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Nanotechnology and Ethics: Assessing the Unforeseeable

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1. Introduction

Nanotechnology is not in consensus. The attempts to answer the question "what is nanotechnology?" are usually inaccurate, and the responses to it, far from being unanimous. There has always been controversy, from defining its conception to establishing the limits of the so-called nanoscience subject, as well as its effects and viability. One of the few points of consensus among scientists is that manipulation of materials at the atomic level may unfold new properties.

The emerging nanotechnology brings great excitement due to its technological potential. In order to analyze its possible ethical implications, the task of starting from the beginning, of introducing the theme from the concept of the object of study itself, imposes the first and fundamental obstacle for those who intend to reflect about the ethical approach of nanoscience and nanotechnology.

This initial challenge comes from the differences found between what each group that uses the term nanotechnology intends to mean. The objects of study, nanoscience and nanotechnology do not seem to be consensually organized. In general, researchers and scientists tend to describe nanotechnology from a perspective of their own activities (Petersen & Anderson, 2007).

The prefix nano, derived from the Greek "dwarf", refers to the tiny size of the particles. In scientific terms, it means a part per billion; therefore, a nanometer (nm) corresponds to a billionth of a meter (10^{-9}). To illustrate the reduced scale in which nanotechnology works, the smallest point seen by a human naked eye is about 10,000 nm, while 1 nanometer corresponds to 10 times the diameter of a hydrogen atom (Medeiros et al., 2006).

Under such perspective, it is possible to understand nanoscience as the field of knowledge that studies the fundamental principles of molecules and structures (sized between 1 to 10 nanometers in at least one dimension) called nanostructures. Nanotechnology, in turn, is the application of these nanostructures in functional nanoscale devices.

However, even according to the official definitions by the National Science Foundation (2000), nanotechnology does not have a clear concept. The NSF defines it as the research and technology developed from new properties as a result of matter manipulation on a nanoscale level – between 1 and 100 nm. However, the same properties can be occasionally found in dimensions below 1 nm and above 100 nm.

Nowadays, the manipulation of objects and devices on that scale is common to almost all new fields of experimental science. The difficulty in establishing what is and what is not nanotechnology has important epistemological and ethical consequences (Ferrari, 2010). The ambiguous nature of such concept results in laboratories claiming that their researches must be added the prefix "nano", along with all resources and prestige it brings. The undefined limits of this new techno-scientific movement influence the debate on its potential and its consequences.

Nanotechnology is expected to advance almost all current technological industry branches such as. Literature approaches an expectation of progress in computer science, micro and nanoelectronics, cosmetic and textile industry, energy production and storage, telecommunications, chemical and petrochemical industries, agriculture and agribusiness, automobile industry, aeronautics and, of course, arms industry (Invernizzi, 2008).

As far as healthcare is concerned, nanotechnology shows one of its most promising announcing revolutionary scientific and technological progress that might deeply affect the way we deal with health and medicine in the near future. In the new field of nanomedicine, devices and nanostructured materials are expected to be applied to monitor, repair, build and control human biological systems (Sahoo et al., 2007). There are countless possibilities: controlled release of therapeutic agents, production of active ingredients, medical imaging, lab diagnoses, biomaterial production and implants, and more (Wagner et al., 2006).

The great promises in nanotechnology are not new. The fact that many laboratories are investing more and more in research shows more than a resemblance between nanotechnology and the latest great advances in biotechnology.

Before the promising scientific advances and their impacts come, major social groups have not waited to express their positions on nanotechnology and society. The media, scientists, policymakers and sectors of society have promptly set out their stances, with the justification that scientific changes require urgency in decision-making. A hasty scenario of extreme positions has been set up. However, the shape of this innovation demands balanced reflection rather than taking unconditional sides on the use or ban of nanotechnology, or definitively halting it, or waiting for it to eventually happen. At this initial stage, therefore, it is opportune to propose a prior discussion that is broader than foreknowledge and assessment of the unforeseeable beneficial effects or risks.

As the establishment of the topics for discussion already seems to be difficult strategies other than discussing risks that cannot be fully foreseen and assessed are strongly suggested. This is how this topic will be brought up and developed here.

The first challenge regards the different appropriations of vocabulary and the diversity of devices and techniques used in the various fields of research. This leads to the notion that nanotechnology is not a single entity to which a single value judgment can be attributed. Actually, one should consider not one, but many nanotechnologies. Thus, it would be extremely difficult and also inappropriate to propose a comprehensive stance for all the fields and products involved.

In different scenarios, the term "nanotechnology" can have a different interpretation, eventually being used for different objectives, leading to different consequences. There are some who even question the innovative nature of nanotechnology , grouping it with other fields of biotechnology. This attitude may diminish the hype around this so-called innovation; however, it also points to the need to analyze the various objectives and definitions upon which the debate is based (Ferrari, 2010).

Consequently, instead of mainly establishing concepts and discussing the possible risks related to the use of nanotechnology products, this is a longer and not so explored path.

First of all, there are some important reference points regarding this scientific phenomenon to be defined. Also, innovations in relation to previous biotechnological-scientific advances must be identified, and the degree to which they demand specific debate on their ethics must be assessed.

2. What is new?

In at least one respect, nanotechnology represents something fairly new among technical-scientific revolutions: the ethical implications of its possible discoveries have become a cause for concern even before the discoveries themselves have been made. Indeed, more than the technological advances themselves, what is most innovative in nanotechnology is the very discussion of its ethics, which is taking place at the same time as or before the scientific events on which it focuses. Long before scientists could explore the manipulation and shaping of compounds at atomic and molecular levels, it was the expectation of the transformation of our relationship with the world, of delving so deeply into the structure of matter, which motivated the visionary Feynman (1961) in the first references to the theme. Possible repercussions precede and obscure the actual facts. Debates regarding the possible transformation of the world, and of humans into post-humans, take place before the basic science has been established. Apocalyptic scenarios are depicted even before methods and procedures for nanotechnology can be clearly established (admittedly, this is not unlike some genetics).

Therefore, according to Schummer (2007), the technological exploration of nanoscale properties is not the real innovation. He states that the innovative aspect lies in how nanotechnology and the way it is depicted reflect the connections between society, science and technology. This innovation affects pre-established boundaries between living and non-living things, the natural and the artificial.

It is significant that a debate on ethical implications is taking place before the scientific advances themselves have actually taken place. An ethical approach, rather than an attempt to explore science fiction, could perhaps state that nanoscience, its structures and scientific approaches, represent a characteristic rupture between new paradigms and the classical scientific model.

Innovations frequently disrupt established moral standpoints, bringing discomfort or a conflict between customs and the new reality that is imposed, and requiring further discussion. Moreover, dealing with novelty brings, to some degree, an urge to explore the paths of the unknown which cannot easily be foreseen (Swierstra & Rip, 2007).

In the case of nanotechnology it is characterized not by the size of the particles it deals with but by the new and unknown chemical and physical properties that derive from their size (Ratner & Ratner, 2003). The great attraction of working on a nanoscale lies in new and unusual physical and chemical properties that are not found in the same materials at micro and macroscopic dimensions. It is therefore unrealistic to expect to know all the possibilities for their use and to foresee their consequences. The specific characteristics of the nanometric dimension diverge from the physicochemical laws that determine the behavior of materials at "normal" macroscopic scales.

3. The scientific paradigm and its implications

Given that nanoscience is based on the diverse and unpredicted behaviour of materials manipulated on a nanoscale, the unknown and the unforeseen are central to it. Scientific knowledge, insufficient in itself to provide moral solutions, is also revealed to be incapable of providing sufficiently reliable information to enable proper reflection on the health-related, ecological, ethical and social impacts of nanotechnology.

The literature on nanotechnology and ethics is incipient in comparison with what has been produced internationally regarding its techno-scientific aspects. However, it is noticeable that the ethical implications that have been identified, and the solutions that have been proposed, vary in accordance with the writer's individual perspective on scientific activity.

There is a tendency for scientists to have an inward-looking perspective that describes scientific activity on the basis of its methods and technical results, in this case producing what one might call a scientific image of nanotechnology. The ethical discourse arising from this image emphasizes ethical implications closely connected to the direct consequences of the applications of nanotechnology.

With regard to practical questions regarding health and the expected use of nanomedicine, the ethical issues arising from the applications of nanotechnology are too numerous and complex to be addressed satisfactorily by scientists alone.

If, in the past, the analysis by scientists of ethical issues surrounding technological advances proved to be limited, and sometimes biased, a new science that reveals epistemological ruptures with the fundamental scientific characteristics of reproduction and predictability would appear to present an even more complex subject for analysis.

Another factor to be taken into consideration is that much of the scientific media defines nanoscience not on the basis of its conceptual reference points or properties but in raltion to expectations surrounding its applications. Nanoscience essentially becomes the expectations that are placed upon it, the things it is deemed to promise. This discourse becomes an apology for scientific progress, instead clarifying any specific aspect of nanotechnology (Swierstra & Rip, 2007). Made the object either of huge optimism or huge pessimism, nanotechnology is depicted either as the future solution to world health problems or the future cause of a great ecological disaster. From such a perspective a sensible assessment is impossible.

A new ethical approach is necessary; an approach that uses the language of this new scientific paradigm. It is especially important to know how to engage in dialogue about a science based on the unforeseeable and the unknown.

This ethical debate on nanotechnology highlights the oscillation between the consequentialist and deontological approach, well known in bioethics. The relevance of the consequentialist approach is clear, due to the central role of risk analysis of nanoparticles in this debate (Ferrari, 2010). This is completely understandable since this kind of analysis is necessary in order to guide political and ethical regulation, but it needs to be based on scientific evidence, which is especially problematic in nanotechnology (Shrader-Frechette K, 2007). The discourses on risks become important, partly because current mechanisms for regulation and control are insufficient, sometimes even inadequate, to address the uncertain, unpredictable aspects of this field (Grunwald, 2005).

Those who intend to establish their ethical approach only by studying impacts and detailed risk analyses based on thorough knowledge of technical possibilities, find themselves thwarted. Such failure occurs primarily because scientists' parameters for risks diverge from the perception of such risks within society (Slovic, 1987). The public perception is that biotechnological advances bring unknown risks that may take time to become apparent or may not be fully observable. It is generally opposed to the scientific discourse based on calculations of risks and benefits. But such calculation is not yet possible (and might never be), as the risks and benefits are not yet well known (Savadori et al., 2004). The principle of precaution is frequently presented as a solution to the difficulty of predicting the direction of scientific development. It is seen as a guideline for decisions under uncertain conditions. It is assumed that negative effects are known, but it is impossible to measure risks due to a lack of data (Ferrari, 2010).

Not only is it impossible to measure the risks presented by nanotechnology but even its effects are unpredictable. This is because nanotechnology involves a new epistemic scenario, the inherent basis of which is uncertainty and ignorance (Stirling, 2007). Decision making in nanotechnology, therefore, is additionally complex because of its epistemic nature, as well as other factors such as the wide variety of its applications (Rip, 2006). Consequently, the precautions taken against unknown risks are not successful in practical life and its interactions with the market. The parameters of the analysis therefore need to be revised. The subject has to be analyzed on an interdisciplinary basis, taking into consideration the complexity of the relationships between many levels of reality, and thus encompassing both scientific and social phenomena (Victoriano, 2006). An increasing number of authors criticize risk analysis as the only approach in debates on the ethics of nanotechnology. They suggest that ethical reflections should go beyond risks and benefits to also address the way science is performed, including its objectives and methods. These would be more complete approaches, taking into account issues such as intellectual property, public opinion, and future generations (Ferrari, 2010).

In recent years, especially in Europe, there has been an increasing number of initiatives calling for a more representative inclusion of public opinion in debates on the control and management of new technologies. This movement grew stronger in the wake of negative reactions to foods derived from genetically modified organisms. Such initiatives aim to re-establish trust in science, establish political innovations, avoid adverse reactions, democratize the governance of new technologies, and promote more responsible, reliable scientific practices. However, public engagement can be hampered by many factors: a lack of awareness of what nanotechnology really entails; the future-oriented and promissory character of nanotechnology, which gives a special role to science fiction in shaping the moral imagination of nanoscientists and nanotechnology policy itself; and the very strangeness of nanotechnology in relation to daily life, introducing a dimension that is not well be understood or even perceived. In addition, the conceptions or discourses that guide and define the development of nanotech science, though crucial, vary between the many branches of nanotechnology and different cultural scenarios. Such disharmony makes it necessary to analyze those discourses with the aim of making possible genuine public participation. (Macnaghten, 2010).

An ethical approach, therefore, would mean that nanotechnology is part of a cultural scenario, simultaneously defining and being defined by it. In this way the issue of the different perceptions of the sciences, and the discourses and expectations that surround them, take on great importance, since the way the future is described influences the way it turns out to be. The ethical approach, therefore, needs to be applied to other levels, overcoming precaution and the search for consequences in order to understand science as a thorough phenomenon, in all scientific, cultural, economic and political dimensions (Dupuy & Grinbaum, 2004). Reductionism is no longer acceptable.

One of the possibilities is to understand nanoscience and nanotechnology, with their promising results and unforeseen risks, within a broader context, such as a practical segment of a new scientific paradigm based on its ability to control and manipulate matter at atomic and molecular scales (Kearnes & Macnaghten, 2006).

Kuhn (1962), in The Structure of Scientific Revolutions, described the evolution of modern science and defined scientific paradigms as the successive models on which scientific theories were based. Normal science would mean research based on scientific accomplishments recognized, for a while, as the basis for subsequent practice. Normal science, therefore, would be based on paradigms, i.e. models that structure and order the current stock of scientific knowledge, thereby determining the methods and subjects for study. Paradigms are therefore the basis of normal science, which is generally developed to state and confirm common theories and concepts among scientists.

In the case of the broad field of nanoscience, the paradigm previously applied was known as Newtonian Mechanics. It originated from the Cartesian hypothesis, which in some aspects it advanced and completed, and describes the interactions of macroscopic bodies. The scientific revolution from which the next paradigm will emerge may be structured from current normal science. Therefore normal research, following the Cartesian scientific model for analysis, study and synthesis, has influenced the study of bodies and interactions. The attempts to apply the current paradigm to miniaturization may have brought about its very specific crisis.

The attempts to verify a theoretical paradigm, i.e. the ultimate goal of 'normal science', have detected imperfections and incoherence between theory and phenomena (Kuhn, 1962). The search for the ultimate explanation of the universal law that governs all bodies in their smallest units is halted due to its great divergence from the macroscopic world. At the atomic or molecular level, the laws governing interactions are related to the wave nature of electrons and the frequency and wavelength of their vibrations. Unlike the phenomena predicted by classic scientific theory, the concern of quantum physics is the observation of behavior on a nanometric scale (Ratner & Ratner, 2003).

The appropriation of the scientific paradigm extends beyond the changing of the physical science paradigm. Nanotechnology represents the "convergence of quantum physics, molecular biology, computing science, chemistry and engineering" (Mehta, 2002), and therefore differs from Cartesian scientific knowledge. Whereas the latter seeks specialization, nanotechnology results from a convergence of interdisciplinary concepts, allowing interactions between methods, applications and theoretical foundations in different fields of expertise (Garrafa, 2006).

Such a scenario is close to the current complex scientific paradigms in which interactions transcend conventional divisions between sciences, humanities and biomedicine. Nanoscience thus diverges from the scientific method in which the production of knowledge is based on analysis. Such object-oriented analysis, within scientific practice, has resulted in a disconnection between human sciences and natural sciences (Morin, 1988).

Morin (1988) stated that such a disconnection made it impossible to observe the complex nature of the world, reducing reality to "mathematized" rules and laws that would appear to explain the world perfectly by ignoring unforeseen events or facing them as errors. Reality was seen as the sum of observable phenomena, not taking into consideration the possible overlaps between science and philosophy or between human and biological sciences (Morin, 2008).

Starting from a perception of realities in their full complexity, new technology and a new scientific paradigm have practical implications which go beyond the limits of their original subjects. This complex thinking is illustrated as a network that seeks to analyze the possible interactions between many levels of reality and the repercussions of events. Also, this new thinking includes an awareness that unforeseen events are characteristic of the phenomena; they are not just the result of errors, and are not to be disregarded (Morin, 1988).

From the viewpoint of complexity, the rupture between ecology and sociology, in which scientific analysis has as its object the environment without man and man outside his environment, is artificial and ethnocentric. An analysis of the possible consequences of nanotechnology should, therefore, avoid disconnecting these dimensions (Victoriano, 2006). This is vitally important for a proper analysis of the actual influences and the distribution of social benefits brought about by the minimization of energy and materials required in the nanotechnology industry (Schnaiberg, 2006).

New paradigms generally emerge as more suitable responses to questions unanswered by previous paradigms. They enable scientists to explain a greater number of phenomena or to increase the accuracy of their existing explanations. For this reason the application of new technologies may be controversial, because they might seem to offer a theoretical solution to the world's problems, and because they unveil a set of unknown phenomena that might be greeted with disbelief or sometimes even panic (Kuhn, 1962).

Nanotechnology is paradigmatic in this sense. Sometimes it is portrayed as a revolutionary technology that will change the way we live through its effects on industry, communications and information technology. It would appear to expand the boundaries of medicine, promising less invasive, more effective surgery, more specific medications, treatments for incurable diseases such as cancer, and even the possibility of improvements in cognition and memory processes (Freitas, 2005).

On the other hand, the current lack of knowledge regarding the potential scope of nanotechnology provokes extreme reactions that tend to emphasize environmental risks and profound transformations in our way of life. One example is the debate on the so-called "grey goo", a scenario where self-replicating nanoscale devices called nanobots would rule the world. Out of human control, they would eventually eliminate our species from the planet (Drexler, 2004).

The advances within nanotechnology have led to debates on the ethical implications of its applications. The ethical issues discussed have included equity, benefit distribution, access to scientific advances, environmental impact (the use of new materials, and of new properties of previously-known materials, might make them insoluble or turn them into pollutants), implications for privacy and security (invisible surveillance equipment, and infinite possibilities for the arms industry), modification of the constitution of living entities (genetically modified organisms), and self-replicating devices (Salvarezza, 2003).

In its methods and in the way it is conceived, managed and practiced, the new scientific paradigm of nanotechnology represents a rupture with the existing scientific model. The current academic scientific model, conceived in 18th-century Europe, especially in French and German universities, has been undergoing profound transformations. Post-academic science shares the objectives of the previous model – the production of knowledge in accordance with epistemic norms, scientific laws, and values – and yet differs from it in at least three aspects: how knowledge is produced (focusing on transdisciplinarity); how knowledge is assessed (for its economic potentials); and the great emphasis on the application of that knowledge, or in other words, the fact that knowledge is produced so as to serve certain technological purposes (Jotterand, 2005).

The common perception of nanotechnology as a revolution is therefore understandable. Nanotechnology not only entails epistemic rupture, as did the other scientific revolutions before it, but introduces new laws and structures of knowledge, or new cognitive categories. Changing the way categories are explained brings changes to the way we experience the world.

Nanotechnology, however, is more than a scientific revolution; it is probably a techno-scientific revolution, because it focuses not on the properties of matter but on its manipulation and transformation.

Therefore, in a way that is quite revolutionary, neither the concept of science nor the concept of technology can perfectly describe the know-how of nanotechnology. Nordmann (2004) states that nanoscience is not structured from a topic but set to a goal. It is not aimed at manifestations of nature, machines, or substances with new properties. Its epistemic effectiveness is not measured based on its devices and the functions of substances. Actually, nanoscience is an attempt to explore an inhospitable territory and to colonize a new world, or an as-yet unexplored area of the world. Epistemic success is now a technical accomplishment; the ability to act in nanoscale scenarios, to see, to move things, to carve a word in a molecule. This means that nanoscience is not traditional "science" per se, and that there is no distinction between its theoretical manifestation and its technical intervention, or between the understanding of nature and its transformation. From now on, therefore, it would be more appropriate for the debate to be focused on nanotechnoscience.

This particular scenario of technoscientific revolution does not only establish nanotechnology’s scientific and technological development, but also influences the development of moral reflections on the social and ethical implications of nanotechnology. The technoscientific revolution brought about by nanotechnoscience is a broader post-academic scientific movement in which science, technology, politics and economics have convergent social purposes. These relationships allow greater integration between ethical and philosophical reflections and scientific practice within the post-academic context, due to its cross-disciplinary nature and to the increasing political and social pressure on the process of scientific knowledge production (Jotterand, 2005).

Sotolongo (2006) pointed out two important ethical issues that require closer attention, both relate to the current type of science exemplified in nanoscience. First, due to humans’ great capacity to intervene in natural phenomena, and unprecedented capacity to interact with and manipulate matter and energy, our physical and intellectual abilities can be enhanced through autonomous integrated systems. The closer science comes to controlling environmental conditions, the closer it gets to potential powers of destruction. The second issue is the huge extent of the knowledge acquired, which makes it impossible to identify all the possible uses and practical interactions of the resulting technologies. As far as natural and social complexity is concerned, not all the practical implications can be known, predicted or manipulated: on the contrary, there is an inherent uncertainty in the implications.

Although many adverse results can be expected in relation to nanotechnology, not restricted to the immediate threat of nanotoxicity to humans, it is a cause for concern that so few studies of its ethical, environmental, political and social implications have been carried out. Even though there was reflection on its potential impacts before nanotechnology entered scientific practice, the fast growth of research in its technical and scientific aspects over recent years contrasts with the lack of investment and scientific production with regard to its ethical and social aspects. Indeed, there has been an increasing distance between the expanding technical-scientific knowledge and the required socio-political and philosophical reflections (Mnyusiwalla et al., 2003).

The convergence of effort and investment in the technical fields is clearly related to the social representation of science: the cultural phenomenon in which interpretive science, which seeks meanings, loses out to empirical science, which seeks laws and rules (Franklin, 1995).

Faced with the innovation and the amount of challenges posed by the ethical debate on nanotechnology, there are those who propose nanoethics, a subject that would be devoted exclusively to the analysis of these challenges. However, immediate questions arise about whether an area of ethical study devoted exclusively to nanotechnology is really necessary. Consequently, comparisons between bioethics and nanoethics are frequently made. Nanotechnology does not demand a genuinely new ethical approach but instead an approach that is different and renewed in relation repertoire of the previous ones. Therefore, instead of declaring that these questions have already been asked and that there is nothing new in nanotechnology, it can be pointed out that if the questions are the same ones as before, it is because they have not yet been answered. It is worthwhile to pose those same questions again, for they might help to elucidate the phenomenon (Khushf, 2007).

The same answers and methods that did not completely illustrate the analyzed phenomenon are dispensable, therefore, but not the ethical concern itself. As previously suggested, the development of nanotechnology casts doubt on whether risk assessments and other analyses that are commonly used will nowadays suffice when it comes to evaluating nanotechnology. Although traditional ethical approaches can be appropriate for some subjects, nanotechnoscience has social and ethical implications of such magnitude that it necessitates the development of alternative approaches that can provide conditions for the development of nanotechnology (Meaney, 2006).

Therefore, whether proceeding from the perspective of nanoethics or from that of other disciplines, the discussion regarding the ethical implications of nanotechnology reveals that the questions do not arise only from within the social sciences: the scientists start to question their own practices.

Despite manifesting this initial interest in reflecting upon their practices, the discourses of natural science and social sciences are not the same. This is due especially to two factors. First, following the events of World War II, scientists acquired a greater sensitivity to their technological impacts. This sensibility focuses mainly on the impact of devices, concentrating concerns on environmental and health issues. Another factor that sets their discourses apart is the different readership for natural science articles when compared with the social sciences and humanities.

4. Some ethical approaches: A typology

The purpose of setting the scenario in which nanotechnology has been established is to show how the concepts of nanotechnology and the corresponding moral considerations of the different actors, including scientists, are heterogeneous. The proposed approach, therefore, starts from this initial effort to identify the concepts, their origins and their effects (Kaiser, 2006).

Aiming to avoid the dualism that is so prevalent nowadays, Kaiser (2006) suggested that the strategy for avoiding utopia or dystopia in the debate was to adopt an observational stance, rather than viewing ethics from a participative perspective. According to him, it would not be necessary to define nanotechnology, given its uncertain and unpredictable nature, in order to conduct a debate on it. The strategy suggested would be to stand back from the topic and observe the scenario within which the actors construct their perspectives on and concepts of nanotechnology, in order, to guide the ethical analysis.

Grunwald (2005), for instance, argues that the innovative character of nanotechnology is being overestimated and that the ethical analysis should focus on the various representations that underlie the discussion. It is not the nanoscale and its processes that have ethical and social consequences. Ethical reflection should embrace science as part of human relationships, with their images, significances and expectations.

Accordingly, to understand technologies in order to develop an appropriate ethical approach, it is necessary to have explored in detail the universe of visions, images, ideas and representations of nature, and of the human being embedded in the discussion (Ferrari, 2010). This perspective relates to the argument of the philosopher Karl Popper, who states that every scientific theory is based on a set of values and world views. Roughly speaking, those world views make up what he calls a Metaphysical Research Program. They are not susceptible to direct empirical testing and are not falsifiable, and do not properly constitute scientific knowledge, but they determine which problems, investigation methods and solutions are considered scientifically (Popper, 2009).

Dupuy (2006) states that in nanotechnology, as in other convergence technologies, the Metaphysical Research Program is characterized by a lack of distinction between knowing and doing. Such similarity, which seems to reach its peak in nanotechnology, is illustrated precisely by the instruments that make it technically possible.

In 1981, the Scanning Tunneling Microscope was developed. Through a very thin tip and a voltage bias, it allowed atomic dimensions and dispositions to be analyzed, and it was later discovered that this same instrument, with a small modification, was capable of manipulating and repositioning atoms very accurately (Cao, 2006).

Dupuy (2006) argues that the Metaphysical Research Program goes beyond this very explanatory metaphor of the microscope. Nanotechnology would make possible the engineering of evolution, enabling man to be the designer in the production of life. According to Dupuy, a project of such magnitude could not be analyzed using pre-established ethical doctrines. A new ethical challenge requires a meticulous exercise of unveiling the conceptions, ideas and images on which the scientific theory is based, so as to then proceed to a critical analysis or a normative judgment of the technological progress.

In reply to the question "what is science?" different answers are given, but all of them are always set in a certain context. The different forms of interpreting this question give birth to at least two different images of science.

Dealing with different representations of science, Olivé (2006) stated that both the “scientific image” and the “philosophical image” of science are derived from the question “What is science?”. While the “scientific image” is usually the way in which scientists describe their own activities, the “philosophical image” seeks to characterize scientific production within the contexts provided.

The “scientific image” is to describes scientific facts and elucidates the rules governing patterns, without concern for the social criticism of its own process of knowledge construction (Franklin, 1995). The “philosophical image” studies the history, sociology and philosophy of science and relates scientific activities to social practices and institutions, to the conditions for the development of science, and to the mutual repercussions of society and science (Olivé, 2006).

It is not specifically the dimension of the nanoparticles, therefore, that is important for studies and consequent debates on the interactions between technology and society. The analysis depends on the views of nanotechnology held by the different actors. What matters is the transformation after human interference, and not the nanometric dimension in itself, given that such a dimension is found in nature regardless of the intervention by human devices. It is emphasized, however, that no intrinsic moral value is derived from human intervention. Whether or not one carbon compound is nanostructured does not make it ethically superior to another. It is in the relations between men, in society, and as part of the natural environment, that the products and their uses will be revealed as more or less adequate.

Some of the ethical implications therefore seem to be clearly demonstrated, such as in the example of a compound that is toxic or pollutes. Other ethical challenges become clear only within complex social interactions, such as the repercussions for the global economy and the social inequality resulting from the introduction and appropriation of nanotechnologies by the market.

Assuming that the ethical approach towards nanotechnology starts from the paradigmatic unpredictability of this technical-scientific phenomenon, a schematic consideration of the possible questions is put forward here. The dilemmas resulting from the interaction between a new scientific paradigm and the complex overall social dynamics, together with the image of nanoscience on which the ethical perspective is based, produce a classification scheme for the implications of nanotechnology that has two categories: autogenous (internal) and heterogeneous (external) (Pyrrho, 2008).

4.1 Autogenous ethical implications

Nanotechnologies are characteristically improvement technologies, which is to say that like many convergence technologies, they refine and improve tools and materials that will be used in other fields. They not only change the existing components and devices but also develop new ones. This is the aspect most closely related to scientifically observable consequences, which sometimes have considerable implications. Although nanoparticles are not present-day inventions, the capacity to structure them systematically for the industrial exploitation of their properties is certainly new. Products developed this way for sporting, nutritive, automotive, cosmetic, information technological and many other purposes are now available on the market. This production on an industrial scale is critical because it may cause significant damage to the environment, to workers, and to the large populations that are eager for technological goods.

The partial lack of knowledge about the properties of the materials goes together with the way in which the national and international regulatory bodies lag behind: the regulations take the chemical composition of the components into account but not their conformation. For example, it is possible for a new nanostructured component to arrive on the pharmaceutical market without undergoing new toxicity tests, even though the reactions within the organism may be completely different.

Such developments are usually accompanied by biased arguments characterized by an assumption that the application of nanotechnology is inevitable, a fascination regarding its implementation, and a reduction of the ethical debate to the analysis of toxicological and environmental risks. The perspective of those making such arguments is that the benefits from research are usually derived more or less automatically, that any negative effects can be attributed to mistakes on the part of others, and that it is impossible to predict how technology will be used once it has been developed (Ferrari, 2010). This perspective clearly attributes moral neutrality to science. Risks and negative effects are external to the scientific activity, so it cannot be responsible for them. This view also produces a common perspective in bioethical discourse – the search for technical solutions for moral problems.

According to Schummer (2004), three different understandings of the "social and ethical implications of nanotechnology" stand out among scientists. Computer sciences researchers associate these implications with radical changes in society, in which everything is possible with software programming. Natural science researchers seem to hold a more modest but still visionary position about industrial revolutions and other deep changes, as in biomedical practices that related to nanotechnology. For toxicologists and environmentalists, meanwhile, the ethical and social implications represent risks for health and for the environment.

Despite the common ignorance regarding nanotechnology and its risks, the scientific image seems to result in a positive perspective on the impacts of nanotechnology. In another study, based on interviews with researchers, many of the interviewees emphasized the difficulty in analyzing the risks due to the lack of research and knowledge regarding important aspects of the nanomaterials. They pointed out difficulties in foreseeing the behavior of the particles in certain environments, the little investment in risk analyses, and uncertainty regarding current methods of risk analysis for the nanoparticles. They described nanoscience as currently going through a latency period between the introduction of the technologies and the evaluation of the adverse effects. They still took the view, however, that nanotechnology is positive for society (Petersen & Anderson, 2007).

The autogenous ethical implications were not highlighted because of an understanding that they are intrinsic to nanotechnology. Such a view could erroneously put value on the applications of this technology. The implications are considered autogenous as they are associated with a causal effect. These are implications that are conceptualized within the technical perspective. They generally result from the application of such approaches, without complex analysis of interference from other factors. They are the repercussions that are most frequently mentioned in debates since they are close to the predominant ethical model of science, which is usually limited to assessing the impact of products and devices on the environment and on health. However, at the point where such use seems to present risks that are more measurable and analyzable, it has to be ensured that the same technology that enables it is capable of supplying instruments that are sufficiently accurate to assess any failures and to propose solutions (Pyrrho, 2008).

4.2 Heterogenous ethical implications

The term heterogeneous refers to the fact that studies on nanotechnological devices and their implications are conceived through different "images" of science. While the devices result from the "scientific image", the social understanding of their use relates to a "meta-scientific" perspective on nanotechnology.

The possible repercussions from the use of nanotechnology that are dealt with here arise from interfaces of various cultural, social, economic, environmental and political dimensions. They are heterogeneous because they result from complex interactions and not from evaluations performed by science itself. They require an ethical assessment that diverges from the search for cause-effect relationships and consequent linear risk analyses (Pyrrho, 2008).

Expectations of technical solutions for social problems, such as the prospect that some of the main applications of nanotechnology could make it easier to achieve the United Nations Development Targets through energy production and increased agricultural productivity (Salamanca-Buentello et al., 2005), have raised environmental, political, economic and public health questions that, due to their mutual implications, trigger a discussion that does not deal in simple solutions.

There is quite a widespread understanding that nanotechnology represents a technological revolution that poses new challenges for traditional understandings about science and knowledge acquisition, its intrinsically unpredictable character serving to question the role of science in searching for truth. The new facets that science has been acquiring are dictated strongly by the avidity of the market for technology. This process through which science is transformed into techno-science is followed by reconfigurations of economic power, and consequently also of political power. This politicization of science, and of nanotechnology specifically, which represents the convergence of science, technology, politics and economy for social and government purposes, offers the possibility of a better integration of ethical and philosophical reflections with scientific and technological development (Jotterand, 2006).

This type of analysis emphasizes nanotechnology as a social-technical system and the cultural values infused in the technologies. The social scientists and ethical consultants who devote themselves to the study of nanotechnology can therefore influence nanotechnology, together with other actors. As a consequence, when understanding nanotechnology as an emerging technology, it is important to address the systems/networks of people and things. While the technology is being developed, the distribution of power and authority is being built, meanings are being contested and consolidated, and social practices involving rights and responsibilities are being established. These social arrangements are a subject that should be examined in the light of ethics, using ethical concepts, language, principles, norms and theories (Johnson, 2007).

In the philosophical image of nanotechnology there is a predominant criticism of the so-called nanohype and of the dualist and reductionist discussion to which it has led. The dystopian and utopian visions frequently provoke extreme reactions: the former frequently produce widespread rejection while the latter often lead to eventual disappointment at the gap between expectations and reality, as in the case of genetically modified organisms. There is a strong suggestion that social engagement take place in an effective way and not only as a form of avoiding public non-acceptance.

Although some heterogeneous ethical implications such as social control, intellectual property, the knowledge economy and social (in)justice have not attracted media or public attention in the way that cinematographic cyborgs and promised panaceas have done, the implications that are often forgotten are the ones that portray the most tangible and important dimensions for an analysis of ethics in nanotechnology.

While recognizing the possibility of problems in classification, the categories proposed here can highlight possibilities for evaluating risks resulting from nanotechnology and the complex interdependencies that are socially related. The categories point towards social dynamics as the locus where diverse ethical reflections and public debates are increasingly necessary.

5. Conclusion

The challenging character of nanotechnology is illustrated by its cross-disciplinary nature and the impossibility of ascertaining all of its applications and implications. Even the theoretical foundations of nanoscience are based on these innovative features. The unfeasibility of attaining this overall knowledge of nanotechnology, and the unpredictability inherent in the properties it explores, are responsible not only for the emergence of new ethical challenges but also for the need for a diverse approach.

It is clear that there can be a distinction between traditional ethics, which seeks answers to questions already posed, and a conception that attempts ethical reflections regarding the possible moral implications of the application of this new technology. This difference, together with an understanding of the complexity of reality, indicates that there is a need for an innovative kind of analysis. Therefore, to debate and eventually come up with moral answers regarding nanotechnology, it is necessary to have a perspective with a sufficiently dynamic basis that is not limited to a strictly codified ethics.

The approach needed to analyze an emerging technology is one that considers not only the complexity of reality as a whole but also specific moral questions of a given socio-cultural context. Consequently, the ethical values required are no longer those that are based epistemologically on principles that lack both a sufficiently stratified theoretical basis and applicability in complex contexts. They must not be based on accumulated segmented scientific knowledge but on knowledge (of the facts) that considers complexity. From this it is may be possible to generate normative implications that are applicable to a moral dialogue that is guided by tolerance to differences and may also point toward decisions in different socioeconomic and cultural situations.

Far from attributing intrinsic moral values, the intention in proposing a distinction between autogenous and heterogeneous implications for the construction of an ethical approach towards nanotechnology, taking into account the fallibility to which all classifications are subject, is to distinguish these perspectives from the interactions that this approach addresses.

The processes of research, production and application of nanotechnology are approached as autogenous themes. Ethical reflections that involve risk analysis, which is not always possible, demand a double ability: technical improvement, with the development of adequate devices for such evaluations, and also the search for new ethical considerations that are sustained even if knowledge is not imminently attained.

The heterogeneous questions, which deal with the complex interactions of society, technology, environment, politics and economics, within the still incipient discussion on the ethics of nanotechnology, are the ones that have received least attention, even though a sober and attentive reading shows that they are extremely relevant and plausible.

In the light of the hype driving the race between laboratories to label their research with the prefix "nano", and between countries to lead the way in producing state-of-the-art nanotechnology, political agents oscillate between disregarding ethical matters and calling for a definitive moratorium on research. Given this scenario, ethical reflection on the subject of nanotechnology has to be free from overreaction and immediacy. The approach taken toward the emerging technologies, as in the case of nanotechnology, should sober, critical and dialectical. A diversity of perspectives and interests should be considered when searching for answers to the ethical challenges imposed by nanotechnology in the complex modern context.

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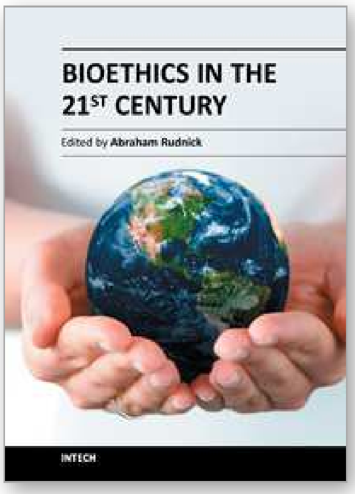

Bioethics in the 21st Century
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Bioethics is primarily an applied ethics of health related issues. It is considered an important guide for health care and its discourses and practices. Health related technology, such as information technology, is changing rapidly. Bioethics should arguably address such change as well as continue to address more established areas of health care and emerging areas of social concern such as climate change and its relation to health. This book illustrates the range of bioethics in the 21st century. The book is intentionally not comprehensive but rather illustrative of established, emerging and speculative bioethics, such as ethics of mental health care, ethics of nano-technology in health care, and ethics of cryogenics, respectively. Hopefully the book will motivate readers to reflect on health care as a work in progress that requires continuous ethical deliberation and guidance.