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Nanotechnology, Bioethics and the Techno-Scientific Revolution:
Philosophical and Ethical Assessment of Nanotechnology and its Applications in Medicine

by

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ABSTRACT

Nanotechnology, Bioethics and the Techno-Scientific Revolution:
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This study draws on analyses on a number of levels. First, it clarifies certain concepts often used loosely in the literature pertaining to nanotechnology. In particular, it focuses on the concept of "revolution" in order to determine whether nanotechnology is a revolution in the making or simply an evolution of scientific and technological development. I then examine the context in which nanotechnology has developed (i.e., postmodernity) and consider how the new scientific culture within the postmodern context ties the production of knowledge to the three key elements of what John Ziman calls post-academic science (i.e., transdisciplinarity; the marketability of knowledge; and the norm of utility).

However, the context of postmodernity challenges the resolution of techno-political controversies due to competing rationalities (modes of explanation) and moralities. To this end, I develop a procedural integrated approach that takes into account the consequences of postmodernity for moral theorizing and our understanding of science and technology. Other attempts have been proposed as integrated model in the field of medical ethics, i.e., principlism. However, this work shows why principlism fails as an integrated model and favors an integrated model based on H.T. Engelhardt, Jr. and Kevin Wm. Wildes' procedural ethics.

Finally, I examine further philosophical and ethical implications of nanotechnology in the biomedical sciences. I argue that in order to prevent the absence of more robust reflections that characterizes bioethical reflections in contemporary debates, it is essential to create the conditions for moral substantial reflections (better integration of "trans-epistemic values" at the core of scientific research and technological development). This requires building bridges across disciplines within the natural sciences as well as between the natural sciences (nanotechnology) and the humanities / social sciences. Subsequently, I raise some suggestive ethical and philosophical questions concerning the impact of these new technologies on the practice of medicine but also in relation to the use of humanized technologies that could transform our understanding of what it means to be a human being and our conception of the human body.

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CHAPTER I

INTRODUCTION

> ...[I] am not afraid to consider the final question as to whether, ultimately – in the great future – we can arrange the atoms the way we want; the very *atoms*, all the way down! What would happen if we could arrange the atoms one by one the way we want them (within reason, of course; you can't put them so that they are chemically unstable, for example)...
>
> R. Feynman (1959)

> Each of these technologies...offers untold promise: The vision of near immortality that Kurzweil sees in his robot dreams drives us forward; genetic engineering may soon provide treatments, if not outright cures, for most diseases; and nanotechnology and nanomedicine can address yet more ills. Together they could significantly extend our average life span and improve the quality of our lives. Yet, with each of these technologies, a sequence of small, individually sensible advances leads to an accumulation of great power and, concomitantly, great danger... The only realistic alternative I see is relinquishment: to limit development of the technologies that are too dangerous, by limiting our pursuit of certain kinds of knowledge.
>
> B. Joy (2000)

I. PRELIMINARY COMMENTS

Academic science, as we know it today, is the outcome of a succession of developments that began in the 17th century in European societies, especially in French and German universities. It has been traditionally understood as a mode of knowledge production taking place within a university setting but is currently being radically transformed and altered. In the last few decades, socio-cultural and politico-economic factors have transformed academic science so as to produce what John Ziman calls the context of post-academic science, that is, a transformation "in the way...[academic] science is organized, managed and performed" (Ziman, 2002, p. 67). While post-academic science does not deny the goals of academic science (i.e., the production of knowledge according to specific epistemic norms, laws and values), post-academic science diverges in three specific ways: (1) in how scientific knowledge is produced (i.e., emphasis on transdisciplinarity), (2) in how it is funded and promoted as a source of economic power (i.e., marketability of knowledge), and (3) in the emphasis on the imperative to find technological applications (i.e., greater stress on the norm of utility).

This work examines how the particular context of post-academic science shapes not only the scientific and technological development of nanotechnology but also moral reflections concerning the social and ethical implications of nanotechnology.[1] In particular, my analysis focuses on the emergence of nanotechnology as an exemplar of post-academic science in which science, technology, politics, and economics converge for social and governmental purposes. At the same time, I argue that this new scientific ethos (i.e., post-academic science) offers the possibility of a *better* integration of ethical and philosophical reflections (that is, how one understands, explains and organizes or systematizes reality according to specific values and norms) at the core of science and technology, because of its trans-disciplinary nature and, to a lesser degree, the pressure from outside constraints (governments, public, and the industry) to consider the social accountability of science (i.e., responsible science).

As my analysis shows, this is not to suggest that a new ethics per se ("nanoethics" as a new moral theory) is necessary or that the integration of moral considerations has not

[1] The need for a definition of nanotechnology appears to be essential in order to have "a meaningful discourse on the societal impact of nanotechnology" (Theis, 2001, p. 75). This task is important since there are many accounts of nanotechnology.

occurred previously in reflections concerning science and technology. The tools provided by moral theory, bioethics, medical ethics, etc., constitute a useful basis to guide our reflections. However, the particular context in which the development of nanotechnology occurs in post-academic science offers the possibility to develop a model (what I call a "procedural integrated model") that emphasizes a *better* integration of ethical reflections in scientific and technological endeavors.

Three areas of analysis characterize my investigation of the ethical and social implications of nanotechnology: (1) the nature of nanotechnology and its alleged revolutionary dimension; (2) the type of theoretical framework necessary to sustain rich philosophical and ethical reflections concerning nanotechnology; and (3) the interface between the disciplines of science and the humanities or the relation between facts and values and how they shape debates concerning nanotechnology.

The first crucial issue, then, concerns the nature of nanotechnology itself, which is often portrayed as revolutionary, as either a scientific revolution, a technological revolution, the next industrial revolution or a revolution in medicine. Mark Ratner and Daniel Ratner in their volume *Nanotechnology: A Gentle Introduction to the Next Big Idea*, for instance, observe that our efforts to fight disease are inherently located at the nanoscale. As they put it "[t]he nanoscale is the natural scale of all fundamental life processes, and it is the scale at which diseases will need to be met and conquered" (Ratner & Ratner, 2003, p. 108). From a scientific and technological point of view, the "miniaturization" at the nanoscale of technology (e.g., nanobots, neuro-electronic interfaces, photodynamic therapy, and nanoscale biostructure) for medical treatment could represent a scientific and technological revolution that requires a thorough philosophical investigation because the development of nanotechnology could be viewed as a technological revolution. The same way European culture witnessed the scientific revolution in the 17th century that gave rise to modern science. In both instances, the source of the revolution concerns a change in the view of the physical world -- how it should be studied, understood and explained. In its contemporary form, however, the revolution does not focus only on understanding the physical world (scientific revolution) but also on how to "domesticate" it and transform it for the sake of human flourishing using technology. This last point is very important because it characterizes and defines nanotechnology as a type of techno-scientific endeavor. The nature of this potential techno-scientific revolution in the making (claim ascertained in a subsequent chapter) needs to be assessed and understood in order to anticipate the potential dangers and benefits it could entail. Without a clear understanding of the nature of nanotechnology (one could speak, as George Khushf does (2004a), of nanotechnology as a philosophical project), ethical reflections will be obscure by a failure to pinpoint the locus of where the moral problems occur.

The second key issue to address is the kind of theoretical framework that would sustain rich philosophical and ethical reflections on nanotechnology within the context of post-academic science. So far, the social and ethical implications of nanotechnology remain mostly underexplored in general, and particularly in medicine. The increasing interest in nanotechnology in the last years has resulted in the publication of numerous articles and books, the creation of centers and university departments focusing on research as well as the development of such technology. Yet, the reflection on this nascent field focuses primarily on defining nanotechnology, on examining potential applications in various fields such as biotechnology (nanomedicine), information technology, cognitive science (cognitive neuroscience) and national security (military applications), and on developing strategies to finance and market the different applications that have resulted from nanotechnology research.

However, philosophical and ethical reflections on the possible impact of nanotechnology on society remain underexplored.[2] There is yet to be a systematic assessment of the literature and an outline of the issues at stake to provide the initial steps for further reflections. Hence, the importance of reflecting on what type of ethical theory and philosophical framework(s) is necessary in order to participate meaningfully in the debate about the ethical implications of nanotechnology, particularly in the biomedical sciences. Due to the potential politico-economic and social benefits of nanotechnology, it appears imperative to spend time, money and human resources in a *trans*-disciplinary effort to think about what a responsive development of nanotechnology would entail for society. Mihail C. Roco and William Sims Bainbridge from the National Science Foundation (NSF), for instance, point out that "proper attention to the ethical issues and societal needs" can result in the beneficial outcomes for the industry, society and human life. If well informed, the public and the politicians will be willing to finance and support new technologies (one might think of how Genetically Modified Organisms (GMOs)

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[2] On this point, see particularly Mnyusiwall, Daar, and Singer (2003) who review the current literature, governmental funding, and policy documents. Their conclusion that there is a "paucity of serious, published research into the ethical, legal, and social implications of nanotechnology" is revelatory of the lack of philosophical and ethical reflections.

have been rejected in Europe by the public due to the failure by the scientific communities to address key controversial questions surrounding GMOs). What follows then is the need for further philosophical and ethical reflections that take into account the implications of the convergence of various technologies and disciplines in science (trans-disciplinarity). Key to the discussion concerning nanotechnology is to determine whether nanotechnology is/will be a discipline in its own right, which would suggest a move toward the unification of science - position defended by Mihail C. Roco and William Sims Bainbridge[3] - or whether the convergence of various scientific disciplines into one discipline is rather less probable.[4]

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[3] Roco and Bainbridge suggest that in the future scientific knowledge could be organized differently: "Convergence of diverse technologies is based on *material unity at the nanoscale and on technology integration from that scale.* The building blocks of matter that are fundamental to all sciences originate at the nanoscale...Developments in systems approaches, mathematics, and computation in conjunction with NBIC allow us for the first time to understand the natural world, human society, and scientific research as *closely coupled complex, hierarchical systems.* At this moment in the evolution of technical achievement, *improvement of human performance through integration of technologies* becomes possible" (Roco & Bainbridge, 2002, p. ix; italics in original). Also, in their discussion concerning the unifying of science and converging technologies they suggest a transformation of scientific education. They write that "to meet the coming challenges, scientific education needs radical transformation from elementary school through post-graduate training. Convergence of previously separate scientific disciplines and fields of engineering cannot take place without the emergence of new kinds of people who understand multiple fields in depth and can intelligently work to integrate them. New curricula, new concepts to provide intellectual coherence, and new forms of educational institutions will be necessary" (Roco & Bainbridge, 2002, p. xi).

[4] Alfred Nordmann, for instance, is rather skeptic as to a general theory for nanotechnology. He points out that "this suggests that nanoscale research may lead the way to a new organization of scientific knowledge, namely a reductionism not to fundamental particles but to hierarchically nested structures of self-organization that are rooted at the nanoscale. Mihail Roco and William Bainbridge are eloquent advocates of this suggestion: 'People will be able to acquire a radically different instinctive understanding of the world as a hierarchy of complex systems rooted in the nanoscale.' While there is little evidence to date that the scientific community at large is following their call for a restructuring of disciplines and a systems-theoretic or holistic view of nature, some philosophers and a few scientists agree with Roco and Bainbridge. If nanoscience is to become a discipline in its own right, a general theory of the self-assembly of complex systems might serve as its paradigm. Such a theory of self-organization would distinguish the structural manner of nanoscientific thinking from that of the various contributing disciplines like physics, engineering, chemistry, biology, materials and computer science. Chemists are especially likely to take the idea of self-assembly seriously, in particular those who emphasize the non-conservative aspects of synthesis or 'chemical becoming'. Unlike mechanics or genetics, this new science of emerging order would not identify causal dependencies in distinct theoretical frameworks. More like botany or zoology, it would discover and populate the hitherto barren and lifeless world with order-seeking structures, that is, a kind of

Finally, the third issue relates to the assessment of the new applications derived from nanoscience/nanotechnology and to the potential threats they might constitute for humans and their environment. The analysis of these questions depends on a set of assumptions concerning freedom of scientific research, the role of state regulations and the type of analytic framework that surrounds reflections on the social and ethical implications of nanotechnology. One of the aims of this work is to show how models of scientific explanations are intrinsically connected to specific values and norms. Therefore, part of the task consists in outlining how values and particular ways of understanding, explaining and organizing reality shape debates concerning nanotechnology. Some of the basic issues to address concern how the government or other political/social institutions should regulate scientific research. Furthermore, questions related to freedom of scientific research as well as to the type of moral ground for pronouncing one type of research dangerous and therefore unacceptable need to be at the forefront of our reflections. Finally, assuming the dangers and risks outweigh the potential benefits of such technology, it is necessary to find a mechanism for a comprehensive assessment of the risk – benefit ratio. As mentioned, some of the immediate benefits could have their impact on many areas of scientific development: the biomedical sciences (particularly medicine), energy production (cheaper and cleaner), and materials (lighter and stronger). The increasing cost of health care, the environmental concerns and the need to provide alternative materials for new technological

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organism. Human beings would find themselves *At Home in the Universe* not because of their predetermined place in a rational order but because, wherever they look, things seem vaguely familiar in that they follow similar patterns at the molecular, economic, and cosmic scales" (Nordmann, 2004b, p. 52).

developments (for instance, lighter materials could change the way airplanes are built, the outcome would be faster and more fuel efficient airplanes) represent incentives for the development of nanotechnology. However, associated with the development of these technologies are risks (pollution, misuse, etc) that need to be assessed. How to balance risks in relation to benefits constitute a great challenge for future analyses.

II. METHODOLOGY

This study draws on analyses on a number of levels. First, it aims at clarifying some concepts often used loosely in the literature pertaining to nanotechnology. To this end, Chapter Two looks at the nature of nanotechnology. After an outline of the major events and historical figures that shaped what is known as the discipline of nanotechnology, this chapter addresses three specific issues. First, it examines the concept of "revolution" in order to determine whether nanotechnology is a revolution in the making or simply an evolution of scientific and technological development. An examination of what has been characteristic of revolutions in the past – for instance, in relation to science and technology, it suggests a fundamental shift in how reality is experienced, understood, explained and systematized – will allow us to determine whether the term "revolutionary", which is often used in a hyperbolic manner, applies to nanotechnology in its current state. Once this is established, we can move further into our examination of nanotechnology.

The second important task is to define nanotechnology and clarify its nature. The difficulty in such a task is that the term "nanotechnology" is a catchword that does not concern one particular area of scientific and technological research but a variety of disciplines and concepts. Despite this difficulty, a definition is provided that captures not only what is novel in nanotechnology but also how science and technology intersect.

The third part of the chapter concerns the risks and dangers associated with nanotechnology. In particular, I argue that the distinctions between manifest risks and dangers, potential risks and dangers, as well as perceived risks and dangers are crucial in order to determine where the key issues lie and to provide a realistic picture of the dangers related to the development of this new technology.

Chapter Three examines the particular context in which nanoscience / nanotechnology has developed, that is, within the context of postmodernity, which is characterized by the recognition of the failure of the Enlightenment to provide a common rationality and the incommensurability of competing discourses at various level of inquiry (morality, politics, science, etc.). In addition, it is important to stress that post-academic is, as Ziman puts it, "defiantly post-modern in its pluralism" (Ziman, 2000, p. 210). Hence, the chapter addresses the relationship of postmodernity to post-academic science and technology and assesses whether postmodernity offers an alternative account to the modern account of science that aims at a unification of knowledge (meta-narrative of science and technology) as well as the contrast of extra-epistemic considerations (e.g., political, economic and ethical considerations) and scientific knowledge. Furthermore, this chapter will determine whether postmodernity affects the way scientists practice science not just the way they think about science.

Situating the context in which science and technology takes place is a key element in my analysis since one of the main objectives of this work is to develop an integrated model that includes political, economic and ethical considerations at the core of scientific and technological development (qua nanotechnology). In particular, three key elements of post-academic science (that is, transdisciplinarity, the marketability of knowledge and the norm of utility) will be examined to show how they shape and frame issues within science and technology, with a particular emphasis on nanotechnology. Crucial to my analysis of the social and ethical implications of nanotechnology is the transition from an academic to a post-academic science constitutes an opportunity to further stress the necessity of a better integration of ethical and philosophical reflections at the core of scientific and technological development, that is, in the context of this work, as an integral part of the development of nanotechnology.

The next chapter (Chapter Four) builds on what is ascertained in the previous chapters, that is, it establishes a framework for ethical reflections (a procedural integrated model) that take into account the consequences of postmodernity for moral theorizing and our understanding of science and technology. Other attempts have been proposed as integrated models in the field of bioethics, the most influential being principlism as proposed by Tom L. Beauchamp and James F. Childress. The task of this chapter is manifold: first, it shows why principlism, as an integrated model, fails mainly due to the lack of acknowledgment of the competing moralities that characterizes contemporary moral reasoning. It will be argued that our pluralistic context does not allow establishing a unique moral account recognizable by everyone and consequently, a proceduralist approach to moral reasoning will be favored. Building on the works of H.T. Engelhardt, Jr. and Kevin Wm. Wildes, both of whom develop proceduralist approaches, I argue that the former type of procedural ethics (i.e., Engelhardt) fails to recognize that the disagreement between moral strangers is not as strong as he assumes but more obvious than what Beauchamp and Childress contend. Hence, a middle ground version of procedural ethics (Wildes' concept of *moral acquaintances*) is attractive because it provides a richer understanding of morality that acknowledges our pluralistic moral condition but also affirms that indeed sometimes moral commitments overlap between people of different communities and traditions. In the last section of the chapter, I develop a *procedural integrated model* based on Wildes' proceduralism and show how it can be applied in the context of reflections on science and technology.

Having established the reason why a procedural integrated model is necessary within our contemporary context of moral reflections, I will then turn to further philosophical ethical reflections on nanotechnology, especially its application in the biomedical sciences. In Chapter Five, I argue that in order to prevent the absence of more robust reflections that characterizes bioethical reflections in contemporary debates it is essential, despite the fragmented nature of Western morality, to create the conditions for moral substantial reflections which imply a better integration of "trans-epistemic values" at the core of scientific research and technological development. This requires building bridges across disciplines within natural sciences as well as between natural sciences and the humanities / social sciences. In this chapter, a comprehensive model of a dynamic (procedural) integrated model for nanotechnology / nanomedicine is developed.

The final chapter is concerned with defining nanomedicine and outlining the various potential applications of nanotechnology in the field of medicine. Subsequently, I raise some suggestive ethical and philosophical questions concerning the impact of these new technologies on the practice of medicine and in relation to the use of humanized technologies that could transform our understanding of what it means to be a human being and our conception of the human body.

III. THE CLAIMS OF THIS WORK

Before turning specifically to the core analysis, it is important to lay out the main intellectual claims defended in this work. This work is built around three working assumptions as to (1) the context in which nanotechnology has developed, (2) the nature of this emerging field of scientific and technological inquiry and (3) the relationship between, on the one hand, the sciences/technology and, on the other hand, the humanities/the social sciences and its impact on the interface between these spheres of human inquiry which are essential for our reflections on nanotechnology.

The first crucial claim is related to the transformation of the context in which academic science and technology has developed in the last few decades. Specifically, in the first part of the work, I recognize the influence of the milieu in which the field of nanotechnology has developed. An examination of the nature of contemporary science reveals that it is postmodern in its pluralism. The modern account of science, as a meta-discourse, has become problematic because it questions the unity of scientific knowledge and it raises the issue of the legitimation of scientific knowledge. The postmodern character of contemporary science, which is manifest in the very nature of nanotechnology as I demonstrate, is due to its trans-disciplinarity and to the presence of various, and sometimes competing, models of explanation of scientific facts.

This is not to say that the scientific method (i.e., empiric demonstration) is doomed to incoherence because of irreconcilable models of explanation. No doubt, postmodernity is a complex intellectual movement reacting to the totalizing account of modernity – postmodernity can lead to a fragmented model of explanation of reality. Acknowledging postmodernity is key to appreciating nanotechnology, given the diverse roles of multiple disciplines, with each assuming particular epistemological assumptions and methods of explanation and participating from a specific point of view (physics, chemistry, biology, etc.) in the "discourse" related to, and development of nanotechnology. Another key concept to keep in mind is the idea of the "democratization of reality", to use Engelhardt's terminology, which regards not only the natural sciences but also the humanities and social sciences, each playing a different role in each case.

In the present work, I demonstrate that a postmodern account provides insights as to the very nature of contemporary scientific research and technological development, particularly with reference to nanotechnology. I show that reflections on science and technology from the perspective of postmodernity, which are echoed in the nature of nanotechnology itself, challenge not only the unity of scientific knowledge because of the trans-disciplinary dimension of nanotechnology but also the scientific model[5] as the sole mode of explanation of reality, i.e., through the inclusion of the insights of the humanities and social sciences. This is a crucial point in the progression of the main argument of this work. A postmodern account of science cannot limit its scope to the explanation of reality through the natural sciences but requires an integration of the cultures, perspectives, and contributions of natural sciences, the social sciences, and the humanities.[6]

Hence, if we accept the claim that contemporary science takes place within the epistemological constraints of postmodernity, we are in a position to introduce the second working assumption of this work, namely, that scientific development occurs in the context of what John Ziman calls "post-academic science." The context of post-academic science is postmodern in its pluralism and includes, as a core feature of its identity "trans-epistemic factors," that is, values and social considerations. While the problem of the disunity of science and the issue of the legitimation of scientific knowledge are addressed in this work, I demonstrate that post-academic science offers the conditions for the integration of trans-epistemic factors at the core of scientific and technological development. In particular, I show why each of the characteristics of post-academic science (i.e., a form of trans-disciplinarity, the marketability of knowledge and the norm of utility) represents a key components of the makeup of science and technology, which demands their integration in the overall structure of scientific development.

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[5] The scientific method model contains six components that can be formulated as follows: 1) hypothesis formulation; 2) hypothesis testing; 3) deductive and inductive logic; 4) controlled experiments, replication and repeatability; 5) interactions between data and theory; and 6) limits to science's domain (Gauch, 2003, p. 11).

[6] As is discussed below, since C. P. Snow's Rede Lecture much has been made of the "two cultures", that of the sciences and that of the humanities. The cultures are not two, but at least three, those of the natural sciences, the social sciences, and the humanities. See Lepenies, 1985.

To recognize the integration of factors considered as extra-scientific at the core of scientific and technological reflections, I develop what I call a procedural integrated model. While I show why our pluralistic context does not support the language of a common morality because of competing moralities, I also underscore the need to develop a model of ethical reflection that permits social collaboration in reflections related to particular social practices (e.g., medicine or scientific research). This procedural integrated model is comprehensive in the sense that it does not limit the integration of "trans-epistemic" factors, but also includes considerations related to law, public policy, economics and politics. This model is specifically developed in order to take into consideration the various factors that are intrinsic to contemporary science and technology.

Having laid out the three working assumptions that frame my examination of the social and ethical implications of nanotechnology, we can now turn to the core analysis. In particular, we need first to determine whether nanotechnology is revolutionary as often mentioned in the literature.

CHAPTER II

NANOTECHNOLOGY: A TECHNO-SCIENTIFIC REVOLUTION IN THE MAKING?

I. NANOTECHNOLOGY: EVOLUTION OR REVOLUTION?

In recent period with the constant progress in science and technology, societal expectations have increased as to what can or could be accomplished for the sake of improving human life to the point that some scholars suggest that these expectations reflect a quest for transcendence and salvation (Noble, 1997, p. 3; Hughes, 2002). Nanotechnology, in its application in biomedical sciences, could have the potential to eradicate disease, control the aging process, enhance human nature (e.g., human capabilities/transhumanism) and even, in a more distant future, could, it is argued, allow achieving physical immortality. Consider, for instance, Robert Freitas who claims that

> In the first half of the 21st century, nanomedicine should eliminate virtually all common disease of the 20th century, and virtually all medical pain and suffering as well. Only conditions that involve a permanent loss of personality and memory information in the brain – such as an advanced case of Alzheimer's disease or a massive head trauma – may remain incurable in the nanomedical era. Because aging is believed to be the result of a number of interrelated molecular processes and malfunctions in cells, and because cellular malfunctions will be largely reversible, middle-aged and older people who gain access to an advanced nanomedicine can expect to have most of their youthful health and beauty restored. And they may find few remaining limits to human longevity in this wonderfully vigorous state. It is a bright future that lies ahead for medicine, but we shall all have to work very long and very hard to bring it to fruition (Freitas, 2002).

In addition to its application in the biomedical sciences, some argue that nanotechnology could play a major role in the stabilization of world politics and economics. Among the various views concerning the potential of nanotechnology, Mihail Roco and William S. Bainbridge, for instance, assert optimistically that nanotechnology could be a factor for a unified society which could bring world peace and universal prosperity due to potential applications that could solve socio-economic problems such as the production of food and other products at lower prices, better life conditions due to improvement in medicine, etc. In their overview on the *Converging Technologies for Improving Human Performance,* they depict such a world and foresee that "[t]he twenty-first century could end in world peace, universal prosperity, and evolution to a higher level of compassion and accomplishment. It is hard to find the right metaphor to see a century into the future, but it may be that humanity would become like a single, distributed and interconnected 'brain' based in new core pathways of society" (Roco & Brainbridge, 2002, p. 6). These assertions are difficult to assess at this junction, but since nanotechnology is still in its early developmental stages, there is no ground to believe that such a world will ever exist. The correlation between peace, prosperity and a unified society seems rather a simplistic projection of hopes and, maybe, a strategy to promote nanotechnology as a solution to the problems related to the human condition.

While the search for the cure of diseases, the enhancement of human capabilities, and the quest for peace and prosperity have been part of the socio-cultural evolution of mankind, the idea of controlling the aging process, the aim of physical immortality and certain kinds of human enhancements (in neurosciences, for instance) through the use of technology are revolutionary on four levels: (1) how scientific research would have to be conducted – trans-disciplinarity; as will be demonstrated later on, nanotechnology is a convergence of various scientific fields each one assuming particular epistemological and metaphysical premises; (2) the extent to which technology could improve human life (human-machine interface); (3) how medicine could be practiced in the future (use of nanodevices); and (4) how we understand philosophical and ethical reflections on the potential problems raised by nanotechnology. The key issue is to determine the revolutionary and disruptive nature of these technological and scientific advancements and to examine how they differ from prior "revolutionary" technologies that raise, at first, similar concerns about the environment, society and human life. In other words, before society moves ahead in fully accepting nanotechnology, it is crucial to investigate the exact nature of the field and its implications for society as a whole.

A. Historical Account of the Development of Nanotechnology

Before we turn to the nature and definition of nanotechnology, it is necessary to lay out the historical development of nanotechnology, from its early stages to the current controversy as to its potentials. The first attempt to conceptualize nanotechnology was made by Richard Feynman who, in his famous talk on December 29th,1959, raised the possibility of arranging atoms one by one. Although he did not use the specific terminology of *nanotechnology*, he provided nevertheless the conceptual ideas that led to what we know today as nanotechnology. In his lecture entitled *There is Plenty of Room at the Bottom*, he provocatively addressed the audience and claimed:

> ...[I] am not afraid to consider the final question as to whether, ultimately – in the great future – we can arrange the atoms the way we want; the very *atoms*, all the way down! What would happen if we could arrange the atoms one by one the way we want them (within reason, of course; you can't put them so that they are chemically unstable, for example)...The principles of physics, as far as I can see, do no speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big (Feynman, 1959).

A crucial invention had to occur before Feynman's ideas could be realized. His vision of manipulating atoms came closer to reality in 1981 when Gerd Binning and Heinrich Rohrer invented the Scanning Tunneling Microscope (STM) at the IBM laboratory in Switzerland. This breakthrough earned them a Nobel Prize in physics and allowed the human eye to see individual atoms for the first time. But more importantly, in relation to Feynman's vision, in 1990 a team of physicists at the IBM Almaden Research Center managed to spell out by manipulating atoms the three letters IBM, using 35 xenon atoms on a crystal of nickel (National Science and Technology Council, 1999, p. 6). This new development in the world of atomic manipulation opened the door to reflect further on the possibility of what is called "molecular assemblers."

The idea of "molecular assemblers" was first introduced by K. Eric Drexler, a leading proponent of nanotechnology. He contends that "nanotechnology" and "molecular technology" are interchangeable terms that describe a "new style of technology" (Drexler, 1986, p. 5). What is new or revolutionary is not so much the miniaturization of how we could build objects but rather the prospect of using nanodevices. This new technology, Drexler argues, is based on the creation of nanomachines, which he calls *assemblers*. These assemblers will, he asserts, revolutionize the way we manufacture things:

> [Assemblers] let us place atoms in almost any reasonable arrangement; they will let us build almost anything that the laws of nature allow to exist. In particular, they will let us build almost anything we can design – including more assemblers. The consequences of this will be profound, because our crude tools have let us explore only a small part of the range of possibilities that natural law permits. Assemblers will open a world of new technologies (Drexler, 1986, p. 14).

In another volume entitled *Nanosystems: Molecular, Machinery, Manufacturing, and Computation*, Drexler develops more specifically his vision and explains more fully, what he means by [molecular] assemblers:

> New fields often need new terms to describe their characteristic features, and so it may be excusable to begin with a few definitions: Molecular manufacturing is the construction of objects to complex, atomic specifications using sequences of chemical reactions directed by nonbiological molecular machinery. Molecular nanotechnology comprises molecular manufacturing together with its techniques, its products, and their design and analysis; it describes the field as a whole. Mechanosynthesis—mechanically guided chemical synthesis—is fundamental to molecular manufacturing: it guides chemical reactions on an atomic scale by means other than the local steric ["molecular shape"] and electronic properties of the reagents; it is thus distinct from (for example) enzymatic processes and present techniques for organic synthesis (Drexler, 1992).

The prospect of such "molecular assemblers," as described by Drexler, is still treated with much skepticism despite recent developments in nanotechnology, particularly from Richard E. Smalley, professor of chemistry at Rice University, who won a Nobel Prize in chemistry for his codiscovery of fullerenes (molecules composed uniquely of carbon –

estimated to be 60 times stronger than high-grade steel, Ratner & Ratner, 2003, p. 56). In his view, "molecular assemblers" are physically impossible due to what he calls the "fat fingers problem" and the "sticky fingers problem" (Smalley, 2001, pp. 76-77). In his discussion concerning the possibility of "molecular assemblers," Smalley simply refutes the idea of molecular assemblers on the ground that the process of production is too slow (the making of 30 grams of whatever material by one nanobot would take 19 million years, see Smalley, 2001, p. 76) and due to the "fat fingers problem," that is, there is not enough room at the nanoscale to "accommodate all the fingers of all the manipulators necessary to have complete control of the chemistry" and to the "sticky fingers problem," that is, the problem of how manipulators will be able to release the atoms at the right location in the atomic structure. He confidently asks, "How soon will we see the nanometer-scale robots envisaged by K. Eric Drexler and other molecular nanotechnologists? The simple answer is never...To put every atom in its place – the vision articulated by some nanotechnologists – would require magic fingers. Such a nanobot will never become more than a futurist's daydream" (Smalley, 2001, p. 76-77).[7] Whether Smalley is right or wrong is difficult to assess at this point and will be the focus

[7] For an overview of the exchanges for and against "molecular assemblers" between Drexler and Smalley see Baum (2003) who put together in one article the open letters between the two scientists. For a rebuttal of Smalley's assertion on the impossibility of self-replicating mechanical nanobots see Drexler, Forrest, Freitas, Storrs Hall, Jacobstein, McKendree, Merkle & Peterson (2001). It is important to note that Smalley does not reject nanotechnology out right. In a testimony before a congressional subcommittee on the potential of nanotechnology, he encouraged the development of the field and sees the potential applications in the biomedical sciences: "...[T]twenty years from now, I am confident we will no longer have to use this blunt tool [chemotherapy]. By then nanotechnology will have given us specially, engineered drugs which are nanoscale cancer-seeking missiles, a molecular technology that specifically targets just the mutant cancer cells in the human body, and leaves everything else blissfully alone. To do this, these drug molecules will have to be big enough – thousands of atoms – so that we can code the information into them of where they should go and what they should kill. They will be examples of an exquisite, human-made nanotechnology of the future...Cancer...will be a thing of the past" (Smalley, 1999).

of further heated debates. Only future technological developments will provide an answer to this difficult question.

B. The Need for Conceptual Clarity

Although the above survey shows that we might never see molecular assemblers, there is an increasing use of the terminology of revolution in relation to nanotechnology. In this section, I aim at critically assessing the claim that nanotechnology is revolutionary. What is common to many characterizations of nanotechnology is the use of the terminology "revolution". However, none of the sources cited specifically address the question of what it means to say that nanotechnology is revolutionary in science, technology, medicine or the industry. Is nanotechnology the kind of revolution that transformed society and science during the Scientific Revolution in Western Europe or is it simply the evolution of science, i.e., the normal next stage in the development of science? What are the necessary and sufficient conditions to call nanotechnology a revolution whether in science, technology, medicine or the industry?

To answer to these questions and for the sake of clarity it is necessary to define conceptually the idea of a revolution. To what we will turn now.

1. Defining Revolution

The idea of revolution has been used to describe many areas of human activity such as in the industry (the Industrial Revolution beginning in the second half of the 18th century) and in science (the Scientific Revolution, 1550 -1700). Originally, however, it was a political concept first developed by Aristotle in *The Politics* in relation to forms of government. Aristotle began his analysis with the starting assumption that any form of government implies specific conceptions of justice and equality. In particular, in Ancient Greece two political factions, the democrats and the oligarchs, fought over the question of the status of each individual in society. On the one hand, democrats stressed that men were equal in all respect; whereas, oligarchs asserted that if an individual was not equal in any respect (in property, for instance) then he was unequal in all respects. Because of this ideological clash, Aristotle argues, revolutions occur: "All these forms of government have a kind of justice, but, tried by an absolute standard, they are faulty; and, therefore, both parties, whenever their share in the government does not accord with their preconceived ideas, stir up revolution" (Aristotle *The Politics*, 5.1). Subsequently, other political thinkers addressed the question of revolutions either by stressing the importance of creating a form of government able to protect the state against revolutions while at the same time recognizing that some changes are sometime necessary in order to insure political stability (Niccolo Machiavelli (1496-1527))[8].

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[8] Machiavelli recognizes the necessity to establish a mechanism that would ensure the political stability of a country. In his *Discourses,* he notes that "among the more necessary things instituted by those who have prudently established a Republic, was to establish a guard to liberty, and according, as this was well or badly place, that freedom endured a greater or less (period of time)...No more useful and necessary authority can be given to those who are appointed in a City to guard its liberty, as is that of being able to accuse the citizen to the People or to any Magistrate or Council, if he should in any way transgress against the free state. This arrangement makes for two most useful effects for a Republic. The first is, that for fear of being accused, the citizens do not attempt anything against the state, and if they should (make an) attempt they are punished immediately and without regard (to person). The other is, that it provides a way for giving vent to those moods which in whatever way and against whatever citizens may arise in the City. And when these moods do not provide a means by which they may be vented, they ordinarily have recourse to extra ordinary means that cause the complete ruin of a Republic. And there is nothing which makes a Republic so stable and firm, as organizing it in such a way that changes in the moods which may agitate it have a way prescribed by law for venting themselves...Whoever becomes Prince either of a City or a State, and more so if his foundations are weak, and does not want to establish a civil system either in the form of a Kingdom or a Republic, (will find) the best remedy he has to hold that Principality is (he being a new

English writer John Milton (1608-1674) insisted that a revolution was a right of society to protect itself against abusive power to establish a new government on new principles that would promote the well-being of citizens.[9] Milton saw in revolutions the means to achieve freedom, as was the case in the French revolution (freedom from an oppressive class) and the American revolutions (freedom from English tutelage).[10] G.W.F. Hegel is another important figure in relation to the notion of revolution since he was very influential in thinkers such as Karl Marx who used Hegelian political theory to advocate freedom in a classless society. More importantly, he developed a philosophy that explained revolutions in terms of a change in categories either in society or scientific

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Prince) to do everything anew in that State; such as in the City to make new Governors with new titles, with new authority, with new men, (and) make the poor rich, as David did when he became King, who piled good upon the needy, and dismissed the wealthy empty-handed. In addition to this he should build new Cities, destroy old ones, transfer the inhabitants from one place to another, and in sum, not to leave anything unchanged in that Province, (and) so that there should be no rank, nor order, nor status, nor riches, that he who obtains it does not recognize it as coming from him" (Machiavelli, *Discourses*, chaps. 5, 8, 26).

[9] See for instance in *The Tenure of Kings and Magistrates* where Milton argues that the power of kings and magistrates comes from the people themselves: "...since the King or Magistrate holds his authority from the people, both originally and naturally for their good in the first place, and not his own, then may the people as often as they shall judge it for the best, either choose him or reject him, retain him or depose him though not a Tyrant, merely by the liberty and right of free born Men, to be governed as seems to them best." However, when tyrants (a tyrant is defined by Milton as "he who regarding neither Law nor the common good, reigns only for himself and his faction") abuse their power, the people who elected them have the right to reject their authority: "...Because his power is great, his will boundless and exorbitant, the fulfilling whereof is for the most part accompanied with innumerable wrongs and oppressions of the people, murders, massacres, rapes, adulteries, desolation, and subversion of cities and whole provinces, look how great a good and happiness a just King is, so great a mischief a Tyrant. As he the public father of his Country, so this is the common enemy... Against whom what the people lawfully may do, as against a common pest, and destroyer of mankind, I suppose no man of clear judgment need go further to be guided by than by the very principles of nature in him" (Milton, *The Tenure of Kings and Magistrates*).

[10] Melvin Lasky remarks that a (political) revolution can be both a means (for change) and an end (creation of a new society according to new principles). As he writes, "revolution, taken only as means, suggests that there are situations of political and social crisis where, all available methods of change – peaceful or gradual or reasonable, or any other approach associated with concessions, compromise, and reconciliation – having proved futile, only a sharp break and basic overturn can now serve to defend justice and establish a tolerable order. So it is that not only radicals but also moderates, reformers, liberals, and even conservatives, find themselves enlisted in a revolution. Revolution, as an end, suggests that a new society is conceivable, and is indeed possible, only on the basis of fundamentally different social, political and cultural principles" (Lasky, 1976, p. 79). A revolution in science is a revolution of the latter type, that is, it conceives new models of explanation and establishes new principles (or categories to use Hegel's terminology) accordingly.

explanation. In his *Philosophy of Nature*, he addressed the question of revolutions in terms of a process in which a change of categories occurs: "All cultural change reduces itself to a difference of categories. All revolutions, whether in the sciences or world history, occur merely because spirit has changed its categories in order to understand and examine what belongs to it…" (Hegel, 1970, p. 202). Hegel's description of revolutions in terms of a change of categories is crucial as we turn specifically to nanotechnology.

It is often the case that reflections concerning nanotechnology describe the field as revolutionary. For instance, the European Commission and the National Science Foundation of the United States at the Toulouse Nanotechnology Workshop issued a document where it refers to nanotechnology as a possible avenue for a "third industrial revolution." As the document stipulates "although still in its infancy, nanotechnology is…likely to underpin the next 'industrial revolution,' proving as effective in the shaping of the 21st century as biotechnology and electronics were in changing the face of the 20th century" (European Commission, 2000, p. 8). Another example is the preface of a document entitled *Nanotechnology: Revolutionary Opportunities and Societal Implications* of the 3th Joint EC – NSF Workshop on Nanotechnology, in which Lance Haworth (National Science Foundation) and Ezio Andreta (European Commission) asserted that the 21st century is "the start of the nanotechnology revolution" (European Commission, 2001-2002, p. 3). Furthermore, the standard definition of nanotechnology provided by governmental agencies refers to nanotechnology as "a scientific and technical revolution [that] has just begun based upon the ability to systematically organize and manipulate matter at nanoscale" (NASA Ames Research Center, 2004).

Finally, the terminology of revolution is also used in relation to medicine. Albert Tsai characterizes the nano-applications in the biomedical sciences in term of a "medical revolution" (Tsai, 2002).

These claims, however, are generally unclear and reveal the presence of new conceptually and morally interesting features without necessarily a thorough analysis that distinguishes between moral technological, and scientific revolutionary aspects of nanotechnology. Similarly, this leads one to draw a distinction among moral concerns, scientific concerns and technological concerns. In great measure, nanotechnology raises new[11] moral concerns and issues but it does not recast the practice of morality itself.

This distinction between revolutionary and non-revolutionary developments is important to the issue of claims regarding the revolutionary character of nanotechnology as both a science and a technology (see section B in this chapter where I argue that nanotechnology is a techno-scientific discipline). The term revolutionary, though at times used in a hyperbolic fashion, suggests a fundamental shift in how a particular area of science and technology is experienced, appreciated, and undertaken. The challenge is not only to give some precisions to such claims, but also to engage them heuristically so as to disclose what is novel and different about the framing of scientific and technological concerns, research projects, etc., within the general project of nanotechnology. (It is not my intention to provide an in depth analysis at this juncture as to what is novel - and therefore revolutionary - concerning nanotechnology compared to other fields. However,

[11] Here a distinction is necessary between new in degree and new in kind. When examining the ethical issues raised by nanotechnology, one must recognizes that no new issues per se are present. However, some of the ethical issues characteristic of contemporary debates concerning science and technology are amplified. Hence, nanotechnology can be said to raise new issues (in degree).

the standard definition of nanotechnology provided by governmental agencies states that it is our ability to manipulate at the nanoscale atoms and exploit novel phenomena and properties at that length scale.)

The distinction between revolutionary versus non-revolutionary developments in science and/or technology is useful because it allows us to indicate those circumstances that are markers of dramatic or revolutionary change, that is, those that are sufficient conditions for holding that such a change has occurred, and those that are necessary conditions for what could be reasonably characterized as a revolutionary development. In so doing, it provides the ground for better understanding of (1) conceptual resources for clarifying and reconstructing otherwise quite confused claims in the literature concerning nanotechnology and (2) conceptual resources for diagnosing where novel development have in fact occurred. Although my analysis draws on the works of Thomas Kuhn[12] and Imre Lakatos[13], my investigation is mostly influenced by Hegel's concept of revolutions,

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[12] See the section entitled "Scientific and Technological Revolutions" in this chapter for Kuhn's views on the concept of revolution.

[13] In one of his last public talks before his death, Lakatos discussed in "Science and Pseudoscience" (subsequently published in *The Methodology of Scientific Research Programmes: Philosophical Papers Volume 1*, edited by John Worrall and Gregory Curie, Cambridge University Press, 1978, but originally delivered in 1973 as a radio address) the status of scientific knowledge as opposed to "superstition, ideology or pseudoscience." His analysis is concerned with the role of beliefs in the production of knowledge. He remarks that "a statement constitutes knowledge if sufficiently many people believe it sufficiently strongly. But history of thought shows us that many people were totally committed to absurd beliefs...Scientists, on the other hand, are very sceptical even of their best theories...So no degree of commitment to beliefs makes them knowledge. Indeed, the hallmark of scientific behaviour is a certain skepticism even towards one's most cherished theories. Blind commitment to a theory is not an intellectual virtue: it is an intellectual crime" (Lakatos, 1973).

One of his main concerns is to examine how scientific change takes place, in particular whether a scientific revolution (i.e., scientific change) "is just an irrational change in commitment, that is a religious conversion" (Kuhn) or whether change is rational, that is, it falls into what Lakatos calls, in relation to Popper's falsificationism (a theory is scientific if and only if it is falsifiable, in the sense that in principle it is possible to make an observation that would demonstrate that a proposition is false, even if that observation has not been made yet), the logic of discovery. In his final analysis, Lakatos refutes both accounts because they turn out to be inadequate. As he points out, "so called 'refutations' are not the hallmark of empirical failure, as Popper has preached...What really counts are dramatic, unexpected, that is, as previously indicated, "All cultural change reduces itself to a difference of categories. All revolutions, whether in the sciences or world history, occur merely because spirit has changed its categories in order to understand and examine what belongs to it..." Hence, all scientific revolutions are changes in categories that can be conceptually categorized in various levels of revolutionary development. This means that when a scientific revolution involves a fundamental change in how one understands and explains an area of reality (i.e., exploitation of new phenomena and properties at the nanoscale), then a technological revolution involves a fundamental change in how one manipulates (i.e., degree of control) a particular area of reality. Usually, but not necessarily, a technological revolution presupposes a scientific revolution. Usually a change in manipulating reality is related to a change in understanding reality.[14] Interestingly, in relation to our discussion of the definition of nanotechnology, the

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stunning predictions: a few of them are enough to tilt the balance..."(Lakatos, 1973). He continues on asking the question of how scientific revolutions occur: "Now, how do scientific revolutions come about? If we have two rival research programmes, and one is progressing while the other is degenerating, scientists tend to join the progressive programme. This is the rationale of scientific revolutions" (Lakatos, 1973).

Hence in Lakatos' opinion, scientific changes do not occur either in the logic of scientific discovery (Popper) or in the (social) psychology of discovery (Kuhn) but rather through what he calls the methodology of scientific research programmes: "As opposed to Popper the methodology of scientific research programmes does not offer instant rationality. One must treat budding programmes leniently: programmes may take decades before they get off the ground and become empirically progressive. Criticism is not a Popperian quick kill, by refutation. Important criticism is always constructive: there is no refutation without a better theory. Kuhn is wrong in thinking that scientific revolutions are sudden, irrational changes in vision. On close inspection both Popperian crucial experiments and Kuhnian revolutions turn out to be myths: what normally happens is that progressive research programmes replace degenerating ones" (Lakatos, 1973). Research programmes have a factual basis. However, they still maintain unresolved problems that are resolved (or if not resolved, rejected) through time.

[14] This is not always the case. For instance, Cilliers remarks that science is in a process of transformation he calls the "technologisation of science." He write that "since we are in the midst of this process [the technologisation of science] of change, a clear description of what is happening is not easy, but the heart of the matter is that our technologies have become more powerful than our theories. We are capable of doing things that we do not understand. We can perform gene-splicing without fully understanding how genes interact. We can make pharmaceutics without being able to explain effects and predict side-effects. We can create new sub-atomic particles without knowing precisely whether they actually exist outside of the laboratory...We can do with technology what we cannot do with science" (Cilliers, 1998, p. 1).

distinction between understanding/explaining (science) and manipulating (technology) is not clearly definable since nanotechnology, it will be argued, is techno-scientific discipline (see section II in this chapter). That being said, science and technology are distinguishable but inseparable as a discipline as I will demonstrate later on in this work.

Having introduced these caveats, we can make the following distinctions among elements, markers, or conditions for a scientific and technological revolution. It should be observed that, even when a particular state of affairs may be neither a necessary nor a sufficient condition for scientific or technological revolution, it might nevertheless serve as a useful marker aiding in the identification of important distinctions and levels of scientific and technological development. Three varieties of conditions or markers of scientific and technological development deserve special emphasis:

1. the introduction of *new descriptive categories* for an area of science and/or technology (i.e., experience is described and in some sense experienced in a different way) – one might think of how subatomic particles are described in a way different from macro-particles,
2. the introduction of *new explanatory categories or frameworks* for an area of science and/or technology, and
3. the introduction of a new way of *organizing or systematizing categories or frameworks*.

These three conditions are jointly sufficient for identifying a scientific and/or technological revolution. When an area of reality is described, explained, and the explanations organized in new ways, a dramatic revolution has occurred. However, each of the conditions may be sufficient for indicating a certain level of revolutionary change. The character of scientific and technological knowledge may be such that when the second condition is satisfied the first must be as well. So, too, when the third condition is satisfied, the first and second must be as well. That is, new explanatory categories may change the way in which we experience reality. Therefore, new ways of organizing or systematizing the categories of explanation may reshape those categories and in reshaping them how we both know and manipulated them.

2. Scientific and Technological Revolutions

In the history of the evolution of human culture, science[15] and technology[16] have been interconnected. This progress, however, did not occur without epistemic crises, that is, without what Marx W. Wartofsky calls "the transformation of cognitive mode" referring

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[15] In what follows, I will use science in the most general terms, that is, "science is a mode of knowledge production" in which "its social norms are inseparable form its epistemic norms – what philosophers call its *regulative principles*" (Ziman, 2000, p. 56). While I am aware of the ethos of science and its different ramifications (politics, economics, epistemology, sociology) I purposively do not want to elaborate on the issue at this juncture due to the complexity of the subject matter, which would go beyond the scope of this section.

[16] The use of the term "technology" is not without problem when we attempt to define it. For the sake of clarity, I will use technology in a rather broad perspective. Arnold Pacey asserts that technology entails three main aspects: 1) cultural aspects (goals, values and ethical codes, belief in progress, awareness and creativity); 2) organizational aspects (economic and industrial activity, professional activity, users and consumers, trade unions); and 3) technical aspects (knowledge, skill and technique, tools, machines, chemicals, liveware; resources, products and waste) (Pacey, 2004, p. 95). Contrary to other scholars who define technology in rather narrow terms (see for instance J. K. Galbraith, cited by Pacey, who defines technology as "the systematic application of scientific or other organized knowledge to practical tasks" Galbraith, 1972, chap. 2), Pacey argues that technology cannot be limited to technical aspects but must encompass cultural as well as organizational aspects. Thus in his view, since "some branches of technology deal with processes dependent on living organisms [brewing, sewage treatment and the new biotechnologies]...[m]any people also include aspects of agriculture, nutrition and medicine in their concept of technology. Thus our definition needs to be enlarged further to include 'liveware' as well as hardware; technology-practice is thus *the application of scientific and other knowledge to practical tasks by ordered systems that involve people and organizations, living things and machines*" (Pacey, 2004, p. 99; italics in original)

to the second technological revolution, i.e., the machine revolution. It implies a transformation at the epistemological level of the "norms and structures of knowledge" (Wartofsky, 1992, p. 24). This transformation provides a new framework in which individuals understand themselves according to how the new cognitive mode functions as a point of reference for their own identity.

Understanding how and why these transformations took place is crucial for our overseeing of the current technological/scientific revolution that is happening in our society. Thus, it is necessary to distinguish between *technological* and *scientific* revolutions.

In order to do so, I will refer to the Scientific Revolution that occurred in Europe in the 17^{th} and 18^{th} centuries so as to draw the distinction between what is mere scientific development (i.e., normal process of scientific inquiry) and what is revolutionary (i.e., disruptive, that is, it changes how we understand, explain and organize an area of reality) in science. This distinction between mere scientific developments vs. revolutions in science provides an important insight as to the distinction often made between science and technology. First, it ought to be noted that the Scientific Revolution was connected to a technological revolution. It did not occur exclusively in science as the name of this period suggests. While scientific advancements took place in astronomy, cosmology, understanding of the laws of nature, optics, and kinematics, technological inventions (for example, telescope, thermometer, barometer, microscope) followed as the outcome of new knowledge acquired at the theoretical / mathematical levels. This is an important point because it shows the close connection between science and technology, which is essential to understand when referring to nanotechnology.

The second element to keep in mind is that the Scientific Revolution brought important changes at all levels of society. It did not simply mark the origin of the "modern world" and the "modern mentality" (Butterfield, 1957, p. viii), but likewise involved a series of changes at the socio-cultural and conceptual levels which was reflected in the transformation of the principles of explanation (metaphysics, as "the philosophical investigation of the nature, constitution and structure of reality", *Cambridge Dictionary of Philosophy*), in how people got to know things (epistemology), who were the interlocutors in scientific discourse (sociology of knowledge) and the values these interlocutors brought in their understanding of scientific facts (axiology).[17] As I will point out later in this work, this web of transformations is complex and needs careful evaluation in our characterization of science and technology.

Now, while these are key issues to remember in our analysis of nanotechnology, a scientific revolution can be said to occur first and foremost at an epistemological level (i.e., at a conceptual or theoretical level or to use Hegel's terminology a change in categories, that is, how to describe, explain and categorize reality). In *The Structure of Scientific Revolutions,* Thomas S. Kuhn provides a description of how the development of scientific knowledge creates crises, which lead to scientific revolutions. His main

[17] As John Henry (2002) remarked, the Scientific Revolution did not take place in a vacuum, but was influenced by many factors. He recognized that economics and politics influenced science but also other considerations: "The lesson to be drawn from these various theses about economic and political influences upon science, even if we do not wish to accept any one of them as entirely correct, is that if we wish to achieve as full an understanding as possible of the Scientific Revolution we need to consider not only the role of natural philosophizing, and of the various technical considerations relevant to any aspect of scientific knowledge, but also religion, theology, politics, economics, metaphysics, methodology, rhetoric and, above all, the complex interplay between *all* these factors" (Henry, 2002, p. 109).

thesis is that crises occur at the epistemological level when old conceptual paradigms are challenged by competing ones, often incompatible with each other. As he explains, a scientific revolution is the displacement of established premises about how one views or perceives reality. He writes,

> This need to change the meaning of established and familiar concepts is central to the revolutionary impact of Einstein's theory. Though subtler than the changes from geocentrism to heliocentrism, from phlogiston to oxygen, or from corpuscules to waves, *the resulting conceptual transformation is no less decisively destructive of a previously established paradigm*. We may even come to see it as a prototype for revolutionary reorientations in the sciences. Just because it did not involve the introduction of additional objects or concepts, the transition from Newtonian to Einsteinian mechanics illustrates with particular clarity the *scientific revolution as a displacement of the conceptual network through which scientists view the world* (Kuhn, 1962 (1996), p. 102; italics mine).

The displacement of the conceptual network is the result of two specific factors. Kuhn, who holds that the parallelism between political revolutions and scientific revolutions is helpful, argues that the prerequisite to a revolution, whether political or scientific, is a "sense of malfunction." This signifies that, in the case of a scientific revolution, an "existing paradigm has ceased to function adequately in the exploration of an aspect of nature to which that paradigm itself had previously led the way" (Kuhn, 1962, p. 92). Needless to say, Kuhn does not think that those outside the new paradigm or that those not being affected by it would perceive the *revolutionary* aspect of a specific scientific development. Unless one's paradigm is affected by new modes of perceiving, explaining and categorizing reality, one may simply accept them as the normal developmental process of scientific knowledge (Kuhn, 1996, p. 93).[18] Furthermore, scientific revolutions do not require a complete replacement of an old paradigm. As in political revolutions, scientific revolutions emerge as the result of elements completely or partially in contradiction within the established epistemic structure.[19] As he points out, "scientific revolutions are here taken to be those non-cumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one" (Kuhn, 1996, p. 92).

On the other hand, a technological revolution is concerned with radical new ways of building objects (applied or practical level). It is often assumed that technological revolutions are the direct outcome of scientific revolutions. Because a scientist makes a breakthrough in scientific research, the argument goes new technological applications should follow. Jacques Ellul, however, makes an interesting point by arguing that historically, technique (doing) preceded science (knowing). He notes that traditionally people understood technique as an application of science or, as he puts it, "technique figures as the point of contact between material reality and the scientific formula" (Ellul, 1964, p. 7). In his view, this perspective is radically false because it takes into account only a short period of time (19th century) and a single category of science (physical

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[18] What Kuhn means by "the normal parts of the developmental process" in science is that new discoveries or a paradigm shift in sciences is often the result of an error in scientific research. It is through a mistake, which challenge the established set of norms that a new paradigm can occur. As Kuhn notes, the emergence of X-rays required the violation of one paradigm to create another (Kuhn, 1962, p. 93).

[19] It is crucial to remark that Kuhn's theory does encompass philosophies of science in a broad perspective, which includes general theories in epistemology, psychology, or the philosophy of language. As Peter Godfrey-Smith points out, in Kuhn's theory science is understood in the narrow sense. For Kuhn, "science is a form of organized behavior with a specific social structure, and science seems only to thrive in certain kinds of societies. As a consequence, science appears in this story as a rather fragile cultural achievement; subtle changes in the education, incentive structure, and political situation of scientists could result in the loss of the special mechanisms of change that Kuhn described" (Godfrey-Smith, 2003, p. 99).

sciences). What is important, in Ellul's analysis, is to understand that the development of technique needed progress in sciences and consequently, the distinction between "technical activity" and "scientific activity" is not as obvious as one might think (Ellul, 1964, p. 8). This is an important point to keep in mind as I will develop and define nanotechnology as a techno-scientific revolution in the making.

As pointed out nanotechnology represents in part a technological revolution in the sense that it opens the door to new applications in various areas of human activities. This has been true throughout the development of human civilization, which witnessed different stages of technological progress. I do not intend to provide a full account of the different technological revolutions but sketch some of the characteristics of important periods.[20] Marx W. Wartofsky distinguishes four main technological revolutions: the first is what he calls "the revolution of the hand tool" – the very creation of technology and use of tools; the second technological revolution is the "industrial revolution" which marks the transition from "hand" to "machine;" the third revolution is characterized by the use of "calculating or computing machines in conjuncture with other machines" – automatization of production; and finally, the fourth technological revolution is the "politicization of technology" in which science, technology, politics, economics and values[21] converge, technology playing a pivotal role in society at large. In Wartofsky's

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[20] I am indebted to Wartofsky (1992) for my analysis. Other scholars have different categories of technological revolutions. See particularly Rodney A. Brooks in *Flesh and Machines: How Robots Will Change Us* (pp. 6-11) in which he provides the following categories: *agricultural* revolution (10,000 years ago); *civilization* revolution (5,500 years ago); *industrial* revolution (18th century – invention of the steam engine); *information* revolution (19th – invention of the telegraph); *robotics* revolution (current); and *biotechnology* revolution (current). Although these categories are helpful, they do not constitute the basis of my analysis.

[21] Values are not specifically mentioned by Wartofsky, but as I will point out they play an important role in the current research culture of post-academic science (Ziman, 2002, p. 73).

opinion, the fourth revolution is characterized by the central role of high technology for society. As he asserts,

> The measure of the fourth revolution's dominance is the degree to which high technology has become central to the economy, to government policy, to the military, a life and death issue of international hegemony, of competitive edge, of military superiority or inferiority. This is, of course, tautological: what I mean by the fourth revolution is just this dominance of technology in national political and economic life (Wartofsky, 1992, p. 28).

What is important to keep in mind is how progress in economics and politics are closely linked to technology or in other words, and more to the point, to nanotechnology. To use Kuhn terminology, a paradigm shift occurred in the conduct of scientific research and development (R&D). Science cannot any longer be construed simply as an ideal, as the quest for truth (pure science). Science (in its broad meaning) becomes the source of economic (through technology) and by extension, political power (development of weapons, economic development). It is the degree to which scientific knowledge and technology intersects that makes nanotechnology a techno-scientific discipline. Although science and technology are distinguishable, they are inseparable as to how they define nanotechnology.

II. NANOTECHNOLOGY: A TECHNO-SCIENTIFIC REVOLUTION

As a matter of methodology, we must now turn to the definition of nanotechnology and the philosophical assumptions related to scientific research. This task is of primary importance since there seems to be no single definition (although two important features of nanotechnology are characteristic, that is, the degree of control over material properties and the exploitation of novel phenomena and properties at the nanoscale) but rather a plurality of accounts of nanotechnology, and a transdisciplinary dimension to its development (consider the nano-bio-info-cogno (NBIC) convergence of science and technology), with each discipline working from its own particular set of presuppositions, concepts and methods - whether in biology, chemistry, physics, electronics. Any serious consideration of nanotechnology will need to understand each of the "thought collectives"[22] implied by the various fields of research and how, as noted earlier, the convergence of science and technology and its multi- and inter-disciplinary dimension will be possible.

A. Definition of Nanotechnology

What the above account shows is that when on tries to define nanotechnology, the task becomes difficult because the term "nanotechnology" is a catchword that includes various fields of research, concepts and ideas.[23] Reflections on what nanotechnology is still remains unclear since, as Thomas N. Theis points out, not only its definitions vary but also it is pivotal to work at the conceptual level in order to have "a meaningful discourse on the societal impact of nanotechnology" (Theis, 2001, p. 75). The difficulty

[22] This terminology is borrowed from Ludwig Fleck. He defines a *thought collective* as "a community of persons mutually exchanging ideas or maintaining intellectual interaction…that…provides the special "carrier" for the historical development of any field of thought, as well as for the given stock of knowledge and level of culture. This we have designated thought style" (Fleck, 1979, p. 39).

[23] Interestingly, in the workshop report of the IWGN, nanotechnology is defined as a *popular* term: nanotechnology is "the *popular* term for the construction and utilization of functional structures with at least one characteristic dimension measured in nanometers" (Roco, Williams & Alivisatos, 2000, p. ix).

in defining nanotechnology is principally because "nanotechnologists" come from various fields of research (e.g., chemistry, physics, engineering, or material sciences). Thus, nanotechnology can be best described as an umbrella that covers a variety of disciples, each presupposing an emphasis on its own particular scientific methodology and area of research, which affects the way one will define nanotechnology.

An oversimplified definition of nanotechnology could simply be the manipulation of atoms at the *nano*meter scale (*nano* means one billionth, thus one nanometer is one billionth of a meter 1/1,000,000,000 – a human hair, for instance, measures 50,000 nanometers across, Ratner & Ratner, 2003, p. 6). However, if we restrict the definition of nanotechnology to a question of a manipulation at the atomic scale[24] then this does not justify all the attention nanotechnology gets considering that nothing new is done in the various fields of sciences involved in this kind of research. Chemists and material scientists have been working at such level of refinement for decades. Cells are themselves constituted of nanoscale building blocks such as nucleic acids, proteins, lipids, which have been manipulated through human intervention (e.g., drugs). Furthermore, there

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[24] Such perspective is commonly accepted. See for instance the National Nanotechnology Initiative (NNI). Its definition of nanotechnology entails "the research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range; creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size, and the ability to control or manipulate on the atomic scale" (The National Nanotechnology Initiative, 2004). See also The Forsight Institute that regards nanotechnology as "*any technology related to features of nanometer scale*...a technology based on the ability to build structures to complex, atomic specifications by means of mechanosynthesis; this can be termed molecular nanotechnology" (italics mine). Available: www.foresight.org/Nanosystems/glossary/glossary_n.html. Anthony Vigliotti, senior materials engineer at the *American Competitiveness Institute*, likewise forcefully proposes to restrict the definition of nanotechnology to "the creation and exploitation of 1 to 100 nm structures" (Vigliotti, 2003, p. 4). He argues that keeping the definition concise will avoid any nonsense. As he eloquently puts it, "Just like the small glitter that relatives send in birthday party invitations, the definitions are sparkling and exciting, yet annoying and quickly thrown in the trash." (Vigliotti, 2003, p. 4). However, for reason discussed in here, nanotechnology must be more than just a question of manipulating atoms at the nanoscale.

seems to be disagreement as to what scale the realm of nanotechnology starts. Some argue that nanotechnology refers to devices that have a size less than 200 nanometers[25] whereas others contend that nanotechnology concerns only the creation of devices smaller than 100 nanometers[26] while still others conclude that the research and technology at the atomic, molecular or macromolecular levels ranging from one to several hundred nanometers.[27] In short, the ability to move around and manipulate atoms is certainly important in how we define nanotechnology, but as Thies correctly points out "nanotechnology must be about more than the ability to build things with atom scale precision" (Theis, 2001, p. 61).[28] If so, how one should define this new technology and to what extent is nanotechnology different from other technologies?

Due to the current early stages of the development of nanotechnology and the "uncertainty" of its potential applications, it appears as if no clear definition can be provided other than what has just been mentioned. However, in order to address the ethical and philosophical questions related to nanotechnology, one must at least take some initial steps towards a definition.

Roco and Bainbridge, in their introductory comments of the report on the *Societal Implications of Nanoscience and Nanotechnology*, contend that indeed the manipulation at the nanoscale is important because the nanoscale is not simply an advancement into further miniaturization, but "a qualitatively new scale" (Roco & Bainbridge, 2001, p. 1).

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[25] See website: www.eppic-faraday.com/glossary.html
[26] See website: www.cogsci.princeton.edu/cgi-bin/webwn
[27] See website: www.solexa.co.uk/Glossary/g.htm
[28] Although this discussion needs further developments, it is noteworthy to look at Theis' understanding of nanotechnology. As noted above, for him nanotechnology is more than just the ability to build things at the atomic level. In his view, nanotechnology is "about the creation and the manipulation of information… Information is now understood to be a measurable, rigorously defined, fundamental construct of physics, on the same conceptual level as energy or entropy" (Theis, 2001, p. 61).

Because of the ability to manipulate atoms at the nanoscale in ways unknown until recently, previously accepted theories and physical attributes of matter will be inadequate (due to the length scales at which nanotechnology can operate, that is, the unpredictable nature of quantum physics) and consequently the basic sciences in several areas (physics, chemistry, material science, electrical engineering, for instance) will need further development before more concrete applications of nanotechnology can emerge (Roco, Williams & Alivisatos, 2000, p. xii). This means that a characterization of nanotechnology goes beyond a simple definition (at least for now). It requires a thorough analysis of the way science describes, explains, and interprets reality. In short, the definition of nanotechnology depends on particular premises about science and must be regarded as a project that requires a dialectic between science and the philosophy science or as Khushf puts it, nanotechnology is "not quite a scientific project itself, it is more a philosophical project, a kind of philosophy of science that does characterize science in revolutionary periods" (Khushf, 2004a). For instance, the revolutionary way to understand matter at the subatomic level could potentially change the study of biological mechanisms, the prevention, detection, diagnosis and treatment of diseases. The reason is that nanotechnology offers (or could offer) the possibility to operate at the same level as biological processes and focus on individual molecules, which is not possible with current technologies. It could provide ways to study how individual molecules work and behave inside cells offering a better understanding and better perspective in the manipulation of fundamental biological pathways and processes (National Institutes of Health, 2003).[29]

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[29] Due to the focus on nanomedicine in this work, I will provide the full definition of nanotechnology as

B. The Techno-Scientific Revolution

Although nanotechnology resists any specific definition because of its complex integration of diverse scientific enterprises and technological interactions, it can be characterized as partly a science and partly a technology. However, nanotechnology goes beyond the distinction between science and technology because nanotechnology, as an outcome of modern technology, relies heavily on scientific expertise for its own development.

Wartofsky's classification of technological revolutions characterized the transformation of technology and by extension, science. The fourth technological revolution, i.e., the "politicization of technology" (the other three being (1) the revolution of the hand tool, (2) the industrial revolution, and (3) the automatization of production), identifies the various considerations that motivate the development of nanotechnology. Nanotechnology, however, raises a new set of issues that reconceptualize the notion of a technological (and scientific) revolution for two specific reasons I shall develop more fully in a subsequent section. For now, suffice to say that the science of nanotechnology encompasses a range of uncertainties / unpredictability related to how the properties of

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provided by the NIH which captures this revolutionary element: "Nanotechnology has the potential to radically change the study of basic biological mechanisms, as well as to significantly improve the prevention, detection, diagnosis and treatment of diseases and adverse medical conditions. The key to this potential is that nanotechnology operates at the same scale as biological processes, offering an entirely unique vantage point from which to view and manipulate fundamental biological pathways and processes. Most other technologies require the study of large numbers of molecules purified away from the cells and tissues in which they usually function; nanotechnology may offer ways to study how individual molecules work inside of cells. Beyond this, we must develop biomedical applications at the nanoscale in order to integrate unique properties and performance to the macroscopic world of patients. The transfer of information and energy across complex interfaces and multiples length scales is a multidisciplinary problem that requires teams of physical scientists, engineers, life scientists, and clinicians to work closely together" (NIH, 2003).

matter change at the nanoscale.[30] The second reason is that nanotechnology requires a definition that involves the merging of doing (technology) and seeing/knowing (science). When combined, these two considerations create the conditions for a revolution within science and technology, hence the terminology of techno-scientific revolution.[31]

Traditionally, science and technology have been distinguished. Science is a field of study that aims at the discovery of new facts or the addition of new knowledge about the nature of things. It starts with the formulation of a hypothesis or a selection of hypotheses to be tested according to rules and procedures established by past scientific facts. Science seeks what Michael Polanyi calls "originality" through the use of an

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[30] See for instance, the definition provided by the IWGN workshop: "Nanotechnology is the popular term for the construction and utilization of functional structures with at least one characteristic dimension measured in nanometers. Such materials and systems can be rationally designed to exhibit novel and significantly improved physical, chemical, and biological properties, phenomena, and processes because of their size. When characteristic structural features are intermediate in extent between isolated atoms and bulk materials, in the range of about 10^{-9} to 10^{-7} m (1 to 100 mm), the objects often display physical attributes substantially different from those displayed by either atoms or bulk materials. Properties of matter at the nanoscale are not necessarily predictable from those observed at larger scales. Important changes in behavior are caused not only by continuous modification of characteristics with diminishing size, but also by the emergence of totally new phenomena such as quantum size confinement, wave-like transport, and predominance of interfacial phenomena." (Roco, Williams & Alivisatos, 2000, p. ix-x, italics mine). See also Roco and Bainbridge who envision the emergence of completely new phenomena at the nanoscale in chemistry and physics (Roco & Bainbridge, 2001, p. 1).

[31] On the connection between science and technology in relation to what we call "nanotechnology" (which includes nanoscience in its use in the literature pertaining to the field) see for instance Alfred Nordmann who speaks of NanoTechnoScience. First he argues that "nanoscience is not an issue-driven but a place-oriented enterprise. It is neither interested in representations of nature nor in devices that work or substances with novel properties. Truth/falsity and confirmation/refutation do not serve as its epistemic standards, but epistemic success is also not measured in terms of functionality of devices or usefulness of substances. Instead, nanoscience is an exploratory attempt to claim foreign territory and to inhabit a new world or a hitherto unexplored region of the world. Epistemic success is therefore a kind of technical achievement, namely the ability to act on the nanoscale, that is, to see, to move around, move things around, carve your name into a molecule, perhaps initiate productive processes, in other words, to inhabit inner space somewhat as we have begun to inhabit outer space and certainly has we have conquered the wilderness." In relation to his main thesis, he remarks that "this passage speaks of nanoscience as opposed to nanotechnology. Roughly speaking, *nanoscale research* concerns molecular architecture, *nanotechnology* aims for the control of this architecture, and *nanoscience* investigates the physical properties that depend on it. However, if the thesis is correct, it turns out that even nanoscience isn't "science" properly or traditionally speaking, and that even for nanoscience there is no distinction between theoretical representation and technical intervention, between understanding nature and transforming it. More properly one should therefore speak of NanoTechnoScience" (Nordmann, 2004a, p. 51).

innovative power of seeing. On the other hand, technology applies and tests new knowledge acquired through scientific research and turns "known facts to a surprising advantage" either materially, economically or more generally in terms of utility (Polanyi, 1974, p. 179).

Although science and technology are distinct, they do not necessarily form two autonomous spheres of inquiry or application. Pure science and pure technology can certainly constitute two independent endeavors without any necessary links, although scientific research requires technical tools; whereas, the development of new technology is based on new scientific knowledge. Hence, these two fields overlap because of the intertwining of science and technology in certain areas of technological and scientific developments.[32] All technologies are based on an application of science, which in turn may be considered as a scientific system. Polanyi, for instance, argues that

[32] While Polanyi asserts that science and technology may overlap (Polanyi, 1974, p. 179), Bruno Latour is less inclined to think that they indeed *may* overlap, since he argues that it is impossible to differentiate science from technology, although it is possible to retain some difference between the two. He distinguishes science (i.e., the scientist) and technology (i.e., the technician/engineer) in terms of "builder of facts" and "builder of objects" respectively, each one depending on the other for his/her own sake: "The problem of the builder of 'fact' is the same as that of the builder of 'objects': how to convince others, how to control their behaviour, how to gather sufficient resources in one place, how to have the claim or the objects spread out in time and space. In both cases, it is others who have the power to transform the claim or the object into a durable whole. Indeed...each time a fact starts to be undisputed it is fed back to the other laboratories as fast as possible. But the only way for new undisputed facts to be fed back, the only way for a whole stable field of science to be mobilized in other fields, is for it to be turned into an automaton, a machine, one more piece of equipment in a lab...Technics and sciences are so much the same phenomenon... (Latour, 1987, p. 131). Despite the impossibility to distinguish them, Latour argues, there are "two moments" that will allow a distinction related to how scientists and technicians/engineers build their relationships. The first is "when new and unexpected allies are recruited", that is, the differences between scientists and technicians/engineers will become apparent in the laboratories or in the literature relevant to their fields. The second is "when all the gathered resources are made to act as one unbreakable whole", that is, how each field will react when pressured to act as a whole. In Latour's view "this is the only distinction that may be drawn between 'sciences' and 'technics'..." (Latour, 1987, p. 132). See also Gibbons, et al. who note that the distinction between science and technology has become highly questionable in contemporary scientific and technological culture: "the distinction between the two (science and technology) is becoming in most regards highly questionable...Technology as a form of knowledge displays some of the traits of the paradigmatic structure of disciplinary science. Technological knowledge is a mixture of codified and tacit components. Codified knowledge need not be exclusively theoretical but it needs to be systematic enough to be written down and stored..." (Gibbons, 1994, p. 24).

electrotechnics and the theory of aerodynamics are instances of "systematic technology" because they "can be cultivated in the same way as pure science" (Polanyi, 1974, p. 179). By the same token, some areas of pure science can provide useful information from a technological standpoint as, for instance, the study of the properties of certain materials, i.e., "a technically justified science" (Polanyi, 1974, p. 179).[33]

Nanotechnology reflects this overlap between science and technology because its development is dependent upon technological applications and the theoretical framework provided by the quest for new knowledge (fundamental knowledge) of the various scientific fields. As Jean-Jacques Salomon notes, commenting on the relationship between science and technology, "there is the increased association and cross-fertilization between science and technology: *the frontiers between science and technology are becoming so blurred that it is more and more difficult to find a part of science that does not nurture or is not nurtured by technology*" (Salomon, 2000, p. 36; italics mine). In contemporary scientific and technological development, there is a close connection between "the process of discovery" and that of fabrication. Although not specifically

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[33] In fact, Polanyi states that pure science and pure technology may overlap completely: "[T]he two fields may overlap completely. The discovery of insulin as a cure for diabetes was an important contribution to science, owing to the intrinsic interest of its subject matter; it was also the invention of an operational principle serving to cure diabetes. The same quality applies over large parts of pharmacology. It holds, indeed, wherever a process inherent in nature is interesting to science owing to the importance of its outcome, while at the same time it can also be operated at will for achieving this desirable outcome" (Polanyi, 1974, p. 179). Interestingly, he points out, that the distinction between pure science and pure technology was challenged around 1930 by the Neo-Marxian theory of science which was partially driven by the willingness to subordinate "cultural values to a radically utilitarian conception of the public good…It denies the effectiveness of pure intellectual passions in guiding scientific discovery, by affirming that every important step in the progress of science occurs in response to a specific practical interest; while it also denounces the pursuit of science for its own sake as irresponsible, selfish, immoral" (Polanyi, 1974, p. 180). Whether this applies to nanotechnology is rather doubtful. The reason is twofold: first, the development of nanotechnology requires significant financial investments, which can only pay off if some industrial application occurs. Second, due to the potential applications, it would be foolish, if not irresponsible, not to take advantage of the opportunity ahead of us.

mentioning nanotechnology, Michael Gibbons et al. make the interesting observation that, "some materials can now be built up atom by atom, or molecule by molecule, by design, in order to obtain a product with specified properties. In this, the product and the process by which new materials are made become integrated in the design process, implying a closer integration of the process of discovery with that of fabrication" (Gibbons, Limoges, Nowotny, Schwartzman, Scott, Trow, 1994, p. 19). Nanotechnology is an instance of the close integration of the process of discovery and that of fabrication.

For instance, the discovery of a new form of carbon (C_{60} molecule or buckminsterfullerene, named after Buckminster Fuller, who suggested the use of the same structure of buckminsterfullerene for the construction of domes) by Harry Kroto (University of Sussex) and Richard Smalley (Rice University) occurred as the result of the evaporation of carbon using a laser beam. The result was the discovery of a new type of material (nanotubes) that displays interesting properties for industrial applications (e.g., 60 times stronger than high-grade steel but very light and flexible). What this example shows is that without the appropriate technology, the discovery of a new type of carbon would have never occurred. Thus, new scientific knowledge is closely dependent on certain technological artifacts - in this case, there was nothing new technologically, though; the revolutionary dimension was rather at the scientific level where fundamental knowledge was gained (the discovery of the C_{60} molecule) - that will enable scientists to experiment and acquire new knowledge.

Another good example to illustrate the interdependence of technology and science is the use of gold nanoshells for photothermal cancer therapy. Because size matters, properties of certain materials (e.g., gold: bulk gold: yellow / nanogold: red) change as the size of the particles are altered (new fundamental knowledge/science). So far, scientists do no understanding fully how the properties of matter change at the nanoscale. However, they know that by varying the size of a nanoparticle core and the thickness of gold coat on nanoshells, absorption of light and heat will change. Since these nanoparticles possess interesting specificities (a highly biocompatible chemical composition, physiologically compatible size range (ideal for in vivo applications), and it demonstrates intense absorption of light), they could be used to remove cancerous tumors (i.e., new technological application). When attached to carcinoma cells and when exposed to infrared light at laser fluence levels, nanoshells literally "cook" (the absorption of light produces heat) the surrounding cells, i.e., cancerous cells (Loo, Hirsch, Barton, Halas, West, & Drezek, 2004).

Thus, the revolutionary dimension of nanotechnology is the combination of science and technology in one trans-disciplinary field that presupposes new understandings of how matter behaves at the nanoscale (materials at the nanoscale have different properties compare to the same materials at the macro scale) in conjunction with the exploitation of phenomena and manipulation at the nanoscale of atoms and molecules, which necessitates a particular ability to *see* more deeply into the nature of things. As Roco, Williams and Alivisatos point out in their report of the Interagency Working Group on Nanoscience, Engineering and Technology (IWGN), the revolutionary dimension of nanotechnology depends on the ability to discover and utilize the new phenomena and properties of materials at the nanoscale: "rational fabrication and integration of nanoscale materials and devices herald a *revolutionary age for science and technology*, provided we can discover and fully utilize their underlying principles" (Roco, Williams & Alivisatos, 2000, p. ix-x, italics mine).

It is this interdependence of science and technology that produce a *techno-scientific revolution* and not merely a revolution in science and technology. The characterizations of nanotechnology by the NASA Ames Research Center and by Kristen Kulinowski, executive director of The Center for Biological and Environmental Nanotechnology at Rice University, are helpful in this regard. These two definitions provide the basis for my contention. On one hand, the standard definition of nanotechnology provided by governmental agencies reads as follows:

> Nanotechnology is the creation of functional materials, devices and systems through *control of matter on the nanometer length scale* (1-100 nanometers), and *exploitation of novel phenomena and properties* (physical, chemical, biological, mechanical, electrical...) [present only] *at that length scale… A scientific and technical revolution* has just begun based upon the ability to systematically organize and manipulate matter at nanoscale (NASA Ames Research Center, 2004; italics mine).

What is radically new from previous ways of understanding how to build things and manipulate materials at the micro level is the possibility for a bottom-up approach to fabrication by exploiting novel phenomena and properties at the nanoscale (carbon nanotubes; smart materials; nanoscale biostructure – self-assembling artificial bones; photodynamic therapy – treatment only of diseased cells or tissue).[34] This approach is

[34] Richard Jones asserts that our ability to observe and manipulate matter at the nanoscale is novel and not in dispute. As he remarks "what is now not in dispute is that scientists have an unprecedented ability to observe and control matter on the tiniest scales. Being able to image atoms and molecules is routine, but we can do more than simply observe; we can pick molecules up and move them around. Scientists also

still in infancy, but the idea of molecular assemblers able to build things, one atom at the time has been developed by Eric Drexler since the 80s (which, we must say, might never happen as Richard Smalley forcefully argues, see Smalley, 2001, pp. 76-77). Other scientists work on different projects such as the production at the molecular scale of nanotrucks able to move objects (see James Tour, Rice University). This represents a major new understanding of fabrication that could change, to some extent, the industry and medicine, among others things. On the other hand, Kristen Kulinoswski makes the claim that it is not only how size determines the fundamental properties of particles at the nanoscale that is revolutionary, it is likewise, the degree of control over material properties at this scale. (Kulinoswski, 2004, Rice University, Course: *Nanotechnology: Content and Context*).

These novel phenomena at the nanoscale and the degree of control over material properties are not fully understood yet (Roco, Williams & Alivisatos, 2000, p. x) and scientists do not have the technology allowing such control (see the problems raised by R. Smalley with regards to molecular assemblers, i.e., "fat fingers problem" and "sticky fingers problems", Smalley, 2001, p. 76-77). What this suggests is that nanotechnology operates on two levels of uncertainty. First, there are epistemic values about the nature of things that still escape human understanding (for instance the problem of tunneling at the quantum level). What used to be the premises of logical positivism (order and coherence) are now challenged by new ways of thinking and understanding scientific facts (the

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understand more about the ways in which the properties of matter change when it is structured on these tiny length scales. Technologists are excited by the prospects of exploiting the special properties of nano-structured matter. What these properties promise are materials that are stronger, computers that are faster, and drugs that are more effective than those we have now" (Jones, 2004, p. 2).

Heisenberg's uncertainly principle). In other words, a fracture has occurred in science that defeats common sense and reveals what physicist Roland Omnès calls a "strange predominance of abstractness, of formalness, [that] exists at the very heart of reality". This, Omnès argues, requires a new way of understanding particularly when we consider the questioning that took place in physics, i.e., quantum physics (Omnès, 1999, pp. 81-82). Second, even the most advance laboratories do not have the technology that would allow the degree of control necessary to materialize Feynman's vision to arrange atom one by one. There are barriers and limitations that render the ideas of molecular engineering and nanobots as parts of the realm of science fiction, at least for now.

What follows from the above analysis is that the particularity of nanotechnology is the ability to work according to principles defined by classical mechanics and/or quantum physics. The nanoworld includes length scales from 1 to 100 nm, the range that encompasses the laws of classical mechanics and its predictability in material properties (Newton), and the laws of quantum mechanics characterized by probabilities and unpredictability (Heisenberg). The technological applications on the quantum side (1 nm) still require further scientific developments in order understand the probabilistic nature of research at that scale. Alternatively, nanoscience needs a strong tie to technology in order to test and apply new knowledge acquired through scientific research.

To summarize, nanotechnology could revolutionize how, at the nanoscale, things are explained/seen (the understanding that atoms can be controlled and manipulated) and built (the ability to build things at the nanoscale from the bottom up). Consequently, nanotechnology is a techno-scientific revolution in the making because there is an interdependence of science and technology for its development and because it allows the unprecedented manipulations of atoms at the nanoscale and the exploitation of novel phenomena. Nanotechnology shows how the connection between science and technology is changing into what Cilliers calls the "technologisation of science," meaning that there is an interdependence between technology and science, but also that the development of technology has surpassed the theoretical dimension of science (Cilliers, 1998, p. 1). In other words, scientists and engineers have the ability to develop innovative technologies that work, but there are some scientific principles associated with them that cannot be explained due to our limited knowledge. Thus, while technology will certainly continue to advance, it will need, at a certain point, to have a better understanding at the theoretical level of its technological applications. Without such theoretical foundation, technology could run the risk of discrediting itself due to a lack of understanding of the possible consequences in the environment and for society and human life.

III. RISKS AND DANGERS ASSOCIATED WITH NANOTECHNOLOGY

The controversy surrounding the potential risks and dangers of nanotechnology finds respected scientists on both camps. On the one hand, those who clearly see imminent and/or serious potential risks and on the other hand, those who think that the projected potentials will remain only futuristic dreams or at least the applications of nanotechnology are limited (for instance, Richard Smalley) and consequently the risks and dangers involved are likewise limited.

Understanding and assessing the pros and cons of both camps will require a careful analysis of the advanced arguments and determine whether these represent real concerns or simply a particular set of socio-political presuppositions concerning scientific research. In order to clarify the type of risks and dangers involving nanotechnology, I delineate three categories: (1) *manifest* risks and dangers, (2) *potential* risks and dangers, and finally (3) *perceived* risks and dangers. Each category assumes different premises that need careful consideration in our final analysis.

A. Three Categories of Risks and Dangers

I recognize that a classification is to some extent arbitrary and that some of the risks and dangers could overlap between categories. However, in distinguishing them, one will have a better sense of the issues at stake, particularly separating imminent vs. potentially ethical concerns and how to address them in a more coherent and systematic manner. Thus, rather than simply listing the risks and dangers associated with nanotechnology, I will distinguish them and categorize them into three main groups: 1) *manifest* risks and dangers; 2) *potential* risks and dangers; and 3) *perceived* risks and dangers.

In what follows, I recognize six categories of issues: a) nanopollution: in the human body (nanomedicine) and in the environment (runabout nanobots, nanomaterials); b) privacy issues: the use of nanodevices for monitoring and surveillance, use of microscopic implants to track people; c) human enhancement: improvement of the brain's mental capabilities or the body's physical abilities (human-machine interface); d) misuses and abuses for military purposes: development of nano-weapons escaping human scrutiny; e) social disruption: decrease of job availability and question of social justice; and f) increased false expectations: false hopes concerning the potential to solve social issues such as famine, pollution, famine and poverty. Each of these types contains sub-categories that do not specifically fit into one group of risks and dangers. My analysis will attempt to show these differences.

1. *Manifest* risks and dangers

Manifest risks and dangers are the type of issues that are already present in different forms in other settings like biotechnology. Particular applications at the nano-level would amplify these risks and dangers due to the nature of the new technologies.

The first issue is the question of privacy in relation to the use of nanodevices. Nanoscientists are looking at applications in the biomedical sciences for revolutionary medical procedures, such as the creation of censors implantable in the human body for the monitoring of cancerous cells. Potentially these censors could be used for purposes other than medical. For instance, one could imagine their utilization for the retrieval of data (e.g., genetics) that could raise issues in relation to health insurance coverage and benefits and employment opportunities. Furthermore, with the miniaturization of computers, microscopic implants could be used to track – willingly or unwillingly – people in the same way current systems are used to track cars using Global Positioning Systems (GPS) (Weckert, 2002, p. 367)[35]. Finally, nanodevices could be used for

[35] See for instance Micheal D. Mehta who looks at nanotechnology from a sociological point of view. Referring to Michel Foucault's analysis of the panopticon, Mehta suggests that some applications of nanotechnology can raise the problem of what he calls "nano-panopticism", that is, issues related to "nano-scale devices for surveillance, tracking, and monitoring." Privacy, he writes, is fundamental for life in

surveillance and hence raising the question individual privacy.[36] So far, we are quite distant from an Orwellian society but the risk of abusive monitoring of people's lives is real.

The second issue is also quite real in the current geo-political context. It concerns the threat of terrorism using nanoweapons. The technology is not ready yet for such arsenal but we are on the verge of a techno-scientific revolution that could encourage the development of new weapons in order for a nation to establish its international hegemony (Wartofsky, 1992, p. 28). As it is the case for other types of weapons, nanoweapons raise the question of its misuses for military purposes. A race for the development of nanoweapons could start for purely political reasons (political power) but could end up, some fear, in the destruction of the environment – whether accidentally, by terrorists or conflicts – by technologies derived from nanotechnology (see for instance Howard, 2002).

Finally, there is the risk of nanopollution in relation to the toxicity of nanotubes, which possess unique electrical, mechanical and thermal properties that have important potential applications in electronics, aerospace industry and computing. A recent research

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society. However nanotechnology could jeopardize this value: "privacy is generally defined as the right to be let alone and the right to control the flow of certain kinds of personally identifiable facts. As a precondition of trust, privacy is an essential ingredient in a society where 'social capital' is required for stimulating innovation. A society with strong social capital is one where social trust facilitates co-operation and networking for mutual benefits. The threat of nano-panopticism creates a paradox that may prove intractable. The wide-scale use of surveillance equipment may create a society with lower levels of trust, less social capital and depressed civic engagement. In short, these uses of nanotechnology could depress innovation and lead society towards an Orwellian future as presaged in the novel *1984*." (Mehta, 2003)

[36] On the legal and policy implications see Gutierrez (2004). The question is not whether such nanodevices should not be used for surveillance but rather to make sure that their use is consistence with the Fourth Amendment (i.e., respect of privacy). As she puts, "[n]anotechnology presents the potential for new surveillance devices, but this does not mean that individuals should abandon traditional conceptions of privacy. Instead, we face a challenge in constructing socially beneficial nanotechnology policy. We should explore and engage in a continuing dialog about how nanotechnology can be implemented to benefit individuals without causing damage to privacy…" (Gutierrez, 2004).

team at the Space and Life Science of NASA Johnson Space Center, Wyle Laboratories, and the Department of Pathology and Laboratory Medicine at the University of Texas in Houston addressed the question of the toxicity of nanotubes in the lungs of mice. The study revealed that, under the test conditions, nanotubes are highly toxic, even more toxic than quartz, for instance, this is considered a significant occupational health hazard if inhaled periodically (Lam, James, McCluskey & Hunter, 2004).[37]

2. *Potential* risks and dangers

Potential risks and dangers involve risks and dangers that have the ability to become real under particular conditions and/or as the result of the lack of proper use of technology. These are the kinds of risks that relate to firearms. For example, a rifle, if properly used and under the right conditions, can be effective in protecting someone against an aggressor or can be used to hunt in order to feed one's family. Similarly, the risks and dangers in this category become actual insofar as certain rules are not respected. However, these risks and dangers are not present in other spheres of scientific research and are specific to nanotechnology.

Nano-pollution in the environment, whether molecular assemblers (gray goo problem) or other toxic nanomaterials, can be categorized as a potential threat insofar as people misuse them by negligence (scientific or else) or purposively decide to misuse them for terrorist actions, for instance. At the scientific level, the problem of runabout self-assemblers seems not to be a major concern at this stage of nanotechnological

[37] Similar concerns are raised in relation to the food chain, usually called bioaccumulation. Bioaccumulation occurs when substances are long-lived, mobile, soluble in fats and biologically active. Many nanomaterials have the first three characteristics (Brown, 2002).

development for reasons advanced by Richard Smalley (2001), although Drexler has a different view of potential future developments.[38] First, there is the "sticky fingers problem," that is, the problem of how technically to release atoms on command (the manipulator's hands will be constituted of atoms, and the issue is then that the atoms to be moved will stick to the atoms of the manipulator). The second issue is called the "fat fingers problems", that is, there is not enough room for the fingers of the manipulator's hands to move atoms around at the nanoscale (a lack of control of the chemistry necessary for atomic manipulation). Finally, there is not enough advanced knowledge in chemistry for such projects. In Smalley's view, nanobots or molecular self-assemblers will never become a reality and remain a "futurist's daydream" (2001, p. 77). For this reason, at least for now, the fear of self-replicating assemblers destroying the environment is far from actuality.

That being said, it is necessary to think proactively and anticipate what could go wrong if society does not take the necessary precautionary measures[39] to provide the right framework for the development of nanotechnology. According to Vicky Colvin, director of the Center for Biological and Environmental Nanotechnology at Rice University, more resources should be available for research in the area of nano-pollution. She points out that in fiscal year 2003 less than half a million dollars out of a total of $700 million in

[38] See Baum (2003) on the controversy between Smalley and Drexler on the potential creation of molecular assemblers.

[39] The use of the terminology "precautionary measures" does not refer to the precautionary principle as the basis for my reflection. As Chris Phoenix and Mike Treder from the Center for Responsible Nanotechnology have demonstrated, a strict adherence to the precautionary principle does not take into account the outcomes of no action at all (Phoenix & Treder, 2003).

funding for the National Nanotechnology Initiative were allocated to the study of the environmental impact of nanotechnology (Colvin, 2002).

The second potential type of risks is related to human enhancement. Two concerns deserve close attention. The first is related to human nature, that is, to what extent, as a society, we should allow the alteration of what we know currently as human nature (i.e., biological functions of the human body).[40] What should be the parameters that would rend illicit particular enhancements outside the bounds currently known as human nature? Who should set the standards and on what ground? Biomedical sciences has always focused on the enhancement of the body's capacities either to fight diseases (decreased mortality and morbidity) or to improve its physical abilities. The general outcome for the population has been better health and increasing life span. However, the potential risks of such transformation/enhancement could be twofold: first, it could end up in prolonging the life span to the extend that it could create a problem of overpopulation (Moor & Weckert, 2003); second, it is not clear how to set the limit in the interface between humans and machines/technology. Some hope to achieve physical immortality through technological advancements (i.e., transhumanists) while others

[40] Biotechnological innovations have rendered the determination of a normative concept of human nature difficult because technology has invaded what is traditionally considered human nature, i.e., the *biological* functions of the human body; now potentially the rational functions (e.g., implant of chips in the human brain). The increasing use of technology has resulted in removing the distinction between what is human (nature) qua biological and human (nature) qua artificial or technological. As Kurt Bayertz remarks, "what a human being is, what he can do and how he looks, will in the future become ever less dependant on default biological facts and ever more on the progress of medicine and biotechnology. In short: human nature will become technologically contingent" (Bayertz, 2003, p. 132). This technologization of human nature finds its way in various applications in medicine and therefore it is essential to reflect on how to draw the line between "legitimate and illegitimate biotechnological interventions" (Bayertz, 2003, p. 133). However, such reflections require first addressing the issue of the normativity of human nature. Due to the complexity of the question, I will not address this issue in this work. For further discussions on the issue of human nature and its normativity, see the special issue in *The Journal of Medicine and Philosophy*, 2003, 28(2), pp. 131-254.

suggest that the development of Artificial Intelligence will result in the creation of machines able to compete with human intelligence[41] which could lead to the merging of humans with machines. To what extend such merging should be allowed and would be beneficial to humans is difficult to assess, but further critical analysis is crucial for the human race as a whole.

The third potential risk related to nanotechnology is the development of mind-control systems and torture nanodevices introduced in the human body (Moor & Weckert, 2003). The same technologies could be used positively for increasing one's memory or intellectual potential, but also to control one's mind by releasing certain chemical in the brain or use nanodevices to torture people. Again, the positive or negative use of this type of technology will depend mostly on who uses it.

3. *Perceived* risks and dangers

The final category, namely "issues *perceived as* risks and dangers", relates to questions for which there are no immediate answers and dependent on one's particular projections in what the future will hold. Because they relate to a new field of scientific inquiry, they have or take a particular dimension unknown up to now. It also implies a broad spectrum

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[41] See for instance Ray Kurzweil who predicted in 1999 that computers will exceed human intelligence by 2020: "One reason for this disparity [between human intelligence and computers] in capabilities is that our most advanced computers are still simpler that the human brain...But this disparity will not remain the case as we go through the early part of the next century. Computers doubled in speed every three years at the beginning of the twentieth century, every two years in the 1950s and 1960, and are now [1999] doubling in speed every twelve months. This trend will continue, with computers achieving the memory capacity and computing speed of the human brain by around the year 2020...Computers will be able to read on their own, understanding and modeling what they have read, by the second decade of the twenty-first century. Ultimately, the machines will gather knowledge on their own by venturing into the physical world, drawing from the full spectrum of media and information services, and sharing knowledge with each other (which machines can do far more easily than their human creators)" (Kurzweil, 1999, p. 3).

of interpretations about socio-political and metaphysical[42] concerns. In other words, it relates to how one views the good and the right in society. [43]

For instances, nanotechnology could be *perceived as* a means to resolve some of the most fundamental questions of human existence and survival: there could be (are?) societal expectations that new technology could solve the problems of poverty, famine, and conflicts throughout the world. If this is the case that nanotechnology could be the source of solutions for socio-political problems, some are eager to point out that it could likewise create social disruption on different levels (Keiper, 2003, pp. 33-34). First, it raises the question of social justice, that is, the issue of availability. Who should benefit from the advancement of nanotechnology? Will the divide between poor and rich countries be decreased considering that the development of nanotechnology requires massive investments, mostly available in rich countries? Furthermore, some argue, there is the threat of increasing unemployment. If molecular manufacturing becomes a reality, it could decrease the jobs availability. Due to the minimum human resources required for the managing of the fabrication of products, society as a whole, in particular economists,

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[42] Jean-Pierre Dupuy, professor at the Centre of Research in Applied Epistemology (CREA) in Paris, captures well the ideological and metaphysical underpinnings of scientific culture and calls for "scientifiques 'reflexifs'" [reflective scientists] who are able to recognize their biases: "Des savant avec des oeillères, c'est précisément ce que nos sociétés ne peuvent plus se permettre de former, d'entretenir et de protéger. Il y va de notre survie. Nous avons besoin de scientifiques 'réflectifs': moins naïfs par rapport à la gangue idéologique dans laquelle se trouvent souvent pris leurs programmes de recherche; mais aussi plus conscients que leur science repose irréductiblement sur une série de décisions métaphysiques" (Dupuy, 2004, p. 70).

[43] On the idea of perceptions, see Emmanuelle Schuler: "The perceived risks of nanotechnology are likely to be overestimated. Some of the concerns expressed in the media, by environmentalist groups, and by a handful number of scientists as well, happen to be the trigger points that lead to risk overestimation. Namely: the lack of familiarity with nanotechnology among the public, the uncertainty over equitable distribution of knowledge and of risks/benefits, the difficulty in predicting the potential hazards, and last but not least, the association of nanotech to the public backlash of genetic modified foods. Moreover, dimensions like beliefs, conviction, morality – what is wrong, what is right – and ethics – what is good, what is bad – have so far received little attention from scholars, these views, too, deserve to be explored" (Schuler, 2003)

sociologists, and politicians, would have to think about what the future would look like in a world allegedly "without much to do." Better products that are more durable, combined with lower prices, could change dramatically the face of global economy. Will the same economic structure survive in the light of these considerations? Of course, these are only scientific and economic speculations and it is difficult to estimate for now the transformation nanotechnology could bring at the various levels of society. However, further analysis is needed in order to anticipate potential changes that could be disruptive and therefore could threat social stability.

For now and according to the data available to us, these are only speculations and therefore, as Emmanuelle Schuler points out, these perceived risks of nanotechnology are overestimated. The dimension of perception and interpretation (including beliefs, conviction, morality) have not been adequately addressed by scholars and deserve further investigation (Schuler, 2003).

CHAPTER III

TECHNO-SCIENCES AND ETHICS IN A COMPLEX WORLD

I. NANOSCIENCE-NANOTECHNOLOGY IN CONTEXT

Two sets of considerations must be explored before addressing the question of the moral theoretical framework necessary to sustain a constructive reflection on the ethical implications of nanotechnology. First, it is essential to situate the status of science and technology in our particular context. One cannot assume an account of scientific research and technological advancement without an assessment of the metaphysical and epistemic presuppositions concerning the nature reality. How the various (scientific and in the humanities) communities interact and exchange ideas and knowledge within the context of the process of the "democratization of reality" (Engelhardt, 1996, p. 227; see also Ezrahi, 1990, p.117) plays a pivotal role in how reality is constructed, defined and lived. It is generally assumed that science appeals to facts and "rigorous reasoning concerning facts" in its attempts to revolve scientific issues. However, many authors have pointed out that cultural assumptions influence the conduct of scientific reasoning, inquiry and findings. As H.Tristram Engelhardt, Jr. and Arthur L. Caplan note,

> [M]uch of Western public policy has presupposed that scientific controversies are resolvable by rational analysis and the investigation of the facts. Science has been presumed to be objective. Yet it has become ever clearer that cultural assumptions influence scientific reasoning, and findings, even apart from controversies that have explicitly interwoven

> scientific, political and ethical issues. As a result, the nature of scientific controversies with heavy political and ethical overlays has been thrown into question... (Engelhardt & Caplan, 1987, p. 3).

What Engelhardt and Caplan underscore is that a modern account of science (i.e., objectivity of facts based on empirical truth) is challenged by "extra-epistemic considerations" that is, all science implies the intervention of values, political and moral assumptions. These considerations (political and ethical considerations) not only frame the conduct of scientific inquiry, but also how scientific controversies are debated and resolved. Hence, without laying out the geography of contemporary scientific rationality(ies)[44], one will not be able to see how various scientific accounts assume particular rationalities and how external forces influence science and technology, which brings us to the second consideration. The second set of considerations relates to the role of economics and politics in scientific and technological development, and for our purposes in nanotechnology.[45] In particular, it is necessary to examine the shift that occurred in science from academic science to post-academic science, which includes the use of scientific and technological development for political and economic purposes (Ziman, 2002).

In this chapter, I first address the relation of postmodernity to science and technology. This is a crucial step in my analysis because a postmodern account of science allows a better inclusion of non-epistemic values to be integrated in the examinations of

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[44] On the idea of competing rationalities, see MacIntyre's *Whose Justice? Which Rationality?* (1988). He writes: "So rationality itself, whether theoretical or practical, is a concept with a history: indeed, since there are a diversity of traditions of enquiry, with histories, there are, so it will turn out, rationalities rather than rationality, just as it will also turn out that there are justices rather than justice" (MacIntyre, 1988, p. 9; see also chapter 1).

[45] Interestingly, the role of economics and politics in science is not a uniquely contemporary phenomenon. During the scientific revolution of the 17^{th} century, economic and political factors played an important role in the development of science (see Henry, 2002, pp. 99ff).

the social and ethical implications of nanotechnology. A modern account of science tends to oppose extra-epistemic considerations (political and ethical) to science since the latter is based on facts and not values.[46] However, in order to locate how scientific research takes place in contemporary culture, it is essential to understand the relationship between postmodernity and science or how "many scientific controversies have heavy political and ethical overlays" (Engelhardt & Caplan, 1987, p. 2). Nanotechnology falls into this category.

I then examine the transformation of science and technology, particularly how economics (and politics) influence how science and technology are conducted.

A. The Challenge of Postmodernity to Science and Technology

A postmodern account tends toward a subjectivist and relativistic notions of perceptions and a fragmentation of knowledge, including scientific knowledge. The NBIC's [Nanotechnology, Biotechnology, Information Technology and Cognitive Science] hope to return to a holistic perspective (Roco & Bainbridge, 2002)[47] on scientific research,

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[46] Engelhardt and Caplan, in their analysis, make the distinction between science, politics and ethics. Although each domain assumes a specific set of issues, there is an overlay between science, politics and ethics: "Scientific controversies…are usually seen to be the sorts of disputes that are to be resolved by appeal to facts and to rigorous reasoning concerning facts. Political controversies are held, by contrast, to involve issues properly amenable to resolution by negotiation. Ethical issues fall somewhere in between. Some of them are viewed as issues resolvable by appeal to the nature of reason or morality; others, by appeal to the facts of the situation…In a number of instances, all three genres of controversy are intertwined. Many scientific controversies have heavy political and ethical overlays" (Engelhardt & Caplan, 1987, pp. 1-2).

[47] M.C. Roco and W.S. Bainbridge develop their argument for a unification of science in reference to the Renaissance and its holistic approach. They write that "[t]he Renaissance, coming a thousand years after the decline and fall of the Roman Empire, reestablished science on a stronger basis than before, and technological advancement has continued on an accelerating path since then. The hallmark of the Renaissance was its holistic quality, as all fields of art, engineering, science, and culture shared the same exciting spirit and many of the same intellectual principles…However, as the centuries passed, the holism of the Renaissance gave way to specialization and intellectual fragmentation. Today, with the scientific

however, might not be as easy as it first appears. The foundational presuppositions of modern science and technology in relation to the socio-political and philosophical underpinnings of contemporary culture constitute a major obstacle to the unification of knowledge (a project of modernity). Thus, one of the key questions is to determine whether the knowledge acquired through nanotechnological developments will challenge such a conception of reality (postmodern) or whether it will reinforce it (modernity). In other words, the task is to examine critically and analyze whether a "holistic perspective" on science and technology is possible, especially considering how various discourses (between various fields in science as well as between science/technology vs. humanities, for instance) describe, explain, and conceive reality shaped by postmodern metaphysical and epistemic assumptions. At the risk of repeating, this point is important because these metaphysical and epistemic assumptions shape what nanotechnology is or how it is understood in this work. But first let us turn to the issue of postmodernity.

1. Postmodernity

This section situates briefly the context of science and technology in contemporary culture. First, however, it is imperative to examine postmodernity so as first to explore its nature and then identify how it bears on the metaphysical and epistemic assumptions of scientific knowledge.

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work of recent decades showing us at a deeper level the fundamental unity of natural organization, it is time to rekindle the spirit of the Renaissance, returning to the holistic perspective on a higher level, with a new set of principles and theories" (Roco & Bainbridge, 2002, p. 4).

The issue as to whether post-modernity aptly describes our period in history is an issue that cannot be settled here.[48] However, current scholarship has increasingly recognized that contemporary Western culture is characterized by various irreconcilable ideologies (i.e., postmodernity), whether in political philosophy under the terminology of "mutually exclusive visions of the public good" (Hunter, 1994, p. 15), in moral philosophy, using the language of "interminable arguments" (MacIntyre, 1984, pp. 6, 59), in bioethics, describing the participants in moral debates as "moral strangers" (Engelhardt, 1996, p. 70), or in scientific discourses, i.e., scientific knowledge as a kind of discourse which requires a particular "language game" (Lyotard, 1984, p.3).

Although certain philosophers, such as Jürgen Habermas, are reluctant to accept the intellectual legitimacy of postmodernity (Habermas claims that "the project of modernity has not yet been fulfilled" and that rather than "giving up modernity and its project as a lost cause, we should learn from the mistakes of those extravagant programs which have tried to negate modernity", Habermas, 1993, pp. 101-102), without the appropriate acknowledgment of the fragmented character of the modern moral and epistemological condition, one fails to appreciate the intellectual and socio-political transformation of Western culture which moved from modernity (characterized, among other things, by an attempt to establish a universal account of an objective science and a universal morality) to postmodernity (characterized by the incommensurability of

[48] For an analysis of the passage of modernity to postmodernity see Harvey (1990), especially pp. 39-65. In his discussion on the relationship between modernism and postmodernism, later in the book, he concludes that "there is much more continuity than difference between the broad history of modernism and the movement called postmodernism. It seems more sensible to me to see the latter as a particular kind of crisis, within the former, one that emphasizes the fragmentary, the ephemeral, the chaotic side of Baudelaire's formulation (that side which Marx so admirably dissects as integral to the capitalist mode of production) while expressing a deep scepticism as to any particular prescriptions as to how the eternal and immutable should be conceived of, represented, or expressed" (Harvey, 1990, p. 116).

competing discourses) as an acknowledgement, among other things, of the failure of the Enlightenment (modern) project (Engelhardt, 1996, p. 8; MacIntyre, 1981)[49].

2. Incredulity Toward Meta-Narrative

French philosopher, Jean-François Lyotard, in *The Postmodern Condition: A Report on Knowledge*, argues that postmodernity reflects the transformation in science, literature and the arts that occurred since the end of the nineteenth century and resulted in a state of our culture that exhibits a crisis of narratives (Lyotard, 1984, p. xxiii). Postmodernity is an "incredulity toward metanarratives" that locates its roots in the progress of science and accordingly reflects the crisis of metaphysical philosophy and of the university as an institution (Lyotard, 1984, xxiv). Echoing Lyotard, the Italian philosopher Gianni Vattimo notes that postmodernity is first and foremost a "dissolution of history", that is, "the breaking down of its unity" which in turn has rendered the constructing of a universal history impossible (contra Hegel – the dialectics of Spirit) (Vattimo, 1988, pp. 8-9).

The result is that competing ideologies challenge the legitimization of one particular tradition or narrative as normative, as what used to be called the meta-history

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[49] Within the context of bioethical reflections, Engelhardt notes the recognition of the failure of the modern project to provide a universal morality: "The recognition of this failure [to provide a canonical, content-full secular morality] marks the postmodern philosophical predicament. It is a circumstance difficult to accept, given our intellectual history and its exaggerated expectations for reason. The failure of the modern philosophical project to discover a canonical content-full morality constitutes the fundamental catastrophe of contemporary secular culture and frames the context of contemporary bioethics. One encounters moral strangers, people with whom one does not share sufficient moral principles or enough of a common moral vision to be able to resolve moral controversies through sound rational argument or an appeal to moral authority. When one attempts rationally to resolve such controversies, the discussions go on and on without a final conclusion. Rational argument does not quiet moral controversies when one encounters moral strangers, people of different moral visions" (Engelhardt, 1996, p. 8).

of Western culture. The break down of history into micro-histories and the lack of trust in one particular narrative, according to Vattimo, force the move from modernity to postmodernity (Vattimo, 1992, p. 2). Modernity sought to establish a meta-narrative or a meta-discourse that could provide, through faith in reason and progress, a secular framework for human flourishing. This faith in reason and progress replaced what Vattimo calls the "sacred vision of existence", and by the same token denies any "providential vision of history" (Vattimo, 1988, pp. 101-102), reflecting the crisis in metaphysics as earlier noted by Lyotard. History is conceived through a rejection of the traditional elements of Western culture (social, metaphysical, political elements). It focuses on the "here and now," it tends towards an ongoing actualization of the new, in which history is understood within contemporary events regardless of its genealogy. In short, the new comes to have cardinal value.

3. Postmodernity as Critique of Modernity

Postmodernity challenges some of the cardinal assumptions of modernity, particularly the possibility of a unified vision of the good life for mankind achieved through advances in technology, science, and human reason. As Richard Bernstein suggests, postmodernity can be said to be "a rage against humanism and the Enlightenment legacy" (Bernstein, 1985, p. 25). Translated into the moral realm, for instance, this involves a critical reassessment of the Enlightenment project and a recognition that this project has failed to provide the moral and (epistemological) foundation for Western societies (see Engelhardt, 1996, p. 23; MacIntyre, 1984, p. 51-78). Rather than having secured a morality acknowledged by all individuals as grounded in the canon of reason, the project has mutated morality into conflicting and competing ideologies in which rationally warranted agreement is limited and difficult to attain.[50]

According to Lyotard, the crisis of belief in a unified vision of the good life has its origin in the character of our capitalist society. The combination of contemporary *capitalism* and *technology* alters social bonds, in turn alienating people from what he calls "the old poles of attraction." He points out that

> [The] economic 'redeployment' in the current phase of capitalism, aided by a shift in techniques and technology, goes hand in hand with a change in the function of the State: the image of society…necessitates a serious revision of the alternate approaches considered. For brevity's sake, suffice it to say that functions of regulation, and therefore of reproduction, are being and will be further withdrawn from administrators and entrusted to machines…What is new in all of this is that the old poles of attraction represented by nation-states, parties, professions, institutions, and historical traditions are losing their attraction…Identifying with the great names, the heroes of contemporary history, is becoming more and more difficult (Lyotard, 1984, p. 14).

Lyotard does not imply that the breaking up of the "grand Narratives" necessarily dissolves the social bond leaving an anonymous mass of individuals. To the contrary, he asserts, individuals exist within a "fabric of relations" regulated by language games -

[50] It does not mean, within the postmodern condition, that ethics is transformed into moral nihilism. Edith Wyschogrod, for instance, develops a postmodern ethics and argues that the relation between "postmodernity" and "ethics" requires a radical rethinking of their meaning and representation. As she points out, "the word postmodern prefixed to ethics as its qualifier becomes neither the mere negation of what has, at various times, been interpreted as lawful conduct nor the sign of a dialectical reverberation between normative ethics and its opposite, the negation or defiance of norms. This is because the term postmodern is not an innocuous modifier, a word that is subordinated to the word it modifies. The relation between 'ethics' and 'postmodern' is complex and requires a radical rethinking of the syntactic and semiotic possibilities of each. A postmodern ethic must look not to some opposite of ethics but elsewhere, to life narratives, specifically those of saints, defined in terms that both overlap and overturn traditional normative stipulations and that defy the normative structure of moral theory" (Wyschogrod, 1990, p. xiii).

games of inquiry - rather than by structures justifiable through a theory of communication (Lyotard, 1984, pp. 15-16). Since people do not refer to the past as a reference for their own identity, Lyotard insists, the structure of the postmodern social fabric requires novelty and self-adjustment (Lyotard, 1984, p. 15).

If Lyotard's account of the postmodern context framing the current social fabric is correct, one important aspect ought to be closely considered. The endless demand for novelty alienates the present condition from the past – the old poles of attraction. A narrative construed in such terms projects the past into the present in such a way that the transition from the "then" to the "now" is obliterated on behalf of this craving for novelty. In other words, history becomes an ever-present actuality that denies its genealogy and development. Postmodernity is an attempt to break with the meta-narrative provided by modernity which supported an account of history defined within a particular account of progress.

This break produces a crisis within modernity (Harvey, 1990, p. 116). Modernity as a rationalistic project of promulgating an intellectual emancipation from the Judeo-Christian heritage of Western culture and the establishment of a rationally justified common morality, whereas post-modernity is an attempt to break with this agenda. Modernity has failed to provide a common morality and epistemological rationality that can be shown to govern all area of human activity, including science and technology.[51] Postmodernity is an acknowledgment of this failure.

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[51] See in particular, MacIntyre in *After Virtue* (1981) and *Whose Justice? Which Rationality?* (1988). In *After Virtue,* Macintyre indicates that the failure of modernity to provide a common morality as part of the failure of the Enlightenment project. As he points out, "the problems of modern moral theory emerge clearly as the product of the failure of the Enlightenment project. On the one hand, the individual moral

B. The Implications of Postmodernity for Science and Technology

As noted, Lyotard extensively addresses the question of the philosophical and epistemological underpinnings of postmodernity particularly within the context of science (Lyotard, 1984).[52] He characterizes modernity as "any science that legitimates itself with reference to a metadiscourse of this kind [discourse of legitimation called philosophy] making an explicit appeal to some grand narrative…" whereas post-modernity is incredulity toward metanarratives (Lyotard, 1984, pp. xxiii, xxiv). Or as Sandra D. Mitchell puts it, postmodernity is the rejection of universal, exceptionless laws

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agent, freed from hierarchy and teleology, conceives of himself and is conceived of by moral philosophers as sovereign in his moral authority. On the other hand, the inherited, if partially transformed rules of morality have to be found some new status, deprived as they have been of their older teleological character and their even more ancient categorical character as expressions of an ultimately divine law. If such rules cannot be found a new status which will make appeal to them rational, appeal to them will indeed appear as mere instrument of individual desire and will" (MacIntyre, 1981, p. 62). The consequence is that moral reasoning is muted into competing expressions of rationality and morality unable to provide "agreed rationally justifiable conclusions." MacIntyre notes that "arguments…have come to be understood in some circles not as expressions of rationality, but as weapons, the techniques for deploying which furnish a key part of the professional skills of lawyers, academics, economists, and journalists who thereby dominate the dialectically unfluent and inarticulate. There is thus a remarkable concordance in the way in which apparently very different types of social and cultural groups envisage each other's commitments…We thus inhabit a culture in which an inability to arrive at agreed rationally justifiable conclusions on the nature of justice and practical rationality coexists with appeals by contending social groups to sets of rival and conflicting convictions unsupported by rational justification" (MacIntyre, 1988, pp. 5-6). See also Harvey who contends that "the moral crisis of our time is a crisis of Enlightenment thought" (Harvey, 1990, p. 41).

[52] Lyotard is indebted to Heidegger in his critical analysis of modern rationality. Technology, Heidegger argues, is a way of revealing which in turn is a mode of ordering reality or seeing (what Heidegger calls enframing or *Gestell*). Technology gives the illusion that it employs "exact physical science" but in fact gives a deceptive appearance of the application of physical science. As he points out, "because the essence of modern technology lies in enframing [*Gestell*], modern technology must employ exact physical science. Through its so doing the deceptive appearance arises that modern technology is applied physical science. This illusion can maintain itself precisely insofar as neither the essential provenance of modern science nor indeed the essence of modern technology is adequately sought in our questioning (Heidegger, 1993, p. 328). Lyotard refers to Heidegger's concept of *Gestell* in order to criticize modernity rationality and its supposedly absence of a metaphysical postulate. He writes in his essay "Time Today" that "the techno-scientific apparatus which Heidegger calls the *Gestell* does indeed 'accomplish' metaphysics, as he writes. The principle of reason, the *Satz vom Grund*, locates reason in the field of 'physics' by virtue of the – metaphysical – postulate that every event in the world is to be explained as the effect of a cause and that reason consists in determining that cause (or that 'reason'), i.e. rationalizing the given and neutralizing the future. What are called the human sciences, for example, have become largely a branch of physics. Mind and even soul are studied as though they were interfaces in physical processes, and this is how computers are starting to be able to deliver simulacra of certain mental operations" (Lyotard, 1991, p. 69).

to ground explanations and guarantee prediction (Mitchell, 2003, p. 115). Needless to say postmodernity is a complex intellectual movement that deserves more reflections and analysis than here provided.[53] However, the contrast already developed between modernity and postmodernity display the cardinal issues bearing on science (and technology), namely, whether there is unity in the reductionist approach to science: scientific explanations are reducible to a limited number of theories and methodologies that unify science or disunity as in the postmodern pluralistic model of explanations in science, as well as how scientific knowledge can be legitimated or justified.

1. The Disunity of Scientific Knowledge

In the literature pertaining to the discussion of postmodernity in the philosophy of science, the debate concerning models of scientific explanation can be summarized in terms of the dichotomy between scientific realism vs. scientific relativism (Rouse, 1991, p. 607). On the one hand, various forms of scientific realism are characteristic of modernity, particularly as they attempt to reduce scientific explanations to a cluster of universal laws and authoritative principles. Scientific realism is aimed at providing a meta-discourse able to describe, explain and categorize the nature of things in universal terms. On the other hand, a postmodern account (that is, scientific relativism) is

[53] The definition of postmodernity provided here is rather limited in scope but is sufficient for our purposes. For a more encompassing definition see *The Cambridge Dictionary of Philosophy* that defines postmodern philosophy as follows: " Postmodern philosophy is…usefully regarded as a complex cluster concept that includes the following elements: an anti-(or post-) epistemological standpoint; anti-essentialism; anti-realism; anti-foundationalism; opposition to transcendental arguments and transcendental standpoints; rejection of the picture of knowledge as accurate representation; rejection of truth as correspondence to reality; rejection of the very idea of canonical descriptions; rejection of final vocabularies, i.e., rejection of principles, distinctions, and descriptions that re thought to be unconditionally binding for all times, persons, and places; and a suspicion of grand narratives, metanarratives of the sort perhaps best illustrated by dialectical materialism."

suspicious of totalizing concepts such as truth and reality in scientific explanations. Instead, a postmodern account stresses the local context of scientific inquiry and recognizes the plurality of scientific discourses (Rouse, 1991; Loetter, 1994; Murphy, 1990)[54]. The conditions for scientific knowledge are not limited to "scientific knowledge"

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[54] Rouse develops a postmodern philosophy of science that revolves around the theme of "global narratives of legitimation" or the absence of a single account that legitimizes a metanarrative in science. In his discussion on modernity and postmodernity in the philosophy of science, he first contends that the classification of modern and postmodern is ambiguous. "The classification of 'modern' and 'postmodern' texts and practices" he writes, "is both slippery and controversial. Discussions of "modernity" or modernization typically invoke a disparate family of attributes - secularization, rationalization, formalism, individualism and/or the construction of the "subject", capitalism and industrialization, Western imperialism, and so on. Different features often come to the fore when modernity is examined from the perspectives of politics, the arts, social theory, or science and technology. It is unclear whether "postmodernity" is supposed to represent a decisive transformation of culture, merely a new disguise for the reproduction of modernity, or a recognition that stories of modernity have always been fictions, and whether postmodernity is a situation we already occupy or a possibility which still needs to be achieved (or opposed)" (Rouse, 1991, pp. 608). He then specifically turn to the philosophy of science and argues that the question of legitimation is central. He notes that "my discussion of modernity and postmodernity in the philosophy of science focuses around the theme of global narratives of legitimation for several reasons. This theme provides perhaps the closest thing there is to a common denominator in recent discussions of modernity. Emphasizing this theme also allows me the advantage of remaining uncommitted to the accuracy of the various depictions of modernity: Even those who regard the stories of modernity as fictions agree that they have been influential stories. Most important, however, the emphasis upon narrative legitimation seems especially relevant to thinking about "modernity" in science and the philosophy of science. On the one hand, the development of scientific knowledge and its technological applications has been crucial to every narrative legitimation of modernity (and to the counternarratives which reconstruct the story of modern progress as one of unfolding disaster). On the other hand, a central and increasingly controversial theme throughout twentieth-century philosophy of science has been the justification for interpreting the history of science in terms of a modernist story of progress or rational development" (Rouse, 1991, pp. 608-609).

Another account of postmodernity and science is articulated by Nancy Murphy who characterizes postmodern thought as a departure from three main axes of modern thought. Hence, she contends, "three central philosophical theses...have dominated modern thought. The first is epistemological foundationalism – the view that knowledge can only be justified by reconstructing it upon indubitable 'foundational' beliefs. The second is the representational or referential theory of language – the view that language must gain its primary meaning by representing the objects or facts to which it refers. A third essential ingredient in modern thought is atomism, exemplified, for instance, by modern individualism – an approach to ethics and political philosophy that takes the individual to be prior to the community...Postmodern thought may...be defined as that which departs decisively from the three modern axes described above, without reverting to premodern categories (Murphy, 1990, pp. 292-293). In her conclusion, she argues that from a postmodern standpoint "no single theory of scientific language should be expected to fit everything..." (Murphy, 1990, p. 302).

Finally, Loetter puts it well when he summarizes a postmodern philosophy of science in these terms: "In short, a postmodern philosophy of science rejects any attempts at legitimating science by means of grand narratives, urges scientists to resolve philosophical issues pertinent to their own work themselves or in interdisciplinary dialogue with knowledgeable philosophers of science, refuses any overall pictures attempting to explain science as a unity with an underlying essence, and makes sense of per se but are rather challenged or complemented by what Lyotard calls "narrative knowledge" (Lyotard, 1984, p. 7). A pluralistic account of science supported by what John Ziman, in his analysis of the transformation of science and the emergence of post-academic science (see section II in this chapter), characterizes as not only transdisciplinary but as "defiantly post-modern in its *pluralism.*" The outcome is that post-academic science "welcomes wide definitions of knowledge, and decentred diversity, without fear of possible inconsistencies" (Ziman, 2002, p. 210). It finds its justification in the context of application.

In short, scientific knowledge cannot be understood in terms of absolute and objective norms but rather as social constructs that do not aim at developing coherence and credibility at the conceptual level but rather find their legitimation in applications (Ziman, 2002, p. 210).

2. Problem of the Legitimation of Scientific Knowledge

Another issue closely related to the status of science and technology in a postmodern context is the question of *legitimation*. More specifically, it relates to the question of how to discriminate between different claims of truth to justify a particular account of "scientific facts". Lyotard, in *The Postmodern Condition* distinguishes among various areas of possible conflict: first, he asserts, as we have seen, that scientific knowledge does not represent the totality of knowledge. Because the bond between the members of society is linguistic (Lyotard, 1984, p. 40) and because no one can speak all the languages

everyday science as being a set of narrative enterprises" (Loetter, 1994, pp. 159-160). This last point is very important as we critically examine the context in which nanotechnology develops.

of ethical, social and political praxis,[55] other types of legitimation challenge scientific knowledge. He distinguishes three different kinds of language games: denotative (science), prescriptive (law, morality) and technical (technology) (Lyotard, 1984, p. 46). Each assumes a particular ethos in which knowledge and reality are described, understood and interpreted. Outside a particular "language game" (i.e., "ethos"), one will be confronted with what Lyotard calls a differend, that is, the tension and incommensurability marking the heterogeneity of phrase regimens, (i.e., discourses; see *The Differend*, 1988; *The Postmodern Condition*; 1984). Since one of the characteristics of the postmodern context is the rejection of universal and totalizing accounts, there are many language games that create a framework in which consensus at various levels (e.g., at the epistemological and moral level) is difficult to achieve. Thus, reality is always mediated and understood through phrase regimes. Only when one is able to see the tensions between the signified and the signifier (to use Saussure's distinction), then is one able to situate the difficulty if not the impossibility of a universal common language (scientific discourse, for instance) in a postmodern context.

When we turn to science and the philosophy of science, the obvious question is then the very nature of scientific endeavor. A postmodern account of scientific inquiry, in the vein of a Lyotardian account, for instance, not only emphasizes the specificity (i.e., incommensurability) of scientific discourse in relation to other types of knowledge (i.e., narrative knowledge, see Lyotard, 1984, p. 7) but likewise tends towards a fragmenting

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[55] Here Lyotard builds his argument on Wittgenstein's description of language as an ancient city: "Our language can be seen as an ancient city: a maze of little streets and squares, of old and new houses, and of houses with additions from various periods; and this surrounded by a multitude of new boroughs with straight regular streets and uniform houses" (Wittgenstein, 1953, sec. 18, p. 8).

of scientific discourse due to the variety of disciplines involved (each assuming their specific language game) in scientific inquiry (Gibbons, Limoges, Nowotny, Schwartzman, Scott, & Trow, 1994, p. 22).[56]

This account of science is challenged by scholars such a Zuzana Parusnikova who asserts that a postmodern account of the philosophy of science is not compatible with the ends and goals of science. The following quote captures the essence of her argument:

> Science is an epistemological activity: its aim is to obtain knowledge of maximum clarity, certainty and general validity. By the same token, scientific knowledge has the form of systematic knowledge: it is firm, sound and solid. Although scientists admit that cognitive subjects are fallible, theories are not perfect and knowledge is not complete, they want to *construct* a body of knowledge which maximizes these desirable characteristics...[Postmodernism] want to *deconstruct* any established way of reading and understanding of (scientific) texts. It goes in the exactly the opposite direction...There cannot be any alliance between this kind of postmodernism and either science or a philosophy of science which takes science as an authority and wants to provide a theory of scientific knowledge – advising science on methodological issues, providing explanations of what kind of knowledge science delivers, elucidating for science its own assumptions and goals, and so on (Parusnikova, 1992, p. 35).

In other words, Parusnikova sees in a postmodern account of science, a contradiction in its inherent aims and goals because the philosophy of science as a reflection of scientific activity seeks to provide a "meta-inquiry" into the epistemology, assumptions and methods involved in scientific inquiry (Parusnikova, 1992, p. 21). This "meta-inquiry", however, is precisely what postmodernity rejects. Thus, what the above analysis shows is that the two accounts (i.e., modern vs. postmodern) are mutually exclusive. The question,

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[56] "Science possesses a variegated internal structure, made of a vast number of communities or specialisms, each with distinct forms of practice and specific modes of internal and external communication" (Gibbons, Limoges, Nowotny, Schwartzman, Scott, & Trow, 1994, p. 22)

then, is to determine whether a certain degree of unity and coherence can still be achieved in science if we accept the postmodern critique of modernity.

II. TOWARD A PLURALISTIC MODEL OF SCIENCE

The impossibility of a meta-discourse within science and technology due to the incommensurable accounts of scientific explanations reflects the socio-cultural context of competing epistemologies and moralities. With this consideration in mind, the challenge is then critically to examine whether a certain degree of unity and coherent can nevertheless still be achieved[57] – or whether it is even desirable – in science since, as Ziman points out, coherence and credibility are not the primary goals of contemporary science (Ziman, 2002, p. 210). Traditionally science has been oriented towards the unification of knowledge and the generation of universal laws and principles governing the natural world. How then should we address the tension between postmodernity and scientific inquiry (in its modern outlook), considering their conflicting metaphysical and epistemic assumptions?

In order to respond to this question adequately, this section examines what kind of conceptual framework would permit various models of explanation to co-exist and interact despite their differences and/or apparent inconsistencies. Drawing on the work of

[57] Or as Gibbons, et al. put it: "In its most radical and theorized form, as post-modernism, it [the social contextualization] can even be carried to self-contradictory extremes. If all is incoherent and unconnected, playful shadows, how is reflexivity [interrogation, critical thinking] possible? Here a key dilemma is encountered, felt more acutely perhaps in the humanities than in science and technology. On the one hand, reflexivity requires rootedness, a context in which and on which it can act...On the other hand, reflexivity appears to demand an ontological insecurity, an institutionalization of doubt, the need to disembed intellectual forms from the 'immediacies of context'" (Gibbons et al., 1994, pp. 102-103).

John Ziman, this section examines the possibility of an integrated model (an integrated pluralistic model) as a possible answer to the conflict between postmodern thought and the assumptions of scientific inquiry, especially with regards to the nature of nanotechnology (i.e., trans-disciplinarity). Ziman's analysis is helpful because it locates science and technology within our socio-political context and provides insight as to the nature and significance of scientific knowledge in contemporary society. His description of science as post-academic allows a certain degree coherence (objectivity) while recognizing the plural character (transdisciplinarity) of scientific inquiry. This is a crucial point to keep in mind in our analysis of the social and ethical implications of nanotechnology. The emergence of the field called nanotechnology, which includes various scientific fields (physics, chemistry, biology, etc.), reflects a post-modern account of post-academic science, which allows a plurality of definitions of knowledge. That is, various scientific accounts and discourses co-exist despite their (sometimes) opposing presuppositions concerning explanations of reality. Furthermore, such account (post-academic science), includes "trans-epistemic factors, such as human values and social interests" (Ziman, 2002, p. 210), which is key to our analysis for the development of an integrated model.

A. Post-academic Science

John Ziman asserts that "science is being pressed into the service of the nation as the driving force in a national R&D system, a wealth-creating techno-scientific motor for the whole economy" (Ziman, 2002, p. 73). In other words, the "politicization of technology," to refer to Wartofsky's categorization of technological revolutions, has transformed science to an extent that the culture and the epistemic structure of scientific research and development have entered a new era characterized by a "post-academic science" (Ziman, 2002, p. 68)[58].

This new scientific culture is highly *trans-disciplinary* (i.e., involving the integration of scientific and non-scientific knowledge, such as the humanities and social sciences) rather than *inter*-disciplinary (collaboration of several disciplines). It ties the production of scientific knowledge to two key elements: the first is the *economic incentive* in which the aims of scientific and technological development are not the production of knowledge per se but economic development, the funding for which depends on governmental agencies or the public sector (e.g., private companies supporting research). Due to the nature of certain technological applications, particularly military applications,[59] the logical outcome of technological development is political supremacy. The second element is what Ziman characterizes as the *norm of utility*. Although this norm is primarily used to evaluate the usefulness (i.e., economic and

[58] The characterization by Ziman of contemporary science as post-academic is meant to capture the social concern to apply pure scientific knowledge to practical problems, i.e., industrial applications. As Ziman remarks, "[h]aving observed the revolutionary capabilities of this knowledge in medicine, engineering, industry, agriculture, warfare, etc., people have become very impatient with the slow rate at which it diffuses out of the academic world. Governments, commercial firms, citizen groups and the general public are all demanding much more systematic arrangements for identifying, stimulating and exploiting potentially useful knowledge" (Ziman, 2002, p. 73). In other words, socio-economic constraints move scientists away from pure science and closer to pragmatic concerns. For an account of the dialectic between pure science and applied science, see Johnson (2003).

[59] See as an instance of military applications the DARPA (Defense Advanced Research Projects Agency) program in Enhancing Human Performance whose goal is to provide technological hegemony and consequently geo-political supremacy.

scientific validity[60]) of scientific projects, it is also a moral concept determined by human ends, goals and values within the social context (Ziman, 2002, p. 74).

The three characteristics of post-academic science, i.e., *trans-disciplinarity, marketability of knowledge*, and the *norm of utility*, are carefully and critically examined in what follows. These points have been explored by Gibbons et al. (1994) in their comparative study between Mode 1 (traditional model of knowledge production/Newtonian model) and Mode 2 of knowledge production (characterized by at least three main elements: trans-disciplinarity, the marketability of knowledge, knowledge production in the context of application and social accountability). I will not critically compare the two modes of knowledge production but instead refer primarily to Mode 2, since it describes the context in which the development of the science of nanotechnology occurs.

1. Trans-disciplinarity – Complexity

The social and ethical issues nanotechnology raises are not unique but mark other areas of technological developments (e.g., biotechnology in general). However, the particular context in which nanotechnology develops and the collaboration (i.e., convergence of disciplines) between various disciplines in science (and as a matter of fact between science and the humanities/social sciences) which it presupposes, give nanotechnology a particular character. It therefore demands close examination because of its *complexity*. As

[60] It is true that scientific projects and discoveries are evaluated from various economic and scientific angles. However, it must be stressed that discoveries are first evaluated commercially before they are validated scientifically. That is, useless science (whether because of no scientific or social value) will be difficult to justify unless it can be proven to have potential economic benefits (see Ziman, 2002, p. 74).

pointed out, nanotechnology is a complex cluster of fields examining the structure of the physical and biological world at the nano-level. This complexity does not stem from *multi*-disciplinarity (i.e., involvement of many disciplines in one research program) but rather from *trans*-disciplinarity, that is, the interaction between, and beyond, particular scientific and non-scientific disciplines. Since each discipline assumes a particular set of premises and understandings not necessarily shared by other fields, it creates *complex relationships* within and outside of science and technology.

The motives of generating economic growth and developing military technologies transformed and changed the ethos of the scientific community (Mode 2). As a result scientific and technological development takes place *trandisciplinarily*. Mode 2 is concerned with problem resolution within the context of application.

However, Mode 2 is intrinsically transdisciplinary because the solution of practical problems usually results not just from the efforts of various scientific disciplines but also from technological innovations. Gibbons, et al. address this question and stress that,

> Mode 2 knowledge production is transdisciplinary. It is characterized by a constant flow back and forth between the fundamental [theoretical] and the applied [practical]... Typically, discovery occurs in contexts where knowledge is developed for and put to use, while results – which would have been traditionally characterized as applied – fuel further theoretical advances...Mode 2 is characterized by a shift away from the search for fundamental principles [pure science] towards modes of inquiry oriented toward contextualized results [applied/post-academic science] (Gibbons, et al, 1994, p. 19).

It is noteworthy that the collaboration between disciplines is not limited to science but also includes non-scientific disciplines. Helga Nowotny remarks that the new model of knowledge production is *trans*-disciplinary because it *trans*-gresses or, in other words, does not respect institutional boundaries. In her view "[t]here is a kind of convergence or co-evolution between what is happening in the sphere of knowledge production and how societal institutions are developing…[T]he transgressiveness of knowledge is better captured by the term transdisciplinarity" (Nowotny, 2005). The role of societal institutions is clearly apparent in two specific areas: economics and public policy. These are the focus of the next two sections.

2. The Marketability of Knowledge

Future economic benefits play an important role in the funding of research and in the development of strategies for industrial applications. In the light of the transformation of the ethos of science, nanotechnology involves a change in the practice of science in which the ideals of "pure science" appear difficult to sustain. Rather, Mode 2 takes place in the context of *application* in which the process of discovery and fabrication are integrated (Gibbons et al., 1994, p. 19). Contemporary scientific research is not limited to the pursuit of knowledge as an aim in and of itself. It is necessarily bound to the imperatives of social utility, political power and economic development set by governments and the industry.

In other words, Mode 2 of knowledge production is directly linked to the *commercialization of knowledge*. Contrary to Mode 1, Mode 2 is oriented toward the "marketability of science" and thus requires not only the ability to generate useful and marketable knowledge but also involves an increasing collaboration with other sources of knowledge production outside in-house resources, i.e., knowledge available in a vast global network where knowledge is exchanged (Gibbons, et al., 1994, p. 50). In Mode 2, the context of application is the locus and the source of legitimation for knowledge production. However, it is not application per se that is the primary focus of attention by the industry and governments. Beyond the "application imperative" lies a broader set of interests, which is the outcome of the shift that occurred in science, as outlined previously. According to Gibbons, et al. "[t]he current upsurge of interest in applications is only partly a reflection of the persistence of commercial and military interests in science and technology. Equally important has been the shift of interest within science to the understanding of concrete systems and processes" (Gibbons et al., 1994, p. 24). This suggests that scientific projects framed in terms of their economic potential are also constrained by another imperative, that of innovation. As in any other aspects of economic development, scientists will determine the focus of their research according to the prospective financial benefits they might gain in the process of developing new technologies. However, scientific projects remain under the obligation to meet certain criteria of objectivity and innovation inherent to science. These criteria will always be mediated:

> Postacademic science will surely defend objectivity as an ideal, impossible to realise completely in practice *but always to be respected and desired.* But if all research arises in contexts of application, there may never be any occasions where this ideal is paramount. Scientific objectivity is not an abstract philosophical virtue. It is a cultural norm embodied in a web of social practices (Ziman, 1996, pp. 77-77; italics mine).

Furthermore, while market forces drive scientific research other considerations are equally important in determining the "scientific merit" of various projects, such as (1) the necessity of a sufficient degree of scientific plausibility – a project must be scientifically sound (i.e., coherent as to its goals and methods), (2) the level of scientific value – determined by the accuracy and systematic importance of the methods used, and (3) originality – the extend to which a research project will provide new and useful information (i.e., utility and innovation) (Polanyi, 2000, pp. 5-6).

3. The Norm of Utility

The norm of utility is closely related to economic considerations and to the context of application, since within the new scientific culture, discoveries are assessed in term of their economic potentials. However, the concept of utility within the new ethos of post-academic science, Ziman remarks, encompasses considerations beyond economico-political concerns. Utility is a moral concept because it necessitates the inclusion of human values and concerns. It is always determined in relation to human existence. Whether or not one agrees with utilitarianism as a defensible account of morality, John Stuart Mill in *Utilitarianism* (1863) raises a good point as he develops an argument for the moral dimension of utility, particularly in Chapter 2 where he asserts that "this theory of morality" (utilitarianism[61]) is grounded in "the theory of life" (i.e., the presence or absence of pleasure and pain). He also asserts that while the principle of utility is largely limited to the private sphere (as a "directive rule of human conduct") in *rare* occasions,

[61] "Utility, or the Greatest Happiness Principle, holds that actions are right in proportion as they tend to promote happiness, wrong as they tend to produce the reverse of happiness" (Mill, 1863, chap. 2).

when the "multiplication of happiness" is possible, utility is extended to the public sphere.[62]

The context of scientific research can be regarded as "an occasion" in which public utility must be assessed in relation to social accountability. The new culture of contemporary science must enlarge its epistemological horizon and include the moral and social considerations related to the human good and ends (Ziman, 2002, p. 74). These considerations are what Ziman calls "trans-epistemic factors" (human values and social interests) in the production of knowledge (Ziman, 2002, p. 210).

The inclusion of social and moral concerns in science requires an interaction between the scientific community and society. Increasing efforts to guarantee *social accountability* in techno-political controversies are principally due to two main factors (Gibbons et al., 1994, p. 36). First, governmental agencies are pressured to justify public expenditures on science. Social accountability, in this sense, is closely related to the context of application and the commercialization of knowledge. That is, the financing of projects is legitimized on the basis of performativity and marketability. As Lyotard puts it, "capitalism solves the scientific problem of research funding in its own way: directly by financing research departments in private companies, in which demands for

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[62] "But to speak only of actions done from the motive of duty, and in direct obedience to principle: it is a misapprehension of the utilitarian mode of thought, to conceive it as implying that people should fix their minds upon so wide a generality as the world, or society at large. The great majority of good actions are intended not for the benefit of the world, but for that of individuals, of which the good of the world is made up; and the thoughts of the most virtuous man need not on these occasions travel beyond the particular persons concerned, except so far as is necessary to assure himself that in benefiting them he is not violating the rights, that is, the legitimate and authorised expectations, of any one else. The multiplication of happiness is, according to the utilitarian ethics, the object of virtue: the occasions on which any person (except one in a thousand) has it in his power to do this on an extended scale, in other words to be a public benefactor, are but exceptional; and on these occasions alone is he called on to consider public utility; in every other case, private utility, the interest or happiness of some few persons, is all he has to attend to." (Mill, 1863, chap. 2).

performativity and recommercialization orient research first and foremost toward technological 'applications'..." (Lyotard, 1984, p. 45). Hence, the production of proof – designed to gain social approval – does not lie in the constraints of truth or coherence but rather in the constraints of performativity (Lyotard, 1984, p. 46).

Second, the scope of concerns is not limited to the practice of science but includes broad social concerns bearing on the conduct of scientific research. The social and ethical issues raised by science and technology are no longer the responsibility of a "relatively closed bureaucratic-professional-legal world of regulation" but are relocated within the public arena which is characterized by competing models of scientific justification and political legitimation. As Nowotny et al. point out

> This [the regulations] is no longer the domain of a relatively closed bureaucratic-professional-legal world of regulation, but of broader cultural-political movements embodying antagonistic forms of interaction which have become part of the repertoire of how novel technologies are embedded and research products come to be accepted and used in wider social context (Nowotny, Scott & Gibbons, 2001, p. 23).

The role played by such factors in scientific research lies at the basis of a major shift in how scientific inquiry is conducted. Contrary to what occurred in the biomedical sciences (that is, a reactive rather than a proactive approach to social and ethical questions raised by biotechnology), for instance, a thorough reflection on the implications of science and technology (including nanotechnology) requires creative new ways to address ethical and moral conundra. Instead of applying the old paradigm of ethical inquiry, philosophers, scientists and ethicists will have to create conceptually, in a proactive manner, a new type of ethical reflection. What I mean by proactive is a *better integration* of ethical reflection at the core of scientific development itself and not an ethical assessment of the problems already in existence.

B. Final Remarks

The transition from an academic to a post-academic science constitutes the opportunity to reintroduce more straightforwardly an ethical and philosophical input into the development of science qua nanotechnology. However, in order to seize the opportunity ahead of us it is important to acknowledge Ziman's account of post-academic science as part of the broader project called post-modernity. A close examination of what post-academic entails (that is, trans-disciplinarity, the marketability of knowledge and the norm of utility) characterizes nanotechnology broadly defined. First, as noted, nanotechnology requires the involvement of many disciplines, each presupposing various assumptions concerning the explanation, description and manipulation of reality/objects. For instance, the debate concerning molecular assemblers between Eric Drexler and Richard Smalley, both reputable scientists, is symptomatic of how various scientific accounts diverge as to what is possibly achievable. Second, due to the high cost involved in the development of nanotechnology, it is very unlikely that this emerging field will evolve without well defined applications that will generate revenues. As it is the case with pharmaceutical products, companies involved in the development of costly products/applications will not invest without expecting a financial gain to recover their costs. Finally, nanotechnology, due to the potential innovative (and sometimes revolutionary) applications requires the integration of thorough philosophical examinations of its implications not only for us, human beings, but also for the environment, the practice of medicine and society in general. In order to avoid the same mistakes made by those promoting Genetically Modified Organisms (GMOs), educating the public and making sure that ethical guidelines are in place is essential for the development of nanotechnology.

In short, nanoscience/nanotechnology fits the model of scientific inquiry articulated by Ziman and his concept of post-academic science, which he describes as post-modern in its outlook. As he points out in his conclusion concerning post-academic knowledge,

> Academic science, the spearhead of modernism, is *pre-modern* in its cultural practices: and yet it turns out to be *post-modern* in its epistemology.
>
> Contrary to the Legend, science is not a uniquely privileged way of understanding things, superior to all others. It is not based on firmer or deeper foundations than any other mode of human cognition. Scientific knowledge is not a universal 'metanarrative' from which one might eventually expect to be able to deduce a reliable answer to every meaningful question about the world. It is not objective but reflexive: the interaction between the knower and what is to be known is an essential element of the knowledge. And like any other human product, it is not value-free, but permeated with social interests (Ziman, 2002, p. 327).

It is precisely the absence of a metanarrative and the presence of values and social interests that requires the development of an integrated model. This integrated model is detailed in the following chapter.

CHAPTER IV

THE NEED FOR A PROCEDURAL INTEGRATED MODEL

I. PRELIMINARY COMMENTS

The characterization of contemporary science (i.e., post-academic science) as outlined in the previous chapter is important for our understanding of how to frame the social and ethical implications of nanotechnology. Ziman's contention that contemporary science is post-modern in its epistemology (i.e., scientific knowledge does not constitute a universal metanarrative) is crucial to acknowledge because it reflects the nature of nanotechnology. That is, the discipline called "nanotechnology" does not represent a general theory concerning the explanation of reality at the nanoscale and how to manipulate atoms at that scale. Rather, nanotechnology is constituted of various scientific fields (physics, chemistry, biology, etc.), each assuming diverging presuppositions concerning reality at the molecular level. For instance, the debate between Eric Drexler and Rick Smalley concerning molecular assemblers is revelatory of this lack of agreement. Both are well-known scientists. However, they diverge sharply concerning future applications of nanotechnology. In particular, the debate turns around a different appreciation of what can be accomplished by nanotechnology at the molecular level. Interestingly each argues from a different standpoint, either from the perspective of chemistry (Smalley) or mechanics, i.e., mechanical processes, (Drexler).[63] Furthermore, if it is true that various

[63] See Baum (2003) for an overview of the debate. In a series of open letters between Drexler and Smalley exchanged in *Chemical and Engineering News,* each scientist defends a particular view as to what

scientific fields intrinsically hold competing models of explanation and understanding, it is also the case that these models intrinsically include competing values and norms in the production of scientific knowledge.

These values and norms are equally important in one's assessment of future applications of nanotechnology. Bill Joy, for instance, vehemently calls for a limitation of the development of nanotechnology. In his article "Why the future doesn't need us" (2000), he raises concerns about further advances in nanotechnology and its possible applications and strongly cautions against the misuses and abuses of such innovations. Himself a respected scientist, he asserts that the only realistic alternative to unregulated research and development is scientific relinquishment. As he writes,

> The 21st-century technologies – genetics, nanotechnology, and robotics (GNR) – are so powerful that they can spawn whole new classes of accidents and abuses. Most dangerously, for the first time, these accidents and abuses are widely within the reach of individuals or small groups. They will not require large facilities or rare raw materials. Knowledge alone will enable the use of them. Thus, we have the possibility not just of weapons of mass destruction but of knowledge-enabled mass destruction (KMD), this destructiveness hugely amplified by the power of self-replication...*The only realistic alternative I see is relinquishment: to limit development of the technologies that are too dangerous, by limiting our pursuit of certain kinds of knowledge* (Joy, 2000; italics mine).

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nanotechnology (qua molecular assemblers) can accomplish. Smalley argues from the standpoint of chemistry and sees limitations to applications. He contends that "the central problem I [Smalley] see with the nanobot self-assembler then is primarily *chemistry*. If the nanobot is restricted to be a water-based life-form, since this is the only way its molecular assembly tools will work, then there is a long list of vulnerabilities and limitations to what it can do. If it is a non-water-based life-form, then there is vast area of chemistry that has eluded us for centuries." On the other hand, Drexler argues from a mechanical perspective and believes that there are no limits to nanotechnology and molecular assemblers: "Although inspired by biology (where nanomachines regularly build more nanomachines despite quantum uncertainty and thermal motion), Feynman's vision of nanotechnology is fundamentally *mechanical*, not biological. Molecular manufacturing concepts follow this lead...Elementary physical principles indicate that molecular manufacturing will be enormously productive. Scaling down moving parts by a factor of a million multiplies their frequency of operation...by the same factor. Building with atomic precision will dramatically extend the range of potential products and decrease environmental impact as well" (Baum, 2003).

The current trend, of course, is not the abandonment of R&D in nanotechnology. In fact, it is the opposite movement we see: more and more funding is allocated to the development of nanotechnology throughout the world and it would seem difficult to support its ban considering the substantial financial investments for its development. Consider for instance the following numbers: in relation to nanotechnology, in 2004 Congress approved 961 million dollars to research and development. Since 2001, funding has doubled. The FY 2005 budget reveals that 982 million dollars will be allocated for research and development (Source: OMB supporting data for FY 2005 Budget).

What this suggests is that nanotechnology will continue to develop. Joy's contention that we should limit its development seems very unlikely considering the great potentials in many areas of human life. Thus rather than (naively) relinquishment, what is needed is a methodology in ethics that addresses the various ethical issues related to nanotechnology and the risks and dangers associated with it.

That being said, the trans-disciplinarity of nanotechnology and the convergence of many fields of scientific inquiry requires innovative ways to address ethical and epistemic questions. Some scholars object to the idea that the ethics of nanotechnology need or will become a distinct field of moral inquiry. James Moor and John Weckert, for instance, assert that,

> [i]t is not our position that nanoethics need or will become a separate field of inquiry at all. What matters is that nanotechnology will raise various ethical issues, some new and some not new but with different slants. These ethical issues need to be addressed. We take the business of nanoethics to

> be the ethical examination of the impact of nanotechnology whether or not it is regarded as a specific academic discipline (Moor & Weckert, 2003).[64]

While it is true that some of the issues raised by nanotechnology are not inherent to its development per se, the particular context in which nanotechnology takes place requires an integration not only of the various disciplines involved in its development and research but more important there must be a convergence (i.e., integration) of the scientific and the humanities cultures (Khushf, 2004a)[65].

What the above preliminary comments suggest is that a critical analysis of the social and ethical implications of nanotechnology is confronted with the difficult task to account for pluralism of scientific discourses and the plurality of values and norms these

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[64] See also Armin Grunwald (2005) who argues that it is not necessary to have a independent field called nano-ethics. However, he points out that reflection on "ethics in and for nanotechnology" are needed. As he writes, "we don't have to reckon with a "Nano-ethics" as a new branch of applied ethics. The propagation of nano-ethics overlooks the fact that many of the ethical questions raised by nanotechnology are already known from other contexts of ethical reflection. The ethics of technology, bioethics, the ethics of medicine or also the theoretical philosophy of technology concern themselves with questions of sustainability, of risk assessment, of the interface between human beings and technology, especially between living beings and technology. These questions are in themselves not new..." (Grunwald, 2005, p. 198). Interestingly, however, he notes the novel element of convergence in nanotechnology and the necessity to reflect across disciplines. "Partially new...," he writes, "is their [the questions'] convergence in nanotechnology. Analogous to the well-known fact that nanosciences and nanotechnology are fields in which the traditional borders between physics, chemistry, biology, and the engineering sciences are crossed, various traditional lines of ethical reflection also converge in ethical questions in nanotechnology...We don't need any new sub-discipline of applied ethics called "nano-ethics" but because new topics and questions are concentrated in nanotechnology and because it accelerates scientific and technical progress, there is a need for ethics in and for nanotechnology. Presupposition is, in particular, willingness on the part of the ethicists for an open reflection on ethical aspects of nanotechnology beyond the scope of classical "hyphenated ethics" and to a dialogue with natural and engineering scientists" (Grunwald, 2005, p. 198).

[65] As Khushf puts it, "By developing an alternative to the traditional modes of ethical reflection, where the values debates are secondary to the science and commercial development, we play a central role in configuring a more responsible future. To do this, yet another kind of convergence must take place: the physical, biological, and social sciences need to themselves converge with those forms of life and culture in which the questions of value are addressed in a normative, rather than purely descriptive way; this is the domain of reflection traditionally associated with the humanities: history, literature and languages, religion, and philosophy. Two cultures that have been separate and distinct, often in tension and even opposition, mistrusting and constraining one another; these must themselves be bridged, and a third culture must emerge as a part of the condition of NBIC seeding itself" (Khushf, 2004a).

discourses entail. To address adequately this concern, a model for moral reflection (i.e., procedural integrated model) that takes into consideration this pluralism is developed in this chapter. Furthermore, it will be important to determine the extent to which the ethical questions raised by nanotechnology can be placed within the traditional concerns of bioethics. To that end, it will be necessary to assess, critically, other ethical theories that likewise stress an integrated model (in particular principlism). In a subsequent section, I will particularly show why one of the most influential theories in bioethics failed in its attempt to provide a framework for an integrated model.

II. WHY AN INTEGRATED MODEL? A PARALLEL WITH MEDICINE

The aim of an integrated model is to consider the factors outside science that constrain and shape scientific research and technological development. Since these factors (political, economic and ethical) determine the justifiability of scientific and technological progress, they need to be integrated in the overall assessment of potential scientific controversies. It is important to stress that this is not a totally new development in reflections on science/technology and ethics. Already in the 1960s and 1970s, scientists and scholars interested in the social and ethical implications of new technologies raised concerns about emerging new technologies, especially genetic engineering (see for instance the Asilomar conference in California).[66] Thus, the main

[66] In 1959, already, Charles P. Snow, in his Rede Lecture, addressed the questions of the problem of how to bridge the cultures of the sciences and the disciplines dealing with values (i.e., the humanities and social sciences). The lecture was reprinted as *The two cultures and the scientific revolution* (1959). Five years later he published a second edition in which he added a postscript, *The two cultures: and a second look*

thrust of my argument is not that nanotechnology raises a totally new set of issues but rather that nanotechnology is a further illustration beyond the reflections that began in the 1970s which reinforces the major shift (from academic science to post-academic science) that occurred in science and technology.

In short, the new development in science and technology can be considered as a second wave of the interplay between science (knowledge), the industry (technology), economics, politics and the academia. The issue is not a question of difference in kind, that is, nanotechnology does not bring new sets of concerns, but the development of nanotechnology reinforces the concerns raised by other scientific and technological advancements (genetic engineering for instance) while at the same time creates a new set of questions. For instance, in Chapter Six, I address the issue of how the applications of nanotechnology in the biomedical sciences could transform the practice of medicine.

(1964). In his analysis, he distinguishes the two cultures as follows: "At one pole, the scientific culture really is a culture, not only in an intellectual but also in an anthropological sense. That is, its members need not, and of course often do not, always completely understand each other; biologists more often than not will have a pretty hazy idea of contemporary physics; but there are common attitudes, common standards and patterns of behaviour, common approaches and assumptions. This goes surprisingly wide and deep. It cuts across other mental patterns, such as those of religion or politics or class…At the other pole, the spread of attitudes is wider. It is obvious that between the two, as one moves through intellectual society from the physicists to the literary intellectuals, there are all kinds of tones of feeling on the way. But I believe the pole of total incomprehension of science radiates its influence on all the rest. That total incomprehension gives, much more pervasively than we realized, living in it, an unscientific flavour to the whole 'traditional' culture, and that unscientific flavour is often, much more than we admit, on the point of turning anti-scientific. The feelings of one pole become the anti-feelings of the other. If the scientists have the future in their bones, then the traditional culture responds by wishing the future did not exist. It is the traditional culture, to an extent remarkably little diminished by the emergence of the scientific one, which manages the western world" (Snow, 1959). In response to some criticisms concerning the expression "the two cultures" he devotes a section in the 1964 edition where he recognizes the ambiguities of the terms "culture" and "two" in reference to the 1959 edition (as he writes, "the number 2 is a very dangerous number: that is why the dialectic is a dangerous process. Attempts to divide anything into two ought to be regarded with much suspicion. I have thought a long time about going in for further refinements: but in the end I have decided against. I was searching for something a little more than a dashing metaphor, a good deal less than a culture map: and for those purposes the two cultures is about right…(1959, p. 9)) but insists that "the phrase 'the two cultures' still seems appropriate…" (1964, p. 68).

Interestingly, medicine has faced the same kind of need for integration. Not only does medicine rely upon basic sciences (biology, chemistry, etc…) but also on two other components: 1) values, i.e., ethics, and 2) politico-economic considerations, e.g., one-tier system vs. multi-tier system. Thus a parallel between the "philosophy of medicine" and the "philosophy of nanotechnology"[67] can be helpful to establish a new paradigm for ethical inquiry as it relates to nanotechnology. Furthermore, it is noteworthy to remark that the problem of complexity/transdisciplinarity has surfaced in the practice of medicine as well. In order to cope with the complexity of the social, economic and ethical dimensions of the practice of medicine, the National Center for Ethics has promoted a new approach as to how to construe the role to ethics committees. The model adopted is based on the concept of an integrated ethic. Ellen Fox, Director of the VHA's (Veterans Health Administration) National Center for Ethics explains:

> Integrated ethics is a shift from what ethics committees have traditionally done. The Integrated Ethics Program applies principles of quality improvement to ethics. Quality involves more than technical expertise and patient satisfaction…In essence, integrated ethics programs bring together representatives from various perspectives, including clinical, administrative, and research, to puzzle out the complex business of how to promote high ethical standards in health care (quoted in Lynch, 2001).

What Fox points out (although it is not clear what she means by "principles of quality improvement to ethics") is the necessity to integrate the perspectives of the various domains that concern an ethics committee. The ethical assessment of clinical cases

[67] See Khushf (2004a) who speaks of a philosophical project referring to nanotechnology.

cannot be limited to moral concerns in the traditional sense but likewise includes aspects related to economics, research and policy.[68]

The parallel is limited in its scope because nanotechnology is not restricted to biomedical science and includes branches of the industry that do not concern human beings themselves but rather their environment and their way of life. For example, the development of new materials that could threat the environment, the so-called "grey goo problem." What is relevant to our analysis is the idea of integration. Various "established" moral concepts, methods and traditions in ethical theory have been proposed to solve moral issues in medicine and biotechnology with more or less success due to the competing models of ethical inquiry characterizing bioethics, none being authoritative (Engelhardt, 1996, pp. 65-67; Jonsen, 1998, p. 345). However, as it has been pointed out, the development of nanotechnology is not restricted to one specific field of scientific inquiry. This raises the question of the possibility of an "integrated ethic" in which diverse considerations and perspectives can provide a framework (or frameworks) for ethical reflections that spring out of different fields of investigations, within science and the humanities.

Reflecting on an integrated model is necessary because the development of nanotechnology requires an even stronger collaboration than previously established between diverse fields within the scientific community (physics, biology, engineering and chemistry) and between science and the humanities (Roco & Brainbridge, 2002, pp. 10-

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[68] For a analysis of the medical model as a paradigmatic case, see Khushf (2004b).

13, 83-84).[69] For instance, researchers are developing "novel hybrid nanomechanical devices with biological components" (dry/wet interface) which will raise questions not only on the ethical use of innovative technologies, but it will also require reflection on the impact of technology on biological/human life.

Thus, the task is to determine how to address ethical, social and legal concerns throughout the different stages of the development of nanotechnology in which a culture of intellectual investigation can be fostered that gathers people from the scientific community and those from the humanities or social sciences. More to the point and in relation to moral reasoning, Paul Cilliers asserts that philosophical (and ethical) reflection can play an important role and be essential to scientific and technological development. Traditionally, he writes, the role of philosophy has been to provide a description of what is occurring in science and technology from outside this particular ethos. Cilliers, however, argues that the current development of technology demands new ways of thinking that should include philosophical reflections at the core of scientific and technological practice. As he writes,

> The rise of powerful technology is not an unconditional blessing. We have to deal with what we do not understand, and that demands *new ways of*

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[69] This is not to say that science will achieve unification but rather should be concerned with transdisciplinarity, that is, building bridges between disciplines so as to "connect scientific findings". As Roco and Brainbridge note "...in order to attain the maximum benefit from scientific progress, the goal can be nothing less than a fundamental transformation of science and engineering...From empirical research, theoretical analysis, and computer modeling we will have to develop overarching scientific principles that unite fields and make it possible for scientists to understand complex phenomena. One of the reasons sciences have not merged in the past is that their subject matter is so complex and challenging to the human intellect. We must find ways to rearrange and connect scientific findings so that scientists from a wider range of fields can comprehend and apply them within their own work. It will therefore be necessary to support fundamental scientific research in each field that can become the foundation of a bridge to other fields, as well as support fundamental research at the intersections of fields" (Roco & Brainbridge, 2002, p. 11).

> *thinking*. It is in this sense that...philosophy has an important role to play, not by providing a meta-description of that which happens in science and technology, but *by being an integral part of scientific and technological practice*. Specific philosophical perspectives can influence the way we approach complex systems, and I want to argue that some of these perspective – often broadly labeled as postmodern – are of special value to the study of complexity (Cilliers, 1998, p. 2; italics mine).

What Cilliers points out is that philosophical inquiry ought to be an integral part of scientific and technological practice. Ethical reflection should be at the forefront of nanoscience and nanotechnology and not a discipline at the periphery that provides input reactively rather than proactively. In short, it is crucial to close the gap in time (proactive-reactive distinction) and in intellectual input between science/technology and ethics/humanities (Mnyusiwalla, Daar, & Singer, 2003; Khushf, 2004a, Grunwald, 2005, p. 198).

III. TOWARD A METHODOLOGY OF AN INTEGRATED MODEL OF MORAL REASONING

A. The Geography of Current Bioethical Discourse

In the intellectual development of moral reasoning, various genres of ethical theories have been acknowledged to address moral problems: virtue ethics, utilitarianism, casuistry, natural law theory, Kantianism, communitarianism. Each theory deals with a particular set of conceptual issues, whether attempting to validate the universality of basic values and norms, ascribing content to principles and values, or describing the nature of moral agency and moral actions.

When we turn to bioethics,[70] it is difficult to discern its theoretical foundation since it does not have any dominant methodology or overarching theory (Jonsen, 1998, p. 345). Not only does our contemporary context presupposes different competing methodologies in moral theories (i.e., plurality of moralities), but it also reveals a plurality of rationalities, i.e., various theoretical understandings of bioethics. As Engelhardt points out in reference to the plurality of moral account in bioethics,

> Many theoretical reflections in bioethics have helped clarify the character of arguments, the force of claims, and the meaning of moral principles...The question is, though, whether bioethics has succeeded in securing a theoretical understanding of the various theoretical understandings of bioethics...In bioethics, the journey from the religious orthodoxies of the Middle Ages, through the rationalist hopes of modernity, to the disappointments of post-modernity, spanned less than 30 years. One has during this brief period been brought to look for theoretical and rational guidance, and then one is shown how little guidance is in fact available...This is not to say that there are not regnant fashions or views regarded as correct, according to some bioethical orthodox consensus. It is just that no particular contentful view can be secured as that which is rational and canonical. The challenge will be to live honestly in this impoverished condition (Engelhardt, 1992).[71]

In one sense, bioethics can be said to be an impoverishment of ethical reflection due to the rise of pluralism and the abandonment of traditional sources of morality which resulted in the transformation of medical ethics (characterized by reflections on the physician-patient relationship up to the 1960s) in relation to traditional moral theories and

[70] This is not to say that the same problems occur in moral theory in general. However, the problem concerning the foundation of bioethical theory is even more salient as the traditional points of reference (i.e., sources of moral authority) in Western culture have collapsed. The result is a plurality of moral accounts, none of them being authoritative per se.
[71] As quoted by Jonsen (1998, p. 345).

is concerned with the intellectual "foundations" of moral reasoning within the context of health care, research, experimentation and health care policy (Wildes, 2000, p. 142).[72]

As the field developed outside medicine, it became conditioned by socio-cultural and ideological factors (pluralism) that created a cluster of conceptual problems. Earlier, I pointed out that bioethics is characterized by competing models of ethical inquiry, none being authoritative (Engelhardt, 1996, pp. 65-67; Jonsen, 1998, p. 345). This lack of theoretical consensus resulted in at least three types of problems. First, there is the lack of normativity. Each methodology in bioethics is either tempted to frame ethical issues in relation to the social context in which bioethical issues occur, leading in its extreme form to moral relativism, or aims at producing a normative ethic that would provide universal principles and norms as well as a common moral language relevant for our pluralistic and secular society. However, different *accounts* of morality result in different *moralities* because each moral theory presupposes certain rational and intellectual premises that ultimately shape one's morality. To a certain extent, a universal ethics assumes a common rationality, a position difficult to sustain in the light of the transformation of Western culture.

The second conceptual problem is how to evaluate the importance of universality of moral norms with regard to content. That is, any reflection on the ethical implications of nanotechnology, for instance, will refer to a set of norms, principles and/or values that

[72] Maybe a broader definition of bioethics should be used in the context of this work. The original meaning of bioethics, first used by Van Rensselaer Potter, referred to "the broad terrain of the moral problems of the life sciences, ordinarily taken to encompass medicine, biology, and some important aspects of the environmental, population and social sciences. The traditional domain of medical ethics would be included within this array, accompanied now by many other topics and problems" (*Encyclopedia of Bioethics*, 1995, p. 250).

should be recognizable by the people of various moral traditions and scientific disciplines. The issue at stake is that a moral theory, in our pluralistic secular context, cannot justify a content-full morality and at the same time aspire to universality. "Universality is", Engelhardt writes, "purchased at the price of content. Content is purchased at the price of universality" (Engelhardt, 1996, p. 67). The norms and values that will guide moral reflections in relation to nanotechnology are inevitably limited in their scope because they will not reflect necessarily each segment of the population or each moral tradition but rather a compromise between various moral understandings that will allow establishing a moral framework.

Finally, the third issue relates to how to achieve consensus despite a variety of competing moralities, political ideologies and assumptions concerning the ends and goals of human life. As previously noted, there are domains of human activity that concern society as a whole and therefore consensus becomes the basis for legitimizing certain social practices, such as medicine and scientific and technological development.

In the light of these theoretical difficulties, what type of conceptual framework(s) is necessary to sustain an integrated ethic? Part of the response to this question will depend on developing a methodology in ethics that will allow consensus and social collaboration while recognizing the fragmented character of Western morality.

A second question to address is why there is a focus on theories in bioethics and not on moral theories in the traditional disciplines. In part, the reason is that nanotechnology is an applied science (i.e., techno-scientific discipline) that has the most promising application in the medical sciences or in the life sciences, thus a cluster of issues are similar (but not identical) to other bioethical issues already discussed and examined in the literature, thus providing some foundation to our analysis. Furthermore, since this work, in the subsequent chapters, will look at the ethical issues raised by nanotechnology in its applications in medicine, it is appropriate to consider moral reasoning in the context of theoretical bioethics.

Finally yet importantly, the question of the possibility of an integrated ethic (which will be defined later in this chapter) should be raised. One could argue that an "integrated ethic" begs the question of the possibility of such an endeavor because it could imply a move towards the creation of yet another moral theory that aspires to universality which seems rather difficult support, especially in the light of recent works in moral philosophy and bioethics (see, Engelhardt, 1996; MacIntyre, 1981, 1988) and our contemporary postmodern context marked by competing moralities. In this work, however, I do not intend to develop a universal ethic, but rather a procedural ethic that will allow the resolution of ethical issues considering the pluralism of moral theories.

Also, one must make the distinction between a *universal ethic* and an *integrated ethic.* A *universal ethic* presupposes a common understanding of the values, moral principles and ends of human existence. The most recognized and respected account in bioethics appealing to a universal ethics is articulated by Tom L. Beauchamp and James Childress in their book, *Principles of Biomedical Ethics,* in which they develop a method of moral reasoning on the basis of four middle-level principles that are held to reflect a common morality (autonomy, justice, beneficence and non-maleficence). On the other hand, an *integrated model for ethics* takes seriously the different point of views (i.e., moral understandings, ethical theories, etc. and the moral and epistemic presuppositions of the various disciplines) providing not only space for disagreement but also acknowledging them in the final analysis.

What follows is intended to provide an assessment of the three difficulties encountered in theoretical bioethics, which, as we will see later on, are likewise important in our analysis of the social and ethical implications of nanotechnology. The reason is that the question of a morality able to provide moral guidance to those (not necessarily sharing a common morality) developing nanotechnology and how to ascribe content to these reflections likewise need to be carefully addressed. These three difficulties concern (1) the attempt to secure a universal ethic based on common principles and norms, (2) ascribing content to moral theory, and (3) describing the nature of moral agency and moral actions. I first critically consider principlism, which has defined in many respects the field of bioethics (Wildes, 2000, p. 55) and aims at establishing a common morality with reference to four middle-level principles. Furthermore, Beauchamp and Childress describe their method as "an integrated model" (with coherence of our various moral commitments as its goals, see pp. 397-401) which must be distinguished from the type of "integrated model" I propose. Then I turn to the work of H.T. Engelhardt, Jr. and argue that his conclusion concerning the *de facto* procedural position of moral theory in bioethics is essentially correct but rather than a strong proceduralism (Engelhardt), a weaker form (Wildes) would meet the conditions for an integrated model in relation to the context of post-academic science because it would foster the type of agreement necessary for reflection on the ethical and social issues raised by nanotechnology in the medical sciences.

B. Principlism

1. Theoretical Framework of Principlism

Principlism[73] is a method in moral reasoning that attempts to establish a common morality using the four middle-level principles of autonomy, justice, beneficence and non-maleficence. The most familiar version of principlism has been articulated by Tom L. Beauchamp and James Childress in their book, *Principles of Biomedical Ethics*. They argue that a common morality is possible in our pluralistic society on the ground that each main moral tradition exhibits some characteristics that are common to all moral theories. "Morality", they write, "refers to norms about right and wrong human conduct that are so widely shared that they form a stable (although usually incomplete) social consensus" (Beauchamp & Childress, 2001, pp. 2-3). In their view, the four middle-level principles allow moral strangers to resolve effectively bioethical issues because "all persons serious about morality" share moral norms that "bind all persons in all places" (Beauchamp & Childress, 2001, p. 3). In other words, Beauchamp and Childress hope to provide a normative ethic for the resolution of moral issues in medicine that should avoid the problem related to foundationalism in moral theory (i.e., a set of basic propositions or

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[73] It should be remarked that the work of Beauchamp and Childress, *Principles of Biomedical Ethics*, has gone through many editions. My rendition of principlism is based on the latest version as it appears in the fifth edition.

beliefs self-evident to moral agents) by proposing a weak form of coherentism (i.e., belief in the coherence theory of justification).

That being said, the distinction between foundationalism and coherentism in Beauchamp's and Childress' work is unclear, if not ambiguous. In the elaboration of their methodology of moral inquiry, they stress the importance of basic moral beliefs that need no justification since they are self-evident to "serious moral agents;" "all persons serious about morality", they stress, "are comfortable with these rules [such as not to kill, not to steal, not to cause harm, etc.] and do not doubt their relevance and importance. They know that to violate these norms without having a morally good and sufficient reason is immoral and should lead to feelings of remorse" (Beauchamp & Childress, 2001, p. 3). Paradoxically, however, their theory requires justification (i.e., coherence) as a principle for grounding moral judgments in sound rational arguments. Their "middle position" is clearly stated in what follows:

> Coherentism does not involve the relentless reduction of a chosen set of beliefs to coherence. We start in ethics, as elsewhere, with a particular set of beliefs – the set of considered judgments that are acceptable initially without argumentative support [foundationalism]. We cannot justify every moral judgment in terms of another moral judgment without generating an infinite regress or vicious circle of justification in which no judgment is justified. The avenue to escape is to accept some judgments as justified without recourse to other judgments...Any moral certitude associated with these norms should derive from beliefs that are acquired, tested, and modified over time [justification/coherentism] (Beauchamp & Childress, 2001, p. 400).

In a nutshell, Beauchamp and Childress articulate a moral theory that sufficiently bear on certain moral beliefs supposedly common to all while at the same time recognizing that these beliefs are subject to justification. The process of moving from a set of beliefs (or *prima facie* norms) to their justification requires two initial steps: specification and balancing.

Beauchamp and Childress recognize that the four middle-level principles are subject to interpretation and do not contain enough content to bear a strong enough moral authority by themselves (Beauchamp & Childress, 2001, p. 15). In order to address this problem, they elaborate a three step process that aims at specifying and balancing these abstract principles. The process entails first *specification*. Specification is a *substantive refinement of the range and scope* of the four principles. It is "a process of reducing the indeterminateness of abstract norms and providing them with action-guiding content" (Beauchamp & Childress, 2001, pp. 16, 18). Without specifying, the content of these principles would simply be unable to guide actions that require moral reflection before they can be executed.

The danger of specification is overconfidence (dogmatism) in the process of ascribing a particular content to principles. Beauchamp and Childress acknowledge this and add another key concept in their methodology: *balancing*. Balancing consists in deliberating and judging the relative weight of norms in moral reasoning. Although in some cases, norms are "virtually absolute" and consequently do not require balancing. In most cases, balancing is the process by which reasons are provided in order to prevent a purely "intuitive or subjective assessment" – i.e., in the process of ascribing content (Beauchamp & Childress, 2001, p. 18). When combined, justification and balancing produce *coherence* or *justification*. Justification is based on the principle - developed by

Rawls in *A Theory of Justice*[74]- of "reflective equilibrium" or "coherence theory." This methodology requires grounding our actions on moral convictions (or what Beauchamp and Childress, in reference to Rawls, call "considered judgments", i.e., one's moral capacities will prevent distortion in those judgments) for which we have the highest degree of confidence and the lowest level of bias (Beauchamp & Childress, 2001, p. 398). Each norm relevant to a moral dilemma and the different facts related to it are *integrated* into a coherent whole (based on credible and trustworthy judgments) that aim at providing the basis for moral action.

2. Assessing Principlism

While principlism allows resolution of bioethical problems and avoids some of the problems inherent of foundationalism in moral theories, it nevertheless contains conceptual problems that deserve critical scrutiny. I do not intend to provide an in depth

[74] Rawls articulates his concept of reflective equilibrium as follows: "We can either modify the account of the initial situation or we can revise our existing judgments, for even the judgments we take provisionally as fixed points are liable to revision...It is an equilibrium because at last our principles and judgments coincide; and it is reflective since we know to what principles our judgments conform and the premises of their derivation...From the standpoint of moral philosophy, the best account of a person's sense of justice is not the one which fits his judgments prior to his examining any conception of justice, but rather the one which matches his judgments in reflective equilibrium...This state is one reached after a person has weighed various proposed conceptions and he has either revised his judgments to accord with one of them or held fast to his initial convictions (and the corresponding conception)" (Rawls, 1971, p. 20, 48). In *A Theory of Justice,* Rawls also distinguishes between two types or interpretations of reflective equilibrium. The first allows some leeway as to the interpretation of the concept of justice whereas the second requires the inclusion of all relevant philosophical arguments in one's final judgments: "There are...several interpretations of reflective equilibrium. For the notion varies depending upon whether one is to be presented with only those descriptions which more or less match one's existing judgments except for minor discrepancies, or whether one is to be presented with all possible descriptions to which one might plausibly conform one's judgments together with all relevant philosophical arguments for them. In the first case we would be describing a person's sense of justice more or less as it is although allowing for the smoothing out of certain irregularities; in the second case a person's sense of justice may or may not undergo a radical shift. Clearly it is the second kind of reflective equilibrium that one is concerned with in moral philosophy" (Rawls, 1971, p. 49). In a later work, *Political Liberalism,* Rawls defines reflective equilibrium as when "judgments at all levels of generality are at last in line on due reflection" (Rawls, 1993, p. 45; see also p. 8).

critique of principlism, since others scholars have already articulated the main problems related to this methodology in moral theory.[75] My aim is to give a brief summary of the standard criticisms so as to show why this type of *integrated* model is doomed to fail because it does not adequately address the differences among competing moral theories.

There is a cluster of at least four problems to be leveled against principlism: (1) lack of content of principles; (2) lack of guidance for action; (3) lack of unity; and (4) lack of an adequate account of what it means to be "serious about morality."

a. Lack of Content

Beauchamp and Childress acknowledge that their principles are subject to different interpretations and therefore they require further substantial refinement and assessment against other factors in the decision making process in order to generate a method of moral reasoning. Their concept of ascribing content through specification aims at providing a "certain content" so as to guide actions. The problem is that the meaning and the justification of this particular content will always be determined by the moral agent who does the specification. Specifying what, for instance, the principle of justice requires morally is embedded in various assumptions and moral commitments that do not escape the determinateness of the context and one's definition of justice.[76] This is not to say that content and meaning are relative exclusively to context, but rather that there are

[75] For a criticism of principlism, see Clouser & Gert (1990); Clouser (1995); and Gert, Culver, & Clouser (1997).

[76] On the plurality of concepts of justice, see MacIntyre (1988, pp. 1-11). While Beauchamp and Childress recognize that there are many philosophical theories and approaches to justice (egalitarian, communitarian, libertarian, and utilitarian theories), they favor an approach based on social justice that incorporates utilitarian and egalitarian standards (Beauchamp & Childress, 2001, pp. 225-282).

competing understandings of what justice entails and therefore unless one is able to elaborate and then justify a moral theory that systematically refers to the principle of justice in specific terms, one will not able to justify content through specification. As Wildes puts it, "for principles to have univocal meaning, they must reside in a univocal justificatory and explanatory context" (Wildes, 2000, p. 150). The consideration of the role of this context is exactly what is missing in Beauchamp and Childress methodology since they assume a common morality (Beauchamp & Childress, 2001, p. 3). Principles, by definition, have a particular content that cannot be provided simply by specification because in this process, the more one looks for content the less universality one will find. Content is gained by restraining universality and universality is gained by restraining content (Engelhardt, 1996, p. 67).

b. Lack of Guidance for Action

The second conceptual problem is that principlism per se is unable to provide a sufficient basis of guidance for action and does not recognize adequately the structure of moral agency or the determination of the moral self as the primordial element in moral reasoning. It is one thing to recognize the necessity to act according to some principles considered as universal basic goods, but a concrete action does not necessarily follow without the presence of a strong motive (or motives) that compels someone to act. It is not obvious that "reasons to act" alone can motivate a person to take action, even though strong grounds for acting are present to the moral agent (i.e., understanding the reasons why it is necessary to act in a particular way). If one considers X to be an obligatory action (based on specific reasons), it does not follow that that person will always act accordingly, though they all have a reason to act in such a manner.

Beauchamp and Childress assert that people "serious about living a moral life" recognize some basic goods that lead to "feelings of remorse" if these basic goods or principles are not respected, or at least not sufficient reasons provided for their breaching (Beauchamp & Childress, 2001, p. 3). If this were the case, it would completely obliterate the idea of self-determination or free will and how choices take place in moral deliberation. Human beings would simply respond to a set of moral propositions without exercising their moral agency – much less a will to act in accord with this assessment. It is in this process of ordering goods that the uniqueness of any particular moral account is brought into question.

What is necessary, then, is to view the nature of the self's agency as a primary condition in the determination of an act and not a set of principles. To put it differently, an action is ultimately interconnected with the agent who caused it because as a self-moving agent, humans can impose their will (i.e., their reasons) on their actions through their intentions. In contrast with animals, for instance, humans are characterized by the capacity to intend what they do, to use their will to power in order to determine their goals and orientations. The moral self must be recognized as an entity that can be shaped by external elements (socio-political context, for instance) and/or determined by particular assumptions that will ultimately decide the content of one's "principles" that ultimately will guide actions. The relation between principles, moral agency and actions is lacking in principlism.

c. Lack of Unity

The third problem inherent to principlism is that it appeals to various competing moral theories (utilitarianism, Kantianism, Rawlsian model of justice) in order to justify the content to the principles. However, Beauchamp and Childress fail to provide any systematic process or justification in order to bring these principles into a coherent theory, that is, they are unable to show how the principles relate to each other and how an all-encompassing content-full morality can be developed from the principles (Clouser & Gert, 1990, p. 233; Wildes, 2000, pp. 72-74).

For instance, depending on which moral theory it is related to, the principle of justice is interpreted and applied differently. While Beauchamp and Childress recognize that various conceptions of justice produce different social aims when applied to health care, for instance (see in particular pp. 230ff), they are unable to justify how their understanding and articulation of the principle of justice can be reconciled with opposing views. To the contrary, they favor a communitarian and egalitarian on the ground that it is an influential challenge to utilitarian and libertarian theories (Beauchamp & Childress, 2001, p. 232) but they do not offer any justification as to why their position is more relevant or more suitable in our current socio-political context.

It might be true that communitarian and egalitarian theories constitute challenges to other approaches to justice that are committed to liberty and procedural justice, but it does not follow that a univocal concept of justice can be identified as pertaining to all. The point is not to assess critically whether a communitarian or egalitarian account is a defensible moral theory here. Rather I aim at underlining the fact that principlism does not present a unified theory but reflects a specific point of view concerning the interpretation of the principles, e.g., the principle of justice. As Wildes remark,

> A strength and weakness of the principlism method is that the principles are content-thin. They are thin enough to be general in appeal. However, the principles need content in order to resolve the issues in bioethics. Beauchamp and Childress use the processes of balancing, weighing, specification, and coherence to link the principles to the issues in bioethics. However, each of these elements carries *moral commitments*. This is why many critics have argued that the meaning, interpretation, and relationship of the principles are points of controversy (Wildes, 2000, p. 71-72; italics mine).

In short, the lack of acknowledgment of the fundamental differences and moral commitments among competing models of moral theories and how these differences result in sometimes opposing ends and goals remained unresolved in principlism. Consequently "principlism" does not present a unified theory but rather an effort to combine the major thrust of four moral theories (e.g., utilitarianism, Kantianism, Rawls's concept of justice and Gert's principle of nonmaleficence) (see Clouser & Gert, 1990).

d. What does it mean to be "serious about morality"?

Previously, I pointed out that for Beauchamp and Childress, human beings have innate "intuitions" or a moral sense concerning core norms and values that should order the moral life of those "serious about morality." This statement is rather unclear because anyone formulating a moral theory is indeed serious about morality. Peter Singer is as serious as Jerry Farwell is when articulating his view on bestiality or the killing of hydrocephalic newborns. Thus, the question is not about being serious about morality but rather about how one will rank and assess various moral norms in relation to specific situations. A "serious" utilitarian might argue that the promotion of the happiness of a pregnant teenager (the pregnancy can be a burden due to the lack of financial resources; or it could jeopardize the mother's educational future) is promoted if an abortion is performed whereas a serious deontologist might argue that abortion is wrong because it kills an innocent life. Hence, to refer to someone as "serious" about morality is rather unhelpful due to the competing moralities characterizing ethical theories, each assuming various ranking of norms and values.

Of course, one might argue that the case of abortion is not representative of all moral problems. There are many issues in which agreat deal of consensus is reached. Let us consider Stephen Toulmin's comments on the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research. In an article, entitled "How Medicine Saved the Life of Ethics," Toulmin asserts that:

> [He] was struck by the extent to which the commissioners were able to reach agreement in making recommendations about ethical issues of great complexity and delicacy. If the earlier theorists had been right, and ethical considerations really depended on variable cultural attitude or labile personal feelings, one would have expected 11 people of such different backgrounds as the members of the commission to be far more divided over such moral questions than they ever proved to be in actual fact. Even on such thorny subjects as research involving prisoners, mental patients, and human fetuses, it did not take the commissioners long to identify the crucial issues that they needed to address, and, after patient analysis, of these issues, any residual differences of opinions were rarely more than marginal, with different commissioners inclined to be somewhat more conservative, or somewhat more liberal, in their recommendations (Toulmin, 1986, pp. 270-271).

A counter-example to the consensual agreement described by Toulmin is the conclusion reached following a meeting of President Bush's Council on Bioethics on human cloning. After a two-day meeting, the members remained "deeply divided over the moral status of a human embryo" and had "given up hope" that a consensus on the ethics of human cloning was possible (Associated Press, 2002).

So what is going on? How can we explain such differences? According to Alisdair MacIntyre (1984), three possible lines of arguments can explain how people from different ideological, political and philosophical backgrounds come to consensus.

Commenting on Toulmin's statement, he first argues that divergent moral principles do surprisingly agree when applied to concrete cases. This argument is not persuasive simply because the disagreements (at the level of norms and principles) involved are too fundamental. The discrepancy between the rules and principles each member refers to and the type of agreement concerning the case in question (applied ethics) is too radical.

The second possible explanation consists in approaching ethics through the lenses of casuistry, namely, cases not rules are the fundamental basis for moral reasoning. But this approach is not convincing either. The participants made their decisions based on their rational ability (rules) to discern the different issues but they "misrepresented to themselves the nature of their own moral reasoning" (MacIntyre, 1984, p. 501). What this means is that each member of the commission reaches an agreement on a rational basis but failed to apply it correctly to concrete cases.

The last possible explanation, which is the one MacIntyre favors, asserts that what is actually considered a rational argument is rather a "nonrational social transaction" (MacIntyre, 1984, p. 501), that is, the decision-making process is mediated through various factors that influence moral reasoning. Furthermore, he notes that this account suggests that the rules of morality as commonly construed may not be applied to practical life without an intermediary stage. The link between the two spheres – the theoretical and the practical – demands an interpretation of the principles that will fit the social and ideological arena independently from their traditional understanding.

What MacIntyre identifies is crucial for our analysis of contemporary moral theories and how "consensus" and collaboration is possible in relation to scientific controversies such as nanotechnology. While there can be agreement at the practical level, it is not the case that this agreement applies at the theoretical level. Thus, a distinction must be made between social consensus and theoretical consensus. The latter is, as pointed out, rather very difficult to achieve, while the former, it will be argued, is possible in a weak form of proceduralism.

Before moving to the next section, it is important to stress that in our pluralistic context – not only at the moral level but also at the level of scientific discourse – it appears difficult to refer to one all encompassing moral and scientific account. This is even more clearly the case when reflecting on nanotechnology for reasons related to the context in which the development of this field takes place. As pointed out, nanotechnology is a cluster of various fields examining, explaining and categorizing the nature of reality at the nanoscale. Each discipline and each individual involved presuppose certain assumptions concerning reality as well as the values and norms that should frame ethical and social issues. In this context, then, I argue that a weak form of proceduralism can provide a framework for our reflections on the ethical and social issues raised by nanotechnology. In order to support my contention I will first look at the work of one of the most important proponents of proceduralism (H.T. Engelhardt) and then move to the work of Kevin Wm. Wildes who articulates a weak form of proceduralism that provides a better theoretical framework for our reflections on nanotechnology.

C. Proceduralism

1. Engelhardt

a. The Concept of Moral Strangers

H.T. Engelhardt, Jr. in *The Foundations of Bioethics* articulates the conditions for the resolution of moral issues within our pluralistic context characterized by competing understandings of morality. Engelhardt looks particularly at the context of bioethics which is, in his view, is a late-Enlightenment attempt to provide a common morality in the field of medicine. Since a common ground (tradition, philosophy, religion, etc.) for establishing moral authority is not possible in contemporary reflections on ethical issues, Engelhardt argues the only justifiable alternative is the principle of permission which provides the basis for a morality of mutual respect, which focuses on individuals as the source of "general secular moral authority" (Engelhardt, 1996, p. 119).

Engelhardt asserts that the Enlightenment has failed to provide a common ground for moral deliberation and a content-full morality through sound rational arguments. Accordingly, he points out that the traditional moral theories that influenced the West have failed for three main reasons: first, all these theories are mostly conceptual in form and therefore they cannot generate any content or any guidance. Secondly, these theories are descriptive rather than prescriptive; they do not have the strength to convey any moral authority. Finally, all of them have particular assumptions or specific rankings of the good that are sometimes in opposition between theories. As Engelhardt puts it,

> Rather than possessing the means for discovering or justifying the canonical, content-full account of fairness, each [account of morality] is rather at best an expository device disclosing the implications of a particular moral vision. These particular alternative attempts to establish a canonical moral understanding are not meant to be exhaustive of all species of attempts to justify by rational argument a concrete morality which all should endorse...Content-full moral controversies cannot be resolved by sound rational argument in the absence of common basic moral premises, rules of evidence and inference, and a view of who is in moral authority (Engelhardt, 1996, p. 42).

From this analysis of how moral accounts differ in substance, Engelhardt asserts that people who do not share a common morality are "moral strangers." That is, moral strangers are persons who do not share enough common moral ground to agree on moral issues. Moral strangers, he writes, are "persons who do no share sufficient moral premises or rules of evidence and inference to resolve moral controversies by sound rational argument, or who do not have a common commitment to individuals or institutions in authority to resolve moral controversies" (Engelhardt, 1996, p. 7).

Thus, moral strangers are intrinsic to the moral fabric of secular morality. The secular morality of the Enlightenment attempted vainly to locate agreement through a common grammar able to sustain a common moral language recognizable and recognized by all. However, the Enlightenment project, Engelhardt argues, did not produce a common account of morality established by human reason, but rather resulted in a polytheism of moral understandings, each of them assuming particular ideas of morality and the good (Engelhardt, 1996, p. 37). All moral theories assume what each tries to justify, i.e., a particular set of assumptions and a specific content.

On the basis of the recognition of the fragmented character of contemporary morality, Engelhardt asserts that in order to find peaceable resolutions to moral issues in a pluralistic society without endorsing particular moral, religious or metaphysical assumptions, an appeal to "permission as the source of authority" is the de facto position.[77] Consent constitutes the basis for the resolution of moral litigations and represents a "necessary and sufficient condition (sufficient when combined with the decision to collaborate) for a general secular ethics...[which] is nothing more or less that the authority of those who agree to collaborate." (Engelhardt, 1996, p. 69). Conversely, while he argues that people have the right to decide about the character of the resolution of moral issues, he also makes the point that moral agents have the right to be left alone

[77] It must be emphasized that for Engelhardt consensus has a moral force in so far as there is univocal consensus. When consensus is the result of "a balance of political power" in which people of different moral traditions and assumptions are forced to collaborate, the moral legitimacy of consensus is difficult to establish (Engelhardt, 1996, p. 63).

and therefore are entitled not to participate in any particular community (Engelhardt, 1996, p. 70).

At this juncture, it is essential to keep in mind that Engelhardt is not concerned to set the conditions for a peaceable society but rather he aims at providing the condition for the resolution of moral issues between moral strangers. As he points out,

> This view of ethics and bioethics is not grounded in a concern for peaceableness. It is not based on an interest in establishing a peaceable community...It should, instead, be recognized as a disclosure, to borrow a Kantian notion, of a transcendental condition, a necessary condition for the possibility of a general domain of human life and of the life of persons generally. It is a disclosure of the minimum grammar involved in speaking of blame and praise with moral strangers, and for establishing a particular set of moral commitments with an authority other than through force. This account can be regarded as a transcendental argument to justify a principle of freedom as a side constraint, as a source of authority (Engelhardt, 1996, p. 70).

What it means is that persons are the source of authority (the good, i.e., beneficence, is ultimately determined by what one agrees) in morality and that permission, as a transcendental condition for morality, is the necessary condition (i.e., procedure) to solve moral issues between moral strangers.

b. Assessing Engelhardt's Proceduralism

The force of Engelhardt's analysis and arguments concerning moral reasoning is that it removes the illusion that there is one unifying account of morality from which certain principles can be derived (i.e., Beauchamp and Childress). As previously mentioned, principles are subject to interpretation and therefore, unless one shares a common source of moral authority, these principles have different meanings and meet various expectations bestowed by individuals. Even the principle of beneficence is almost empty by itself if we don't consider how the process of moral reasoning takes place, that is, how moral assumptions about the good, the right and the just will depend on the moral agent. For instance, the diagnosis of a defective fetus constitutes a clinical judgment concerning a particular medical condition. However, although the diagnosis relies on a set of empirical data, the physician's assessment of this clinical case takes place within a cluster of moral values that inform the prognosis and how he or she communicates to the mother the bad news. Whether the physician will suggest, as the best course of action, the abortion or the nurturing of the fetus will depend on his or her particular moral, political and religious commitments.

Furthermore, Engelhardt's procedural ethics takes differences in moral reasoning seriously and set boundaries for the protection of these differences so as to provide the conditions for moral communities to exist peacefully. He is willing to take the risk that certain moral communities might be involved in morally reprehensible acts so as to preserve specific moral commitments considered "unacceptable" according to secular standards. For instance, most secular people would abort a fetus with Down syndrome or severely handicapped because, among other things, of the cost to society to care for such individuals and the quality of life the child would endure. Engelhardt, however, argues (if I am correct in my analysis) that if a community is committed to the principle of the sanctity of human life on a religious ground and therefore is opposed to the abortion of deformed fetuses, the state or any institutions have no right to impose any particular moral visions on that community and should respect, if not protect, these moral commitments. The danger that Engelhardt rightly perceives is the imposition of moral values and norms on communities that do not share, for instance, secular socio-democratic values.

That being said, the concept of moral strangers articulated by Engelhardt is not without problems: while it is certainly the case that people do not share a common morality, there are social practices (medicine, science and technology, for instance) that require common reflections and a willingness to collaborate at the moral level for their implementations in society. The most obvious cases concern issues of abortion, reproductive technologies, human cloning and lately the controversy surrounding the fate of Terry Schiavo (the question is whether society has a particular interest in intervening or whether the case should simply be left to lawyers and the families). However, the concept of moral strangers, if understood as the impossibility to collaborate at the moral level (i.e., foundational level) but the possibility to collaborate at the political level (i.e., procedural level), can lead to a very restrictive understanding of morality in which some moral problems can be reflected upon exclusively within particular communities (whether ideological, political or religious), hence indirectly promoting a moral *laissez faire* in which people are disengaged from moral reflections in the "market of ideas" while engaged in procedural reflections.

Does this mean that people cannot solve moral problems due to the lack of a common and content-full morality? Of course, Engelhardt will answer negatively since he articulates a "proceduralist morality" grounded on the individual as the source of authority and permission as the safeguard for the respect of such individual authority. But morality, Engelhardt stresses, cannot be understood as content-full but rather as procedural. He describes morality, in our particular secular context, as a peaceful resolution of moral controversies, which requires the agreement, or consent of those engaged in situations requiring moral reasoning.

To sum up, a proceduralist ethic provides an attractive alternative to moral theories such as principlism since it recognizes the plurality of moral accounts and provides a peaceful solution to moral quandaries. Contrary to other theories that attempt a priori to ascribe a particular content to principles without any reference to a specific moral tradition or community, Engelhardt articulates an ethic in which the principles of permission and beneficence do not require any content (of the good, one of the main problems in contemporary moral theory) but rather content is given only by what one agrees. The problem, however, is that Engelhardt does not take into account that indeed there can be overlaps between various moral communities, that can offer the basis (limited, I recognize) for a common reflection on various moral issues in science, technology and the biomedical sciences. In what follow, I intend to examine Kevin Wm. Wildes' version of procedural ethics, since it offers, in my view, a richer understanding of morality that takes into account these "limited overlaps."

2. Wildes' Proceduralism

a. Moral Acquaintanceship

Kevin Wm. Wildes articulates a methodology in bioethics, as an alternative to Engelhardt's proceduralism, that captures the pluralistic condition of our society while at the same time acknowledges that indeed different moral communities (philosophical, religious, or scientific) do overlap to a certain extent and therefore moral problems are not limited to particular communities in their analysis. The main thrust of his argument is captured in the following quote:

> In spite of strong differences, there is no reason, a priori, to hold that communities cannot overlap. A consideration of methodology in bioethics needs to address how to account for this overlap. Health care, in secular societies, is a collaborative enterprise and moral problems are not contained only within the boundaries of particular communities. Nor do most men and women live, strictly, within the boundaries of a particular moral community. The categories of moral ecumenism and moral acquaintanceship provide a way to understand and map the different intersections that can and do take place (Wildes, 2000, p. 141).

It must be emphasized that Wildes does not argue for a single communitarian bioethics or morality. Rather, there are various "bioethical communities" competing in the market of ideas, which is marked by a lack of general moral agreement. However, he emphatically makes the point that there may be some overlap between various moral accounts and moral traditions.

Thus, in order to account for the absence of moral unity as well as to recognize that people do not live in isolation and that certain practices (medicine, scientific research for instance) contain a social dimension, Wildes articulates an alternative to both principlism and the type of proceduralism envisioned by Engelhardt. As Wildes puts it "there is a common morality that is less robust than many assume [Beauchamp and

Childress] but more vibrant than Engelhardt concludes, and procedures are a fruitful way to identify the common ground" (Wildes, 2000, p. 56). Hence, Wildes follows Engelhardt in his procedural ethics but differentiates himself by adopting a middle ground position (what I would call a weak form of proceduralism) and develops an alternative to the concepts of "moral strangers" (Engelhardt) and "serious moral agents" (Beauchamp and Childress) by proposing the concept of "moral acquaintances" as a characterization of how people of different moral traditions can come together to resolve moral questions not in terms of a naïve moral ecumenism but rather by including these differences in moral deliberations. Moral acquaintanceship occurs when "there is managed agreement, which is reached when people seem to arrive at the same judgments without sharing the same moral framework and ranking of values. This agreement is characteristic of moral acquaintances" (Wildes, 2000, pp. 152-153).

It is crucial to remark that this type of agreement is not based on a common morality in the traditional sense, that is, the sharing of common values and norms. Rather agreement is reached through a series of procedures not grounded on substantial claims about moral norms and values (content) but rather through deliberations (procedures) that create spaces for moral disagreements and recognize points of overlapping. As Wildes contends,

> Space must be made for a peaceable moral diversity that will not require morally compromising collaboration in evil or seek to enforce a political correctness that would compromise the integrity of peaceable moral communities... In a procedural method, we can identify points of overlapping agreement for moral acquaintances, and we can find ways to frame and talk about disagreements... Procedural ethics provides a way in

> which the terrain of moral acquaintances can be identified and helps us understand the roles of different methods (Wildes, 2000, pp. 172-173).

The degree of overlap between moral perspectives depends on the extent to which moral agents share others moral commitments and the level at which moral judgments occur (as we will see later on Wildes distinguishes three levels of moral judgments: *object-level* judgments, *justificatory* judgments, and *choices/foundational* judgments). Wildes distinguishes two types of acquaintanceship: type A1 describes people who may understand the moral perspectives of others but do not share them; while in type A2, people understand each other morality and *partially* share some aspect of it (Wildes, 2000, p. 139). In his view, many bioethicists assume a type A2 of acquaintanceship that distinguishes people from moral strangers, but at the same time does not separate or isolate people in their moral commitments and presupposes some overlap between moral communities.

Now, the distinction between type A1 and type A2 of acquaintanceship is key to our analysis in how to develop a methodology useful to frame the ethical and social issues related to nanotechnology (i.e., integrated procedural model). The development of nanotechnology is an enterprise that does not occur in isolation within a particular group of people with specific values and norms. Rather, it takes place in a collaborative fashion. Nanotechnology is dependent on the collaboration of many scientific and technological disciplines and various individuals holding sometimes diverging views concerning politics, morality and religion. Moreover, each individual occupies a professional role that assumes certain values and norms that might conflict with personal moral commitments.[78]

Hence, the development of a methodology that takes into account the context in which nanotechnology develops (post-academic science, i.e., transdisciplinarity, the marketability of knowledge, the norm of utility) and the necessity to provide the conditions for limited consensus (i.e., type A2 of acquaintanceship) is possible in an integrated procedural model.

b. Middle Ground Position

When reflecting on the type of moral theory or methodology necessary for examining the ethical and social implications of a field such as nanotechnology, a middle ground position constitutes an attractive approach to moral reasoning because, as mentioned previously, it considers the social dimension in which science and technology take place (the development of nanotechnology and its potential problems concern society in general and cannot be reduced to one particular community or group of individuals; people of various social, political and moral ideologies are part of the process of developing nanotechnology) and avoids some of the problems intrinsic to

[78] On the issue of professional roles versus personal moral commitments, see Arthur Isak Applbaum (1999). He points out that "actors occupying professional or public roles are not to make all-things-considered evaluations about the goodness or rightness of their actions, but rather, they are to act on restricted reasons for action, taking into account only a limited or partial set of values, interests, or facts" (Applbaum, 1999, p. 5-6). That being said, Applbaum does not hold that a limitation on certain values, interests or facts (i.e., "restricted actions") results in social institutions dictating a particular morality. He makes a clear distinction between what an institution may require and what an individual within that institution may do. He remarks that "good forms of social organization do not by themselves dictate the forms of moral reasoning particular actors within institutions ought to employ. The gap between what an institution may allow and what an actor within an institution may do is especially great when the action in question deceives, coerces, or violates persons in other ways (Applbaum, 1999, p. 7).

foundationalism which limit the ability of various moral communities to reflect on some crucial ethical issues related to the development of science and technology.

Of course, we live among competing moral systems that do not necessarily share a sufficient moral language able to sustain a content-full common morality. However, rather than simply adopting a status quo position, or a type of moral regress (that is, the idea that any moral commitment must be justified and grounded on various assumptions; if these assumptions are not shared no common ground is possible), it is crucial to provide the conditions for the creation of moral spaces in which people can affirm their moral convictions while at the same time reach a limited or managed consensus or comprehension of other moral perspectives – acquaintanceship (A2).

Wildes recognizes the challenge of moral pluralism but refutes the two extremes in which differences are either simply ignored or so emphasized that a dialogue between moral communities becomes impossible. In the former case, Wildes points out that sooner or later these differences will resurface anyway so this position is not very helpful because it does not allow serious moral reasoning. The latter case, what he calls a "communal relativism" is not helpful either because the social dimension of certain practices is indisputable since they are not "private or local enterprises" (Wildes, 2000, p 162).[79]

Thus, on the one hand, some could argue that discursive reasoning and the abandonment of particular irreconcilable moral commitments for the sake of political consensus could constitute the basis for ethical principles and moral actions. John Rawls,

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[79] Not only does Wildes argues that this position is not helpful, but he also stresses that it can be dangerous because it can make assumptions concerning particular communities that might not be true for some others (Wildes, 2001, p. 126).

for instance, exemplifies this political move. He argues that in a modern democracy the distinction between what he calls "a pluralism of comprehensive religious, philosophical, and moral doctrines" and "a pluralism of incompatible yet reasonable comprehensive doctrines" is necessary in order to insure a neutral framework in which political consensus can take place (Rawls, 1993, xviii). The doctrines of the former kind are the source of disagreement and cannot constitute a basis for social collaboration. The latter kind represents the necessary conditions for social consensus and consequently establishes, it is argued, a morality in itself in modern democracies (Rawls, 1993, 1997).

On the other hand, one could confine moral reflection exclusively in relation to the teaching of a particular tradition and mores (intrinsic to a specific community), what Wildes calls "communal relativism", independently of what professional values and obligations require. Thus, the content of moral discourse and moral actions is restrained by individuals' (e.g., physicians, nurses, scientists) socio-political or religious background belonging to that particular community. In other words, such an understanding of morality holds that the outcome of the decision making process within a professional setting is almost exclusively the result of the practitioner's own moral commitments, based on the moral tradition of his/her community independently of professional obligations and values.

These two positions need critical assessment because they are problematic as Wildes suggests. In the first approach, the quest for political consensus raises the issue of the danger of emptying morality of its content and depriving it of rigorous moral analysis. This "political move" transforms morality into a set of procedures designed to provide a justification for what is socially suitable and acceptable for the sake of a particular social order without acknowledging the deep moral disagreements that are characteristic of competing moral theories. More importantly, if we accept the second approach ("communal relativism"), it implies that one's understanding of medicine, science and technology, for instance, and certain ethical issues related to them are understood only within particular communities independently of what the practice of medicine, science and engineering requires for professionals. For instance, we could image a physician belonging to a community that encourages, on a moral ground, the killing of people considered as burdensome for society (people in a vegetative state, for instance). It does not follow, however, that that particular individual can justify the killing based on his personal convictions while acting as a professional in a clinical setting. As a doctor, this individual is obliged to act according to some particular professional standards. Of course, one might answer that a professional association may impose on a minority of physicians the professional obligations to practice what would be considered as morally wrong actions (i.e., abortion) for them.

However, a distinction here is necessary. It is important to distinguish between refraining from partaking in unethical actions (which has no consequences for one's moral integrity) and imposing on others, through specific actions, one's moral views (i.e., the moral obligation to kill burdensome people for society). In the latter case, moral wrong is acted upon the patient and the family (by imposition) while in the second case one is free to refrain from participating in a specific action, thus leaving the decision to others and creating a moral space in which one can act as a professional and as a moral agent. Furthermore, even if a professional association would impose particular obligations contrary to one's convictions, there is always the possibility to resign or simply not be a member of the association. In the United States, for instance, there is not an obligation to be member of the American Medical Association (AMA) in order to practice medicine.[80]

What is important to keep in mind is that practices such as medicine or scientific research are practiced by a variety of people of different socio-cultural backgrounds who are required to respect fundamental professional principles and a set of moral norms regulating their practice. Undoubtedly, our social context reveals various communities with different competing and sometimes incompatible moral understandings. Nevertheless, despite these differences, it does not follow that some overlap between communities and moral traditions cannot occur. As Wildes argues, health care (and by extension science and technology qua nanotechnology) is a collaborative enterprise that does not limit moral problems to particular communities (Wildes, 2000, p. 141). Moral discourse in bioethics, from a collaborative perspective, can take the form of what he calls acquaintanceship. In this type of moral relationship people do not necessarily share moral views but rank values (e.g., freedom, justice, etc.) differently and understand the differences that separate them from others. The result is that a moral discourse can be established between moral acquaintances through a web of partial understandings of moral issues, in spite of moral disagreements.

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[80] Interestingly not all physicians in the United States are members of the American Medical Association. Statistics show that membership rose from 51% in 1912 to 73% in 1963. In 1990, membership was less than 50% (Krause, 1996, p. 45).

c. Consensus and Proceduralism

Engelhardt and Wildes agree that a procedural ethic represents the only option for moral discourse in a pluralistic and secular society between people of different moralities. They both contend that in order to engage in human relationships that require moral reflections, the principles of permission and consent are essential in moral deliberation. However, there is a crucial difference between the two scholars. Engelhardt's foundationalism is very restrictive as to the possibility of moral discourse in society (here I am making the distinction between moral discourse and political discourse. Engelhardt procedural ethics is more in the realm of bio-politics than bioethics). Unless people share a content-thick morality, he argues, they are not able to solve moral and social issues because of the lack of "sufficient moral premises" to sustain a moral discourse. Hence the alternative: proceduralism and the principles of permission and consent that do not require a content-thick morality since content is determined by what moral agents agree.

However, as Wildes points out, the division between a content-thick morality (moral friends) and a content-thin morality (moral strangers) is too simple because people of various moral traditions have reached agreements despite their different moral assumptions (Wildes, 2000, p. 164). Furthermore, and more importantly for our analysis of the social and ethical implications of nanotechnology, a proceduralist ethic is based on a certain type of agreement that necessarily requires "an overlapping moral consensus" (Wildes, 2000, p. 160). This means that proceduralism is not a methodology in ethics that is void of moral assumptions.

In order to support this claim, let me use an example that illustrates how procedures imply particular moral commitments. Let us consider, for instance, person X and person Y who mutually agree to enter into a business relationship that involves the use of X's resources to take care at home of his (X's) mother who is in a terminally ill condition (cancer) and incompetent. X and Y disagree on what type of care ought to be provided to the mother since Y thinks it would be better to let her die on the ground that it is a waste of resources and that keeping her alive in this state is only a prolongation of her misery. Now, the reason why X hires Y is because Y is a friend (a long time family friend but a moral stranger), needs money and has the medical expertise to take care of X's mother at home.

In this case, two people enter into a business relationship which involves respecting an agreement, that is, X will pay Y to take good care of X's mother. (For the sake of the argument, I will not take into consideration that X could choose a person of the same moral sentiments as his; this would solve the problem between moral strangers. However, people always interact and make decision with moral strangers, reaching a certain consensus despite different moral sentiments). These two persons are moral strangers: they do not share what is morally required in relation to the mother. However, how can we explain that these two people, despite being moral strangers, can agree on what has to be done, that is, X granting permission to use resources for the care of the mother according to certain stipulations? After all, Y could indeed use certain medical procedures that could harm the mother if not kill her but decides to respect X's wishes.

This case illustrates that although people are moral strangers, they can still enter into a mutual agreement that requires consensus. However, this agreement is not purely procedural as such. It assumes certain moral premises that justify the type of agreement made. For instance, in the case above, the agreement between the two parties assumes the consent of X to have Y taking care of the mother and the toleration of conflicting moral visions. It requires trust from X that Y will not kill his mother and honesty from Y in the sense that he will perform his duty as a medical professional according to the wishes of X.

The main point is that any type of agreement requires certain moral assumptions (trust, keep promises, respect of others' liberty, etc.) which secure and justify consent. In other words, in order to avoid assertion of power by one of the parties, there must be a certain overlap or consensus that allows the resolution of moral questions among people of different moral sentiments. Without such overlap or some commitment to moral content agreements, would not be possible. Thus, procedures are not abstractions that bind people independently of some moral commitments. To the contrary, as Wildes explains,

> ...*[P]rocedures* [are] *moral practices*...[that] embody certain moral commitments. The use of procedural ethics, which has been so important to the contemporary practice of medicine and health care, challenges the field of bioethics to examine the moral assumptions underlying common procedural resolutions (Wildes, 2000, pp. 163-164).

Thus, while the language of a thin common morality is problematic without qualification and while it is not clear how to delineate clearly the locus of moral agreement, it is crucial to keep in mind that even within the context of a weak form of procedural ethics, the possibility of moral discourse is possible between moral acquaintances because procedures imply moral assumptions concerning the nature of agreements in general (Wildes, 2000, p. 164-165). These moral assumptions reflect the nature of the fabric of our pluralistic and secular society, which include, according to Wildes, (1) a commitment to liberty (a necessary condition for the principle of consent); (2) the respect of the rule of law, which secures that procedures are fair and impartial; (3) recognition of the limits of the moral authority of the state, that is, as we have pointed out earlier, individuals are the source of moral authority and not the state; (4) toleration, that is, a recognition that there are competing moral accounts and that no one can impose a moral perspective without the approval of a moral agent – by the same toke toleration also secures the moral integrity of individuals since they are respected in their moral commitments (Wildes, 2000, p. 167-173).

The moral commitments listed above could imply that Wildes' procedural ethic is intrinsically individualistic, that is, the moral principles of liberty, consent, permission, toleration and limits of the state's moral authority constitute the necessary conditions for the protection of individuals liberties independently of social considerations. Wildes, however, is critical of this form of strict individualistic approach. Rather, he suggests that an individualistic approach is not suitable because "it is inappropriate, indeed incomplete, to consider individual human beings apart from the community. The communitarian approach supports the importance of autonomy but emphasizes that no autonomous person lives in isolation" (Wildes, 2000, p. 125). What he calls the "communitarian turn," in his view, attempts to recapture some important elements (in particular the mean of being human) in moral reasoning that have been omitted since the Enlightenment.

IV. INTEGRATED MODEL

A. The Failure of Principlism as an Integrated Model

Before we can move further into what an integrated model is and how it would function in relation to the resolution of moral issues in nanotechnology, let me briefly recapitulate some of the key points raised so far concerning principlism and proceduralism.

The main reason for a critical analysis of principlism is that its authors, Beauchamp and Childress, describe it as an "integrated model" which is distinct from the version of an integrated model I propose in this work as I will demonstrate in what follows. For reasons I articulated previously, principlism is an illustration of a failed attempt to provide an integrated account of ethics and is doomed to fail because of the lack of content of the principles of autonomy, justice, beneficence and maleficence; the lack of guidance principlism offers for action; the lack of unity as a moral theory; and the ambiguity of the meaning of being "serious about morality." These four problems in principlism are closely related to an insufficient consideration of the differences characteristic of competing theories and the lack of acknowledgement of the fragmented nature of Western morality.

In other words, principlism does not recognize the importance of *substantive debates* in moral deliberations. In substantive debates consensus is not the primary concern because initial attention is given to recognizing the fundamental moral disagreements that constitute the social and political order of our culture. Substantive debates seriously recognize the implications of the philosophical and metaphysical assumptions one brings to discussions concerning moral issues, the nature of reality, and the character of human life. The recognition of these assumptions is crucial because the conclusions one reaches depend precisely on one's metaphysical and philosophical presuppositions.

Now, that being said, while principlism fails to recognize the differences between competing models of moral reasoning, Engelhardt does not take into account that sometimes, moral theories have certain affinities that provide the basis for consensus. Hence, the type of proceduralism proposed by Engelhardt creates a dichotomy (moral strangers vs. moral friends) that accurately describes people who limit their social and ideological horizon to their specific communities. However, ethical reflections bearing on medicine, science and technology cannot be limited to specific groups of people because these fields concern society in general. The need to ensure ethical conduct in science and technology has become a pressing issue not only at the governmental level (due to the funding of research and development of new technologies) but also at the societal level (to appease the fear of science running amok that could impact our way of life; see for instance, the issue related to the grey goo problem with regards to nanotechnology).

In the next section, I will use Wildes' model of ethical inquiry (i.e., weak form of preceduralism) but argue that it demands further refinements in order to allow a better integration of what Ziman calls trans-epistemic values, socio-political and economic considerations. Hence, in what follows, my aim is to show first what it is to have such an integrated account, and second how it functions.

B. Toward a Procedural Integrated Model

1. Its Purpose and Function

As previously indicated in Chapter Three (section entitled Post-academic Science), the new ethos of scientific research and development (post-academic science which is characterized by its trans-disciplinarity, the marketability of knowledge, and the norm of utility) is an opportunity to further address the ethical issues raised by science and technology. The potential changes that *could* happen not only in our way of life but likewise in our very understanding of human nature (human-machines interface) require further philosophical investigations. This new context is characterized by complex relationships between the industry, science, the academia, economics, and politics that determine what type of research and development ought to be pursued on the ground of ethical, economic, political and social reasons. In order to avoid the type of controversial public debates associated with technologies such as Genetically Modified Organisms (GMO), where poor dialogue between the scientific communities and the public occurred, more sustained critical reflections ought to take place among scientists, scholars and the public. In his analysis of how to integrate ethical reflections to the development of nanotechnology, Khushf points out that a bridge between the cultures of the humanities, the social sciences and science/technology ought to be built. He writes,

> Through critical reflection on the scientific and engineering enterprise itself, the values and core ideals of nanotechnology need to be made explicit, so that a more sustained form of ethical reflection can be developed which might accompany the research at the most preliminary stages. This...is probably the single most important development that needs to take place...Without this, nanotech will continually struggle with the kind of polarization of scientific and ethical analysis that characterize other areas of science, and, especially in the more controversial areas of nano, this is likely to provoke a public debate like that associated with GMOs and nuclear technology, where there is *poor integration* of the realities of scientific practice and the public perception of what is at issue (Khushf, 2004a, italics mine).

Note that one of the main differences between issues related to genetic engineering or GMOs is the insistence of the necessity to integrate moral reflection at the most preliminary stages of scientific development. This is not to say that the increasing need to reflect on the ethical and social implications of science and technology is a new phenomenon. Already in the 1970s, there have been scholars and scientists raising ethical issues concerning new technologies (see the Asilomar conference). Yet, in recent years, a second wave of reflection concerning the interplay between science, the industry, economics, politics and the academy has taken place. What Khushf points out is the fact that in previous scientific controversies a *poor* integration of the scientific realities in public (i.e., social/ethical) discourse took place. In order to avoid the same mistake in "publicizing" new scientific and technological advances related to nanotechnology, better dialogue and collaboration is necessary between the various cultures (i.e., natural sciences, social sciences, and the humanities). Hence, it is necessary to develop an integrated model.

When we turn specifically to nanotechnology, one realizes that this new field of scientific research is a further illustration beyond what began in the 1970s in relation to ethical reflections and reinforce the idea of a major shift (from academic to post-academic science) that occurred in science and technology. As a matter of fact, Adil Shamoo and David Resnik, echoing Khushf, remark that in recent years a stronger awareness by the scientific community to ensure ethical conduct occurred. As they point out,

> In recent years universities, research organizations, professional societies, funding agencies, politicians, the media, and most scientists have come to realize that ensuring ethical conduct is an essential part of basic, applied, and clinical research. Little more than a few decades ago, many scientists would not have accepted this statement (Shamoo & Resnik, 2003, p. 4).

One of the reasons invoked by Shamoo and Resnik for recognizing the necessity to reflect on the ethical implications of science and technology is that for decades science was considered objective while ethics subjective thus reinforcing the idea that pure science was not concerned with ethical issues, since, it was argued, social and ethical issues occur in applied sciences. However, since nanotechnology is a pure and applied science (in other words a techno-scientific discipline), Shamoo and Resnik's point becomes even more relevant for our discussion.

There are also four other reasons Shamoo and Resnik mention that need close attention in our analysis (Shamoo & Resnik, 2003, p. 5-8). First, Shamoo and Resnik point out that modern research does not occur in a lab independently of other research institutions or scientists. Because of the collaborative nature of modern science, standards of conduct and ethical principles (honesty, trust, integrity, respect, confidentiality, accountability and fairness) are developed in order to insure good research and appropriate ethical conduct.

Second, research takes place within the social context, which is shaped by various socio-political, economic, religious and cultural ideologies that influence the ends and means of research. Broader reflections outside the scientific community should take place in order to include the public in discussions related to the role of science and technology in society.

Third, scientists need the approval of the public in order to engage in various types of research that could be controversial. To a certain extent, if scientists raised ethical concerns about their research, the public is less inclined (if scientific facts are presented in an adequate fashion that reassure the public about the risks involved in a particular scientific project) to question such research because it presupposes (naively?) that the adequate processes to ensure ethical conduct in research have been implemented.

Finally, Shamoo and Resnik note that the close relationship between the academia and the industry (post-academic science) raises the issue of conflict of interests between academic freedom (unbiased research) and economic incentives. How economic considerations should influence research requires careful scrutiny in order to insure integrity in research.

When analyzing how these four concerns (that is, (1) collaboration between scientists, (2) the social context in which science takes place, (3) the attention of societal concerns raised by science and (4) the science-industry collaboration) would integrate the type of procedural ethic proposed by Engelhardt, it appears difficult to account for the social dimension of scientific research in order to sustain the type of moral language necessary in our pluralistic and secular society. The reason is that Engelhardt presupposes too much about our inability to reach any consensus other than through procedures only. On the other hand, Wildes' articulation of a proceduralist ethic allows accounting for the social dimension of science and technology and therefore, constitutes a constructive alternative to Engelhart's proceduralism because it solves partially the problem of moral pluralism and provides a conceptual framework for ethical discourse to take place.

Now, there is a cluster of three main issues that an integrated model addresses. First, the problem of pluralism. At the risk of being repetitive, it should be clear at this juncture that an integrated model is not meant to solve the problem of moral pluralism per se but rather provides an avenue of how to reflect on moral issues raised by science and technology in a fragmented moral world. It aims at further developing a procedural process that allows rigorous moral reflections despite competing moral views. The second issue is the antagonism between the cultures of science/technology, the humanities, and the social sciences or more to the point, the question of how to build a bridge between the three cultures. Khushf argues that in order to go beyond past controversies between the sciences and the humanities (controversies related to Darwin and Gallileo, for instance), the development of "'new models for constructive interaction' between the humanities and sciences" ought to be created which would avoid not only the antagonism between science/technology, the social sciences, and the humanities but would also foster a new intellectual culture that aims at providing reflection on the social and ethical implications of science and technology (Khushf, 2004a, p. 12). The third and final issue is the question of consensus. While it would difficult to support the possibility of the type of social agreements at the moral level that occur between moral friends in the current pluralistic context of moral reflections, the concept of moral acquaintances offers an avenue that recognizes that in the past various committees and commissions have reach moral agreements (Wildes, 2000, p. 153).

Thus, an integrated model in relation to the social and ethical issues in science and technology addresses the question of how to partially solve moral problems (how to reach consensus) in a pluralistic and secular society (characterized by three categories of moral relationships: moral friends, moral strangers and moral acquaintances) while recognizing that the issues raised by science and technology include a broad spectrum of considerations within the sciences/technology and the humanities/social sciences (ethics, economics, politics, etc…).

2. Moral Judgments and Consensus

a. Three Levels of Discourse in Moral Judgments

Now, the next question to address is how people accept or reject certain moral propositions. On what basis do people make judgment calls concerning specific circumstances or cases and reach consensus?

Wildes, in his articulation of the concept of moral acquaintances, is helpful in this regards. He points out that there are three levels of discourse in moral judgments (Wildes, 2000, pp. 147-153). The first level of judgment is what he calls *object-level judgments*, which are the kind of judgments used in order to assess what ought to be done in specific cases. At this level of judgment, people can agree on what ought to be done without necessarily sharing the norms, principles, or values that guide decisions. For instance, a Conservative Christian might be opposed to physician-assisted suicide on the basis of his/her religious and moral commitments, while a secular physician might reach the same conclusion (i.e., physician-assisted suicide is wrong) but for a different set of reasons (it is against the ethics of the profession, for instance). People can arrive at the same conclusion without necessarily sharing the same moral sentiments.

The second level is *justificatory judgments*. This type of judgments justifies the reasons and moral values a moral agent will refer to in order to assess particular situations. In the previous example, the religious person might justify his/her opposition to physician assisted suicide because of his/her belief in the sanctity and dignity of human life; whereas, the physician might justify his opposition on the ground that the medical profession should not be involved in such practice (an argument that other people in the health profession might challenge).

The third and final level of judgment is the realm of *choices*. Choices are the preliminary stages in moral judgments (i.e., prior to *object-level* and *justificatory judgments*) that qualify the basis and acceptability of justification. These are "foundational judgments" that affect how one justifies the reasons (justificatory judgments) concerning specific course of actions (*object-level* judgments). At this foundation level, Wildes argues, only moral friends can reach agreement because it requires shared assumptions concerning moral foundations.

Based on Wildes' analysis we can classify these three types of judgments as follows[81]:

Type of judgments	**Agreements**	**Domains**	**Fields**
Object-level judgments	Cases	Practical	Facts/Science
Justificatory judgments	Reasons	Justificatory	Public Policy/Law
Foundational judgments	Choices	Theoretical	Ethics/Moral Theory

Note that the second column describes the type of agreement possible between people. Agreement can occur:

(1) concerning cases or particular situations independently of the moral assumptions or the reasons one brings to the process; see the example above concerning physician-assisted suicide;

(2) concerning the justification but not necessarily with regard to cases and/or choices. For instance, let us image two people concerned about the principle of the dignity of human life in relation to a terminally ill patient. It might be the case that both persons

[81] My classification of judgments is inspired by Wildes' model but does not reflect his own classification of agreements, justifications and foundations. For such summary see Wildes (2000, p. 152).

articulate the reasons and moral values that apply to this particular case (dignity of human life – opposition to physician assisted suicide), but for different reasons, one based on Kant's categorical principle, "Act in such a way that you always treat humanity, whether in your own person or in the person of any other, never simply as a means, but at the same time as an end," the other on a religious concept that states that all human life is sacred and that only God is the arbiter of when a person should die;

(3) concerning the moral foundations, that is, this type of agreement occurs between moral friends and constitutes "the most powerful type of agreement" and assumes shared moral language, values and assumptions (Wildes, 2000, p. 150). This does not mean that disagreement cannot occur at the level of justification and/or object-level judgments despite agreeing on the foundational level. As Wildes points out, this common framework permits agreement and disagreement to take place. A good example is how people from the same community disagree on various issues related to medical matters.

b. The Complexity of the Process of Agreement

This general framework is meant to show that agreements occur in a complex set of relationships that do not require people to be necessarily moral friends in order to agree upon moral issues. As articulated earlier, even in its most limited form (i.e., proceduralism), consensus assumes moral assumptions. Of course, the type of agreement between people of different moral traditions and commitment is limited but it can indeed occur, maybe not as strong as some scholars assume (i.e., Beauchamp and Childress) but the degree of disagreement can be managed in order to reach consensus.

A procedural integrated model of ethical inquiry is the attempt to build a bridge between levels 1-2 (*object-level* and *justificatory* judgments) and level 3 (*choices/foundational* judgments) of moral judgments. Again, consensus in its strongest form is achieved only between moral friends because this type of consensus requires sharing common assumptions about the right, the good and the just and about human flourishing. However, the need to develop an integrated model comes out of a realization that the discourse used in bioethics has more to do with politics and social conventions than with ethics and therefore a better consideration of the role of ethics per se is needed. It is certainly the case that our pluralistic context limits our ability to achieve a strong consensus at the ethical level, as Engelhardt has argued. But Wildes points out that even the use of proceduralism as a methodology in ethics implies certain moral values that are inherent to the process of agreement. It is on that basis that moral reflections must take place within our particular context.

Hence, my contention is that level 3 of judgments should be integrated in one's moral discourse independently on whether it is relevant for the other parties in the process of attempting to reach consensus. Rawls, for instance, in his distinction between "a pluralism of comprehensive religious, philosophical, and moral doctrines" and "a pluralism of incompatible yet reasonable comprehensive doctrines" generates, as seen previously, the locus for social consensus in modern democracies but avoids level 3 judgments, thus prevent ethical (as opposed to simply politico-legal) reflections to take place in the public arena (that is, articulating philosophical, moral and religious concepts). Consider for instance the following statement:

> Political values are not moral doctrines, however available or accessible these may be to our reason and common sense of reflection. Moral doctrines are on a level with religion and first philosophy. By contrast, liberal political principles and values, although intrinsically moral values, are specified by liberal political conceptions of justice and fall under the category of the political (Rawls, 1997, pp. 775-776).

In order to prevent the lack of integration of ethical analysis in bioethical discourse (as shown by the example of Rawls) that goes beyond legal and procedural matters and in order to foster further rigorous ethical reflections, an integration of level 3 judgments should characterize the discourse of those involved in the market of ideas, especially in the context of moral reflections concerning science and technology for reasons addressed in this work. Moral spaces must be created in order to maintain the moral integrity of various individuals and institutions (Wildes, 2000) but where some moral consensus occurs it ought to be exploited in order to advance ethical reflections.

The division between levels 1-2 (*object-level* judgments and *justificatory* judgments) and level 3 (*foundational* judgments) not only limits our ability to confront and discuss - despite our differences - issues that concern society in general (medicine, nanotechnology, science and technology) but also prevents moral reflections (because controversial) from being part of a broad set of concerns. Thus, morality, on this model, is mutated into a set of rights and procedures in which agreement on the nature of what constitutes the good for society is based on a divergent set of preferences that often conflict due to the rival interests present in society and the competing views of the nature of the good life. Moral discourse takes place in a context in which moral agents are liberated from social constraints. As Alasdair MacIntyre observes "the self had been liberated from all those outmoded forms of social organization which had imprisoned it simultaneously within a belief in a theistic and teleological world order and within those hierarchical structures which attempted to legitimate themselves as part of such a world order" (MacIntyre, 1981, p. 60). The modern self requires a new social backdrop that will allow its existence and development. The ultimate cost, however, is a slow but undeniable erosion of society's ability to reflect on moral issues. Bioethics is a reaction to this situation and an attempt (a failing attempt) to fill the void created by conflicting moralities in our socio-political context.

The problem of contemporary bioethics is addressed by Edmund Pellegrino who is critical of the current trend in bioethics that locates morality within social conventions and procedures. He writes, in reference to his attempt to articulate a moral philosophy of medicine, that:

> [m]y realism and search for objective foundations [in the philosophy of medicine] contravenes the current bioethical trend toward social convention, social construction, and dialogue as means of arriving at transient moral truth. These are valid as methods of political democracy but dangerous. Society is not per se the final arbiter of moral truth. There are sadly too many pathological societies past and present to entrust the canons of morality entirely to politics and social convention. Ethics is not a matter of polls or plebiscites (Pellegrino, 2003, p. 11).

Whether or not Pellegrino's attempt to discover the objective moral foundations of disciplines, such as medicine, is a possible and worthy intellectual endeavor and is an important question we cannot address in this work. However, Pellegrino is right in his diagnosis concerning the field of bioethics: bioethical discourse has become a political discourse which contains deep political and philosophical assumptions concerning how such discourse is articulated in the public arena and used to implement various laws, values and norms.

From the inception of the field of bioethics and its aims at reflecting on the moral issues raised by new technologies in the 1960s (at that time, the questions were about the process of selecting patients for scarce resources; the invention at the University of Washington School of Medicine by Dr. Belding H. Scribner of the first dialysis machine that did not require surgery, raised the question of the selection of patients who would benefit from this innovation) to its present form, bioethics has been transformed into bio-politics, that is, one's "bioethical views" will reflect one's political assumptions. One example is how and by whom ethical reflections are conducted at the federal level depending on who occupies the White House. Under Bill Clinton, the National Bioethics Advisory Commission (NBAC) was chaired by Harold T. Shapiro and reflected a certain political agenda and specific moral perspectives. The National Bioethics Advisory Commission expired in 2001 and was replaced by the President's Council on Bioethics, created in 2001 by President George W. Bush and headed by L. Kass. The Council reflects likewise specific political and moral sentiments as various issues such as the use of embryonic stem cell for research and human cloning attest.

My contention is not to assert that no intrinsic authority and respect ought to be attributed to each participant's understanding of a well-ordered society. To the contrary, individuals' opinions and moral commitments, respect of personal moral integrity, and liberties are important and necessary for the fabric of social life. Society, however, ought not to be construed exclusively in terms of personal rights and individual freedoms. Law, as the embodiment of rights, must be the necessary prerequisite for the safeguarding of morality and not as its substitute. As philosopher, Marvin Fox remarks "once human beings enter society – and historically they are always social and political beings – they can no longer afford to allow morals to be treated as purely private matters of personal taste. For the protection of society, morals are reinforced with the power of convention, changing finally into law" (Fox, 1990, p. 141). The force of Fox's argument resides in its ability to maintain a close relationship between morality and law whereas Rawls' political liberalism undermines not only the role – limited I concede, but still present – of morality in shaping public discourse but also the social fabric of our culture. An integrated model is meant to re-integrate moral discourse at the core of the issues raised by science and technology.

The next issue to address is to see how a procedural integrated model would work in concrete applications. This will be the focus of the next two chapters, where I examine how a procedural integrated model offers an avenue for an ethical analysis of the implications of nanotechnology in the biomedical science. In the next chapter, I show why a procedural integrated model can be a fruitful method for critically analyzing moral questions in nanotechnology/nanomedicine. The subsequent chapter contains two main sections. The first section looks at the definition(s) of nanomedicine and gives a brief outline of the various applications of nanotechnology in medicine. The second section concerns the ethical and philosophical issues raised specifically by nanomedicine (e.g., in the practice of medicine and the use of enhancement technologies). I do not intend to assess critically these issues per se, but rather provide some reflections on where potential problems could reside and why it is necessary at this juncture to develop a methodology in moral reasoning that will help examine and assess issues related to nanotechnology /nanomedicine.

CHAPTER V

ETHICS AND NANOTECHNOLOGY

At this juncture, it has become clear that the moral issues raised by nanotechnology / nanomedicine are not specific to the biomedical sciences. Most of the ethical issues raised are also intrinsic to other areas of scientific research, the biomedical sciences included. The increasing use of technology in medicine and its impact on the practice of medicine, for instance, is not a new phenomenon and therefore, the focus should be extended to broader considerations. That is, as mentioned previously, the most promising applications of nano-devices are likely to occur in the medical field but the issues at stake are not whether the medical profession should use them or not, but rather whether society at large should allow the use of various devices for which the risks and dangers are not yet well established. The reason is that the medical profession does not have the power to sanction or approve the use of controversial devices since what decides how certain new devices or new procedures are implemented lies mostly outside medicine itself. Economic, social and political pressures create particular conditions that provide the incentives for the development of specific products, devices or services. As pointed out earlier, the norm of utility (i.e., the usefulness of scientific projects) is an indicator as to how innovative medical devices and procedures will find their industrial applications.

Hence, a project that looks at the social and ethical implications of nanotechnology and nanomedicine concerns not only those who develop these new technologies or the practitioners who will use these technologies in the medical fields but likewise various people with specific "expertise."[82] What this means is that people from various disciplines ought to enter in conversation at various levels of analysis, whether in science, law/public policy/economics, the industry or ethics. My point is not that people of these various disciplines *do not* currently dialogue or reflect on ethical and social issues related to science and technology. Rather, my contention is that so far a *poor integration* has occurred in how disciplines in the humanities/social sciences have participated in the debates at the scientific and social levels (Khushf, 2004a).

That being said, the question then is how to articulate a cogent vision that fosters further reflections on the social and ethical issues raised by nanotechnology / nanomedicine while recognizing the fragmented nature of Western morality. In what follows, I will argue that our analysis must be articulated through the various levels of moral judgments described previously so as to build bridges between, on the one hand, the three levels of moral judgments (in particular the inclusion of foundational judgments in moral reflections) but also, on the other hand, between the disciplines in the natural sciences / technology and the disciplines in the humanities and social sciences.

I. BEYOND PROCEDURES AND PUBLIC POLICY

The particular context, as articulated in Chapter Three, in which the development of

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[82] I use the term "expert" or "expertise" with caution since when it is applied to ethics it becomes ambiguous as to what a "moral expert" is. In this work, I use the idea of a "moral expert" as someone who is able to map ethical issues but does not necessarily provide a normative answer as to the type of solutions a particular issue requires.

nanotechnology takes place, requires a careful analysis of how to set the conditions for a better integration of the various levels of judgments (*object-level* judgments, *justificatory* judgments, and *foundational* judgments) in ethical discourse and for a more substantial type of ethical reflections. The reason is that we live in a fragmented world of competing moralities and political ideologies but at the same time, there are areas of human activities (medicine, science) that concern society as a whole that demand social collaboration. How to bring these two realities together is the task of an integrated approach.

The current malaise concerning the nature and goals of the field of bioethics is characterized by a lack of substantive reflections, which is mirrored in the difficulty of establishing a normative ethics for science in general and the biomedical sciences, in particular. Edmund Pellegrino, for instance, is rather pessimistic concerning contemporary bioethics' ability to generate moral guidance. In his assessment of the trajectory of the field of bioethics as a tool for reflections concerning science, technology and medicine, he notes that there is a tendency "toward the gradual abandonment of the idea of normative ethics and moral truth of any kind" and the tendency to emphasize procedures and public policy (Pellegrino, 2000).

It is not my goal to debate whether a normative ethics as envisioned by Pellegrino is possible in contemporary culture in this work, although previous chapters indicate my skepticism about it. However, I wish to stress an important point he makes, that is, in its actual form "bioethics", as a thorough analysis of ethical issues related to science, technology and the biomedical science, is a misnomer, since it is not concerned with *foundational* judgments (the locus of moral reasoning/ethics) but rather with *justificatory* judgments and *object-level* judgments, that is, public policy and legal considerations as well as practical considerations (i.e., politics and science). In its current state, what we commonly call "bioethics" should rather be called "bio-politics" because it is not concerned – a claim that many would refute - with foundational judgments, i.e., ethics and moral reasoning but with law and public policy. A reconsideration in the way we approach bioethical issues should be at the forefront of a critical assessment of the field of bioethics in order to recover more substance in ethical debates.

In order to avoid the type of minimalist ethics engendered by procedures, it is essential to resist the temptation to simply accept moral pluralism as a fact without some questioning as to where bioethics is heading in its current condition. Pellegrino, for instance, calls for a serious reconsideration of the field of bioethics as an intellectual enterprise and calls for further philosophical reflections to provide what he calls "stable moral truths." This, he argues, will require a better dialogue between people of various moral and philosophical traditions. In his view,

> contemporary bioethics is a young organism freshly sprung from its chrysalis. What its next stage of metamorphosis will look like is unclear. What is clear are the trajectories along which it is traveling. They point to a troubled future for normative ethics at least in the sense of a guide to moral truth. What the actual future will be depends on the resolution of the four questions of identity, methodology, justification and foundations. If society is to avoid a teratological species of morality, some recovery of stable moral truths is mandatory. This is a project for which the traditionalists, the modernists and the postmodernists must share responsibility (Pellegrino, 2000, p. 22).

While it would be naïve to think that various methodologies in bioethics will converge to give a more substantial and common type of morality, the main point I want to stress, in reference to Pellegrino's quotation, is that our ethical reflections should go beyond mere procedures and public policy. It is necessary to recover what bio-*ethics* ought to be by engaging ethics and moral theory within the current context of bio-*politics*. Hence, avoiding the Rawlsian distinction between "a pluralism of comprehensive religious, philosophical, and moral doctrines" and "a pluralism of incompatible yet reasonable comprehensive doctrines" (Rawls, 1993, xviii), which assumes that the doctrines of the first type are irrelevant in order to secure political consensus. This, I suggest, will only take place if foundational judgments are brought back into contemporary reflections with more vigor than what characterizes the field of contemporary bioethics. This can be accomplished through the development of an integrated model.

II. STRESSING DIFFERENCE TO FIND A COMMON GROUND

Thus, the question to ask, considering that the field of bioethics qua bio-politics in its current forms fails to provide a fruitful avenue for moral reflection (at least in my judgment), is whether we should develop a field of ethical investigation specifically devoted to the field of nanotechnology so as to depart from the current approach to bioethical issues. Although I recognize that moral reasoning cannot be totally recast in order to fit a particular area of ethical inquiry, I am inclined to argue that a new approach to ethical reflection is necessary in order to avoid the kind of cacophony that characterizes the field of contemporary bioethics (whose ideology is mostly politically oriented rather than ethically motivated). It would also provide a more substantial type of intellectual inquiry because it emphasizes the integration of foundational judgments (theoretical or in Rawls' terms "a pluralism of comprehensive religious, philosophical, and moral doctrines") in moral discourse concerning issues related to medicine, science, technology, and nanotechnology (practical) while recognizing how various moral theories are in competition within the context of the market of ideas.

In other words, the linkage between the two spheres – the theoretical and the practical or between facts and values and science and the humanities – is what needs, among other things, to be established in a more rigorous fashion. The independence of the discipline of applied ethics (bioethics qua bio-politics) from ethics (bioethics qua moral theory) represents a misconception of moral reasoning because applied ethics tends to separate rules of morality (*foundational* judgments, in our analysis) from their specific applications (*justificatory* judgments and *object-level* judgments, in our analysis). The lack of linkage between moral theory and applied ethics is a key problem in current bioethical reflections. As MacIntyre points out,

> The relationship between a rule [ethics] and its applications [applied ethics] cannot be what on the dominant view it is taken to be; that is, it cannot be the case that we can first and independently comprehend the rules of morality as such and then only secondly enquire as to their application in particular specialized social spheres. For were this to be the case, the rules of morality as such would be effectively contentless (MacIntyre, 1984, p. 501).

MacIntyre's insight is important for our analysis. He suggests that rules (theoretical domain) and applications (practical domain) ought not to be separated otherwise it would produce a contentless morality (lack of substantive analysis), which is precisely the type of morality characterizing contemporary bioethics. Hence, in order to make the linkage between practice and theory as well as between theory and practice, MacIntyre does not limit his understanding of morality to the mere observance of rules. Moral rules must be interpreted as society faces new challenges and must avoid two extremes. On the one end, he notes, there are rules that constrain us to obey the conditions stipulated, so that the infraction of them would lead to a sanction. For instance, the non-observance of speed limit is sanctioned, if caught, by the payment of a fine. On the other end, there are rules with explicit stipulations for particular contexts. For example, the rule, "Do not enter the building *except* if permission granted" relies on the conditions set by the exception. Thus, in this case the rule and its applications form an indissoluble entity.

MacIntyre contends that moral rules are and must be of some intermediate type because they aim at regulating human behavior in concrete situations. He remarks that "it is characteristic of moral reflection… that we move to and fro from the rule to some range of examples of its application and from these particular applications back to the rule; and this movement is an important clue to the nature of moral reflection" (MacIntyre, 1984, p. 503). This movement from applications to rules and rules to applications is key as we analyze and reflect on the type of theoretical framework necessary in order to develop an integrated model for ethical reflections on nanotechnology and nanomedicine.

Throughout this work, I have emphasized the necessity to reconnect *object-level* judgment and *justificatory* judgments with *foundation* judgments in order to foster richer and more productive reflections on the ethical and social implications of nanotechnology / nanomedicine. The current division between these domains in conjunction with political ideologies such as the one articulated by Rawls creates a moral vacuum in which "morality" is muted into pure proceduralism. In short, it sets the conditions for impeding substantial moral reasoning at the core of reflections on issues such as the impact of nanotechnology on society and medicine. The reason, the argument goes, is that since our current context does not allow consensus to occur, it is, in some way, pointless discussing issues from a moral perspective (moral in the sense of foundational judgments as opposed to the common mistake to think that moral can be equated with legality).

Bioethics is an attempt to recast morality for a secular society based on "legality, consensus and public policy" which reveals the lack of a "unified practice of bioethics" (Wildes, 2000, p. 179). Interestingly, however, Wildes, who recognizes that bioethics is plural, concludes that rather than attempting to produce or discover a universal morality at the onset of moral reflections, we ought to take the opposite view. He argues that people of various moral traditions should first start listening to each other's differences to determine where there can be some common ground. As he writes,

> The emergence of many voices in bioethics challenges the assumption that we do really have a common morality or even a common moral rationality. If listened to attentively, these voices raise the question of whether there is a unified practice of bioethics. Our conclusion can be baldly stated: rather that begin with an assumption of a common method into which diverse voices can be placed, we must begin by listening to the

> diversity that is already there. Only so can we discover common ground (Wildes, 2000, p. 179).

The pertinence of Wildes' argument is that it fully recognizes that we do not share a common morality but at the same time it emphasizes that there is the possibility to come to a common ground where it can be established, which in Wildes' opinion it can. Rather than looking at what is common to "all persons serious about morality," in Beauchamp and Childress's words, Wildes argues that we should first look at what separates various moral communities in order to find a common ground. The main reason is that eventually differences will arise in moral debates, which will be counter-productive since they will be the center of attention rather than focusing on what could potentially be a common ground for ethical reflections.

Thus, in so doing, we are not left with a context in which each moral community remained sealed (in the sense that no collaboration is possible because of the lack of common premises concerning the nature of moral reasoning as well as the principles and values characteristic of a moral community) or are suspicious about certain disciplines (for instance, although theologians were influential during the early stages of the development of bioethics, in the current context religious voices or theological arguments are often marginalized if not simply ridiculed[83]). Rather, an integrated approach to

[83] On the early influence of theologians on the nascent field of bioethics, see chapter 2 ("The Theologians: Rediscovering the Tradition') in Jonsen (1998). Jonsen remarks that "The bioethics that began to appear during the 1970s, while generated by the new medicine and science encountering human values and customs, was their (the theologians') creation. Theologians were the first to appear on the scene" (Jonsen, 1998, p. 34). However, due to the divisive nature of theological arguments concerning values and human nature and the process of secularization of American culture, theology and theologians became marginalized: "There were good reasons for this fall from faith. Some early bioethicists resigned their ordinations in the church. Many of them found employment at medical schools where a secular and scientific culture dominated. Most bioethicists quickly discovered that, while rumination about human

bioethical issues encourages and requires tolerance of diverging views within the academic setting, the public arena and in the world of politics.

Within this context of toleration and moral pluralism, those involved in bioethics can assume roles (i.e., expert member of a specific community; translator of different moral languages; geographer of authority and ideas; and social critic) at various levels of moral reflections, each level requiring different types of argumentation and sometimes analysis according to the type of audience one addresses. For instance, Wildes distinguishes at least four roles bioethicists can endorse (Wildes, 2000):

First, bioethicists are members of a particular community and are recognized as authority due to their training, status and knowledge. They can help their own community (religious, philosophical, political) understand what the issues are and how to deal with the new challenges that this particular community faces in order to respond adequately according to the tradition and morality the community endorses, but also in order to explain and justify in the public forum why that particular community believes what it believes. Second, bioethicists can be translators, that is, they are able to understand others moral traditions and lay out the differences between them. The third role is the one of "geographer of authority and ideas." In this role, bioethicists help set the limits of professional authority and articulate standards that respect the concepts of consent and permission. Final, bioethicists can have the role of analyzing how institutions and

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nature and destiny invites the transcendent references of theology, discussion of the practical problems of bioethics, such as regulation of research or allocation of resources, can be carried out quite satisfactorily in more mundane terms. Although in recent years, some theologians have summoned theologically trained bioethicists back to their roots, they remain, in their bioethical analyses, outside the faith" (Jonsen, 1998, p. 58).

organizations maintain their moral integrity. In this role, bioethicists have the function of social critics.

What these four roles of bioethicists show is that a particular role requires a specific function in relation to reflections on bioethical issues. An individual assuming a particular role must first recognize what function is appropriate for what setting. In order to participate cogently in bioethical discourse, it is essential to be able to understand the various moral discourses involved in the debates to articulate one's moral vision in a coherent and understandable fashion. Obviously, no one will be able to speak from a neutral standpoint or in a manner that will necessarily produces consensus. Each participant in moral debates is a member of a community that assumes values and moral commitments intrinsic to the community. However, as Wildes points out, a bioethicist or, in fact, any individual involved in ethical reflections, has different roles and might belong to various communities. Once this is acknowledged, one can easily see the importance of being able to discern the type of discourse that is required according to the type of audience. In this sense, a bioethicist is an expert because he or she is able to map how various moral discourses interact and diverge. However, he or she is not an expert in the sense of providing a comprehensive and normative answer to specific moral issues in bioethics.[84]

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[84] On the concept of ethicists as experts see Wildes (1997) for a critical approach. He argues that "the ethics expert who can normatively judge most particular moral decisions is one that can be found *within a particular moral community*. Within a moral community, that has a normative moral code and tradition, one can identify the experts…A community may also have members who are 'in' authority that gives the authority figure the responsibility to make recommendations, assessments, judgments, or give absolution. This is the authority of office. It is held in virtue of the office. Police officers and priests have the authority of office. The expertise of such men and women, those who are *in* authority and those who are *a* authority, will depend on the nature of the moral community and its traditions. From within a moral community the answer to the concern can there be an ethics expert for normative questions, is 'Yes' (Wildes, 1997, p.

Therefore, what is necessary is the ability to discern the type of arguments that will be understandable for people from other communities. Not that people will necessarily agree or accept these arguments but at least they are aware of their presence in debates. For instance, from a religious point of view (let us say a conservative Christian perspective), abortion is wrong because it is the killing of an innocent life based on the argument that human life belongs ultimately to God and therefore human beings are not supposed to intervene in the taking of human life. Now, it is clear that, to echo Nietzsche famous motto, (the concept of) God is dead (or it is becoming more and more marginalized) in the public square in the United States. To invoke God as a basis of morality has become the source of much uproar in the last decades as American society has moved toward secularization.

Should we then avoid the language of God in bioethical discourse? Of course not! Those who have strong religious commitments should remain faithful to their religious and moral convictions in order to preserve their integrity as free individuals. There is also another reason, which is, in my view, specific to the context of the United States. Recently, I heard someone comparing American bioethics and European bioethics in the following terms. On the one hand, European bioethics is more like a trip to the post office, that is, it is characterized by a heavy bureaucracy whose goals are to centralize the decision making process pertaining to bioethical issues. On the other hand, American

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367). For less skeptic approach see Agich and Spielman who contend that "expert testimony can be of genuine assistance not only when it provides access to that about which the judge or jury completely lacks knowledge or skill, but also when it incrementally improves their reasoning process. As John Strong…has pointed out, an expert may be in a position to qualify, quantify or otherwise refine the general knowledge of the trier of fact. She may also add to the degree of confidence a jury places in common sense and experience and thus help the jury to use them less tentatively" (Agich & Spielman, 1997, p. 395).

bioethics is like a beauty contest where the ones who are the most "boisterous" and more "eloquent" about their arguments will eventually win the contest.

This of course is a gross caricature of the field of bioethics on the two continents. Nevertheless, I think it reveals something about how American bioethics functions. Those involved in the bioethics ought not to think of themselves as part of a broad dialogue concerning various issues in science, technology and the biomedical sciences. Rather, each participant is part of a market of ideas in which people aspiring for moral guidance pick and chose according to their own moral commitments and political ideology. Therefore, to come back to Wildes' argument, rather than beginning our moral investigations under the assumption that people share a common morality (as part of a broad discussion), we must start our reflection by looking at the differences and tensions reflected in the market of ideas. Only in a secondary stage can we move toward the attempt to establish a common ground.

Now where do we go from here? How is this relevant in our discussion concerning the ethical and social implications of nanotechnology? Am I not bringing one more voice in the cacophony of contemporary bioethics by proposing yet again a new approach?

III. FRAMEWORK OF AN INTEGRATED MODEL

At the onset, it must be clear that I do not propose a new set of principles, values or norms in moral theory. Nanotechnology raises some concerns that are "unique" but most of the ethical questions can be framed and addressed according to the ethical theories already articulated in various methodologies in bioethics and moral reasoning.

My contention is rather that what is necessary is a new approach of ethical reasoning that stresses a *better integration* of concerns (social, ethical, economic and political) that lie outside nanotechnology qua science and technology. Specifically, I suggest that an integrated model constitutes an attractive methodology since it stresses the social and scientific responsibility of researchers, which must be part of the process of scientific research. As already pointed out earlier in this work, this integration is required because of two specific aspects of the current model of scientific research and development: (1) the transition from academic science to post-academic science (which includes the ideas of trans-disciplinarity, the marketability of knowledge and the norm of utility), and (2) the interplay between the disciplines in science/technology and the disciplines in the humanities/social sciences.

A. Transition from Academic Science to Post-Academic Science

Due to the transformation of science, i.e., transition from academic science to post-academic science, it is crucial to reflect on how the integration of economic/political and trans-epistemic factors (i.e., values; intrinsic dimensions of post-academic science) can occur to set a framework that encourages the examination of moral and social issues in science and technology. Jean-Jacques Solomon, for instance, points out that the idea of the social responsibility of scientists and researchers is rather rarely contested in what he calls the conditions of the "new contract" (i.e., "contract" between society and the scientific community) of science and technology. He notes that in the current context researchers have the responsibilities to take into account the problems generated by scientific research and, to some extent, develop innovations oriented toward the resolution of social problems, such as famine, poverty, new sources of cheap and clean energy (Solomon, 1999, p. 68).[85]

Nanotechnology is an instance of this new context of scientific and technological development. The reason is that nanotechnology cannot develop without economic and political support and that the social and ethical questions it raises need examination before full acceptance by the public of the various potential applications. Obviously, at this juncture, it is not clear whether the field of nanotechnology is simply part of the normal development of science and technology or whether we can detect under the emergence of nanotechnology a new kind of science with specific features. That being said, some scholars speak of nanotechnology as "a movement in science" or "a new regime in science" in which science, politics, economy and culture interact with one another to change actual scientific practices. Consider, for instance, Ann Johnson's article, "The End of Pure Science: Science Policy from Bayh-Dole to the NNI" (2004). In her analysis, she recognizes that nanotechnology represents a transition in how science is

[85] As Solomon point out, "Les temps ont vraiment changé: il est de plus en plus difficile et rare de voir contesté l'idée qu'il existe une responsibilité sociale des chercheurs. Le nouveau contrat requiert que les problèmes imposés à la société par les développements mêmes de la recherche scientifique soient mieux pris en compte par la communauté scientifique...En ce sens, les politiques de la science et de la technologie, plutôt que d'être à la traîne des options économiques et stratégiques, devront davantage peser sur les choix économiques et sociaux par des recherches et des innovations directement orientées sur les fléaux dont souffre l'humanité et sur les dommages qui menacent l'environnement" (Solomon, 1999, p. 68). "Times have changed: it is more and more difficult and rare to see contested the idea of the social responsibility of researchers. The new contract requires that the problems imposed to society by scientific developments be better taken into account by the scientific community...In this sense, the politics of science and technology, rather than being behind the economic and strategic options, will have to have more influence on the economic and social choices of researchers and the innovations directly oriented towards the resolution of the plagues which humanity suffers and the damages threatening the environment" (translation mine).

being done, but stresses that it is too early to say whether nanotechnology is characteristic of scientific practice in the future. She writes that,

> Given the coherence of the politics, economics, and culture of science in this new regime, would it be fair to characterize the emergence of nanotechnology as a crystallizing moment in science? While it may be too early to tell, examining the context of science, politics, economy, and culture into which nanotechnology was introduced in the 1990s seems like a fruitful avenue for investigation. Cultural historians of science often seek historical episodes where changes in actual scientific practices can be related to socioeconomic, political, and cultural contexts...Often these works look at the emergence of new disciplines and fields of inquiry and show how these developments happened in light of particular circumstances outside of the science itself. The emergence, and particularly the hype, of nanotechnology and the government's attention to it are just such a case of an odd-looking event that can be made to look expected through attention to its political and economic context. Nanotechnology, in particular, seems to require, or at least benefits from, such a multidimensional explanation (Johnson, 2004, p. 226).

While acknowledging this is not the case, Johnson provocatively asks whether nanotechnology is the end of pure science due to the new economics of science, that is, how industrial applications play a crucial role in the scientific development. Rather than maintaining the distinction between theory (pure science) and application (applied science), she points out, referring to John Ziman's analysis of the transformation of science in the last few decades, that there is a new stress on the utility of science (political and economic context) which is translated into a common interest of science for scientists, politicians and the public. In her conclusion, she points out that nanotechnology could become many things but "in the current environment of policy, it is best to be an economic engine" (Johnson, 2004, p. 227).

If this is the case, issues related to economics, which includes moral values and norms, must be integrated in reflections concerning nanotechnology. Due to the high cost for the development of these new technologies, questions of justice and access will not only be raised but will need to be addressed. This can occur in a more fruitful manner if disciplines (i.e., the humanities and the social sciences) provide more forcefully their input and are invited to collaborate with scientists and engineers.

B. Interplay between Natural Sciences and the Humanities

The second aspect to consider, in relation to the current model of scientific research and development, is that the new approach to scientific research and development requires the interplay between the disciplines in the natural sciences and the disciplines in the humanities and social sciences.

As a preliminary comment, one must note that the stress on a better linkage between the two domains of inquiry has already taken place in the field of medical ethics, for instance. Some scholars hold a M.D./Ph.D. degree that enables them to understand and converse in both intellectual cultures. This is an ideal situation but in the majority of the cases, people who are interested in the ethical issues raised by nanotechnology either come from the humanities/social sciences or from a scientific discipline relevant to nanotechnology.

Hence, until recently the traditional distinction between the sphere of facts (science) and the sphere of values (the humanities), which rendered the interplay between these two domains difficult because dealing with different understanding and explanation of reality (science was considered as objective while the humanities (i.e., ethics) subjective), has resulted in a poor dialogue between disciplines and a lack of integration of particular insights each discipline intrinsically holds (Shamoo & Resnik, 2003, pp. 4-5). Since the locus of the applications of nanotechnology concerns human ends in general and when applied to the medical field, human nature, the human body as well as human identity, reflections on how science and technology impact who we are as human beings must be integrated more systematically at the core of scientific research. Khushf, for instance, remarks that this integration must occur within science itself, that is, between the various bodies of scientific knowledge that characterize nanotechnology (i.e., nano-, bio-, info-, cogno- sciences) so as to maximize how to achieve specific human ends (healing, enhancement, etc.). On the other hand, he argues, the integration must also consider human ends in relation to values (i.e., ethics and the disciplines of the humanities) within the context of scientific research. He notes that "the relevant basic science must be organized and integrated for a given end, and… a rich liaison between this integrated knowledge and more general scientific research is required. Further, there is a need to integrate the reflection on human ends (associated with ethics and the humanities) with the sciences that advance those ends" (Khushf, 2004b, p. 18). The NBIC report (Nanotechnology, Biotechnology, Information Technology and Cognitive Science) also recognizes a connection between the various scientific disciplines so that they are organized in a hierarchy in which "each one rests upon and informs the one below." The report likewise insists on the necessity of unifying knowledge in the sense of integrating natural sciences, social sciences and humanities (Roco & Brainbridge, 2002, pp. 10-13, 83-84).

To sum up, the reason for such integration is that scientific and technical advancement are organized and point toward specific *human* ends which requires a linkage between what science and technology can achieve in relation to those human ends. Furthermore, the "science of nature" does not take place in a vacuum but is influenced by cultural forces and philosophical and metaphysical assumptions. Natural sciences (facts) present only a partial understanding of reality that is not completely autonomous from "les sciences humaines" (the human sciences or the humanities) (Prosperi, 2000, p. 89).

C. Good vs. Bad Integration

Before I further elaborate on how an integrated model works in relation to nanotechnology, it is necessary to emphasize that the type of integration developed in this work does not refer to convergence, in the sense of the search for a common ground between theories in which a partial mutation occur, that is, a particular theory might have to adapt in order to fit an overall system. This type of integration is precisely what my model attempts to avoid, that is, the removal of the specificities of a particular discipline. Hence, it is crucial to make first a distinction between integration and convergence.

The ability to provide a coherent model of integration that captures the necessity to acknowledge moral pluralism and the need to reflect on the ethical implications of new technologies depends on how the decision-making process in ethical reflection takes place. In order to understand better how integration works, it is first crucial to make a distinction between integration and convergence. This is not just a semantic distinction but also a crucial differentiation. Integration is a process by which various parts of an entity or an organism are made a functional and structural whole whereas convergence is a type of overlap that is characterized by a common ground between theories. In the former case, there is not necessarily a mutation of what is integrated in order to fit the structural whole but rather it is an addition to what is already in existence. In the latter case, it is the search for a common ground between theories that defines convergence and therefore, there is a partial mutation in the sense that a particular theory might have to adapt in order to fit the whole.

These definitional remarks seem gratuitous in the sense that they do not help us understand how an integrated model works. However, the distinction between integration and convergence reveals one important aspect to keep in mind: an integrated model does not necessarily imply convergence in the sense of an intrinsic consensus or overlap. An integrated model works on the assumption that consensus is a *managed* consensus between moral acquaintances who, despite their diverging moral views, can reach a certain type of consensus based on a collaborative dialogue (which assumes certain moral values such as trust and respect). Thus, consensus is not discovered but rather created through mutual agreement. The creation of an agreement does not mean that no moral content is implied in the process of consensus. To the contrary, as it will be shown in what follows, an agreement requires certain values and norms that allow moral acquaintances to accept or reject certain propositions.

Having made the distinction between integration and convergence, we can now turn to the concept of interdisciplinarity. Jean-Pierre Desclés, in his discussion on interdisciplinarity, distinguishes between what he call bad interdisciplinarity ("la mauvaise interdisciplinarité") and successful interdisciplinarity ("l'interdisciplinarité réussie"). While I do not use specifically the terminology of "interdisciplinarity" in this work, since I characterized nanotechnology as a transdisciplinary field of research, a closer look at Desclés' analysis of what constitutes good interdisciplinarity is helpful because it offers some insights relevant to understanding the type of integrated model developed in here. It must be noted, however, that Desclés' definition of interdisciplinarity is very similar to the term transdisciplinarity in the way I define it. In both cases, it refers to the interaction between different disciplines that look at the properties of the same object of study in order to provide a more complex understanding of that object.[86] The main difference between interdisciplinarity and transdisciplinarity (in the way I use it in this work) is the fact that transdisciplinarity implies the interaction between, and *beyond*, particular scientific and non-scientific disciplines. In other words, interdisciplinarity is more focused on disciplines with some affinities while transdisciplinarity goes beyond these affinities in order to invite other sources of following knowledge (for instance, in the field of the humanities and the social sciences) to participate in the debates.

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[86] Desclés defines interdisciplinarity as follows: "l'interdisciplinarité articule différentes disciplines qui scrutent les propriétés d'un même object d'étude, de façon à en avoir une vision théorique plus complete, et éventuellement, explicative" (Desclés, 2000, p. 109). ("Interdisciplinarity includes different disciplines that examine the properties of the same object of research so as to have a more complete theoretical, and eventually explicative, vision of it." Translation mine)

Now, bad interdisciplinarity, Desclés asserts, is characterized by a type of analysis that works at the margin of disciplines, that is, it tends at moving towards a space that is the most congenial to the interaction with various disciplines or where a common ground is easy to establish. The problem with this approach to interdisciplinarity is that it tends to nullifying what is specific to a particular discipline but also undermines what is different from other disciplines. Bad interdisciplinarity develops concepts and ideas that are too broad, often obscure and lack precision in order to provide each discipline's particular insight. The result is that this type of interdisciplinarity, in putting aside the particularities of each discipline, relies on vague metaphors and analogies unable to capture the core facts and concepts of each discipline (Desclés, 2000, p. 120). In other words, what this type of interdisciplinarity generates is unique level of discourse that is difficult to validate because it lacks the ability to speak precisely according to a set of concepts and ideas particular to an area of scientific research.

On the other hand, successful interdisciplinarity (for instance, one might think at the role of philosophers and bioethicists in medical schools who provide their insights not according to the ethos of the scientific communities but for the perspective of the disciplines of philosophy and ethics) has as a starting point the core of the fundamental principles and concepts of each discipline, what Desclés calls "le noyau dur de chaque discipline." Hence, each discipline does not look necessarily at the common ground or area of potential overlap it shares with other disciplines but rather, it continually reassesses and develops its own concepts, key ideas and foundational premises (Desclés, 2000, p. 120). In short, successful interdisciplinarity tends at respecting the autonomy of each discipline in order to provide a richer picture of reality based on different level of representations and discourses. As Desclés puts it,

> A successful interdisciplinarity is often set in many representations articulated between them in a structure of different levels; as such, it is possible then to have multiple discourses controlled by each composing discipline. Due to the regulated articulations, this architecture has in the horizon an epistemology that is at the same time unified as well as diversified, whence the possibility of a theoretical integrative and inclusive aim (Desclés, 2000, p. 121, translation mine).[87]

The preservation of each discipline's insights and characteristics is crucial for the type of integrated approach I am proposing. On the one hand, there must be unity in the sense that the object of research must be well defined and clearly articulated at the conceptual level so as to give a common perspective concerning the object of research. On the other hand, however, each discipline understands, explains and organizes differently reality. Hence the necessity to allow a diversity in models of explanation.

D. A Dynamic Model of an Integrated Approach for Nanotechnology/Nanomedicine

The development of nanotechnology and nanoscience concerns a cluster of complex relationship between several domains of human activities and inquiry. Various levels of analysis must take place in order to provide the necessary framework for a thorough assessment of the social and ethical implications of nanotechnology. My investigation into the world of nanotechnology revealed that many factors influence how this new field

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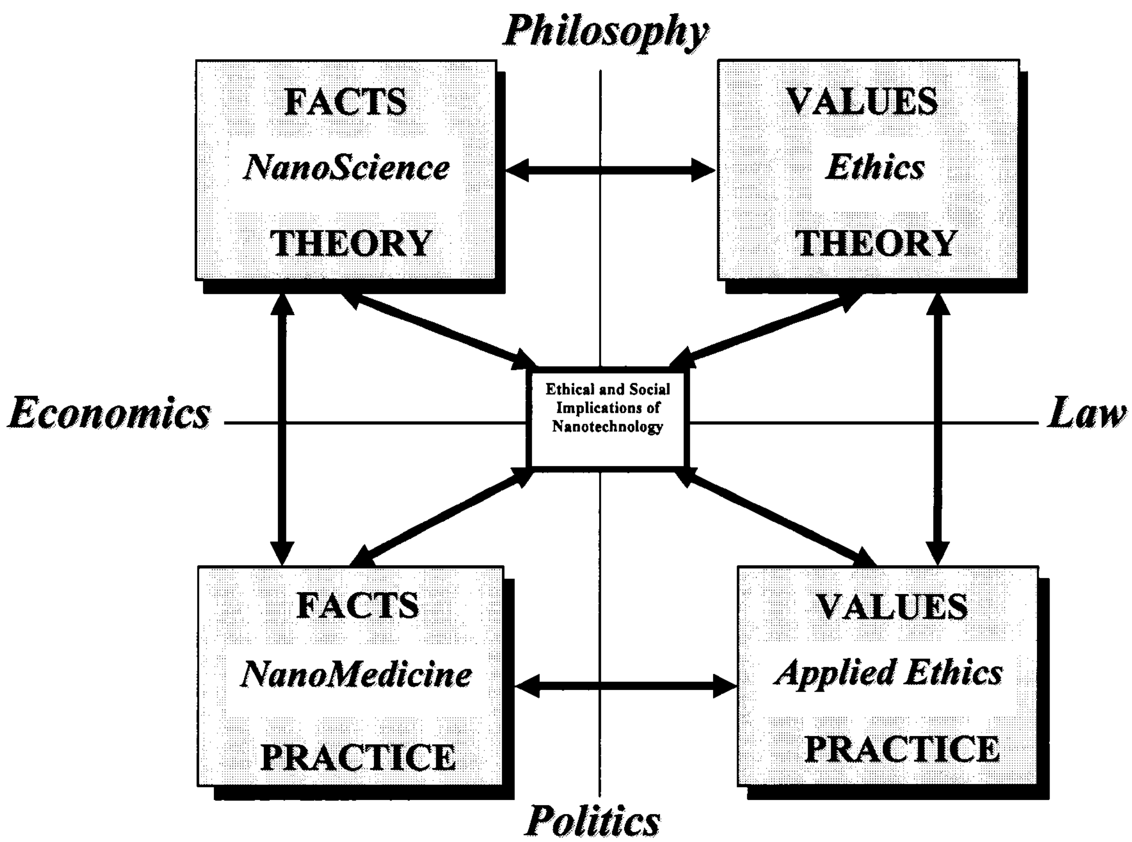
[87] "L'interdisciplinarité réussie se déploie souvent avec plusieurs représentations articulées entre elles dans une architecture en niveaux; il lui est alors possible de tenir des discours multiples et contrôlés par chaque discipline composante. Grâce aux articulations régulées, elle a pour horizon une épistemologie à la fois unifiée et diversifiée, d'où la possibilité d'une visée théorique intégrative et englobante" (Desclés, 2000, p. 121).

of inquiry is perceived by the public and within the scientific community. However, it has become clear that the development of nanotechnology and its applications in different areas of human life demand a *better* integration of ethical reflections than what has occurred so far. The reason is that nanotechnology could have the potential to change our way of life as well as our understanding and conception of what it means to be a human being.

As pointed earlier, a *poor integration* of social and ethical values has characterized science and technology so far. Therefore, an approach that would foster such integration within science and within the humanities and the social sciences should be at the forefront of our inquiry. On the one hand, people in science and technology, while they understand the economics and politics involved in the development of their disciplines (due to the process of applying for funding and the role of political powers involved in it, for instance), usually are only slightly concerned with the philosophical and ethical underpinnings of their work, and not to the degree as people in the humanities and the social sciences, for instance. On the other hand, those in the disciplines of the humanities and the social sciences often lack the ability to appreciate the scientific and technological cultures and their specific ways to understand, explain and organize reality. Hence, in order to bring these three areas (the natural sciences, the humanities, and the social sciences) into collaboration, it is necessary to develop a model of ethical investigation that allows the integration of the various areas intrinsic to reflections on the social and ethical implications of nanotechnology.

To be sure, building bridges between these three cultures is an arduous task because of the different epistemologies, rationalities and philosophical assumptions each discipline brings into the debate. However, if society is willing to harvest the potential benefits of nanotechnology and avoid the same kind of opposition that occurred in Europe concerning Genetically Modifies Organisms (GMOs), it is essential to be proactive and provide the conditions for a constructive dialogue. To that end, a dynamic integrated model represents a description of how the various areas of human knowledge and practices can interact and provide their particular insights concerning nanotechnology in the debate of its ethical and social implications. Below I represented in a diagram how the various levels of reflections interact but also how they should converge toward the discipline of "nano-ethics." This diagram is not intended to imply a clear separation between facts and values as well as theory and practice. Rather the goal is to stress the necessity of a better understanding of how facts/values and theory/practice are connected.

DYNAMIC INTEGRATED MODEL FOR NANOTECHNOLOGY



This approach is based on the specific context in which scientific and technological development (qua nanotechnology) takes place. First, it recognizes that nanotechnology involves various disciplines within and outside science itself. In other words, nanotechnology is trans-disciplinary by nature. This transdisciplinarity requires philosophical investigation to be able to build a bridge between the natural sciences (facts) and the humanities (values). Second, the new regime of science is post-academic, that is, scientific and technological development occurs outside academia and depends on the funding of the government and private institutions. The success of funding scientific projects is contingent upon their ability to find their applications in the industry - what Ziman call the norm of utility, that is, scientific and economic validity. Third, this norm of utility is not restricted to economics and industrial applications but also contains trans-epistemic values in the production of knowledge, i.e., human values and social interest. Ultimately, these norms and values will be translated into public policy that will bridge the gap between moral theory and the various areas of applied ethics. Finally, how the values, norms and principles are implemented in the industry will depend on the politics involved in the decision process, which is closely related to the role of economics. The above diagram aims at describing how these various disciplines can interact with each other and in relation of the locus of the ethics of nanotechnology.

CHAPTER VI

LOOKING INTO THE FUTURE: NANOTECHNOLOGY IN THE BIOMEDICAL SCIENCES

I. RECAPITULATION

Throughout this work, three working hypotheses framed my analysis. First, the potential ethical issues related to nanotechnology must be *contextualized*, that is, unless close attention is given to the transformation of the ethos of science (i.e., the transition from academic to post-academic science), the analysis of the ethical questions raised by nanotechnology and nanomedicine is partly misguided and incomplete. It is misguided because ethical issues are always located within a particular context that affects partially how these issues are framed, examined and understood. It is incomplete because the questions raised by nanotechnology do not concern only ethical considerations but likewise economics, public policy, politics, etc. In short, a better understanding of the ethos of post-academic science is essential because it locates science and technology in a broad context that is not limited to the production of knowledge (science) and its implementation in concrete applications (technology). The role played by economics and politics in contemporary (post)-academic scientific culture is as important as science and technology themselves. As Ziman observes, "state patronage inevitably brings politics into science – and science into politics…The emergence of *science policy* – more generally, *science and technology policy* – is a major factor in the transition to a new regime for science" (Ziman, 2002, pp. 74-75). Partly, the aim of this work is to lay out the geography in which the development of nanotechnology takes place in order to provide a necessary conceptual framework that should guide our subsequent ethical and philosophical reflections.

The second working hypothesis is that the context of post-academic science offers the conditions for a better integration of philosophical and ethical concerns at the core of scientific and technological development. Scientific knowledge will continue to progress but without the prospect of concrete applications in the industry, it will either be under-funded or partially ignored due to the lack of economic incentives. It is precisely the context of application that generates ethical conundra. The reason is that innovative technologies such as nanotechnology can interfere with particular human ends and goods. That is, they might inadvertently restrain human flourishing through unanticipated consequences for humans themselves and/or their environment.

The third hypothesis is that the concept of a *better integration* is key to reflections on science and technology. In order to foster an intellectual culture that promotes further substantive reflections at the moral level, a procedural integrated model is developed in this work. Such a model aims at facilitating the integration of ethical reflections in scientific and technological discourse but also to account for the socio-political factors as well as the philosophical and ethical arguments from various traditions and competing moralities that shape the debates over the ethical and social implications of nanotechnology.

These three working hypotheses form the background of my analysis of the ethical and social implications of nanotechnology. In the light of these reflections, I now turn to an overview of various applications of nanotechnology in medicine and biotechnology and provide some suggestive conclusions concerning the impact of new technologies concerning the practice of medicine and the use of humanized technologies. I purposely do not intend to give an in depth examination of these issues, since each of them would require an analysis that goes beyond the scope of this work. The purpose of this chapter is more modest in its scope and is rather suggestive. It aims at pinpointing where potential ethical issues might occur in the application of nanotechnology in the biomedical sciences.

II. NANOMEDICINE / NANOBIOTECHNOLOGY

Among the many applications of nanotechnology, some of the most promising and those likely to be first on the market are within the biomedical sciences as they have the potential directly to impact the very existence of humans by conquering disease and/or enhancing their nature. So far, the applications remain at the early stages of their development and therefore, the promises of nanotechnology should not blind the ethical and social issues at stake in the development of nanomedicine. However, an overview of the potentials benefits for humans help us see the importance of nanotechnology/ nanomedicine for our society as a whole, medicine and health in particular.

A. Definitions

Before we look at the potential applications of nanotechnology in medicine, let us first turn to the definition of nanomedicine. As with nanotechnology and with nanomedicine, an authoritative definition is not possible at this juncture for the same reasons articulated in reference to nanotechnology. There is a lack of consensus as to whether nanotechnology is an emerging field with distinct features compared to what has occurred so far in science and technology or whether it is simply the evolution of science and technology. However, in order to contextualize and articulate more clearly what we mean by nanomedicine (a subset of nanotechnology), it is essential to provide at least some definitions. In particular, I consider two definitions, one provided by Robert Freitas, author of two important volumes on nanomedicine (*Nanomedicine, Volume I: Basic Capabilities* and *Nanomedicine, Volume IIA: Biocompatibility*) and the other by the National Institute of Health. First, let us consider Freitas' definition. He defines nanomedicine as,

> the process of diagnosis, treating, and preventing disease and traumatic injury, of relieving pain, and of preserving and improving human health, using molecular tools and molecular knowledge of the human body (Freitas, 2002).

In light of this brief definition, Freitas articulates his futuristic vision concerning the future of nanomedicine. First, he predicts that in the near future, nanomedicine should be able to address and resolve major medical problems using new types of nanostructure materials that will allow the interface between biological systems and nanomaterials (e.g., hybrid nanomechanical devices with biological components, such as sensors for the detection of cancer or dispensers of drugs). Second, he foresees nanomedicine as an important tool for advancement in biotechnology, particularly in molecular medicine and biobotics (microbiological robots). And third, in 10-20 years, Freitas contends, molecular machine systems and nanorobots, in conjunction with "medical armamentarium" should provide the tools necessary to conquer disease, ill-health and suffering (Freitas, 2002).[88]

A more realistic approach as to the potential of nanomedicine is advanced by the National Institute of Health. In 2003, in a statement before the Senate Committee on Commerce, Science, and Transportation, the potential applications of nanotechnology in the biomedical sciences were discussed. The statement reads as follows:

> Nanotechnology has the potential to radically change the study of basic biological mechanisms, as well as to significantly improve the prevention, detection, diagnosis and treatment of diseases and adverse medical conditions. The key to this potential is that nanotechnology operates at the same scale as biological processes, offering an entirely unique vantage point from which to view and manipulate fundamental biological pathways and processes. Most other technologies require the study of large numbers of molecules purified away from the cells and tissues in which they usually function; nanotechnology may offer ways to study how individual molecules work inside of cells... (NIH, 2003).

The important and innovative aspect of nanotechnology, in its applications in the biomedical sciences, is the potential to combine nanochemistry and biology (the wet/dry

[88] At this stage of the development of nanotechnology, Freitas' vision is rather optimistic concerning what it can achieve. There are more radical views about the use of nanotechnology and nanomedicine. Although not specifically mentioned, Freitas' visions to conquer disease fuels, for instance, the ideology of the Immortality Institute which is dedicated to the eradication of human physical death: "The mission of ImmInst [Immortality Institute] is to conquer the blight of involuntary death. ImmInst shall function as an umbrella organization to help its members succeed in working towards the possibility of human physical immortality. This Institute shall serve as a platform for the exhibition, exchange, debate, and creation of concepts and methods toward that end as well as to disseminate any and all relevant information for the purpose of human physical immortality" (Immortality Institute, 2005).

interface of nanoscience).[89] This means that researchers are studying how inorganic nanomaterials and biological systems interact in order to develop applications for living organisms. Some of these applications are outlined in the next section so as to give an overview of what can be accomplished in nanomedicine and provide a better understanding of where potential ethical issues could lie.

B. Applications

The various potential applications (some already in existence) of nanotechnology in the biomedical sciences include new types of drugs, either based on the human genome or structural genomics (e.g., information related to functionality to be translated into protein structures) or biomimetics (e.g., use of synthetic molecule/copy of the functional elements of a protein); targeted drug delivery (i.e., bioavailability), nanoscale biostructures which include artificial bones, tissue engineering and cell therapy; nanobots – nanoshells; and various types of devices, for instance neuro-electronic interfaces – these nanodevices should allow the interaction between computers and the nervous system. There are five areas of applications that I wish to consider[90]:

[89] Here a word of caution is needed. While it is true that nanotechnology operates at the same scale as biological processes, there are some important differences. Jones notes that "a radical nanotechnology must be possible in principle, because we are here. Biology itself provides a fully-worked-out example of a functioning nanotechnology, with its molecular machines and precise, molecule by molecule, chemical syntheses…Yet the engineering approach that radical nanotechnologists have proposed to make artificial nanoscale robots is very different to the approach taken by life. Where biology is soft, wet, and floppy, the structures that radical nanotechnology envisions are hard and rigid" (Jones, 2004, pp. 2-3).

[90] I am indebted to Gordon and Sagman (2003) for the summary of the various applications of nanotechnology in the biomedical sciences. This section is a summary of their document on nanomedicine taxonomy.

1. Biopharmaceutics

The first area of application is drug delivery, that is, the optimization of drug delivery. New technologies should influence the rate of absorption, distribution, metabolism, and excretion of the drug in the human body (Gordon & Sagman, 2003, p. 7). Nanotechnology could offer new delivery solutions in two areas: drug encapsulation and functional drug carriers.

The advantage of using encapsulation materials at the nanoscale is that they present better solutions for the delivery of certain drugs. For instance, silica and calcium phosphate (hydroxyapatite) have proved to be more effective at the nanoscale than at the microscale in the delivery of certain drugs. Currently, the use of nanoparticle encapsulation is under investigation for the treatment of neurological disorders such as Prakinson's, Huntington's, and Alzheimer's diseases. The aim is to develop drugs that would be able to deliver therapeutic molecules directly to the central nervous system.

Functional drug carriers are another type of drug delivery that uses nanomaterials to carry drugs to a particular location in the human body. For instance, certain nanostructures (fullerenes/Buckyballs, dendrimers and nanoshells) can be used to target specific cells and subsequently release the payload as they enter the cells (cells can absorb materials below 100 nm, hence the importance to develop nano-products)

2. Implantable Materials

The possibility of repairing and replacing human tissues is another remarkable application of nanotechnology in the biomedical sciences. Scientists are developing a new generation of nanoscale biostructures that should solve some of the problems related to the repair and replacement of tissues in the body (most common problems are immune rejection and invasive surgery). Nanotechnology offers new biocompatible nanomaterials and coatings that should increase the adhesion, durability and lifespan of implants (Gordon & Sagman, 2003, p. 10).

Other areas of application of nanoscale biostructures include bone repair, bioresorbable materials and smart materials. In the case of bone repair, calcium phosphate apatite (CPA) and hydroxyapatite (HAP), for instance, are two nanoceramic materials that can be used in bone repair since they have the ability to conform to and bond with bone. Bioresorbable materials have the advantage of having the capacity to disintegrate without human intervention. For instance, these nanomaterials can be used in sutures and orthopedic fixation devices but more importantly, they could be used as temporary implants, which would avoid subsequent surgery due to their biodegradable nature (Gordon & Sagman, 2003, pp. 11-12). Finally, smart materials are nanomaterials that have the ability to react to the environment (to temperature, for instance). These types of applications are usually considered as ways to restore or enhance human performance at the mental level (sensory) and physical level (increase strength or restore mobility).

3. Implantable Devices

When we turn to implantable devices, nanotechnology offers new technologies that allow the monitoring and the collection of data in a more efficient way. Nanosized *sensors* could be used for the monitoring of blood sugar in diabetes. Texas A&M and Penn State University are developing implantable sensors for such applications. Researchers at these institutions use "polyethylene glycol beads coated with fluorescent molecules...The beads are injected under the skin and stay in the interstitial fluid. When glucose in the interstitial fluid drops to dangerous levels, glucose displaces the fluorescent molecules and creates a glow. This glow is seen on a tattoo placed on the arm" (Gordon & Sagman, 2003, pp. 14). Other applications include the development of sensor microships by NASA in order to be able to monitor body parameters such as pulse, temperature and blood glucose.

Devices can also be implanted in the human body for specific *medical* applications. For instance, very small implantable fluid injection systems can be placed in the body in order to dispense drug on demand for the treatment of diseases such as cancer. The advantages are the ability to target the tumors to be treated and such devices allow a better dosage of the medications. Other applications include implantable heart sensors to monitor the heart's activity and can be used as implantable defribulator. There is also research done in Denmark at Aalborg University where researcher uses Functional Electrical Stimulation (FES) to help people regain mobility to their paralyzed limbs by stimulating muscles electrically with implanted electrodes (Gordon & Sagman, 2003, pp. 14).

Finally, some nanodevices are being developed to restore vision and correct hearing dysfunctions. These types of devices are built to collect and interpret information and transform them into electrical signals transferred directly to the nervous system of an individual. Retinal implants use nanodevices to stimulate electrically the functional neurons in the retina. There are two methods currently under development. The first uses a tiny video camera attached to the glasses of the blind person. The camera collects images processed by a microcomputer. Subsequently, images are transmitted to the brain by electrodes that stimulate optical nerves. The other approach consists in the use of "subretinal implant designed to replace photoreceptors in the retina...The implant makes use of a microelectrode array powered by as many as 3,500 microscopic solar cells" (Gordon & Sagman, 2003, pp. 17).

Hearing loss is usually caused by the absence or malfunction of sensory cells in the cochlea (spiral-shaped cavity of the inner ear that contains nerve endings essential for hearing). Cochlear implants function as a substitute for the task of the middle ear, cochlear mechanical motion and sensory cells. The implants are placed in the skull behind the ear and include wires that are inserted into the cochlea. When sound energy, captured by an external microphone, is produced electrodes stimulate auditory nerves (Gordon & Sagman, 2003, pp. 15-16).

4. Surgical Aids

Another category of nanodevices that could change the practice of medicine is medical nanodevices that would allow greater precision, better monitoring of physiological and biomechanical parameters, as well as safer and potentially less expensive (because less invasive) surgical procedures. For instance, a company called Verimetra, is developing smart medical instruments (catheters able to measure the blood velocity along a vessel) that use sensors using micro-electromechanical systems (MEMS) technology. Robotic surgical systems are also under development to provide surgeons unparalleled precision instruments. The great advantage of such technology is that it should allow less invasive surgical procedures.

5. Diagnostic Tools

Finally, nanotechnology offers new applications in the area of genetic testing. In particular, these innovative solutions can increase speed and accuracy in the process of identifying genes and genetic materials either for treatment oriented applications or the development of new drugs. So far, various new technologies have been developed. They include, for instance, the use of gold nanoparticle probes that are coated with chemicals so as to stick to target genetic materials. Another promising application is the use of nanomaterial as instruments for analysis. This lab-on-the-chip approach could multiply the types of analysis performed, since "micro and nanofluidic devices…can integrate mixing, moving, incubation, separation, detection and data processing is a small device" (Gordon & Sagman, 2003, p. 22).

The miniaturization of diagnostic devices can also be used in the production of high quality images of abnormal medical conditions such as tumors that escape the scrutiny of our current technology. Due to the location of certain tumors in the human body, their detections is difficult and require, if found, invasive surgical interventions. Also, currently, research is being done to develop nanodevices such as miniature video systems contained in a pill that could produce pictures of the entire digestive system.

Other applications use nanoprobes to detect cancerous tumor in the brain (Gordon & Sagman, 2003, p. 22).

II. ETHICAL AND PHILOSOPHICAL ISSUES RAISED BY NANOMEDICINE

The five areas of application outlined in the previous section do not disclose specific controversial issue per se. Rather, a closer look reveals that the potential problems ought to be situated in a broader perspective. In particular, two set of issues are considered in what follows. The first issue is related to how these new technologies could potentially change the practice of medicine due to the increased use of technology such as smart devices. The second issue concerns the ethical issues raised by enhancement technologies which could transform our understanding of what it means to be human (human-machine interface) and raise the issue of how to regulate the use of new powerful technologies. But first, let us turn to how the use of nanotechnology in the biomedical science could transform medical practice.

A. Transforming the Practice of Medicine

First, then, there is the prospect of transforming how medicine will be practiced. This will require a new understanding of medical practice and a new philosophy of medicine (new in the sense that further dependence on technology redefines the clinical encounter).

1. Reconceptualizing the Role of the Physician

The role of the physician will have to be reconceptualized in relation to the traditional components of medical practice but now possibly also in relation to "smart" medical devices such as nanobots or sensors able to monitor and collect important data concerning bodily functions and possible diseases. Considering that patients should know how to collect the necessary information concerning their health and know how to interpret the data, they will be able to assess even more so their own medical condition and provide their own pre-diagnosis. For instance, the use of sensors (monitoring and collection of data in conjuncture with new drug delivery systems) could limit, to a certain extent, the role of the physician as a medical expert in the sense that patients have become more knowledgeable as to their medical conditions.

Hence, a shift could occur as to the specific role of the physician in the clinical encounter since patients might be able to make decisions on their own because new innovative technologies could make it easier to implement certain low risk treatments. For instance, blood tests and the injection of insulin for people with diabetes can be performed without the intervention of a medical professional. A few decades ago, this was not possible. However, new technology has made this a reality. We can image that in the future other medical conditions for which patients will be able to treat themselves, assuming they have the right training. In these instances, the physicians might have not only the role of explaining and teaching how certain devices work, but also a role of consultant as to the interpretation of the medical data. As such, the traditional model of the patient-physician relationship could be reconfigured.

2. Rethinking the Traditional Model of the Patient-Physician Relationship

The second reason for a potential transformation of the practice of the medicine is the ability to monitor one's health could reshape how the clinical encounter takes place. In order to support my argument, I will use the work of Edmund D. Pellegrino and David C. Thomasma and demonstrate how the clinical encounter could be transformed (as it has already been by economic considerations) by new technologies.

The traditional model of the patient-physician relationship is based on the assumption that there is an imbalance of expertise and power between the sick and the medical professional. Edmund D. Pellegrino and David C. Thomasma develop a specific model of the clinical encounter and argue that medicine, as a form of human activity, implies *internal goods and standards of excellence*.[91] These are "moral imperatives," they contend, that constitute an "internal morality of medicine – something built into the nature of medicine as a particular kind of human activity" and constitute the essence of the clinical encounter (Pellegrino & Thomasma, 1993, p. 42). Pellegrino and Thomasma formulate five imperatives that characterize the relationship between the physician and the patient. They are (1) the inequality of the medical relationship; (2) the fiduciary nature of the relationship; (3) the moral nature of medical decisions; (4) the nature of medical knowledge; and (5) the ineradicable moral complicity of the physician in whatever happens to the patients (Pellegrino & Thomasma, 1993, p. 42).

[91] Pellegrino and Thomasma derive their definition of medicine as a human activity from Alasdair MacIntyre's definition of a practice he develops in *After Virtue*. He defines a practice as "any coherent and complex form of socially established cooperative human activity through which goods internal to that form of activity are realised in the course of trying to achieve those standards of excellence which are appropriate to, and partially definitive of, that form of activity, with the result that human powers to achieve excellence, and human conceptions of the ends and goods involved, are systematically extended" (MacIntyre, 1981, p. 187).

First, the *vulnerability and inequality* of the medical relationship is related to the fact that illness produces a mental state in which the patient becomes anxious, fearful, and dependent on others – primarily the physician. It creates a dependence and vulnerability of the ill person who must refer to a skilled professional in order to regain control of his health and life. This inescapable situation of vulnerability "imposes *de facto* moral obligations on the physician. In a relationship of such inequality, the weight of obligations is on the one with the power....The physician...has the obligation to protect the vulnerability of the patient against exploitation" (Pellegrino and Thomasma, 1993, p. 42). The condition on how the relationship is established logically implies the second moral imperative, that is, the *fiduciary nature* of this relationship. Trust and confidence are "ineradicable" for the benefit of the sick and in order to achieve the ends of the medical endeavour (Pellegrino & Thomasma, 1993, p. 43).

Third, *the nature of medical decisions* makes the medical relationship a moral enterprise in the sense that most of the medical decisions are the combination of technical and moral components (Pellegrino & Thomasma, 1993, p. 43). This means that the physician must refer to his/her technical knowledge in order to make a scientific assessment (diagnosis, prognosis, and choice of therapy) of the patient's condition without undermining the ends of medicine, that is, the good of the patient. As Pellegrino and Thomasma put it, "the good of the patient is the end and purpose of that relationship. But this is as much a moral as a technical good. To see the relationship between the technical and moral aspects of medical decisions, and to place them in the right relationship to each other, is an inescapable moral obligation and the test of a true physician" (Pellegrino & Thomasma, 1993, p. 43). Hence, in Pellegrino's and Thomasma's views, technology and morality ought not to be dissociated but rather combined to enhance the well-being of the patient.

Fourth, *the characteristics of medical knowledge* impose certain moral obligations on those who possess it. Medical knowledge is not acquired primarily for its own sake but rather for a specific purpose – the care of the sick. Consequently, it is argued, physicians have the obligation to be stewards of that knowledge and not the exploiters of medical techniques for reasons of self-interest or monetary gain. "As stewards, they [the physicians] are obliged to preserve, validate, teach, and extend medical knowledge and see that it is available and accessible to those for whom it is acquired in the first place. Medical knowledge can never be a commodity since, unlike commodities, it is produced not for its exchange value but because it is needed by sick human beings" (Pellegrino and Thomasma, 1993, p. 44).

Finally, by virtue of the kind of agreement established between the patient and the physician, there is an implicit *moral complicity* necessary for the healing process to be achieved. "The physician is therefore *de facto* a moral accomplice in whatever is done for good or ill to the patients" (Pellegrino & Thomasma, 1993, p. 44). The obligation to serve the patient's good, Pellegrino and Thomasma argue, cannot be overridden on behalf of any other party such as the hospital, the economic or fiscal policy, or the law (Pellegrino & Thomasma, 1993, p. 44).

These five imperatives preserve, to a certain extent, their relevance even by the introduction of innovative technologies in medical practice. However, personalized medicine (i.e., the use of smart devices) will undermine certain aspects of the clinical encounter as conceived by Pellegrino and Thomasma, for at least three specific reasons.

First, the notion that patients are in "total dependence" and are vulnerable because of the inequality of power in the relationship between the physician and the patient must be reassessed in the light of the potential use of new technologies and new sources of medical knowledge. The reason is that the power of the physicians and/or medical professionals is related to the type of knowledge they possess. However, nowadays patients have access to medical information (see for instance the website MedicineNet.com that provides information concerning various medical conditions, diseases, medications, symptoms and signs, and medications[92]) that reconfigures how patients collaborate with their physicians. It is not unusual to see patients asking for alternative treatments or simply asking for a second opinion before accepting a particular diagnosis and treatment because of the level of knowledge they already have acquired through personal investigation concerning their medical condition. It is certainly the case that not all patients have the willingness to contest the doctor's diagnosis or simply the ability to understand medical data, but it is not unusual to hear patients with no medical education or expertise being able to talk about their medical condition in a well articulated fashion.

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[92] On the website, MedicineNet.com presents itself as "an online, healthcare media publishing company. It provides easy-to-read, in-depth, authoritative medical information for consumers via its robust, user-friendly, interactive web site. Since 1996, MedicineNet.com has had a highly accomplished, uniquely experienced team of qualified executives in the fields of medicine, healthcare, Internet technology, and business to bring you the most comprehensive, sought after healthcare information anywhere. Nationally recognized, 100% Doctor-Produces by a network of over 70 U.S. Board Certified Physicians, MedicineNet.com is the trusted source for online health and medical information."

The fact that patients have become "smarter" is of course not a new phenomenon, but the use of innovative devices as the ones presented in the previous section is likely to even further reconfigure the role of physicians.

The second reason why innovative technologies could transform the clinical encounter is related to the type of relationship between the patient and the physician. The fiduciary nature of the clinical encounter is likely to be transformed by the use of "smart devises." Trust is built out of an established relationship between the patient and the physician. In contemporary health care, however, it is rare to have the same physician over a long period of time, as it used to be the case with family doctors in the past. Consequently, trust cannot be established in the same way as with family doctors due to the inability to create the bonds necessary for trust to happen. The use of "smart devices" creates yet another alternative for the source of medical information which could undermine the trust of the patient in the physician's ability to diagnose a specific medical condition, especially if the diagnosis of the physician is different from the results of diagnostic nano-devices. For instance, physicians are not always able to detect cancer in early stage despite lab tests due to the location of some cancerous tumours. The use of new diagnostic devices might create doubt in the minds of patients as to the ability of physicians to make the right diagnosis appropriately and therefore; the use of diagnostic tools might become an imperative in the mind of patients, which could reinforce the need for a technocratic medicine even for "benign" medical conditions.

The third point gathers together the last three imperatives mentioned by Pellegrino and Thomasma, that is, the nature of medical decisions as a combination of technical and moral components, the characteristics of medical knowledge and the moral complicity between the physician and the patient. The use of technology raises moral questions that demand a clear articulation of how to solve them. However, as it has been pointed out in the last chapter, the resolution of techno-moral issues is confronted to competing moralities that characterizes our culture. As scientists and engineers continue to develop innovative (and sometimes controversial) devices and technologies, the nature of medical decisions will not be defined necessarily in terms of the good of the patients. The prospective of the development of enhancement technologies will challenge the idea that physicians are stewards of medical knowledge and moral accomplices since the purpose of using these technologies goes beyond therapeutic purposes (i.e., enhancement). In a market oriented medicine as the one in the United States, economic considerations play an important role as to what medical procedures doctors and health care professionals agree to perform. Hence, the decisional power lies partially outside the medical profession.

B. Social/Ethical Issues

The second set of questions involves the *use of nanotechnology in the human body* or *humanized technology*. There are three distinct clusters of concerns to consider: (1) the moral acceptability of humanized technology (i.e., the ethical use of technology); (2) the moral acceptability of the transformation of human nature (i.e., transforming human nature); and (3) the extent of the transformation of the human body (i.e., where to set the limits of the transformation).

I do not intend to provide a normative account as to how to respond to this set of issues because it is very unlikely that one will be able to provide a normative assessment of the various aspects related to the enhancement of the human body.[93] As Ludwig Siep remarks, throughout history, the body has been treated in various ways and the best account we can provide is the way particular cultures, traditions, philosophies and religions have understood the body. Moreover, ethical reflections are rather unsympathetic to such an approach. Although Siep does not necessarily share this point (he develops a conception of the human body as a valuable *common* heritage[94]), he nevertheless stress that "this [account] seems to be of no interest for contemporary *ethics*, since we live in pluralistic societies and autonomous citizens have constitutional rights to think of their bodies and to treat them according to their own views" (Siep, 2003, p.173, italics in original). In liberal societies as ours, marked by pluralism, it appears then difficult to conceive the human body or human nature per se as objects of ethical reflections so as to provide a normative account. For this reason, our analysis must rather turn to how the socio-political context shapes moral reflections concerning humanized technologies.

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[93] An examination of the interface between technology, the body and ethics is provided by Gerald P. McKenny. In his view, a recovery of the moral significance of the body is mandatory in contemporary medicine. He points out that "the task…is not simply to reorient health care toward the living body, but to become aware of the attitudes and practices that have formed us in connection with the technological control of medicine over our bodies and to determine which attitudes and practices should form us – whether those of modern societies or some others…These attitudes and posture in turn make us capable of exercising prudence, and prudence alone enables us to choose wisely with regard to what role medicine and its technology will have in our lives" (McKenny, 1997, pp. 217, 146).

[94] For instance, the legal systems of some Europeans countries such as France, Spain, Great Britain and the Netherlands do not recognize ownership rights so that individuals can do as they wish concerning their bodies (especially with regards to its commercialization) (Bayertz, 2003, p. 133).

1. Setting the Limits – Socio-Political Considerations

The question to address then is where to set the limits of the transformation of human nature through the use of humanized technologies and according to whose standards. Should scientists have the moral, financial and political freedom to attempt such transformations and if yes, according to whose standards?

The issue is whether the use of nanotechnology in biomedical sciences will always be beneficial to society and to patients as well as where and how to set the limits as it is applied to the human body. This in turn raises the question of the fundamental task of medicine. One of the fundamental goals of medicine is to treat what is considered as dysfunctional, abnormal or distressful in one's health condition. However, the criteria for assessing what is considered as a dysfunctional condition will have to be reexamined since one cannot refer simply to species-typical levels of species-typical functions[95] because the functions of the human body could potentially be altered in various ways. Thus, how can we assess what is a normal function (i.e., normative) of the human body according to the new paradigm? Should medicine promote the radical enhancement of human (mental and physical) capacities? Should the goal of medicine be restricted to the cure of illness or obliteration of all diseases? Should one be allowed to transform his/her

[95] Christopher Boorse articulates the concept of disease according the notion of *species-typical levels of species-typical functions*. The main idea underlining Boorse's concept refers to the biological organization of the natural functions of a living organism. It includes four principles summarized as follows: (1) the *reference class* is a natural class of organisms of uniform functional design; (2) a *normal function* of a part or process within members of the reference class is statistically typical contribution by it to their individual survival and reproduction; (3) a *disease* is a type of internal state which is either an impairment of normal functional ability, i.e., a reduction of one or more functional abilities below typical efficiency, or a limitation on functional ability caused by environmental agents; and (4) *health* is the absence of disease (Boorse, 1977, pp. 562, 567). See also his more recent essay "A rebuttal on Health" (1997).

body indefinitely? In our socio-political context, who is to say where to set the limits of such transformation? Should medicine itself set the standards?

These are difficult questions that require a reevaluation of the cardinal moral, scientific, and social assumptions brought into current debates concerning science, technology and medicine. One of the problems is that biomedical issues apply technology to human beings who are moral agents and masters of their own bodies. Hence, one could argue that in principle there is no philosophical argument that would prohibit the transformation of one's body through the use of humanized technologies. The collapse of traditional values removed the limitations set by social expectations as to what medicine and technology can achieve in relation to the human body and therefore, in the absence of such boundaries, the body has been transformed into an "object of practices of technological control" (McKenny, 1997, p. 21). Although not addressing specifically the question of humanized technologies, Gerald McKenny points out that the lack of an evaluative framework is problematic. As he notes,

> Traditional moral injunctions that limit or inhibit what medicine can do appear arbitrary, but there is no broader framework to evaluate and criticize the commitments of modern medicine. In the absence of such a framework, the commitment to eliminate all suffering combined with an imperative to realize one's uniqueness leads to cultural expectations that medicine should eliminate whatever anyone might consider to be a burden of finitude or to provide whatever anyone might require for one's natural fulfillment. This does not mean that individual conceptions of this burden or this fulfillment are necessarily arbitrary. But it does mean that modern moral discourse provides no vocabulary with which to deliberate about what makes such conceptions better or worse than others (McKenny, 1997, p. 20).

The use of humanized technologies is an attempt to transcend humane finitude either at the level of physical capacities or mental abilities. However, in the absence of a common language, there is no framework for the justification of the limitation of the transformation of the human body due to diverging expectations and understandings of embodiment.

Furthermore, there is no definitive answer concerning the social responsibility of scientists and the role of the medical profession in the regulation of the use of innovative technologies that could transform human nature. There are indeed professional requirements and standards that regulate scientific research but these are partially the reflections of the socio-political context in which science and technology take place. It follows then that the key issue is whether we should allow, as a society, the development of such technology knowing the potential transformation of human nature with unknown consequences. How to determine whose (e.g., the state, social institutions, particular countries, individuals or the world community) arguments, norms, values or reasons should be authoritative and decide on what basis we should forbid or limit the application of nanotechnology to human enhancement requires a good understanding of the cultural fabric of the societies in which nanotechnology develops (consider for instance the different cultures of Europe versus the United States and their implications for technological development).

This leads directly to political considerations. The debate has at its core the relation between freedom of scientific research and the regulation by institutions or the government of such enterprise. Three main conceptions of freedom as a principle or source of order for the development of science and technology are relevant to our analysis.[96] The first model is the *marketlike* model, which implies the interaction among free and responsible individuals who contractually agree about certain ends and goals. In this model, it is assumed that "freedom can generate order without the requirements of cooperation or purposeful public-mindedness on the part of the participants" (Ezrahi, 1990, p. 19). This conception of freedom is defended by people such Adam Smith (*The Wealth of the Nations*) and Friedrich Hayek (*The Road to Serfdom*), both emphasizing that the promotion of public interest is first of all, the outcome of individual actions organized around the principle of freedom.

The second model presupposes a *process of rational persuasion* by which individuals adjust and cooperate on the ground that actions can be informed and voluntary (Ezrahi, 1990, p. 20). A good example of this type of approach is developed by Juergen Habermas, in his essay "Discourse Ethics" where he articulates the ideas of "communicative action" in which each participant in society coordinates his or her plan of action consensually.[97] The goal of modern society, he argues, is to find consensus through argumentation so that participants attempt to convince others of the necessity of specific actions. In order to arrive at a consensus, there are two necessary conditions: the first is to be able to justify a norm. The validity of a norm is determined by the kind of agreement people have between them. Thus, a norm is valid only if all those affected can

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[96] I am indebted to Yaron Ezrahi (1990, pp. 19-28) for these three conceptions of freedom as principle of order.

[97] As Habermas puts it "By entering into a process of moral argumentation, the participants continue their communicative action in a reflexive attitude with the aim of restoring a consensus that has been disrupted. Moral argumentation thus serves to settle conflicts of action by consensual means" (Habermas, 1990, p. 67).

accept the practical consequences of its observance. Only then, can a norm be acceptable within the social context.

The third approach to the concept of freedom relates to the *centralized socio-democratic administrative state*. This model assumes the governing of the few not through rational processes of persuasion and enlightenment but through publicly established standards within the political arena. "What supposedly ensure that the actions of the few are not arbitrary or subjective are the publicly established – extrapolitical – standards of adequate performance" (Ezrahi, 1990, p. 21).

This brief outline of the different approaches to freedom as a principle of order shows that depending on one's political assumptions and understanding of the concept of freedom, the analysis of the ethical and philosophical issues related to nanotechnology will take on different and particular orientations. Thus, the politicization of scientific research and technological development (see Chapter Three) requires a careful consideration (or integration) of the economico-political assumptions one brings into the debate. As noted throughout this work, the impossibility of establishing a universal moral account by sound rational argument is in part due to our inability to reach consensus on a foundational level (i.e., a normative account of human nature/human body). However, a procedural ethic allows the possibility of a *managed* consensus, that is, it permits people of various moral and political commitments to enter in dialogue without necessarily agreeing at the foundational level.

A procedural ethic limits the role of the states and recognizes the limitations of social collaboration without necessarily ruling out the possibility, through a political process, to reach a managed agreement. This is the case, in that the type of procedural ethics developed in this work identifies individuals and not the state as the source of moral authority; it likewise emphasizes that there are certain practices (medicine and science/technology, for instance) that cannot be understood apart from their social dimensions and requires moral (as opposed to political) reflections as a society despite competing moralities.

The fields of bioethics and moral theory have the arduous task of establishing the conditions for a pluralistic debate on moral issues pertaining to science and technology. The difficulty lies in the co-existence of competing ideologies in the face of the need to make concrete decisions. There is as well an inevitable tension between allowing a pluralism of ideas to exist and the globalization of (bio)ethical values. Pluralism has permeated moral reflection as is expressed in seemingly interminable disagreements (MacIntyre, 1981, p. 6ff). That being said, the current trend is to settle moral controversies in a legal language of rights, which tends to universalize its authority beyond cultural and social diversities. It follows that the politicizing of morality emerges as the only option social-democratic societies of the West can produce.

John Rawls epitomizes this political move. He attempts to remove the discussion from endless debates by appealing to political values, which are, in his view, morally neutral. As previously indicated, he distinguishes two kinds of doctrines: the ones that cannot be used in public discourse and those that, although incompatible, remain reasonable or belong to what he calls "public reason." In Rawls' work, the idea of a "public reason" is closely related to the concept of justice in the sense that "public reason" reflects a political conception of justice outside moral doctrines. Although he recognizes that the concept of justice is a moral concept (i.e., the content of justice is provided by certain ideals which reflects certain political values and norms), he points out that justice is a moral conception for *political*, *social*, and *economic* institutions (Rawls, 1993, p. 11). Hence, justice within the context of political liberalism does not refer to morality per se, but to a *reasonable* understanding of justice that attempts to provide the basic structure of society without any reference or commitment to any other doctrines, i.e., philosophical, religious and moral doctrines (Rawls, 1993, pp. 11-13). Justice, then, is limited to the realm of the political (i.e., public reason) and is understood as the implementation of established rights and liberties so that each individual can justify his or her use of freedom. It also implies that any reference to secular philosophical doctrines (what he calls "first philosophy"), moral and religious arguments cannot provide public arguments not only because they are susceptible to disagreements but also because they are at odds with the ideal of discourse in a constitutional social democracy. By recasting the notion of justice in terms of reasonableness, Rawls separates the realm of the political from the concept of the good (morality), thus grounding the social order exclusively on hypothetical consent and a new theory of the good independent of a common substantive understanding of the good for society.

The various new developments in science and biomedical sciences concern society as a whole and raise questions that cannot be limited to their political dimensions in the Rawlsian sense. It is my contention that an integrated procedural approach provides the conditions for avoiding a Rawlsian model of "moral" (i.e., political) reflections characterized by the absence of moral arguments due to their contentions. Such an approach recognizes our particular pluralistic and secular context but at the same time focuses on re-integrating moral reasoning (as opposed to the Rawlsian model characterized by public policy/law) is in the public arena.

2. The Moral Acceptability of Humanized Technology – Moral Considerations

With the rapid progress and considerable promise of nanotechnology, there is the potential of transforming the very nature of human beings and of how humans can conceive of themselves as rational animals. The interface between humans and machines (neuro-electronic interfaces, particularly the intrusion of technology into the human body – nanobots), can potentially change what it means to be human, i.e., the very idea of human nature and of normal functioning will be changed. A fundamental issue is the extent to which we should allow and promote human enhancement so as to: (a) *expand human cognition and communication* (see for instance, *The Human Cognome Project* which aims at understanding the structure, functions, and potential enhancement of the human mind while other projects of research aim at developing "humanized technology" in order to enhance human communication) and (b) *improve human health and physical capabilities*. This type of investigation includes the following areas of research: nano-bio processors for research and the development of treatments (bioinformatics, genomics, and proteomics); nanotechnology-based implants and regenerative biosystems as replacements for human organs or for monitoring physiological well-being; utilization of nanoscale machines (nanobots) for medical interventions; multi-modality platforms for increasing sensorial capacities; and brain-to-brain and brain-to-machine interfaces (Roco & Bainbridge, 2002, p. xi).

The use of humanized technology has as its primordial goal the enhancement and transformation of human nature. The aim in future decades is to use converging technologies to transform the human sensory and physical capabilities and find ways for a better synthesis between the human mind and various technologies (Roco & Bainbridge, 2002, p. 4).[98] Consequently, our understanding of human nature will need to be transformed due to the potential use of technologies: humans will no longer be rational animals, but rational animal-machines (transhumanism). The traditional conception of human beings as biological and rational entities will be transcended by a new dialectic between technological devices and the *biological* human body.[99] Furthermore, as an increasing number of biomedical applications of nanotechnology appear possible, the idea of the pursuit of immortality, at least in its immanent dimension (i.e., physical), has emerged in the literature on nanotechnology. An examination of the socio-cultural considerations is essential so as to assess how nanotechnology might undermine and transform religious views about human nature which have been, in Western culture, the dominant perspective for many centuries.[100]

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[98] These should includes: broadband interfaces between the human brain and machines, wearable sensors and computers, robots and software agents, strengthening of human body, combination of technologies and treatments that should eradicate particular diseases.

[99] For a further examination on the transformation of human nature, see Cooney who asserts that the impact of technology will be more profound in relation to the biological human condition than our environment. He writes that "although our accelerating technology will bring enormous changes in our social and natural environments, it will have an even more profound effect. It will give us increasing power to alter our biological human condition by modifying and enhancing the human body and mind (Cooney, 2004, p. xix); see also Fukuyama (2002).

[100] Interestingly, the transhumanist movement addresses the question of religion in these terms: "Transhumanism is a philosophical and cultural movement, not a religion. Transhumanism does not offer

Obviously, further investigations are needed than what is provided in this work. However, this is by no means a way to minimize the issues at stake. The assessment of the impact of technology on notions of embodiment and conceptions of human nature are necessary and must follow along scientific and technological developments. These issues are mentioned in the service of laying out the geography of future potential problems that the use of innovative technologies such as nanotechnology may occasion. In addition, it shows that the nature of the issues cannot be revolved exclusively at the procedural level. The possible transformation of human nature requires an analysis of the fundamental considerations concerning who we are as human beings and as a society as well as how science and technology could transform our identity as humans. This demands substantive reflections at the ethical level despite our conflicting moral views. However, without an acknowledgement of the socio-political context (i.e., liberal societies) such reflections are doomed to fail.

III. CONCLUDING REMARKS

A task of this work was to reflect upon the type of framework that would allow collaboration between rival ideologies from various domains of inquiry. In particular, the goal was to explore how different disciplines within the sciences and the

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answers about the ultimate purpose and nature of existence, merely a philosophical defense of humanity's right to control its own evolution. Consequently the transhumanist philosophical stance is compatible with humanist interpretations of the world's religions. On the other hand, transhumanism is generally a naturalistic outlook and most transhumanists are secular humanists. Although scientific rationalism forms the basis for much of the transhumanist worldview, transhumanists recognize that science has its own fallibilities and imperfections, and that critical ethical thinking is essential for guiding our conduct and for selecting worthwhile aims to work towards. Religious fanaticism, superstition, and intolerance are not acceptable among transhumanists" (World Transhumanist Association, 2005).

humanities/social sciences participate in not only the development of nanotechnology but also how they contribute to reflections on the ethical and social issues nanotechnology raises. Prior to developing a procedural integrated model, two important tasks had to be accomplished. First, the claim of the alleged revolutionary dimension of nanotechnology had to be evaluated. Second, the particular context (postmodernity) in which the development of this new discipline takes place had to be explored.

The claim that nanotechnology is revolutionary had to be critically assessed, because too often in the literature people characterize nanotechnology as revolutionary but do not provide the basis to support this claim. Nanotechnology has developed in what Wartofsky refers as the fourth technological revolution, characterized by the politicization of technology which is an outcome of the transition from academic science to post-academic science. However, the claim that nanotechnology is the next revolution in science, technology, medicine, or the industry demanded clarification prior to further analysis. On the one hand, I argued that the ability of manipulating atoms at the nanoscale in ways unknown until now and the capacity to exploit novel phenomena and properties at that scale could be considered revolutionary.

On the other hand, I also pointed out that nanotechnology is not revolutionary in the sense that a change in categories, to use Hegel's language, occurred. In order to produce a scientific (and technological) revolution of the dimension of the European Scientific Revolution of the 17^{th} century, a change in categories had to take place by introducing (1) *new descriptive categories* for an area of science and/or technology; (2)

new explanatory categories or frameworks for an area of science and/or technology; and (3) new ways of *organizing or systematizing categories or frameworks*.

Nanotechnology does not introduce new categories either at the descriptive, explanatory or systematic levels. Advances in nanotechnology allow the manipulation of atoms at the nanoscale and, by the same token, the discovery of (seeing) new phenomena. However, these advances do not provide new categories nor contradict previous ones. Rather, the claim that nanotechnology is a "techno-scientific revolution" (claim made in this work) is grounded on the fact that the development of nanotechnology requires a strong connection between the process of discovery and of fabrication (i.e., the technologisation of science) in conjuncture with the exploitation of new phenomena and the manipulation of atoms and molecules at the nanoscale. When combined, these four features of nanotechnology are revolutionary in the sense of radically augmenting what is already taking place in science and technology (i.e., the connection between the process of discovery and fabrication) in conjunction with scientific/technological advancements (i.e., manipulation of atoms and exploitation of new phenomena).

In addition, the scale at which scientists and engineers manipulate atoms and molecules can be said to be revolutionary because it questions the premises of classical physics characterized by order and coherence and are challenged by the Heisenberg's uncertainty principle characterized by uncertainty and unpredictability. Consequently, at this stage in our understanding of the structure of matter and our ability to observe phenomena taking place at the nanoscale, it seems inadequate to speak of a revolution in terms of a change of categories. Rather, nanotechnology is "revolutionary" in terms of introducing innovative or novel approaches to the manipulation of matter at the subatomic level without necessarily understanding, in theory, how certain phenomena occur. In short, it is not revolutionary in kind but rather in degree.

The second consideration I examined prior to the development of a procedural integrated model was the context in which nanotechnology has developed. In particular, it was necessary to respond to and assess the challenge posed by postmodernity to scientific discourse. Recognition that pluralism (the key characteristic of postmodernity) affects not only philosophical and ethical reasoning but also scientific and technological discourses is pivotal to a *procedural* integrated model of ethical investigation. In my analysis of the implications of postmodernity for science and technology, I pointed out that a modern account tends to exclude extra-epistemic considerations (values) because of their "subjective" nature as opposed to the "objective" nature of scientific facts. However, because of competing epistemologies and cultural assumptions one brings to scientific discourses, no meta-discourse within science and technology can be established. From this analysis, I drew two conclusions concerning nanotechnology.

First, I concluded that the field of nanotechnology is a good illustration of the pluralistic nature of scientific inquiry since it is constituted by various fields (e.g., physics, chemistry, biology and engineering). These fields traditionally respected their own area of inquiry but are now required to collaborate despite their sometimes competing epistemologies. With the emergence of nanotechnology, the boundaries between disciplines have become fuzzy. The reason is that the creation of certain devices such as hybrid nanomechanical devices with biological components, for instance, requires the interface between disciplines in chemistry (nanochemistry) and biology. At the same time, the ethical issues raised within each particular discipline have been imported, so to speak, in the broader context of reflections on nanotechnology. These two characteristics in the conduct of science give nanotechnology its trans-disciplinary character (i.e., because the development of nanotechnology requires the involvement of a variety of disciplines) and integrative dimension (i.e., because various fields have to collaborate).

The second conclusion is the realization that the examination of moral concerns within science and technology extends beyond scientific and technological disciplines. Integral to these reflections are issues related to the humanities and social sciences. This by itself is not a new phenomenon. However, previous examinations of the interface between the natural sciences and the humanities/social sciences have demonstrated a *poor* integration and consequently further efforts for *better* integrating "trans-epistemic factors" are needed. The model developed in this work provided one possible option as to how this integration can be accomplished through a procedural integrated model.

One of the key features of a procedural integrated model is that it allows a partial collaboration between rival ideologies while acknowledging their differences. The procedural dimension of this approach lies in the recognition that the pluralistic context in which science and technology develops does not allow reflections at the foundational level. Hence, agreements and consensus occur on the basis of what each participant in a moral debate advances. That being said, in order to produce a more substantial exploration of the divergent points of view, matters at controversy were discussed and assessed, not as a means to create barriers or insurmountable obstacles to a managed consensus, but rather in order to understand and partially or completely reject or accept a particular position. In so doing, we avoid limiting ethical reflections to procedures and legislations so as to acknowledge how key moral concepts frame and shape particular procedures and legislative acts. In short, the approach was chosen in order to create the conditions for more substantial debates. A transdisciplinary orientation encourages the inclusion of core ethical concepts (or foundational judgments) in the development of science and technology, despite their controversial nature.

A procedural integrated model is an avenue for reflections that takes into account the pluralistic and post-academic context in which science and technology take place. The transition from an academic to a post-academic science offers not only the opportunity to (re)introduce philosophical and ethical reflection into the development of science qua nanotechnology but likewise shows how a specific model of ethical inquiry for nanotechnology and nanoscience can facilitate our reflections. I recognized that the traditional tools of ethics (moral theory, bioethics, medical ethics, etc.) represent valid and useful methods for the analysis of moral issues related to nanotechnology. However because of the potential radical applications and the changes nanotechnology could bring in relation to the human body, human nature and the environment, it is essential to frame a practice enabling ethical and philosophical reflections to take place in collaboration with scientists and engineers. This is not to say that a procedural integrated model will solve all the conundra of scientific and technological controversies. As mentioned, there are fundamental moral disagreements that cannot be resolved unless one changes his or her moral premises at the foundational level. However, by setting the conditions for discussing diverging points of view, room for revisions and/or critical assessment of one's own position is thus provided.

Undeniably, nanotechnology and its applications in the biomedical sciences could provide new opportunities that could change and improve our way of live. Industrial applications and the development of procedures and devices in medicine generate great hopes for the resolution of social issues (e.g., pollution, energy) and the improvement of the human condition (e.g., the curing of diseases). As with other technological innovations that create ethical controversies, how to establish consensus and/or collaboration between the various participants in the research and development of nanotechnology/nanomedicine and those individuals concerned with regulations, public policy and ethical standards is an important task that will require further analysis and study beyond the scope of this work.

In addition, our reflections must also consider how technology affects not only the practice of medicine but also our understanding of human nature. The use of "smart medical devices" for the diagnosis and treatment of diseases has the potential to transform our understanding of illness and the role of the physician in the clinical encounter. Recognition that one of the fundamental goals of medicine is to treat what is considered as dysfunctional, abnormal or distressful in the human body, demands further reflections as to what is indeed a "normal" function of the body since the use of humanized technology can alter various aspects of our bodily functions. Furthermore, the use of "smart medical devices" gives patients access to medical data that could diminish the patients' vulnerability and thus change how the clinical encounter takes place. These considerations require further analysis and explorations of the nature of medical practice and the philosophy of medicine (e.g., because of how technology may reconceptualize the clinical encounter and the notions of illness and disease).

For reasons articulated in this work, the development of nanotechnology requires a dialectic between diverse fields within science and technology as well as between the sciences and technologies, as well as the humanities and social sciences. The task ahead for those reflecting on various dimensions of nanotechnology, whether from a scientific, practical, ethical or philosophical standpoint, is to continue to examine critically how to address ethical, social, practical, economic and legal concerns throughout the different stages of the development of nanotechnology and nanomedicine. This requires a culture of intellectual investigation that gathers people from science, technology, politics, economics and the humanities. The integration of the insights of each discipline is crucial for future reflections on the ethical and societal implications of nanotechnology.

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