J. Verbr. Lebensm.
1661-5751/00/000249-3
DOI 10.1007/s00003-008-0349-1

Journal für Verbraucherschutz und Lebensmittelsicherheit
Journal of Consumer Protection and Food Safety

First Choices – Talking about "Nanotechnology"

A. Nordmann[1]

Technische Universität Darmstadt, Germany

Correspondence to: Prof. Dr. Alfred Nordmann, Institut für Philosophie, Technische Universität Darmstadt, Schloss, D-64283 Darmstadt,

Tel. ++49/(0)6151/162995; Fax ++49/(0)6151/163970,
e-Mail: nordmann@phil.tu-darmstadt.de; http://www.philosophie.tu-darmstadt.de/nordmann

Received: February 5, 2008; accepted: February 11, 2008

1. Introduction

The task of describing and defining nanotechnology is no innocent undertaking. Depending on how we define it, the outcome may be anything from numbed amazement or helpless speculation to critical awareness or policy-shaping capability. Our definition will prompt us either to expect every aspect of our lives to be revolutionised or else to believe that what we are dealing with is nothing much more than a fashionable, though far from inconsequential trend. Finally, our definition tells us whether nanotechnology is a technology of the future with as yet unforeseeable impacts or whether it is a set of visions and objectives relating to the present.

The normal way of defining the terms namely first to establish the lowest common denominator of nanotechnology research, is by no means innocent either: this smallest common factor is still far too large for any meaningful thinking or acting. Minimal definitions in terms of size or novel properties serve merely to establish the domain of nanoscientific research. Nanotechnology then appears as the just about infinite potential of possible applications arising from work on these research objects (The Royal Society and Royal Academy of Engineering, 2004).

For example a typical assertion is that nanotechnology makes use of properties that only occur on the molecular scale of 1 to 100 nanometres (10^{-9} to 10^{-7} metres) and are distinct from macroscopic properties. Gold is often used as an example of this: its colour, its chemical inertness and therefore its impact on health are all well known. However, if its chemical composition is retained and the gold is reduced merely to the size of a nanoparticle, these properties change. This is where nanotechnology comes in. It encompasses all that makes use of these sorts of changes. And what might that be? At this point, the definition no longer offers any guidance but leaves us with boundless possibilities. If carbon nanotubes possess interesting optical properties, wouldn't it be conceivable to construct a completely different kind of computer, one that no longer works on the basis of binary electronics but rather photonically, using the colour spectrum? If nano-structured fibres are especially light and strong, couldn't we make a rope out of them and attach it to an elevator going up into space? If the self-organisation processes of nature are among the new properties, can't we imagine nanosystems, or even small robots, that produce and reproduce themselves? And so on.

[1] Alfred Nordmann, born in 1956, is Professor of the Philosophy and History of Science at the Technische Universität Darmstadt. After studying in Tübingen, Hamburg and New York he held a position at the University of South Carolina from 1988 until 2002. Along with his interest in the nanosciences and the convergence of enabling technologies, a further emphasis of his work is the development of philosophy of science and epistemology from Kant through Wittgenstein to contemporary theories of models and representations. He is President of the Lichtenberg Society.

2. Beyond Comprehension

None of these hypothetical scenarios is complete nonsense; every one of them has been proposed, and many others besides. If nanotechnology comprises the sum of all these scenarios, then we are faced not only with fantastic possibilities but also with worrying prospects. Either way, we find ourselves in a state of helpless amazement in the face of such immense potential and look to this or that speculation to provide us with some degree of orientation. Whichever way we look at it, we start to believe that nanotechnology is capable of anything and end up fixated on a future – be it near or far-off – in which nothing is as it used to be. This way, nanotechnology eludes the power of our imagination, becomes unavailable to critical thinking or political action. It is a pawn in a game of vague suppositions. As a consequence, those who are generally well disposed towards technology have no objections to nanotechnology, and those who have reservations about technological development have little trust in nanotechnological promises either (Gaskell et al., 2004).

"Nanotechnology" can be defined in a completely different way, however – namely, as a political construct that ties together heterogeneous research trajectories. These trajectories do have something in common, of course. They are all expected to open up new markets, and they all manipulate properties or structures in the range of 1 to 100 nanometres. However, it is not these common factors that are the key here; rather, it is the sum of programmes that come together at this point. As the following overview will show, it is possible roughly to identify four distinct nanotechnological approaches or trends.

3. From Micro to Nano.

The first of these four trends is also the most well known, being the one that leads from microtechnology to nanotechnology. Its driving force, the seemingly unstoppable trend towards miniaturisation, should not be underestimated. It is a "law," after all, which some take to be a law of nature regarding technological development and which the chip manufacturers, at any rate, take for their roadmap. According to "Moore's Law", technological development will continue to accelerate, which is why semi-conductor technology in particular must advance to the nanometre scale. In doing so, it comes up against physical limitations that demand new nanotechnical building blocks. Thus, the vision of molecular electronics, for example, encompasses the notion of a wire consisting of a single molecule and possessing the diameter of an atom.

Whether or not it proves to be realisable, this vision appears to conjure up nothing but stereotypical notions of things becoming ever smaller, faster and cheaper. If anything fundamentally new is to emerge here, it is only because never-ending miniaturisation *has* to be of some use or other. Entire computers on a microchip, distributed processors in smart environments, sensors that are no longer perceptible and are breathed in along with air are examples of discontinuous fields of application that might fundamentally alter our relationship to ourselves and to the world. It may indeed turn out that the nanotechnological continuation of what is only a boring trend towards miniaturisation will bring about the most far-reaching social change.

4. Atom by Atom

Whereas the trend towards miniaturisation sounds so familiar and has lasted so long that it can already be considered to be a modest kind of vision, the second nanotechnology programme deserves an ambitious title along the lines of the "molecular construction of the world." The US-American National Nanotechnology Initiative, for example, published a brochure in 1999 entitled "Shaping the World Atom by Atom". Though hardly any reasonable researcher actually believes in it, this vision of nanotechnology nonetheless exerts an extremely powerful influence behind the scenes.

This vision lacks credibility, largely because it would be extraordinarily difficult and not especially efficient to construct molecules first and then to build an entire world atom by atom. And yet this vision played a part in each of the four most famous founding moments of nano research. First there was the lecture given in 1959 by Richard Feynman, entitled "There's plenty of room at the bottom". Ignored for almost forty years, it is now considered revolutionary in retrospect since Feynman describes the possibility of mechanically moving individual atoms using a system of levers. Eric Drexler, the most speculative and perhaps most influential of all the "nano" visionaries, bets on gears and cogs that are constructed with atomic precision by arbitrarily assembling individual atoms. Although most nano researchers distance themselves from Drexler's vision, they still think that the decisive breakthrough for nanotechnology came with arbitrary positioning of individual atoms. This was brought about by the invention of the scanning tunnelling microscope which prepared the legendary feat of spelling "IBM" with 35 xenon atoms that was performed by Don Eigler and Erhard Schweizer in 1990.

Everyone involved knows, of course, that what Eigler and Schweizer were able to achieve on a flat surface under extreme conditions and by excluding a whole range of influences is light years away from the construction of a three-dimensional molecule. If the degree of control demonstrated by producing the letters "IBM" remains exemplary in spite of this, then it has to do with far-reaching suppositions that are deeply embedded in the research culture. Here, a scientific-reductionist worldview is combined with a mechanical-technical worldview according to which nature itself is just an engineer. And since we are now allegedly able to appropriate nature's principles of construction for ourselves, we begin to see machines wherever we look – be it in human cells or in the envisioned products of nanotechnology.

For some, this means that nanotechnology will have the greatest impact when our conventional machines are replaced by nanotechnological ones. Such visionaries imagine that "molecular manufacturing" will lead to the disappearance of waste-producing factories that will be replaced by a mode of production that promises global abundance and a solution to every environmental problem. This is how it would work: material of any kind is placed in a device designed to look something like a microwave oven. This is then programmed to transform the molecular matter so that base earth turns into gold and dirt into an edible steak. No serious researcher believes in this scenario, but many like to play with the idea nonetheless – from the so-called "Center for Responsible Nanotechnology" to the highly respected nano researcher Wolfgang Heckl in Munich. It can also be found between the lines of communications issued by the European Commission (2004).

5. New Materials

The stubborn persistence of machine-related fantasies is also interesting because the actual success stories of nano research point in precisely the opposite direction: the programmatic search for new materials with new properties by no means progresses with atomic precision or according to a mechanical blueprint. It was a nano researcher from Saarbrücken, Herbert Gleiter, who as early as 1981 prepared the way for nano materials, new surface coatings and new methods for the production of nano particles. All this comes under the heading of "nano-structuring": new material properties emerge even when a kind of nano-scale disorder occurs in the material. It is a well-known fact, for example, that metal can be hardened by hammering, and that hammering builds defects into the material that make it harder to change its shape. In some nanomaterials this principle is driven to the extreme, so that they seem to consist of nothing other than defects.

This is a prime example of the fact that new properties are discovered and become useful wherever nano-scale structures predominate. The search for new material properties thus fits especially well with the general definition offered by way of the smallest common factor, and indeed, so far it is able to boast the greatest economic successes as well. Dirt-repellant surfaces, scratch-proof glasses, increasingly friction-free bowling balls are currently among the most well-known commercial nanoproducts. But just as machines and devices that have not yet been developed enjoy greater technical prestige than mere materials, so too do Herbert Gleiter and his new materials disappear from the founding narratives of nanotechnology (Nordmann, 2006).

This prejudice is reflected at the level of ethical and social reflection about nanotechnology. Molecular machine-based fantasies may lack scientific-technological credibility, but their revolutionary potential has demonstrated its fruitfulness in terms of exciting speculations about the future of humanity. What is all too hastily overlooked, however, is how the quality of life on our planet has been altered by the comparatively unspectacular introduction of new materials such as plastic and asbestos (Nordmann, 2007).

6. Ideal Bodies

Last of the four is a nanotechnological programme that relates to simple building blocks that are to facilitate new means of construction. Wires, shells, dendrimers, nanotubes and Bucky balls are such ideal bodies. The latter, in particular are so perfectly structured that they appear to be engineered and themselves already a product of atom by atom nanomanufacturing. However, even "the most beautiful molecule", as the Buckminster fullerene has been called, does occur naturally – in soot, of all things.

As nano researchers are learning to control these prominent structures, they are simultaneously thinking up possible applications for them. Carbon nanotubes could serve as fibres for strengthening materials or as components in a new chip architecture. Perhaps they will be able to transport medication directly to diseased cells inside the body or replace liquid crystals in computer screens. It has yet to be seen, though, what their real use is.

Especially with these kinds of building blocks nanotechnology presents itself as an "enabling technology". It devises technical goods and services for which there is as yet no application and no demand. The answer to the question of what carbon nanotubes are good for cannot be found in their structure or their properties alone – it depends just as much on what kinds of problems we most want to solve with their help. By portraying itself as an anebling technology, nanotechnology invites public deliberation and social shaping of nanotechnological research programs.

7. Conclusion

In view of these four very different trajectories, why would anyone want to speak of "nanotechnology" in the singular? Rather than pushing towards unification, each of these trajectories stimulates critical questions and further differentiations. Vague promises of "green nanotechnology", for example, and the equally diffuse environmental concerns that have been raised require just such differentiations to make them more tractable. Only this will allow for nanotechnological mises to be taken at their word.

8. Literature

Gaskell, G., Eyck, T. T., Jackson, J. and Veltris, G. (2004) Public Attitudes to Nanotechnology in Europe and the United States. In: Nature Materials 3:496.

European Commmission (2004) Communication from the Commission. Towards a European Strategy for Nanotechnology, Luxembourg, p. 10.

Nordmann, A. (2006) Unsichtbare Ursprünge. Herbert Gleiter und der Beitrag der Materialwissenschaft. In: Nordmann, A. et al. (eds.) Nanotechnologien im Kontext. Berlin, pp. 81–96.

Nordmann, A. (2007) If and Then: A Critique of Speculative Nanoethics. Nanoethics 1:31–46.

The Royal Society and Royal Academy of Engineering (2004) Nanoscience and Nanotechnologies: Opportunities and Uncertainties. London, p. 5.

To access this journal online:
http://www.birkhauser.ch/JVL