Nature and Artifact in Nanotechnologies

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Abstract: This paper discusses the common view that nanotechnology blurs the boundary between nature and artifact. At first glance, this claim seems to be justified by the 'artificial molecular machines' which play a central role in the development of nanotechnology. However in considering a few examples of design of artificial molecular machines, I first argue that the dual trend of artificialization of nature and naturalization of artifacts is not consistent. This antinomy is based on a tacit and never-questioned metaphysical assumption: nature and artifacts cannot be ontologically balanced. Their opposition relies on other conceptual divides between structure and operation, between being and becoming in classical metaphysics. I try to demonstrate that nanotechnology undermines this traditional metaphysical view. Nature cannot be described as a separate and permanent entity. It is more adequately characterized as a set of processes homogeneous with technological processes. Thus, far from erasing nature, nanotechnology conveys an operational view of nature that precisely belongs to a *Techno-logy*.

Keywords: *artifact*, *metaphysics*, *nature*, *operation*, *technology*.

1. Introduction

It is commonly stated that nanotechnology is going to drastically change our relation to nature. This assumption not only concerns our technical abilities, but also our representation of nature loaded with metaphysical presuppositions. In fact, nanotechnology should be used in the plural (nanotechnologies). As suggested by a recent list set up by Fern Wickson (2008) there is more than one narrative of nature in current laboratory research in the nanoscale field. This variety of views is largely generated by the wide spectrum of applications envisaged and their potential impacts on environment, health, and society. However if we consider exclusively the kind of basic research that is conducted in French laboratories it is possible to identify one predominant view of nature, which deserves to be closely examined.

Let us start with a reference to the French philosopher Maurice Merleau-Ponty who delivered a lecture on nature at the Collège de France by the end

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of the 1950s (Merleau-Ponty 2003). Nature, he said, can no longer be discussed (philosophically) without considering cybernetics. Merleau-Ponty did not mean that cybernetics had shaped a definite philosophy of nature and that cyberneticists were *de facto* philosophers. He claimed that cybernetics did outmode some conceptions of nature and that a new ontological basis was needed. The same goes for nanotechnologies today. We cannot deal with nature without dealing with nanotechnology and also biotechnology. As with cybernetics, these so-called transformational technologies certainly do not contain a ready-made view on nature – conceived by whom anyway? By the scientists themselves, giving their research a truly philosophical turn? That is not their role. However these technologies force us to give up some metaphysical presuppositions underlying our usual representations of nature. This is what we mean by a new conception of nature in nanotechnology, and this article is an attempt to give an insight on that new conception.

This view of nature cannot be separated from a view of artifacts. As Merleau-Ponty argued in the same lecture, our idea of nature is always pervaded with artifacts. To display the concept of nature in nanotechnology means first and foremost to describe the artifacts designed by nanoscientists. To do so we will rely on a few examples of artifacts designed in a number of French laboratories that have been studied in our research program.

2. Artificializing Nature, Naturalizing Artifact

Nanotechnology blurs the boundaries between nature and artifact. This seemingly clear and simple statement suggests that nanotechnology generates new underlying views of nature. The role of the philosopher would be to turn them into explicit statements. The task turns out to be more complicated than expected when comes the need to clarify the meaning of this 'blur'. Is it to say that there is a shift in the boundaries, the artificial field cutting down on the natural field? One would object that there is nothing new about that: *Homo habilis* had already thoroughly altered his relation to matter and 'blurred' the boundary between nature and artifact. Nanotechnologies would only be the continuation of a process started with *Homo habilis* two million years ago. Yet specifying the meaning of this process brings forward another difficulty, as two alternative theories conflict.

The first theory stipulates that nanotechnologies genuinely achieve the program of 'artificialization of nature' which is said to define modernity. We are now in the all-artificial era. The ability to operate at the nanoscale in order to manipulate nanoobjects one by one, whether they be atoms or molecules, would gradually erase nature from our environment and even from our body.

The second theory on the contrary stipulates that the realm of nature is increasing, because artifacts become less and less distinguishable from natural beings. Molecular machines are just molecules provided by nature. For instance a group of French physicists managed to control the motion of a biphenyl molecule adsorbed on a silicon surface. By means of electronic stimulation, they designed a bistable molecular configuration – the biphenyl bistable – which acts as a molecular switch (Mayne *et al*. 2004). According to a physicist met at a conference, this is an entirely 'natural' object, as a molecule is a natural thing – as opposed to the switches we use in our daily life at the macroscale and which are typically 'artificial'. This physicist obviously sees the molecule from the point of view of its action. On the other hand, he considers the 'macro' switch from the point of view of its production: it is 'artificial' because it has been manufactured. But strictly speaking, this switch is as 'natural' as the biphenyl molecule when seen from the point of view of what it does. On the other hand, the molecule is as 'artificial' as the switch when considered from the point of view of its production: it has been synthesized in a laboratory. In this case, the 'blurring' of the boundary between nature and artifact comes from a confusion between action and production, between how nano-objects work and how they are produced.

The claim of the 'naturalization of artifacts' holds another argument, chiefly defended by the physicist Richard Jones (2004): scientists will operate successfully at the nanoscale if they rely on the design strategies invented by nature. Nature has indeed optimized its operations at the nanoscale. There is no way we can do any better than nature at that scale. This argument stands in favor of an approach to nanotechnology in terms of 'making do', or 'driving natural processes' instead of manufacturing strictly speaking. The point is not to impose a blueprint on matter, but rather to 'drive' natural processes that would happen without us.

As pointed out by a number of scholars there is a tension between the two processes of 'artificialization of nature' and 'naturalization of artifacts' in nanotechnologies. Jean Pierre Dupuy (2004) for instance stressed what he believes to be the 'metaphysical research program' underlying the program of Converging Technologies. According to him, the so-called Nano-Bio-Info-Cogno convergence program displays a tension – the same one that undermined the first cybernetics – between the ambition to control nature and the ambition to give rise to emergent properties in complex systems – complex in the way Von Neumann defined it. The behavior of complex systems would thus be unpredictable like living beings (naturalization of artifact). According to Dupuy, the absence of control is no accident, but the very aim of the designers of nanodevices.

Alfred Nordmann (2005) came to similar conclusions: we are now technically able to operate on nature at the nanoscale, but we cannot actually have a

genuine representation of the causality implied by this operation. During a seminar, a physicist mentioned that he was puzzled by the action of a molecular machine that can be individually activated. We can fuel power in the molecule but we do not know when and how it will start working. We are able to trigger effects that are impossible to track or to observe (like GMO dissemination or wild self-replication of Drexler's universal assemblers: once released in nature, it becomes impossible to discern GMO from a natural process). In the end the artifacts we manufactured act like nature. There is no difference anymore between technological objects in action and natural processes ('naturalization of artifacts').

We are thus confronted with two apparently conflicting statements: nanotechnologies are integral part of a process of 'artificialization of nature'; nanotechnologies are related to a process of 'naturalization of artifacts'. Both theses can be supported by equally valuable arguments. Now this situation is what Kant called an antinomy, that is to say a dialectical use of our ability to know beyond the limits of possible experience. We claim to forge an objective criterion allowing us to distinguish nature from artifact, like others claimed to objectively define the world as being finite or infinite. The French philosopher François Dagognet (2000) suggested to get out of this antinomy by considering the idea of nature a 'misconception', while still acknowledging its regulating value. He consequently proposed to consider nature as a regulating idea of pure reason rather than as a set of phenomena. At this point our initial question can be reformulated in these terms: How do we understand that the distinction between nature and artifact needs – apparently – to be cast beyond the limits of objective knowledge?

3. Nanosciences and the Critic of Metaphysics

I suggest here to turn to the criticism of western metaphysics developed by the philosopher Gilbert Simondon (1952/53). Metaphysics relies on a disjunction between being and becoming, between the structures and the operations in the being. This disjunction is, according to Simondon, the metaphysical basis of modern science. To become an object of science the being had to be placed in the framework of absolute determinism, deprived of any internal dynamism, as opposed to the subject who retrieved all the operating dynamism from which the being has been emptied of. Thus operations devoid of all objectivity were identified with the spontaneity of the subject applied to phenomena, *i.e.* to structural realities. The Kantian theory of objective knowledge, which was Simondon's main target, rests on the dichotomy between structures and operations. In particular this dichotomy under-

lies the contrast between nature, defined by the stability of a safe ontological ground (structures), and artifact (operations) that connotes corruption, instability, becoming, and process. Nature is a primary stable state, and technology spoils it, corrupts it. Technology denatures.

This might be a way of interpreting the awkward situation nanotechnology confronts us with. Our trouble can indeed be explained by our commitment to a kind of spontaneous Kantianism. We tend to evaluate nanotechnology on the basis of this classical divide between structures and operations, underlying the Kantian theory of knowledge. This common sense Kantianism is also expressed in the definition of artifact as 'what is man-made': products (constituted structures) can be sorted into two categories according to whether man is or is not involved in their production. Artificial beings refer to human designers while natural beings refer to nature – their producer. In both cases, the productive operations are separated from their results, and referred to an external origin (man or nature). The working structures can be described apart from their production process. In thus isolating working structures from their production process, we can adopt Descartes' famous claim according to which all things that are artificial are also natural. Obviously 'artificial' and 'natural' things work according to the same natural laws. According to Kant (1790), only living beings challenge the divide between structure and operation. Kant defined them as 'organized beings' meaning that they self-organize: structure and operation ('formative force', *bildende Kraft*) are inseparable. That is the reason why Kant assumed that self-organization was beyond the boundaries of objective knowledge.

Now laboratory nano-objects also resist the metaphysical divide between structure and operation, which generates the apparent antinomy between 'artificialization of nature' and 'naturalization of artifact'. The striking point is not that they blur the boundary between nature and artifact, which would not be new. Rather they blur a more fundamental distinction between structures and operations. Considering the common sense Kantianism, nano-objects would not fulfill the conditions for objective knowledge, hence the antinomy. In other words, nano-objects (at least some of them) do not fit in the metaphysical divide between structure and operation, between their production and action.

The distinction between nature and artifact in nano-objects should therefore be interpreted in terms of operations immanent to structures rather than in terms of operations separated from working structures, according to the opposition between what is 'man-made' and what is not.

Nanoscientists, as it happens, are very serene in expressing the prevalence of 'process' and 'operations' both in nature and artifacts. They do not make any difference between structures and operations. To them, nature is not a field of ontological stability, a set of given structures that technological op-

erations would denature. When they talk about nature, they are more concerned by 'what it does', than by 'what it is'.

The shift from being to doing could be misunderstood as a reactivation of the old cliché of God as the great architect. However to nanoscientists, there is no 'art' at work in nature. Their vocabulary simply suggests that nature is better described in terms of operations, processes, rather than in terms of structures. That nature 'does this or that' does not mean that nature is a kind of skillful engineer, but that nature is pure processuality, operationality. Although the metaphor of the skilful engineer occasionally surfaces in their discourse, most scientists who refer to the engineer, do not mean that there is an intelligent design in nature imposing a pre-established plan upon a passive matter. It is the 'processualization' of nature that makes the analogy between technical and natural operations possible.

4. A Laboratory Experiment: Remaking the E. Coli Flagellum Nanomotor

Nanoscientists do not bother much about Kantian metaphysics. But the re-evaluation of nature in terms of process actually existed in contemporary science long before the nanotechnology boom. Science does not describe nature anymore, it establishes it, creates it, invents it; *doing* is replacing *being*; science is more concerned with intervening than with representing, as Ian Hacking (1983) already pointed a few decades ago.

Let me illustrate this with a current research project on the synthesis of a nanomotor. The researchers involved in this project aim to remake the E. Coli flagellum nanomotor.[1] The structure and the operation of this nanomotor remain a mystery to biologists. They do neither know how its forty-five proteins are arranged, nor how they produce electromechanical motion, nor do they know its building design. The experiment aims at testing a model describing the mechanical working of the nanomotor: does it or not conform to the proteins' actual spatial arrangement?

The *design* strategy consists in building the nanomotor on a solid surface using the proteins' self-assembling mechanisms. The first step consists in isolating the four proteins responsible for the motor's rotation, to produce more of them and to purify them. The second step consists in preparing the solid surface on which the proteins will be printed and will have to self-assemble. The idea is to make the surface mimic the bacterial membrane. This strategy uses the soft lithography technology at the nanoscale. It relies on the hypothesis that the proteins will self-assemble on this biomimetic surface the same way they do in a living organism. The third step consists in imaging the

thus obtained molecular structures at their different stages – by means of an Atomic Force Microscope – to test the mechanical model.

Three *design* strategies were considered: (i) a bottom-up strategy consisting in assembling the motor step by step according to a pre-established plan – which is impossible to put into practice considering that the actual building plan of the biological motor is still unknown.; (ii) a genetic engineering strategy consisting in 'emptying' the bacterium of its functionalities to replace them by others – the aim here is not to re-engineer the nanomotor in the laboratory, but to functionalize the bacteria; iii) the third strategy is the one described earlier. From the point of view of the production process, in the first strategy the motor is purely artificial; in the second one its functionalities are artificial but the motor is natural (bacteria are instrumentalized); but in the third one, the one I am dealing with here, the situation is more complex. Christophe Vieu, head of a Nano research group in Toulouse, claims that if they succeed in their experiment, their nanomotor could be as 'natural' as biological motors. According to him, the distinction between natural and artificial machines is fading away, which is definitely anti-Kantian. Indeed, Kant (1790) carefully distinguished the beings that exist as art products – for instance a watch made by a watchmaker – from beings that exist as natural ends, that is to say living beings as self-organizing systems. The distinction between artificial and natural machines is not justified considering their behavior once they are produced: take a living being and a watch, both are 'machines' that behave following the universal laws of nature (according to Kant). However, considering their production, the two kinds of machines should be distinguished: the production of a self-organized being, according to Kant, follows a kind of causality unknown to us, that can neither be assimilated with *nexus effectivus* (the causality of the universal mechanism) nor with *nexus finalis* (the causality linked to finality, following the example of the watch).

However nanoscientists may well manage to create artificially the conditions under which this very weird kind of causality would operate. The reason why they claim that in case of success there would be no difference between the nanomotor built in the laboratory and biological motors, is that they look at nature as a set of operations. Far from considering nature as a set of structures devoid of operations (which according to Simondon (1952/53) is the foundation of Kantianism) they see nature as a process. If they seem to ignore the divide between nature and artifact it is because they only look at nature's operations. If they occasionally talk about nature's plan, thus bringing back the figure of the skillful engineer, this term does not refer to a hidden metaphysics. It is just a metaphor. On the other hand, when nanoscientists claim that the same mechanisms are at work in biological nanomotors and in laboratory nanomotors, they reintroduce the distinction between

natural and artificial based on the production origin (the self-assembling mechanisms) and no longer refer to the working conditions. In the case of the biological motor, bacteria and the processes determine these conditions; in the case of the laboratory nanomotor, the conditions are defined by the coupling between the solid surface, the probe microscope, and the production and purification of proteins. The two objects can be considered identical abstractly speaking, but considering their actual production and working conditions, the two motors cannot be identified. If we push further this coupling between operations and structures, the laboratory nanomotor can neither be called 'artificial' (the nanoscientists are right) nor can it be called 'natural' (they are therefore also wrong). But what remains of the distinction between nature and artifact in this case? Is it obsolete, ineffective? My answer is no.

5. Towards a New 'Natural State'?

The experiment on the biphenyl molecule is uppermost significant from a cognitive point of view. The aim here is to study natural phenomena such as molecular dynamics or electron transfer through a single molecule. One would say that these phenomena have always been there, even if we have had to wait for the scanning tunneling microscope to observe them. This assertion seems hard to refute. A robust realism tells us that nature is not the product of our activity; it does not owe us anything. However, this conception of nature as a timeless reality to be progressively unveiled is based on a fiction. It assumes indeed that we could have a view of nature devoid of any historical context. We know that our view of nature radically changed over time according to the investigation tools that have been used. Nature has changed for us. However, all this does not affect nature in itself, eternal and unalterable. As if we could pull out of the '*dispositif*'[2] that we use to investigate nature that shapes us historically and defines at a given moment what is visible and what is not, what is expressible and what is not. As if we could take a timeless view on nature – that is a fiction, of course, making us believe that it is possible to rise above the '*dispositif*' that shapes us. As if we could actually climb on our own shoulders. Common sense realism is misleading in assuming that nature contains the '*dispositif*' that shape human existence historically, but it is actually the other way round. Nature is not a construction of our mind; it is external to us, however the relationship we have with it is shaped by our '*dispositif*'. What belongs to nature at a given moment is therefore determined by our '*dispositif*'.

This distinction between nature 'to us' and nature 'in itself' is a consequence of the metaphysical divide between structures and operations. Nature is on the side of ontological stability; technology is about becoming, corruption, instability, and process. In rejecting this metaphysical divide we get rid of the fiction of a timeless nature waiting for being unveiled by our '*dispositif*'. As the French philosopher Serge Moscovici (1977) claimed, what is in nature at a given moment depends on our artifacts. Material forces have no reality without the skills and mediations allowing to access them. Nature and artifact are not located on either side of a boundary that would shift or fade away, as if there could be, as if there ever was nature distinct from artifact. Nature and artifact are two abstractions from the same reality, that of a historically given 'natural state', defined by a specific coordination system between human skills and material forces.

At this point a new question follows: to what extent do nanotechnologies generate a new relation between material processes and human actions, a new 'natural state'? Far from impoverishing the concept of nature, nanoscience enriches it, by adding more content to it. For example, the re-engineering of E. Coli flagellum nanomotor induces a new relationship between man and matter. In this case, the task of machine building is commissioned to matter itself. In other words, the machine building is embedded in the mechanisms of nature. As the machine maker's substitute, nature is not necessarily assimilated to a kind of skillful engineer. Nanoscientists carefully avoid all anthropomorphic interpretation.

6. Conclusion

The new 'natural state' conveyed by the experiment on the E. Coli flagellum nanomotor (if the experiment turns out to be a success) results from an approach to both nature and artifact as processes, and has nothing to do with the Kantian dichotomy between structures and operations. The description of a 'natural state' is part of a rather neglected discipline, technology (Simondon 1989). Technology does not focus on technological applications but on the working principles of tools and machines. It describes the articulation between human skills and material forces. And, as Simondon claimed, today the true technologist is the laboratory scientist. The experiments on biphenyl molecule and E. Coli nanomotor are neither basic science nor applied science: they are more adequately defined as technological science (Hansson 2007). In technological science, it makes no sense to separate nature from the artifacts that give access to it. Our view of nature is necessarily dependent on artifacts. The notions of nature associated with nanotechnologies should therefore be understood from the point of view of technology as a science of operations.

Notes

[1] Nano Group of the French Laboratoire d'Analyse et d'Architecture des Systèmes (LAAS, Toulouse) led by Dr Christophe Vieu [http://www.laas.fr/laas/1-5595-Nano-Moteur.php].

[2] In the way Foucault, followed by Deleuze, defined this term: the *dispositif* (apparatus) consists in 'lines of force' determining visible objects, affirmations that can be formulated, forces exercized, and subjects in position (Foucault 2001).

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