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ABSTRACT
It is now widely accepted that Research & Development in nanotechnology and biotechnology should be accompanied by research programs in ethics. This paper first critically assesses the initiatives that characterize this "ethical turn" by clarifying its underlying philosophical assumptions and its consequences. Current trends in nanoethics enhance the concern for responsibility and develop an attitude of prudence. However nanoethics focused as it is on designers' responsibility, reinvigorates the anthropocentric modern ideal of man as the lord of nature and master of the future. Technological objects are viewed only as means for human needs and sources of profit. An alternative approach to nanoethics considers artefacts as individual entities with a life of their own and takes into account the specificities of the nanoworld.

KEYWORDS
Economy of promises, prospective, responsible innovation

1. *Introduction*

Over the past decade nanoethics has been promoted as a necessary complement of nanotechnology research programs. This 'ethical turn' might be seen as a major feature of what the German social theorist Ulrich Beck (1992) defined as "reflexive modernization". The awareness and the management of the potential risks generated by scientific and technological choices has prompted new initiatives. Instead of the creation of ethics committees, the ethical concern prompted the implementation of research programs about 'ethical, legal and societal impacts' (ELSI) that are integral parts of the national nano-initiatives. These programs have attracted a number of humanities scholars around the world and prompted the creation of a new journal *Nanoethics* in 2007. It was clear from the outset that nanoethics would not be a new branch of applied ethics, like biomedical ethics for instance. The editors of the journal encouraged a broad and loose definition of ethics.

> "The Ethics for Technologies that Converge at the Nanoscale provides a needed forum for informed discussion of ethical and social concerns related to nanotechnology, and a counterbalance to fragmented popular discussion. While the central focus of the journal is on ethical issues, discussion extends to the physical, biological and

> social sciences and the law. *NanoEthics* provides a philosophically and scientifically rigorous examination of ethical and societal considerations and policy concerns raised by nanotechnology". (http://link.springer.com/journal/11569)

Just as the view of ethics developed in this journal goes far beyond moral concerns to encompass legal and societal issues, the notion of nano itself is extended to all "technologies that converge at the nanoscale", thus embracing the famous NBIC quartet (nano-bio-info-cognitive) promoted in the USA by Mihaïl Roco and William Bainbridge (2004). Consequently nanoethics emerged as a wide and loose domain pioneered by social and political scientists as well as lawyers and philosophers. Most of them have been sponsored by science policy agencies and some of them have been "embedded" in research laboratories. Nanoethics, as it has been promoted, is closely associated with the notion of responsibility. As early as 2002 the champions of nanotechnology gathered around Eric Drexler created a Center for Responsible Nanotechnology in Palo Alto, dedicated to anticipating the societal and environmental implications of nanotechnology. The European Commission also spread the word "responsible research and innovation", which has been taken up by various think-tanks and civil associations. The notion of responsible nanotechnology is mainly focused on the anticipation of the potential environmental, health, security impacts (EHS programs) and the ethical, legal, societal impacts (ELSI programs) of the applications of this emerging technology. In this framework, diverse topics such as risks, environment, privacy, patent thickets, human enhancement, social justice, cultural diversity, and public perception have been addressed over the past decade.[1]

The "ethical turn" initiated in nanotechnology is thus based on a loose notion of ethics promoted as a kind of "boundary concept" bringing together actors from various spheres and backgrounds.[2]

The purpose of this paper is first to critically assess this "ethical turn" by clarifying its underlying philosophical assumptions and its consequences. The current trends in nanoethics favour an attitude of prudence. But as it is focused on the designers' responsibility, it reinvigorates the anthropocentric

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[1] Such were the topics covered by one of the earliest programmes sponsored by the National Science Foundation whose results were published in 2008 : Fritz Allthoff, Patrick Lin, *Nanotechnology and Society. Current and Emerging Issues*, Springer, 2008.

[2] Star Susan L, Griesemer J. (1989) 'Institutional ecology. Translation and boundary objects. Amateurs and professionals on Berkeley's museum of vertebrate zoology', *Social Studies of Science*, 19 (3): 387-420.

modern ideal of man as the lord of nature and master of the future. Technological objects are viewed only as means for human needs and sources of profit. An alternative approach to nanoethics considers artefacts as individual entities with a life of their own and takes into account the specificities of the nanoworld.

2. *Ethics in the race for innovation*

The official aim of ELSI programs is to "accompany" the development of nanotechnology. They proceed from a proactive attitude in stark contrast to the passive submission heralded by the motto of the 1933 Chicago World Fair - *science finds, industry applies, man conforms.* The integration of ethics in nano-research testifies to the death of the credo in the inexorable march of "technological progress".

However the ethics companion is not supposed to question the relevance of nanotechnological research and development. Ethics is confined in a very narrow space of freedom, clearly delineated by Jean-Pierre Dupuy (2008: ix).

> "What is to be done? It would be naive to believe in the possibility of a moratorium, or even, in the short term, a legislative or regulatory framework, which, in any case, would have to be worldwide. Such an approach would not stand a chance given the forces and dynamics in play. The best we can hope for is to accompany at the same pace and if possible to anticipate the onward march of nanotechnologies with impact studies and a permanent scrutiny no less interdisciplinary than the nanosciences themselves. A sort of real-time reflection on scientific and technological change would be a first in the history of humanity. The acceleration of the phenomena at issue would seem to make it inevitable".

Most initiatives in nanoethics seem to tacitly assume that the movement of technological innovation is inescapable since their unique concern is to prevent society to lag behind. The main objective is to catch up as suggested by the title of a famous paper - 'Mind the gap' -which called for the implementation of ELSI programmes (Mnyusiwalla et al. 2003: R9): "As the science leaps ahead, the ethics lags behind. There is danger of derailing NT [nanotechnology] if the study of ethical, legal, and social implications does not catch up with the speed of scientific development". Ethics is integral part of a global race where the ethical tortoise has to catch up with the innovative hare. Her ultimate achievement would be a "real-time reflection on scientific and technological change". Thus ethics is caught in the tempo imposed by the global competition for the leadership that technological innovations in nanotechnology is supposed to secure.

As pointed out by Alfred Nordmann (2010), the ELSI approach broke with the debates raised around the methods of technology assessment developed in the 1980s, concerning the right moment for a technology to be subjected to social control. In ELSI, the right moment is upstream, before the technology is disseminated or even proved feasible through anticipation of its potential consequences. To a certain extent, the efforts to anticipate the future impacts of technological innovations could be seen as a consequentialist approach to ethics. In practice however, it is essentially a prospective exercise focused on the potential consequences of the expected applications of today research. It is focused on potential risks or conflicts with the values of society as it is now. Ethical reflections are based on the promises made by the proponents of nanotechnology: promises of clean manufacture and cheap energy; promises of quantum computers or DNA information storage; promises of nano-implants that would repair tissues, control the body chemistry and enhance our performances. Far from being questioned or discredited, the economy of promises, which has been driving research efforts in nanotechnology over the past decade has been taken at face value by ELSI researchers. As a result ELSI programs delivered a list of a dozen of problems ranging from safety and security, privacy, human enhancement, intellectual property, global justice…The list has been widely circulated and quickly became a standard checklist for travelling safely along the roadmap set up by the proponents of the nano-initiative. However do we travel more safely with this checklist? It may generate an illusory sense of safety and control but it provides no clues about the practical measures needed to avoid potential adverse effects, especially non-intentional effects.

Furthermore the prospective exercise meant for preventing adverse consequences of nanotechnology applications has a perverse effect (Nordmann 2007, Nordmann and Rip 2009). By taking at face value the hype and hopes of the proponents of nanotechnology, the ethicists have endorsed the plausibility and feasibility of speculative and fantastic visions of the future.

> "The true and perfectly legitimate conditional 'if we ever were in the position to conquer the natural ageing process and become immortal, then we would face the question whether withholding immortality is tantamount to murder' becomes foreshortened to 'if you call into question that biomedical research can bring about immortality within some relevant period of time, you are complicit with murder' – no matter how remote the possibility that such research might suc-

ceed, we are morally obliged to support it". (Nordmann 2007:33)

Thus the ethical turn in nanotechnology assumes that our technological future is present and can be regulated or modulated. Given that the imagined futures are never questioned the ethical exercise basically boils down to generating preparedness and social acceptability.

3. *Responsible innovation and anthropocentrism*

In addition to aiming at anticipate potential adverse effects, nanoethics has been concerned with balancing the costs and benefits of the potential applications of nanoresearch. This approach certainly helped develop an attitude of prudence. But what kind of prudence is being encouraged? Is it the virtue described by Aristotle in *Nicomaechian Ethics* as a practical wisdom (*phronesis*)? Or is it the prudential attitude displayed by the managers of industry and business through the routine of costs/benefits analysis? The motto "responsible innovation" does not really encourage a virtue ethics. It rather pays attention to the values held by civil society and tries to avoid conflicts with widely shared values. According to a detailed report on responsible research and innovation to the European Commission three core values seem to emerge that can be memorized with 3 P's: people, planet and profit.

> "The ultimate gain of new technologies, to provide socially or environmentally beneficial solutions to intractable problems and drive the growth of European economies, sounds like a simple, laudable goal, but brings with it many dilemmas and difficulties. Responsible Research and Innovation, *as a process*, seeks to explore these dilemmas in a thoughtful, inclusive, though still practical way. Responsible Research and Innovation *as an outcome* seeks to generate the 'right' end points which benefit people, planet and profit." (Sutcliffe, Hilary (2011)

Responsible innovation is respectful of political, environmental and economical values. It is concerned with the "right end points", the applications that might come out from current Research & Development. Responsible scientists and engineers have to redesign nature for the sake of the three core values of our society. They have to secure the control of their technological productions, to anticipate the consequences of their actions. Responsible innovation thus appears as the ethical translation of the traditional anthropocentric doctrine, which celebrates humans as "lords and masters of nature". The human grandeur is a source of moral duties: *Noblesse oblige.* Such duties are based on the assumption that the future is in our hands and that objects of our design are entirely transparent and under control.

In this perspective, objects matter only for their potential impacts on society, on environment and economy. They are assimilated to their roles in economy and society as means for generating wealth, profit, employment, safety or security. It is an anthropocentric view of technological objects, even though the interests of society are mitigated with concerns for the planet conceived as our environment. Objects are never taken into account for themselves as artefacts.

This anthropocentric perspective on technology does not do justice to the intrinsic value of artefacts and to their active part in shaping the world we live in. As Gilbert Simondon argued, technical objects are more than entities created in the service of humans. They are defined by their operations rather than by their functions. In stark contrast to the usual utilitarian view of technical objects, Simondon insisted on their dual nature. Technical objects are "stable mixtures of the human and the natural" (Simondon 1989: 241). They are not only mediations between mankind and nature, they are inscriptions of human reality within the objective world. (Guchet: 2010) "While they are not living, they [technical objects] nevertheless crystallize some living action: the hours of human work consumed for producing them, and the effort of invention required for designing them". (Simondon 1960: 129) Simondon valued the technical performances of artefacts, their "technicity" as well as their cultural meaning and values. He deplored that in our society submitted to the logic of profit, only the market value and commercial success of technical objects matter. Both producers and users ignore the intrinsic value of the artefacts and consequently they treat machines as "slaves". (Bontems 2013) They buy them, use them and get rid of them when they no longer need them or want them. The current accelerated pace of innovation is based on the obsolescence of artefacts as servants in our power. Technical innovations are just means for making profit or objects for our consumption. For Simondon our society suffers not from an excess of technology but from a lack of respect for technology.

Both producers and users of attractive gadgets want to ignore that technical objects are individualities with a life of their own, and a special way to interact with their environment. They come into being for human purposes, but the results of technological design - the works in Hanah Arendt's terms - are enduring artefacts that survive beyond their uses. (Arendt 1958) Technical objects make up the world where they display capacities and material effects that were not anticipated by their designers. As we share the world with them, it is crucial to build a 'common world' instead of dumping our debris in a no-men's land.

4. *Dignifying nano-objects as partners*

The common attitude of disrespect for technical objects that Simondon deplored in the twentieth century is even more pronounced in nanotechnology because the products of design are hardly seen as things. Nano-objects are so tiny that they seem almost immaterial. They are so harnessed with functionalities that they seem to be the pure products of human design. The access to the nanoscale and the perspective of designing from bottom-up has refreshed an old dream: to get rid of the constraints of the material world, to emancipate human design from the limits imposed by matter to human inventions. The strong claim of "shaping the world atom by atom" used as the subtitle of the US National NanoInitiative launched in 2000, has framed nanotechnology in the familiar anthropocentric framework. It even reinforces the ideal of mastery over nature with repeated claims of controlling the properties and behaviour of artefacts "with atomic precision".

However it does not mean that nanoethics, as a reflective and normative activity, has to be shaped in such terms and to spread this anthropocentric view of the emerging technology. It is time to create a distance vis-à-vis the dominant anthropocentric view of nanotechnology and to explore an alternative approach to nanoethics that would give up the anthropocentric framework and refocus ethics on the world of objects.

This urge is not driven by a preference for alternative ethics such as biocentrism or eco-centrism. It is not a doctrinal choice. It is required by the very nature of this technology, which renders the modernist ideals of mastery and sovereignty over nature inadequate to the nanoworld. One major reason for initiating a "Copernican revolution" in naoethics is that nano-objects are special. Unlike Eric Drexler's description of a "molecular manufacture" in *Engines of Creation*, the nanoworld is not our familiar world simply shrunk to the nanometre scale. Nano-objects have specific and unusual properties and behaviours, which are the driving forces of research at the nanoscale and the *raison d'être* of nanotechnology. Because of the unusual ratio between bulk and surface the properties of nanomaterials depend more on their interfaces and interactions than on their inner structure. Nano-objects are mainly relational entities, which behave differently according to their neighbours and their environment. They spontaneously assemble into aggregates. They are able to move across all biological barriers. They interact with complex inorganic or organic milieus. For instance graphene is a star material worth of a European one billion program because of its amazing dispositions: It is stronger than diamond, and at the same time versatile and flexible ; it is also a transparent conductor, affording electrical and optical functionalities. Yet the promises of graphene are due to its extreme dimensions : a monolayer of carbon atoms. Such monolayers can be obtained by carefully peeling graphite with a sticky tape or growing pure graphene in a clean laboratory. But how to manufacture by the ton this extreme material while preserving its purity and functionalities?The rhetoric about control and atomic precision may be adequate for describing the behaviour of nano-objects designed in laboratory conditions, but in the outside world nano-objects are not fully predictable and extremely vulnerable.

In addition, as Drexler clearly acknowledged, for designing at the nanoscale engineers have to take inspiration for biology because biomaterials are built from bottom-up. However living organisms do not assemble functional building along assembly-lines like in a car factory. The "soft engineering" displayed in biological evolution displays mechanisms that have no equivalent in human design. (Jones 2004) Even in following the instructions of the genetic code, soft engineering relies on the floppiness of nanoscale structures, which allow molecular shape changes. It takes advantage of Brownian motion combined with surface forces to correct errors and to self-assemble the parts. Because no human machines or robots can operate at the nanoscale, self-assembly is a key process for designing nanostructures and has attracted a lot attention over the past decades among nanoscientists. (Whitesides 1995, Whitesides & Grzybowski 2005) Although self-assembly is not an obscure and mysterious vital force, there is no simple calculus for predicting a continuous variation of output. The designers do not have full control of the movements of individual molecules. Self-assembly relies on the instructions embedded in the material components themselves or resulting from their mutual relations. Matter is not the passive receptacle upon which information is imprinted from the outside. Molecules have inner dispositions, an intrinsic *dunamis* and they also display collective behaviours. Self-assembly or self-organization means that the designer delegates the task of building up to a "society" of interacting molecules. (Bensaude Vincent 2009)

Consequently designers at the nanoscale have to contract alliances with molecules. Such alliances are based on a specific relation to nature. Galileo's view of Nature as a set of inexorable laws indifferent to human projects and ends, (Hamou 2008) gives way to a view of nature as a bank of toolkits. Instead of trying to compose with nature's rigid mechanisms, nanoscientists are exploring all potentialities and taking advantage of what they find at the nanoscale. The basic blocks of matter - atoms and molecules - are reconceptualized as machines. The ultimate components of living cells - DNA, RNA, ribosomes, polymerases - are seen as exquisite devices that can be reengineered for technological purposes. In brief, nature affords opportunities for human design. It is a set of affordances. This term introduced by the psychologist James J. Gibson to develop an ecological theory of perception, refers to the possibilities of action that are offered to an agent by the environment. (Gibson 1979) [3] Nature offers cues for action in a specific environment that are exploited for performing specific tasks and achieving human goals.

Consequently the nano-objects designed by scientists and engineers are not entirely the products of their hands and brains, like a clock for instance. They combine – or rather they compose - generic dispositions with specific human purposes. As co-productions of nature and humans they have to be considered as full partners in technological projects. In this respect, they deserve a moral status close to that of domestic animals in farming. They are neither instruments nor slaves they belong to the house (the *oikos*, the world) and co-operate with their "masters".

Just as domestic animals need care and surveillance, nano-objects also require continuous attention because of their extreme dimensions and condition. In addition to being unpredictable because of their high potential for interactions, they are also extremely vulnerable because their properties depend on the complex apparatus and process of their manufacture. They have to be maintained and repaired. Although the affordances of the nanoscale are often presented as the promises of unlimited power for enabling and enhancing all kinds of technologies, nano-objects are difficult to handle. They will have to be labelled and continuously traced along their life-cycle, from the manufacture through the environment in their 'second life' as garbage.

In conclusion, responsible innovation in nanotechnology has been shaped as the anticipation of the potential impacts of the applications of nanotechnology. This prospective approach meant for preventing risks and adverse effects is no more than a form of managerial prudence. It does not take into account the specificity of nano-objects. Neither does it address the issue: how to interact with the nanoworld, how to build a common and habitable world with nano-objects?

It is therefore time to elaborate an ethics taking into account the specific relation of nano-designers with nature. Designing nano-objects is not just introducing functionalities in a passive support. It means seizing and taking advantage of the specific properties and spontaneity of matter at the nanoscale for assembling smart artefacts. Therefore the conventional image of the engineer assembling a machine according to an overall scheme is not really adequate. As designing at the nanoscale requires negotiation with molecules,

[3] The term 'affordance' is also used in design theory to refer to the 'cues for action' offered by things in a specific environment (Norman, 1990) and in epistemology to refer to complex world-apparatus (Harré, 2003)

nano-engineering is neither the inscription of human intentions or projects on a passive matter nor the construction of a building, bricks by bricks, *partes extra partes*. It is better understood as contracting alliances with active molecules. The standard portrait of *homo faber* is not adequate. Nano-engineers are more like pilots (or hackers) of spontaneous processes occurring at the nanoscale. And like pilots at sea, they not only have to know that all journeys involve a good deal of uncertainties but they also have to take care of their ship as the partner in their adventures.

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