESRC Centre for Organisastion and Innovation. He is also Chief Editor of the *British Journal of Industrial Relations* and a member of the CEP.
Richard Jones is a professor in the Department of Physics and Astronomy, University of Sheffield, and co-ordinator of inter-disciplinary research in Nanotechnology at Sheffield and co-director of the Sheffield-Leeds MSc in Nanoscale Science.
Alison Geldart is a research assistant in the ESRC Centre for Organisation and Innovation, University of Sheffield.

Stephen Wood, Richard Jones and Alison Geldart are authors of *The Social and Economic Challenges of Nanotechnology*, published by the ESRC and available by request to Rachel.Blackford@esrc.ac.uk.

Reference
Dinkelacker, J. (2002). *Transition to Tomorrow: Social Institutions at the Threshold of Nanotechnology's Molecular Epoch*

http://www.hpl.hp.com/personal/Jamie_Dinkelacker

The majority of its products will be fairly prosaic