INSTITUT FÜR PHILOSOPHIE DARMSTADT

Enhancing Material Nature

Alfred Nordmann

In Kamilla Lein Kjølberg and Fern Wickson (eds.) *Nano meets Macro: Social Perspectives on Nanoscale Sciences and Technologies*, Singapore: Pan Stanford, 2010, pp. 283-306

Nanotechnologies and the idea of their convergence with other technosciences are rooted in the notion that they are capable of mobilizing nature in order to go beyond nature. At times this notion declares itself with surprising clarity and at others it is merely implied. Often it is rhetorical accompaniment to conventional research, and sometimes it pronounces far-flung possibilities. As a dream (or nightmare) of reason (Dupuy 2007, p.242), this visionary theme deserves close examination. The main purpose of this examination is to appreciate its queerness – in other words, the way in which this notion transgresses traditional categories and expectations, the way it tweaks language and stretches received concepts. The aim is not to question the significance of the notion, but to create a certain critical distance to it. Such distance is needed not only in regard to its technical feasibility, which ought not simply to be assumed by an all too obliging ethical discourse (Nordmann 2007a). Critical questions also need to be raised about the desires and hopes that are brought into focus by nanotechnological aspirations to enhance material nature. This is because quite independently of their fulfillment, these desires and hopes are producing effects even now which are far from insignificant. Especially one of these effects will come to the fore in the following pages: in our thinking about nature we are challenged by nanotechnologies to adopt an unthinking attitude of engineering rather than to reflect and debate, for example, the kind of materialism and reductionism that is associated with genetics.[1]

---

[1] This is a revised and expanded version of "Mit der Natur über die Natur hinaus?" which appeared in K. Köchy, M. Norwig, G. Hofmeister (eds.) Nanobiotechnologien: Philosophische, anthropologische und ethische Fragen, Munich, 2009, pp. 131-147. It benefited from discussions at the EthicSchool on Ethics of Converging Technologies, 21-26 September 2008, Romrod/Alsfeld, Germany (a Specific Support Action funded by the European Union under Framework Programme 6, Science and Society programme, contract number 036745). I would like to thank its participants and contributors, especially Bernadette Bensaude-Vincent and Astrid Schwarz, also Thomas Vogt and Michael Stöltzner at the University of South Carolina. Finally, Kathleen Cross, Reinhard Heil, Daniel Quanz, and Travis Rieder offered valuable advice on editorial questions and the translation.

I. Introduction

The notion that we might recruit nature to surpass nature is not new. It has a long history, at least in alchemy and other magical sciences, in romantic philosophy of nature (Naturphilosophie), but also in theories of self-organization and, not least, in biomimetics or bionics. If there is anything new about it in the context of nanotechnologies, then it is its innocuous appearance and the way in which it is taken for granted. In fact, it assumes a kind of spectacular prominence only in the debates about so-called transhumanism and its goal of technologically enhancing human nature, which is to be enabled, somehow, by nanotechnologies and their convergence with other emerging technologies. In contrast, the idea of mobilizing nature to go beyond nature goes just about unnoticed where it proves to be fundamental, namely with regard to the project of technologically enhancing or surpassing material nature. This basic idea therefore needs to be brought to light before it can be properly contextualized historically and appreciated philosophically.

The first of these tasks and just bringing the idea to light can be absorbing enough. It is not simply a matter of providing exhaustive documentary evidence of the fact that among the founding myths of "nanotechnology" in the singular is the expectation of recruiting nature to surpass nature.[2] Conceptually, it requires a different approach: how can one make any sense at all of the programmatic notion to venture "with nature beyond nature!" and how, then, might nanotechnological research and its associated discourse render it meaningful?

Mobilizing Physical Knowledge to Leave behind Biological Givenness

On first sight, the program to go 'with nature beyond nature!' sounds too dubious to be considered meaningful at all, and perhaps this is why it often remains silently in the background. One way of assigning meaning to it would be to allocate different indices to the word 'nature' which occurs twice in the phrase: recruiting nature_1 to go beyond nature_2, where nature_1 would be nature as it is conceived by physicists, based on laws and regularities, and nature_2 would encompass all the conditions of life that we encounter in the world and that are the subject-matter of evolutionary biology and ecology. In this view, then, nanotechnologies are seen as using the principles, rules and laws of nature as elaborated by physics to surpass nature, our natural environment, or conditions of life in the evolutionary or ecological sense.

In this dual use of the concept of nature, though, there resides a certain disingenuousness that plagues nanotechnologies, biomimetics, synthetic biology, and nanobiotechnology in equal

[2] Indeed it would not be easy to produce such evidence systematically and in a methodologically sound manner without incurring the accusation of selectivity and over-interpretation. But see Bensaude-Vincent & Hessenbruch 2004; Dupuy 2009; Hayles 2004; Milburn 2008; Schwarz 2004; Toumey 2008.

measure. The first, physicalist concept of nature is thin: it holds any particular form of existence to be contingent or accidental, especially the existence of humans or of the earth as a habitable place. From that point of view, these forms of existence are the lawful consequence of some initial conditions that happened to obtain at some time and place. Accordingly, those who go down to the level of molecules and adopt the perspective of how molecules "see" one another (to cite a popular metaphor) do not see certain categorical differences and thus do not see what is usually called 'life.' In contrast to this, the biological concept of nature is thick.[3] Essential to this concept are the highly specific conditions of life that have emerged in the course of evolution. Generally, those who call for sustainability or worry about environmental and resource problems, or about the dignity of particular entities in relation to universal laws, are not arguing at the nanoscale but in respect to human scale and conditions of life. 'With $nature_1$ beyond $nature_2$' would mean to surpass, overhaul, or recreate the contingently given highly specific conditions of life with reference to the abstract regularities of nature's principles. Accordingly, some of the most pointed formulations of this idea refer to a second creation story or to the fact that from now on we are in a position to take evolution into our own hands.[4]

The aforementioned disingenuousness arises from the fact that this construction of "with $nature_1$ beyond $nature_2$" enables an opportunistic line of reasoning: nanotechnologies can legitimize themselves as being in agreement with nature even when, judged against the standards of sustainability or nature conservation, it acts against nature and the protection of those conditions of life that make human existence possible. On this account, nanotechnologies are not actually bound to $nature_2$-as-given and yet do not violate in any way the natural order as denoted by $nature_1$ which is inviolable since it is constituted by the laws of nature.[5]

In order to construct a seamless transition between the lawfulness of inanimate nature and the construction of specific conditions of life, one speaks of "nature's own nanotechnology" not only at

[3] The differentiation between "thick" and "thin" refers back to what was first characterized by Gilbert Ryle as "thick" and "thin description" and was then taken up by Clifford Geertz for ethnography. The physicists' concept of nature offers a comparatively thin description that does not appreciate our rather tenuous dependence on historically evolved features of the world that are contingently given and lack physical necessity. See Ryle 1968 and Geertz 1973.

[4] Nobel laureate Horst Störmer is quoted in one of the founding documents of nanotechnology as saying: "Nanotechnology has given us the tools … to play with the ultimate toy box of nature – atoms and molecules. Everything is made from it … The possibilities to create new things appear limitless" (NSTC 1999, p. 2). Gerd Binnig also received the Nobel Prize (for the development of the scanning tunnelling microscope) and expresses himself even more explicitly: "At this time we humans are witnesses and shapers of a second genesis, a fundamentally new evolution of material structures that we are as of yet not even able to name properly" (Binnig 2004). Binnig develops this idea more extensively in his book *Aus dem Nichts*: "We have to become familiar with the idea that there is nothing inferior about dead matter. All the wonders of the world are contained, for example, in a stone, as all the laws of nature (and thus all the possibilities that can emerge from them) are reflected in it" (Binnig 1992).

[5] Bionics has for some time now been suspected of using this sleight of hand: "Even bionics has no direct, unmediated, value-free access to nature. Instead it chooses a technically mediated and technically induced access to nature in order to create a bridge from life understood in technical terms to technologies optimized for life: not from life to technology, but from technology to life!"(Schmidt 2002).

"higher" levels when clams build their shells or when proteins and whole organisms are constructed from DNA and RNA interactions, but also in relation to perfectly ordinary biochemical 'lock and key' causalities at the nano level (e.g. Davies 2007, p.4). In either case, the fact that nature uses technology to achieve its ends signals that it can be used to construct different things, including the ones that are, in fact, being constructed by nature now.

Likewise, only the physicalist conception of "nature's own nanotechnology" can explain the use of the word "incidentally" in the following statement by chemist Roald Hoffmann: "Nanotechnology is the way of ingeniously controlling the building of small and large structures, with intricate properties; it is the way of the future, a way of precise, controlled building, with incidentally, environmental benignness built in by design" (NSTC 1999, p. 4). Thus, right from the start and quite effortlessly it appears that the ecological benignness of nanotechnologies is unquestionable, simply because it cannot do otherwise but to follow the principles of nature and obey the laws of nature. Environmental problems – so it has been said rather pointedly elsewhere – will take care of themselves once we have nanotechnologies,[6] because anyone who is guided by the fundamental ways of nature will supposedly reach their goal directly and efficiently, without producing any waste and without squandering any resources. Indeed, anyone who has understood the basic principles of $nature_1$ may be capable of judging and relativising $nature_2$-as-given and of seeing that inefficiencies and redundancies have crept in over the course of evolutionary history. Nano researchers Frans Kampers and Bernhard Roelen, for example, state that cows are extremely inefficient meat producers and that a sustainable, green nanotechnology would manufacture meat more efficiently in the laboratory (Kampers 2007; Löhe 2009). Freeman Dyson goes further with his opinion that nano and biotechnologies – and especially synthetic biology – can clean up, correct, and straighten out the tortuous course of evolutionary history *in toto*. Green biotechnology need no longer frantically concern itself with the diversity of species because there is no longer any need for species once any number and variety of phenotypes can be engineered genetically.[7]

Whether or not all this represents a perversion of biomimetics, of the idea of sustainability or of "green technology", is a question I shall leave open. What is abundantly clear, however, is that in this view it is $nature_1$ – nature conceived of purely in terms of physics – that opens up spaces of possibility and horizons of expectation for nanotechnologies. Anything that does not contradict the laws of nature counts as technically feasible and permissible. Just as technoscientific research is

[6] This was said in the introductory presentation by the Wuppertal Institute at a citizens' conference organized by the European "NanoDialogue" project on 7 October 2006 in the German Museum in Munich.

[7] Freeman Dyson makes a single exception for the human species: it can and probably will be preserved, if only because it is humans, after all, who are synthesising other organisms using biotechnology (Dyson 2007).

loath to restrict itself to $nature_2$ as its technological role model, as its regulatory idea, moral instance or point of reference, it is quite reluctant to distinguish between what is physically possible and what is technically possible. In this way it gives itself carte blanche – in line with the motto "shaping the world atom by atom" – to create, in the name of physicalist $nature_1$, what might turn out to be a totally new, totally different $nature_2$, or at least to technologically optimize the latter and to surpass it even in the name of green technology. 'With $nature_1$ beyond $nature_2$,' then, signifies an intensification, improvement, or *enhancement* of nature within which we exist as living creatures and to which we owe the fact that this planet is habitable for us at all.

II. Technological Processes for the Self-enhancement of Nature

There may be various other possibilities for assigning nanotechnological meaning to the seemingly paradoxical notion of venturing "with nature beyond nature." However, only one other makes sense to me.[8] It represents both a more subtle and a more naïve approach that puts to the test traditional concepts of nature and technology in terms of their relationship to one another.

This second reading does not interpret the word 'nature' in a deliberately ambiguous way that draws on different scientific conceptualizations, namely at first on that of physics and then on that of biology. Rather, the concept of nature is framed technologically from the very start: nature is an engineer and employs technical processes of self-formation, and thereby surpasses itself all the time. In this view, nature is a technical system, a collection of processes and properties which, like all technical systems, is capable of extrapolation, optimization, and enhancement – not in the sense of biological evolution with its gradualistic mechanism of selection and adaptation, but in the sense of algorithms and procedures that can be mobilized for the purpose of enhancing nature as a system. In this case, the two-fold occurrence of the word "nature" refers to the two manifestations of a single process. To put it in anachronistic terms by using old language for a new way of thinking, the motto of this technological programme is: 'With *natura naturans* beyond *natura naturata*.' *Natura naturans* encompasses the dynamic and creative principles that produce or realize any particular state of nature (the *natura naturata*) where each manifested state is merely contingent, thus accidental, questionable, incomplete, and imperfect.

---

[8] It should be noted here that the point is to assign to the formulation a "nanotechnological" meaning. In principle, of course, another candidate would be the "autopoietic" variant from the 19th century tradition of philosophy of nature which is clearly distinct from the technological appropriation that is developed in the following. Far from considering a technical process, 19th century *Naturphilosophie* starting with Immanuel Kant and ending, perhaps, with American philosopher Charles Sanders Peirce viewed all of nature as a kind of organism with its dynamic, self-organizing life-processes.

Now, when it is said that each given *natura naturata* is intensified, enhanced, surpassed or improved by *natura naturans*, this involves far more than noting that as a matter fact there is always a next state of nature after the present one. And it also means more than claiming that the next state is differently configured and may represent a higher level of complexity and organization, while preserving and processing all that went before within a single ongoing process of formation.[9] Beyond all that, this technological conception of nature refers to a radical liberation, a 'setting free' of nature by technology such that the improvement of nature and the increase of its efficiency are only side-effects. This places the notion of a technical enhancement of human and material nature into a tradition of thought that appears to be at odds with a technological conception of nature. According to this tradition, "to philosophize about nature means to heave it out of the dead mechanism to which it seems predisposed, to quicken it with freedom and to set it into its own free development" (Schelling 2004, p. 14).

It may indeed seem well-nigh blasphemous to interpret as a technological concept of nature something that is associated principally with an idealist-romantic, dynamic conception of nature. But this is exactly what nanotechnology does, as do the discourses of ethics and present day philosophy of nature: they secularize and vulgarize philosophy of nature by absorbing it into the idiom of engineering.[10] And herein lies the main thrust of this second mode of interpreting the notion "with nature beyond nature". If there is anything new and different about nanotechnologies and anything that we don't already know from well-worn technological utopianism and hype, it is this incidental, if not entirely unreflected appropriation by a technological programme of a theme from philosophy of nature and an ideal for natural science. The lofty and provocative idea of 'self organization' accordingly reappears quite matter-of-factly in the notion of 'bottom-up engineering'.[11] So, much of what is new and different here is simply the casual confidence with which this appropriation is undertaken. It occurs in the absence of metaphysical or epistemological reflections on the limits of knowledge and control, on the methodological problems with, perhaps outright untenability of the technological programme. As technical concepts of 21st century technoscience, the concepts *natura naturans* and *natura naturata* are anachronistic – out of time and out of place. In the following, therefore, I want to illuminate the queerness of this technical appropriation of a conception of nature that sees it as a kind of self-organizing dynamism.

---

[9] Only G. Khushf interprets the development of nanotechnologies in the context of convergence as a process of intellectual and moral self-formation. He therefore rejects the distinction of a *naturphilosophische* and technological interpretation of "with *natura naturans* beyond *natura naturata*." See Khushf 2007.

[10] See the previous two notes: Along the way and as if in passing, this "vulgarized" *Naturphilosophie* obliterates the distinction between organism and technical artifact. Schelling's dynamic conception of self-organizing nature has precursors, of course, especially in Spinoza, and it has descendants such as Charles Sanders Peirce, whose philosophy of nature prepares the ground for technoscience. On this, see Nordmann forthcoming.

[11] To be sure, even this "novelty" has been prepared, for example, by J. von Neumann's theory of automata.

II.I. Enhancements

What, then, is that nanotechnological programme of liberating nature, and setting it free? This is currently much discussed especially in regard to *human enhancement* and the discourse of surpassing human nature. Supposedly, the convergence of nanotechnologies with other technosciences will realize human potential far beyond its current development (Roco & Bainbridge 2002). Ordinarily, these transhumanist techno-phantasms are not considered in the context of the 19th centuy theme of enhancement as a purpose of nature. Instead, they are usually discussed as a program for the technological perfection of a technically deficient human being. However, the narrower construal fails to acknowledge the particularity of a discourse that is informed especially by nanotechnological programs and achievements.

The term "converging technologies" is often taken to denote the integration at the nanoscale of biotechnologies and information technologies with the insights and objectives of the cognitive sciences.[12] The idea is that the natural principles of self-organization at work on the nanoscale should feed into the technical design of a new human being, into improving his or her physical and intellectual performance (Healey & Rayner 2009). Only in alliance with nature's self-organising, bottom-up strategies can this enhancement take place. The lofty ambition of this programme which is to involve a renewal of the sciences and therefore promises a 'new Renaissance' (Roco & Bainbridge 2002, p. 1ff.) is suggestive of Ernst Bloch's term *Allianztechnik* which draws on Schelling's philosophy of nature and pronounces that human emancipation depends on the liberation of nature and vice versa (Bloch 1995, p. 803-817). Humanity will realize its full potential only by technologically allying itself with nature's dynamics of self-organization.[13] Here, then, the project of the nanotechnologically enabled convergence can no longer be considered merely as part of an anthropological trajectory that views the history of technology as an ongoing compensation of human deficiency (Gehlen 1965).[14] Instead, it is apparent that the project aims to enter into an alliance or 'unparalleled entanglement' that 'really builds humans into nature' (Bloch 1995, p. 817). And this implies a re-contextualization of the currently all-too intense debate about technologies for improving human performance: human enhancement now appears as merely a special limiting case at the far horizon of the more general and more significant programme of enhancing material nature.

---

[12] This is not the place to discuss the various conceptions of "convergence" that were developed in the US, Canada, and Europe. Here, I limit myself to "NBIC-convergence" because it is most clearly indebted to the nanotechnological enhancement theme.

[13] G. Khushf makes this connection to Bloch explicit, at least in conversation. See Nordmann 2007b.

[14] I refer to this as an anthropological trajectory because it found its most lucid expression in A. Gehlen's philosophical anthropology that goes back to G. Herder and F. Kapp and has since been taken up, at least implicitly, by J. Harris.

II.II. New neighbours for free atoms

The term 'enhancement' offers a fitting technological expression for the appropriation of a notion of nature that is permanently surpassing, if not transcending itself.[15] However, with regard to material nature this does not tell us as of yet how the idea of nature liberated by nanotechnologies concretely manifests itself. A first pointer in this direction leads back to one of the origins of nanotechnology (Nordmann 2009).

As far as concrete applications of nanotechnologies are concerned, it is currently nanoparticles that are being discussed first and foremost. While they occur naturally and have been manufactured for many years first by artisans and then on an industrial scale, their technologically promising particularity has only been appreciated since the early 1980s. Accordingly, there is nothing novel about nanoparticles themselves. But nevertheless, they were reborn in a very real way to become interesting new nanoparticles through the way in which they were characterized by materials researcher Herbert Gleiter.

Materials properties of solids had normally been determined from the point of view of solid state physics. It derives material properties from knowledge of the crystalline structure on the assumption that nearly all atoms in a solid body are integrated into crystal lattices and that comparatively few atoms are located on or near the surfaces or at boundary layers that have been introduced into the solid by way of displacements. The atoms' neighbourhood relationships are fixed within the crystal lattice in which they are bound up. As far back as 1972 Herbert Gleiter and Bruce Chalmers inquired how to envisage "departure from the perfect crystal." What interested them most in this was the question of what happens when "an atom moves to a position in which its nearest-neighbor configuration is changed and its departure from equilibrium interatomic spacing is outside the linear Hookean range" (Gleiter & Chalmers 1972, p. 2).

Gleiter presented the corresponding technological vision along with his first experimental findings in 1981: when a body is so small that more than 50% of its atoms are localized in the surface area, and when this body is compacted with other bodies like this to form a material, new degrees of freedom and unforeseeable material properties emerge from the resulting neighbourhood configurations on the numerous boundary surfaces that now dominate the compacted material (Gleiter 1981). Liberated from their crystal lattices, atoms enter into new neighbourhood relationships and when these comparatively unconstrained and unpredictable atoms dominate the

[15] What is noteworthy here is the contrast between the technical metaphor of "human enhancement" and the organismic metaphor of "human flourishing" which derives from "flowering." These metaphors frame the improvement of the human condition in very different ethical and metaphysical perspectives.

material, they open up new technical possibilities. The structural properties of the new material thus obtained (the crystalline structures from which the nanoparticles have been dislodged, so to speak) are irrelevant to the discovery and technical use of these possibilities; by contrast, the unpredictable properties that only become observable through the creation of the new material are crucial.

Here, then, the liberation of material nature means quite literally the 'liberation' of atoms from the 'dominance' of the crystal lattices, where there is a free play of properties that is not tied to structure and where a space of new material possibilities opens up that represents at the least a technical expansion of nature.

II.III. Licensed properties

This reconstruction of the discovery of nanoparticles sounds exaggerated – a poetic interpretation of a rather mundane development, namely the pursuit by materials science of ever smaller grain sizes with ever larger surface areas. However, the language of dominance on the one hand, surprising behaviour on the other comes from the researchers themselves, as does their sense of euphoria about unpredicted novel properties and the associated technical possibilities. Even if these researchers did not for the first time encounter particles of this size, Gleiter's approach signaled, quite literally, a kind of nanoparticle renaissance.

Euphoria about an old and familiar material becoming reborn as a fundamentally different kind of entity can be found in places other than research laboratories. It is part of a larger, mythical process of supposed "dematerialization" (Bensaude-Vincent 2004) that extends to what is known as the knowledge economy.

One small case-study may serve to illustrate this. It concerns the company Evonik Degussa, which has made its new business model fit a general conception of nanotechnology and nanotechnology fit its new business model.[16] Under the heading "What is nanotechnology?" it announces quite casually: "Substances with structures in the nanometer range often have completely new properties. These can be used to create innovative applications and improved products" (Evonik 2009).[17] The story behind this innocuous formulation is that of a material called Aerosil®, which Degussa has been producing since the 1940s and which literally changed its nature or state of being when it was reborn as a nanostructured material.

---

[16] Evonik Degussa takes part in many public debates and political initiatives on nanotechnologies (see, for example, the explicit statement on dealing responsibly with nanotechnology at www.degussa-nano.com/nano/en/dialogue/positions/leitlinienanotechnologie/ (accessed: 14.4.09).

[17] Evonik Degussa GmbH, "What is nanotechnology?", not dated, accessible at www.degussa-nano.com/nano/en/nanotechnology/ (accessed: 14.4.09).

Aerosil® is a powder that has all kinds of uses and occurs in many technological applications. As long as it was conceived as a material substance, Degussa's contribution consisted in manufacturing it on an industrial scale and selling it in large quantities. Its buyers used it as a component that added a desired quality to their end-product. With the advent of nanotechnologies, however, Aerosil® ceased being a manufactured powder. It was transmuted into a collection of properties that owe not so much to their structural substrate and material nature but to a nanostructured surface.[18] Moreover, this collection of properties represents actual and potential solutions to present and future technical problems. Accordingly, Aerosil® is no longer marketed principally as a powder or bulk product but for its potential functionalities as an innovative solution – for example in dispersions that meet buyers' needs.

Over the course of 50 years, the material had become commonplace and routine, but the advent of nanotechnology turned it into a bundle of surprisingly attractive possibilities, and research efforts are now devoted to discovering novel uses and market-opportunities which will attract developers.[19] Instead of selling a bulk product, Evonik Degussa is moving towards licensing its knowledge of these properties, their potential functionality, and its skill in handling them. Unlike the material itself, this knowledge does not change owners when it is sold: like the buyer of a software package, the buyer of Aerosil® uses this knowledge without becoming its sole owner, and the nanoparticles themselves are something akin to the DVD on which the software is delivered.

This transition from control through the industrial reproduction of a defined structure to the creative diversification of useful properties amounts to an uprooting and reorientation of these properties. They are no longer conceived primarily as dependent on structure and thus on their nature, but in regard to how they can be functionalized and thus in regard to varied human interests and uses. Now that nano research has devoted itself to discovering surprising properties at a scale where there are no lawfully predictable structure-property relations, Evonik Degussa is celebrating this liberating separation of functional properties from causally determinate structure.[20]

---

[18] It is no accident that the word "transmutation" is used here. There are frequent references to nanotechnology as a kind of new alchemy (NSTC 1999, p. 4), and there is an alchemical background also to 19th century philosophy of nature (Magee 2001; Liedtke 2003).

[19] Evonik Degussa's business model also involves coming up with these potential applications themselves and stimulating interest among buyers. On this, see the company history of "Degussa Advanced Nanomaterials" at www.advanced-nano.com (accessed: 14.4.2009). This start-up firm within the Evonik Degussa company structure offers "Solutions for You" in the areas of coatings, cosmetics, electronics, catalysis, adhesives. Under the first of these headings it advertises that "We offer joint developments based on our experience in nanomaterials in order to provide you with a tailor-made solution."

[20] This agrees with a conception of the knowledge economy that refers to the sale of licenses (non-tradable goods like knowledge) instead of classical products (tradable goods like powders). – To be sure, cynics will maintain that the story of Degussa Evonik is not a story about nanotechnology and the changing nature of a nanostructured material at all but instead a story of opportunistic marketing. But there is no contradiction here. The marketing strategy brought about the liberation of the material from its defined substantial nature and the shift to the free play of novel properties as potential functionalities – and vice versa.

II.IV. From matter to material to function

The release of properties described here is not, of course, a liberation as envisioned by Schelling, Bloch or Khushf, namely a setting-free of self-organising processes that emancipate humans and nature simultaneously. Instead, what is going on is the technical appropriation of a quite simple idea: freed from a context of nature which ties them down to their causal structure, the properties enter a context of human use that relies on their relatively more flexible capacity of being adapted to technical purposes. Liberation here, then, means first and foremost the opening up of innovative potential, the discovery of new markets and the disclosure of technical possibilities.

The studies of Bernadette Bensaude-Vincent serve to place this transition in a historical and philosophical context (Bensaude-Vincent 1992; 2001; 2006; Bensaude-Vincent & Hessenbruch 2004). Chemical substances were initially defined largely by their phenomenological manifestation and their local origins. Each had its own natural history until the end of the 18th century when in the context of Antoine Lavoisier's reform of chemistry and its nomenclature they became standardized and comparable samples of chemically composed matter. They became subject to common measures and universal treatment through a novel use of scales in closed laboratories that were governed by the principle of conservation of matter. These samples of matter were further transformed by the materials science of the 20th century. Now, matter became material. At first, this meant that naturally occurring substances were examined as to their suitability to serve as, for example, building materials. In the course of its development, though, materials science has itself undergone a transition. Whereas it first inquired about the functions that the materials known to us can fulfill, it soon began the more ambitious project of actively developing materials capable of fulfilling specific desirable functions. Bensaude-Vincent shows that this approach involved a 'de-substantialisation' of matter: the substance or material object is no longer the recognized starting point or point of reference for research but is rather seen as a constraint that needs to be overcome. This development continued until the relationship between structure and function became marginal and until process and function came to be considered independently of underlying structure. In evidence of this Bensaude-Vincent quotes Ahmed Zewail, who received the Nobel Prize in chemistry in 1999 and heralded a new era of chemistry. According to him, functions are now directly accessible through the interpretation of their dynamics, without having to trace them back to structures or a corresponding set of causal events. So, if 'with nature beyond nature' refers to the realization of as yet unrealized possibilities of nature, then this story of emancipation deals first and foremost with the discovery of an unlimited space of possibilities in which poor old pathetic dead matter is replaced by new, 'intelligent' designer materials, much as was the case when plastic was introduced (Barthes 1957).

II.V. Technological use of self-organization

The foregoing discussion has been restricted to the area of new materials, an area that, while important for nano research, is still rather limited in view of the larger ambitions associated with nanotechnologies. In contrast to this, the programmes of nanobiotechnology and synthetic biology open a huge gulf between accomplished research and envisioned application. Especially in synthetic biology the intent is to merge technology and nature and thus to go beyond nature with technical means. One perhaps extreme vision speaks of plants with black silicon leaves whose purpose is to gather and store energy (Dyson 2007). Such envisioned syntheses express the aspiration of a technological convergence (VDI 2003) that is enabled by nanotechnologies' indifferent manipulation of all molecular structure: by surpassing the distinction between the organic and the inorganic, between the natural and the artificial, molecular recombinations are to enable the fusion of plants and solar panels. This programme of technological convergence is dedicated by no means to human enhancement, in particular, but includes, for another example, visions of using information technology to penetrate and enhance all ecosystems (Banfield 2002).

II.VI. Material and device

The anachronistic queerness of the notion 'with nature beyond nature', interpreted in a technical sense, becomes ever more apparent when one includes in the analysis also the rhetoric of nanotechnological programmes. In regard to this rhetoric it is immediately apparent that materials research is used to illustrate the immediate economic success of nanotechnological research but that the materials themselves are far from being seen as the real thing as of yet. The nanotechnologies that are yet to come are thought to be technical systems, devices and machines. Nanotechnological ambition demands more than taking materials out of their context of nature and placing them into a context of use with its greater degrees of freedom where properties can serve a variety of functions. For nature to surpass itself by technical means and for technology to become natural, the agency of self-propelled nature would have to link up with technical functionality. This merely regulative or heuristic idea has not been realized as yet but is anticipated in the marketing rhetoric of nanotechnology, especially in attempts to ascribe to as yet dead and dumb matter that it is now animated and has become smart 'self'-acting material.

The expectation that nature might become technical and technology natural through their alliance in the production of self-acting systems finds expression, for example, in talk of 'selective surfaces', 'intelligent materials', 'self-propelled' or 'autonomous' motion, 'self-organized structures', and most prominently of 'self-cleaning glass', much of it is hardly more than 'dirt resistant.' Where an activity of cleaning and self-maintenance is invoked, most self-cleaning glass is actually an entirely passive structure. It is the rain that provides the action of rinsing dirt from a finely prickly surface that prevents dirt from sticking too well in the first place. Other kinds of self-cleaning glass claim a 'dual-action process.' The sun's ultraviolet light provokes the release of oxygen ions from a coating on the glass, these ions break down the dirt on the glass (this is the first action) and the rain then washes it off (the second action). If this glass has a more proper claim to agency, this is because 'the greatest feature of Pilkington Activ™ Self-Cleaning Glass is that it relies on the forces of nature to keep your windows looking beautiful' and with this, indeed, 'an impossible dream' has become reality (Pilkington 2009). The glass appears to have incorporated within itself what appears to be a natural propensity or affordance that may well continue in perpetuity (compare Harré 2003). If it still sounds like an exaggeration to speak here of a perfect and transcendent fusion of nature and technology and the transformation of glass from inert and dumb translucency to active and smart self-maintenance, the reason for this is only that the glass in question does not quite live up yet to the expectations associated with nanotechnological systems.

II.VII. Uncontrollably controlled agency

Nowhere is the ascription of the 'self' so enigmatic and ambiguous than in the concepts of self-assembly and self-organization, whose many and varied uses in the context of nanotechnological research and whose philosophical interpretations cannot be analyzed here. At times these are nothing other than a fancy way of stating what happens in any chemical reaction; sometimes, though, it is also used to describe a technology that is no longer constructed but grown by mobilizing powers of self-organization.

The fact that this ambiguity is preserved, that these and further connotations are implied in terms such as "bottom-up engineering," and that there is no sense of urgency to clarify these terms, testifies to the 'ontological indifference' identified by Peter Galison in nanotechnological research (Galison 2006). Traditionally, scientific understanding is not indifferent at all to what exists and what does not, and to what is the precise meaning of theoretical concepts. In contrast, the striking indifference regarding nanotechnological appeals to "self-organization," "self-assembly," or "bottom-up engineering" can be viewed as a resultant of two forces that are acting together. There is on the one hand a powerful idea that was articulated by Bernadette Bensaude-Vincent, namely the implicit notion of the presumed totipotency of technoscience and converging technologies (Bensaude-Vincent 2009). The notion of "totipotency" came to the fore in discussions of adult and embryonic stemcells where the latter are said to be more powerful and significant because they can become any cell whatsoever. It is their totipotency that makes embryonic stemcells attractive objects of biomedical desire since it expresses a kind of organic and biological power that is projected in a general way by nanotechnologies on the free play of functions, on molecular recombination, and unbounded technological potential in the material world (Schwarz 2004, 2009). The notion of "self-organization" serves as a cipher for this totipotency. There is on the other hand the queerness that owes to the technical appropriation of a concept from philosophy of nature: whatever might be meant by "self-organization" philosophically or scientifically, the technical meaning of the term is not in question because nature, as a kind of super engineer, always already shows its human imitators how 'bottom-up engineering' is done. To note that nature organizes itself is merely another way of saying that it has constructed everything we see – including ourselves.

At this point it becomes clear how nanotechnologies adopt nature as their role model – but only after they conceptualize nature as nothing other than an engineer. This shift in meaning allows visionaries of self-organization to describe technical control over natural and technical processes at the nanoscale as a mere illusion without renouncing the idea of control: »The problem is the illusion of control – what we want to do is reverse engineer. We harness self-assembly in a non-linear way to get what we want. To do this at the nanoscale will be a big breakthrough because we can then start to control things, put them in compartments and let them evolve. We don't need the illusion of control. We let the system select what it needs according to its local environment. We can't be an engineer at that level if we want to use bottom up. Nature takes this approach and it works very well.«[21]

This on first sight rather confused notion of control is another sign of ontological indifference: converging on the business of creating and recreating a world, nanotechnologies and the various technosciences put themselves at the mercy of a self-organizing and thereby presumably self-controlling nature. This enables nanotechnological researchers to distance themselves from false notions of precision control at the nanoscale and at the same time to wait and see what interesting and useful properties they might discover there.

III. Conclusion

'With nature beyond nature' could mean that there are evolutionary processes that lead to emergent phenomena, to a 'higher' level of organization or further development of nature. This is a notoriously difficult conception to grasp. In the technoscientific practice of nanotechnological

[21] Statement made by a nano researcher at a scenario workshop run as a part of the EU project DEEPEN, see Macnaghten/Kearnes 2007.

research it becomes even more exasperating precisely because a grand conceit has become a matter of casual indifference. According to this conceit, nature reveals itself as a nano engineer and thus vanishes inside a generalized notion of technical construction, while technology entrusts itself to nature by seeking to absorb the dynamics of self-organization into the design process.

I here described this unassuming indifference to the grand conceit as queer because it violates received categorical distinctions without paying the price of justifying itself theoretically. It neither reduces spirit and culture to matter and nature, nor does it celebrate the scandalous creation of hybrids or monsters. Instead, it simply dissolves the received categorical difference of science and technology, nature and culture, organism and artefact, the natural and the artificial into the idiom of engineering.[22]

Three ›Questions for Reflection‹

1. This text follows the common assumption that there is a sharp distinction between philosophy and basic science on the one hand, and engineering and technology on the other hand. Where does this assumption come from and how might it be justified?
2. Some argue that technology always goes beyond the limits of nature. Others maintain that technology can only work within the limits of nature. Given this contrast, what do you think the nanotechnological ambition to go 'with nature beyond nature!' means?
3. How do you feel about the program to enhance material nature vs. the program to enhance human performance? What do you think is the relationship between the two?

Contact

Alfred Nordmann
Professor of Philosophy
Technische Universität Darmstadt

nordmann@phil.tu-darmstadt.de

References

Banfield, J. (2002). "Making Sense of the World. Convergent Technologies for Environmental Science", in: Roco, M.C. and Bainbridge, W. S. (eds.), *Converging Technologies for Improving Human Performance*, Arlington: National Science Foundation, pp. 260-264.

---

[22] One of the few explicit statements to that effect can be found in Roco & Bainbridge 2002, p.11: "Some partisans for independence of biology, psychology, and the social sciences have argued against 'reductionism,' asserting that their fields had discovered autonomous truths that should not be reduced to the laws of other sciences. But such a discipline-centric outlook is self-defeating, because as this report makes clear, through recognizing their connections with each other, all the sciences can progress more effectively. A trend towards unifying knowledge by combining natural sciences, social sciences, and humanities using cause-and-effect explanation has already begun, and it should be reflected in the coherence of science and engineering trends and in the integration of R&D funding programs."

Barthes, R. (1957). “Plastic”, in: Barthes, R., *Mythologies*, New York: The Noonday Press, 1991, pp 97-99.

Bensaude-Vincent, B. (1992). “The Balance: Between Chemistry and Politics”, in: *The Eighteenth Century*, 33(2)/1992, pp. 217-237.

Bensaude-Vincent, B. (2001), “The Construction of a Discipline: Materials Science in the U.S.A.”, in: *Historical Studies in the Physical and Biological Sciences*, 31(2)/2001, pp. 223-248.

Bensaude-Vincent, B. (2004), *Se libérer de la matière? Fantasmes autour des nouvelles technologies*, Paris: INRA editions.

Bensaude-Vincent, B. (2006). “Materials as Machines”, paper at workshop “Science in the Context of Application” at the Centre for Interdisciplinary Research (ZiF) Bielefeld, October 2006.

Bensaude-Vincent, B. (2009). *Les vertiges de la technoscience: Façonner le monde atome par atome*, Paris, La découverte.

Bensaude-Vincent, B. and Hessenbruch, A. (2004). “Materials Science: A field about to explode?”, in: *Nature Materials*, 3(6)/2004, pp. 345-346 .

Binnig, G. (1992). *Aus dem Nichts: Über die Kreativität von Natur und Mensch*, Munich: Piper.

Binnig, G. (2004). Foreword in: N. Boeing, *Alles Nano?! Die Technik des 21. Jahrhunderts*, Berlin: Rowohlt, pp. 7-9.

Bloch, E. (1954). *The Principle of Hope*, Cambridge, Mass.: MIT Press, 1995.

Davies, G. (2007). “Introduction”, in: Davies, A.G., Thompson, J.M.T. (eds.) *Advances in Nanoengineering: Electronics, Materials and Assembly*, London: Imperial College Press, pp. 1-7.

Dupuy, J.-P. (2007). “Some Pitfalls in the Philosophical Foundations of Nanoethics”, in: *Journal of Medicine and Philosophy*, 32(3)/2007, pp. 237-261.

Dupuy, J.-P. (2009) *On the Origins of Cognitive Science: The Mechanization of the Mind*, Cambridge: MIT Press.

Dyson, F. (2007). “Our Biotech Future”, in: *New York Review of Books*, 54(12)/2007, pp. 4-7. http://www.nybooks.com/articles/20370 (accessed 14.04.09).

Evonik Degussa (2009). “What is nanotechnology?” at www.degussa-nano.com/nano/en/nanotechnology/ (accessed: 14.4.09).

Galison, P. (2006). “The Pyramid and the Ring”, lecture given at a conference of the “Gesellchaft für analytische Philosophie” (GAP, Society for Analytical Philosophy), Berlin, September 2006.

Geertz, C. (1973). “Thick Description: Toward an Interpretive Theory of Culture”, in: ibid., *The Interpretation of Cultures*, New York: Basic, pp. 3-30.

Gehlen, A. (1965). "Anthropologische Ansicht der Technik", in: Freyer, H., Papalekas. J., Weippert, G. (eds.), *Technik im technischen Zeitalter: Stellungnahmen zur geschichtlichen Situation*, Düsseldorf: Schilling, pp. 101-118.

Gleiter, H. (1981). “Materials with Ultra-Fine Grain Sizes”, in: Hansen, N., Leffers, T. and Lilholt, H. (eds.), *Proceedings of the Second Risø International Symposium on Metallurgy and Materials Science*, Roskilde: Risø National Laboratory, pp. 15-22.

Gleiter, H. and Chalmers, B. (1972). *High-Angle Grain Boundaries*, Oxford: Pergamon Press.

Harré, R. (2003). “The Materiality of Instruments in a Metaphysics of Experiments“, in: Hadder, H. (ed.), *The Philosophy of Scientific Experimentation*, Pittsburgh: University of Pittsburgh Press.

Hayles, N.K. (2004) (ed.). *Nanoculture: Implications of the New Technoscience*. Bristol: Intellect Books.

Healey, P. and Rayner, S., (2009) (eds.). *Unnatural Selection: The Challenges of Engineering Tomorrow's People*, London: Earthscan.

Kampers, F. (2007a). “Frans Kamper on food and environmental applications of nanotechnology“, presentation given at the “NanoBioRaise Second Horizon Scanning Workshop”, 19 – 20 March 2007, Frankfurt am Main.

Kampers, F. (2007b). Interview in the *BBC Focus Magazine*, No. 175/April 2007, p. 42.

Khushf, G. (2007). “An Ethic for Enhancing Human Performance Through Integrative Technologies”, in: Bainbridge, W.S. and Roco, M, (eds.), *Managing Nano-Bio-Cogno Innovations: Converging Technologies in Society*, Dordrecht: Springer, pp. 255-278.

Liedtke, R. (2003) *Das romantische Paradigma der Chemie*, Paderborn: mentis.

Macnaghten, P. and Kearnes, M. (2007). “DEEPEN Deliverable 4: Working Paper - Scenario Planning and Draft Design of Focus Groups”, unpublished, Durham, April 2007.

Magee, G.A. (2001) *Hegel and the Hermetic Tradition*, Ithaca: Cornell University Press.

Milburn, C. (2008) *Nanovision: Engineering the Future,* Durham: Duke University Press.

National Science and Technology Council (NSTC) (1999). *Nanotechnology. Shaping the World Atom by Atom*, Washington: National Science and Technology Council/Committee on Technology.

Nordmann, A. (2007a). “If and Then: A Critique of Speculative NanoEthics”, in: *Nano-Ethics*, 1(1)/2007, pp. 31-46.

Nordmann, A. (2007b). “Renaissance der Allianztechnik? Neue Technologien für alte Utopien”, in: Sitter-Liver, B. (ed.), *Utopie heute. Zur aktuellen Bedeutung, Funktion und Kritik des utopischen Denkens und Vorstellens*, Vol. 1, Fribourg/Stuttgart: Academic Press/Kohlhammer, pp. 261-278.

Nordmann, A. (forthcoming a). “The Hypothesis of Reality and the Reality of Hypotheses", in: Heidelberger, M. and Schiemann, G. (eds.), *The Significance of the Hypothetical in the Natural Sciences*, Berlin: deGruyter.

Nordmann, A. (forthcoming b). "Invisible Foundations: Herbert Gleiter and the Contribution of Materials Science", in: *Perspectives on Science*.

Pilkington (2009) . *Pilkington Activ™ Self-Cleaning Glass*. http://www.pilkingtonselfcleaningglass.co.uk/ (accessed March 21, 2009).

Roco, M. C. and Bainbridge, W. S. (2002) (eds.). *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science*, Arlington: National Science Foundation.

Ryle, G. (1968), “The Thinking of Thoughts. What is ‘Le Penseur’ Doing?”, in: Ryle, G. *Collected Papers*, Vol. 2, London: Hutchinson, 1971, pp. 480-496.

Schelling, F.W.J. (2004). *First outline of a system of the philosophy of nature Ideas for a Philosophy of Nature*. Albany: State University of New York Press.

Schmidt, J.C. (2002). “Wissenschaftsphilosophische Perspektiven der Bionik” in: *Thema Forschung. Das Wissenschaftsmagazin der Technischen Universität Darmstadt*, 2/2002, p. 19.

Schwarz, A.E. (2004). “Shrinking the 'Ecological Footprint' with Nanotechnoscience?” in Baird, D., Nordmann, A. and Schummer, J.. eds. *Discovering the Nanoscale*, Amsterdam: IOS Press, pp. 203-208.

Schwarz, A.E. (2009). “Green Dreams of Reason: Visions of Excess and Control” in Nordmann, A., Malsch, I., Quesada, M.A., Simons, E. *Ethics of Converging Technologies* (e-learning DVD developed in the EU funded EthicSchool project), Nijmegen: Radboud University.

Toumey, C. (2008) “Reading Feynman Into Nanotechnology: A Text for a New Science” in *Techné* 12:3, pp. 133-168.