From science fiction to science fact
– a nano-scientist’s views on the current debate on nanotechnology

Sylvia Speller
Institute for Molecules and Materials (IMM),
Radboud University Nijmegen, 12 August 2005

There’s an old saying: what the farmer doesn't know he doesn't eat. People have always been afraid of the unknown, and this fear has often led to irrational thinking and actions. Basically, the problem is that the public –at least in large parts of Europe - no longer trusts science, and does not believe in the future. Especially, when science leaps forward, ethics and acceptance lag behind. Then people tend to look to the past and take comfort in tradition and in all kinds of irrational beliefs.

But we need to believe in the future to confront the real problems in the world. It is therefore important for us as scientists to explain what we're doing and what it means for society. Scientists have tended to take their social identity for granted, so few have put much effort into promoting it. In my view, science needs to be made glamorous again (as it was in the 1920s and again in the 1960s), so that more young people want to study it and the public understands it better.

Nanoscience and, in particular, nanotechnology, are rapidly gaining public attention due to potentially far-reaching consequences for society. Nanoscience is the ability to measure, predict, construct and control objects on the scale of atoms and molecules, and to make use of the unique properties available at that scale. Nanotechnology involves devices, materials, and processes that embody nanoscience. Neither biomolecular motors, nor the magnetic layers in the current read/write heads in our computers are nanotechnology in the narrower sense, since in the former there is no external control of the actuation and in the latter there is no lateral control of the atoms in the layer.

Self-assembly and organization, as well as scanning probe microscopy, are currently the most promising approaches in nano-science; they are used to fabricate nanostructures and to characterize and manipulate material on a nano-scale.

You ain't seen nothing yet

Nanotechnology is highly interdisciplinary, yet we have only just started to combine physical, chemical, biological and medical concepts. Many projects seek to combine the hard (physical) and the soft (bio-inspired) nano-worlds, for instance in protein-based transistors, proteomics and metabolomics chips, and artificial organels.

Nanotechnology is both an enabling and a disruptive technology, which worries established industries, given their difficulties with extrapolating current concepts to the future. For instance chip and hard-disk developers are almost at the limit of what they can achieve with current technology. Small, dynamic flexible start-up companies are usually in a better position to react to new developments.

As with earlier technologies such as nuclear fission energy, pesticides, (global) positioning systems and GM, it is precisely the power of nanotechnology that gives rise to the risks. For instance, the enhanced reactivity of nano-particles is beneficial in catalysis, but free-floating nano-particles can be detrimental if they come in contact with organismal tissues. A couple of regulations on this are being prepared and scientists are acting as advisors. However, many regulation gaps have not yet been recognized.

We've seen a growing polarization between nano-optimists and nano-pessimists since 2001. This has been fed by the media on the one hand with scenarios such as those presented in science fiction thrillers like *Prey* [1] and on the other by true progress such as logic components on a molecular level [2] and the synthesis of complex functional bio-agents [3]. The latter really does represent progress because modified viruses can be used e.g. in medical treatments.

The public is confused and sceptical because it cannot assess the probability of scenarios such as the following:

- Nano-electronics could be developed to create `smart dust´ of electronic-grains that could be used for communication and surveillance purposes. This scenario raises issues of privacy as well as of pollution control.
- Artificial RNA/DNA sequences that can code for undesired proteins in organisms could be assembled from fragments and use cell biochemistry to function as a messenger or a switch. The possibility of run-away self-replication is usually raised.
- Biotechnological hybrid systems could be implemented to achieve unknown levels of remote-control capabilities (even of human beings), with deep implications for ethical accountability of individuals and a radical transformation of the way warfare (both manned and unmanned) is carried out.

Despite increasing interest in the social and ethical implications of nanotechnology [see e.g. 4, 5], the dialogue between scientists and the public has not got very far, so acceptance of nanotechnology remains low. Scientists' opinions are governed by their research experience, sensing that progress towards true nano-devices is slow and awkward. The public, however, has the impression that scientists are acting like 'sorcerer’s apprentices' [6], playing with powerful procedures that are little understood, but dangerous and irreversible.

External factors which affect this perception are the widespread airing of irrational views on genetic manipulation and the slow response from politicians with regard to regulation of the abuse of such technologies. All this has exacerbated regressive views among the public.

An exact discipline such as nanophysics has a 'vertical' structure, i.e. without knowing the concepts at level (n-1), it is impossible to understand level n. So scientists must be exceptionally creative when attempting to explain the core issues. The dialogue also suffers from scientists taking too much for granted – scientific concepts have become an unconscious part of their language. They hardly recognize the knowledge gaps and so a conversation can easily degenerate into a slanging match.

Let's sustain a culture of science

Another part of the knowledge gap is due to ignorance among the general public. The interest in exact sciences is still disappointingly low in countries such as Germany, the UK and the Netherlands, and the numbers of those pursuing an education in physical sciences are extremely low.

The media, especially the movie industry, has tremendous potential to develop a better appreciation of the exact sciences. Just look at the way it has improved the general public's understanding of disciplines such as forensics, medicine, law, history and art, and the social sciences. The problem is that Hollywood can make more money by exploiting peoples' psychological and emotional need to retreat into illusion than by tackling the tough intellectual demands of understanding the world we live in. There is also the problem that the physics presented in movies is often wrong (for instance, explosions in space producing sound).

The extent to which nanotechnology will permeate our daily life will depend on the way in which the interaction of society with nanotechnology develops. There are a number of potential scenarios, all the way from a denial of technology to a technology-driven existence [see e.g. 7]. Where we end up between these two extremes partly depends on scientists' ability to explain nanotechnology to the public as well as involving wider sections of society in technology assessment studies.

However, since governments are embedded in a global power play, there will always be a tendency to move towards the technology-driven scenario, even if the public does not favour it. This is because international political power depends on economic power. Other forces that shape technology, include funding, consumer choice, and geopolitical events.

Modern life is complex and abstract. People don't acknowledge the science and technology on which their lives depend, because it's invisible (only the user interfaces are visible). We love the devices we use every day, but are ignorant and oblivious of the technology that is needed to produce them. At the research stage in particular, the larger the knowledge gap, the more everyone is suspicious. That's more true in Europe and less true in US. This is the challenge facing us as scientists and interpreters of science. We need to make smarter use of the media to reach a wider audience. As a minimum, a modern nation should maintain an appropriate number of research facilities and expert teams on each type of technology in order to be able to react to new developments as well as to the catastrophes that may occur in other countries.

A universal ethical injunction for scientists might be to tackle the hard issues, to expel illusion and fantasy, and present the public with the facts as we know them. These should be communicated in captivating stories, accompanied with realistic, controlled future scenarios [8]. We should convey the wonder of the work we do without avoiding the tough questions about both the good and the ill that it can lead to. While stem cells may offer ways of curing a wide range of currently incurable diseases and handicaps, they can also be used to manipulate human beings in ways that are considered ethically unacceptable. There may well be similar dilemmas surrounding nanoscience and nanotechnology, but we must move the discussion from science fiction to science fact.

[1] Prey: A Novel, Michael Crichton, HarperCollins (2002)
[2] http://domino.research.ibm.com/comm/pr.nsf/pages/rsc.cascade.html or Molecule cascades, Heinrich AJ, Lutz CP, Gupta JA, Eigler DM, Science 298: 1381-1387 (2002)
[3] Chemical Synthesis of Poliovirus cDNA: Generation of Infectious Virus in the Absence of Natural Template, J. Cello, A.V. Paul, E. Wimmer, Science 297, 1016 (2002)
[4] A. Arnall, D. Parr, "Moving the nanoscience and technology debate

forwards" in Nanotechnologies: A preliminary risk analysis (2004) p.43, http://europa.eu.int/comm/health/ph_risk/documents/ev_20040301_en.pdf

[5] Benefits, Risks, Ethical, Legal and Social Aspects of Nanotechnology Report, Nanoforum publication 2004, http://www.nanoforum.org/

[6] A. Dupuy, "Complexity and Uncertainty" in Nanotechnologies: A preliminary risk analysis, (2004) p.71, http://europa.eu.int/comm/health/ph_risk/documents/ev_20040301_en.pdf

[7] Horizons2020, commissioned by Siemens (2004), http://w3.siemens.de/horizons2020/pdf/inhalt/presse/Horizons2020_szenarioreport_e.pdf

[8] Instruments for future scenario reflection should be elaborated jointly by exact nanoscientists and philosophers of science.

[~1400 words]