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In Pursuit of Nanoethics

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Contents

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Chapter 1
In Pursuit of Nanoethics: An Introduction

Bert Gordijn and Anthony Mark Cutter

1.1 Nanotechnology and the Birth of Nanoethics

Nanotechnology is a relatively new interdisciplinary field of technology that explicitly focuses on objects with incredibly small dimensions. The prefix "nano" signifies one billionth of something. Thus one nanometer is one billionth of a meter. Norio Taniguchi from the Science University of Tokyo is generally assumed to have coined the term "nanotechnology" in the early 1970s (Taniguchi 1974). Somewhat later, in 1986, the term became more widely know, when Eric Drexler published his *Engines of Creation. The Coming Era of Nanotechnology*, a book written for a large audience with an engaging style. Due to its good readability and visionary character *Engines of Creation* greatly influenced the popular perception of nanotechnology.

In Drexler's vision of nanotechnology the idea of the 'universal assembler' is imperative. It is an infinitesimal construction gadget that can use surrounding matter as its basic building material. Due to its small size it can assemble virtually any chemically stable molecular structure that it has been programmed to put together in an atom-by-atom manner (Drexler 1986, p. 14). Of course, building macro scale products in this way with only one single assembler would take quite a long time (Drexler 1986, p. 58). In *Engines of Creation*, however, Drexler envisions huge numbers of assemblers that would jointly undertake this task in an organized way. First one would have to generate a critical mass of assemblers. To this effect the available assemblers at the start would initially create copies of themselves.

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This would set off a process of exponential growth of the number of available assemblers. Given the exponential character of this initial process, sufficient numbers of assemblers would be available fairly soon, and self-replication would be stopped. In the second stage of production the newly generated assemblers would be reprogrammed for more specialized tasks so as to manufacture specified macro scale products collaboratively. In this way Drexler envisages ultra precise nanotechnological construction of macro scale products that can yet be completed within an acceptable timeframe (Drexler 1986, pp. 58–63).

Drexler was aware that nanotechnology, were it to come to fruition as conceived in his book, might have very powerful effects, both beneficial and detrimental: "With assemblers, we will be able to remake our world or destroy it" (Drexler 1986, p. 14). As with many other novel technologies there would be a risk of accidents and abuse. In the case of nanotechnology, however, these might have an especially harmful impact. Through some unforeseen malfunction, for example, the process of self-replication of assemblers might run out of control. If this were to happen, these assemblers could just carry on devouring their material surroundings turning everything into copies of themselves (the "gray goo" scenario) (Drexler 1986, pp. 172–173). In another chilling potential future scenario nanotechnology would be used in order to make extremely powerful weapons. "States could use replicating assemblers to build arsenals of advanced weapons, swiftly, easily, and in vast quantity. States could use special replicators directly to wage a sort of germ warfare – one made vastly more practical by programmable, computer-controlled "germs."" (Drexler 1986, pp. 173–174).

However, full-grown nanotechnology might also have exceptionally positive effects. It might, for example, facilitate clean and low-priced production of a plethora of novel products. Due to the fact that they would have been put together with molecular precision, these products would have new and fascinating properties. Moreover, nanotechnology might lead to more effective methods of environmental protection as well as countless medical gains. "Assemblers will be able to make virtually anything from common materials without labor, replacing smoking factories with systems as clean as forests. They will transform technology and the economy at their roots, opening a new world of possibilities. They will indeed be engines of abundance." (Drexler 1986, p. 63).

Understandably, these radically contrasting future perspectives of nanotechnology have triggered a polarized public debate (see Gordijn (2005) for further analysis). Nowadays, however, Drexler's early prophetic vision of the new field seems to have lost its center stage position. Most contemporary scientists and technologists involved in nanotechnology do not focus on the development of universal self-replicating assemblers. Instead, they are focused on the development, exploration and application of a wide array of different nanoscale structures, such as nanotubes, nanoparticles, molecular motors, quantum dots and quantum wires. In trying to create these and similar structures, they employ both top-down techniques and bottom-up methods.

Having said that, this does not mean at all that nanotechnology has lost its capacity to engender what *prima facie* appear to be somewhat inflated future projections. In recent times, for example, proponents of nanotechnology have advanced

far-reaching views about the convergence of nanotechnology, biotechnology, information technology and cognitive science (NBIC). Not only has it been claimed that NBIC convergence is a truly novel and fairly exceptional phenomenon. It has also been argued that it can – and should – be used to significantly enhance human performance (Roco and Bainbridge 2003; Roco 2004; see Gordijn (2006) for an analysis of said claims surrounding NBIC convergence).

However, equally staunch views have been advanced by critics of nanotechnology. For example, the Action Group on Erosion, Technology and Concentration (ETC group) has called for a global moratorium on the production and use of synthetic nanoparticles because of the uncertainties regarding their effects on health and the environment (ETC 2003). Likewise, Greenpeace has proposed a freeze on the release of nanoparticles into the environment until we have adequate knowledge of the hazards involved (Greenpeace 2004).

Against the backdrop of the polarized perception of nanotechnology in the public domain serious ethical discussions about nanotechnology started in the early 2000s. According to Google Scholar the term "nanoethics" first popped up in the titles of scientific publications in 2004. Three years later, Springer started a journal entitled *Nanoethics. Ethics for Technologies that Converge at the Nanoscale*. In his first editorial the new editor-in-chief, John Weckert, stated "The aim of this journal is to advance the examination of ethical and social issues surrounding nanotechnologies in a philosophically rigorous and scientifically informed manner" (Weckert 2007, p. 2). Over the past 6 years the new Springer journal has indeed contributed to transforming somewhat distraught early reflections on the ethics of nanotechnology into a more sophisticated and sustained scholarly debate.

1.2 The Current Volume

The volume at hand contributes to the ongoing nanoethics debate in four topical areas. The first part tackles questions of what could be called 'meta-nanoethics'. Its focus lies on basic concepts and the issue of what – if anything – is truly novel and special about the new field of nanoethics or its subject matter. The second part of this volume presents a selection of interesting perspectives on some of the opportunities and challenges of nanotechnology. Part three takes a more in depth look at one of the most pressing current concerns: how to deal with the risks and uncertainties surrounding nanotechnology in a responsible manner. In its fourth and final part the volume touches on issues of public debate and policy.

1.3 Concepts and Novelty

In emerging arenas of human intellectual and creative endeavor, be they in science, philosophy, art or technology, it is perfectly natural for discussions on basic notions to occur. Agreement on common concepts advances effective communication and

successful collaboration. Besides, an idiosyncratic and clearly defined terminology may help to pitch a novel approach by more unmistakably distinguishing it from more traditional viewpoints. Accordingly, in new and interdisciplinary field of nanotechnology there has been a good deal of discussion about the precise meaning of the concept of nanotechnology.

Drexler introduced a fairly narrow concept of "nanotechnology" in his *Engines of Creation*, where the term was used to refer to a technology using assemblers operating material with molecular precision in order to construct specified products. Drexler proposed using the words "nanotechnology" and "molecular technology" interchangeably (Drexler 1986, p. 5). In contrast to this early conception one could also regard nanotechnology simply as a technology focusing on things that are smaller than the subject matter of microtechnology, which would arguably involve the broadest possible concept of nanotechnology.

However, like good Aristotelians most contemporary nanotechnologists seem to have adopted a concept in between the above extremes. Accordingly, they understand the term "nanotechnology" as referring to a technology concerned with structures that have at least one dimension smaller than 100 nm. In the Strategic Plan of the US National Nanotechnology Initiative, for example, nanotechnology is defined as "… the understanding and control of matter at dimensions between approximately 1 and 100 nm, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling and manipulating matter at this length scale" (NNI 2007, p. 5).

A similar process of developing a *communis opinio* around a key concept has not yet taken place in the case of the terms "NBIC convergence" and "nanoethics". With regard to the first term, there is ample discussion about what – if anything – is exactly converging in the fields of nanotechnology, biotechnology, information technology and cognitive science. It is still an open question, for example, whether the so-called NBIC convergence primarily involves the academic research scenes, the vocabularies and discourses, the main theories, or any other aspect of the NBIC disciplines (Gordijn 2006).

Similarly, there has been an ongoing discussion about the concept of nanoethics, what it entails precisely and whether it has any novel or unique features that may perhaps justify its coming into being as a separate field of applied ethics. To a certain extent the novelty discussion is a debate about semantics. After all, the assessment of any novelty claim with the structure "φ is novel" depends greatly on the level of abstraction with which one analyses φ. Thus, if framed on a high level of generalization, the ethical issues in nanotechnology will not appear to be new. Privacy threats, for instance, and health and environmental risk have been around since the dawn of times. However, if the ethical issues in nanotechnology are analyzed in a more contextualized way, against the backdrop of specific applications of the technology, novel characteristics are more likely to pop up in the analysis. Thus whether ethical issues relating to a new technology can be regarded as novel depends on the degree to which the analysis zooms in on the specifics of these issues (Gordijn et al. 2011).

Given these intricacies of the phenomenon of novelty, the issue needs a thorough analysis. Not only is the novelty discussion philosophically interesting in its own right. In addition, novelty phraseology is sometimes inappropriately used to serve the agendas of certain interest groups, for example, when no-nonsense proponents of nanotechnology argue that it is unnecessary to invest time and energy discussing the ethical issues in nanotechnology, since none of them are really new. Similarly, it is sometimes argued that we should not bother to be concerned about artificial nanoparticles, since natural nanoparticles have already been around for ages without any evident detrimental health effects. Clearly these arguments are *non sequiturs*.

Against the backdrop of the philosophical complexity of the novelty discussion and the political use and misuse of novelty claims Joachim Schummer starts off in the first part of this volume by systematically elucidating the concept of novelty and its various meanings. He then analyses novelty in science and engineering generally and zooms in on the novelty of nanotechnology more specifically. Finally, Schummer touches on the ethics and politics of novelty in relation to nanotechnology.

Next Søren Holm asks whether the developments in nanotechnology really call for a new discipline, i.e. "nanoethics". The answer, of course, depends largely on what is exactly meant by the question. Holm analyses four different senses in which nanotechnology might require a new field of ethics. The most drastic claim would be that nanotechnology triggers the need to develop a new ethical theory. A second way of understanding the need for nanoethics is by referring to the uniqueness of the ethical issues raised by nanotechnology. Yet another approach would involve claiming that the already existing tools and analytical methods within applied ethics do not suffice to deal with the issues raised by nanotechnology, thus necessitating the creation of the additional field of nanoethics. Finally, a call for nanoethics might consist in a need for experts in the ethics of nanotechnology.

Finally, Ronald Sandler looks at the parallels between the debates about the social and ethical aspects of nanotechnology and GM food. His interest in doing so is to gauge to what extent this comparison might be helpful in elucidating and tackling the social and ethical challenges of nanotechnology. Based on an analysis of resemblances and differences between the two, he explores what might be learned from the GM food experience that is still relevant for contemporary nanotechnology. The three potential lessons Sandler reviews are on public engagement and outreach, on techno-fixes, and on case by case assessment.

1.4 Opportunities and Challenges

The second part of this volume focuses on opportunities and challenges of nanotechnology. It is obviously an impossible task to present anything remotely approaching a complete account of these in just one single volume. After all, as a key technology for numerous different scientific arenas and technological endeavors, nanotechnology is expected to affect numerous different fields significantly. Random examples are biotechnology, weapons, security, cosmetics, water treatment,

electronics, sensor technology, computing, medicine, aeronautics and energy. Accordingly, the opportunities and challenges associated with the further development of nanotechnology are likely to be extremely wide-ranging. Therefore, this book abandons in advance any endeavor to be exhaustive. Instead, it aims at highlighting a few selected important topics: medicine, biodiversity and the military.

When thinking about the opportunities and challenges of nanotechnology one faces the well known Collingridge dilemma (Collingridge 1980). Whenever one tries to analyze the impact of a technology *prospectively*, it is difficult to avoid a certain degree of speculation. After all, the imagined possible future scenarios involved might or might not unfold as conceived. On the positive side, at an early stage of the technology's development one can still effectively influence the way, in which it develops. When, in contrast, one assesses the impact of a technology *retrospectively*, all the facts are readily available. Of course, there is still a problem of understanding and interpreting the facts. However, these issues can be tackled by methods of historiography, which are as yet more developed and agreed upon than methods of futurology. Unfortunately, in this case the increased knowledge about the impact goes hand in hand with a decreased capacity to change the course of the technology, since it is much more difficult to modify a technology that is already well-established. In Collingridge's own words: "When change is easy, the need for it cannot be foreseen; when the need for change is apparent, change has become expensive, difficult and time consuming" (Collingridge 1980, p. 11).

That leaves us with the difficult question of when in the course of a technology's development one should ideally start to think about the desirability of its possible impact. The answer is probably that critical reflection about desirability of a technology's impact should ideally be an ongoing open and flexible intellectual process, starting early on and revisiting its assessments on the basis of new information (cf. Moor 2005). Be that as it may, the analyses in this second part of the volume about opportunities and challenges are prospective. This means that the projections concerning the future impact of nanotechnology on which they are based are necessarily somewhat tentative. Accordingly, they might have to be adjusted as more facts nanotechnology's actual impact become available.

In the first chapter of this second part of the volume, Melanie Latham zooms in on nanomedicine and its potential for body modification. As a result of economic growth and advances in medical technology, more and more people – especially women – have become interested in undergoing medical interventions for aesthetic purposes. Yet nanomedicine is likely to further push the boundaries for people seeking cosmetic enhancement. Against this backdrop, critical analysis is needed concerning the risks inherent in such procedures, patient rights, autonomy, informed consent, cultural pressures and agency. On the basis of solid analyses of these and similar issues, regulation must be established in order to guarantee a responsible use of nanomedicine as a means for body modification.

Subsequently, Darryl Macer analyses and assesses the effects nanotechnology might have on biodiversity. He is first and foremost interested in the issues raised in complex systems involving different organisms. In his analysis Macer focuses on both the benefits and the risks to biodiversity. He also identifies important

areas of much needed further research in this field and stresses the need for policy development.

Finally, Robert Simpson and Robert Sparrow analyze the ethics of nanotechnologically enhanced combat systems. Since the Second World War, military conflicts initiated by rich countries have tended to focus on enemies that are significantly poorer. This has resulted in wars that show a considerable asymmetry of forces. According to the authors further developments in military nanotechnology might significantly enlarge this divide. Their analysis focuses on a possible future scenario, in which nanotechnologically enhanced combat systems would make those who dispose of them virtually invulnerable to those without these military systems. Simpson and Sparrow argue that this extreme form of asymmetric warfare would generate its own particular ethical problems and would increase the odds of unjust military conflicts.

1.5 Risks and Precaution

The third part of this volume looks at the concerns about the risks of nanotechnology. Early worries focused on the risks of self-replicating assemblers running amok. It was feared that technical flaws might trigger unbridled exponential self-replication. Depending on what the uncontrolled assemblers would use exactly as material resources for self-replication, they might consume large segments of their material surroundings (Drexler 1986; Joy 2000).

These early concerns about "gray goo" and self-replicating nanobots have now been replaced by more warranted and down to earth qualms about the potential detrimental health and environmental effects of nanoparticles. However, nanotoxicity has turned out to be a complex phenomenon. After all, the toxicological effects of a substance organized in the form of nanoscale particles may be very different from the behavior of the same material organized as a macro scale object. Nanoparticles might, for instance, cross the blood–brain barrier and, in this way, have a direct impact on the brain (Lenk and Biller-Andorno 2007). In addition, compared to bigger objects of the same substance, the larger surface-area-to-mass ratio of nanoparticles increases their chemical reactivity (Schrader-Frechete 2007). A continued research effort will undoubtedly yield more solid knowledge about nanotoxicity in the future. For the time being, however, our knowledge about nanotoxicity is still relatively embryonic. This means that we are left with the question of how to handle risks that are hard to characterize precisely.

In debates about this difficult question the precautionary principle has gained a certain prominence. In the *Rio Declaration on Environment and Development* (1992) it is presented as follows: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (Rio Declaration 1992, principle 15). Obviously this Rio version of the precautionary principle is open to a wide variety of interpretations.

In spite of its imprecision, or perhaps precisely because of this, the precautionary principle has since been included into a variety of policy documents and international law. Besides its use in policy circles, the precautionary principle has also been intensively discussed in the scholarly community (see Beyleveld and Brownsword (2012) for an interesting new approach).

Against this backdrop, Fritz Allhoff, argues in the first chapter of part three that there is still a lack of thorough scholarly work on the nature of the concept of risk. In addition, it is still far from obvious what would be the best rational way to deal with risk. Both dominant approaches towards tackling risk, cost-benefit analyses and precautionary approaches, do seem problematic and in need of more systematic and comprehensive scholarly analysis. Allhoff sheds more light on these topics through a literature review and the development of novel arguments.

In the next chapter, Roberto Andorno and Nikola Biller-Andorno, zoom in on applications of nanotechnology within medicine. Here, one of the dominant concerns is the uncertainty surrounding the health risks of medical nanotechnology. In trying to tackle this problem the precautionary principle can give limited but helpful guidance as it offers a useful set of criteria for charting a sensible course of action in situations of possible risks that are not yet well delineated and demonstrated by scientific evidence. However, being first and foremost a call to prudence primarily directed to policymakers, it does not present a directory of fixed solutions.

Kevin Elliott, finally, argues that normative judgments about nanotechnology do not only occur downstream in the public-policy domain where technology implementation is regulated but also upstream in the realm of scientific research. Zeroing in on nanotoxicology Elliot analyses how important aspects of this research are influenced by normative points of view. Nanotoxicology researchers, for example, do not only have to choose the specific nanomaterials they wish to investigate and the particular biological models they would like to make use of; they also have to make up their mind about the effects to focus on as well as the standards of evidence to apply. As these choices are unavoidably value laden – i.e. they can be more or less precautionary – it is important to incorporate more thorough and organized ethical reflection into this early stage of research. Elliot advances several proposals to this effect.

1.6 Public Debate and Policy

The fourth and last part of this volume touches on issues concerning public debate and policy. It would be great, if all the relevant ethical issues concerning nanotechnology could be identified and analyzed in a methodological and comprehensive public debate. This ethical review might then serve as a basis for policies and regulation to steer the further development of nanotechnology in a desirable direction. However, such a debate is not easily achieved (cf. Patenaude et al. 2011). In addition, it should be asked who exactly should make the necessary decisions about the future

direction of nanotechnology? Should citizens be involved in the decision-making process and if so, what kind of involvement would be desirable?

In an interesting paper entitled "Cultural Diversity in Nanotechnology Ethics" Joachim Schummer distinguishes three models of technology governance: the autocratic model, the "information-plus-debate" model and the democratic model (Schummer 2006, p. 225). In the first model, governments or large companies direct the development, application and regulation of emerging technologies without providing any public information. Instead of constructive citizen engagement, the secrecy about emerging technologies may foster conspiracy theories amongst the public. In the second model, the public is provided with information about emerging technologies for the purpose of open debate. However, citizen participation in the actual decision-making processes about the development of technologies is still lacking. In the democratic model, finally, citizens are also actively involved in structures of decision-making and governance steering the future of technologies (Schummer 2006, pp. 225–226).

In academic debates about emerging technologies attempts at creating more democratic models seem to be increasingly favored. In Western Europe and North America upstream public involvement in the R&D process has gained interest as it is argued that it increases public confidence and the legitimacy of technology governance (Rogers-Hayden et al. 2007). However, upstream public engagement involves prospective discussions about the future impact of an emerging technology that is still in a fairly embryonic stage. This means that one has to face the difficult problem of trying to foresee and assess the effects of a technology that may still develop in various directions (see Lucivero et al. 2011; Brey 2012 for interesting new approaches towards tackling this challenge). Therefore, as suggested in Sect. 1.4, a reassessment of earlier appraisals might be appropriate when new facts about the technology's actual impact become available.

In part four Philip Macnaghten starts with a review of the literature on public perceptions of nanotechnology. The literature suggests that there is significant optimism for nanotechnology. Naturally enthusiasm is specifically focused on those nanotechnologies which are expected to yield certain social benefits. At the same time the majority of studies also point towards concerns, for example about risks, uncertainty and regulation. In addition, research shows an appreciation of lay publics of access to transparent data and better communication concerning nanotechnology, which is an indication for a desire to be more actively involved in shaping its development.

Looking at the future-oriented debate about nanotechnology, Simone Arnaldi observes that, whilst the importance of public participation is generally emphasised, attempts at public engagement are sometimes unfortunately reduced to narrow kinds of risk assessment. Instead, they should aim at discussing the ethical and social issues more broadly. As a result, large parts of the public do still seem relatively sidetracked and ignorant. Hence nanotechnology discourse is still too much dominated by a technocratic model. It is therefore pivotal to open up the public debate to a greater variety of social actors.

In the final chapter of this volume, Henk ten Have stresses the importance of international debates and policies on nanotechnology. In this regard the European Union plays an important role. Moreover, European policy reports do also seem to address the issue of how nanotechnology might have beneficial effects in a global context. Having a clear mandate in the arena of science, UNESCO would be an appropriate organization to take up this challenge by helping its Member States to steer the development of nanotechnology towards the achievement of the Millennium Development Goals, which the UN Member States have committed to accomplish by the year 2015. Unfortunately however, notwithstanding interesting European initiatives, policy responses of the international community are still near the beginning.

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Part I
Concepts and Novelty

Chapter 2
On the Novelty of Nanotechnology: A Philosophical Essay

Joachim Schummer

2.1 Introduction

Nanotechnology has from its very beginning been surrounded with an aura of novelty. For instance, on the 28 introductory pages of the report that prepared the US National Nanotechnology Initiative (NNI), *Nanotechnology Research Directions* (NSTC/IWGN 1999), we read 73 times the term "new", 15 times "novel", 7 times "innovation", and 21 times "revolution". The authors concede that one should distinguish between different nanotechnologies, because "Many existing technologies do already depend on nanoscale processes. Photography and catalysis are two examples of 'old' nanotechnologies" (ibid, p. xxvi). One might conclude here that, if all the existing nanotechnologies are "old" nanotechnologies, "new" nanotechnologies do not yet exist but are only promises of the future. However, without further explanation and distinction between presence and future, they suggest that most nanotechnologies are or will be new. Furthermore, they claim that nanotechnology (in singular) is a generator of further new technologies, since "Nanotechnology will give birth to new fields that at present are only visions of leading researchers" (ibid., p. xviii).

Whenever science managers speak of nanotechnology (in singular), sophisticated distinctions seem to give way to plain claims about the present *and* future novelty of nanotechnology. As the NNI director Mihail Roco wrote in a 2001 report, "A revolution is occurring in science and technology […] Nanotechnology will fundamentally transform science, technology, and society. In 10–20 years, a significant proportion of industrial production, healthcare practice, and environmental management will be changed by the new technology" (Roco and Bainbridge 2001, pp. 1, 19). When they put on their hats as science managers, scientists rarely reject but mostly

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support such novelty claim, as did for instance, the chemists George Whitesides and Paul Alivisatos in the earlier report: "Nanostructures are the entry into a new realm in physical and biological science" (NSTC/IWGN 1999, p. 1). Backed by such support, scientific laypersons, from journalists to business consultants to ethicists, feel confident to deliver the novelty message to their respective audiences. For instance, up to the present day (13 March 2008), news articles routinely speak of nanotechnology (singular) as a new technology, and ethicists usually introduce their papers on nanotechnology by emphasizing its novelty.

As the 1999 report illustrates, the issue of the novelty of nanotechnology has frequently come up, but dealt with only marginally in a way that is obscuring rather than clarifying. One reason, I assume, is that the general concept of novelty is, despite its frequent use, so complicated that its use typically invites misunderstandings. It seems appropriate therefore to keep the daily negotiations and rhetoric of novelty apart for a while, and ask what it actually means to say that something is novel.

In this philosophical essay, I first try to clarify the different meanings of the concept of novelty. This helps us understand that many paradoxes and fallacies dominate ordinary discourses on novelty, which any serious approach needs to avoid. Equipped with these conceptual clarifications, I discuss novelty first in science and engineering in general and point out the unique role that novelty plays in these areas. Then I discuss the novelty of nanotechnology by distinguishing between different levels and aspects of nanotechnology. The results allow reassessing public novelty claims about nanotechnology not only from an epistemological but also from ethical and political perspectives. I conclude with some remarks on the politics of producing and claiming novelty.

2.2 Kinds and Paradoxes of Novelty

Compared to its frequent ordinary use, the concept of novelty is quite tricky – indeed full of paradoxes and fallacies lurking beneath the surface.

The *first novelty paradox* is that anything can be novel and non-novel at the same time. On the one hand, each and every event is novel because it has not yet happened before in exactly the same manner. Every moment differs from past and future moments, if we consider its location in time as unique. Since time flows irreversibly, as thermodynamics tells us, there are no two events that are identical. This is the *trivial sense of novelty* in which everything appears to be novel. On the other hand, there is "nothing new under the sun", to quote a book of the Bible written in the Greek tradition of skepticism (*Ecclesiastes*, 1:9–14). Everything happens within fixed constraints – laws of nature, if you want. Since these constraints define and circumscribe anything that is possible, nothing happens that really surprises those who know the constraints. This is the *trivial sense of non-novelty* in which nothing appears to be novel.

What then do we mean by singling out certain events as novel or new, while counting other events as old or recurring? Obviously we do not refer to the trivial

meanings of novelty and non-novelty. While the trivial meaning of novelty highlights the uniqueness and individuality of every event, the trivial meaning of non-novelty focuses on its commonness and generality. Between both extreme views on the world, there is a broad range of considering events more or less individual or more or less general, because there is space to distinguish between uniqueness and commonness and thus between novelty and non-novelty. It all depends on our conceptual framework and the level of generality of our concepts. If we have different views, we may have an argument about the novelty of an event.

As with the novelty of events, the novelty of objects is very ambiguous and essentially depends on our conceptual framework. Assume you have discovered a flower and claim that this is a unique and novel one. Someone else may object that this flower is as any other flower so that there is nothing unique or novel about it (trivial non-novelty). So you refer to botanic taxonomy and explain that the flower is an exemplar of a new species that has never been described before. Your novelty claim thus turns out to be a claim of novelty of kind on a certain level of generalization, here the biological level of species. You take for granted that the flower is unique and novel as an individual entity (trivial novelty). At the same time you do not claim that your flower is an exemplar of a new genus, family, order, class, or division on the higher levels of the classificatory hierarchy of biology. You only claim that it is an exemplar of a new species. A more versed critic might object that your flower appears to be an exemplar of a new species only from a phenomenological point of view, whereas from a genetic standpoint, in terms of its DNA, it belongs to a well-known species. A skeptic might even maintain that the entire biological classification scheme, including the distinction between species, is an arbitrary way of imposing conceptual order on what in reality is a continuous variation in biological populations. In the end you have to defend a conceptual framework as naturally given in order to support your novelty claim.

Distinguishing something as novel thus depends on how you conceptualize it, which in turn depends on your conceptual framework. Strictly speaking you do not claim the novelty of an object, because the flower existed before. Instead, you claim that, within the existing conceptual framework of biology, you have made a novel conceptual discovery, which the flower only helped you to do. The alleged novelty of the object thus turns out to be the novelty of an event, of your own conceptual activity. Moreover, as the example of phenomenologically versus genetically founded classifications in biology illustrates, there are different ways of conceptualizing the world, depending on what one takes as more important. Any novelty claim is thus based on assumptions about what matters and what not. Novelty claims about objects in the world are thus hidden claims about the "truth" of conceptual frameworks and about the values that support the importance of that framework.

Novelty claims that refer to an existing conceptual framework, such as the finding of a new species within the existing biological classification, are cases of *normal novelty*. Normal novelties simply fill a gap within an existing framework. Because the gap was pre-configured or even anticipated by the conceptual framework, normal novelties are not novel in a strict sense. *Radical novelty*, on the other hand, requires a different framework to be conceptualized and understood, what is

sometimes called “thinking outside of the box”. If you are unable to assume the different framework, because it is uncommon, unfamiliar, or foreign to you, you can neither comprehend the novelty nor appreciate it as novel. This poses a *second novelty paradox*: While normal novelty is not novel in a strict sense, because it was conceived before, radical novelty is incomprehensible.

Compared to the framework of biological taxonomy and other scientific classifications, which despite (or, historically speaking, because of) critics and sceptics are rather precise and robust, our ordinary concepts to describe the world are much more fuzzy, flexible, and guided by personal interest. In ordinary life disputes, claims about novel objects are frequently made in order to argue for a new or different conceptual framework in a way that suits best those who make these claims. To support such claims, a range of fallacies are available.

2.3 Fallacies of Novelty

Fallacies have an intellectual double-history. On the one hand, they are compiled in logic as typical forms of logical error. On the other, they are compiled in rhetoric as rhetorical means to convince people of something when sound arguments are missing. Understanding fallacies thus helps both avoid drawing wrong conclusions and protect against rhetorical seductions. Not surprisingly, several classical fallacies are developed around the concept of novelty.

The most famous one is the *appeal to novelty* (in Latin, *argumentum ad novitatem*). Something is considered good or important, or better and more important than something else, only by virtue of being novel. For instance, companies frequently advertise their products by emphasizing the newness, assuming that consumers have a strong preference for new products over old ones. If the appeal to novelty convinces many people such that they all want to have the new thing, the *bandwagon fallacy* further supports the appeal to novelty: according to that fallacy, the novelty is good only because everybody wants it. However, in general the appeal to novelty works only for certain audiences whose personal taste prefers modern things to traditional ones. Traditionalists, on the other hand, are often convinced by the counter-fallacy, the *appeal to tradition* (*argumentum ad antiquitatem*). For instance, they consider something right just because it has ever been done so before and, accordingly, wrong if it is novel. In some specific areas, the appeal to novelty can be supported by arguments and thus is no fallacy proper. If a project has a clear definition of progress and works accordingly, the latest step is arguably better than the previous one. For instance, the latest computer anti-virus software that considers all available viruses is better than the previous version because it is more complete and thus safer. In general, however, the appeal to novelty relies on the idea of universal progress that every step in the course of time is an improvement, which in turn is frequently based on the related historiographical fallacy of novelty.

The *historiographical fallacy* of novelty relies on a naive way of writing history, which British call Whiggish history. In this view, the past is constructed so as to

fulfill the goals of the present. Thus, everything of the past that does not suit the idea of a steady growth towards the current state, such as weird ideas, dead ends, and irresolvable conflicts, is simply ignored. In retrospect every novel step in history thus appears as improvement. From such a flawed history, people draw evidence for the claim that novelty is per se good which makes them subject to the appeal to novelty. However, one can similarly construct a history that focuses on weird ideas and dead ends and which would support the counter-claim according to which every novelty is a mistake.

The appeals to novelty and tradition and the historiographical fallacy all draw unwarranted conclusion about the relevance of novelty. There are other fallacies that lead one to claim novelty where there is none. The two most frequent ones are the confusion of subjective and objective novelty and the confusion of term and object. Both fallacies are related to what Jean Piaget in his developmental psychology called egocentrism, i.e. that children are unable to distinguish between their perceptions and descriptions, on the one hand, and the world to be perceived and described, on the other. However, particularly if both fallacies come together, also many adults are prone to these fallacies which again can be fostered by the bandwagon fallacy.

Considering something novel only because one has never perceived or heard of it before, is committing the *subjective/objective fallacy*. Changing one's personal attention can thus generate novelties at will. However, the fallacy can easily be corrected by someone else arguing that the alleged novelty has been known by others before, which is how we usually learn to distinguish between subjective novelty and objective or intersubjective novelty. Things become more complicated if the alleged novelty comes with a new name by applying the *term/object fallacy*. Because language is a social institution that incorporates and conveys social knowledge, the new name suggests that the alleged novelty is also novel for anyone. If people are unable to distinguish clearly between terms and objects to be referred to by terms, the introduction of a new term is a powerful rhetorical tool to make novelty claims where there is none. And the more people adopt the new term, the more powerful becomes the rhetorical tool. Moreover, if the alleged novelty comes with a bunch of new terms that suggests a new conceptual framework, the term/object fallacy even allows one to introduce allegedly radical novelty.

The more diffuse the object is, the more difficult is it to identify the term/object fallacy. If the new term has an obscure meaning, such that it is hard to determine if it refers to a hitherto known or unknown object, the term/object fallacy is particularly powerful. On the other hand, introducing a new term for a diffuse range of known or unknown objects, in particular for abstract objects, can be semantically productive. As the Wittgensteinian theory of meaning suggests, the social establishment and continuous use of a new term may create and shape a new meaning. In that case, the use of the new term eventually creates a new object, such that the novelty claim works like a self-fulfilling prophecy.

We will see that most, if not all, novelty fallacies have played a role in the establishment of nanotechnology. Before discussing nanotechnology, however, it is useful to look at science and engineering in general, because these are unique fields of producing novelties.

2.4 Novelty in Science and Engineering

Despite the intricacy of the concept of novelty, there are only three cultural areas that seem to put strong emphasis on the production of novelty: news media, art, and science and engineering.[1]

The news media largely rely on the concept of trivial novelty, i.e. that any event is novel per se. However, an event qualifies to be reported as "news" only if it matters, if it meets the interests of the intended audience. This includes that the event happened only recently or was not known before, so that it is newly or freshly reported, because there is nothing worse for the media than old news. Therefore, the concept of newness in the news media refers to the report rather than to the event and to the subjective knowledge of the audience, such that the news media are prone to the subjective/objective fallacy. For instance, a well-established technology can be reported as news in the mass media if no other media has covered it before. Moreover, for the news media the antonym of new is old rather than common or recurrent, which allows selling common or similarly recurrent stories as "news" so long as people are interested in. Hence, unlike what one might expect, novelty in the non-trivial sense does not play an important role in the news media.

That is entirely different in art and science, which are two cultural areas where the production of novelty is a necessary condition. Indeed, reproducing or imitating the works of others disqualifies people from being true artists or scientists – those who do so might even be accused of fraud. The concept of novelty in art is difficult, however, because artworks are, particularly in the formative arts and unlike the products of science, first of all unique objects that per se meet the criterion of trivial novelty. To which degree non-trivial novelty applies is a matter of theoretical interpretation and cannot be resolved here. It essentially depends on the conceptual level one is willing to consider in artworks.

In contrast, science and engineering are the only cultural areas in which novelty is produced and professionally managed on an international level, with strict measures to exclude the subjective/objective and term/object fallacies. This includes regular novelty checks of any research result as well as archives for storing previous results in a systematic manner to allow for quick novelty checks. In science, this is conducted by peers, particularly through the peer review procedure, who check research results for their epistemic reliability, disciplinary relevance, and novelty before their publication in professional journals.[2] In engineering and applied science, where results are usually published as patents, national and transnational patent offices check patent filings for their non-obviousness or inventiveness,

[1] One might be inclined to add fashion here. However, the recurrent stylistic repertoires and, indeed, the launches of "retro looks" clearly disqualify fashion from being a cultural area focused on novelty. Fashion works with relative novelty that depends on the time period after which consumers are willing to buy new products.

[2] Interestingly, peer referees have a strong aversion to novelty rhetoric, i.e. they frequently criticize authors if they use terms such as "novel" or "new" in their manuscripts, instead of clarifying the novelty of their research by references to the pertinent literature (Daniel 1993).

usefulness or industrial application potential, and novelty. In both cases the novelty is checked against previous publications, both articles and patents, which are indexed and archived in databases by professional information managers.

Both in science and engineering, trivial novelty does not matter because research results are not merely unique events but general results that must be reproducible by any other peer with the same research equipment. Such as an individual flower creates novelty only by virtue of being an exemplar of a hitherto unknown species, such creates an experimental research result non-trivial novelty only by being reproducible, by being an exemplar of all possible research results of the same kind. If, for instance, the research yields a piece of a hitherto unknown material, the novelty claim is about a new material species of which the piece is only a specimen. Similarly, if the research finds a causal relation between two parts of the individual experiment, the novelty claim is about the causal relation between the corresponding parts in any experiment of the same kind. In general, the novel finding must be communicable in professional language, i.e. by using general concepts that are known and well understood by peers and that precisely describe all the objects and operations of the experiments. That is to say that the novelty must be comprehensible within the established conceptual framework of the respective discipline. Such novelty thus meets the criterion of non-trivial normal novelty described above.

Following Thomas S. Kuhn's work on scientific revolutions and "paradigm changes" (Kuhn 1962), philosophers and historians of science have widely discussed radical novelty in science, when new results and their interpretation challenge the established conceptual framework to the point that they appear incomprehensible or even weird by peers. In standard evaluation procedures, such radical novelty can at first be hardly distinguished from so-called "pathological science" (Bauer 2002). If radical novelty in science comes with a fully developed alternative conceptual framework that is incompatible with the established one, the evaluation procedure is unable to make a rational, unbiased decision, because any evaluation would presuppose the preference of either conceptual framework. This means that by any rational standards, it is impossible to decide if radical novelty through scientific revolutions or paradigm changes is an improvement over the established state of science. Historically, debates on radical novelties have been settled only by common social factors, i.e. by the distribution of power and rhetorical talent on either side. Rhetorical devices include various fallacies, such as the appeal to novelty and its counterpart, the appeal to tradition, discussed above. Yet, such arguments have no sound basis. Instead, and contrary to a widespread popular understanding, radical novelty in science through scientific revolutions or paradigm changes is neither good nor bad by rational standards.

Apart from research results, there are other aspects of science that can be novel in one sense or another. Most importantly, scientists frequently explore research areas that have been neglected before. Because every research explores something new, this means only that the research lies outside of the main focus of a discipline. However, disciplinary focuses can and do change in many regards. Because science has continuously grown over the past two centuries, with annual growth rates of about 5 %, disciplines are no static entities. They grow, split into subdisciplines,

merge at their boundaries with other disciplines, give birth to new disciplines, and so on. Because the dynamics of disciplines does not essentially differ from the social dynamics of other populations, it is driven by common social factors rather than by the particularities of science. However, these social factors, which include internal and external forces, have an impact on the research areas in which scientific novelty is created.

Sometimes certain research results are considered to bear surplus novelty. In addition to being novel in the normal sense, they are said to induce further novelty in the future more than other research, as the quote on nanotechnology in the Introduction illustrates. Typical phrases that express this hope or promise include "key innovation", "groundbreaking", "land mark", "milestone", "revolutionary", and "cutting edge" research. One should be careful, however, with such phrases and claims if they are used to describe current research. Every research is meant to induce further research and thus further novelty, but the degree to which it will do so is largely unpredictable simply because science is unpredictable. Hence, those expressions are either used to make unwarranted predictions and promises or they function as rhetorical means to push the importance of certain research in the struggle for public attention and funding.

Now that we have clarified the different meanings and fallacies of novelty as well as the different levels and aspects of novelty in science and engineering, we are better prepared to discuss the novelty of nanotechnology.

2.5 Scrutinizing the Novelty of Nanotechnology

Because every published research result is supposed to meet the scientific requirements for normal novelty, we can assume that any published result in nanotechnology is novel in that regard. However, recalling the first novelty paradox, that does not mean that there is anything novel about nanotechnology, unless we find novelty on a more general level.

One of the most widely used definitions defines nanotechnology as the study of material structures in the scale of 1–100 nm in order to discover and exploit new properties of materials and devices that depend on the nanoscale structures for useful applications.[3] However, almost any material happens to be structured at the nanometer scale in such a way that the structure essentially determines its properties. The definition perfectly describes the activity of most of chemistry since more than a century, as well as that of molecular biology, biochemistry,

[3] For instance, the US committee on Nanoscale Science, Engineering and Technology (NSET) that launched the National Nanotechnology Initiative, defined nanotechnology as: "Research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1–100 nm range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size." (http://www.nsf.gov/home/crssprgm/nano/omb_nifty50.htm, retrieved in 2004).

pharmacology, solid state physics, materials science and engineering, larger branches of electrical, chemical, mechanical engineering, and so on since several decades. Because the definition is much too broad, it makes nanotechnology a case of trivial non-novelty.

The broadness of the definition suggests that "nanotechnology" is only an umbrella term that tries to encompass a multitude of distinct and long established science and engineering fields. Although the prefix "nano" is part of the old scientific standard nomenclature to describe a billionth of any measurement unit (such as in nanosecond, nanogram, or nanoOhm), scientists hardly used it before about 2000 to describe lengths other than wavelengths of light. Instead, because of some historical incidents, scientists used different units to describe the structure of materials and the size of particles, particularly Ångström (0.1 nm) and micron (1,000 nm). Since huge national research budgets are available for nanotechnology, these conventions have suddenly changed such that the nanometer has largely replaced the other units. Because the units can simply be converted, that is only a change of terms without a change of meaning or object. Those who are unaware of the conversion, might fall victim to the term/object fallacy and assume new objects where only a new term was introduced. And because relabeling research nano has been a scientific mass movement, the bandwagon fallacy reinforces the term/object fallacy.

One might object that the broad definition of nanotechnology is only a conceptual clumsiness that should not be taken too seriously, because nanotechnology actually describes a range of very specific and novel research fields that cannot be put under a common definition by providing necessary and sufficient conditions. In this regard, nanotechnology as the total of these research fields is novel because each of the fields is novel. However, if there are no necessary and sufficient conditions to define nanotechnology, how are these research fields selected to belong to nanotechnology? The only way to select them by conceptual standards would be according to their novelty. That approach would seem to make nanotechnology novel by definition as the total of novel research fields at any time. Yet, because there has always been a set of novel research fields in the past, the set per se is not novel, even if we introduce a new name for it.

Moreover, the individual research fields that are nowadays called nanotechnology have a history that did not start in 2000 but goes back far into the twentieth century if not earlier. The lack of history of science knowledge, and of scientific knowledge more general, makes people prone to the subjective/objective fallacy, such that they consider well-known things novel only because they have never heard of it before. A few examples of research fields that are all widely considered nanotechnology might illustrate that.

Chemical catalysis has been systematically studied and industrially exploited since the early twentieth century, including for instance the use of size-tailored nanoscale pores in engineered zeolites since the 1950s (Sherman 1999). The history of molecular modeling started in the first half of the twentieth century and then largely developed along with improvements of computer technology (Simões and Gavroglu 2001; Peyerimhoff 2002). Carbon nanotubes, which have become iconic of nanotechnology, were produced, studied, and characterized with transmission

electron microscopy already in 1952 (Monthioux and Kuznetsov 2006). Chemical vapor deposition, which was already known in the nineteenth century, has been used since the 1960s in the micro- and nanoscale production of films for ultra-thin coatings and semiconductor lithography, particles, and doted semiconductors (quantum dots) (Allendorf 1998). The production of molecular nano-devices, which until recently was called supramolecular chemistry, started in the 1970s (Lehn 1992; Balzani et al. 2003) as did genetic engineering, while atomic probe microscopy was developed in the early 1980s (Mody 2004; Baird and Shew 2004). A brief look into patent databases reveals that hydrogen storage systems, drug delivery systems (e.g., with liposomes, polymers, or cyclodextrins), and many other systems that are nowadays considered nanotechnology have been researched and heavily patented since the early 1970s, although the drug delivery systems hardly ever came up to the expectations by passing clinical studies (e.g. Szejtli 1996). In addition, nanoparticles, nanocolloids, liquid crystals, polymers, nanocomposites, nanostructured materials, nanofilms, vesicles, and so on have been manufactured and studied for much of the twentieth century, frequently following up nineteenth-century research and earlier artisan practices and products (Woyke 2008; Ede 2007; Kelker 1973; Kawamoto 2002; Furukawa 1998; Bensaude-Vincent 1998; Nordmann 2006; Roberts 1990, chap. 1).

Of course in each of these fields, there is ongoing and important research that brings about new discoveries and inventions, as we should expect from any good research. However, that makes neither the individual research fields nor its total called nanotechnology new. It is true that some research fields have been neglected in the past, particularly the size and shape dependency of nanoparticle properties, and that more recently much stronger efforts have been made to exploit them for commercial purposes. But, again, that does not make the fields new. Instead, pouring more research money into these fields is meant to increase the rate of new discoveries and inventions, i.e. the rate of normal novelty within each of the fields, which brings them to public attention. One might object that there is a difference between research fields and technologies, arguing that although the research and development fields are old, they are meant to prepare new technologies in the sense of commercially available technological products and solutions. However, the argument hinges on the assumption that both can be clearly distinguished, whereas the current use of the term “nanotechnology” radically blurs the distinction. Even if we assume that there were a clear-cut distinction, it is not clear why the long-term research and patenting activities in these fields should now all of a sudden produce more of the long-wanted technological products, other than by suddenly increased research funding. In that case, the novelty claim would only be a promise or hope of future novelty in need of substantiation.

In sum, although each individual research result is novel in the normal sense, neither nanotechnology as a whole nor its individual research fields are new apart from the name. Since the individual research fields have developed continuously rather than revolutionary and changed only their names rather than their conceptual foundation, we can exclude both normal and radical novelty.

And yet, there is something new about nanotechnology that is not to be found on the research level but in the social organization of science. First and foremost, there is a new research budget in addition to, and mostly at the expense of, the established disciplinary budgets. Indeed, the national research funding agencies of industrialized countries, and increasingly of developing countries, have established a budget called "nanotechnology" – in Japan it was formerly called "atom technology". These budgets are largely earmarked for research across the disciplines with particular focus on bringing science and engineering closer together for the research and development of commercially useful products. Nanotechnology as a science policy idea stands for the goals of increased interdisciplinary research and for adjusting so-called fundamental research to the needs of applied science. More than just redistribution of money, the social reorganization of science requires scientists actively engaging in the movement for which they need to see new opportunities. To that end nanotechnology has from the very beginning been surrounded by, if not created from, visions, which were mostly derived from Eric Drexler's futuristic ideas of molecular scale robotics and other science fiction. For instance, the US national nanotechnology initiative has propagated that nanotechnology would bring about the next industrial revolution, unprecedented wealth, health, and security, that it will reshape the entire world atom-by-atom, and that it would allow enhancing human capacities beyond anything we have known before, even beyond our concept of what a human being is. Although visions have played an important role in the propagation of earlier science policy projects, from nuclear energy to genetic engineering, nano-visions have reached a new level regarding both their all-encompassing totality and futuristic dimensions.

Moreover, because science fiction writers had employed these visions under the name of "nanotechnology" long before scientists and science policy makers used the term, nanotechnology owns its origin from a new kind of interaction between science, science policy, literature, and the broader public. This includes also so-called investment consultants who have turned these visions into the next "big thing" for investors; journalists who have used the visions to write interesting stories about science; the techno-religious transhumanists who yearn for salvation by the help of molecular robotics; and ethicists who ponder on the ethical issues of futuristic, i.e. nonexistent, technology; and so on (Schummer 2004, 2009). The more the term "nanotechnology" has been used by a growing number of people, the more have the term/object fallacy and the bandwagon fallacy gained impact and the more has the conceptual distinction between visionary (but nonexistent) and new (and existent) been blurred.

We may conclude then that the novelty of nanotechnology lies in ideas about the future rather than in current technologies, beyond the usual production of novelty. On a social level, nanotechnology in this regard is a broad social movement that tries to direct and control current research towards these ideas. It is not about current novelty but about predictions and recommendations where the regular production of novelty by science and engineering will and should be focused in the future.

2.6 The Ethics and Politics of Novelty

Any new technology that provides solutions to hitherto unsolved societal problems has social and ethical dimensions, because the new opportunities, as well as the predictable and unpredictable risks and unwelcome consequences, need to be justly distributed. Therefore, the mere announcement, even the promise, of technological novelty, whether founded or not, induces both hopes and fears. Those who are considered experts and entitled to announce or promise novelty have political power with which they can deal responsibly or not. Three examples might illustrate the ethical and political dimensions of novelty: personal fears and hopes, regulatory issues, and international competition.

When nanotechnology is publicly propagated as a novel technology to solve whatever societal problem, that is frequently a misrepresentation that misleads the public, because the specific technology has usually been researched long before, and the novelty claim makes it neither more powerful nor novel other than by term/object and subjective/objective fallacies. Even if the novelty rhetoric is aimed at fostering public attention and research, such that it might become a self-fulfilling prophecy, that is a risky play on the people's hopes and fears. Imagine someone suffering from cancer or another serious disease in a state when existential decisions have to be made, for instance about a therapy with severe side effects. The promise of a forthcoming novel remedy by nanomedicine, as well as the omnipresent breakthrough rhetoric repeated by uncritical journalists, might have a crucial impact on such existential decisions. If the promise is unfounded propaganda, the person might be misled to make wrong existential decisions, for instance to postpone the therapy and wait for the new remedy and ultimately die because of the misinformation. Of course, novelty claims rarely affect life-and-death decisions, but the case illustrates that they can do so and that playing on the hopes and fears of people is ethically relevant. On the other hand, suppressing novelty claims, for instance by referring to the trivial sense of non-novelty, can equally misinform and mislead decisions, such that it is ethically relevant too.

If a technology is said to provide revolutionary new products and effects, only a fool would assume that these are all desirable and beneficial. As a rule, a new and unresearched, i.e. unknown, range of products and properties includes surprises, both welcome and unwelcome. If one announces the novelty of a range of products and properties, as has been done with nanoparticles, the novelty claim refers, strictly speaking, to *both* welcome and unwelcome effects. The logic of novelty thus requires pointing out both novel opportunities and novel risks of nanoparticles. And the more powerful the novel opportunities are praised, the more questionable are the received regimes of risk management. The novel opportunities of nanoparticles consist in the (hitherto neglected) exploration and exploitation of the range of properties that depend on the size and shape rather than on the chemical composition of the particles. While the phenomenon and its basic understanding is anything than new to scientists, the search for commercial applications of nanoparticles has drastically increased. However, all the regulatory frameworks for workplace safety and the

production and marketing of chemicals just disregard the size- and shape-dependency of properties and identify the materials to be regulated only by chemical composition. Thus, a material that is well known and old in terms of its chemical composition but new in terms of its nanoparticle size and shape could be regarded safe in the legal framework even though it is toxic. Since nanoparticle products are already on the market, and many more are in the developmental state, our policy-makers follow a dangerous double strategy. They celebrate the novelty of nanotechnology in their funding and rhetoric, but irresponsibly stick to received and long outdated regulations.

We have seen that the science policy claims and promises of novelty should rather be understood as a means to direct and control the future production of novelties. On the international level, the promise of future novelty in a certain technological field might induce a competition among countries about who will be the first to make the breakthrough and harvest the economical potential. However, not every country has the international authority to make novelty promises and claims. Those who have the authority can always make sure they have a head start in the competition by selecting research fields for their novelty claims in which they are already particularly strong. Whereas those who lack the authority and are seduced by the promise to jump on the bandwagon will certainly lag behind. Thus, the authority to make novelty claims is a strong advantage in the international technological competition, because it allows determining international research agendas for one's own benefit.

As has been argued above, nanotechnology is neither in total nor in its individual fields novel, but it comes with the promise of future novelty that has even more aggressively been propagated as enabling the "next industrial revolution". Which economy would not want to be part of that? Following the US National Nanotechnology Initiative, numerous countries, both industrialized and developing, have launched similar nanotechnology initiatives and programs to engage in the competition. And most, if not all, have uncritically bought the novelty rhetoric and repeated it in their national agendas and pamphlets that are meant to inform the public. Although nanotechnology is particular because of its obscure definition, formerly hyped technologies, like information and biotechnologies, followed the same general pattern of international science policy leaders and epigones who are destined to lag behind. With each hype-cycle the hegemony of novelty claims thus helps reinforce the global technological and economic imbalance by producing winners and losers.

2.7 Conclusion

Science and engineering are unique in our society because they produce novelty on a regular basis in a highly professionalized manner that allows drawing clear distinctions between what is novel and what not. In contrast, ordinary language talk of novelty is prone to numerous confusions, paradoxes, and fallacies, which makes

it an ideal rhetorical means in commercials. As a social movement, the propagation of nanotechnology has not only occurred at the interface between science and its publics, it has also merged the precise scientific meaning and the confused public meanings of novelty. In particular, science managers have spread the novelty claim about nanotechnology as a rhetorical means to direct future research, and thus to control future novelty production. Whether the political control of novelty production is possible at all and whether it leads to creative rather than monotonous research is still an open question. As a suddenly generated global mass movement it might favor opportunists rather than creative minds, both among scientists and science managers who prefer to follow the lead of others. By publicly spreading visions about possible future technological innovations in the disguise of novelty claims, science managers have gone beyond the usual financial incentives of science policy. While this might inspire some of those who actually produce novelty, it also affects ethical and political dimension of science and technology, because it stirs public hopes and fears, questions regulatory regimes, and induces international dynamics. The novelty talk thus reaches dimensions that science managers alone can hardly handle. Instead of making rhetorical novelty claims, they should better put the issue on the political agenda and ask in advance what kind of novelty people really want.

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Chapter 3
Does Nanotechnology Require a New "Nanoethics"?

Søren Holm

3.1 Introduction

Nanotechnology is one of the most scientifically exciting and technologically promising fields of research to emerge during the last decades, and there are already nanotechnological products on the supermarket shelves. As many other emerging technologies (some) nanotechnologies raise ethical and societal issues that have to be discussed and analysed, but does this entail that we need a new field of ethical inquiry called "Nanoethics" to handle these issues? That is the question that this chapter attempts to answer. The chapter builds on and significantly extends arguments I have made in a previous paper (Holm 2007).

Given that a journal with the title "Nanoethics" has been published by Springer since 2007 and that there are several books with the word "nanoethics" in the title it may seem a little late to raise this question as a practical question. But as we shall see the question is still an open question. Even if it was no longer an open question in relation to nanotechnology it would still be worth answering because nanotechnology is unlikely to be the last new technology that emerges with attached ethical issues. The future is likely to hold other new transformative technologies. For each future technology the question will become relevant again, do we need a new field of ethics to handle the issues raised by the technology? Our exploration of nanoethics will hopefully enable us to draw some more general conclusion.

Nanotechnology does, however raise one issue that many other technologies may not raise and that is the issue concerning coherence as a field of inquiry. There is very little that unites all the disparate activities undertaken under the labels of

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nanoscience and nanotechnology. There is no unified set of scientific questions, no unified set of methods and no unified vision or research program in a Lakatosian sense. "Nano" is simply a label which, partly for strategic and tactical reasons can be applied to a set of endeavours loosely held together by the fact that they are related to the properties of matter at the nano-scale.

This could be seen as a potentially serious problem for the putative field of nanoethics. It might be claimed that you can only have an ethics of something, if that something is coherent, can be defined and have its boundaries delimited. Alhoff for instance claims that: '… nanoethics can only be as coherent as nanotechnology itself.' (Alhoff 2007, p. 185).

But although there is some truth to this, it does not allow us to dispose of the possibility of a fruitful field of nanoethics. This is because the boundaries of the activity that we are reflecting ethically upon do not have to be sharp and they do not have to be unanimously agreed. The field of health care is not sharply delimited and its precise delimitation is contested, but this does not entail that health care ethics is an empty category.

So does nanotechnology need a new nanoethics? The strategy that will be pursued here is to distinguish four different ways in which nanotechnology might *need* a new ethics and analyse them sequentially from the most radical and expansive claim to the most moderate and conservative claim. The questions that will be analysed and answered are thus:

1. Do we need a new nanoethical theory?
2. Are the ethical issues raised by nanotechnology unique?
3. Can existing approaches handle all issues raised by nanotechnology?
4. Do we need experts in the ethics of nanotechnology?

There is already a considerable literature on this topic so many of the arguments discussed here have already been discussed by others or by the author of this chapter elsewhere (Allhoff 2007; Brownsword 2009; Ferrari 2010; Grunwald 2005; Litton 2007; Nordmann 2007; van de Poel 2008). Some of the already extant arguments are, however deepened, nuanced or criticised.

3.2 Do We Need a New Nano-Ethical Theory?

The most radical claim that can be made for nanoethics is that there is something about the technology which requires us to develop new ethical theories or frameworks in order to properly analyse the ethical issues that the technology raises. Maybe nanotechnology is simply so potentially transformative that we cannot encompass it within our current ways of thinking.

It is difficult to prove that this cannot possibly be the case without committing to any particular ethical theory. If we assume that a particular ethical theory is correct, we will in some instances be able to show that we do not need a new nanoethics in the sense discussed in this section. This does, for instance follow straightforwardly

for most types of maximising consequentialism since all the possible consequences flowing from the development of nanotechnology are already encompassed by the theory. But even if we do not commit to any particular ethical theory there are some general considerations counting against this radical claim.

First, although nanotechnology is potentially transformative it is unclear that it is any more transformative than previous technologies (e.g. fire, plastic technology, micro electronics etc.) that have transformed society in quite profound ways. None of these previous technologies have required us to fundamentally modify our ethical theories. Consequentialist have found ways to handle them within their theoretical framework as has Kantians, Aristotelians, Care and Narrative ethicists, Casuists etc.. Unless there is something very specific about nanotechnology that differentiates it fundamentally from other transformative technologies we do not have even *prima facie* reasons to think that nanotechnology requires a new ethics.

Second, it is unclear what the relation would be between a new nanoethics and any existing ethics. Nanoethical issues cannot in general be isolated from issues in other areas of ethics, so there must be some relation between our new nanoethical approach and our traditional theories. If the claim is that a new nanoethics is necessary because there are issues that the traditional theories cannot handle, or issues that cannot be adequately conceptualised within the traditional theories then the overlap between nano issues and other issues seem to imply that nanoethics, being a better theory, should simply supplant the old theories and approaches across the board.

Based on these considerations it seems safe to conclude that there is no need for a new nanoethics understood as a new ethical theory or a new set of ethical concepts.

This negative conclusion concerning the need for a new nano-ethical theory thus echoes the conclusion that Roger Brownsword has reached through a very different set of arguments, namely that:

> I remain to be persuaded that any new technology, including nanotechnology, demands a rethink as to the formal matrix of ethical deliberation. The basic shells of ethical thinking feature goals, rights, and duties and our judgments about nanoethics will be shaped by this formal template. (Brownsword 2009, p. 377)

Ibo van de Poel thinks that the approach pursued above is problematic because it implies a deductive model of applied ethics and evinces an "… apparent lack of awareness of well-known objections against the deductive model." (van de Poel 2008, p. 33, footnote 7). This criticism is, however, misguided and/or question begging. It is question begging if it simply relies on identifying "theory" with "the deductive model", because many ethical theories do not imply the use of any deductive model for reaching ethical conclusions, but they are theories never the less. Aristotle does, for instance have a theory of ethics in the Nicomachean Ethics a centrepiece of which is the concept of *phronesis*, the very antithesis of deduction. And casuists would also feel offended by the claim that they proceed by deduction.

And even when van de Poel is not question begging he is misguided. There is simply no implication from the claim that a given normative theory can be used to analyse the ethical issues created by a given technology, to the claim that this analysis has to proceed from applying overarching ethical principles in a deductive way.

3.3 Are the Ethical Issues Raised by Nanotechnology Unique?

Even if it is accepted that nanotechnology raises no new issues of ethical theory it might be claimed that we need nanoethics because nanotechnology raises new ethical issues. This could either be the strong claim that nanotechnology creates new and unique ethical issues or the weaker claims that nanotechnology actualises problems that although not new have previously not been discussed in detail, or that although the issues are not qualitatively different they are never the less sufficiently different to warrant new exploration.

What new and potentially unique issues does nanotechnology raise? It is important first to note that we may not yet know which ethical issues nanotechnology will raise. It may well be the case that issues will arise at some point in the future that we have not imagined, foreseen or predicted in the present. Even if none of the presently foreseen issues is unique, it might thus be the case that a unique but unforeseen issue arises in the future. But the mere possibility of the emergence of a possibly unique issue in the future seems to be a very weak justification for the establishment of a new field of inquiry. Although human beings have been using fire for thousands of years we cannot logically rule out that fire use will, at some point in the future give rise to a unique ethical issue, but that is not a good reason to develop or maintain the area of fire-ethics in the present. And even if stone age humans had been able to foresee global warming following from the burning of enormous quantities of fossil fuels in industrial and post-industrial societies it is not obvious that they should have spent much time developing an ethics of precaution in relation to fire and global warming. If there are no unique issues foreseen for nanotechnology now, we should park nanoethics until one arises (if uniqueness of issues is the justification for the existence of the field).

One set of potentially unique issues arise from the vision that nanotechnology may be such a powerful technology that it will fundamentally change everything. It may converge with bio-, cogno-, info- and other technologies to allow us to enhance ourselves and perhaps later transform ourselves to a trans- or posthuman state; or it may allow us to solve all our environmental problems and provide us with clean, sustainable energy. This vision of a nano-utopia has been promoted by Erich Drexler since the 1980s (see his web-site at E-drexler.com).

But a nanotechnology that is predicted to become immensely powerful also enables the creation of visions of a nano-dystopia. The most "popular" doomsday scenario among nano-dystopians is the "grey goo" scenario in which self-replicating nano-robots get out of control and devour all matter turning the earth into a seething mass of grey goo. A slightly more refined version of this scenario in which the nano-robots only devour organic material forms the basis for Michael Crichton's 2002 novel "Prey" (Crichton 2002). Certain other uses of nanotechnology have also attracted particular negative attention. These are the use of nanotechnology for pervasive surveillance or for military purposes.

Are these issues unique or sufficiently specific to warrant the creation of a new field of nanoethics? Let us first note that whatever issues the human enhancement

scenario raises they are not first and foremost issues raised by the technology by which enhancement is produced. The primary ethical issues are issues concerning the ethical value of the goal (the post-human state) and about its distributive and other effects if it can be achieved. Nanotechnology is just one of the many enabling technologies and we could just as well analyse the issues within the frame of bio-, cogno-, info- or "some other technology"-ethics.

Similar considerations apply to the nano-dystopian visions of the destructive powers of nanotechnology. The grey goo scenario is dramatic, see for instance the cover of the novel 'Nano' where the Golden Gate bridge in San Francisco is being devoured by a swarm of nanobots (Marlow 2004), but nanotechnology is not the first technology to have potentially large destructive powers. In contradistinction to nanotechnology where the destructive powers are at present only quite hypothetical predictions, nuclear technology has proven ability to destroy on a massive scale both in its military and its civilian form. We are thus not unfamiliar with the ethics of dangerous and destructive technologies and we have developed regulatory structures to handle them.

The issues raised by nano-surveillance or by dual military and civilian use are not specific to nanotechnology either. Most of the ethical issues concerning surveillance are technology independent. Even if we hypothesise that nanotechnology will in the future allow much more pervasive and undetectable surveillance we have to realise that such surveillance is already technologically possible today, for instance using radio frequency identification devices (RFID). RFIDs are already today miniaturised and present in many consumer goods and the reason that we, as a society does not currently utilise their surveillance potential have very little to do with any defects in the technology that nanotechnology could remedy.

Nanotoxicology also raises interesting issues, but they are again neither unique nor very specific. The science needed to develop methods and heuristics for assessing the toxicity of nano-materials and particles may be complex and specific, but we have ample prior experience both in handling uncertainties about toxicity and complex toxicities. The emergence of a broad new class of potentially toxic materials may well lead to refinement in how we regulate the entry into the market of new materials, but it does not raise any qualitatively new issues.

3.4 Can Existing Approaches Handle All Issues Raised by Nanotechnology?

Maybe the problem that nanoethics is supposed to solve is not at the level of theory or of ethical issues, but at the level of the tools that are (claimed to be) the stock in trade of applied ethics. Maybe the impulse for developing a new nanoethics comes from the belief that something like the four principles approach medical ethics/bioethics developed by Beauchamp and Childress and popularised by Gillon cannot adequately handle the issues that nanotechnology creates (Beauchamp and Childress 2009; Gillon 1986). The analytical or normative resources afforded by respect for autonomy, non-maleficence, beneficence and justice are simply insufficient.

The author of this chapter is on record for suggesting that the four principles approach does not even contain the analytical resources necessary for an adequate medical ethics (Holm 1995), so he clearly has some sympathy for the idea that this particular framework is unlikely to be sufficient for nanotechnology. It is very focused on the discrete interactions between individuals (e.g. a patient and a doctor) and potentially overemphasises personal autonomy. Similar arguments can be made in the context of many other frameworks for analysis commonly used in applied ethics, e.g. Gert's 10 rules (Gert 1973; Gert et al. 1997).

But these kinds of prescriptive frameworks do not exhaust the already existing toolbox of applied ethics.

Despite his rejection of the deductive approach and his criticism of the existing debate concerning the newness of nanoethics van de Poel does, for instance dig into his own existing toolbox in the final part of his paper and suggests that a procedural approach developed by him and his colleagues for quite different purposes is also suitable for discerning the ethical issues raised by nanotechnology.

When we thus look more closely at the existing toolbox of applied ethics we realise that it is very big. There is very likely to be a tool or a set of tools that can easily be adapted to nanotechnology. The perception that this is not the case is probably primarily driven by a too narrow focus on medical ethics.

3.5 Do We Need Experts in the Ethics of Nanotechnology?

In this chapter it has so far been argued that (1) we do not need to develop any new ethical concepts to handle the ethical issues raised by nanotechnology, (2) that nanotechnology raises no unique ethical issues, and (3) that existing approaches in applied ethics can handle all issues raised by nanotechnology. If all of this is correct it seems to strongly imply the conclusion that we do not need a new nanoethics.

But this conclusion might be too hasty. There may be other reasons for speciation or specialisation within the overarching field of applied ethics than differences in ethical theory, ethical problems or analytical approaches. All ethical analysis and argument involve empirical premises and the arguments are only sound if these premises are true. It is of little use to have a formally valid ethical argument, if it is undermined by one or more of the premises being false.

In order to properly discuss, for instance the ethics of organ transplantation and donation factual knowledge is necessary concerning a whole range of medical, organisational, social and psychological factors that are involved in this context.

In the same way proper analysis of the ethical issues raised by nanotechnology requires mastery of the relevant set of facts.

It might be suggested that this does not imply that the person performing the ethical analysis need to know these facts at the outset. He or she just needs to have access to experts on nanotechnology and related matters who can provide the facts if and when they become necessary for the argument. But such a division of labour between the ethical analyst and the subject expert cannot be successfully

sustained (Holm 2004). Being able to identify what factual premises that are needed in an argument requires subject knowledge. And even deeper subject knowledge may be necessary in circumstances where knowledge claims are contested or incomplete; or where the available knowledge does not quite give an answer to the question that is crucial for the ethical analysis.

To be a good analyst of ethical issues in nanotechnology producing relevant and sound ethical analysis it is therefore necessary to have solid background knowledge about nanoscience, nanotechnology and possibly the sociology of nanotechnology. Acquiring this knowledge takes time and may involve continued engagement with nanoscientists, industrialists and current and potential users of nano-engineered products.

There is no in principle reason why, say an environmental ethicist or a bioethicist should not be able to acquire this knowledge, but it is specialised knowledge and it will take time to acquire. The time needed to acquire the necessary background knowledge may be quite substantial given that the (1) development of nanotechnology relies on a very complex set of methodologies, (2) that the potential uses of nanotechnology are manifold and span most industries and areas of life, and (3) that nanotechnological developments interact significantly with other new technological and social developments.

We may therefore have purely pragmatic reasons for wanting some people to focus their attention on the ethics of nanotechnology, because we have reason to believe that they will provide better and more nuanced ethical analysis of the issues than someone like the author of the present chapter who is primarily a philosopher of medicine and bioethicist but who dabbles in nanoethics. They might also be less likely to be seduced into believing that analysis of the nano-utopian and nano-dystopian scenarios ought to be the central core of nanoethics.

If the creation of a new sub-specialisation of applied ethics called 'nanoethics' with its own journals and web-sites will help to create a cadre of people focusing their attention and energy on the ethics of nanotechnology it may be all to the good.

3.6 Conclusion

This chapter has argued (1) that the ethics of nanotechnology does not differ sufficiently from the ethics of any other technological field to warrant the establishment of a new sub-specialty of applied ethics called 'nanoethics', and (2) that nanoethics may never the less be a valid field of sub-specialisation because good ethical analysis of nanotechnology requires in-depth knowledge of nanoscience, nanotechnology and the social field in which nanotechnology is becoming embedded. In so far as the acquisition of knowledge is always an exercise in prioritisation of what knowledge to acquire – no one can know everything about everything – the development of the field of nanoethics may simply be justified by the effort needed to gain the relevant knowledge to become a good ethicist of nano-matters. In brief, what we need is not a new nanoethics, but a new field of nanoethicists.

Some may hanker for a deeper metaphysical or ontological justification for the separateness and necessity of nanoethics, but such a hankering is misplaced if it is based on the idea that only a metaphysical or ontological justification can make nanoethics secure. There is no metaphysical or ontological justification for the separation between surgeons and physicians, it is a separation based on different knowledge and skill sets, but this does not make surgery any less secure as an important, separate area of expertise and skill. The surgeon/physician divide may not be stable *sub specie aeternitatis*, but there is no reason why this should worry present time surgeons. Similarly nanoethics may, as other kinds of sub-specialised technology ethics only be a transient phenomenon in the forward march of applied ethics, but this does not make it less important or worthwhile in the here and now.

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Chapter 4
GM Food and Nanotechnology

Ronald Sandler

4.1 Introduction

In matters characterized by a high degree of complexity or uncertainty, such as the social and ethical dimensions of an emerging technology, it is often useful to begin with historical analogies (Steinbruner 2002). In the case of nanotechnology, one of the favored analogs is genetically modified (GM) foods. Even a cursory read of the first generation of social and ethical issues (SEI) literature on nanotechnology reveals that the GM food analogy plays prominently in motivating and framing the discourse, if not the agenda of SEI research.[1] This chapter offers critical reflections on the comparisons between nanotechnology and GM foods. The aim is to identify the respects in which the comparisons are helpful in clarifying and responding to the SEI associated with emerging nanotechnologies, as well as the respects in which the comparisons are unhelpful or misleading. After reviewing several similarities and dissimilarities between the two types of technologies, three potential lessons from the GM food experience for emerging nanotechnologies are evaluated: a lesson on public engagement; a lesson on technological fixes; and a lesson on case by case assessment.

[1] The analogy appears in scholarly articles, congressional testimonies, popular articles, public lectures, opinion pieces, and government publications. For example: Colvin (2003, April 9), Mnyusiwalla et al. (2003), Woodhouse (2004), Wilsdon (2004), Gorman et al. (2004), Moore (2002), The Royal Society (2004), Mehta (2004), Kulinowski (2004), Sweeney et al. (2003), Geoff Brumfiel (2003, July 17), Giles (2003, December 18/25), Wilsdon and Willis (2004), President's Council of Advisors on Science and Technology (2005), National Research Council (2002), Thompson (n. d.), Marchant (2007), Burube (2006).

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4.2 Some Similarities

There are several reasons that GM-Nano comparisons are popular. First, there are significant similarities between nanotechnology and GM foods both with respect to the technologies themselves and how they are standardly characterized. They are both novel, emerging technologies that are projected and hyped to be drastic, indeed revolutionary, improvements over their technological predecessor (hybridization in the case of GM crops and microtechnology in the case of nanotechnology). They also are both characteristically "reductive" or "deep" technologies. GM technologies involve characterizing, designing, and controlling life at its basic, genetic level, whereas nanotechnologies involve the same for matter at the basic, atomic level. Moreover, tools, techniques, and products of nanoscale science and technology are now and increasingly will be employed in the genetic modification of food crops, as well as in agriculture (e.g. field sensing and data collection, agricultural inputs, product enhancement) and the food/food-stuff supply chain more generally (e.g. processing, packaging, tracking, and monitoring). Some nanotechnologies are, therefore, GM or food technologies as well. For these nanotechnologies in particular, the ongoing GM experience is a nanotechnology experience, and *vice versa* (Thompson n. d.; Kuzma and VerHage 2006).

Second, there are socio-historical reasons that the analogy is attractive. As mentioned above, the use of analogy when studying the social and ethical dimensions of an emerging technology is common and often illuminating, and "the GM debate" is recent, indeed ongoing, so it is fresh to many involved with nanotechnology, and provides a familiar framework for scientists, representatives in industry or government, social and ethical researchers, public interest groups, and the media when dealing with nanotechnology. Nanotechnology also is emerging in what is generally the same socio-political context as did GM foods,[2] and some of the public interest groups and NGOs that encouraged and led opposition to GM foods are critical as well of nanotechnology and how it is being developed.[3] In addition, there is at present a considerable elite-public knowledge gap regarding nanotechnology, as there was, and continues to be, with GM technologies (The Royal Society 2004; Cobb and Macoubrie 2004; Peter D. Hart Research Associates 2007), and research suggest that the public relies on certain heuristics when developing attitudes regarding emerging technologies, and these are likely to be similar with nanotechnology as

[2] This point is emphasized by Moore (2002), who highlights the following: affluences levels sufficient to allow discriminating decisions about new technologies; the pervasiveness of technologies; the high rate of technological change; widespread acceptance of the importance of individual choice; public demandingness for greater accountability and evidence on unintended and unwanted consequences of new technologies; and the rapid pace at which SEI discussion can proceed and opposition form. Also relevant is reduced (and trending downward) levels of public trust in industry and government.

[3] Prominent among these are Greenpeace and the ETC Group, formerly Rural Advancement Foundation International (RAFI), which has advocated shutting down research and development of molecular manufacturing and a moratorium on the commercial production of new nanomaterials (ETC Group 2003).

with GM technologies (Scheufele and Lewenstein 2005; Peter D. Hart Research Associates 2007; Kahan et al. 2007). There also are some negative portrayals of nanotechnology in popular media—e.g. Michael Crichton's (2002) *Prey*, Bill Joy's (2000) "Why the Future Doesn't Need Us", and Bill McKibben's (2003) *Enough*—as was, and continues to be, the case with GM foods. Moreover, as with the GM backlash, a nanotech backlash would have significant economic, technological, and social consequences (Colvin 2003).

Third, nanotechnology ostensibly poses many of the same types of social and ethical challenges as GM crops—e.g. managing environmental and human health risks, and ensuring distributive and participatory justice. In fact, surveys reveal that among those who have opinions about nanotechnology, many have some of the same concerns about nanotechnology that are often expressed about GM foods—e.g. environmental and human health risks, adequate regulatory oversight, distribution of burdens and benefits, and who controls and is responsible for the technologies (The Royal Society 2004; Cobb and Macoubrie 2004; Kahan et al. 2007). Issues concerning power, authority, control, oversight, responsibility, political influence, governmental capacity, corporate responsibility/accountability, access and distribution of burdens and benefits (distributive justice), due process (procedural justice), and informed consent (civil liberties), which are characteristic of emerging technologies, frame the social and ethical discourse surrounded nanotechnology just as they have with respect to GM foods.

There are thus quite a few similarities between GM food technology and nanotechnology that make comparisons between them attractive and potentially illuminating.

4.3 Some Dissimilarities

There are, however, also a number of dissimilarities between nanotechnology and GM foods that also need to be attended to when attempting to draw lessons for nanoscale science and technology from the GM food experience. Many of these dissimilarities are due to the significant differences in the scopes of the technologies. Nanoscale science and technology is a general technological platform. According to the widely employed U.S. National Nanotechnology Initiative (NNI) definition, it includes: "Research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1–100 nm range; Creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size; Ability to control or manipulate on the atomic scale" (National Nanotechnology Initiative 2007). On this definition, any tools, techniques or methods that enable characterizing, designing, constructing, or manufacturing with precision at the nanoscale is part of the practice of nanotechnology. This is a much broader research and development domain—one that includes the work of physicists, engineers, molecular biologists, and chemists, for example—than that associated with GM foods, which standardly is limited to

the "use of recombinant DNA techniques in genetic engineering, inserting genes or other sequences of genetic code from one class of organisms into another" (Thompson 2007, p. 3).

One implication of this is that nanotechnology encompasses a much more diverse range of applications than GM foods. Whereas GM food crops are a particular type of agricultural technology, nanotechnologies have applications in, for example, medicine, energy, textiles, agriculture, sporting goods, weapons, data collection, computing, and environmental remediation. This difference in scope persists even when nanotechnology is compared to agricultural biotechnology generally—which includes, in addition to rDNA techniques applied to plants, transgenic or GM animals, cloning, synthetic ingredients/enzymes/agricultural inputs (including some that are genetically engineered), and tissue culturing, for example. Due to the enormous difference in the domains of GM foods and nanotechnology, agricultural biotechnology is not always an appropriate model for thinking about the social and ethical dimensions of nanotechnology, the fact that some nanotechnologies are agricultural biotechnologies notwithstanding. Many of the features characteristic of GM foods that have contributed to ethical concerns about them and public resistance to them are neither characteristic of nanotechnology as such nor applicable to most nanotechnologies.

Food related technologies can be particularly susceptible to public scrutiny for the obvious reason that food goes directly into our bodies and sustains us, as well as for the less obvious reasons that there are significant social, cultural, and religious aspects to food production, preparation, and consumption, and that farming remains the most common occupation globally. Novelty in food and agriculture therefore often invites public concern in ways that, for example, novelty in communication and computing technologies do not. There is also a special concern regarding the "naturalness" of food, and one of the primary objections to GM foods is that they are, in some unacceptable sense, unnatural (Comstock 2000). But this concern does not attach to non-food technologies that are already conceptualized, and accepted, as artificial—e.g. most therapeutic medical technologies, appliances, and communication technologies. The same is true of objections to genetic modification that are grounded in beliefs about the sanctity of life—i.e. that GM technologies involve unacceptably commodifying life, reducing it to genomic sequence, modifying it, patenting it, or pirating it (biocolonialism) (Di Chiro 2007; Shiva 1997, 1999)—and the inviolability of species barriers (Rifkin 1983). GM food technologies standardly offend these views, whereas most nanotechnologies do not. This is true also of the 'playing God' and 'disrespecting nature' objections commonly leveled against GM technologies—i.e. that redesigning "creation" or "nature" according to the human conception of how it should be is to sacrilege God's benevolence and rationality or to disrespect inherent goods and intrinsic values in nature (Comstock 2000). Like the other concerns, these have been most prominent, in modern western traditions, with respect to certain contexts—e.g. natural or agricultural ecosystems and living organisms. They have not attached to technologies in contexts that are already considered artificial—e.g. medicine, communications, and electronics. So the basis of many objections to GM food technologies—particularly those that involve claims

about there being something inherently wrong with them, not just something too risky about them—cannot be applied as easily to most nanotechnologies.[4]

Nanotechnology also may be less exposed to many of the risk-related objections that are applied to GM crops—i.e. objections that trade on probable or possible consequences of the technologies. GM technologies are intended to be "released" into the environment through cultivation and then "released" into the body through consumption. Exposure to the technologies is, therefore, inseparable from the use of the technologies. With most nanotechnologies, however, exposure is not inherent to them, since the nanomaterials often are encased or embedded in the product and manufacturing waste and by-products can (at least in principle) be contained or remediated at the sources. The exception, of course, is nanomedicine. But with nanomedicine the risks are assumed voluntarily, and are confined primarily to the person who stands to benefit from the treatment. It may be that containment is (or is considered to be) a more manageable type of problem than controlling something that is designed to be released; and risks assumed voluntarily by the one who stands to benefit are less objectionable than risks to those who are not intended beneficiaries and do not assume them voluntarily. In addition, as Paul Thompson has emphasized, "[a]grifood biotechnology was presented to the public in the form of specific applications—herbicide tolerant and pest-protected crops—that provided no benefit to food consumers" (Thompson n. d., p. 3; Marchant 2007). Even according to their proponents, these crops are "substantially equivalent" to non-GM crops. Moreover, the GM crops did not appreciably decrease the price of food products containing them (particularly in comparison to the robust effect that industrial farming generally and farm subsidies and protections have had). From the perspective of the consumer, GM foods are virtually all risk and no reward.

Another potential difference between nanotechnology and GM foods is that the development of nanotechnology has an increasingly public profile and there are education efforts, SEI research efforts, and efforts to gather public input already underway (Roco 2003; The Royal Society 2004). There is, therefore, at least the appearance of responsible development, including efforts to provide the public with an accurate picture of the possible benefits and costs associated with nanotechnologies and opportunities for substantive public input and participation in decision-making regarding those risks and benefits, as well as at least the appearance of a commitment to orient the technologies throughout the funding, research, development, and commercialization stages towards the public good. This is in contrast to GM technologies, which had (and continues to

[4] This is not to deny either that many food related technologies are widely accepted without any public scrutiny or that when there is public scrutiny a majority of consumers are not among those concerned (Thompson n. d.). The claims above are comparative and qualified. Food related technologies are more exposed to public opposition for the reasons given than technologies in fields that are already conceptualized by the public as technologically dominated and artificial; and among those who are concerned about food related technologies their concerns often are grounded in the role that food plays in human life/affairs, conceptions/expectations regarding naturalness, and so on.

have) a much more modest and localized public education effort (with the exception of the UK's belated GM Nation program), and seemed to have been thrust onto the public without consent or consultation. Related to this is GM food's image of being developed and controlled by powerful transnational corporations with the goal of maximizing profits, as well as the appearance of being to the advantage of large monocultural farming operations and thereby the detriment of small, subsistence and family farmers (Comstock 2000; Shiva 1997, 1999). Corporate control of the global seed supply and food system has been a powerful frame in motivating opposition to GM foods. It remains to be seen whether a similar frame can be applied to the broader nanotechnology sectors and, if it can, whether it will be similarly motivating.

So while many of the concerns that have been raised regarding GM food technologies appear applicable to nanotechnology, others cannot be easily or plausibly applied to most nanotechnologies.

4.4 A Lesson on Public Engagement

Perhaps the primary lesson drawn from GM foods for nanotechnology concerns the importance of public education and outreach. The predominant view among science, industry, and government communities is that something went wrong with society and GM foods that led to widespread public resistance to them, and nanotechnology has the potential for following the same course. Therefore, public communication and engagement are needed in order for nanotechnology to avoid the unfortunate fate of GM foods. Here is the standard reasoning/narrative in support of this GM food lesson:

1. There was a scarcity of communication between those who developed and controlled the GM technologies and the public regarding what the technologies are, their potential risks and benefits, and how the risks would be managed. When concerns were raised by members of the public they were often ignored or dismissed; and when engagement was attempted, there was a general failure to do so in ways that addressed the concerns.
2. This lack of disclosure, communication, and responsiveness led to a public atmosphere of suspicion, misunderstanding, and susceptibility to mischaracterizations of the technologies and their risks and benefits, which organized opponents of them were able to exploit.
3. The result has been a backlash against GM foods.
4. The negative consequences of this backlash have been technological, economic and social. It has slowed the development of new agricultural biotechnologies; it has cost the industry billions of dollars in lost revenues and created international trade tensions; and it has stalled dissemination of the technologies and food to many who would benefit from them, as well as stymied development of GM technologies designed to benefit those most in need.

5. There are, therefore, technological, economic and social reasons for open communication and early engagement with the public regarding emerging technologies.[5]

Application of this lesson to nanotechnology yields this conclusion:

6. The scientific communities and industries involved in nanotechnology must openly confront the social and ethical dimensions of nanotechnology, which requires public engagement and SEI research, or they run the risk of a costly backlash against nanotechnology.[6]

The foregoing account of the actual and potential dissimilarities between nanotechnology and GM foods suggests that a broad-based opposition against nanotechnology in general is not as likely to materialize as proponents of this lesson suppose, even while opposition to particular applications or forms of nanotechnology is probably. For example, it is reasonable to expect that nanotechnologies in agriculture will face much of the same opposition as GM crops. Nanotechnologies that involve human enhancement or have military applications are also likely to encounter public resistance; so too might efforts to develop molecular manufacturing capabilities, since molecular manufacturing feeds into grey goo concerns more than particle nanotechnology and is more susceptible to the playing God and disrespecting nature objections. But as nanotechnologies continue to improve pants, sunscreens, televisions, tennis balls, paints, communications, energy production and medicine, it will be increasingly difficult to motivate opposition against "nanotechnology," even if it will be possible to do so against nano-weapons, some nano-biotechnologies, and nano-assemblers.[7]

A second limitation of this lesson is that it invites misconceptions about the reasons for public engagement and SEI research, as well as their appropriate roles in nanotechnology research, development, application, commercialization, and regulatory processes. The lesson, again, is that industry and the scientific community must openly address the SEI of nanotechnology, which requires effective

[5] "[E]arly and open discussions of the societal and ethical impacts of new technologies improve their staying power, save taxpayers money, and benefit our society" (Colvin 2003, April 9).

[6] Here are a couple representative statements of this lesson:

> We believe that there is a danger of derailing NT if serious study of NT's ethical, environmental, economic, legal, and social implications…does not reach the speed of progress in the sciences…The only way to avoid such a moratorium [on nanotechnology] is to immediately close the gap between the science and ethics of NT. The lessons of genomics and biotechnology make this feasible. Either the ethics of NT will catch up, or the science will slow down (Mnyusiwalla et al. 2003, pp. R9, R12).
>
> No nanotechnologist wants the field to go the way of GM foods, which are largely viewed as the poster child for misguided public policy. With sound technical data about nanomaterials' health and environmental impacts and a commitment to open dialogue about potential social and ethical implications with all stakeholders, nanotechnology could avoid traveling along the wow-to-yuk trajectory (Kulinowski 2004, p. 19).

[7] It is possible that opposition to GM foods carries over to nanotechnology through social and psychological inertia. The point here is not to deny this possibility, but to show that it is significantly less likely than has standardly been supposed.

public communication and engagement. However, the emphasis is not on orienting the technologies around a publicly defined set of objectives, but rather avoiding a certain kind of public response. Moreover, the "problem" in the GM food case is not taken to be the technologies or their consequences, but the general public's ignorance and misconceptions about them, as well as the lack of effective effort on the part of GM food proponents to first preempt and later dispel the public's largely unjustified concerns. Social and ethical research and public engagement on nanotech are enlisted to forestall those problems from materializing with regard to nanoscale science and technology. That this is how the public engagement lesson from GM foods has been interpreted, at least in the United States, is evidenced in core NNI documents, where the emphasis regarding public engagement and SEI research is consistently on public support, not public input. Here is a characteristic passage from *The National Nanotechnology Initiative at Five Years*: *Assessment and Recommendations of the National Nanotechnology Advisory Panel*:

> Support for the continued advancement of nanotechnology research, and eventual integration of nanotechnology into consumer products and useful applications, will depend heavily on the public's acceptance of nanotechnology … In addition to its coordinating role, the NNI, through the [National Nanotechnology Coordination Office], should vigorously communicate with various stakeholders and the public about the Government's efforts to address societal concerns. Without such communication, public trust may dissipate and concerns based on information from other sources, including the entertainment industry, may become dominant (National Nanotechnology Advisory Panel 2005).

This interpretation of the GM-Nano public engagement lesson is troubling. The proper end for nanotechnology, as with all technologies, is to promote human welfare in just and sustainable ways, within appropriate moral boundaries. The reason for doing SEI research and engaging the public is that there are potential social and ethical issues associated with nanotechnology, and if the technology is to do what it should—contribute to human welfare in sustainable and just ways—those need to be identified, discussed, and addressed, so far as possible.

Moreover, although the scientific community has technical expertise and industry has economic expertise, they do not have expertise in the social and ethical issues associated with technological innovations or the standing to claim to represent the public's views about them. They are not properly empowered to make decisions about where we ought or ought not aim our material resources and technology in the future or what limits we ought to place on our efforts to get there. Science and industry experts have an important role to play in these discussions. They are well positioned to see what is possible, what is feasible, and what is required to achieve certain economic and technological ends. They thereby play a crucial informational role (Sanchez 2004). But knowledge of what can and cannot be done, and of what is and is not required to do it, is quite different from knowledge of what ought and ought not be done. What ends should be prioritized, how resources should be allocated in pursuit of those ends, and constraints on how those ends ought to be pursued are social and ethical questions to be addressed in the public and political spheres (where, in a liberal democratic

political system, outcomes are open-ended and actors are not excluded on the basis of their worldviews), not economic and technological ones to be worked out in boardrooms or laboratories. They depend on value judgments and conceptions of the good regarding which business acumen and scientific knowledge afford no special privilege or insight. So while scientists and industry leaders may be "elite" in their knowledge of the science and business of nanotechnology, this status does not imply that they are "elite" with respect to the SEI associated with nanotechnology, and it in no way justifies a limited "promote acceptance" position on the appropriate role of social and ethical discourse and public engagement regarding emerging nanotechnologies.

Furthermore, perhaps the public, or some subset of it, will have strong social and ethical reasons for rejecting certain forms or applications of nanotechnology, or good reasons against letting nanotechnology proceed to application and commercialization before adequate regulatory capacities, decision-making mechanisms, or oversight are in place. It cannot be assume from the beginning that all of the public's concerns about nanotechnology will either be based on misconceptions, and therefore are appropriately addressed through education and outreach, or be risk management problems that are best left to the experts. After all, there is an alternative narrative around the public backlash against GM crops, which, given the foregoing discussions, appears not wholly without merit: that it was a (partially) successful grassroots social movement in defense of the public good against powerful transnational corporations attempting to disseminate a potentially controversial and unproven emerging technology without any substantive public input or regulatory oversight.[8]

The GM lesson on public engagement is correct in general: public engagement and SEI discourse regarding emerging nanoscale technologies are crucial to responsible development of nanotechnology. However, the predominant interpretation of the lesson, insofar as it favors a public-acceptance objective version of what education, engagement and SEI research involve and why they should be undertaken, has the potential to confuse about how they should be framed and oriented. A better interpretation of the lesson is that these are crucial to responsible development of nanotechnology because they may substantially contribute to nanotechnology's realization as a social good in robust, pre-emptive, and impactful ways.

4.5 A Lesson on Technological Fixes

A common objection to GM crops is that they are a "techno-fix" (Scott 2005; Raffsenberger 2002). By this is meant that they do not actually resolve any significant environmental or agricultural challenge, in the sense of addressing its

[8] In addition, it is not clear that increased knowledge or awareness of nanotechnology is associated with increases acceptance or support of it (Kahan et al. 2007).

underlying causes, but rather treat a problematic facet of the practice—e.g. the perpetual need for novel and increasingly potent herbicides and pesticides. What is worse, according to this critique, by doing so, they contribute to the perpetuation of chemically intensive industrial agriculture, which has contributed substantially to biodiversity loss, depletions of water resources, pollution of waterways, and displacement of subsistence farmers in developing nations and family farmers in developed nations. This section evaluates this objection as it is raised against GM crops and whether it is applicable as well to emerging nanotechnologies as well.

The techno-fix objection is situated within a general critique of the sources of our obtaining agricultural and environmental challenges—e.g. pollution, habitat loss, malnutrition, and global warming. The causes of these challenges are, of course, complex, and an adequate explanation for them must incorporate a variety of social, political, economic, ecological, technological, and attitudinal factors. But one factor emphasized by many environmental ethicists is the tendency to favor technological or control-oriented practices regarding the environment, such as damming rivers, filling wetlands, cultivating water-intensive crops in arid locations, clearing forests, monocultural and chemical agriculture, species introduction, and species eradication (Carson 1999; McKibben 1999; Katz 2000; Plumwood 2002). On their view, the detrimental legacy of this tendency establishes a presumption against it in addressing the problems that it is in part responsible for creating. Applied to GM crops—yet another technological, control-oriented innovation—the implication is that instead of relying on their development and dissemination to address agricultural challenges, we should work to address the practices and social, economic, and institutional factors that contribute to creating the challenges (and the "need" for GM technologies) in the first place—e.g. consumption patterns, agricultural subsidies, regulatory capacity and infrastructure, market and distribution mechanisms, international trade practices and agreements, and industrial farming operations.

One response to this argument might be that it is the drive to control our environments that has enabled us to expand our range and population, as well as increase the length and comfort of our lives (at least for those in industrialized nations). Admittedly, the response continues, it has also generated some very serious environmental and agricultural problems; but these are relatively recent, and once we focus our technological ingenuity upon them, we will surely be able to handle them. However, this response relies on an inaccurate framing of the historical case. The sort of technological power at issue is the kind realized with the industrial revolution. Given that starting point, our ecological and agricultural challenges, as well as the social challenges these have fostered (which fall disproportionately on the global poor, who do not enjoy the associated benefits), have arisen with remarkable rapidity and on a global scale. In just a few hundred years our technology has enabled us to significantly and detrimentally reduce the availability of fresh water in many places around the world, deplete ocean fisheries, and significantly alter the earth's climate, for example (IPCC 2007; Millenium Ecosystem Assessment 2005; United Nations Environment Programme 2007).

A better response to the techno-fix argument against GM crops is that it is not actually an argument against the technology. It is an argument against relying on focused technological- or control-oriented solutions. Such strategies are, because of their narrowness, highly susceptible to unanticipated and undesirable ecological, agricultural, and social consequences. They tend to focus on managing undesirable effects, rather than eliminating underlying causes, and often depend for their success upon our ability to control the effects of the technology in complex biological systems (organism and ecological), as well as on our capacity to find new technological solutions for whatever undesirable side effects the latest technological fix might have (Scott 2005). However, there is no reason that GM crops cannot be included as part of an integrated approach to addressing agricultural challenges that address as well the underlying social, institutional, cultural, or economic causes. There is nothing about them that precludes their being part of, for example, crop diversity in agriculture or reforms in resource allocations and distribution systems. Nor is there anything about them that requires that they be developed and owned by large transnational seed corporations and inadequately regulated by national governments and international trade organizations.

This is so even if, as is presently the case, the vast majority of GM crops in the field are in fact inadequately regulated, corporately controlled techno-fixes—i.e. corn, cotton, soybeans, and canola that have been engineered for herbicide tolerance, insect resistance, or both. Reliance on herbicides and pesticides in agriculture is a paradigmatic example of the techno-fix strategy. The target through which the solution is pursued—killing the pest—is narrow when considered in light of the social, economic, cultural, ecological, and evolutionary contexts in which agricultural pests arise and operate (Scott 2005). Corn, cotton, and soybeans engineered for insect or herbicide resistance are part of the general chemical pesticide and herbicide strategy, and as such do not address the larger social, economic, ecological, and evolutionary contexts that give rise to the need for a "GM solution" in the first place. The techno-fix criticism is therefore appropriate to them; though it is not appropriately attached to all GM technologies as such.

Applied to emerging nanotechnologies, this GM lesson is not that nanoscale science and technology is problematic because it is a "deep," "reductive," or "control-oriented" technology. Rather, the appropriate lesson is to avoid promoting, developing, and implementing particular nanotechnologies as technological "solutions" to social or environmental problems in ways that in fact enable the perpetuation of the practices that give rise to the problems rather than address their underlying causes. This lesson is a useful one, since at least some nanotechnologies are susceptible to being developed as techno-fixes, as is evidenced by how nanotechnology is often conceptualized. With nanotechnology, it is often intimated, we have accomplished control of matter at the basic, atomic level. We can design with construct with precision. We can collect and process more detailed and comprehensive data, thereby allowing us to better understand problems at both the systemic and molecular levels. More than ever, environmental, health, and, even many social problems, are conceived of as engineering problems. (There are similarities here

with GM crops, which encourage conceptualizing agricultural problems as engineering problems, rather than also ecological, economic, political, or social problems.) The concern is that this engineering-oriented conceptualization of social and environmental problems and confidence in our capacity to design, monitor, predict, and control with detail and precision will encourage deploying nanotechnologies as techno-fixes (particularly within complex biological systems).

The rhetoric surrounding some nanotechnologies exacerbates this concern. Claims regarding how nanotechnology will reduce or eliminate pollution, solve world hunger and global health crises, remediate fresh water shortages, and provide indefinite amounts of cheap, reliable, clean energy are routine (Berube 2006). One reason to be cautious about these claims is that many of these applications are in areas where techno-fixes are pervasive—e.g. energy, agriculture and environment. The fact that nanotechnologies are being developed that increase available supplies of useful or potable water, for example, does not ensure that those technologies will be social or environmental goods. If they are deployed in ways that enable cultivation of water intensive crops in arid locations or encourage population migrations to unsustainable locations, they may perpetuate and create problems, rather than resolve them. Another reasons for caution is that when claims about nanotechnology's potential for addressing social or environmental problems are made the predominant focus is on the distinctive features of nanoscale science and technology or the products they enable. The broader contextual factors are rarely acknowledge, let alone addressed.[9] For example, advocates of nanotechnology often emphasize its potential to contribute significantly to improving the lives of the global poor—the approximately 980 million people that live on less than $1 ppp/day and the 2.5 billion people that live on less than $2 ppp/day (United Nations 2007). But among the potential barriers to its doing so are lack of research infrastructures in developing nations, lack of incentives for researchers in developed nations to work on pro-poor technologies, intellectual property restrictions, high capital costs associated with nanotechnology research, ineffective or inefficient distribution systems, incompatibility with the conditions and lifestyles of those who the technologies are intended to benefit (e.g. lack of access to parts, expertise, or reliable energy), and inadequate regulatory capacities. Technologies that could be beneficial to the global poor often never get deployed because they are not created, they are not in a form well-fitted to people's needs, living conditions, or culture, or they are not manufactured and disseminated due to policy, infrastructure, or cost constraints. The case of the $100 laptop project is instructive here, not because the project is a failure, but because its limited success has been accomplished only after enormous effort to overcome these sorts of barriers, and the resources (material and social) associated with the project are exceptional (One Laptop Per Child 2007). Few nanotechnology projects that claim to be or have the potential to be pro-poor projects have that level of resources

[9] Exceptions include Hillie and Hlophe (2007), Salamanca-Buentello et al. 2005, Project on Emerging Nanotechnologies (2007), and Invernizzi and Foladori (2005).

or commitment.[10] Again, the techno-fix lesson is relevant: nanotechnologies can be effective in addressing social and environmental problems only when they are appropriately situated within inclusive efforts that consider as well the broad (non-technological) contextual factors that create and perpetuate the problems. When proffered as magic bullets, they run the risk of being ineffectual, inefficient, or worsening the situation in the long run. It also is important to be attentive to the fact that in many cases there may be alternatives that are less technologically sophisticated, lower cost, more immediate, more likely to succeed, and less susceptible to unintended effects.

The techno-fix lesson can be instructive for some nanotechnology research programs in some fields, although whether particularly nanotechnologies are developed and deployed as techno-fixes remains to be seen. It is not forgone, and awareness of their susceptibility, as well as the difficulties associated with techno-fixes, on the part of researchers, policy makers, and advocates may contribute to their being developed and disseminated in alternative, more promising ways.

4.6 A Lesson on Case by Case Assessment

The forgoing discussion of GM crops as often, but not necessarily, techno-fixes is an instance of a more general lesson regarding GM crops: different GM technologies have different social and ethical profiles. Compare, for example, GM creeping bentgrass and GM golden rice. GM creeping bentgrass was engineered by Monsanto and The Scotts corporations to provide better fairway grass for golf courses. It is easily dispersed (because its seeds are very light), grows vigorously, is highly out crossing, and is engineered to be resistant to Roundup herbicide (Waltrud et al. 2004; Reichman et al. 2006). Golden rice was engineered, originally by researchers at the Swiss Federal Institute of Technology and the University of Freiberg and later by researchers at Syngenta, to produce beta-carotene, the precursor to Vitamin A, which is not otherwise present (or present in only trace amounts) in traditionally cultivated rice (Ye et al. 2000; Paine et al. 2005). The engineered rice is intended to be crossbred with local rice varieties favored by farmers (and freely distributed to impoverished farmers) in areas where there is chronic vitamin A deficiency (efforts are underway in India and the Philippines), to serve as a supplement to other, crop diverse sources of vitamin A (Stein et al. 2006, 2007; Ye et al. 2000). This is significant because between 140 and 250 million children, many of whom live in developing countries where rice is a staple food, suffer from vitamin A deficiency, which in severe cases causes symptoms ranging from vision impairment to increased susceptibility to diarrhea and measles (World Health Organization 2006). The United Nations Children's Fund (UNICEF) reports that between 250,000 and 500,000

[10] Ongoing efforts and possible pathways to overcome some of these barriers for nanotechnology are described in Rodrigues et al. (2007).

severely vitamin A-deficient children go blind each year, and estimates that vitamin A deficiency is a significant contributing cause to a million childhood deaths each year. UNICEF also reports that many of the childbirth-related complications that cause the deaths of nearly 600,000 women each year could be significantly reduced by remedying vitamin A deficiency among pregnant women (UNICEF 1998, 2006; Micronutrient Initiative and UNICEF 2004).

The social, ethical, and environmental profiles of GM creeping bentgrass and golden rice are divergent along multiple dimensions. Creeping bentgrass is owned and controlled by transnational corporations that have a fiduciary obligation to shareholders to maximize profit. It is intended to serve a peripheral interest—better fairway grass—and does not address any significant social or environmental problems, and instead (for the reasons enumerated above) poses significant environmental risks. In contrast, golden rice is being promoted and disseminated (freely to those who most need it) through the Golden Rice Humanitarian Project, which has accomplished the requisite intellectual property and sub-licensing agreements, and is not corporately controlled (Golden Rice Humanitarian Project 2007). It has the potential to contribute significantly to addressing a serious humanitarian problem, at a cost significantly lower than a vitamin A distribution program (Stein et al. 2006, 2007) (which would not actually address the cause of the problem—inadequate reliable dietary sources of vitamin A—but only treat the problematic effect). It likely will not promote monocultural chemical agriculture, or diminish agricultural biodiversity, since it is being engineered into locally favored seed varieties and is intended as a supplement to other vitamin A sources, not a replacement for them. Moreover, because the transplanted genes increase beta-carotene production rather than, for example, hardiness, aggressiveness, or fertility, it is not likely that golden rice will be detrimental to biodiversity even were the transplanted genes to spread through gene flow, interbreeding with wild plants, or unintended dispersal of seed—or, at least, it is no more likely to be disruptive than conventional (non-GM) varieties that are widely cultivated and accepted. There is, of course, the possibility that such characteristics will be accidental to the genetic modifications, which can (and should) be determined from controlled field tests.[11] GM golden rice and how it is being developed and disseminated therefore appears to be far less ethically objectionable that GM creeping bentgrass.

The general upshot of this comparison is that different GM crops have different ethical profiles—one might unjust while another is just or ecologically risky while another is safe, for example. As a result, neither a position of global opposition nor

[11] Other GM crops being developed or in the field that might be acceptable upon evaluation, depending upon how they are situated within broader approaches to resolving the relevant agricultural challenges, include rice with the capacity to fix nitrogen, cassava (a staple food in much of Africa) with resistance to the cassava mosaic virus, corn with resistance to the stem borer (which takes about 15 % of Kenya's corn crop each year), crops with high salinity tolerance, and potatoes, canola, bananas, sorghum, and cassava with nutritional (e.g., protein, vitamin, or mineral) enhancement.

a position of global endorsement is likely to be tenable. Candidate GM technologies need to be evaluated on the basis of their own features, informed by the social and environmental contexts into which they are to be introduced (and which they will reciprocally impact).

The case by case assessment lesson is directly applicable to nanotechnology. As discussed earlier, the fields, processes, applications, and actors involved with nanoscale science and technology are far more diverse than GM food technologies. Compare, for example, a synthetic biology research project situated within a biological defense program sited in an urban center with an industry-funded research project to develop a carbon nanotube-enabled memory chip sited within a far suburb. These are both nanotechnology, but their ethical profiles differ substantially along (at least) the following dimensions: objectives, risks, benefits (and beneficiaries), control, oversight, regulation, and, not least of all, controversial moral practice. The former raises sanctity of life issues, biological weapons issues, public health and safety issues, public funding issues, and transparency/oversight issues that the latter does not; whereas the latter might raise information security, privacy, and (other) transparency/oversight issues that the former does not.

The diversity in social, ethical, and environmental profiles of emerging nanotechnologies in areas such as energy nanotechnology, computing nanotechnology, medical nanotechnology, agricultural nanotechnology, monitoring/sensing nanotechnology, environmental nanotechnology, military nanotechnology, materials nanotechnology and communication nanotechnology—both in general and with respect to particular areas, actors, projects, social contexts, and applications within these fields (Sandler 2007a, 2009)—is such that it is not particularly useful to reflect on the ethics of nanotechnology as such. Nanoscale sciences and technologies have little in common, *qua* nanoscale science and technology, that is relevant to social and ethical evaluation, in comparison with all their other socially and ethically significant features discussed in this chapter—e.g. distributions of burdens and benefits, risks, intended objectives, control, techno-fix, regulatory/oversight capacities, political implications, and relationship to individual rights and liberties. It is more productive to disambiguate particular nanotechnology practices and applications (as well as their particular social and political contexts), and evaluate them on the basis of their specific features, only one aspect of which is their taking advantage of the novel properties or functions of materials or processes at the nanoscale. As with GM foods, when this is done, neither a position of global endorsement nor a position of global opposition is justified. Moreover, effectively pursuing the goal of developing emerging nanotechnologies so that they, so far as possible, contribute to human flourishing in sustainable and just ways (while respecting appropriate moral boundaries), requires being attentive to the specific opportunities afforded and challenges posed by particular nanotechnologies in particular contexts. In a field as broad as nanotechnology, there is no single strategy for effectively promoting the social good.

4.7 Conclusion

Preemptively identifying and responding effectively to social, ethical, and environmental issues associated with emerging nanotechnologies would constitute a significant dissimilarity from the GM experience (Sandler and Bosso 2007). Nevertheless, critically reflecting on that experience can contribute substantially to anticipatory responsible development efforts. The abundance of similarities between GM food technologies and nanotechnologies suggests that there are many lessons to be learned for emerging nanotechnologies from the GM food experience; the abundance of dissimilarities between the two technologies requires that drawing these lessons be done carefully, critically, and with attentiveness to the complexities involved.

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Part II
Opportunities and Challenges

Chapter 5
Nanomedicine and Body Modification: Critical Perspectives

Melanie Latham

5.1 Introduction

This chapter examines nanomedicine in relation to body modification, in particular the increasingly popular form of body modification that is cosmetic surgery. It asks what possibilities nanomedicine might offer patients seeking cosmetic enhancement, and whether there are risks inherent in such procedures which patients might need to be warned about and which require strict regulation. I would argue that this is *nanomedicine* as opposed to the cosmetic use of *nanotechnology* as it necessitates the same medical procedures and invasive treatments, with their inherent risks, as non-cosmetic use of nanomedicine. The chapter goes on to examine these possibilities and risks from the perspective of theorists who have sought to safeguard health care rights, particularly those of women patients. Currently in the UK 91 % of cosmetic procedures are carried out on women, and the most requested invasive cosmetic surgery is for breast implants, with the number increasing rapidly year on year: approximately 5,646 breast enlargements were carried out in 2005 (BAAPS 2006); and 8,565 in 2009 (BAAPS 2010).

Body modification is available to people in the form of surgical and non-surgical procedures, and on clinical and non-clinical grounds. *Plastic* surgery is carried out largely on clinical grounds. It entails surgical procedures which aim to reconstitute a body; to make a body whole; or to resolve physical or psychological needs, or cultural perceptions of abnormalities as a result of illness, accident or genetics. This might include breast implants following mastectomy; the correction of serious facial deformities; or transgender surgery. *Cosmetic* surgery, by contrast, is a branch of surgery which makes surgical procedures available to patients as a result of their requests for aesthetic improvements of the physical appearance of the body, and not

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on clinical grounds. The gamut of cosmetic surgical procedures now on offer range from rhinoplasty, to liposuction, and breast implants. Non-surgical cosmetic body modification is also now more effective and thus increasingly popular in the form of, for instance, Botox injections to paralyse facial muscles and diminish wrinkles and dermal fillers to smooth skin. Body modification can also refer to treatments to the skin such as tattooing or piercing (Pitts 2003).

This chapter concentrates on cosmetic surgery as a form of body modification. Cosmetic procedures have become increasingly popular and widespread. The British Association of Aesthetic Plastic Surgeons reported that its members carried out 10,738 procedures in 2003 (BAAPS 2004) and 32,453 in 2007 (BAAPS 2008). It has also been estimated that many thousands of UK citizens also travel abroad annually for cosmetic surgery at reduced prices. Nanomedicine could offer yet more treatment possibilities to the cosmetic patient. Already anti-ageing skincare treatments are available from the cosmetics giant L'Oreal which use nanomedicine to deliver products more deeply into the skin (Rogers 2005). It would not be unimaginable for nanomedicine to be used to change the skin of the body or face to be more uniform in colour, blemish-free, smooth, plump, and firm. Nanomedicine might also be used perhaps to deliver fat-dissolving products to thighs, buttocks, legs or upper arms. Patients who are aiming for a youthful appearance that is wrinkle free, fat free or otherwise akin to some ideal female form already request procedures that will enable them to project a silhouette that is slim, curvaceous and smooth. Nanocosmetic treatment could include treatment to induce changes to the external body's hair or skin or silhouette; topical or via ingestion; self-administered or requested from a practitioner. Chronologically, such patients have utilised invasive surgery, then cosmetic medicine, and now perhaps nanomedical procedures for the same ends (Hertz 2007).

5.2 Feminism and Cosmetic Surgery

Cosmetic surgery, along with other forms of body modification and cosmetic enhancement, have all posed problems for theorists who concern themselves with the condition and oppression of women. The critique of cosmetic surgery that has come from feminist quarters forms the backdrop to this chapter. However, it is important to note that there have been differences of opinion between critics. Some have emphasised the effects of systemic *cultural* pressures on women to meet stereotypical gendered ideals of beauty (Dodds 2000). By contrast, more liberal feminists have argued that the pressures of patriarchal cultural are better resisted by promoting individual choice. Liberals have thus emphasized the *agency* and rationality of cosmetic surgery patients as those who can make autonomous choices, and display control and self-determination (Davis 1995). As an extension of this, drawing on the work of feminist ethicists and others, a third perspective emphasises the importance of autonomous self-direction and offers more pragmatic solutions (Latham 2008).

5.3 The Culture of Cosmetic Surgery

From within these three or more feminist schools of thought arguably the largest proportion has been those who are critical of cosmetic surgery. This is due to the apparent effects of systemic cultural pressures on women. Such writers have been keen to discourage patients from undergoing cosmetic surgery because of what they see as an insidious culture which emphasises a particular female aesthetic. They have pointed out that this pressure to conform to a certain physical ideal even undermines the validity of any consent patients might give to cosmetic surgery (Sherwin 1993). Many commentators writing in this vein have applied Foucauldian theories about the clinic, medical control, self-control and the internalization of state power to the phenomenon off cosmetic surgery. The male gaze of the father, husband and doctor who pass comment on a woman's image now extends to that of the cosmetic surgeon, "In contemporary patriarchal culture, a panoptical male connoisseur resides within the consciousness of most women: they stand perpetually before his gaze and under his judgment. Woman lives her body as seen by another, by an anonymous patriarchal Other" (Lee Bartky 2003, p. 34).

This school of feminist thought believes that cosmetic surgery is rarely acceptable as a medical treatment within the prevailing culture and are therefore uneasy lest regulation might lead to an increase in the numbers of women patients undergoing it. Cosmetic surgery could be seen as another cultural mechanism for constructing representations of the female form when it is seen (consciously or sub-consciously) by women as, and indeed sold to women as, a means of achieving an image that is seen as normal for the female form. This might encourage women to undergo risky and dangerous invasive cosmetic surgery (Bordo 1989). Such feminist writers might therefore argue against government regulation as not necessarily going to resolve these cultural problems and, by its apparent endorsement of cosmetic surgery, make it appear safe and harmless. This might then paradoxically increase the likelihood of women being harmed as increasing numbers of women request it as they feel reassured and confident that government regulation and standards are in place to protect them.

Kathryn Pauly Morgan has also underlined the social norms which women conform to as opposed to freely choose. She has pointed out that this is in fact an essential ingredient for the success of those women. "For virtually all women, as women, success is defined in terms of interlocking patterns of compulsion: compulsory attractiveness, compulsory motherhood, and compulsory heterosexuality, patterns that determine *the legitimate aims of attraction* and motherhood" [emphasis added] (Pauly Morgan 2002, p. 32). Society offers its approval to this attempt by women and thus legitimates it.

Furthermore, this compulsion can be driven and enabled by biotechnology and surgery. Morgan has linked this use of technology to the rise in cosmetic surgery, particularly in the West, "Now technology is making obligatory the appearance of youth and the reality of 'beauty' for every woman who can afford it. Natural destiny is being supplanted by technologically grounded coercion, and the coercion is camouflaged by the language of choice, fulfillment and liberation" (ibid, p. 40). She has been critical of cosmetic surgeons who have categorised normal female physique as abnormal with technology offered as a remedy, and has pointed to cosmetic surgery

literature where normal female body shape is described as deformed, diseased or ill, with surgery as the antidote. Morgan has therefore argued that the risks and dangers of anesthesia and post-operative complications are only worth taking when surgery is necessitated by illness or disease and not merely for cosmetic purposes which result from cultural forces, "(i)n the face of a growing market and demand for surgical interventions on women's bodies that can and do result in infection, bleeding, embolisms, pulmonary edema, facial nerve injury, unfavourable scar formation, skin loss, blindness, crippling, and death, our silence becomes a culpable one" (ibid, p. 28).

A new form of body modification currently being debated is that of anti-ageing techniques. As with cosmetic surgery here the patient is pursuing eternal youth by way of retarding or reversing old age and its associated diseases such as cancer or arthritis. Anti-ageing technology espoused by controversial biogerontologist Aubrey de Grey and others, has been suggested as, "potentially feasible", with "the prospect of controlling human aging within the foreseeable future" (De Grey et al. 2002, p. 667). The authors argue that more research is warranted in this field as engineered negligible senescence (ENS) (anti-ageing technology) could reduce chronic disability related to old age as well as enable people to live longer. For the authors these outweigh any possible risks for patients exposed to experimental clinical techniques. In a similar vein, one might ask whether the risks and dangers for patients associated with these other forms of new cosmetic technologies might be acceptable given the risks that people who use them might be subjecting themselves to. Such risks, which are arguably shared with other new technologies used only for cosmetic reasons such as cosmetic surgery and nanomedicine, might include the experimental nature of a new technology which may expose a patient to iatrogenic risks associated with clinical treatment in the short and long term as in the Morgan quote above, coupled with the waste of money paid for a technique which does not improve health.

5.4 Cosmetic Surgery and Agency

This emphasis on cultural forces and physical ideals is at odds with the opinions of those who request aesthetic surgery. Such patients invariably perceive these new medical procedures as broadening patient choice and only as hazardous as other surgical procedures. There are a growing number of more liberal feminist writers who have offered a perspective that attempts to understand this choice, empathises with the women involved, and even recognises that these decisions can be made autonomously by cosmetic surgery patients. Such writers have therefore highlighted the *agency* and rationality of cosmetic surgery patients, their ability to be self-governing and self-directed in their treatment decisions.

The work of Kathy Davis has been seminal in this area. Her empirical studies led her to argue that women become accustomed to the idea of the objectification of their bodies and hence objectify their bodies themselves (Davis 1995). At the same time, they are dissatisfied with the portrayal of themselves as nothing but a body and are left feeling uneasy about themselves and their bodies. Women's use of cosmetic surgery

demonstrates their objectification of their own bodies, and their struggle to be inside and in control of their own body, "to be embodied subjects rather than mere bodies" (ibid). Through cosmetic surgery women are attempting to be their own bodies and to control their own identities, "I can treat women's ongoing struggles to justify a contradictory practice like cosmetic surgery as *a resource for developing a feminist response which speaks to women's experiences* rather than simply reiterating the correct line on women's involvement in the beauty system" [emphasis added] (ibid, p. 60).

Davis and other liberal feminists have emphasized the agency of cosmetic surgery patients. She and others have been critical of cultural feminists as they only highlight the oppressiveness of the beauty industry and portray women as, 'cultural dopes', "(i)n doing so they fail to acknowledge the extent to which women know the risks and limitations of body modification" (ibid, p. 40). Debra Gimlin has carried out empirical work on women's use of the beauty and fitness industries. She has argued that women in these settings seek to enhance their own self-identity and has noted how women in gyms particularly gain a sense of themselves as strong and powerful (Gimlin 2002). In a similar vein, Susan Bordo has observed that narcissism, for example, in Western society determines a particular but certain route to economic and personal success. People are not necessarily 'dopes' if they recognize this (Bordo 2003, p. 30). Women are prepared to endure pain and risk in order to access the power that eludes them elsewhere. What is more they can select how to transform themselves and this confers on them an amount of self-determination and hence empowerment. Such a woman feels she has chosen her own identity, "(a)nd under those circumstances, it may not be possible for her to register her resistance in the form of refusal. The best one can hope for is a heightened sense of the nature of the multiple double-binds and compromises that permeate the lives of virtually all women and are accentuated by the cosmetic surgery culture" (Pauly Morgan 2002, p. 43).

These two perspectives of culture and agency have been criticised as being mutually incompatible and thus offering limited pragmatic solutions for the shortcomings identified in women's health care and its regulation (Dodds 2000). But elsewhere I have argued that the liberal acknowledgment of autonomy and agency could be synthesized with cultural critics' concerns about needing to tackle the conditions that make the realization of autonomy difficult. This leads to a particular critique of regulation that could respond to both sets of concerns (Latham 2008).

My suggested third way builds on the observations of feminist ethicists. Developing the influential ethic of care approach, Susan Sherwin for example, has stated, "in my view, feminist ethics must recognize the moral perspective of women; insofar as that includes the perspective described as an ethics of care, we should expand our moral agenda accordingly … [and] determine when caring should be offered and when it should be withheld" (Sherwin 1993, p. 16). This third perspective encompasses theorists then who emphasise women's autonomy, agency and context, but who also talk of practical steps to empower women and remedy imbalances in power relations, education and prestige, social norms, practices and (interconnected) relationships, through active encouragement of patient empowerment through social and economic support. McLeod and Sherwin refer to this as a relational model of autonomy, "If health-care providers are to respond effectively to these problems …

they must understand the impact of oppression on relational autonomy and make what efforts they can to increase the autonomy of their patients and clients" (McLeod and Sherwin 2000, p. 276). Health professionals must accordingly be aware of their own power. This would make self-reflection and a fuller choice possible. In relation to cosmetic surgery in particular, they argue that professionals should not promote youth and beauty. "If they wish to promote the autonomy of patients who seek these procedures, they should not simply respond to informed requests for surgical "corrections" but, at least, also encourage their patients to consider the forces that lead to these choices, as well as alternative responses" (ibid, p. 270). This would also apply to the anti-ageing research referred to earlier.

This third perspective, which sits somewhere between these two apparently incompatible critiques, builds then on the common element found in the writings of liberal feminists, feminist ethicists, and those feminists who have emphasised autonomous selves and relational autonomy. What they each appear to emphasise in relation to cosmetic surgery regulation is the importance of constructive dialogue between a patient and her surgeon. This dialogue would enable a more fully informed consent to be given where the true risks of treatment to that particular patient are fully explained by the surgeon. In addition this would encompass counselling, but counselling that is a two-way process where the professional attempts to assist the patient to choose the treatment that is most appropriate to her circumstances, or, of course, to choose not to have treatment at all no matter if this leads to a loss of income to the private surgeon. The type of autonomy I would promote as a principle of regulation then, is one that entails fully informed consent; constructive dialogue and counselling that build self-trust and recognise structural oppression; professional self-awareness and ideally an institutional recognition of social and cultural oppressive structures (ibid, p. 276). This might help shift the patriarchal cultural terrain that various feminists are concerned about.

5.5 Nanomedicine, Autonomy and Regulation

Feminists and others then have rightly pointed out that the risks of body modification are both clinical and cultural. Some have emphasised culture, others agency, and I have suggested a synthesis of these that incorporates relational autonomy and which could improve cosmetic surgery practice and hence reduce those risks. It could produce a more acceptable informed consent, but is still reliant on extensive information on cosmetic surgery being available from surgeons and others for patients. This might involve greater responsibility for governments and bodies which regulate the private health care sector.

In the following section an assessment of nanomedicine is made which incorporates these arguments. It asks a series of questions: What opinion might feminist ethicists and cultural and agency feminists have about women undergoing body modification that incorporated nanomedicine? Could nanomedicine only ever be chosen by patients as a result of cultural or medical pressure? Or is the autonomous patient able to select nanomedical cosmetic treatments through their own agency?

Is it possible for them to be well-informed enough to give a fully informed consent to treatment? Does nanomedicine pose too many risks to patients and society, no matter the information available to patients?

5.6 Feminism and Nanomedicine

Nanomedicine that made *visible* changes to the body would be open to the same criticism from cultural feminists as cosmetic surgery. Such visible changes which might result from the cosmetic use of nanomedicine might be changes to the appearance of skin – its colour, uniformity or smoothness, for example – or changes to the appearance of body contours and size through an effect on fat deposits. In effect these would amount to the same visible results which already result from cosmetic surgery or cosmetic medicine and which inspire the cultural feminist critiques highlighted above.

But is feminist criticism of cosmetic surgery only relevant to surgery that makes visible and tangible changes to appearance? If it was due to *cultural* pressure to change the natural then perhaps it could also be open to criticism. Following the arguments of feminist ethicists that individual women have a responsibility to consider the effect of their choices on the dissatisfaction of women more generally, if cosmetic nanomedicine made other women feel dissatisfied with the *natural* female body then again perhaps it could be open to criticism (Sherwin 1993). Other feminist ethicists' arguments about care, context, and relational autonomy would imply that those health professionals practising cosmetic nanomedicine should themselves be more aware of the effect of their decisions on women in a cultural context where women are pressurised to conform to a particular ideal. Practitioners should alter their practice to reduce hierarchy and lay emphasis on non-hierarchical treatment and counselling.

5.7 Nanomedicine, Risk and Regulation

Women who have agency are in a position to decide for themselves what happens to their bodies. In order to be fully autonomous, patients would thus need to be well-informed, but how far is this possible? Through research, safety tests, labelling, regulation, and non-hierarchical dialogue between patient and doctor as outlined above? Indeed I would argue that nanomedicine might be just too risky to health even if patients were well-informed. The particular risks of nanomedicine have been highlighted by various authors. "In the three areas of nanomedicine (nanotechnology-based diagnostics, including imaging, targeted delivery and release, and regenerative medicine) possible side effects have to be considered … the unknown properties of certain nanostructures call for careful attention regarding their reliability and potential side effects" (European Technology Ethics 2006, p. 26). Concerns have been expressed about whether nanoparticles cross biological barriers such as blood–brain barriers, or air-blood barriers in lung or skin and safety issues associated with "medical applications based on free nanostructures: systemic distribution; accumulation

phenomena; disturbance of cellular metabolism; protein conformational change; and tumour formation" (ibid).

Renn and Roco, report on a governance gap between nanotechnology innovation and the policy and regulatory environment (Renn and Roco 2006). The authors identify a governance gap for 'passive' nanostructures currently in production and which have high exposure rates. But they also especially note this in relation to 'active' nanoscale structures and nanosystems that are expected on the market in the near future, as these potentially affect human health and the environment as well as social lifestyle, human identity and cultural values.

Where a medical treatment such as cosmetic nanomedicine is available and does pose risks, patients and the public at large naturally need to be able to assess published information about possible side effects and be informed by their medical practitioners who might be using such treatments or cosmetics. They in turn need to be informed by manufacturers. The availability of such information depends on manufacturers themselves choosing to publish it, having carried out appropriate research. Or it depends on governments regulating such medicine in order that sufficient independent research is carried out or forcing manufacturers to publish information by the use of guidelines or regulation.

Rafael Capurro emphasises the responsibility of patients of nanomedicine to make wise and informed choices and feels that this new technology will pose challenges to autonomy, free will and privacy as it has the potential ability to 'redesign our brains' (Capurro 2006, p. 19). The European Group on Ethics in Science and New Technologies to the European Commission, of which Capurro is a member, have also labelled nanomedicine and nanotechnology as a rapidly developing research area about which it is not possible to give information on future research possibilities, or make a realistic risk assessment, due to the many unknowns and complexities (EGE 2007, p. 40). They thus identify knowledge gaps yet emphasise the increased speed of diagnosis and implications for personal responsibility of patients.

Risks to the public and to patients of cosmetic medicine are already apparent. The EGE have also emphasised the growing number of cosmetic products using nanotechnology already on the market and estimate that these are growing at an estimated 10 % annually (ibid, pp. 21–35). They stress that no toxic effects of cosmetic nanomedicine are reported so far, but report that bodies such as the Food and Drug Administration in the US and the Royal Society in the UK have stressed the lack of knowledge in this area (The Royal Society and the Royal Academy of Engineering 2005). The EGE also argue that the, "toxic effects of some nanoparticles have been already demonstrated in cells, tissues and small animal experiments" (EGE 2007, p. 21). The EGE aim to discover what effect the minute particles may have if they enter cells in the human body or leach into the bloodstream, and whether a trialling and licensing system should be introduced for cosmetics similar to that used for pharmaceuticals. Lois Rogers identifies products, which include anti-wrinkle creams such as L'Oreal Revitalift, that are already on the market and which are said to be absorbed deeper into the skin than more traditional treatments because of the far smaller size of their particles and reports that L'Oréal, the world's largest cosmetics company, is devoting a significant part of its £350 m research budget to nanotechnology (Rogers 2005). The UK consumer organization, Which?, published a report in

November 2008 which highlighted the dangers for consumers of products manufactured by eight different companies and already widely available as sun screens, skin moisturizers, cosmetics, toothpaste and hair products which contained nano ingredients. These included Green People's 'organic' products as well as those by Boots, Body Shop, Avon and Unilever. Only one of these referred openly to customers using its website about its use of nano ingredients. These came in the form of carbon fullerenes, colloidal silver, titanium dioxide and zinc oxide in nano form (Which? 2008).

The EGE have also argued that although EU legislation, international instruments and general principles do already regulate medicinal products and medical devices, and that there are published bioethical principles on information, consent, safety and justice which could be applied in these new areas, the current legal systems in Europe were not designed for nanomedicine as such (EGE 2007). Cosmetics are currently covered by Directive 1976/768/EEC, whereby the basic obligation is on a manufacturer is to carry out a risk assessment, not an independent body. Regulatory concerns identified by the EGE in 2007 include whether current regulation secures adequate protective measures, including the evaluation of health-related risks. They also argue that it is not clear to the public which directives apply to manufacturers. Future regulatory challenges are identified as the need for adequate risk evaluation in all areas of nanomedicine; the implementation of risk evaluation measures in a scientifically sound and transparent manner; legal clarity where regulations overlap; and the incorporation of ethical dimensions in legal provisions. In 2009 the European Parliament voted in favour of a new Regulation to harmonise cosmetic product regulation in the EU. From July 11 2013, under the new EU cosmetic regulation (EC) No 1223/2009 took effect, notifications of cosmetics are to be submitted to a database developed jointly by the European Committee and the European Cosmetics Association (COLIPA) instead of each individual member state: if, for example, content includes nanomaterials. The word 'nano' should also follow the name of the nano-materials in the list of ingredients on the label. For cosmetic products containing nano-materials put on the market before January 11, 2013, companies had to notify the Committee by electronic means for approval to use before July 11, 2013. Though this improves the regulation somewhat, it falls arguably short of the recommendations by the EGE in terms of the risk evaluation and ethical dimensions the EGE identified.

I would argue that there is a distinct lack of regulation of nanomedicine at this point, which in itself poses a risk for the patient and public at large and which might make it too risky to use even if the patient were well-informed. These are of course relatively early days for nanomedicine, but government bodies in Europe and the US have already commissioned reports to investigate nanomedicine and nanotechnology. These have examined ethics and clinical risks and the need for guidelines or regulation. There would appear to be more of an emphasis in the US about the positive aspects of nanomedicine and the need for minimal amounts industry-led regulation (Powell et al. 2008). This differs slightly from the overall European reaction to nanomedicine which has been more likely to underline the possible ethical issues around patient safety and the need for regulation. Within both areas of governance, however, the potential benefits of nanomedicine to industry, health services and economies have been highlighted.

Of course one of the inherent difficulties with any new technology, is that a lack of knowledge about it can preclude appropriate regulation, but regulators who give the benefit of the doubt to the manufacturer are arguably putting the health of the consumer or patient at risk. Barbara Cullton, has highlighted the clinical risks of nanomedicine: "nanoparticles behave chemically and physiologically in ways that are different from the same particle at a larger scale" (Cullton 2008). She reported on an interview she undertook with a member of the Food and Drug Administration who worryingly commented that they had assessed their ability to evaluate and regulate such products before they reached the American marketplace in 2006 thus, "(Our conclusions were that) this technology is really no different than any other new technology. We do not see the need for new regulation. We also recognise that because of these nanoparticles' unique biological and physical properties, there is a lot we do not and cannot yet know" (ibid w137). The US National Nanotechnology Initiative Report in February (2008) did apparently lay out environmental, health and safety concerns as priority areas for research, and recognised the importance of human health and environmental health. However, there was also a lack of independence in the research that was being funded in the US by the National Cancer Institute. Overall this representative of the FDA, was strikingly positive in his assessment of nanomedicine, referring to the "amazing" potential uses for nano-engineered materials, and arguing incredibly that nanotechnology presented no new ethical issues. It was seen as a very exciting area and the FDA did not see the need to label these products in a special way. European commentators appear more likely to highlight the importance of common regulations and international standards (Hermeren 2007). However those representative of industry such as the EU's Directorate General for Enterprise and Industry have been more likely to want flexible guidelines not strictly legally binding rules so as not to "impair the development of novel medicinal products" (D'Silva and Van Calster 2008). The policy approaches in Europe and America are also equally mindful of the potential for nanomedicine to reduce the cost of health care in an ageing population (European Technology Platform 2006, p. 24). Europeans cannot afford to be complacent: in November 2007, Friends of the Earth called for a ban on the sale of all commercial products containing nano-silver until there was more legislation to regulate nanotechnology. They also wanted mandatory labeling and referred to a regulatory vacuum in Europe (Rye and Illuminato 2008). This appears to continue a pattern of attitudes and approaches, where the US is largely accepting and the EU is much more circumspect, as seen in relation for example to GM food where the EU imposed a moratorium on its use in stark contrast to the US which approved of its use. Overall, however, ethicists in the European Union appear to have considered nanomedicine more extensively, and appear to be linking this with regulation to a larger extent than their counterparts in the US. Phillippe Galiay (2008) for example, reports on the European Commission's efforts in this area with the 2005 nanotechnologies action plan (IP/07/1321) and the code of conduct in July 2007 (IP/07/1140). Their objective is reported by Galiay here as, "promoting integrated safe and responsible nanosciences and nanotechnologies" and incorporating seven main principles in relation to what research activities on nanomedicine and nanotechnology should be: comprehensible to the public, respectful of fundamental rights; conducted in the interest of the

well-being of individuals and society; sustainable; in accordance with precautionary principle balancing progress and precaution; inclusive and accessible; and attaining the highest scientific standards of integrity, innovation and accountability.

5.8 Conclusion

Body modification can take many forms, but an increasingly widespread use of surgery and medical treatment is being requested worldwide for cosmetic purposes. Nanomedicine is already being used for cosmetic purposes, and could form the basis of cosmetic treatments of the future. Many of the patients who request cosmetic procedures are women, and criticism of cosmetic surgery has come from those, mainly feminist, theorists who seek to promote autonomy and patient rights and informed consent, inter alia. Those particularly critical of cosmetic surgery have highlighted the importance of cultural pressures on women to conform to a particular image. If this critical perspective is applied to body modification using nanomedicine, many of the arguments about risk, autonomy, cultural pressure and agency still apply. This is due to the fact that visible changes to the body or the skin promote a certain image of womanhood, which pressurises other people to feel dissatisfied with their natural body and to change their own bodies. That is not to say that it is not possible for informed choices to be made about cosmetic nanomedicine, as with other surgeries. However, regulation is needed which echoes the findings of ethical committees such as the EGE, scientists such as the UK's Royal Society, and environmentalists such as Friends of the Earth: patient safety must come before benefits to industry or government healthcare budgets. Were such extensive regulation to come into force worldwide, then a dialogue about cosmetic nanomedicine might be more confidently entered into between patient and clinician which was based on trust, safety and autonomy. Based on current levels of knowledge about nanomaterials and their effect on the body, then a patient who entered into such a dialogue and was sufficiently well informed about nanocosmetics would be unlikely to jeopardise her health in this way merely for cosmetic gain.

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Chapter 6
Nanotechnology and Biodiversity

Darryl Macer

6.1 Biodiversity

This chapter addresses the questions raised by the use of nanotechnology that may influence biodiversity. There are various definitions of biodiversity, and this chapter will use that of the United Nations Convention on Biological Diversity (CBD)[1] which is, "*the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species and of ecosystems*." There can be variations within genes, species and ecosystems.

The Convention on Biological Diversity (CBD) has not conducted a systematic study of the potential impacts of nanotechnology impacts. However there have been several discussions in international fora of the particular issues (GBSC 2009). The OECD Working Party on Nanotechnology (WPN) was established in March 2007 to advise upon emerging policy issues of science, technology and innovation related to the responsible development of nanotechnology.

The U.K. Royal Commission on Environmental Pollution (RCEP 2008) undertook a review of properties of human-made nanomaterials, and possible pathways into the environment and resulting threats. The review looked at government coordination on nanotechnology, environmental protection, evidence, regulations and benefits. A major recommendation of the report was that a more coordinated and concerted effort is required by National Research Councils on research to assess the properties of nanomaterials and their possible environmental impacts. Another recommendation was that environmental monitoring should be the responsibility of the environment agencies in each country.

[1] See UNCBD Article 2.

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Life in some form has existed for at least three and a half billion years on the planet Earth. All that is called living that we find in the natural environment has at some point evolved from a common predecessor, resulting in the diversity of life forms (species) we find today, estimated to be between 3 and 100 million species, with 1.5 million already identified.[2] As the evidence has shown that a wider range of genes, species within an ecosystem improves the ecosystem's functioning, and alternately declining biodiversity affects ecosystem functioning. Biodiversity provides insulation from declines and improves reliability in ecosystem functioning. The concept of ecosystem can be described as the system of living organisms or biotic factors and physical environment or abiotic factors in an area functioning as a unit. The size of an ecosystem is variable, depending on the interactions in question, from microbial ecosystems to the earth as a whole. The complexity of ecosystems can be enormous as it is constituted by the sum of its organisms, environment and its processes between and within all its parts (Bosworth et al. 2011).

Ethical analysis depends on whether we take an anthropocentric (human-centred), biocentric or ecocentric view of the problems (Macer 1998). A biocentric approach values particular biological species, be they *Homo sapiens*, dogs, trees or fungi. That can be directly applied to questions of biodiversity, such as the survival of a particular species, or its welfare. Endangered species protection laws illustrate how policy is developed to protect non-human species, and these can also be used to protect organisms against risks caused by nanotechnology, the same as any other factor. An ecocentric view focuses on a complete ecosystem analysis over time, of an ecosystem such as a forest, coral reef, or farm etc. Depending on our viewpoint the process and conclusions of ethical analysis will be different. We can see certain policies that are ecocentric, such as acts to protect habitats as a whole, not just endangered species.

The issue of measuring biodiversity is of tremendous importance when considering pragmatic factors such as impacts of nanotechnology on biodiversity. There have been numerous methods of measuring biodiversity used in the field of ecology since its inception but the inherent difficulties of quantifying biodiversity have yet to be completely removed. The difficulties in measuring biodiversity fall into various categories from definitive to practical. Conceptually, the difficulty lay in the deep interconnected nature of biodiversity and its ecosystem, as neither exists independently of the other and thus defining the roles and functions biodiversity plays through quantitative methods is abstract. Measuring diversity requires a definition of diversity. Even a simple definition of diversity, the one used in conservation, focuses on the total number of species or total biomass and requires less than simple quantification tools (Bosworth et al. 2011). Measuring species richness is simple in theory, but is not without discrepancies. Several concepts of 'species' are used when contemplating species richness, such as the biological species concept, phylogenetic species concept, and the cohesion concept. Each concept

[2] Wilson EO (2010) Lecture at launch of the International Year of Biodiversity, January 2010, Paris.

with its own boundaries as to what constitutes a species can either inflate or deflate the total number.

Although this chapter will primarily address issues that are raised in systems of different organisms, broadly considered environmental issues, however, even a single person, usually called *Homo sapiens*, is actually an ecosystem containing many different species within DNA and as organisms. Dietary habits and medicines are known to affect the biodiversity of the intestinal tract, as well as other parts of the human body. The same is true of many animals, who exist as collections of many species living together. Thus the concept of biodiversity is rather broad.

6.2 Nanotechnology, Genetics and Biodiversity

The OECD website says: "Nanotechnology is the set of technologies that enables the manipulation, study or exploitation of very small (typically less than 100 nm) structures and systems. Nanotechnology contributes to novel materials, devices and products that have qualitatively different properties. Its advances have the potential to affect virtually every area of economic activity and aspect of daily life. Nanotechnologies are likely to offer a wide range of benefits, including in helping address a range of societal and environmental challenges, e.g. in providing renewable energy and clean water, and in improving health and longevity of many species, as well as the environment. However, unlocking this potential will require a responsible and coordinated approach to ensure that potential challenges are being addressed at the same time as the technology is developing."

Genes, in modern biological terms, are defined as sections of DNA. A genome is an organism's complement of DNA which contains the information for its self production. Genes dictate the inherent properties of a species along with their environment, through protein production. However, the form of any gene may vary at the allelic level and at the protein level. There are debates about what constitutes the genetic component of diversity, and where the gene pool lines should be drawn to define individuals and species. DNA or genotype holds the information and the phenotype is the varied representative form of the genotype.

Nanotechnology has the potential to modify both genotype as well as phenotype, depending on the target of the intervention. There could be some ecological advantages of targeted alteration of phenotype without modification of the genotype, in that the future offspring will not be modified. Though it also means that the nanotechnology agent will need to be applied in the environment, perhaps constantly, which raises the chance of pollution. Whereas if a desired change is introduced permanently genetically, no external agent will be required to achieve the ends. Thus from the engineering and consequential side, genetic change is preferable to nanotechnology as an agent to modify organisms. There are few intrinsic concerns about direct genetic modification of plants (nor most animals), when compared to normal agricultural breeding.

It is also possible for nanotechnology to change the genetic composition of species. In Thailand, scientists at Chiang Mai University's nuclear physics laboratory have rearranged the DNA of rice by drilling a nano-sized hole through the rice cell's wall and membrane and inserting a nitrogen atom, changing the colour of the grain from purple to green. Thus nanotechnology techniques can be used to effect DNA change, including genetic engineering. In this way we match genotypes to conditions that produce the wanted phenotypes. Although the invisibility of nanotechnologies has been a point of criticism of the control, the same can be said of genetic engineering. There exist sensors for many nanotechnology agents, like DNA probes. However, the rapid pace of development in nanotechnologies creates difficulties in the identification of and response to potential impacts, especially long-term impacts because many techniques and molecules are rapidly introduced to industry before there is a method for detection, nor before their potential impacts on biodiversity are quantified.

The use of nanotechnology in military trials which often involve particular habitats with unique biodiversity, such as fragile desert ecosystems, have raised significant concerns. In this area deleted uranium (DU) is a particular concern. Nanotechnologies pose potential impacts on habitats, ecosystems and countries even if they are not the initial site of use because we can expect nanotechnology molecules to widely disseminate in the environment.

Kraft, Nestle, Unilever and other companies are employing nanotechnology to change the structure of food. Kraft is creating "interactive" drinks, for example, that can change colour and flavour. These may be attractive, but potential impacts of these agents in the ecosystem on all species needs to be examined. The philosophy of manipulation of life is one of the basic ethical questions that will need to be further explored as composite life-forms are constructed with non-biological nanoparticles.

6.3 Benefits to Biodiversity

It is not only species or genetics that deserve consideration in respect to biodiversity, it is appropriate to include the entire ecosystem as something worthy of a unique and valuable status with protection from loss of diversity. The ethical implications are equally prevalent yet different when considering ecosystems, as to when considering species. Systems as a whole are perhaps more delicate than species, as slight variations reverberated through interconnected relationships to alter the whole. Fluctuations in any of these variables of dynamics result in differing states of biodiversity and therefore can affect the diversity of ecosystems as a whole.

Nanotechnology has been claimed to remove pollution particles in water and air. In some countries nanomaterials have been deliberately introduced to improve degraded ecosystems. Zero-valent iron nanoparticles have been applied in soil

remediation in the USA (Li et al. 2006) and sensors that rely on nanotechnology are being developed to monitor ecological change (Doty et al. 2006). Nanocoatings to prevent soiling of windows and other surfaces reduce the need for detergents and hence the potential environmental damage caused by detergent use.

There is much interest in developing nanomaterials to benefit the environment. There are many potential benefits in the energy sector, which could reduce climate change. One such idea is the liberation of energy from mass and the creation of a global energy net that transfers renewable energy across continents through wires consisting of bundles of nanowires. The technology may be used in energy generation and electricity storage, fuel cells, and hydrogen storage and generation. Some may improve energy efficiency, including insulation, lighting, engine and fuel efficiency, 'lightweighting' of materials and the development of other novel materials with environmental benefits (e.g. the development of ultra hydrophobic coatings to reduce the icing-up of wind turbine blades). Nanotechnology can be involved in hydrogen economy both at the stages of catalysis of reactions, as well as in developing better storage materials for energy (Esteban et al. 2008).

The techniques using nanotechnology could be used to improve water, air and land quality, including environmental sensors, soil remediation, agricultural pollution reduction and water purification. The introduction of nanomaterials may benefit the environment if improved monitoring devices that are less expensive and more sensitive than current devices are produced. For example, protein-based nanotechnology sensors make possible the detection of mercury at very low concentrations (one part in 10^{15} or one quadrillionth), while nanoparticulate europium oxide can be used to measure the pesticide atrazine in contaminated water. Nanotechnology has also improved the monitoring of atmospheric pollutants by utilising thin layers of nanocrystalline metal oxides as crucial components of solid state gas sensors. Measuring small changes in electrical conductivity allows detection and quantification of methane, ozone and nitrogen dioxide, for example.

6.4 Risks to Biodiversity

The most direct ethical issues related to nanotechnology are toxicity and exposure of species in the environment to nanotechnology molecules, or their products. This is firstly a safety issue, of non-maleficence, rather than an intrinsic ethical issue of modification. The lack of our understanding of biodiversity and ecological webs, confounds the lack of understanding of nanomolecules, which means that the technology might pose new forms of hazard or exposure risks, and there needs to be research into how to deal with them. This area of 'risk management' is a form of assessment (Marchant et al. 2008; Schummer and Pariotti 2008). This approach has the benefit of more accurately stating the risks (and benefits) of newly created substances, materials and devices.

Further analysis is required to address wider issues of the ethical or political meaning of this risk – such as who will bear it, how it will be distributed internationally, and who will be given the power to make decisions based on these analyses (Macer 1998; Owen and Depledge 2005; COMEST 2007). The risks of nanoparticles concern the biological and chemical effects of nanoparticles on ecosystems. Further research on the movement of the nanoparticles is required to understand the degree, and impact of, leakage, spillage, circulation, and concentration of nanoparticles that could cause a hazard to ecosystems or species.

Studies on the toxicity of fullerenes suggests that they are hazardous but they can be engineered to be less so, in particular by conjugating other chemicals to the surface of buckyballs, thus changing their chemical properties. Thus after initial the better question for regulators and policy makers to ask of nanotechnology is not 'Is it safe?' but 'How can we make nanotechnology safer?' International cooperation and coordination is required because biodiversity is global in nature, knowing few political boundaries.

As a recommendation we should request scientists to discover not only the nanoparticles, but the requirements necessary to make them safe, or safer than other materials that achieve the same purposes in the ecosystem. However, environmental and ecological impacts can be complicated to assess. Because of the natural complexity of ecological cycles, and the difficulty of directly experimenting with the natural environment, knowledge about the hazard and exposure risks of nanoparticles to various ecosystems is limited. Of course we can see many nanoparticles being used and spread in a variety of ecosystems, therefore there is plenty of scope for conducting studies even though they may be already used. Many nanoproducts are imported into countries, such as titanium dioxide used in sunscreens that are ubiquitous among tourists who travel on ecotourism tours, or in other types of tourism. The distribution is universal, and ironically risks are associated with those tourists who may be travelling in order to marvel at biodiversity itself.

As in many other cases, however, the most pressing issue may not be determining the exact toxicity of nanoparticles, but creating new and enforcing old regulations on the industries who create and process these new materials. In many countries oversight of some of the most clearly hazardous chemicals, such as arsenic and mercury, is weak – and if nanoparticles are shown to be less toxic than such substances, the challenge to regulators will be significant. Corporations who practise green chemistry and who develop processes for recycling and reusing waste products should be expected to create fewer exposure risks than those that do not; but creating incentives for practices that are more costly is an economic and political problem much older than nanotechnology.

There is no consensus on whether nanoparticles or nanomaterials should be treated as something entirely new, or as a subset of existing materials, for the purposes of regulation or labeling. The standards bodies that oversee materials including national standards organizations and the International Organization for Standardization (ISO), would have to determine what, if anything, makes nanoparticles novel substances distinct from larger structures of the same chemical composition.

The factors used to predict environmental risk, in combination with production volume, include persistence, bioaccumulation and toxicity (RCEP 2008). Although nanoparticles and nanotubes have diverse properties and fall within a wide size range (1–100 nm in at least one dimension), some common toxic mechanisms may be associated with different kinds of nanomaterials. Toxicity due to the generation of reactive oxygen species is frequently attributed to nanomaterials, giving rise to effects on cell membranes, cytoplasm, nuclei and mitochondria (Lewinski et al. 2008).

Nanotoxicity has been related to the capacity of nanoparticles and nanotubes to act as vectors for the transport of other toxic chemicals to sensitive tissues of organisms (the Trojan Horse effect). In a study with carp, cadmium accumulation was increased 2.5-fold when titanium dioxide nanoparticles were added concurrently with cadmium salts (Zhang et al. 2007). This so-called Trojan Horse mechanism was also seen when aggregates of fullerenes and a representative range of organic contaminants were investigated.

Pesticides containing nano-scale active ingredients are already on the market, and many of the world's leading agrochemical firms are conducting R&D on the development of new nano-scale formulations of pesticides. Thus agricultural applications of nanotechnology can be expected to impact significantly biodiversity. According to industry, encapsulation offers the following advantages: Longer-lasting biological activity; Less soil binding for better control of pests in soil; Reduces worker exposure; Improves safety by removing flammable solvents; Reduces damage to crops; Less pesticide lost by evaporation; Less effect on other species; Reduced environmental impact; Prevents degradation of active ingredients by sunlight; Makes concentrated pesticide safe and easy to handle by growers. All of these so-called advantages will affect the impact on biodiversity that pesticides themselves have. Particular concerns raised by encapsulation include: Both biological activity and environmental/worker exposure can be longer-lasting; Beneficial insects and soil life may be affected; Nano-scale pesticides may be taken up by plants and introduced into the food chain; Microcapsules are similar in size to pollen and may poison bees and/or be taken back to the hives and incorporated in honey. Because of their size, "micro- encapsulated insecticides are considered more toxic to honey bees than any formulation so far developed."

The grey-goo scenario is based on the fear that nanotechnological devices will either be programmed to self-replicate, or that they will 'evolve' into devices capable of self-replicating, and that should they proceed to do so, they may destroy the natural world. Currently there are no nanotechnological objects capable of self-replication (unless one includes objects such as DNA and viruses). UNESCO (2006) claimed that the "Grey goo" is a distraction because it forces the discussion of ethical and social issues to revolve around the technical risks and possibilities of future research rather than the real system for research oversight and regulation that exists today. Researchers are coaxing living organisms to perform mechanical functions precisely because living organisms are capable of self-assembly and self- replication (ETC 2004). There is a critical need to evaluate the social implications of all nanotechnologies; in the meantime, the ETC Group believes that a

moratorium should be placed on research involving molecular self-assembly and self-replication.[3]

The solutions for guarding against grey goo are as hypothetical as the scenario itself, and this distracts attention away from the current practices of science and technology and the need for careful oversight and deliberation that attends to current problems and practices, not imagined future scenarios (UNESCO 2006; COMEST 2007). While that point is important to focus attention on the regulatory gap that exists, in terms of the timescale of biodiversity, that is billions of years, the grey goo phenomenon is very important.

We also need to take note of the natural tendency of certain types of inorganic systems to order themselves in time and space. The future ethical challenge will be when nanomolecules are self-replicating, they may be considered as "life", and then they will be part of the biodiversity directly. Self-assembly that is popular in nanotechnology discussions is based on a fundamental character of matter to form under certain circumstances, in contrast to the law of maximization of entropy and disorder. These discussions are relevant also to the origins of life itself. We can see patterns in inorganic matter however, for example ordered ripples in clouds, sand dunes and waves. While Bensaude-Vincent (2009) discussed self-assembly and vitalism, with the extension to organic matter and living organisms, order in the universe is not limited to living organisms. Ultimately these issues can also relate to the definitions of biodiversity in the future, when we challenge what is "bio" or biological/life.

The manufacture of some types of other nanomaterials is energy intensive and is itself highly polluting. In one report of the process used for manufacturing fullerenes, only 10 % of material was usable and the rest was sent as waste to landfill (Piotrowska et al. 2009). Nanotechnology is one of the most pressing challenges for biodiversity directly, along with its involvement in designer or artificial life and biomimetic robots. Nanotechnology may be used in many ways that are difficult to predict, thus complicating the prediction of the types of expected environmental impact.

6.5 Microorganisms and Nanotechnology

The majority of life-forms on the planet are microbes. Microbial diversity can occur in places not usually thought of as life bearing or worthy of diversity protection, for example oil wells. Secondly, that if microbial diversity is given the same consideration as other components such as species, the valuation becomes infinitesimally more difficult. This difficulty occurs as people rarely value or have affinity for

[3] Hands Off Mother Earth! Civil Society Groups announce new global campaign against geoengineering tests – urge public to join in. www.handsoffmotherearth.org, http://www.etcgroup.org/en/node/5131

microbes despite that fact they are a necessity of survival for all species and play invaluable roles in the healthy functioning of every living being. For that reason perhaps microbes are the perfect microcosm example of why all life must be valued (Bosworth et al. 2011).

Possible mechanisms of nanoparticle uptake into bacteria are non-specific diffusion, non-specific membrane damage and specific uptake. Entry through damaged bacterial membranes has been demonstrated for highly reactive manufactured nanomaterials such as halogenated nanoparticles. Endocytosis as an active process of particle uptake can also act as a delivery mechanism. Once inside the organism, the bactericidal activity of silver particles and titanium dioxide has also been extensively recorded, including detailed studies of the mechanisms of antibacterial activity and the use of photosensitisation to augment the formation of reactive oxygen species. Bacteria are integral members of most ecosystems o the planet, and killing of bacterial species will affect biodiversity of not only bacterial species, but the whole ecosystem.

There are different mechanisms for the transformation of nanomaterials by microbes. Reduction–oxidation reactions are mediated directly through enzymatic activity or indirectly through the formation of biogenic oxidants or reductants. Biological modifications, as well as degradation of the surface properties of nanoparticles, may result in modification of structure and the release of metals, for example. This means that the precise impacts of different nanomolecules will differ according to the ecosystem. It is thus difficult to extrapolate current risk studies to complex microbial ecosystems in the absence of information about the environmental fate and behaviour of nanomaterials. Such studies will need to be done in situ for each ecosystem.

Mechanisms allowing manufactured nanomaterials to pass through cell walls of algae and fungi are not well understood. However, once inside cells, nanomaterials behave similarly to how they behave in higher organisms; effects include physical restraints (clogging effects), solubilisation of toxic compounds and production of reactive oxygen species (RCEP 2008).

Fungi are important for bioremediation and a recent report has shown their utility in recovering depleted uranium from military activities. We can also make the point that existing pollution results in a particular biodiversity, especially in specific species of bacteria and fungi that utilize the pollutants in some way. The greater the variety of pollutants potentially the higher degree of biodiversity will exist. Removing pollution will affect the ecosystem and biodiversity as well by removing the energy supplies of some species.

One study has described the formation of nanocrystals of cadmium on phytoplankton. The toxicity of silver nanoparticles to the marine diatom *Thalassiosira weissflogii* has found a near linear relationship between toxicity and the release of silver ions from the particles. Plant tissues might serve as scaffolds for aggregation of metallic nanoparticles in situ. Thus, carbon nanotubes can be taken up by microbial communities and by root systems to accumulate in plant tissues. Although nanomolecules can be toxic, through evolutionary selection other species may be

able to evolve that will cope with the new molecules and construct a new ecosystem and thus a new biodiversity. Thus depending on the framework by which we value biodiversity, the relationship is not always negative.

6.6 Affects on Animals

In most ethical theories, there will be greater ethical concern expressed about sentient animals as moral agents, than to the concerns expressed for plats or microbes. In aquatic animals, nanomaterial uptake across gills and other epithelial body surfaces occurs. Detritivores and filter-feeders which ingest large amounts of particulate matter and consequently are most likely to encounter nanomaterials and concentrate them from water (RCEP 2008). Early life stages appear to be particularly sensitive to toxicants, including manufactured nanomaterials. Zebrafish embryos exposed to single-walled carbon nanotubes revealed reduced hatching success (Cheng et al. 2007). In a study with Japanese Medaka fish, fluorescent nanomaterials accumulated in various organs and were able to pass through the blood–brain barrier. An in vivo study of quantum dot uptake by embryos of the amphibian Xenopus showed that internalised quantum dots could be transferred to daughter cells upon cell division (Dubertret et al. 2002). This may have important implications for transgenerational effects of nanomaterials, but these have to be further researched. There has been some study of the interactions between dissolved and component metals and manufactured nanomaterials in fish.

Titanium oxide is very common in cosmetics and sunscreens. The accumulation of cadmium in carp has been investigated in the presence and absence of titanium dioxide nanoparticles or sediment particles (Zhang et al. 2007). Sediment particles alone had no effect on the uptake of cadmium, but when titanium dioxide nanoparticles were present bioaccumulation of the metal was observed. This indicated that titanium dioxide nanoparticles had a higher adsorption capacity for cadmium than natural sediments and that the metal and nanoparticles could accumulate in the viscera and gills of fish (RCEP 2008). Exposure studies that have been performed with fish have been hindered because high concentrations of nanomaterials in aqueous media aggregate, resulting in reduced uptake. Under these conditions it is difficult to determine lethal concentrations.

There are few studies of how manufactured nanomaterials are dealt with by terrestrial wildlife species, other than studies on laboratory rodents. As with other unexpected toxicity problems in the past, careful study of mammalian wildlife species is necessary to provide greater understanding of potential toxic threats to humans. Bioaccumulation and entry of nanoparticles and tubes into the food web has yet to be understood. A preliminary study of single-walled carbon nanotubes ingested by the nematode *Caenorhabditis elegans* showed movement of the nanotubes through the digestive tract. They did not appear to be absorbed by the animals (Oberdörster et al. 2006). Still their presence in the gut suggests the possibility of

entry into the food web if the nematodes were subsequently ingested by other animals. In terms of biodiversity nematode worms compose around one fifth of the estimated species present on the planet.

6.7 The Need for Ongoing Research

In trying to assess the potential of manufactured nanoparticles to cause adverse effects in organisms, it is important to understand the relationships between their physical and chemical structures and their biological effects. Two criteria have been proposed to identify nanomaterials which may present a unique potential risk to health:, (1) the material must be able to interact with the body in such a way that its nanostructure is biologically available; and, (2) the material should elicit a biological response associated with its nanostructure different from that associated with non-nanoscale material of the same composition. Many nanomaterials, including fullerenes and silver nanoparticles, are likely to persist in the environment and therefore remain bioavailable. Chronic effects on growth, reproduction and viability of offspring of any species are of particular concern and might ultimately affect inter-specific relations and the functioning of multi-species systems. If we want to understand the effects upon biodiversity we need to carry out tests with a number of species of organisms, from different taxa and those that represent different feeding types, reproductive strategies, and habitats, in order to appreciate the natural variability of response.

The RCEP (2008) report said: "The evidence available is from studies performed in the laboratory with animals, plants, micro- organisms, fungi and various cell lines. It suggests that there is a plausible basis for concern that harmful effects might arise. At present, however, we have not seen evidence of actual ecological damage or harm to humans resulting from exposure to manufactured nanomaterials." The fate and effects of nanomaterials in the environment are not well understood and the characteristics of various nanoparticles under different environmental conditions need to be determined.

Free manufactured nanoparticles and nanotubes are likely to present the most immediate toxicological hazard to living organisms as they are at liberty to interact with organisms in the wider environment (RCEP 2008). There is not the same level of concern regarding fixed nanomaterials, although they can become detached and enter natural ecosystems, especially when products containing them abrade or weather during use or when they are disposed of as waste or recycled. Broken fragments of objects with intact surface coatings of nanomaterials provide an example of how fixed nanoparticles might pose a threat if they enter the environment. This could be significant because many microhabitats are built in or around fragments of human-made objects discarded into the environment. The consumer economy also tends to discard physical objects in many sites, including dumping of rubbish into wild sites such as forests or the ocean. Nanomaterials enter ecosystems from both point and diffuse pollution sources. Many are discharged directly into rivers or the

atmosphere by industry, or escape as products, such as paints, cosmetics, sunscreens and pharmaceuticals, in the environment. A variety of processes can modify their functional properties and influence the likelihood of their uptake into living organisms. Many characteristics of the environment can change the availability, mobility and toxicology of manufactured nanoparticles, e.g. pH, salinity, the presence or absence of organic matter. Aggregation, size, morphology and kinetics of the aggregate, is one of the key determining factors for the bioaccumulation and ecotoxicity of nanoparticles (Lead et al. 2008). As a particle mass grows in size through aggregation it has generally been assumed that the toxicity of a nanoparticle will diminish. However, we have received evidence that the process of aggregation does not necessarily constitute a permanent change. Other processes such as re-suspension and disaggregation may result in a reversal of the aggregation.

At the NATO Advanced Research Workshop held in April 2008 in Portugal, extensive discussions resulted in proposals for the augmentation of current risk assessment procedures for nanomaterials. This included development of additional toxicity tests using a wider range of species representing more phyla and paying more attention to the likely fate of nanomaterials when selecting test species (RCEP 2008). For example, as nanoparticles often aggregate and accumulate in sediment, it might be more appropriate to conduct some tests with deposit-feeding organisms rather than pelagic fish species. It was also noted that biochemical toxicity might not be the only mechanism by which ecological effects are generated by nanoparticles. Research has demonstrated behavioural changes in annelid worms encountering low concentrations of aluminium oxide nanoparticles in sediment (RCEP 2008). Risk assessments based on the aforementioned toxicity tests and other information need to be carried out on nanomaterials at each stage in their life cycle prior to widespread use.

Marchant et al. (2008) have reviewed risk management principles for nanotechnology, suggesting that nanotechnology does not fit traditional risk management models. However that approach can be questioned if we examine the assumptions of the debates. The fear over risks of nanotechnology to biodiversity could be placed in a similar category to those felt about genetically modified organisms (GMOs). In the case of GMOs there are several decades more experience through controlled field trials of GMOs to study potential genetic pollution. However, for a number of nanotechnology processes there has no controlled trials but rather direct expansion into industrial use.

6.8 Future Technology and Self-Assembly; Designer Life

So-called third and fourth generation nanoproducts might involve self-assembly capabilities, self-replication and artificial intelligence. The newly-emerging discipline of synthetic biology might utilise nanotechnologies and nanomaterials in the pursuit of novel products, some of which may have military and space applications where enhanced performance of particular naturally occurring species

may outweigh cost factors. Much of the discussion of these products is considered to fall well outside conventional discussions of biodiversity and ethics.

There are methods for synthesizing protein-sized polymer particles with a binding affinity and selectivity comparable to those of natural antibodies by combining molecular imprinting nanoparticle synthesis with a functional monomer optimization strategy. In effect, they have created a plastic antibody, an artificial version of the real thing. They have also demonstrated that it works in the bloodstream of a living animal. As a result, we can now consider synthetic polymer nanoparticles, prepared by an abiotic process in the chemical laboratory, as alternatives to biological macromolecules.[4] This will be one further danger once used, to add to the concerns about the release of antibodies into the environment as a side effect of industrial agriculture (Kanaly et al. 2010).

6.9 Governance Questions

Public understanding of nanotechnology needs to be explored further to examine the concerns and expectations that people have, based on informed public discussion and information (Cobb and Macoubrie 2004; UK Royal Society and Royal Academy of Engineers 2004; Macoubrie 2005). In social science there is also a need for understanding of the value systems of indigenous persons and their traditional knowledge, in order to be able to see how changes to biodiversity effected by nanotechnology will be considered. Ecological systems do undergo change, but in the modern times these changes are much more rapid (Macer 1998). There are a variety of world views that people have beyond the predominant ethical principalism of Western environmental ethics (Rai et al. 2010).

Biocentrism, which in a broad sense encompasses approaches and ethical theories which ask for moral consideration of all life, differs from enlightened anthropocentrism through its presumption of an intrinsic or inherent value within all beings. Ecocentric approaches take a point of view that recognizes the ecosphere, rather than the biosphere, as central in importance, and attempts to redress the imbalance created by anthropocentrism. Ecocentric approaches can be useful in bridging the gap between individual or population and habitat, or more commonly referred to in philosophical through as self and environment. While both anthropocentric and biocentric approaches represent the value of the beings within the life bearing matrix, the ecocentric approach represents the value of the matrix in sustaining the beings.

That the primary threat to biodiversity loss is habitat destruction, or in other words destruction of the equilibrium of the matrix resulting in both decimation of individual and species numbers, suggest that an ecocentric approach is a valid and worthy approach from which to synthesis policy choices (Bosworth et al. 2010).

[4] http://www.nanowerk.com/spotlight/spotid=16668.php

Nanotechnology is one of the emerging risks that will alter biodiversity, although with creativity it could be used to assist in preservation of biodiversity. Like all ethical dilemmas, the consequences will depend on a greater awareness of the science of what we are doing, and development of clear policy. There is still a lot of research to do, as discussed above.

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Chapter 7
Nanotechnologically Enhanced Combat Systems: The Downside of Invulnerability

Robert Simpson and Robert Sparrow

7.1 Introduction

In the late twentieth century and early twenty-first century, military conflicts have often been characterised by profound asymmetry between the armed forces of the belligerent parties. There have been relatively few open hostilities between the highly industrialised states of Europe and North America since the end of the Second World War. When these states do go to war nowadays, they tend not to go to war with each other; instead, their opponents are typically either (i) economically less-developed states with relatively modest military capacities—as in the US-led 2003 invasion of Iraq, or the 1982 British war with Argentina—or (ii) even more modestly equipped sub-state military insurgencies—as in the US-led counter-insurgency operations in Afghanistan since 2002. In conflicts like these, the military forces of highly industrialised states hold a twofold advantage. First, they have more war-fighting resources: warfighters, weapons, munitions, ships, planes, tanks, and communications/intelligence infrastructure. Second, these states also enjoy an advantage with respect to the technological capacities of the equipment at their disposal; the militaries of modern industrial states don't just have more war-fighting resources than their less-developed military opponents, they have decidedly better resources as well. A number of contemporary authors have argued that there are distinctive problems in the ethics of warfare which arise because of these 'military-technological divides' (Dunlap 1999; Kahn 2002; Boot 2006). According to these authors, profound disparities in war-fighting capabilities can make it especially

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difficult for warring parties—on either side of the divides—to pursue their military objectives in an ethically defensible manner.

Our aim in this chapter is to explore the ways in which future developments in military nanotechnology may exacerbate and reshape the distinctive ethical problems to which these divides give rise. While the precise nature and future of "nanodivides" remains contested (Sparrow 2007a), it seems probable that capacity to manufacture weapons with significantly enhanced functionality due to nanotechnology will be confined to a relatively select group of highly industrialised states. Moreover, it is possible that the introduction of nanotechnologically enhanced military hardware will result in larger gap between the capacities of successive generations of hardware than has previously been the case. One of the main impacts of nanotechnology may therefore be to greatly increase the extent of the asymmetry of forces in wars between First World and Third World nations. It is possible that the extent of the asymmetry may become so large that in many contacts between warfighters armed with the latest generation of nanotechnologically enhanced military systems and those without, the former will be effectively invulnerable to the latter. We will suggest that this would increase the likelihood of modern wars being fought unjustly on both sides of the technological divide. The prospect of invulnerable or near-invulnerable warfighters may, on the face of things, be desirable but there is a downside to invulnerability.

7.2 Just War Theory

Contemporary discourse on the ethics of warfare is usually conducted within the moral framework provided by just war theory (JWT). We will be following suit for the purposes of this essay, to the extent that our discussion will proceed under the two assumptions which together constitute the core of the just war theoretical tradition. Those assumptions are: firstly, that under particular circumstances states or state-like actors can be justified in resorting to war, and secondly, that once states or state-like actors do resort to war, warfare can be carried out in a just manner. In making these assumptions we are rejecting, for the purposes of this essay, two competing traditions in the discourse warfare ethics, namely political pacifism (roughly, the view that states are never justified in resorting to war) and political realism (roughly, the view that the resort to war and the conduct of warfare are not amenable to ethical evaluation, and hence that they can neither be deemed just nor unjust). However, although we will hereafter be disregarding these alternatives to the JWT tradition, we do not thereby mean to generally endorse JWT against the rival pacifist and realist traditions. Rather, we are adopting a JWT framework for practical reasons. Our brief is to investigate the ethical implications of nanotechnological developments in relation to the ethics of warfare, but for political pacifists or political realists, nanotechnology—like any other kind of technology—simply has no ethical implications in relation to the ethics of warfare. Whatever nanotechnological developments may come, pacifists will still regard all war as unjust, and

realists will still regard war as an element of political life that is outside the scope of moral judgement. It seems to us, then, that if there is anything interesting to say about the ethical ramifications of nanotechnology in the context of contemporary warfare, it will need to be articulated within a just war theoretic framework.

The two central claims of the JWT tradition—that states can justly resort to war, and that wars can be carried out in a just manner—find their formal expression in two sets of normative principles, known in the JWT literature as the doctrines of *jus ad bellum* (justice in the resort to war) and *jus in bello* (justice in the conduct of war) (Coates 1997; Coppieters and Fotion 2002; Walzer 2000). On typical accounts, the doctrine of *jus ad bellum* stipulates six principles of justice in the resort to war, while the doctrine of *jus in bello* stipulates two principles of justice for the conduct of war.

In order for the decision to resort to war to be justified, it must meet al*l of* the following six tests of *jus ad bellum*.

1. *Just Cause*: There must be a just cause for war—with defence against an unjust attack being the clearest case of a just cause.
2. *Legitimate Authority*: War must be declared by the proper authority—typically the internationally recognised government of a sovereign nation.
3. *Right Intention*: The primary motive for war must be the just cause that justifies the decision to resort to war.
4. *Last Resort*: All reasonable alternatives to war must have been pursued and exhausted.
5. *Reasonable Chance of Success*: War should only be embarked upon if there is a reasonable chance of achieving the goals established by the just cause.
6. (Macro) *Proportionality*: The goods that the war is intended to achieve must be sufficient to justify the evils that we can expect to result from the war. This principle must be distinguished from the *jus in bello* principle of proportionality (see below).
   (Brough et al. 2007, pp. 244–46)

A war that fails to meet one (or more) of these conditions will not be a "just war". Note that because it is extremely hard to imagine circumstances in which both parties would have a "just cause" for going to war, this means that, at most, only one side of a conflict will ever be fighting a "just war". However, it is possible—and may even usually be the case—that *neither* side in a conflict is fighting a "just war" according to *jus ad bellum* as, even if a nation is fighting for a just cause, the resort to war may fail one of the other tests.

Regardless of whether they are fighting in a "just cause" or not, just war theory *also* requires all participants in armed conflict to obey the principles of *jus in bello*. That is, the justice of the means used in war is independent of the ends for which the war is fought. Thus, for the conduct of war to be just—and therefore for the war "as a whole" to be just—it must also meet the further tests of:

7. *Discrimination*: Conduct in warfare can be deemed just only if war-fighters discriminate between combatants and non-combatants, and do not intentionally target the latter.

8. *Proportionality*: The use of force—and in particular the number of people killed—must be proportionate to the military goals the force is intended to serve. Even attacks on enemy military personnel may not be justified if they might reasonably be expected to result in a "disproportionate" numbers of casualties. (Brough et al. 2007, pp. 246–48)

For the purposes of our arguments here, we are primarily concerned with the *jus in bello* principles of discrimination and proportionality. It is possible that if some of the more speculative claims about nanotechnology came true then this *might* have implications for *jus ad bellum*. For instance, if nanotechnological weapons of mass destruction become available then possession of such weapons might justify attacks by other nations under the (controversial—and to our mind implausible) assumption that another nation's possession of such weapons established a just cause for "preventative" war. Similarly, if a sufficiently powerful nanotechnology were developed by some nations but not others then perhaps nations without access to this technology would never have a "reasonable chance of success" in fighting wars against their technologically superior foes.[1] For that matter, if the development of nanotechnological "assemblers" (Drexler et al. 1991) meant that we entered a "post-scarcity" age then this might remove many of the grounds—and consequently, just causes—for going to war! However, all of these possibilities are extremely speculative and presuppose technological advances that we currently have no reliable way of anticipating. We have therefore chosen to concentrate on issues that we believe might be raised by nanotechnologies of the sort currently under development in materials laboratories around the world today.

7.3 The Ethics of Asymmetric Warfare

At this point it will be useful for us to introduce some terminology. We will use the term (highly) Industrialised Military Power (IMP) to describe a state that has the capacity to research, manufacture, and field state-of-the-art military technologies (e.g. weapons, munitions, vehicles) and para-military technologies (e.g. information technology or surveillance resources).[2] Conversely, we will use the term "underdogs" to describe less technologically capable states or sub-state political groups which have relatively modest military capacities in comparison to IMPs.

[1] While we will argue below that nanotechnology is likely to contribute to asymmetry between the military forces of wealthy "Northern" and poor "Southern" states, the claim that it will make it impossible for militarily weaker states to defeat more powerful ones is a much stronger claim and one that we believe is extremely implausible given that victory in military conflict as often as much a matter of political will as it is of success on the battlefield.

[2] Strictly speaking, these states are probably "post-industrial" rather than merely "industrialised"—what matters for our purposes is their relative capabilities when compared with other "less-developed" states.

Expressed in this vocabulary, our suggestion from Sect. 7.1 was that when IMPs and underdogs oppose one another in military conflicts, certain distinctive ethical problems arise due to the extent of the asymmetry between the forces and capacities available to each. To be clear, the suggestion here is not merely that wars between IMPs and underdogs are characteristically marred by injustice, either in their provenance or their execution. Whilst that claim is entirely plausible, the same could be said of wars between competing IMPs, or wars between competing underdogs, or wars involving states and political groups that do not sit comfortably in either camp. The claim that we are interested in, by contrast, is that there are distinctive reasons why injustices are likely to occur—and indeed frequently do occur—in military conflicts between underdogs and IMPs. We will focus on two problems of this type.

7.3.1 The Guerrilla Problem

This first problem arises due to the vast differences in the capacities of IMP forces and underdog forces to injure or kill opposing personnel in orthodox theatre conflicts. In conflicts between IMPs and underdogs, IMP war-fighters can locate, identify, and assault underdog warfighters who are in uniform or who are openly bearing arms with relative ease and with a relatively low degree of risk to their own lives. Underdog war-fighters, on the other hand, often lack the capacities to effectively attack IMP forces and, even when the opportunity for a potentially lethal attack does present itself, underdog warfighters typically carry out such attacks at great risk to their own lives. In short, IMP warfighters are able to kill and/or maim underdog warfighters much more easily than underdog warfighters can kill or maim IMP warfighters. This kind of asymmetry gives rise to an ethical problem, because it typically occasions a resort to more pernicious war-fighting methodologies by underdog forces.

In order to avoid being targeted and killed by opponents with vastly superior intelligence and surveillance capacities, underdog warfighters will not carry arms openly but will instead try to conceal themselves within the civilian population. This tactic makes it much more costly and frustrating for IMP warfighters to abide by the requirements of the principle of discrimination. By mingling with civilian populations underdog warfighters may also be able to provoke the IMP into attacks that will cause large numbers of civilian casualties that will undermine both local and international political support for the IMP's strategic aims. Furthermore, the inability of underdog warfighters to carry out effective attacks against military targets may drive underdog warfighters to inflict violence or the threat of violence upon noncombatant individuals, who *are* relatively susceptible to violent assault, thus violating the principle of discrimination. It may also encourage them to employ weapons and tactics—such as IEDs and car and truck bombings of military targets—that will tend to violate the principle of proportionality by virtue of not having a military goal that would justify the ensuing casualties. Through these methods,

while they may not be able to win any *military* battles, underdog forces may still be able to win a political/strategic victory by undercutting their enemy's will to fight.

To say that underdog war-fighters are driven to violate the principles of *jus in bello* in these ways is not to absolve underdogs of moral responsibility for those violations, nor is it to re-assign moral responsibility for such actions to IMP military forces. Rather, it is simply to acknowledge that the resort to pernicious war-fighting methods happens predictably, and for identifiable reasons. When an underdog is unable to resolve hostilities with a IMP via non-military methods, it is highly unlikely that the ensuing conflict will be carried out in mutual adherence to the principles of *jus in bello*; for if the underdog did adhere to those principles, it would almost certainly consign itself to defeat (and the further political, cultural, and economic consequences thereof) from the outset. Thus, if the underdog is unwilling to accept military domination, the use or threat of violence against non-combatants and the use of disproportionate force predictably follows.

We can briefly summarise the guerrilla problem as follows. Violations of the principles of *jus in bello*—especially the principle of discrimination—are more likely to occur in military conflicts waged between IMPs and underdogs than in wars between forces with relatively similar capacities. This is because (i) underdogs in many cases are unwilling to acquiesce to the prospect of inevitable defeat and domination, and (ii) their best or only chance of avoiding this prospect is to resort to the use of tactics that either directly violate the principles of discrimination and proportionality or that make it extremely costly for their opponents to respect the principle of discrimination.

7.3.2 The Problem of Riskless Warfare

The second ethical problem also arises due to the vastly different degrees of ease and risk involved for IMP and underdog warfighters attempting to kill their opponents in situations of profound asymmetry. In order to get a grasp of this second problem we first need to turn our attention to a foundational question in the ethics of warfare, namely: why it is that, during wartime, warfighters in general can justifiably be the targets of lethal violence (assuming with the just war theorist that this is indeed the case). Once war has commenced then according to just war theory—regardless of the justice of the cause in which they fight—combatants may both kill (other combatants) and be killed without necessarily being guilty of murder or the victim of a war crime, whereas noncombatants maintain the same immunity and status they possess during peacetime.

The explanation for this state of affairs clearly cannot be that warfighters in general are guilty of egregious wrongdoing such that they deserve to be killed or maimed. The rights and privileges that are extended by the doctrine of *jus in bello* to the combatants in armed conflict are independent of whether they fight in a just or unjust cause and the distinction between non-combatants and combatants is not that former are "innocent" while the latter are "guilty". The responsibility for

the decision to go to war rests with the political leadership of the nation (or sub-state actor) rather than those who fight. Nor can the justification for attacking combatants be that warfighters have given up their rights in choosing to enlist, for we know that many warfighters are conscripted, and many more take up the vocation out of economic necessity. Rather than appealing to features or actions of individuals who take on the role of the warfighter, then, it seems that the answer to this question must appeal to something about the war-fighting vocation itself. That is, in explaining why warfighters can justifiably be attacked and killed during warfare, we have to make reference to the distinctive capacities and abilities that individuals acquire in becoming warfighters, and also the ways in which those capacities have implications for other individuals (both combatants and non-combatants) in the context of war.

The just war theorist Michael Walzer (2000) offers such an explanation when he suggests that the distinction between individuals who can justifiably be the targets of lethal violence in warfare and those who cannot should be drawn on the basis of whether the actions of the individuals in question are "threatening and harmful to their enemies" (p. 146). By engaging in threatening and harmful activities, Walzer argues, the individual relinquishes the rights in lieu of which he or she—like the rest of us—is normally immune from being the target of violence. Similarly, according to Yale legal philosopher, Paul Kahn, the moral privileges of combatants have their origins in the right to self defence; combatants in warfare are only justified in attacking one another "as long as they stand in a relationship of mutual risk" (2002, p. 3).

This account of the foundations of the moral privileges of combatants in a right to self-defence in circumstances of mutual risk is not completely satisfactory. We suspect that it is insufficiently sensitive to the extent to which the ethics of war must be understood as a function of war's nature as conflict between states (Sparrow 2005). It is because combatants are in the armed services of states that are at war that they become enemies and so come to pose a risk to each other. Warfighters are not, for instance, allowed to target the warfighters of states with which their own nation is not at war, regardless of how much of a threat these warfighters may pose at the time. However, while mutual risk may not be a *sufficient* condition to justify the moral privileges of combatants, it is more plausible to think that it is a *necessary* condition. In circumstances where the targets of lethal violence pose no risk to those killing them the moral character of individual engagements with the enemy will come to seem less like combat and more like *massacre*.

To the extent that circumstances of mutual risk are a condition of the ethics of war then circumstances in which one of the parties in conflict is immune to threats from the other are morally problematic. Paul Kahn (2002) has described this as the "paradox of riskless warfare". It is a paradox because circumstances that establish it are themselves a product of the logic of war. No responsible military leader wishes to meet the enemy in a "fair" fight. Instead, the goal of military leaders and military strategists should indeed be to achieve total battlefield supremacy over their enemies. However, if they actually succeed in this then the justification for the use of lethal force against enemy "combatants" disappears. Enemy soldiers who are incapable of mounting an effective attack ought not to be seen as combatants at all, and should

be afforded the same presumptive (albeit still defeasible) immunity from violence that is afforded to non-combatants generally. Thus, Kahn suggests that absent the imposition of mutual risk, militarised conflict between hostile parties ceases to be warfare, and becomes a form of policing (2002, p. 4). The moral distinction between combatants and noncombatants can no longer do the work required for it and instead the relevant distinction becomes the distinction between guilt and innocence. Forces involved in policing must restrict the use of deadly violence to the apprehension or punishment of people whose individual conduct warrants the use of force, e.g. those actually engaged in the commission of war crimes and the leaders of egregiously abusive political regimes.

We can summarise the challenge posed by riskless warfare for the ethical conduct of war as follows. Violations of the *jus in bello* principle of discrimination are more likely to occur in military conflicts waged between IMPs and underdogs than in wars between forces with relatively similar capacities. This is because (i) IMP warfighters will frequently be called upon to attack and kill putative "combatants" in such conflicts, and (ii) the classification of underdog warfighters as combatants—and the moral justification for IMP forces to attack combatants, which depends upon that classification—is rendered specious if and when underdog forces do not pose any threat to IMP forces (as is at least sometimes the case).

7.4 Military Nanotechnology

Discussions of the ethics of nanotechnology are hampered by the failure of nanotechnology to achieve the dramatic results in application predicted for it and also by lack of consensus about what nanotechnology might make possible in the future (Berube 2006; Sparrow 2007b; Smalley 2001). This difficulty is further compounded in relation to *military* nanotechnology because military secrecy makes it difficult to know what *has* been achieved and because researchers and manufacturers need to "sell" their products and their research and the tendency of the media to hype military technologies combine to exaggerate what *might* be achieved. The most thorough survey of research into military nanotechnology available to date (Altmann 2006) is notable for the extent to which it is forced to discuss what "might" or "could" be done with nanotechnology.

What does seem clear is that "nanotechnology" itself is not a weapon. Moreover, the hypothetical applications of nanotechnology that would rely upon all the components of a military system having properties relating to the nanoscale, such as "smart dust" or swarms of "nanobots", are the most speculative and the furthest from realisation. Where control over structure of the nanoscale is having most impact is in materials science. In particular, nanotechnological innovation is contributing to (i) the miniaturisation of electronic components (Altmann 2006, pp. 72–73), and (ii) the development of advanced materials which are stronger, more flexible or rigid, lighter or denser, more or less permeable, better insulators or conductors, etc., as required (Altmann 2006, pp. 76–78).

These advances have tremendous military utility but do so because they offer to improve the functioning of familiar types of military hardware. Advanced alloys and composites will provide better protection against chemical and ballistic assault to individual warfighters as well as to military hardware such as tanks and aircraft (Altmann 2006, pp. 76–78, 84–85; Lau 2002, p. 350). At the same time, the development of new materials, including more powerful explosives, and smaller and more sophisticated electronics, will allow the production of weapons that are lighter, smaller, more accurate, and more destructive (Altmann 2006, pp. 76–82, 85–88; Altmann and Gubrud 2004, pp. 35–36). While we are cynical about the prospects for robots with dimensions anywhere near the nanoscale, it is clear that increases in computer power associated with the development of smaller components due to nanotechnology (Altmann 2006, pp. 72–75), alongside developments in sensor technology, will make it more feasible to develop sophisticated robots capable of functioning in a wide range of military roles (Altmann 2006, pp. 91–93; Shipbaugh 2006, p. 746; Sparrow 2009).

Rather than talking about the impact of nanotechnological weapons, then, we would therefore prefer to speak of "nanotechnologically *enhanced* weaponry". However, even this term misrepresents what we believe to be the most plausible trajectory for the use of nanotechnology in military contexts, which will include a large role for nanotechnology in defensive systems and in other hardware supporting the military in its role of facilitating the use of force in the pursuit of political ends. The appropriate object of analysis then might usefully be described as "nanotechnologically enhanced combat systems" (NECS), where such systems may include defensive systems such as armour plating or the Institute for Soldier Nanotechnologies' "battle suits" (2009), as well as nanotechnologically enhanced offensive weapons.

7.5 Nanotechnology and Asymmetry

The question we now want to consider is whether and how the development of NECS is likely to bear on the problems discussed in Sect. 7.3 above. If NECS will be used on both sides of future conflicts then they will have little implication for questions of the ethics of asymmetric warfare. However, there are reasons to believe that the possession of NECS will be confined to a small number of highly industrialised military powers for at least the next two decades. While interest in nanotechnology is worldwide and while many nations have research programs into one or more nanotechnologies (Hassan 2005), the vast majority of nanotechnology research continues to be confined to a small number of nations in the wealthy "North" (Sparrow 2007a). The vast majority of research into *military* nanotechnology is being carried out in the United States, although a number of other industrialised nations, including France, Germany, Japan and (possibly) China, also have significant research programs in this area (Altmann 2006, Chapter 3). Third World or "Southern" nations, on the other hand, are devoting comparatively little of their

already scarce resources to military nanotechnology and have little prospect of making significant breakthroughs in this area.

Of course the fact that a technology is researched and manufactured in the North does not mean that it will not be used in the South. Many of the weapons manufactured today are not in fact manufactured for the purpose of national self defence or even service of the developing state's military forces but for export, largely to nations in the Middle East and Africa. Thus it is possible that in the future when IMPs go to war in the Third World they will find themselves facing enemies armed with weapons that they themselves—or other highly industrialised nations—have sold them. However, while there *is* an enormous trade in military hardware, which will undoubtedly extend to include weapons containing nanotechnology, arms manufacturing nations—and especially the United States—do tend to reserve their most lethal weapons for themselves and (occasionally) their allies. This is especially the case when the weapons systems concerned represent the culmination of many years of development and research and/or provide a significant military advantage over the previous generation of weapons technology. Moreover, the effective use of some NECS—unmanned systems—in their most powerful applications will require a satellite communications infrastructure that is only available to a few highly industrialised nations. Thus the best NECS are likely to remain confined to the possession of those nations that develop them.

Importantly, the difference in capacities between NECS and existing weapon systems may well be greater than that between previous generations of military hardware. Control over the structure of matter at the nanoscale represents a whole new way of producing desired properties in materials. Nations that have mastered nanotechnology will be able to do things—in terms of realising desired applications—that previous material technology could only dream of (as we discuss further below). This, in turn, will allow rapid and dramatic "progress" in the development of lethal weapons and other military hardware (Altmann 2006, pp. 104–105).

When IMP's meet Third World militaries in the future, then, they will be armed with NECS while their opponents will be armed with "legacy" weapon systems with markedly inferior capacities. Of course, *ex-hypothesi*, encounters between IMPs and underdogs are marked by asymmetry. What nanotechnology adds to this equation is to further increase the extent of the asymmetry and also increase the chance that in individual encounters between IMP warfighters and underdogs the IMP warfighters will be effectively invulnerable to enemy attack.

These developments could have several implications in relation to the two ethical problems discussed in Sect. 7.3. In relation to the guerrilla problem, the use of NECS by IMP war-fighters may serve to discourage underdog fighters from even attempting to attack and kill IMP warfighters. After all, the risk that underdog personnel expose themselves to in carrying out an attack on IMP warfighters is already considerable. The prospect of attacking warfighters armed and defended by NECS may be too forbidding for the underdog to even contemplate.[3] In order to have

[3] Even warfighters who are prepared to engage in suicide attacks may hesitate when these attacks are incapable of inflicting casualties on their targets.

any chance of victory against an IMP, underdog forces will need to concentrate their efforts on "softer"—illegitimate—targets. One significant downside of invulnerability, then, is that one's enemies will attack one's compatriots, who *are* vulnerable.

Interestingly, the aura of invulnerability that NECS provide for IMP warfighters could turn out to be just as significant as whatever degree of near-invulnerability they impart. The resort to pernicious war-fighting methods which characterises the guerrilla problem is driven by a perceived absence of alternative strategic war-fighting options (short of surrender) for the under-equipped party. We think NECS would contribute to those perceptions—regardless of how accurate the perceptions actually are—and would therefore have the potential to exacerbate the guerrilla problem. Even if bullet-proof nano-enhanced supermen who can single-handedly lift a tank aren't a reality, the military superiority provided by the possession of NECS will only add to the existing pressure for underdog forces to take the battle with IMP forces away from the battlefield.

Turning to the question of riskless warfare, we think the development of NECS could greatly increase the number of situations in which the ethical issues associated with riskless warfare arise. To date, the phenomenon of riskless warfare has emerged only in relation to military campaigns conducted entirely from the air—and most obviously in air campaigns conducted using Uninhabited Aerial Vehicles (UAVs). In present-day conflicts between IMPs and underdogs, the life of an individual IMP warfighter remains vulnerable in a range of war-fighting situations, even when the IMP forces at large don't face the threat of defeat. For troops on the ground, war has always been a risky business. However, the development of NECS arguably has the potential to reduce the risk to individual members of IMP forces involved in asymmetric warfare to a level sufficient to trigger concerns about the ethics of riskless warfare.

Three developments in particular might go a long way towards bringing this situation about. First, if nanotechnologically enhanced fabric technologies, such as those being investigated by the Institute for Soldier Nanotechnologies (2009), manage to extend the protection against ballistic penetration afforded to the chest and torso by the best of the current generation of body armour to the entire body of future warfighters (Lau 2002, p. 350). Second, if improvements in electronics and sensing technology due to nanotechnology make possible the deployment of unmanned systems so as to extend surveillance across the entire battlespace to the point that underdog warfighters cannot move without being watched and without being vulnerable to long-range attack with precision munitions. Third, if improvements in armour plating or in reactive counter fire systems render vehicles and aircraft immune to attacks by rocket propelled grenades and man-portable missile systems. Together, these developments could render IMP warfighters effectively invulnerable to small-arms fire from their underdog opponents.

An important qualification to this claim involves improvised explosive devices (IEDs), which have emerged as a potent threat to the lives of US (and allied) soldiers in the current conflicts in Iraq and Afghanistan. The second development, vastly improved surveillance technology, might make it much more difficult for insurgents to plant IEDs and thus greatly reduce the threat posed by these devices. Yet it is hard

to imagine any advances in material technology being able to protect individual warfighters against a tactic that makes possible the employment of artillery and anti-tank rounds against dismounted infantry. While it remains possible for insurgents to deploy IEDs, then, the risk of being killed or maimed will remain a feature of occupying hostile territory. However, the extent to which the existence of an IED campaign justifies the use of lethal force against enemy warfighters other than those directly involved in planting or triggering the devices is unclear. *Ex-hypothesi*, in the situation we are imagining, enemy soldiers not actually involved in executing attacks with IEDs are not a risk to IMP forces. Thus the threat they pose to the IMP forces may be insufficient to establish a *general* right to fire on opposing forces. Instead, the ethical framework appropriate to responding to an IED campaign may be closer to policing than to warfare, with only those actually involved in carrying out an IED attack losing their right not to be killed.

It is possible, then, that future developments in NECS may significantly expand the phenomenon of riskless warfare. If this occurs, it will undercut the justification for IMP warfighters to treat all enemy "combatants" as legitimate targets for the use of lethal force. Thus, the second downside of invulnerability is that the moral privileges of personnel involved in the policing actions that may come to replace (some) wars are much reduced; invulnerable soldiers would need to be much more careful about who they kill. If "riskless warfare" becomes sufficiently widespread, the principles of *jus in bello* may need to be revised or extended to address circumstances where one nation may be justified in going to "war" with another but where the warfighters of the more powerful nation must confine their use of force to targets who may individually deserve to be killed rather than to the class of "combatants" as a whole. At a practical, policy level, the development of "riskless warfare" will leave IMP forces with the dilemma of how to subdue a hostile population *without* the use of lethal force. Paradoxically, the best weapon for an "invulnerable" warfighters may turn out to be a non-lethal one.

7.6 Conclusion

The idea of the invulnerable high-tech warrior has been a fantasy of the military-industrial complex since at least the 1960s. Yet for all the human effort and ingenuity dedicated to allowing some people to kill others without being exposed to any risk of being killed in return, this goal remains elusive. New weapons provoke new defences: advances in defensive systems are met with new offensive technologies or new ways of applying existing technologies. The recent history of the US invasion and occupation of Afghanistan and Iraq has shown that a sufficiently determined enemy is still capable of inflicting casualties on the most powerful and technologically sophisticated military in the world. The phenomenon of asymmetric warfare is characterised precisely by the evolution of new tactics to allow a state (or insurgency) to continue to pursue its political/strategic goals in the face of overwhelming

military superiority. Thus, the military superiority afforded to some nations by nanotechnology will not mean an end to politically motivated violence. Instead, the nature of this violence will change and with it the nature of the ethical issues faced by parties involved in violent conflict.

We have argued that large increases in asymmetry between forces armed with NECS and those without might dramatically exacerbate the ethical problems of asymmetric warfare. It may place pressure on the just war principles of *jus in bello* by encouraging the resort to tactics that either make it much more difficult to respect these principles or that directly violate them by virtue of attacking non-combatants or by creating disproportionate numbers of casualties without a clear military goal. It may also require the principles of just war theory to be extended to include the ethics of "fighting" an enemy who is, in many circumstances, unable to pose a realistic threat to the lives of warfighters with the benefit of NECS.

Given the relatively modest contribution made by nanotechnology to contemporary military systems, we have, inevitably, had to frame our discussion in terms of what might or could be possible in the future. However, by focusing on broad-brush technological and political trajectories rather than particular applications we hope we have avoided the reliance on predictions about the future of technological breakthroughs that bedevils many discussions of the ethics of nanotechnology. Nevertheless, it remains the case that, to a large degree, we will simply have to "wait-and-see" whether NECS to provide the level of military superiority that would raise the dilemmas that we have discussed here. The closer that warfighters possessing NECS come to being truly invulnerable, the more salient (and the more pronounced) the ethical problems discussed in Sect. 7.5 become.

The application of our discussion is also limited by the fact that the particular set of problems we have been concerned with here will not arise in conflicts between parties who are both armed with NECS. We have given reasons for believing that at least some future conflicts between wealthy First World and poor Third World states (or insurgencies) will involve only one party armed with NECS. However, as global climate change continues to accelerate, the relative peace between the states we have described as IMPs may come to an end in wars triggered by mass movements of population or conflict over increasingly scarce resources. We have nothing to contribute here about the ethics of wars between two sides both armed with NECS except to observe that we can see no reason for thinking that the mere presence of nanotechnology on the battlefield will require any revision of the principles of just war theory; it is asymmetry as a result of nanotechnology rather than nanotechnology itself that we believe might generate ethical dilemmas. Moreover, presuming that NECS will *eventually* become accessible to armed forces and armed militants all over the world, as arms are traded, transferred, or captured across national borders, there is probably a limited number of years in which the issues we have identified here might arise with particular force.

Finally, like many of the ethical issues associated with nanotechnology, the issues we have identified here are not unique to situations involving engineered

features at the nanoscale. Indeed, the fundamental origin of these problems is the logic of armed conflict itself. As Hobbes (1981) famously observed, it is the vulnerability of individuals—and political organisations—to violence and the threat of violence that requires each to prepare for war. Our discussion suggests that the achievement—however fleeting—of invulnerability to violence would come with its own peculiar problems.[4]

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Part III
Risks and Precaution

Chapter 8
Risk, Precaution, and Nanotechnology

Fritz Allhoff

8.1 Introduction

Nanotechnology offers much promise, both in terms of the development of new nanotechnology and the development of novel uses for extant nanotechnology. Alongside these developments, commentators enumerate various associated risks; such risks could be specific (e.g., environmental, economic) or else more general (e.g., social, ethical).[1] But comparatively little conceptual work has been done on the very nature of 'risk': what does it mean for something to be a risk (or to carry a risk)? And how does the nature of risk integrate, most fundamentally, with rational deliberation? On this latter question, proposals are often made regarding

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[1] My own research in this regard has predominantly been in the social and ethical issues of nanotechnology, though this essay generalizes beyond nanotechnology. For readers interested in these more specific discussions, see Fritz Allhoff *et al.*, *Nanoethics: The Ethical and Social Dimension of Nanotechnology* (Hoboken, NJ: John Wiley & Sons, 2007). See also Fritz Allhoff and Patrick Lin (eds.), *Nanotechnology & Society: Current and Emerging Ethical Issues* (Dordrecht: Springer, 2008). See also Fritz Allhoff, Patrick Lin, and Daniel Moore, *What Is Nanotechnology and Why Does It Matter?: From Science to Ethics* (Oxford: Blackwell Publishing, 2010).

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cost-benefit analysis or precautionary principles, but there are various issues with these proposals.

First, regarding cost-benefit analysis, it is unclear how this framework is meant to deal with much of the uncertainty inherent with risk, whether uncertainty about the probabilities of that risk being realized or else uncertainty about what the risks actually are. And, second, regarding precautionary approaches, the theoretical commitments of such approaches are rarely made transparent. It is easy enough to find instantiations of precautionary principles, but more work needs to be done to understand what these have in common with each other and what underlying structural features all precautionary approaches share.

Finally, the relationship between cost-benefit analysis and precautionary approaches is one that needs elucidation; I think that false claims have been made about these being "alternatives" to each other. This chapter aims to clarify the aforementioned issues, both by undertaking a substantial review of the literature (Sects. 8.2, 8.3 and 8.4) as well as by advancing that literature with new arguments (Sect. 8.5). This theoretical discussion floats free of nanotechnology in particular and instead offers a general platform by which to understand risk and precaution. This generality, though, hardly makes the present project of less interest to those of us thinking specifically about nanotechnology; rather the level of generality on offer is precisely that which we can apply to more specific contexts.

8.2 Risk

In philosophical discussions, there are various different senses in which 'risk' is used; here, I will follow Sven Ove Hansson and discuss four.[2] First, risk can be some unwanted event which may or may not occur. So we could say that environmental impacts are one of the risks of some technology; this is to say that the technology may or may not have these impacts and, furthermore, that the impacts would be negative. Note that both of these features are important for attribution of risk. If the technology definitely had some specific impact, then we would more appropriately call it a consequence of that technology rather than a risk: the uncertainty is one of the features of risk. And, second, the impact needs to be a bad thing for it to be a risk; otherwise we would call it something else, such as a (potential) benefit. These points might be obvious, but should help us in trying to conceptualize risk. Second, risk can be the *cause* of an event which may or may not occur. If we say that nanotechnology carries environmental risks, what we mean is that nanotechnology either might cause, tends to cause, or will cause negative environmental impacts. This postulation of a causal mechanism is more committed than the first conception of risk.

The third and fourth conceptions of risk are quantitative, as opposed to qualitative. The third conception holds that risk is the probability of an unwanted event which

[2] Sven Ove Hansson, "Philosophical Perspectives on Risk", *Techné* 8.1 (2004): 10.

may or may not occur. So imagine that someone asks about the risk is of some nanotechnology having a certain environmental impact. An appropriate answer here might be, for example, 10 %. The first sense of risk treated the environmental impact itself as the risk, whereas the second treated the nanotechnology as the risk (i.e., that which caused the impact). This third conception, though, tells us how likely it is that some impact will be realized. Fourth, and similarly, we could talk about the *expected outcome* of unwanted events. So imagine that there are 100 fish in some river that we are going to purify using nanoparticles. Further imagine that those nanoparticles are toxic to the fish population, and that some of the fish will die through the purification. We do not know which fish will die, but, given various epidemiological studies, we might reasonably issue a projection of 20 %. The risk, then, is 20 fish, in the sense that we expect to lose that many fish. On the third sense, we are given the likelihood that something will happen (e.g., as a percentage), whereas the fourth sense gives us an expected outcome (e.g., in terms of some number of units lost). This fourth conception is the standard use of 'risk' in professional risk analysis. In particular, "'risk' often denotes a numerical representation of severity, that is obtained by multiplying the probability of an unwanted even with a measure of its disvalue…"[3]

For the remainder of this chapter, it is this fourth conception that I shall be most interested in, though some of the other conceptions will also recur. There are various reasons to focus on this fourth conception; as already mentioned, it is the standard use in risk analysis. One advantage that it has is that it allows us to assess risks quantitatively, which helps make them commensurable with benefits. For example, if we can say that some remediation will lead to an expected loss of 20 fish, this loss can then be compared, somehow, to the benefits of the remediation, such as more long-term benefits for fish, cleaner water for a local township, and so on. On the first conception, the risk would just be "the loss of fish". The second conception acknowledges that the remediation will *cause* the loss of fish, and the third conception tells us the likelihood. The fourth conception, though, ties all of these things together, telling us what we can *expect* to happen, given the remediation. And this is why it is the most useful for risk analysis, even if we can speak of risk in the other three senses.

Now that we have various conceptions of risk, including our preferred one, we can try to think more about how decision-making relates to risk. Of course, one of the hallmarks of risk is that we do not know for sure what will happen, given some course of action. It is this lack of certainty that makes decision-making under risk philosophically and practically interesting. If we knew that some course of action had a set of determinate consequences, some of which were good and some of which were bad, then decision-making would be a lot easier. To be sure, we might disagree about how to weight those good and bad consequences, such as if some nanotechnology had a positive economic upshot while having a negative environmental impact. Some might think that the environmental consequences were worth it, while others might not; this problem will occur in any society with pluralistic

[3] *Ibid.*

values. In such a situation, we have to think about how to render positive and negative consequences commensurable, and we further need to establish some democratic (or other) process for adjudicating disagreement. But in the case of uncertainty, this problem is exacerbated by the epistemological one, which is to say that we not only have to deal with a plurality of values, but we also do not even know what the consequences will be. The values problem, then, is common to either scenario and is therefore not endemic to our discussion on risk.

Logically, there are four epistemic situations that we can be in with regards to risk.[4] The first of these is that we know the probability of some negative outcome. Imagine, for example, a case of Russian roulette in which a bullet is placed in one of six chambers of a revolver. Here we know the probability of a bullet being discharged, which is 1/6. Call this decision making under known probabilities: someone makes a decision whether or not to fire the gun, knowing what the probability is that a bullet will fire. Contrast decision making under known probability with decision making under uncertainty, wherein we know the probability only with insufficient precision. Return to the gun scenario and imagine that, last week, I put either two or three bullets in the chambers, but I have forgotten how many. If I choose to fire this gun, then I am doing so without known probabilities for the risks.

Finally, think of an extreme case of decision making under uncertainty: decision making under ignorance.[5] The ignorance, though, could be of two different sources, either of which would compromise our ability to determine some expected outcome. First, we might have little to no information about some specific outcome. Again, return to the gun example. Imagine that I pick up someone else's gun, not having any information about how many bullets are in the chamber, and then contemplate firing it. Assuming that I do not look in the chamber (and cannot otherwise tell anything by weight), I then have no information about the probability of a bullet discharging: that probability could be anywhere from zero if all chambers are empty to one if all chambers are loaded. Second, though, we might not even know what the outcomes *are*, much less how certain they are. Consider asbestos, for example, which became increasingly popular in the late nineteenth century as insulation. Despite the fact that even the Ancient Greeks observed lung damage in the slaves who wove it into cloth, the proclivity of asbestos to cause lung damage was not widely noted until the 1920s.[6] When asbestos became prevalent, the adverse health effects were largely unknown altogether, not just the probabilities that those effects would occur. It was not just that certain specific effects (e.g., mesothelioma and asbestosis)

[4] Sven Ove Hansson, "What Is Philosophy of Risk?", *Theoria* 62 (1996b): 170.

[5] See Sven Ove Hansson, "Decision Making under Great Uncertainty", *Philosophy of the Social Sciences* 26.3 (1996a): 369–386.

[6] See, for example, W.E. Cooke, "Fibrosis of the Lungs Due to the Inhalation of Asbestos Dust", *British Medical Journal* 2 (1924): 147–150. In 1899 a London doctor, H. Montague Murray, connected the death of a factory worker to asbestos inhalation, after doing a post-mortem examination. The Cooke paper, though, as well as a report that came out shortly thereafter, were what established widespread recognition of the link. For the report, see E.R.A. Merewether and C.W. Price, *Report on Effects of Asbestos Dust on the Lung*. London: H.M. Stationery Office (1930).

were unknown, but it was not even common knowledge that anything bad would happen to those who inhaled asbestos.

Technically, these three situations are all instances of decision making under uncertainty, though it is useful to think about the different variants in that regard. Putting all four together, then, here are the epistemic situations we can have in relation to risk:

(1) Decision making with full knowledge of outcomes and probabilities;
(2) Decision making with full knowledge of outcomes and some, though not all, knowledge of probabilities;
(3) Decision making with full knowledge of outcomes and no knowledge of probabilities; and
(4) Decision making with incomplete knowledge of outcomes (as well as their associative probabilities).

Again, (2)–(4) are all instances of decision making under uncertainty and (3)–(4) are both instances of decision making under ignorance; what separates these from each other is not their formal relationship, but rather the degree (or type) of uncertainty.[7]

When dealing with technology in general, or even nanotechnology in particular, in which epistemic situation are we likely to find ourselves? A ready observation is that it almost certainly is not the first one. The only time that we have full knowledge of outcomes and probabilities is likely to be in sorts of idealized cases, such as when we are talking about rolling dice or flipping coins that are known to be fair.[8] In reality, epistemic uncertainty is sure to abound. When trying to decide whether to pursue some course of action—especially more complex ones, like policy decisions—there will almost certainly be some negative consequences that may or may not follow, and it is very unlikely that we will have epistemic certainty either what those relevant probabilities would be or else even what the relevant consequences are. Of course, we at least hope to know the latter, and we also hope to know the former within some reasonable range of error. Whether this is true with risks given any particular application of nanotechnology remains to be seen, though there is little reason to be optimistic given the often unknown risks of those technologies, or at least a wide range of uncertainty regarding the probabilities of those risks.

So what do we do with the uncertainty that we almost certainly face? Hansson, following Charles Sanders Peirce, offers an account of "uncertainty reduction" (cf., Peirce's "fixation of belief").[9] Hansson proposes that we reduce decision making under unknown probabilities to decision making under known probabilities, or even to decision making under certainty. For example, imagine that we are trying to figure out whether it will rain tomorrow. Various meteorologists get together and they all

[7] Technically, everything could be classified as decision under uncertainty, so long as zero and one were allowed as the probabilities that some consequence would attain.

[8] *Ibid*., 171.

[9] *Ibid*., 172. See also Charles Sanders Peirce, "The Fixation of Belief" in Charles Hartshorne and Paul Weiss (eds.), *Collected Papers of Charles Peirce* (Cambridge, MA: Harvard University Press, 1934), pp. 223–247.

come up with estimates as to the likelihood of rain. Just for simplicity, suppose that three camps converge on reasonably close estimates: 70, 80, and 90 % chance of rain. We must now make a decision about our day that hangs on whether it will rain (e.g., whether to plan a picnic). Further suppose that this is an instance of (2) above; we know what the outcomes are, but we do not have epistemic certainty as to the probabilities since the meteorologists disagree. What we will probably do is look at the testimony and aggregate it in some manner, thus, psychologically, abrogating the uncertainty. So, for example, we might take the testimony on board and then take the likelihood of rain to be 80 %, effecting something like an average of the reports. There are other things we could do, such as taking the median, picking our favorite meteorologist, excluding our least favorite meteorologist, and so on. But, pragmatically, we are certainly going to look to a way to reduce the uncertainty.

This reduction, seemingly, improves our epistemic status from (2) to (1). Of course, our actual epistemic status has hardly changed at all: we have not gained any more information, but have rather just adopted some strategy to convince ourselves that we know more than we do. Hansson thinks that we often take it a step further, moving ourselves toward known probabilities and then toward certainty. If we collapse the different testimonies to an 80 % aggregation of rain, do we go on our picnic? Probably not: 80 % is high enough that we convince ourselves that it *will* rain (i.e., that the chance of rain is 100 %). And now our epistemic status is even better than (1) since we have full knowledge of the outcomes. Or so we would like to think; obviously we are still, actually, in (2).

What are we supposed to do with all this uncertainty? Some approaches, like Bayesianism, would have us assign probabilities to everything.[10] If we have no information at all, then maybe we could assign probabilities of 0.5; those prior probabilities will thereafter be revised as we start to garner evidence. In the long run, maybe these sorts of approaches will get it right, though they are not terribly practical, and they otherwise face short-term limitations. For example, imagine that some technological application may have some disastrous consequence, but we really have no idea whether it will. Should we proceed with the application? We could take the consequences, multiply them by 0.5, and then derive some expected cost; this expected cost can be compared to the expected benefits. But if, unbeknownst to us, the objective probability of the negative consequence is 0.9 (rather than our subjective 0.5), we could be really far off with our risk assessment. Of course, we could be off with it in the other direction, too, thus overestimating the risks rather than underestimating them. However, we might think that there is some sort of *asymmetry* between these sorts of errors: it is worse to be insufficiently cautious than it is to be overcautious. This sort of attitude gives rise to precautionary approaches, which will be presented in Sect. 8.4 and critically evaluated in Sect. 8.5. In the next

[10] For an accessible introduction to Bayesianism, see Peter Godfrey-Smith, *Theory and Reality: An Introduction to the Philosophy of Science* (Chicago: University of Chicago Press, 2003), ch. 14. For a more technical discussion, see John Earman, *Bayes or Bust: A Critical Examination of Bayesian Confirmation Theory* (Cambridge, MA: MIT Press, 1992).

section, though, let us take a step back and talk about cost-benefit analysis in general; the relationship between cost-benefit analysis and precautionary approaches will receive further discussion in subsequent sections.

8.3 Cost-Benefit Analysis

Section 8.2 was meant to have two upshots. First, I wanted to try to conceptualize risk: various conceptions were considered and a proposal was issued to focus on the expected outcome conception. Second, I wanted to highlight the central role that uncertainty plays in risk, including the various guises under which it can appear. Now I propose to consider how cost-benefit analysis can be applied to decision-making under risk, with particular emphasis on how it looks under conditions of uncertainty.[11] This emphasis will be used to motivate precautionary approaches, though I will then return to the relationship those approaches bear to cost-benefit analysis.

Imagine that we are considering whether to perform some action, say φ. If we knew that φ had good consequences G and bad consequences B, then we could just think about whether the net effect was positive or negative (i.e., whether $G - B > 0$). There are a lot of challenges here: the consequences need to be commensurable, they probably need to be (at least somewhat) quantifiable, people might disagree on how to weight them, and so on.[12] But we can imagine stripped-down examples that elide all of these interesting features. Imagine that we are running a business and are considering some marketing plan for the new the new carbon nanotubes that our company has just developed; furthermore imagine that the marketing plan would cost $10,000 to execute and would increase our sales by $20,000. Finally, imagine that there are no other marketing plans under consideration and that, given your fiscal cycles, the decision has to be made immediately (i.e., before any other marketing plans could be developed). In this case, it seems straightforward that we should effect the plan since the benefits outweigh the costs, there are no other alternatives to consider, there are none of the messy complexities mentioned above, and so on.

[11] For our purposes, various nuances and conceptions of cost-benefit analysis are largely unimportant, though there is an important literature in this regard. One of the most ardent defenders of cost-benefit analysis is Richard Posner; see, for example, his *Catastrophe: Risk and Response* (New York: Oxford University Press, 2004). Cass Sunstein has written extensively on this topic; see, especially, his *The Cost-Benefit State* (Washington, DC: American Bar Association, 2002) and *Risk and Reason: Safety, Law, and the Environment* (Cambridge: Cambridge University Press, 2004). Frank Ackerman and Lisa Heinzerling critique cost-benefit analysis in *Priceless: On Knowing the Price of Everything and the Value of Nothing* (New York: New Press, 2003). Sunstein offers a review essay of contemporary scholarship, including Posner (2004) and Ackerman and Heinzerling (2003) in "Cost Benefit-Analysis and the Environment", *Ethics* 115 (2005a): 351–385. See also Kristen Shrader-Frechette, *Taking Action, Saving Lives: Our Duties to Protect Environmental and Public Health* (New York: Oxford University Press, 2007).

[12] See, for example, W. Kip Viscusi, *Fatal Tradeoffs* (New York: Oxford University Press, 1993). See also Ackerman and Heinzerling (2003).

Now imagine that, unlike the epistemic certainties of that case, there is the sort of epistemic uncertainty postulated in (1) above: we have known probabilities, but not certainties. The marketing plan still costs $10,000 to execute, but there is a 40 % chance that it will fail, thus eliciting no increased sales. There is a 60 % chance that it will succeed, thus eliciting the $20,000 in increased sales. All other details are the same. What do we do now? We already know the costs with certainty (viz., $10,000), but there is uncertainty about the benefits. We therefore calculate the expected benefits, which are: *0.4*$0 + 0.6*$20,000 = $12,000*. The $12,000 in expected benefits is greater than the $10,000 in actual costs so we are still justified in pursuing the marketing plan, even given the possibility of its complete failure. Cost-benefit analysis, then, works not only when we have certainty regarding outcomes, but also when we have uncertainty but known probabilities.

Again, there are numerous other complexities to the cost-benefit approach; some were mentioned above. Returning to our earlier example of the river purification project, imagine that 100 fish will be killed, but the local township will have cleaner drinking water. These sorts of assessments have myriad complexities. Some of them are empirical: how *much* cleaner would the drinking water be? Would this *matter* in any significant way, such as health outcomes? Again, how *much*? And then come the issues of commensurability and values: imagine that the purification, while killing 100 fish, will lead to a 10 % decrease in the local incidence of a certain waterborne disease, giardiasis, while having no other demonstrable effects. Is this worth it? There are not general answers to these sorts of questions, though we will return to some of them below; I just want to acknowledge some of these complexities.[13]

But, for present purposes, let us press on with our discussion of uncertainty. As shown above in the marketing plan cases, cost-benefit analysis seems promising when dealing with either known outcomes or else with known probabilities. Known outcomes, though, are not instances of risk at all, and so are not germane to that discussion. Cases of known probabilities, as mentioned in Sect. 8.2, are only likely to occur in idealized cases, such as ones involving fair dice and coins. While known outcomes or probabilities constitute positive epistemic statuses, these are not the epistemic statuses in which we are likely to find ourselves. Rather, we are more likely to find ourselves in (2)–(4) above: uncertain probabilistic knowledge, no probabilistic knowledge, and/or incomplete knowledge about outcomes. What guidance can cost-benefit analysis offer us now? Return to the marketing example and make the parameters as follows: the plan still costs $10,000 to execute, and it will either increase our sales or it will not (known outcomes). Imagine there to be a 40–80 % chance that the plan will succeed in increasing revenues and a 20–60 % chance that it will not (i.e., such that the chances of success and failure sum to 100 %); our experts just cannot agree on the proper assessments. As before, sales go up by $20,000 if the plan is successful. Do we implement it? It is hard to figure out what to say. We could try to effect the sort of uncertainty reduction discussed above: maybe we act as if the probabilities are in the middle of the ranges, thus there being a 30 % chance that the plan will fail and a 60 % chance that it will succeed.

[13] Sunstein (2002), pp. 153–190 offers more discussion in a chapter called "The Arithmetic of Arsenic".

The expected outcome, then, is $12,000, which means that we should execute the plan. But there is something overly simplistic about this approach. For example, even though there was a 20–60 % chance of failure, it hardly follows that the *actual* chance of failure is 30 %; all we really know is that the probability falls somewhere within that range. The same is true with the probability of success. Maybe the actual chance of failure is 60 % and the actual chance of success is 40 %. In that case, the expected increase to sales is $8,000, which is less than the cost of the marketing plan, so it should not be pursued. So, unlike when we know the probabilities and such privileged epistemic status leads to infallibility, we could make the *wrong decision* by applying cost-benefit analysis (in the above way, at least) when the probabilities are uncertain.

It is even worse when we move from limited knowledge of probabilities to no knowledge of probabilities. Imagine that we are considering the marketing plan, but we just have *no information* whether it will succeed or fail; maybe the CEO calls in looking for an immediate decision while all the relevant advisors are indisposed. Should we pursue the plan? As mentioned above, we could just give arbitrary assignments of probability to each outcome, 0.5 being the most plausible in cases of full ignorance. So there is a 50 % chance that it will succeed and a 50 % chance that it will fail, with an expected outcome of $10,000. Since this is how much the plan cost, we are neither any better nor any worse off by pursuing it or not. But this is almost certainly the (objectively) wrong answer since *any* other probability assignment would give a deterministic answer about our course of action. It is worse yet again if we do not even know what the outcomes are. Imagine that, unbeknownst to us, the marketing plan infringes on copyrights held by another company, thus exposing us to legal liability. If there is a 60 % chance of success and a 40 % chance of failure, then we might put our expected outcome on $12,000, thus meaning that we should pursue the plan. But this would actually be a disaster because, once we release it, we get sued for $50,000. Obviously, if we do not have all the information regarding outcomes, our abilities to make good decisions can be compromised.

These epistemic situations—(2)–(4) from above—are the ones in which we are most likely to find ourselves, and we see how cost-benefit analysis can get the wrong answer in these cases. This is not to say that we should not use cost-benefit analysis; indeed, as we will see in Sect. 8.5, it is not obvious that there is even an alternative. Rather, the point is just to show how uncertainty challenges cost-benefit analysis. This should not be surprising as uncertainty challenges *any* decision making approach but, in these contexts, we might think more about how and when to move forward on decision-making. Return to the above example where the CEO needs a decision on whether to effect the marketing plan, and we do not have any information on its prospects. One thing we might consider is to delay the decision until we have more information. Or, in the case where there is some unknown lawsuit waiting in the wings should we pursue the marketing plan, maybe we should not pursue the plan until we have reasonably convinced ourselves that no lawsuits are likely, or that there are any other negative externalities. I shall critically evaluate these possibilities in Sect. 8.5, but now let us consider the sort of approach that they suggest: precaution.

8.4 Precautionary Principles

Cost-benefit analysis under uncertainty poses risks, namely the risk of making the wrong decision. If we could somehow reduce the uncertainty, then we would occupy an improved epistemic status and be correspondingly more likely to make the right decision. The most obvious way to get rid of uncertainty is to hold off on making the decision until we have better knowledge regarding probabilities and outcomes. For example, if there is uncertainty regarding the probability of some outcome, then we could do more research and try to reduce the uncertainty. If there are unknown outcomes, then we could take more time and try to make sure that we have uncovered all of them. Particularly when we risk substantial and negative consequences, we should be wary of making hasty decisions. To wit, we might adopt something like a "precautionary principle".[14] Part of the challenge with the precautionary principle approach is getting clear about exactly what such a principle says, and various formulations abound. Charitably, there definitely seems to be merit to a principle that says we should not act hastily given the potential for substantial and negative consequences. When we try to pin down the details, though, it gets somewhat more complicated. Precautionary principles have been offered in various contexts, with environmental applications being the most common; the reasons for this emphasis will become more clear below.

From the outset, let us look at some actual precautionary principles in the hopes that we can try to understand their key features. There are many different formulations, as codified in national laws or international treaties.[15] For present purposes, however, we can take the context of issuance, as well as details regarding the issuing bodies, to be largely irrelevant. Consider the following three examples, which are representative. The first comes from the 1992 Rio Declaration of the UN Conference on Environment and Development (2008) (Principle 15)[16]:

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

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[14] Note that much of the literature refers to *the* precautionary principle, though I shall talk about *a* precautionary principle or else precautionary principle*s*. The reason is that there is hardly any sort of definitive statement of "the" precautionary principle, but rather many different formulations that bear various relations to each other.

[15] Sunstein (2005a) argues that Europe has been more sympathetic to precautionary approaches whereas the US has defended cost-benefit analysis (p. 351). I am more interested in the philosophical underpinnings of the approaches than their applications, but this phenomenon bears notice. See also Sunstein (2002). See also Arie Trouwborst, *Evolution and Status of the Precautionary Principle in International Law* (London: Kluwer Law International, 2002). Finally, see Poul Harremoës et al. (eds.), *The Precautionary Principle in the 20th Century: Late Lessons from Early Warnings* (London: Earthscan, 2002).

[16] Available online at http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm (accessed July 27, 2013).

Another formulation is the 1998 Wingspread Consensus Statement on the Precautionary Principle, which holds that "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically."[17] And, finally, consider the European Union's Communication on the Precautionary Principle (2000):

> The Communication underlines that the precautionary principle forms part of a structured approach to the analysis of risk, as well as being relevant to risk management. It covers cases where scientific evidence is insufficient, inconclusive or uncertain and preliminary scientific evaluation indicates that there are reasonable grounds for concern that the potentially dangerous effects on the environment, human, animal or plant health may be inconsistent with the high level of protection chosen by the EU.[18]

These formulations are so varied that it is not even immediately obvious what they all have in common. We are told of a precautionary approach, precautionary measures, and a precautionary principle, though it hardly seems clear what any of these entails; reading the full documents, rather than just these excerpts, is not much more help. Risk (or threat) resounds throughout the different formulations, as does lack of evidence or certainty. But how do these pieces fit together in any meaningful sort of way? And, furthermore, how can we use those pieces to yield a *generalized* precautionary principle that abstracts away from the particular language used in these cases? In other words, what is the *logical structure* of precautionary principles? Is there one that they all share?

Before moving forward, it is worth acknowledging that much of the discussion regarding precautionary principles takes place in environmental contexts. The reason, as should become clear, is that the environment is an especially complex system; this complexity then gives rise to a lot of uncertainty regarding risks. For example, consider the introduction of rabbits into Australia.[19] Rabbits first came to Australia in the late 1780s, though the population explosion is thought to date to 1859. That fall, a landowner living near Melbourne released 24 rabbits into the wild to simulate British hunts, and other landowners then followed suit. Within 10 years, there were literally millions of rabbits in the wild, and as many as 600 million nationwide by the mid-1900s; there are myriad ecological reasons for this population explosion, including mild winters and widespread farming (i.e., availability of food). The effects on Australia's environment have been disastrous, from species loss to erosion. Various countermeasures have been employed, such as shooting, poisoning, and fencing. Most dramatic (and effective) was the intentional introduction of a myxomatosis, a disease fatal to rabbits; the disease caused the rabbit population to fall to approximately 100 million, though resistance eventually spread.

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[17] Available online at http://www.sehn.org/wing.html (accessed July 27, 2013).

[18] Available online at http://ec.europa.eu/dgs/health_consumer/library/press/press38_en.print.html (accessed July 27, 2013).

[19] For a further discussion of this account, see Tim Low, *Feral Future: The Untold Story of Australia's Exotic Invaders* (Chicago: University of Chicago Press, 2002). For a more general theoretical account of invasive species, see Julie Lockwood, Martha Hoopes, and Michael Marchetti, *Invasion Ecology* (Hoboken, NJ: Wiley-Blackwell, 2006).

Australia again has in excess of 300 million rabbits, despite the introduction of calicivirus—another biological measure—in 1996.

The upshot of this example is that apparently trivial and benign acts can have catastrophic consequences: the release of 24 rabbits led to a rabbit population of over 600 million with dire economic and environmental impacts. Furthermore, those consequences could be unpredicted (or unpredictable) given the best scientific and other theories available. In addition to the consequences being negative and substantial, they can also be *irreversible*.[20] Once those first rabbits were released, thus began an inexorable march to the present circumstances. This is not to say that things could not possibly have been any other way than exactly as they are today (i.e., the first round of hunters could have caught all of their prey, myxomatosis could have had a slightly different epidemiological trajectory, etc.), only that the impacts on the relevant environmental system have been so substantial that any sort of complete remediation of the problem is virtually impossible. And, pragmatically, aside from the hunters catching all/most of the first rabbits, some roughly similar cascade of events would probably already have been prefigured.

More generally, any intervention into a well-functioning and complex system can have profound (and often negative) consequences. By definition, complex systems have many parts that fit together in complicated ways. Affecting either the parts or the relationships among them can have implications for the other parts and their interactions. Furthermore, feedback cycles can multiply these effects. And, finally, complex systems are the most epistemically intractable. In such systems, we are almost certain to have limited knowledge about their proper functioning and, therefore, knowledge about how some intervention will affect that functionality. As in the case of the Australian rabbits, small perturbations can be disastrous. The environment is obviously one such system, but there are others. Perhaps most analogous is the human body, on which many emerging technologies bear (e.g., genetic technologies, nanomedicine,[21] and so on). Human enhancement continues to receive much attention and is another realm in which complex systems carry novel challenges.[22] The present point, though, is just to establish the particular risks that complex systems offer, given our limited knowledge about them. As intimated and exemplified above, many precautionary approaches derive in environmental contexts for exactly this reason. Now we have seen the motivation for precautionary

[20] The concept of irreversibility is hardly transparent, though we shall not pursue further discussion here. For some of the conceptual complications, see Cass R. Sunstein, "Two Conceptions of Irreversible Environmental Harm" (May 2008). *University of Chicago Law & Economics, Olin Working Paper No. 407*. Available at http://ssrn.com/abstract=1133164 (accessed June 6, 2009). See also Neil A. Manson, "The Concept of Irreversibility: Its Use in the Sustainable Development and Precautionary Principle Literatures", *Electronic Journal of Sustainable Development* 1.1 (2007): 1–15.

[21] See, for example, Fritz Allhoff, "The Coming Era of Nanomedicine", *The American Journal of Bioethics* (in press).

[22] See, for example, Patrick Lin and Fritz Allhoff, "Untangling the Debate: The Ethics of Human Enhancement", *Nanoethics: The Ethics of Technologies that Converge at the Nanoscale* 2.3 (2008): 251–264.

principles: to recognize the potential for dramatic and irreversible damage in complex systems and to appreciate the limited epistemic situations in which we are likely to find ourselves in regards to those systems. With this in mind, let us return to our discussion of the logical structure of precautionary approaches.

In doing this, let us consider work done by Neil Manson.[23] Manson develops an account of precautionary principles by first looking to see what sorts of generic features they share; he then considers what relationship those features have to each other. In doing so, he does not presuppose that there is a single and general precautionary approach, as those features might have different relationships (or even be different) in different formulations. Nevertheless, he thinks that there is at least something that the different formulations must have in common in order for them to be plausibly considered precautionary principles.

Manson argues that given some *activity*, which may have some *effect* on the environment, a precautionary principle must indicate some *remedy*.[24] I think this sounds right, though a couple comments are worth making. Note the use of 'may', which bears emphasis. Central to all precautionary approaches is the notion of uncertainty: if we knew what the consequences were, then we could just see whether the net effect was positive or negative. Even if we had known probabilities for the consequences, we could formulate an expected outcome, as we worked through in Sect. 8.3. But, if we have unknown probabilities or unknown outcomes, everything becomes more complicated; I used these unknowns to motivate the idea of precaution in the first place. So it is critical to precautionary approaches that there be unknowns, as is reflected by 'may' above; other weak modal language, like 'possible', would also be appropriate, though see further discussion below. Second, Manson frames his discussion explicitly in terms of the environment, but I think that it generalizes beyond that context; as mentioned above, there are other contexts in which we have the same salient features, and my discussion will apply to those contexts as well. In what follows, I will offer the discussion at this more general level.

In addition to this acknowledgment of activities, effects, and remedies, Manson then argues that all precautionary principles must share a three-part structure. The first part is the *damage condition*, which specifies some characteristics of the effect in virtue of which the precautionary approach is warranted. The second part is the *knowledge condition*, which specifies the state of scientific knowledge regarding the relationship between the activity and the effect. Finally, the third part specifies the *remedy*, which is the course of action that decision-makers should take vis-à-vis the activity. Putting this all together, all precautionary principles must share this structure: if the activity meets the damage condition and if the link between the activity and the effect meets the knowledge condition, then decision-makers ought

[23] Neil A. Manson, "Formulating the Precautionary Principle", *Environmental Ethics* 24 (2002): 263–272. See also Per Sandin, "Dimensions of the Precautionary Principle", *Human and Ecological Risk Assessment* 5.5 (1999): 889–907 and Carl F. Cranor, "Toward Understanding Aspects of the Precautionary Principle", *Journal of Medicine and Philosophy* 29.3 (2004): 259–279.

[24] Manson (2002), p. 265.

to effect the remedy. This is a very general structure, leaving many possibilities for particular precautionary principles. For example, consider the damage conditions, which could characterize the relevant effects in any of the following ways, among others: serious, harmful, catastrophic, irreversible, destructive of something irreplaceable, reducing or eliminating biodiversity, violating the rights of future generations, and so on. Knowledge conditions could invoke parameters like: possible, suspected, indicated by precedent, reasonable to think, not certainly ruled out, not reasonably ruled out, etc. And remedies could be: bans, moratoria, postponements, research into alternatives, attempts to reduce uncertainty, attempts to mitigate the damage conditions, and so on.[25]

So, for example, we could say that if some effect is serious and possible given some activity, then we ought not to perform that activity. The damage conditions do not always scale in a simple way (i.e., in terms of increasing damage) but, to the extent that they do, as the damages become greater, then we might require improved epistemic status before avoiding the remedy. For example, imagine that the damages could be either "serious" or "catastrophic", the latter obviously being worse. And then imagine that knowledge conditions could be "possible" or "not certainly ruled out". If catastrophic harms are possible, then we might trigger the remedy more readily than we would were the harms to be merely serious. Since "not certainly ruled out" carries a higher epistemic threshold than "possible" (i.e., it requires us to have greater knowledge), we should apply that knowledge condition more readily to the catastrophic damages than to the serious ones, all else being equal.

But all else does not have to be equal: rather than adjusting the knowledge condition as the effects become more negative, we could also adjust the remedy. Keeping the knowledge condition the same, then, again think of whether the effects proffer serious or catastrophic harms. As the harms become more substantial, then the remedy can simply become more restrictive. For example, we could say that, if the harms are serious, then the activity should be postponed. Alternatively, we could say that, if the harms are catastrophic, then the activity should be banned. This is not to say that, in either case would the harms necessarily be realized—because of the uncertain relationship between the activities and the effects—just that, all else equal, the remedy should be sensitive to the damage condition. All this is to say (and somewhat contrary to Manson's presentation) that these three conditions are not completely interchangeable, but rather should be interrelated to each other such that the above comparative desiderata attain. Given two different harms, which should be adjusted, the knowledge condition or the remedy? It depends. In some cases, our epistemic situation might be fairly hard to improve, so we might then adjust the remedies as the harms look more severe. In others, it might be the case that the remedies are hard to move (e.g., for legislative reasons), so we might then adjust the knowledge condition.

There are other things worth discussing, though many of them take us too far afield. Let us nevertheless make a few more observations before moving on.

[25] These various possibilities are adapted from Manson (2002), p. 267.

First, note that the knowledge condition effectively amounts to a burden of proof issue between the would-be practitioners of the activity and its opponents.[26] As this condition becomes more stringent proponents of the activity have more work to do in terms of ruling out some negative effect of their activity. For example, and perhaps counter-intuitively, 'possible' is more stringent than 'likely' in the sense that it is easier to rule out some effect being likely than its being possible; we might be able to show that it is not likely that our carbon nanotubes will have some negative effect on the environment without being able to show that such an effect is impossible. Whether we are willing to proceed with some activity given a possible effect rather than a likely effect, as suggested above, probably has to do with what that effect is, as well as whatever other recourses are available to us vis-à-vis remedies. Second, the remedies postulated by precautionary principles are quite commonly bans on the corresponding activities, though this hardly need be the case; above, we saw a wide range of other available remedies. Bans might make particular sense as the effects become worse, but it bears emphasis that the precautionary approach is not committed in this way.

Having gone through much of this abstract and theoretical discussion, let us return to the examples of precautionary principles presented above in order to see how well this theoretical account holds up against actual principles.[27] Consider again Principle 15 from the 1992 Rio Declaration of the UN Conference on Environment and Development (2008):

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.[28]

The damage condition here is explicit, namely that the specified damages are ones that are "serious or irreversible". The knowledge condition is also apparent: lack of full scientific certainty. The remedy is the non-postponement of measures to prevent environmental degradation. Putting it all together, and simplifying some of the language: If the damages are serious or irreversible, and if we lack full scientific certainty that those damages will occur, then we should not postpone measures to prevent environmental degradation. These statements are hardly transparent, though recognition of the underlying logical structure is definitely useful. To make this even less abstract, return to our example about river purification with nanoparticles. If we cannot rule out (cf., lack of scientific certainty) the possibility of those nanoparticles destroying the biodiversity of the river (cf., serious and irreversible), then we should not postpone measures that would prevent those harms. Those

[26] For more discussion, see Carl F. Cranor, "Asymmetric Information, the Precautionary Principle, and Burdens of Proof" in Carolyn Raffensperger and Joel Tickner (eds.), *Protecting Public Health and the Environment: Implementing the Precautionary Principle* (Washington, DC: Island Press, 1999), pp. 74–99.

[27] Though also see Cranor (1999) for more discussion.

[28] Available online at http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm (accessed July 27, 2013).

measures could include, for example, preventing the use of the nanoparticles at all. Now that we have a well-formed conception of the precautionary principle, let us subject it to critical evaluation.

8.5 Evaluating the Precautionary Principle

In evaluating precautionary approaches, it will be useful to have a particular conception in mind. The account developed above gives us the logical structure of precautionary principles, and there is nothing inherently problematic with a formal proposal that, given some potential for damage and given some epistemic status regarding the causal links between some activity and that damage, we should then effect some remedy. Rather, it is when we start specifying the damage condition, knowledge condition, and remedy that substantive critiques are possible. The hazard of picking a specific precautionary principle, though, is that criticisms of it will not necessarily apply to other variants; those variants could have different features that immunize them from the criticisms. Aware of this hazard, we nevertheless propose to proceed by focusing on a particular conception, though we will offer discussion of alternatives as we proceed.

The specific principle that we will consider is that one that is most commonly discussed in the literature: the catastrophe principle.[29] This principle specifies the damage condition as catastrophic, as opposed to lesser damages, such as harmful or serious ones. Its knowledge condition specifies possibility, which is comparatively permissive: a lot of effects are possible even if they are not, for example, likely. And, finally, the remedy is a ban. As mentioned above, bans are common remedies offered by precautionary principles even if they are not, strictly speaking, required by such principles. So let us specify the catastrophe principle as follows: if, given some activity, some catastrophic effect is possible, then we should ban the activity. This formulation is substantive enough to be evaluated (i.e., the constitutive parts are specified) while still being general enough that the following discussion cuts across various ways it could be further specified vis-à-vis the particular activities or effects. There are three broad sorts of criticisms that have been lodged against this formulation; we shall consider them in turn.[30]

The first criticism goes to the knowledge condition, particularly its (extremely) weak modal operator: possibility. On the catastrophe principle, mere possibility of some catastrophe is enough to produce a ban against some activity. It is possible, in at least some sense, that some nanotechnology could destroy the world. Surely that is catastrophic; ergo, no nanotechnologies. But what is the sense of 'possibility' that matters? It has to be something stronger than mere logical possibility: it is

[29] See also Manson (2002), pp. 270–274. Note that Posner (2004) explicitly defends cost-benefit analysis even under prospective catastrophe.

[30] See also John Weckert and James Moore, "The Precautionary Principle in Nanotechnology", *International Journal of Applied Philosophy* 2.2 (2006): 191–204.

(logically) possible, for example, that our nanotechnology could lead, tomorrow, to some catastrophe on some inhabited planet in the deepest recesses of some other galaxy. But surely this is not physically possible, if for no other reason than it could not get there fast enough. Rather, what we need is some sort of physical possibility or, even better, empirical possibility: things may be physically possible that are nevertheless not likely to happen (e.g., decreased entropy in some complex system). This sort of possibility at least forestalls straw man objections against the catastrophe principle.[31]

Still, though, empirical possibility is extremely weak: a *lot* of things are empirically possible. For example, consider the notion that self-replicating nanobots will somehow cause human extinction. Is that empirically possible? In some sense, yes: these nanobots could replicate to the extent that they take over whatever environments humans would otherwise occupy. Is this likely? No. Does any reasonable scientific evidence suggest that it would happen? No. But is it (empirically) *possible*? Yes. So, on the catastrophe principle, it would seem that we cannot have whatever technology might give rise to the nanobots. This seems like the wrong answer, though, particularly given the (extreme) unlikelihood that these negative consequences would be realized.

Proponents of such an approach, however, could point out that the *magnitude* of the catastrophe justified the triggering of the remedy (e.g., a ban) *despite* the low probability of the catastrophe. And there has to be at least something right in this sentiment. Consider, for example, two cases. In the first, something extremely bad is going to happen with a 1 % probability and, in the second, something somewhat bad is going to happen with a 50 % probability. Which scenario is better? It has to matter what the magnitudes of the bad effects are. Imagine that we could render them financially, just to make the conceptualization simple. The first case has a 1 % chance of having US$1B in damage. The second has a 50 % chance of having US$1M in damage. Even though the probability is lower in the second case, the expected damages are 20 times higher in the first case. Therefore, we cannot just look at the (low) probability and say that we should proceed regardless. But what if the probabilities are really low and the consequences really bad (cf., the self-replicating nanobots)? From an expected outcome approach, it does not matter; these would just "cancel out", thus giving results commensurable with more moderate values.

This gives rise to a second worry about the precautionary principle, which is to identify its relationship to traditional cost-benefit analysis. I think that this relationship has been poorly understood, particularly insofar as the precautionary approach is sometimes characterized as an "alternative" to cost-benefit analysis.[32] To motivate

[31] For more discussion, see David B. Resnik, "Is the Precautionary Principle Unscientific", *Studies in the History and Philosophy of Biological and Biomedical Sciences* 34 (2003): 329–344.

[32] See, for example, Manson (2002), p. 264; Weckert and Moor (2006), p. 191. Sunstein (2005a) alleges a "tension" between precautionary and cost-benefit approaches (p. 352) though then goes on to suggest that the views are "complementary" (p. 355). These certainly look like different claims, but I am ultimately sympathetic to the latter, as will be expressed below.

this part of the dialectic, consider that the precautionary approach is either something new (vis-à-vis cost-benefit analysis) or else it is not. On the former, it is supposed to be problematic and, on latter, it is not even interesting. Starting with the latter, remember that the defender of the catastrophe principle owes us some account of 'possible', both in terms of what it means and why it matters. Following the above discussion, let us assume that it means something like "empirically possible" and it matters because, despite the low probabilities, the potential effects are catastrophic. This sounds perfectly plausible, but then it just says the same thing as cost-benefit analysis; cost-benefit analysis can certainly accommodate low probabilities of catastrophes in terms of formulating expected outcomes.

Another way to go is to say that the precautionary principle really is saying something different. For example, the defender of the precautionary approach might deny that the environment is or has some singular value, which is commensurable among other values. Given that there is some catastrophic risk to the environment—however unlikely—that risk just trumps all other considerations. This sort of line is different from cost-benefit analysis in the sense that the latter would allow us to consider the *benefits* of some activity, rather than merely having to stop at an identification of the risks. But, for a number of reasons, this has to be wrong. First, it allows extremely low probabilities to derail entire activities. (Again, one could point to the magnitude of the consequences, but then this just brings us back to the first horn of the dilemma.) Second, these low probabilities—which nevertheless establish *possibility*—could be effectively impossible to reduce to zero. Imagine we can show a 1 % chance of some effect, or a 0.1 % chance, or a 0.01 % chance: in no case have we shown that it is impossible. If the precautionary approach is meant to do something different than cost-benefit analysis, then it would be paralyzing. Third, this is simply irrational. Imagine that, if we φ'd, there was an X % of some cost C; further imagine that C is really bad. Should we φ? It is impossible to even conceptualize this question without knowing benefits would attain by φ'ing (as well as their associative probabilities). Imagine there is some evil deity who asks for a tithe, lest he destroy the planet. Furthermore, imagine that he might destroy the planet anyway, given the (remote) probability that he finds the tithe unacceptable. So, if we tithe, then it is possible that he will destroy the planet. The defender of the catastrophe principle therefore has to say that we cannot tithe, even if the deity will certainly destroy our planet if we do not. This does not make any sense: it is completely irrational to allow remote risks to completely preclude our consideration of the associative benefits for some course of action.

The evil deity example gives rise to a third criticism of the catastrophe principle; this criticism holds not just that the principle is false, but rather that it is incoherent. Consider Cass Sunstein: "Because risks are on all sides of social situations, and because regulation itself increases risks of various sorts, the principle condemns the very steps that it seems to require."[33] So imagine that it is possible that some activity

[33] Sunstein (2005a), p. 355; see also pp. 366–369. Sunstein means this criticism to apply to the precautionary principle more generally, rather than to the catastrophe formulation in particular. I disagree and think that the criticism, at best, attaches to catastrophe-like formulations because

give rise to some catastrophe. Therefore, we ban that activity. But surely it is possible that *the ban* risks a catastrophe as well. So we cannot ban the activity. Return to our example about water purification using nanoparticles: this practice could (even if not likely) have disastrous effects on the environment. But a failure to have clean water could (and probably more likely would) lead to disastrous effects, particularly vis-à-vis the world's poor who are increasingly without drinking water.[34] The effects on them directly are bad enough, but there could be added effects in terms of political destabilization, global conflict, and so on. The catastrophe principle would say that we cannot purify the water and, similarly, that we cannot effect the ban against the purification. In other words, it says we cannot φ and we cannot ~φ. This is logically impossible, therefore the principle is incoherent. The incoherence charge is a strong one, and certainly one best avoided. For example, so long as one of the catastrophic effects is more likely than the other (e.g., as follows from φ or ~φ), then maybe the advocate just guards against the most likely catastrophe. But this would require further emendation to the principle, and then risks some of the other criticisms presented above.[35]

Having seen various criticisms, let me now offer my own view.[36] I think that there are two fundamental issues with precautionary approaches. The first has to do with the knowledge condition. In the catastrophe formulation, mere possibility was enough to force the ban on some activity. Some people have wanted to say that this leads to bans too easily since negative effects will always be possible, even in our sense of empirical possibility. This does not worry me, though, because of the potential magnitude of those effects. If the probability of the effects is really low, but the negative consequences of the effects are really high, then we should take the risk seriously. Part of the problem is undoubtedly epistemic as we will not always know what the probabilities are, and we certainly cannot rule out that they are zero (as the catastrophe approach would seemingly require). I will return to that below, but suffice it to say, that unlikely but catastrophic risks should obviously play a part in our decision-making. We hardly need a precautionary approach, though, to tell us that; no reasonable person would deny it.

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different knowledge conditions (e.g., ones requiring "likely" rather that "possible") are unaffected by the criticism. See also Cass R. Sunstein, "Beyond the Precautionary Principle", *Pennsylvania Law Review* 151 (2003): 1003–1058 and Cass R. Sunstein, *Laws of Fear: Beyond the Precautionary Principle* (Cambridge: Cambridge University Press, 2005b). For a detailed response to the incoherence objections, see Jonathan Hughes, "How Not to Criticize the Precautionary Principle", *Journal of Medicine and Philosophy* 31 (2006): 447–464.

[34] See, for example, Allhoff et al. (2010), pp. 126–149.

[35] Another criticism, not presented here, is that precautionary approaches contribute to, and even promote, unfounded public fears. See Adam Burgess, *Cellular Phones, Public Fears, and a Culture of Precaution* (Cambridge: Cambridge University Press, 2004).

[36] For more detailed responses to some of these criticisms, see Stephen M. Gardiner, "A Core Precautionary Principle", *Journal of Political Philosophy* 14.1 (March 2006): 33–60. Gardiner defends a particular version of the precautionary principle, arguing that his formulation—different from the catastrophe principle—is immune to standard criticisms.

One obvious way to make the precautionary approach more permissive is to relax the knowledge condition. For example, we might say that the negative effects need to be, not just possible, but likely. This project becomes more epistemically tractable in the sense that it is easier to establish likelihood than it is to rule out possibility; this is not to say that establishing likelihood is easy, but ruling out possibility is extremely hard. Note that, pragmatically, this suggestion transfers the burden of proof from the proponent of some activity to its detractor. For example, we might not be able to rule out the possibility of self-replicating nanobots destroying the world, but can it be proven to be likely? Defenders of precautionary principles think that the burden of proof should be on the would-be facilitator of some catastrophe; opponents claim that the principles are too restrictive. Where should the burden of proof go? I do not think that this question or corresponding conception is very useful. Rather, what matters are what the risks *are*. They might be hard to determine but, conceptually, the risks are what matter, not where the burdens of proof fall. From a procedural or regulatory perspective, burden of proof might be important, but there are ways of dealing with it (e.g., further research, independent commissions). But, philosophically, the focus should be on the risks themselves.

This, then, brings us back to the second fundamental issue with the precautionary approach, which is its relationship to cost-benefit analysis. As suggested above, I think that there has been a lot of confusion regarding this issue, particularly in claims that precautionary principles are alternatives to cost-benefit analysis. Cost-benefit analysis cannot possibly be wholesale wrong as an approach to decision making. In our everyday lives, we continually weigh costs and benefits (discounted by their perceived probabilities) and make decisions based on those assessments; such an approach is almost the paragon of rationality.[37] If you were facing a great but unlikely benefit versus a great and likely benefit for opposing courses of action, which would you pick? The answer is so trivial as to lead us to wonder what all this dialogue over the precautionary principle is supposed to contribute.

There seem to be two possibilities in this regard. The first is that there are certain domains in which the precautionary principle is supposed to supplant cost-benefit analysis. For example, consider environmental contexts in which serious and irreversible harm is possible; this is the sort of context in which we often see precautionary principles surface. But why would cost-benefit analysis be ill-equipped to handle this situation? Certainly cost-benefit analysis can accommodate concepts like ‘serious’ and ‘irreversible’ since these have obvious upshots in terms of risk assessment. It cannot be those concepts that activate the precautionary approach as

[37] A similar attitude is expressed by Posner (2004), who argues that cost-benefit analysis “is an indispensible step in rational decision making”, even in under catastrophic risk (p. 139); quoted in Sunstein (2005a), p. 363.

an alternative to cost-benefit analysis. What about the environmental context itself? Maybe we should exercise extra caution when dealing with the environment because of the sort of thing that it is or the moral features that it has. Even if this is true, though, cost-benefit analysis would still work: only the *weighting* of the relevant considerations would change once we properly appreciated environmental values. In other words, imagine that we rally behind the precautionary approach because we really decide that the environment is important. What have we gained? We could just do cost-benefit analysis and maintain that environmental costs are really bad and environmental benefits are really good. If precautionary approaches effectively increase the weighing of environmental considerations, we could afford similar weightings through cost-benefit analysis.

Whoever wanted to defend the "supplanting" model would now have to argue that the environment is not simply one value among many—or even an important value, as cost-benefit analysis could surely accommodate—but rather that it is patently incommensurable with other values. So, the argument would go, we cannot use cost-benefit analysis because the environment is special and cannot be compared to other values. To figure out whether to destroy the Redwood Forest, we hardly focus on the joy that would be derived from the proposed theme park, or on how much money people would be willing to pay to access those trees as against the alternative theme park. This joy and the associative economic preferences are morally relevant, but these are incommensurable with the value of the forest.[38] Surely the forest must be preserved regardless. Or so the dialectic might proceed. However, it cannot be right that environmental values are incommensurable with others: imagine that terrorists will destroy the entire world unless we destroy a single tree. Save the tree? Forests and trees matter, but so do a lot of other things, and we have to have a complex value system that accommodates all of those values. For these reasons and those above, I therefore reject the idea that precautionary approaches are meaningful alternatives to cost-benefit analysis.

Rather, I think that precaution *supplements* cost-benefit analysis *given uncertainty*.[39] As we saw in Sect. 8.2, there are various epistemic situations in which we might find ourselves with regards to risk. If we know that some act A has an X% chance of realizing some benefit B while, at the same time, having a Y% chance of realizing some cost C, then we just compare X*B + Y*C with the alternatives to A and pick the best expected outcome. As I discussed in Sect. 8.3, this becomes more complicated when we do not know X or Y. It is even worse when we do not know B and C, either. Precaution is a risk-averse strategy for dealing

[38] A classic on this issue is Mark Sagoff, "At the Shrine of Our Lady of Fatima; or, Why All Political Questions Are Not All Economic", *Arizona Law Review* 23.4 (1981): 1283–1298.

[39] Cf., Posner (2004). See Gardiner (2006) for a contrary proposal.

with uncertainty.[40] If we know that there is an X %–Y % chance of some cost C, precaution might, for example, tell us to act *as if* the probability were the higher value, Y %. And, if we were considering some uncertain benefit, we might act as if the probability were the lower value. But this then integrates quite well with cost-benefit analysis: it just requires us to be conservative in our assessments.

Whether we should be conservative does not depend on the (non-epistemic) values at stake nor their probabilities, which are treated straightforwardly through cost-benefit analysis. Rather, the conservativeness is dictated by the (epistemic) value of uncertainty and our predilections against it. The disvalue of uncertainty is hardly obvious; there are certainly contexts in which most of us prefer it (e.g., opening presents). When making decisions about applications of nanotechnology, we just have to think about how tolerable uncertainty is, particularly given the potential consequences.

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[40] Consider, for example, Ackerman and Heinzerling (2003), who mean to be offering a critique of cost-benefit analysis and a defense of precaution. If, for example, our nation spends more than it needs to on regulatory protection, its "preference is to tilt toward overinvestment in protecting ourselves and our descendents." (p. 227); quoted in Sunstein (2005a), p. 359. But this "precaution" is just demonstrating a collective agreement that the prospective negative consequences are really bad and that we hardly want to countenance their actualization.

However, this is hardly antithetical to cost-benefit analysis, which has to be able to accommodate our preferences: what else would "cost" and "benefit" even *mean* as wholly independent of our preferences? There might be cases, like the forests, where we want to ascribe value independently of our preferences, but there are other cases, like whether to effect a tax increase to support a farm subsidy, that cannot be understood without thinking about how put off we would be by the tax increase, what impacts it would have on the food supply (and whether we would care about those), and so on.

So, when we "over"-invest, all we are doing is demonstrating that we take the cost to be worth the protection that it affords us against a negative outcome; this protection could be economic, psychological, moral, or symbolic. (Cf., for example, the war on terror, which almost certainly costs far more money than it could ever prevent in terms of economic damages.) This is not to say that we are infallible with all of our protective investments, though it is to say that we can rationally accommodate risk-aversion under a cost-benefit framework.

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Chapter 9
The Risks of Nanomedicine and the Precautionary Principle

Roberto Andorno and Nikola Biller-Andorno

9.1 Introduction

In a famous passage of his *Pensées* which aims to emphasize the need for humility about our limited capacities, Pascal calls the attention to the fact that we as human beings are engulfed between two infinite spaces, the infinitely great of the cosmos and the infinitely small of the microcosmic world. And he adds: "The eternal silence of these infinite spaces frightens me" ("Le silence éternel de ces espaces infinis m'effraie") (n° 187).

This intuitive terror of the abyss of infinite spaces that escape our senses and our control explains perhaps the fear that the development of nanotechnologies raises in many people's mind. This fear may be aggravated further when we are confronted with the idea that artificial microdevices could randomly circulate through our body, reaching all organs and tissues, maybe irreversibly, no matter what therapeutic purpose they could serve.

The aim of this chapter is firstly to discuss the potential adverse health impacts of medical nanotechnologies, and secondly, to address the role, if any, that the precautionary principle could play in this field in order to protect public health from serious harm.

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9.2 The Uncertain Risks of Nanomedicine

Nanomedicine has been defined as the "comprehensive monitoring, control, construction, repair, defense, and improvement of all human biological systems, working from the molecular level, using engineered nanodevices and nanostructures" (Freitas 1999). Nanomedicine is, in a broad sense, the application of nanoscale technologies to the practice of medicine, namely, for diagnosis, prevention, and treatment of disease and a better understanding of underlying pathological mechanisms (Bawa and Johnson 2007).

There is no doubt that the potential beneficial impact of nanomedicine on health care practice and on society is huge. Nanotechnologies could drastically improve patients' quality of life, reduce societal and economic costs associated with health care, offer earlier detection of diseases, provide better targeted drug delivery and with less side effects than current treatments, and result in a substantially improved clinical outcome for patients.

However, while the expected benefits of nanomedical technologies are widely publicized and "hyped" by the media, serious discussion of their potential negative impact on health is just beginning. This can be explained by the difficulty of predicting in advance what kinds of issues nanomedical technologies will raise. However, on the basis of other biomedical technologies that have posed ethical problems in the past as well as the potential risks that nanotechnologies in general pose, it is possible to conjecture some of the moral dilemmas that nanomedicine might raise. Such issues mainly relate to the possible toxicity of nanomaterials, to the increasing gap between diagnostic and therapeutic capabilities that nanomedical technologies may create, to need to protect patients' confidentiality, and eventually to the use of nanotechnologies for enhancement purposes.

9.2.1 Toxicity of Nanomaterials

At present, the most diffused and immediate concern about possible adverse health impacts of nanomedicine is related to the potential *toxicity* of nanoparticles. It is the same unique chemical and physical properties of nanomaterials that explain the interest in their exploitation for medical purposes (such as high surface reactivity and ability to cross cell membranes) that raise concerns whether they might result in specific toxicological properties. Although studies performed to date are inadequate to provide a full picture of the risks of engineered nanomaterials, they offer reason for concern. Studies have demonstrated that some nanomaterials can be toxic to animals as diverse as fish and rats (Balbus et al. 2005; Borm et al. 2006). In this respect, it is often suggested that nanomaterials could become a kind of "new asbestos", i.e. a product initially hailed as a wonder material thanks to their unique properties, but which later is found to be extremely dangerous for health.

Nanoparticles could have greater toxicity due to both their small size and their ability to carry large loads of toxic substances into various organs and tissues.

Paradoxically, the smaller the particles that enter into some organs (e.g., the lungs), the greater is the harm they could cause (Hett et al. 2004, at 16). Nanoparticles enter into the body through various routes. They can be inhaled, ingested, and possibly also enter via the skin; they can also be deliberately introduced into the body in the form of drugs. In these various ways they can get into the blood stream, circulate round the body and reach different organs and tissues. Special attention is paid to particularly vulnerable organs such as the brain, because nanoparticles have the potential to cross the blood-brain barrier, which normally restricts the entrance into the brain of potentially harmful chemicals from the blood. This ability of nanomaterials creates new hopes when it comes to get drugs into the brain, but also entails new risks. What if certain nanoparticles enter into the brain when in fact they were intended to reach another part of the body (for instance, to attack a tumor)? What if they accumulate in the brain, producing a lasting change in this delicate organ? Some advance that neurodegenerative diseases, such as Alzheimer's or Parkinson's, may result from this invasion of the brain by nanoparticles (Hett et al. 2004, at 24). In this respect, a study by Oberdörster showed that fullerenes (buckyballs) cause significant oxidative damage in the brain of juvenile largemouth bass. The author concludes that "it is possible that [adverse] effects in fish may also predict potential effects in humans." (Oberdörster 2004). In addition to this, a number of pathologies, including hypertension and allergic encephalomyelitis have been associated with increased permeability of the blood-brain barrier to nanoparticles in experimental set ups (Borm et al. 2006).

Nanodevices could also damage the body's natural defences or, conversely, cause increased responses to common allergens. This may happen because nanoparticles, if they exceed a certain threshold, could "overload" the phagocytes (white blood cells), which are responsible for destroying invading micro-organisms. This "overloading" of phagocytes would, on the one hand, cause inflammation in the surrounding tissue and, on the other hand, prevent the phagocytes from performing their function in other parts of the body and therefore weaken the body's resistance to disease (Hett et al. 2004, at p. 16).

The surface reactivity of nanoparticles could also lead to the formation of free radicals (i.e. atoms or molecules with an unpaired number of electrons), which are highly reactive and can damage or destroy cells and cause inflammation (Hett et al. 2004, at p. 16). In this respect, the potential carcinogenic effect of nanoparticles (especially on the lung) is another important issue that needs to be further explored. Since surface reactivity is known to be a factor that influences inflammation (Duffin et al. 2002), the ability of any particle to cause chronic inflammation and fibrosis, and therefore to be potentially carcinogenic, will depend on the product of surface area and reactivity. This has important implications for manufactured nanoparticles, which have high surface reactivity. This means that, at least theoretically, nanoparticles have a potency to induce lung tumours, even if there is no definitive evidence of this relationship yet (SCENIHR 2007, at para. 3.4.3.5; and 4.1.3.9).

Furthermore, a 2005 study by Zhao et al. (2005) predicted that DNA repair, another vital biological system that operates at the nanoscale, is also susceptible to modification by nanoparticles. When DNA is damaged, fullerenes can occupy the

damaged site, possibly impeding the self-repairing process of the double-strand DNA and thus negatively impacting on the structure, stability, and biological functions of DNA molecules (Balbus et al. 2007).

In sum, the above mentioned examples suggest that there are reasons to fear that the unique interactions between nanoparticles and human biological systems may lead to unintended harmful consequences for human health.

9.2.2 Increasing Gap Between Diagnosis and Therapy

Nanomedical technologies will eventually provide the ability to detect and characterize individual cells, subtle molecular changes in DNA, or even minor changes in blood chemistry. This means that the possibilities of early detection of diseases could become considerably more precise than at present. But on the other hand, this greater diagnostic accuracy may also create new ethical dilemmas. What will it mean in a nanoworld to be a "healthy person" versus a "sick person"? Will people be really able to reconceptualize, on the basis of the new diagnostic possibilities, the common understanding of human disease? Is the presence of, say, a genetic mutation known to have a predisposition for causing cancer in a single cell a "diagnosis" of cancer? How many cells from the body must be of a cancerous nature for it to be defined as a "cancer"? 1? 50? 1,000? (Bawa and Johnson 2007).

Nanotechnology expert Robert A. Freitas Jr. (1999, at para. 1.2.4.3) describes the same phenomenon by saying that "in the nanomedical era, the sheer number of 'truths' that may become available for disclosure will increase enormously, even as the terminal prognosis becomes rare". He points out the problem that "people will gain the ability to specify their own physical structure to minute detail, but many patients will not be ready, willing, or able to assume responsibility for this knowledge." And he emphasizes that, in such a context of overinformation, "the doctor's interpretative abilities and judgements on behalf of the patient", and especially, the "humanistic quality of the good doctor" will probably be more important than ever before.

In addition, there is the concern that the new nanodiagnostic methods may drastically widen the gap between diagnosis and therapy, because more and more diagnosis will become possible for diseases for which there are not treatments yet. The fear, which has also arisen in the context of genetic testing, is that the benefits of receiving this overwhelming and often merely probabilistic information could be outweighed by the psychological harm resulting from the absence of therapy (Gordijn 2007, at p. 112). In such a context, the so-called "right not to know", which has been especially invoked to deal with the potential burdensome results of genetic tests, will be of special importance (Andorno 2004a). This means that nanodiagnostic methods will presumably need to include some procedure for leaving patients the possibility not to receive potentially harmful (and in many cases useless) information about their health condition and to be able to continue their lives in peace.

Furthermore, some have expressed the concern that the development of "labs-on-a-chip" for diagnostic purposes using nanotechnology will increase the pressure on patients to choose between various possible tests and confront them with different symptoms, which will result in a greater psychological burden on them. This is particularly problematic since such tests often provide secondary (i.e. unwanted) information, and it is not clear how individuals will be able to deal with such complex technical data and their interpretation (Bachmann 2006, at p. 107).

9.2.3 Privacy and Confidentiality Issues

Another important ethical concern about the impact of nanomedicine relates to the protection of personal health information. Nanotechnologies might allow to monitor and collect an large amount of data regarding cellular activities and biochemical events within organs, tissues, or individual cells, and even to transmit this information remotely (Bawa and Johnson 2007). This will create, of course, a serious challenge for the protection of such highly sensitive data, especially when one considers the great ease with which information can be stored and exchanged in our digital age. Therefore, the performance of the doctors' duty of confidentiality will require the establishment of special safeguards for the protection of health data resulting from the use of nanotechnological devices.

Certainly, this ethical issue is not entirely new, because the increasing availability of genetic testing and the setting up of human genetic databases have created a very similar challenge in recent years. The novelty of nanomedicine in this respect is that the potential new threat to confidentiality it creates covers a different and wider range of health data, which is obtained through technological means other than genetic testings. The important point is that, like personal genetic information, cellular and subcellular level data can also be of a sensitive nature and should also be seen as confidential, at least insofar as they have not been anonymized. This means that such personal information should not be disclosed to third parties, or used for any different purpose than the one originally intended, without patients' consent. The guidelines that have been developed in the last decade for ensuring a responsible use of human genetic data could, with the necessary adaptations, inspire the elaboration of specific ethical and legal guidance for the collection, storage and use of health data resulting from nanomedical technologies.

9.2.4 The Challenge of Enhancement

Beyond the immediate potential risks associated with nanomedical devices, there is also a long-term ethical issue that also needs to be addressed: the acceptability and, if so, the limits of the technological enhancement of the normal human capacities by means of nanotechnologies. It is indeed conceivable that nanodevices could be used

to strengthen normal tissue, to manipulate certain DNA to alter traits; or to augment mental function, either via enhanced electronic interfaces at the cellular level or by direct stimulation of certain neural pathways (Hook 2004).

The problem arises because the notion of "enhancement" is extremely broad, covering human improvements of very different kinds, and this makes it difficult to reach a clear-cut conclusion about its ethical acceptability. Enhancement has been defined as the "non disease-related improvement or modification of physical or mental functions or qualities by medical or biotechnical interventions, mostly to fulfill aesthetic, athletic, sexual, cultural, work-related or other goals and standards" (Lenk and Biller-Andorno 2007). The discussion on human enhancement by means of the new possibilities offered by biotechnological advances began in the 1980s in the context of reproductive techniques and germline interventions. But only in recent years have scholars engaged in a serious discussion about the potential uses of nanotechnology for enhancement purposes.

The issue is particularly complex, among other reasons, because the distinction between "therapy" and "enhancement", on which the objections to enhancement are often based, is far from clear. It is indeed usually argued that while "therapy" (i.e. the treatment of individuals with known diseases or disabilities) is fine, "enhancement" (i.e. the use of biotechnical power to alter the "normal" human capacities) would be unacceptable. But beyond the fact that the boundaries between these two categories are becoming increasingly blurred with biomedical, chirurgical and pharmaceutical developments, it is unclear why this distinction should have the ethical relevance that it is usually attached to it. In this respect, the proponents of enhancement argue that people have been using technology to enhance their lives and their abilities from time immemorial. On the other hand, there seems to be of course a big difference between wearing glasses and, say, implanting people an extra eye in the back of the head. Should we therefore conclude that unethical enhancement is a matter of degree rather than a matter of kind? But assuming that this is the case, where should we put the limits between the acceptable and the unacceptable forms of improving the human capacities? In an attempt to answer to this question, some have argued that "the ethical limits of self-manipulation arise at the moment when such changes become a threat to human self-awareness, based on a radical transformation of the human body" (Capurro 2006).

An additional problem that arises from nanoenhancement technologies is that by embarking in this new direction, medicine risks losing sight of its primary mission – preventing and curing human suffering – to become a "medicine of desires", i.e. a vast endeavor aiming at promoting "customer satisfaction", no matter how irrational the enhancement desires of the individuals could be. In this regard, Freitas has suggested, in an uncritical acceptance of this metamorphosis of medicine, that nanotechnology will require a new concept of disease that transcends the classic model of disordered function. He calls this new model "the volitional normative model of disease", in which disease is characterized not only as a failure of "optimal" bodily functioning, but also of "desired" bodily functioning (Freitas 1999, at 1.2.2). But this new situation, in which any limitation or undesired trait could be declared "disease", is not without problems (EGE 2007, at 4.3.5). Some suggest

that the balance between beneficence and non-maleficence may be inappropriately tipped towards what the patient desires, rather than needs. Moreover, claims to nanoenhancement "treatments" would unjustly deplete healthcare resources, depriving those in real need of legitimate healing (Hook 2004, 2007) and diverting the current efforts of the international community to promote access to essential medicines in developing countries (ETC 2006).

Another, even more complex issue relates to the possible threat to *human identity* that some enhancements may constitute. Would the nano-improved individuals be able to experience the transformations of their bodily or intellectual capacities as genuinely *theirs*? Would they really perceive their new abilities as fully "human" capacities? Would such additional skills resulting by various nanoimplants not lead individuals to feel a deeply distressing doubt about what they are really able to do *by themselves*? The potential psychological harm resulting from nanoenhancement technologies has been acknowledged in the literature. Gordijn points out that if a human being were constantly subjected to new bioelectronic interventions to improve his sensory, motorial and/or cognitive abilities, it could become increasingly difficult for him to answer questions such as: "What am I good at? How do I perform? Do I act responsibly? What is my particular character? What makes me unique? What can I remember? What is my life history?" (Gordijn 2007).

9.3 Is the Precautionary Principle Useful in Nanomedicine?

9.3.1 The Precautionary Principle: A Tool for Dealing with Uncertain Risks

As most of the health risks posed by nanotechnology are still uncertain, it is not surprising that several ethical and policy documents on the issue appeal to the precautionary principle, which aims to provide guidance for protecting public health and the environment in the face of uncertain risks. The recourse to the precautionary principle in this field has been explicitly supported by various bodies, such as, for instance, the European Commission's Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR 2007, at para. 4.1.4); the European Group on Ethics in Science and New Technologies to the European Commission (EGE 2007, at para. 4.2.3); the UK Royal Society and the Royal Academy of Engineering (UK-RSRAE 2004, at pp. ix–x; 69; 76–78); the French National Consultative Committee for Health and Life Sciences (CCNE 2007), among others.

The precautionary principle, which is mainly addressed to policy makers, states that the absence of full scientific certainty shall not be used as a reason to postpone decisions where there is a risk of serious or irreversible harm to public health or the environment. It aims to emphasize that, in such situations, even though scientific information may be inconclusive, decisions have to be made to meet society's expectations that risks be addressed. As one of its proponents says, all this principle

actually amounts to is this: "if one is embarking on something new, one should think very carefully about whether it is safe or not, and should not go ahead until *reasonably* convinced it is." (Saunders 2000). Thus, far from resting on a complicated theory, this principle is just an *appeal to caution* when we are dealing with technologies that may be potentially harmful. In the end, it is nothing more than a specific application of the classical virtue of *prudence* (*phronesis*), or "practical wisdom", especially in its form of "political prudence". This is so because this principle mainly serves as a guide for policy makers, who have to assess the pros and cons of alternative courses of actions regarding potentially harmful products and take the most appropriate decision in every case (Andorno 2004b).

Examples of public health issues in which the precautionary principle has been advocated in recent years (although it has not been always accepted by all the parties concerned) are: the HIV contamination scandals of blood products used for transfusion; the consumption of beef products contaminated with the bovine spongiform encephalopathy (BSE) or "mad cow disease", suspected to be associated with the development of the Creutzfeldt-Jakob disease in humans; the consumption of genetically modified foods; xenotransplantation, i.e. the use of animal organs for transplantation purposes in humans, which might create new and uncontrollable diseases; the use of growth hormones in meat production, which, according to EU authorities, may pose health risks (including carcinogenic effects) to consumers; health threats linked to phthalates in PVC toys, and the possibility of modifying human genes through germline interventions, which may cause irreversible damage to future generations.

9.3.2 The Origins and Diffusion of the Precautionary Principle

Since at least the early 1980s, European policy-making has progressively adopted precautionary approaches in order to achieve high levels of public health, environmental protection and consumer safety without compromising science or technological innovation. In December 2000, following to the adoption of the Treaty of Nice on the European Union, the European heads of governments endorsed a Resolution on the Precautionary Principle recognizing that "the precautionary principle is gradually asserting itself as a principle of international law in the fields of environmental and health protection" (Paragraph 3). In an attempt to define it, the resolution states that the precautionary principle should be used "where the possibility of harmful effects on health or the environment has been identified and preliminary scientific evaluation, based on the available data, proves inconclusive for assessing the level or risk" (Paragraph 7).

At a global level, the precautionary principle has been included in virtually every recently adopted international treaty and policy document dealing with issues that are at the intersection between environmental protection, sustainable development and public health. The most significant ones are the 1992 Rio Declaration on

Environment and Development (Principle 15); the 1992 Convention on Biological Diversity (Preamble); the 1992 UN Framework Convention on Climate Change (Article 3.3); and the 2000 Cartagena Protocol on Biosafety (Article 1).

During the last decade there have been also significant developments in the interpretation and application of the precautionary principle by some international courts and arbitration bodies. The most salient example is the European Court of Justice, which has adopted a clear position in support of the precautionary principle. In 1998, the ECJ confirmed the validity of the decision of the European Commission that prohibited the United Kingdom from exporting bovine meat because of the suspicion of a link between the "mad cow disease" (which was widespread in the UK at the time) and the Creutzfeldt-Jakob disease in humans. Although the Court's judgment does not explicitly mention the precautionary principle, it is clearly inspired by it, especially when it states that: "Where there is uncertainty as to the existence or extent of the risks to human health, the institutions may take protective measures without having to wait until the reality and seriousness of those risks become fully apparent" (ECJ 1998, at para. 99). On 21 March 2000, the ECJ reaffirmed the validity of the precautionary principle in a controversy regarding the release into the French market of genetically modified varieties of maize produced by the company Novartis. On the other hand, it should be recognized that, beyond the purely European jurisdiction, international courts are still reluctant themselves about the status of the precautionary principle. For instance, the International Court of Justice (ICJ) has cautiously avoided taking a position on the principle whenever it was invoked.

9.3.3 Conditions for the Application of the Precautionary Principle

It would be a mistake to expect from the precautionary principle more than it can actually offer. Far from what some may believe, this principle does not intend to provide a catalogue of predetermined solutions to the new dilemmas raised by scientific uncertainty. Since it is, in the end, no more than *prudence*, it only aims to provide some broad *guiding criteria* to policy makers, who retain a wide margin of interpretation of what is the most adequate response to each particular problem. Because of the *flexible* nature of this principle and its potential for misuse (for instance, as an unqualified excuse for radically protectionist measures), it is important to clearly specify the conditions that must be met for its application: (European Council 2000; European Commission 2000; Andorno 2004b; COMEST 2005):

1. Uncertainty of risk;
2. Scientific assessment of risk;
3. Seriousness or irreversibility of the potential damage;
4. Proportionality of measures;
5. Transparency of the risk assessment and risk management processes;
6. A shifting burden of proof.

1. *Uncertainty of risk*
   Precaution should not be mistaken with *prevention.* The precautionary principle goes indeed beyond prevention because it urges policy makers to anticipate problems *before* scientific proof of harm is definitively established. While in the case of *prevention* the harmfulness of the product or activity is well-known (e.g. the health risks associated with smoking) and the only thing that remains unknown is whether the damage will occur in a particular situation or time period, in the case of *precaution,* measures are adopted *before* a clear causal link between a technology and a harm has been established by definitive scientific evidence. This means that precaution is only relevant when the *existence* itself of the risk cannot be fully demonstrated due to insufficient or inconclusive scientific data. In other words, preventive measures face situations of *actual risk*, while precautionary measures respond to situations of *potential risk.*
2. *Scientific assessment of risk*
   Although the precautionary principle operates in the context of scientific uncertainty, it should be only applied when, on the basis of the best scientific advice available, there is *good reason* to believe that harmful effects might occur to public health or to the environment (UK-ILGRA 2002, at para. 10). Therefore, a purely hypothetical or imaginary risk, which is not based on any scientific indication for its possible occurrence, cannot justify the adoption of precautionary measures (Schmid et al. 2006, at p. 375). In other words, the implementation of the precautionary principle "should start with a scientific evaluation, as complete as possible, and where possible, identifying at each stage the degree of scientific uncertainty" (European Commission 2000, at para. 6.1).
3. *Serious damage*
   According to the above mentioned international instruments, the recourse to precautionary measures is only justified to avert "threats of serious or irreversible damage." This means that the suspected harm should be *significant enough* to justify measures that may in some cases lead to restrictions on free trade and manufacture. Hence, the application of the precautionary principle requires the determination of a threshold of non-negligible damage. In general terms, it can be argued that damage is "serious" when it affects the life and health of individuals, vital natural resources, the climate, and the balance of the ecosystem. But, if we leave aside the damages that are unquestionably serious, it must be acknowledged that the determination of a more precise threshold of damage ultimately depends on the cultural context where the measure is to be implemented. What is precautionary in one society may not always be regarded as precautionary in another. This is why, in the end, it will be a political task to determine if the potential risk is "serious".
4. *Proportionality of measures*
   Precautionary measures should be proportionate to the seriousness of the threat. This means that not every potential risk justifies any kind of precautionary measure and, in particular, that the intended measures should take into account their impact on society. This requirement goes far beyond the classic cost-benefit

analysis based on economic criteria and includes, more broadly, the socio-economic sacrifices required by the measure (e.g. the elimination of job positions), the efficacy of different possible options, their acceptability to the public, and, in general, the potential benefits and costs of action or lack of action (European Commission 2000, at para. 6.3.4). As happens with the other conditions for the implementation of this principle, these heterogeneous elements can certainly not be estimated alone by experts on risk assessment, and ultimately need to be based on a judgmental evaluation of policy decision makers.

5. *Transparency of the risk assessment and risk management processes*
   The requirement of "transparency" means, first, that the procedures and criteria used by public authorities for the risk assessment process and for the adoption of precautionary measures must be known to all parties concerned, including proponents of new technologies and the public. As the potential risks of new technologies (in this case, nanotechnologies) would directly affect the public, it is essential that citizens be informed and consulted about the timing or content of the decisions taken – either directly or, for example, through the involvement of health care consumers representatives. Transparency also means the commitment of those who promote potentially risky products to disseminate their studies about the magnitude of the potential risks and the efforts they have made in order to minimize or eliminate such risks.
6. *A shifting burden of proof*
   Traditionally, public authorities have to demonstrate reasonable grounds, based on definitive scientific evidence, to restrict the sale of certain products or the use of some technologies. This means that, until proven wrong, proponents of technology can continue the activity in question. The precautionary principle challenges this traditional policy by proposing to shift the burden of proof towards those whose actions may seriously threaten the public health or the environment. However, this should not be interpreted as meaning that proponents of technology are obliged to provide definitive evidence that their products or activities are harmless ("zero risk"). It means rather that hazard creators must show that they have undertaken the necessary research to establish the nature and extent of any potential risk, having come to the conclusion that their products or activities offer an acceptable level of safety. Thereafter it will be the responsibility of the public authorities to decide what course of action is the most appropriate, taking into account the conclusions of their own experts or specialized agencies.

9.3.4 The Precautionary Principle and Nanomedicine

After having outlined the nature and aim of the precautionary principle and the conditions for its implementation, the key questions that arise are: could this principle be helpful to prevent at least some of the potential harms that may be associated with nanomedical devices? If yes, to what extent (i.e. for which measures) would it be reasonable to appeal to it? (Kenny 2007).

The above characterization of the conditions for the recourse to the precautionary principle puts in evidence that, among the possible adverse effects of nanomedical technologies, the ones that better suit the precautionary principle are those related to the potential toxicity of nanoparticles. In this regard, some have advanced that, while the risks of nanoparticles in medical applications will significantly overlap with the general toxicological risks posed by nanomaterials, "it is possible to make more specific predictions as certain parameters such as dosage, biodegradability and size are known and can be controlled to some extent" (Faunce and Shats 2007, at p. 130).

Other negative impacts (for instance, the widening gap between diagnostic and therapeutic possibilities) are much more diffuse and controversial and largely depend on the philosophical assumptions and on the public's perception of the harm. Still other risks, such as the threats to confidentiality of personal health data, are not merely potential, but real, and therefore some *preventive* (and not simply precautionary) measures must be taken. What about the use of nanotechnologies for enhancement purposes? Neither in this case is the precautionary principle of great utility because enhancement technologies are usually discussed on the grounds that they are "intrinsically" acceptable or unacceptable, and not because they are strictly speaking a "risk".

Regarding the potential toxicity of nanoparticles, as it has been above explained, the existing risk assessment studies (for instance, those based on animal research) show that there are reasonable grounds to fear that nanoparticles might have harmful effects on human health. Although the causal link has not been conclusively established yet, the potential risks appear to be non-negligible. Therefore, the basic conditions for the recourse to the precautionary principle are met. Its application certainly requires an active engagement of the public in the discussion of viable options (Stebbing 2009).

Thus, according to present knowledge, public authorities cannot responsibly ignore the possibility of some adverse health effect of nanotechnologies and are morally obliged to adopt some measures. But the devil is in the details, and while most experts, governmental commissions, NGO's and insurance companies would agree that *something* should be done to avoid harm (Bachmann 2006, at p. 84), they are not close to agreeing on what concrete precautionary measures need to be taken.

It needs to be stated that, contrary to what many may believe, the application of the precautionary principle does not necessarily lead to a ban on a potentially harmful technology or product. Of the wide range of available precautionary measures, an outright ban on a technology is only a last resort, in case the potential risk is very serious.

In relation to this, some groups have called for a generalized global moratorium on nanotechnologies, and have demanded, on the grounds of the precautionary principle that, until nanotech companies do not demonstrate the safety of their products, no market approval should be granted (ETC Group 2003, 2006, at p. 45; Ad hoc coalition of international NGOs 2007). But, as we have argued above, the precautionary principle does not mean that proponents of new technologies need to provide conclusive scientific evidence of "zero risk." Such a requirement would not

only be impossible to fulfil, but would also virtually block every new technological development. What the precautionary principle requires from companies is to demonstrate that they have undertaken risk assessment studies and have come to the conclusion that there is no reason for serious concern. Then it will be of course the responsibility of policy makers to decide whether, or under what conditions, the products should be authorized (or not), taken also into account their own risk assessment studies.

Drawing on such a more nuanced understanding of the precautionary principle, many reports and expert opinions on the issue stress the need for a case by case risk assessment rather than calling for a generalized moratorium on nanotechnologies (see, for instance, Schmid et al. 2006, at pp. 377–379; SCENIHR 2007, at para. 4.1.4; Hett et al. 2004, at pp. 47–48; Phoenix and Treder 2003). Similarly, the UK Royal Society has expressed the view that "sensible, pragmatic steps can be taken now by regulators to control possible risks from new manufactured nanoparticles without the need for a cessation of development activity, and that such steps should be taken alongside action to understand further the possible mechanisms of toxicity" (UK-RSRAE Royal Society and the Royal Academy of Engineering 2004, at p. 75).

This does not mean, however, that a moratorium on the use of nanomaterials in medicine should be categorically excluded, but only that the adequacy of such a strong measure would need to be judged on a case by case basis. As soon as policy makers come to the conclusion that some specific applications of nanotechnologies pass a certain threshold of risk to public health, they can (and must) adopt all the necessary measures to prevent harm, which may also include the provisional ban on the sale and use of such products.

9.4 Conclusion

The use of nanotechnology for medical purposes carries potential risks that cannot be ignored. It is precisely the uncertainty that surrounds the use of nanomaterials for diagnostic, preventive or therapeutic purposes that warrants invoking the precautionary principle, albeit in a nuanced and critical way. At a minimum, it seems reasonable to require from now on that nanodevices be labelled so that consumers (patients and physicians) can be aware of the potential toxicity of nanoparticles and make informed choices.

The usefulness of the precautionary principle should however not be overestimated. It is not an algorithm for managing uncertain risks. It does not offer a predetermined solution for every new challenge posed by technological developments. In the end, this principle is no more than an *appeal to caution* which offers some valuable criteria for determining the most reasonable course of action when facing with uncertain risks. In addition, it does not operate alone and needs to be completed with other criteria.

In sum, the utility of the precautionary principle in nanomedicine is limited but not negligible. It offers a workable set of criteria for decision-making in a field

plagued by scientific uncertainty, such as the toxicology of nanoparticles. This is not a minor problem: virtually all, and not some merely futuristic, potential risks of nanomedical devices are in a way or another related to their possible toxicity.

How should the decisions regarding the adoption of precautionary measures in this area be made? As several experts have pointed out, the active involvement of the public is particularly important in such a sensitive field, where the life and physical integrity of people are immediately at stake. But the recourse to precautionary measures must also meet all the other conditions mentioned above, in particular, they should be preceded by scientific assessment of the possible risks, and subjected to on-going scientific evaluation after they have been implemented, and second, they should be provisional and limited in time with an obligation for review within a certain time period.

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Chapter 10
Ethical and Societal Values in Nanotoxicology

Kevin C. Elliott

10.1 Introduction

Perhaps the most immediate ethical concerns about nanotechnology revolve around the potential risks that nanomaterials pose to public health and the environment. Because of their small size (less than 100 nm in one or more dimensions), they have the potential to move through cells, tissues, and even the blood-brain barrier more easily than larger particles of the same substances. Moreover, their high surface-area-to-mass ratio tends to increase their reactivity (Oberdörster et al. 2005; Royal Society 2004). Particular nanomaterials may also be especially problematic because of their shape (such as carbon nanotubes that resemble asbestos fibers) or because of their tendency to carry other toxic substances along with them (Balbus et al. 2007; Poland et al. 2008).

Ethicists and policy makers have previously spent a good deal of effort considering how to make societal decisions in response to public- and environmental-health risks like those posed by nanomaterials. Many of these discussions have focused on the strengths and weaknesses of decision-making approaches such as risk-cost-benefit-analysis or the precautionary principle (Raffensperger and Tickner 1999; Shrader-Frechette 1985, 1991; Sunstein 2005). Important questions about these approaches include deciding how to address the inequitable societal distributions of risks and benefits (e.g., Schmidtz 2001; Shrader-Frechette 1985), how to ensure due process and informed consent when imposing health risks (e.g., Shrader-Frechette 1993), and how to identify appropriate margins of safety when regulating hazards that are poorly understood (e.g., von Schomberg 2006). In this chapter I want to explore how these sorts of ethical and societal value judgments about responding

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to nanotechnology's environmental health and safety risks arise not only in the public-policy domain but also "upstream," in the performance of scientific research.

The next section examines previous scholarship on the ways that ethical and societal value judgments permeate scientific research. It focuses especially on the notion that particular forms of research can be more "precautionary" than others, in the sense that they tend to facilitate the identification and prevention of environmental or public health threats. Section 10.3 turns to a specific case study, nanotoxicology, and shows how ethical and societal values could influence at least four aspects of this research:

1. the nanomaterials studied;
2. the biological models used to investigate them;
3. the effects examined; and
4. the standards of evidence required for drawing conclusions.

Finally, Sect. 10.4 proposes some mechanisms for integrating more careful ethical reflection into these "upstream," value-laden decisions that pervade research on nanotechnology as well as other policy-relevant areas of science.

10.2 Value Judgments in Scientific Research

The basic notion that scientific research incorporates a range of value judgments is not new. It is widely accepted that scientists incorporate "epistemic" or "cognitive" values in their judgments about what hypotheses, models, or theories to accept (Kuhn 1977; McMullin 1983). For example, researchers have to consider which hypotheses best display valued characteristics like explanatory power, coherence with other scientific theories, and predictive success. The distinguishing feature of these epistemic values is that they promote the truth-seeking goals of science (Steel 2010). It is somewhat less clear how various "non-epistemic" values (e.g., personal, social, ethical, religious, or political considerations) should play a role in scientific practice. There are some aspects of science where the influence of these values seems appropriate. For example, few would doubt that large-scale choices about how to allocate public research funding (e.g., choosing to study cancer treatments as opposed to space exploration) should be subject to the social values of taxpayers. Similarly, choices about how to formulate public policy in response to scientific information (e.g., deciding whether the risks of a nuclear accident are small enough to justify building nuclear power plants) should also be subject to ethical and societal value judgments.

It is much less obvious that these sorts of non-epistemic values should play a role in the very "heart" of science, when scientists make decisions about whether to accept or reject particular hypotheses. Nevertheless, many philosophers of science have argued that even these sorts of decisions should sometimes be influenced by non-epistemic considerations (see e.g., Douglas 2009; Elliott 2011; Longino 1990). Section 10.4 will return to these difficult *normative* issues about how these values

ought to play a role in science and how to adjudicate among competing values. The remainder of the present section, as well as Sect. 10.3, focuses on the somewhat simpler but still important *descriptive* question of how scientific research *does* in fact incorporate or privilege some non-epistemic values over others. Because this is a vast topic (see e.g., Elliott 2011; Longino 1990), the present chapter focuses specifically on values concerning how aggressively we should try to identify and prevent threats to public and environmental health.

The remainder of this section examines work by advocates of the precautionary principle who have previously highlighted ways in which scientific practice is implicitly permeated by non-epistemic values. Specifically, these thinkers argue that choices about what questions to pursue and what research methodologies to employ can influence our ability to identify and prevent threats to environmental and public health. The following statement from the 1992 Rio Declaration is typical of many interpretations of the precautionary principle: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (quoted in Sunstein 2005, 18). This relatively narrow statement of the principle focuses on the realm of public policy, clarifying the amount of evidence required for justifying regulatory actions. However, those who espouse broader interpretations of the precautionary principle sometimes argue that it calls for wide-ranging changes in how society approaches environmental health and safety threats, and one of these changes is to perform scientific research differently (Tickner 2005).

One important statement of this view comes from Katherine Barrett and Carolyn Raffensperger (1999). They contrast dominant contemporary approaches to scientific research, which they call "mechanistic science," with the sorts of "precautionary science" that would facilitate policy actions in accordance with the precautionary principle.[1] According to Barrett and Raffensperger, precautionary science would accept a wider variety of data (including more qualitative and citizen-generated data), focus on a wider range of harms (including various disruptions to ecological and social systems), and emphasize more complicated and multidisciplinary research projects that are better for addressing real-life concerns. The goal of all these changes would be to lessen the frequency with which scientists make false negative claims about environmental health and safety threats (i.e., cases where scientists falsely claim that a substance or activity is not harmful when it actually poses a hazard). Barrett and Raffensperger suggest that, whereas scientific research practices may appear to be value-free, there are a variety of subtle ways in which they presently support the values of those who want to minimize false positive

[1] I should emphasize that, while Barrett and Raffensperger do an admirable job of highlighting the implicit value judgments that can permeate scientific research, their proposal of a sharp distinction between "mechanistic science" and "precautionary science" is questionable. Particular research practices can arguably be classified as precautionary only relative to a particular context (including, for example, the threats that are under consideration, the preventive actions being considered in response to the threats, and an alternative set of research practices that are less precautionary).

errors rather than false negatives. In other words, current practices tend to protect producers from claims that their products are harmful.

David Kriebel and his colleagues (2001) also argue that scientific research could be altered to facilitate precautionary public policy. One of their suggestions is to place more emphasis on studying interactions between various potentially hazardous causal factors rather than studying them independently. (For example, some substances that might not be particularly toxic on their own could be quite harmful in combination; see Biello 2006.) Another of their suggestions is to present scientific findings in a manner that provides a more complete sense of the uncertainty associated with the results. Like Barrett and Raffensperger, they also encourage multidisciplinary work to address pressing social problems that might otherwise be set aside because of the difficulty of addressing them within individual disciplinary approaches. Finally, they agree that current scientific practices are designed preferentially to minimize false positive rather than false negative errors, which does not accord well with the precautionary principle.

Many of these suggestions are summed up in an issue of *Human and Ecological Risk Assessment* (Vol. 1, No. 1, 2005) that focused on the implications of the precautionary principle for environmental health research. Philippe Grandjean introduced the journal issue with the following clarifications:

> The PP [i.e., precautionary principle] has … been misunderstood as anti-science. However, what has been called for [by advocates of the PP] is not an embargo of science, but rather the initiation of 'new science.'… The ways in which science can support PP-based decisions is … likely to differ from the science that has supported traditional risk assessment. (Grandjean 2005, 14)

Articles throughout the issue emphasized the importance of altering traditional practices that asymmetrically favor false negative errors over false positives. They also encouraged scientists to place less emphasis on replicating findings and hammering out highly detailed understandings of specific hazards; instead, they encouraged researchers to perform strategic studies that would be of most help to societal decision makers. Along these lines, they also encouraged scientists to consider how best to present their results in order to promote fruitful interactions with the stakeholders who would use their findings.

Finally, although philosopher of science Hugh Lacey (1999) does not explicitly use the label of "precautionary science," he has very perceptively argued for different approaches to scientific research. According to Lacey, contemporary scientific practice is far from neutral with respect to different value systems, because it focuses on employing "materialist strategies." He claims that scientific "strategies" constitute informal guidelines for how research is to be done. They establish constraints on the kinds of theories entertained, they select the kinds of data to be sought, and they guide the choice of categories used in describing scientific findings. Lacey (2002) claims that *materialist* strategies focus on generating quantitative descriptions of underlying structure, process, and law, while abstracting from social arrangements and values. Unfortunately, in policy-relevant fields, these strategies can end up subtly privileging some societal values over others. Lacey focuses especially on

agricultural research, suggesting that materialist research strategies often focus solely on increasing crop yields under "optimal" conditions. He argues that such approaches fail to consider the broader social and environmental consequences of heavily employing fertilizers, pesticides, and irrigation. He suggests that alternative, "agroecological" research strategies would promote the study of more complicated questions, such as "How can we produce wheat so that all the people in a given region will gain access to a well-balanced diet in a context that enhances local agency and sustains the environment?" (1999, 194).

10.3 Value Judgments in Nanotoxicology

We have seen that some proponents of the precautionary principle have identified a number of ways in which scientific research can subtly support some ethical and societal values over others, especially regarding the identification and prevention of environmental and public health threats.[2] I now want to consider four aspects of nanotoxicology research (materials studied, biological models, effects examined, and standards of evidence) and examine how one can provide a similar analysis of the values implicit in this field. Nanotoxicology has arisen as part of the broader discipline of toxicology in an effort to characterize the potentially unique environmental and public health threats associated with nanomaterials. Because the properties of these materials often differ from those of larger particles of the same substances, existing toxicological knowledge may be of limited help in predicting risks associated with nanotechnology (Oberdörster et al. 2005). Moreover, there are a huge number of variables that could potentially alter the toxicity of nanomaterials, including their dose concentration (measured in surface area or the number of particles and not just in mass), size distribution, shape, composition, surface chemistry, surface contamination, surface charge, crystal structure, particle physicochemical structure, agglomeration state, porosity, method of production, preparation process, heterogeneity, and prior storage of the material (Oberdörster et al. 2005). In an effort to alleviate this confusion, researchers are recommending broad screening strategies, in which nanomaterials with a range of properties are tested for toxicity using various *in vitro*, *in vivo*, and even *in silico* systems.[3]

[2] It is important to recognize that advocates of the precautionary principle are by no means the only thinkers who have studied how scientific practices can privilege some ethical or societal values over others. I have focused on this particular group of thinkers because they have done a good job of highlighting the value-ladenness of scientific research and because their concerns apply well to nanotoxicology.

[3] It is worth emphasizing that even decisions about whether to emphasize in vitro, in vivo, or in silico experimental systems involve a wide range of value judgments about how to prioritize considerations like the speed of research, avoidance of false positive and false negative errors, expense, and animal welfare.

10.3.1 Materials Studied

One value-laden set of questions that immediately arises when developing a screening strategy concerns the types of nanomaterials to prioritize for research, given the extraordinary range of variables that could be investigated. One example of these questions comes from my personal experiences with a group of scientists who were developing a grant proposal to study the environmental effects of nanotechnology. They were inclined to study various metal- and carbon-based nanomaterials, and they were debating whether to include ceramics (i.e., metal-oxides) as well. On one hand, some of them noted that consulting firms were predicting that ceramics were likely to become very widely used nanomaterials in the future. On the other hand, others expressed the concern that it is more difficult to obtain replicable toxicological findings about ceramics, in part because they react with light to form a range of different structures and because they agglomerate into particles of varying sizes.

The scientists' discussion about the merits of studying ceramic nanoparticles highlights the subtle ethical and societal value judgments that are often implicit in the choice of research projects. In the ceramics case, researchers had to balance the desire to gather socially relevant information (which would count in favor of studying widely used materials like ceramics) against the scientific imperative of obtaining high-quality, replicable, publishable data. A second example of decisions about which nanomaterials to study highlights many of the same trade-offs. Toxicologists in general, and nanotoxicologists in particular, have noted that studying the biological effects of samples that contain fairly homogeneous particles of a single material may not generate reliable estimates of the real-life effects produced by mixtures of very heterogeneous substances (Eggen et al. 2004). It is understandable that toxicologists have often focused on studying single materials. They tend to yield reliable, replicable data that is publishable and that can be used for developing structure-activity models to predict the toxicity of new chemicals. Nevertheless, those who advocate studying mixtures emphasize that regulators should also try to understand the synergistic effects produced by the wide variety of toxic agents to which biological organisms are generally exposed (Balbus et al. 2007, 1657; Biello 2006).

To illustrate the value of studying nanoparticle mixtures, consider an excellent study that examined how single-walled carbon nanotubes affected tiny estuarine crustaceans called copepods (Templeton et al. 2006). The researchers studied not only purified samples of the nanotubes but also "as prepared" samples, which included both the nanotubes and a range of byproducts associated with the manufacturing process. Strikingly, the nanotubes themselves were much less toxic than the byproducts. This study highlights the fact that efforts to study purified substances can be very misleading when predicting toxicity associated with real-life exposures. Unfortunately, it takes a good deal of additional effort to purify various components of a mixture and to test them individually. In the case of this study, for example, the researchers studied the nanotubes by themselves, the "as prepared" mixture as a whole, and a subset of the mixture that contained particular byproducts of the manufacturing process. It is not always feasible to engage in such detailed investigations, and even this study was not able to identify individual byproducts that were most responsible for the toxicity.

10.3.2 Biological Models

Another set of value-laden questions related to the development of screening strategies involves the choice of biological models used for studying toxic effects. Consider, for example, choices about which fish species to use for studying aquatic effects of nanoparticles. Researchers have to decide whether to study biological models that are more ecologically useful, such as large-mouth bass, or whether to employ those that are better understood scientifically, such as zebrafish (Tara Sabo-Attwood, personal communication). If one's goal were to obtain information that is most relevant to ecosystems in the U.S., large-mouth bass would be a much better model to study, given that zebrafish are native only to the southeastern Himalayas. Nevertheless, reviewers for grant proposals tend to be more sympathetic to studies of zebrafish, because it is an important model organism in biomedical and toxicological research (e.g., Hill et al. 2005). Because so much is known about its genetics and development, it may be easier to develop detailed understanding of the biological mechanisms responsible for toxicity by studying zebrafish.

Another important issue associated with choosing biological models is to decide how sensitive an organism to use. Toxicologists are well aware that some biological species, as well as specific strains or subspecies, are more likely to exhibit toxic effects to particular substances than others (see e.g., Boverhof et al. 2006). For example, rats appear to be more sensitive than mice to nanoparticles of carbon black, diesel engine exhaust, and titanium dioxide (Heinrich et al. 1995). The stage of an organism's life cycle can also make a difference; one recent study showed that adult *Drosophila* were harmed by carbon nanomaterials in ways that the larvae were not (Liu et al. 2009). Industry groups have sometimes taken advantage of these differences between biological models in order to design studies with "tough" animal strains that are unlikely to exhibit toxic responses (see e.g., vom Saal and Hughes 2005). Value-laden decisions about the choice of organisms can also arise in a more benign fashion. Some biological models are more widely discussed in the scientific literature or are easier to study in a laboratory environment than others (Hill et al. 2005). Therefore, researchers occasionally have to weigh considerations of scientific popularity and convenience against other values, such as the desire to use appropriately sensitive models or ethical concerns about animal experimentation.[4]

[4] Regarding the sensitivity of biological models, Tom Chandler (personal communication, 2009) provides a good example. He notes that daphnia and copepods are both small crustaceans that are used for studying the effects of environmental toxicants. Daphnia have been used more frequently, in part because they have generally been more convenient to study and to grow in the laboratory. Nevertheless, copepods tend to be more sensitive to some toxicants. Regarding the ethics of animal experimentation, Lafollette and Shanks (1997) provide an excellent overview of the issues. In some cases, computer modeling and bioinformatics may enable researchers to identify potential threats more quickly and with less harm to animal welfare than by using traditional in vivo approaches.

10.3.3 Effects Examined

The specific biological effects and endpoints to be studied constitute another important set of value-laden decisions for nanotoxicologists. Many scientists have worried that short-term studies of acute toxicity (i.e., death) are likely to miss a wide range of important long-term, chronic toxic effects (Calow and Forbes 2003; Eggen et al. 2004). These worries become even more serious when researchers try to estimate the long-term effects of a pollutant on an entire ecosystem based on its acute effects in a limited number of species. These problems were vividly highlighted by Thomas Chandler and his colleagues (2004) in a study of the pesticide fipronil, which is widely used for insect control both in residential areas and on golf courses. Estimates of its aquatic effects based on its lethality in fish had previously yielded the conclusion that its risks at realistic water concentrations were "small" (Chandler et al. 2004, 6413). In contrast, Chandler's group studied the effects of the pesticide and its degradation products at the same concentrations but on a much wider variety of endpoints (survival, development rates, sex ratio change, fertility, fecundity, and hatching success) for several generations in the life cycle of a small aquatic crustacean. They concluded that the pesticide "would cause almost total reproductive failure" (2004, 6413) in their test organism, thereby potentially causing significant problems in the ecosystem as a whole.

Some nanotechnology experts have been quite sensitive to this potential for wide variations in risk assessments for a single substance, depending on the effects examined. For example, an expert working group led by Oberdörster et al. (2005) recently proposed a screening strategy for identifying hazards from nanoparticles. They called for *in vitro* studies of a very wide range of targets, including numerous cell types within the lung, multiple skin assays, and numerous organs and organ systems (e.g., spleen, liver, blood, nervous system, heart, and kidney). Moreover, they worried about the potential for nanomaterials to move throughout the body, producing unforeseen effects remote from the source of exposure. To alleviate this problem, they called for *in vivo* studies of nanoparticles, focusing especially on the reproductive system and on compromised animal models (which might display evidence of otherwise unnoticed effects). They also called for genomic and proteomic analyses to highlight potential effects that might not be obvious based on other experimental methods. The problem, of course, is that the extensive battery of studies recommended by Oberdörster and his colleagues is costly and time-consuming. Therefore, researchers are generally forced to make difficult choices about which effects are most important to investigate in the near term.

10.3.4 Standards of Evidence

As we have seen throughout Sect. 10.3, there are an extraordinary number of variables that could be relevant to studying nanoparticle toxicity. To perform a systematic investigation of all the nanomaterials envisioned for consumer use,

taking into account the wide range of biological effects that they could produce, would be extremely difficult. Therefore, nanotoxicologists are calling for the development of modeling techniques that can assist in predicting the toxicity of materials before requiring extensive *in vitro* or *in vivo* tests (Balbus et al. 2007; Barnard 2009; Oberdörster et al. 2005). The crucial difficulty with this strategy is that, even if somewhat reliable models could be developed, there would still be very difficult decisions at the interface of science and policy about how to respond to the resulting findings.

Advocates of "precautionary" approaches to public policy have long argued that regulators could streamline their systems if they would give more credence to quicker, inexpensive, less-reliable approaches to predicting toxicity (see e.g., Cranor 1999; Wahlström 1999). For example, chemicals could be considered "guilty until proven innocent" if they failed the sorts of structure-activity predictions that nanotoxicologists are trying to develop. Carl Cranor (1995) has argued that it would frequently make economic sense to expedite risk-assessment procedures with quicker estimates of toxicity, because the environmental and public-health costs of leaving harmful products on the market (while waiting for the results of detailed toxicity studies) are quite significant. Nevertheless, many industry groups have insisted that regulatory actions must be based on very detailed scientific information, and this strategy has often assisted them in slowing the regulatory process to a near-stand-still (Fagin et al. 1999; Michaels 2008).

The field of nanotoxicology exhibits a number of other interesting cases where scientists and policy makers need to decide how much evidence to require for drawing conclusions and formulating regulations. Nanotoxicologists have been worried for some time that, because of their similar shape to asbestos fibers, carbon nanotubes might have some of the same carcinogenic properties as asbestos. Preliminary research has shown that nanotubes do appear to produce pre-cancerous lesions similar in kind to those produced by asbestos fibers (Poland et al. 2008). The question faced by scientists and regulators is how much evidence to demand before concluding that particular kinds of nanotubes are carcinogenic and should be regulated. Another important question concerns the amount of evidence needed for regulatory regimes to start differentiating nanoparticles of common substances (e.g., titanium dioxide, silver, or gold) from bulk quantities of those materials. While numerous commentators have argued that nanoparticles are unlikely to behave in the same manner as bulk materials, most countries have been very slow to take account of this fact (Bowman and van Calster 2008, 8; Royal Society 2004).

One might be tempted to consider these questions about standards of evidence to be primarily a policy issue rather than a scientific one. Nevertheless, it is sometimes difficult to disentangle these sorts of policy considerations from scientific practice. When researchers choose models, characterize data, and interpret their results, they are frequently forced to make methodological decisions that influence their likelihood of drawing false positive or false negative conclusions about environmental or public health threats (Douglas 2000; Elliott 2011). Therefore, scientists engaged in policy-relevant research cannot entirely avoid ethical and societal value judgments about what standards of evidence to demand (and therefore how to characterize data

and interpret results). In some cases, it may be possible for scientists to provide relatively uninterpreted data to policy makers and allow them to make the value-laden decisions about what conclusions should be drawn on the basis of the available evidence. In many other cases, however, it is impractical for scientists to avoid these value-laden decisions entirely (Cranor 1990).

10.4 Integrating Ethical and Societal Values in Nanotoxicology

The previous section showed that the field of nanotoxicology, like other areas of policy-relevant science, is permeated with implicit value judgments. In the case of nanotoxicology, at least four judgments are important to consider:

1. the nanomaterials studied;
2. the biological models used to investigate them;
3. the effects examined; and
4. the standards of evidence required for drawing conclusions.

In some cases, the social ramifications of making one choice rather than another are not particularly clear. In other cases, however, one can foresee that some decisions (e.g., choosing to study a particularly sensitive biological model) will assist in identifying and preventing threats to public and environmental health, whereas others will promote the economic success of regulated industries. Therefore, the normative questions that we set aside in Sect. 10.2 reemerge; namely, should we intentionally allow ethical and societal values to play a role in these four decisions, and, if so, how?

For many of these judgments, it is uncontroversial that ethical and societal concerns have a legitimate role to play. It is widely accepted that non-epistemic values are relevant to deciding what research projects to pursue, including questions like which materials to study, what biological models to use, and which effects to investigate (Elliott and McKaughan 2009; Longino 1990). Choosing standards of evidence is more complicated, because it straddles "policy" issues about how to act in response to limited information as well as "scientific" questions about what conclusions to draw on the basis of incomplete evidence. Although this is a complicated issue, a number of authors have argued that scientists should not ignore the societal consequences of choosing standards of evidence (see e.g., Douglas 2009; Elliott 2011; Shrader-Frechette 1994). One can argue for this conclusion either by appealing to special responsibilities that scientists have to society by virtue of their professional role, or by arguing that scientists are moral agents who have the same responsibilities as everyone else to avoid negligently causing harm to those around them.

Let us assume for the purposes of this chapter that ethical and societal considerations should be intentionally brought to bear on all four research choices discussed

in Sect. 10.3. The next question is how to incorporate and weigh various values and concerns. While this is a difficult and multi-faceted problem, I would like to briefly explore three proposals:

1. providing strategic training in research ethics for scientists working in policy-relevant fields;
2. carefully diagnosing appropriate mechanisms for deliberation between scientists and stakeholders; and
3. supplying significant government funding and leadership for research in nanotoxicology.

The motivation for the first proposal is that many of the value-laden judgments associated with policy-relevant science are deeply embedded in the practice of research. Therefore, it would be highly impractical for policy makers or other stakeholders to be constantly scrutinizing the details of scientists' research choices. If researchers are to be given a significant degree of autonomy to make these decisions for themselves, however, it is important to equip them with awareness and sensitivity of the societal ramifications of the decisions that they are making (Douglas 2003). Unfortunately, research ethics curricula have frequently focused on fairly narrow issues that have little do with scientists' social responsibilities (Pimple 2002).

In the field of nanotechnology, however, there have been a number of creative initiatives to improve research-ethics training for scientists, especially at the major Centers for Nanotechnology in Society (CNS) funded by the National Science Foundation (NSF) at Arizona State University (ASU) and the University of California at Santa Barbara (UCSB). ASU, for example, has instituted a PhD *Plus* Program for graduate students in science and engineering. As part of this program, the students work with a special faculty mentor to add a chapter to their dissertation that addresses political, societal, or ethical dimensions of their work.[5] CNS-ASU has also created a 2-week immersion seminar in Washington, D.C., that allows graduate students to learn about the societal and policy dimensions of their chosen fields. Finally, Erik Fisher, Joan McGregor, and Jameson Wetmore have reported on a variety of efforts (at ASU as well as other universities) to bring humanists and social scientists into close contact with natural scientists over extended periods of time, with the goal of developing constructive dialogues about the scientific work being performed (Fisher 2007; McGregor and Wetmore 2009). Along these lines, CNS-UCSB has been offering graduate fellowships for students in the sciences, engineering, humanities, and social sciences so that they can work together and with appropriate faculty to analyze the social dimensions of scientific work.[6] Ideally, these programs will provide scientists with greater sensitivity both to societal concerns and to the ways in which those values intersect with their own work.

[5] For more information about this program, see http://www.cspo.org/outreach/phdplus/; last accessed on August 19, 2009.

[6] For more information, see http://www.cns.ucsb.edu/education/; last accessed on August 19, 2009.

Despite the value of these research-ethics strategies, there are still normative, substantive, and instrumental reasons for attempting, under at least some circumstances, to broaden the range of people involved in making the value-laden judgments associated with scientific research (Fiorino 1990). To put the point briefly, it is doubtful that nanotoxicology researchers have the political legitimacy to decide all by themselves how to handle the range of decisions that impinge on their work, and other stakeholders can often make helpful suggestions for handling these difficult issues. Fortunately, there are now numerous precedents for using deliberative approaches to address such issues (see e.g., NRC 1996; Kleinman 2000). Formats can range from National Academy of Science (NAS) or Environmental Protection Agency (EPA) panels that consist primarily of scientists all the way to approaches that are geared primarily toward the public, such as citizen juries or consensus conferences. Some nanotoxicology experts already appear to be sympathetic to efforts along these lines, insofar as they have called for "great care and deliberation" in choosing a representative set of nanomaterials that will receive extensive characterization and toxicity testing (Balbus et al. 2007, 1657).

It is very important that the deliberative formats for making these sorts of decisions be chosen carefully. Existing research suggests that broadly based deliberation can, under the right circumstances, alleviate conflict and improve the quality of environmental decisions (see e.g., Beierle 2002; Fischer 1993; NRC 1996). Unfortunately, deliberative approaches can also sometimes result in increased cost, wasted time, poor decisions, and even the creation of increased hostility among stakeholders (see e.g., Irvin and Stansbury 2004; Kleinman 2005). What is needed, then, is a careful "diagnosis" of the sorts of deliberative formats that are likely to be most effective and appropriate in particular contexts (Elliott 2008; NRC 1996).

It is encouraging to see that there have already been a number of efforts to experiment with creative approaches for incorporating members of the public in broadly based deliberations about nanotechnology. These include the National Citizens' Technology Forum organized by CNS-ASU, a variety of innovative exercises funded by the European Commission under the auspices of the DEEPEN project (Deepening Ethical Engagement and Participation with Emerging Nanotechnologies), and a set of nanodialogues organized by the UK think tank Demos.[7] Sometimes, critics worry that deliberative forums like these operate at overly high levels of abstraction and have a fairly limited actual influence on decision making (Guston 1999). Focusing on some of the concrete questions identified in this chapter (about materials, biological models, effects, and standards of evidence) might help to alleviate these concerns about deliberative forums.

A third recommendation for integrating ethical and societal concerns into the value-laden judgments associated with nanotoxicology is to ensure that government

[7] For more information about the National Citizens' Technology Forum, see Philbrick and Barandiaran (2009). The final report for the DEEPEN project is available at http://www.geography.dur.ac.uk/projects/deepen/NewsandEvents/tabid/2903/Default.aspx (last accessed on March 5, 2010), and more information about the Demos project and its nanodialogues is available at http://www.demos.co.uk/ (last accessed on March 5, 2010).

bodies provide adequate organization and funding for this area of research. This is particularly important, because privately funded research in the environmental and public-health domains is often strategically designed to protect industry interests, without including transparent discussions of the value-laden decisions being made. There is now an extensive body of work cataloging strategies that interest groups routinely employ in order to challenge environmental health and safety regulations (see e.g., Elliott 2011; Fagin et al. 1999; McGarity and Wagner 2008; Michaels 2008). To take just one prominent example, a review found that 94 out of 104 published government-funded studies concerning the endocrine disruptor bisphenol A (BPA) found that it had significant biological effects at doses of less than 50 mg/kg/day (vom Saal and Hughes 2005). In contrast, 0 out of 11 industry-funded studies found biological effects at the same dose levels. According to the review, these results could be attributed to questionable features of the industry study designs, such as using an insensitive strain of animals and examining inappropriate endpoints.

In the conclusion to an NSF-funded project that evaluated oversight models for nanotechnology, a group at the University of Minnesota argued that these sorts of financial conflicts of interest in nanotechnology safety testing could perhaps be addressed through a two-pronged strategy of developing standardized research procedures and then vetting data through a peer-review process (Ramachandran et al. 2011, 1361). Unfortunately, past experience with drug- and pesticide-safety testing indicates that this approach still leaves room for a great deal of abuse (Elliott and Volz 2012). Instead, a growing chorus of scholars is insisting that governments or other relatively independent sources must provide more funding on policy-relevant research topics like nanotechnology risks, and industry funding for chemical safety tests should ideally be funneled through an independent agency (e.g., Angell 2004; APHA 2003; Krimsky 2003; Shrader-Frechette 2007a, b; Volz and Elliott 2012).[8]

Unfortunately, the U.S. National Nanotechnology Initiative (NNI) has come under fire for failing in this regard. According to a report by the U.S. National Research Council (NRC), recent plans for funding environmental health and safety research on nanomaterials amount "to an ad hoc collection of research priorities" from the 25 federal agencies associated with the NNI (Service 2008, 1779). Andrew Maynard, the Chief Science Advisor for the Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars, has also criticized the NNI for failing to fund environmental health and safety research adequately. While the NNI claims to be putting about 5 % of its nanotechnology research budget into environmental health and safety studies, Maynard claims that only about one-fifth of this funding is on *highly relevant* risk research (Maynard 2008, 11). The NRC report calls for the NNI to develop "an overall vision and a plan for how to get there and to come up with the money to do so" (Service 2008, 1779). On this point, the three recommendations discussed in this section converge. We need socially- and

[8] Admittedly, government agencies are also influenced by a wide range of values and concerns. The point of promoting government funding is not to remove all value influences from scientific research but rather to counteract the radical, egregious biases associated with much industry-funded research (see McGarity and Wagner 2008; Michaels 2008).

ethically-sensitive scientists, deliberating among themselves and with appropriate stakeholders, to decide how to make the value-laden decisions involved in nanotoxicology research. This should occur both at the general level of developing a vision for funding environmental health and safety research in government agencies and at the more detailed level of choosing strategic research projects that help to fulfill that vision.

10.5 Conclusion

This chapter has explored a variety of ways that ethical and societal values associated with environmental policy making move "upstream" into the practice of policy-relevant scientific research. In the case of nanotoxicology, researchers face value-laden decisions about what materials to study, what biological models to employ, which effects to examine, and what standards of evidence to demand. Depending on how these choices are made, they can support the interests of those who want to aggressively protect environmental and public health, or they can benefit the regulated industries that are trying to market new products. In order to incorporate more effective ethical and societal reflection on these decisions, this chapter suggests developing socially-sensitive research-ethics training, developing appropriate forms of deliberation, and strategically investing in independently funded research. Using approaches like these, we can hope to develop a nanoethics adequate to the task of addressing the ethical and societal values associated with nanotoxicology.

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Part IV
Public Debate and Policy

Chapter 11
Nanotechnology, Risk and Public Perceptions

Philip Macnaghten

11.1 Introduction

In the past 10 years, a policy and media debate about nanoscience and nanotechnologies has emerged, characterised by competing visions of promise and threat (Selin 2007). For their advocates nanotechnologies are seen to have unprecedented economic and social potential, ushering in a 'new industrial revolution' that will include breakthroughs in computer efficiency, pharmaceuticals, nerve and tissue repair, surface coatings, catalysts, sensors, materials, telecommunications and pollution control (European Commission 2004; House of Commons Science and Technology Committee 2004; Lloyds 2007; Roco and Bainbridge 2003). Worldwide research funding for nanotechnologies has increased rapidly, with public investments in the US, Japan and the EU each topping $1 billion in 2005. Corresponding R&D investments by industry worldwide are around the same level, and increasing, with an average annual increase of approximately 25 %, year on year (Lux Research 2008; Renn and Roco 2007). The Project on Emerging Nanotechnologies as of August 2008 lists 620 consumer products on its inventory of nanotechnology-based consumer products, while Lux Research estimates that by 2015 the market for nanomaterials and processes will exceed $4.0 trillion (Lux Research 2008; Project on Emerging Nanotechnologies 2008).

At the same time, ethical, social and regulatory concerns which originated with dystopian fears of 'grey goo' and self-replicating nanobots running 'out of control' (Joy 2000; Drexler 1986), are rapidly taking on a sharper focus around a growing debate on the potential toxicity of nanoparticles and carbon nanotubes and their

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unknown and potentially hazardous impacts on the environment and human health (Nature 2003; The Economist 2007). Not surprisingly for such a novel technology, risk assessment remains at an early stage but mounting evidence appears to suggest the potential for significant harm. Such concerns are shared across learned societies, government departments, international bodies and industry as well as NGOs (see, amongst others, Council for Science and Technology 2007; Defra 2007; Friends of the Earth 2007; Lloyds 2007; Royal Society/Royal Academy of Engineering 2004), leading to various initiatives aimed at the 'responsible development' of nanotechnology (BASF 2007; Defra 2006; Dupont 2007; European Commission 2007). Given the novel properties that materialise at the nanoscale, not least the enhanced chemical reactivity arising from increased surface area (dissecting a 1 cm cube of any material into 1 nm cubes increases the total combined surface area some ten million times), it is perhaps not surprising that there might be unforeseen and unanticipated effects. Gold and silver are good examples. Normally inert and unreactive, at the nanoscale gold acts as a highly effective catalyst, and silver displays bioactive properties (Smith 2004).

This brief account of the current policy and regulatory debate on both sides of the Atlantic provides a backdrop to review current understandings of public perceptions, to appraise diverse methodologies and approaches, and to evaluate their significance to current debates on governance. However, there is a further reason why questions of public perceptions have risen in prominence both in public policy and academia. Traditionally it has been assumed that technological innovation should proceed according to its own logic of assumed social benefit, relatively untainted by matters of ethics, democracy or social norms, and to find its eventual acceptance or rejection in the market place. It was assumed that any attempt to create 'barriers' to innovation, over and beyond matters of predictable harm, was anti-competitive and in breach of principles of free trade. The associated policy ambition was that of creating a society literate and confident in science, cognisant of its importance to social and economic well-being, and enabled by governmental and private sector educational programmes aimed at the so-called public understanding of science. However, of course, society has rarely accepted such claims of inevitable benefit without question, not least due to a range of contemporary experience of technological controversy and scientific mishap arising from unforeseen consequences of scientific advance, ranging from thalidomide to BSE to endocrine disruptors to chlorofluorocarbons. Part of the policy response to such critique, fuelled in part by the largely unanticipated political controversy surrounding GM foods and crops, has been to promote dialogue models of public engagement, starting with the prescient 2000 report from the UK House of Lords Select Committee on Science and Technology, and its call for more open, two way, exploratory and participatory forms of public engagement (House of Lords 2000). The appeal for more proactive involvement and deliberation in debates about the social and ethical dimensions of science and technology are now commonplace in policy papers and reports (see Department of Trade and Industry 2000; European Commission 2004; HM Treasury/DTI/DfES 2004; Royal Commission of Environment and Pollution 1998) with nanotechnology presented as the current focus (see Kearnes et al. 2006; Wilsdon and Willis 2004; Wood et al. 2003, 2007).

One of the implications that arise out of this 'anticipatory' turn in technological governance is that it reinforces the need to understand and characterise better the public, its perceptions of novel technology, and crucially, the factors that structure and underpin public attitudes and response. This is especially challenging for those analysts specialising in public perceptions since it is not clear precisely what constitutes the object of inquiry: i.e. nanotechnology. Indeed, the very definitions and constitutions of the term has been the subject of lively debate, within the scientific community and beyond (House of Commons Science and Technology Committee 2004). As conventionally understood, the term 'nanotechnology' refers to the design or manipulation of structures and devices at a scale of 1–100 nm (or billionths of a metre). Yet scale is but one characteristic that unites the diverse activities and applications commonly referred to in this way. Additional complexities flow from the convergence of nanoscale innovations in different domains: notably, the life sciences, cognitive sciences and information technology (Nordmann 2004; Wood et al. 2003; European Commission 2004). With these cautionary remarks to hand I now survey the current literature on public perceptions starting with survey data, paying particular attention to how nanotechnology has been framed in the research process.

11.2 Review of Survey Research

Analyses of public understanding to nanotechnology have been dominated by survey research. Over the last 6 years there have been several key studies which have examined different aspects of public perceptions of nanotechnology, starting with an early, internet-based survey by William Bainbridge (2002) sponsored by the National Geographic Society and the National Science Foundation. The survey suggested high levels of enthusiasm and expectation of future social benefit for nanotechnology and little concern about possible dangers. Over 57 % agreed that 'human beings will benefit greatly from nanotechnology' while only 9 % agreed that 'our most powerful twenty-first century technologies – robotics, genetic engineering, and nanotechnology – are threatening to make humans an endangered species, leading Bainbridge to interpret little public support for Bill Joy's prognosis of the likely future perils posed by nanotechnology and related fields. The respondents were seen also as more likely to associate mentally the future benefits of nanotechnology with the future benefits of the space programme, nuclear power and cloning, as opposed to the 'pseudo-science' ideas of 'time travel machines' and instruments that can measure the 'human spirit', again leading Bainbridge to claim that association of nanotechnology as science fact rather than science fiction. While Bainbridge's non-random sample arguably was biased in favour of those who were already 'pro-science', the survey nevertheless found broadly equivalent 'pro-nanotechnology' views across age, educational and political orientation variables – the only significant difference being gender with 69 % of men agreeing with the pro nanotechnology statement compared with just 47 % of women.

Two years later Michael Cobb and Jane Macoubrie conducted the first national phone survey of Americans' perceptions of nanotechnology, set up to measure public knowledge, levels of familiarity, sources of information, perceptions of risks and benefits, and levels of trust (Cobb and Macoubrie 2004). Critically, and as expected, the survey found that most citizens of the United States are unfamiliar with nanotechnology with 80 % of survey respondents reporting that they had heard 'little' or 'nothing' about nanotechnology, and with only one in three correctly answering questions designed to measure accurate factual knowledge. Notwithstanding this lack of factual knowledge, the respondents nevertheless anticipated the greater probability of benefits over risks, with 40 % agreeing that benefits would outweigh risks compared to 22 % agreeing that risks would outweigh benefits. The finding was coupled with strong correlations between the level of respondents' knowledge of nanotechnology, positive emotions and positive predictions of benefit versus risk. Drilling into the substance of risks and benefits, when asked to choose between alternatives, the survey found 'loss of personal privacy due to tiny surveillance devices' as the most important risk to avoid (31.9 %), while identifying 'new and better ways to detect and treat human diseases' as their most preferred potential benefit (57.2 %). Interestingly, and in contrast to corporate interest and investment in nanotechnology, only a small minority of respondents identified with 'cheaper, better consumer products' as of most potential benefit (3.8 %). The survey found respondents expressing low levels of trust in the nanotechnology industry with 60 % of respondents stating that they had 'not much trust' in business leaders' ability or willingness to minimise the risks of nanotechnology to human health. The survey was interpreted to suggest that Americans are basically positive towards nanotechnology (even when it is presented within negative frames) but that trust in elites is low.

A more elaborate and follow-up study was conducted by Jane Macoubrie in 2005 aimed at providing an in-depth look at 'informed public perceptions of nanotechnology and trust in government' (Macoubrie 2005, 2006). Funded as part of the Woodrow Wilson's 'Project on Emerging Nanotechnologies', this research differs from most other work by focusing on informed lay publics and by incorporating more sophisticated qualitative aspects into its design: at this stage, at least, it appears to be definitive within this type of study (and given its limited geographical focus). In many respects its findings echo those of previous work. Awareness of nanotechnology was low (and the media did not appear to be a significant source of information); general attitudes towards nanotechnology were enthusiastic (50 % being positive rather than neutral or negative); 71 % thought that benefits would equal or exceed risks; and there was little support for a ban. Reported concerns included uncertainty as to effects, regulation and risks, and the effects on human health and the environment. As with previous studies, there was a deep distrust of government, industry and regulatory authorities – largely ascribed to prior experiences of these bodies. Macoubrie notes that in the context of a lack of information (and trust) in the oversight processes designed to manage risks, the respondents drew on analogies drawn on 'experiential knowledge about past "breakthroughs" whose limitations and negative effects were poorly understood initially, and even when once known, were poorly managed' (2006, 221). While analogies to past

controversies – such as asbestos, dioxin, Agent Orange or nuclear power – may be misleading in strict scientific terms, they nevertheless may have resonance as social process, including, for example, latent concern in the ability of political and regulatory systems to keep pace with the commercial development and diffusion of scientific advance (see Grove-White et al. 2000). Finally, she reports a widespread desire for more information and openness and to be included in decision-making processes.

The studies above all focus on the United States. A 2004 report commissioned by the Royal Society and the Royal Academy of Engineering's Nanotechnology Working Group provides a UK perspective. The research aimed to assess awareness about nanotechnology, and also whether nanotechnology would have a positive or negative effect on quality of life (BMRB Social Research 2004). They found that there was limited awareness about nanotechnology (29 % of respondents said they were aware of the term). Awareness was higher among men (40 %) than women (19 %), and was slightly lower for older respondents. There was also a clear pattern by social grade, with awareness peaking at 42 % for ABs and falling to 16 % of DEs. The majority (68 %) of those who were able to give a definition of the word felt that it would improve life in the future, compared to only 4 % who thought it would make things worse, depending on how it was used. Use of the Eurobarometer survey tool provided a European comparison, revealing some key differences as well as similarities (Gaskell et al. 2004, 2005). When asked whether nanotechnology will improve our way of life, 50 % of the US sample agreed against only 29 % of Europeans. The authors suggest that "people in the US assimilate nanotechnology within a set of pro-technology cultural values" (2005, 81) and are thus more positive about science and technology generally. By contrast, in Europe there is "more concern about the impact of technology on the environment, less commitment to economic progress and less confidence in regulation" (Gaskell et al. 2005, 81).

Recent work has also sought to examine the mechanisms by which 'attitudes' towards nanotechnology are created. Thus Lee et al. (2005) look at the ways in which knowledge and affect interact to define attitude: they suggest both that knowledge about science is used to evaluate nanotechnology and that affective factors (such as trust or anxiety about science) provide important frameworks for those evaluations, while Kahan et al. (2007) explore the role of values in mediating expressed opinions to nanotechnology under conditions of unfamiliarity. Where there are strong emotions towards science, they argue, additional knowledge about nanotechnology may not change attitude. Schefuele and Lewenstein (2005), in a study based on data from a US phone survey, argue that 'cognitive shortcuts' (such as ideologies, religious beliefs or – particularly, they suggest – media portrayals) are used by laypeople to inform judgements rather than their using "all available information to make decisions" (p. 660; see also Scheufele and Lewenstein 2005). This, they suggest, means that understanding media coverage around nanotechnology will be vital for understanding likely public responses. A further study conducted in 2007 claimed that public concern over some risks of nanotechnology was actually less than that within nanoscience communities, possibly reflecting an increased sensitivity in the expert framing of risk and scientific uncertainty (Scheufele et al. 2007).

11.3 Underlying Frameworks

While illuminating in various guises it is important to note that much of this survey-based work is problematic in several regards. Perhaps most importantly, surveys tend to utilise a framing in which risk is the assumed key point of interest for publics with regard to new technologies: public attitudes are understood to be focussed on issues of safety and to involve assessments of the 'risks and benefits' of nanotechnologies (see Bowman and Hodge 2007; Peter D Hart Research Associates 2007). Benefits, similarly, tend to be either assumed or framed in economic terms with little attempt devoted to examine how the promised benefits relate to social values. Broader framings, concerns and meanings are thus either ignored or under-represented with little scope provided for meanings and understandings to be expressed in participants' own terms. This limitation has potentially profound implications in that surveys may be unwittingly imposing pre-defined categories, questions and issues that reflect the researcher's own assumptions, often in close alignment with regulators and corporate interests, and possibly at odds with wider public sentiment. Recent work, for example, continues to operate under the explicit belief that public "understanding of nanotechnology will be an important challenge to avoid a backlash by a less than informed public" (Waldron et al. 2006; see also Castellini et al. 2007) and therefore focuses on public knowledge of particular 'facts' relevant to nanotechnology. Indeed, in the related domain of GM foods and animals, a clear research finding was the inadequacy of such official framings in capturing the character of legitimate public concerns (Grove-White et al. 1997, 2000; Macnaghten 2004). Further limitations, arising from the specific character of the technology, include: the highly questionable assumption that nanotechnology exists as a unified research programme to which it is possible to have a single, stable response or 'attitude'; the fact that most nanotechnologies remain at an early or pre-market stage of development, existing largely in terms of their promise; and the reality that most people are unfamiliar with the term, and so presumably do not have pre-existing attitudes as traditionally conceived;

More generic critiques of the limitations of survey research are well-rehearsed (see Hill and Michael 1998; Macnaghten and Urry 1998). One dynamic that seems especially important is how survey research addresses participants as citizens and/or consumers. Hill and Michael (1998) have shown that the Eurobarometer survey instrument is ambiguous as to whom it addresses: at times it seems to be concerned with the 'citizen', while at others it constructs the user as consumer and seeks to measure 'product recognition'. Similarly, much of the work discussed above assumes that the publics which they are interested in will exercise choice and control at the level of products. Publics are understood to be consumers (or not) of individual technologies rather than citizens with broader concerns: thus such work asks about "intentions…to purchase lamb or beef made using nanotechnology" (Cook and Fairweather 2007) or opinions on the safety of the food supply (Peter D Hart Research Associates 2007). Previous research (Grove-White et al. 1997) has indicated that people reflect in rather different ways when addressed as

citizens or consumers, bringing in particular framings, perspectives and rationalities to suit the context: the issue of exactly how participants are being framed is therefore an important one.

A further criticism concerns one of methodological individualism that resides within conventional survey research, and the embedded assumptions of human thinking, attitudes, values and opinions as internally coherent, reflecting as is presumed underlying cognitive processes. An alternative approach seeks to locate consistency not within the individual subject but rather in the cultural milieu out of which repertoires of understanding and argument emerge. Such 'discursive', 'narrative' or 'rhetorical' approaches to human thought and action develop a different mode of research praxis and analysis favouring qualitative and ethnographic methods where the analytical task is to observe the evolution and contestation of attitudes in context, and typically in conversation. Whether explicit or not, qualitative approaches offer the potential for understanding not simply what people think about nanotechnology, but the factors that underpin such thinking.

11.4 Review of Qualitative and Public Engagement Research

The Royal Society and Royal Society of Engineering working group commissioned the marketing group BMRB to undertake both qualitative and quantitative research as part of its study activity (BMRB 2004). The qualitative research aimed to examine public awareness and attitudes, public views on potential environment, health and safety impacts, as well as social and ethical dimensions. Perhaps not surprisingly, the research found considerable ambivalent attitudes towards the technology. While considerable enthusiasm and excitement was expressed towards prospective applications, notably in the medical domain, and in its potential to improve quality of life, concerns were also expressed as to its impending transformative impacts in restructuring social and economic life coupled with unease on possible long-term and unforeseen effects. The report concluded that considerable 'public engagement' initiatives were required to ensure that constructive and proactive debate about the future of the technology developed, before deeply entrenched or polarised positions appear. Clearly influenced by recent and bruising experience of genetically modified foods, where public attitudes were seen to have played a formative role in the development of the controversy, the UK Government and associated funders launched a series of initiatives aimed at proactive or 'upstream' public engagement.

A report by the Nanotechnology Engagement Group (NEG) summarises the findings of UK research on public engagement on nanotechnology: these included the 2005 NanoJury UK (a citizen's jury); the 2004–2006 Small Talk programme, which sought to coordinate science communication-based dialogue activities; Democs, a conversation game designed to enable small groups of people to engage with complex public policy issues; and the Nanodialogues project, a series of practical experiments to explore whether the public can meaningfully inform

decision-making processes related to emerging technologies in four different institutional contexts (2005–2006) (Gavelin et al. 2007). The NEG report usefully discusses each project's findings in detail, as well as synthesising these in the form of recommendations for science policy and for public engagement. The authors suggest that there are three key areas which are consistently raised by lay publics deliberating nanotechnology:

First, public attitudes are formed not only in relation to particular technologies, but also to the policies and values that shape the direction of technological development, and to the social and political conditions in which they emerge. Public participants were not only concerned with the potential benefits and risks of nanotechnologies, but also with broader questions concerning who the benefits and risks are most likely to affect, why this technology and not another, and what this will mean for questions of control. This is an important finding and one that has important implications for traditional forms of technology assessment. The second observation concerns the institutional dimensions of risk perceptions. Public attitudes to risk, uncertainty, and regulation were found to be interconnected with the perceived ability of regulation and regulatory authorities to manage complex risks. Perceptions of risks were thus mediated by public perceptions of those institutions charged with oversight – their honesty, independence, competence and so on – all of which 'rationally' influenced people's reception of current claims (see also Wynne 1980, 1992). And thirdly, there was a consistent demand for more open discussion and public involvement in policymaking relating to the management of nanotechnology policy invoking the sense that such matters were too important to be left to 'experts' but needed instead to become part of public discourse and civic life.

The reports from the individual projects discussed in the NEG report flesh out these findings in more detail and with more specific emphases (see Kearnes et al. 2006; Smallman and Nieman 2006; Stilgoe 2007). For example, the ESRC-funded 'Nanotechnology, Risk and Sustainability' project (Kearnes et al. 2006) incorporated a focus group phase where laypeople were introduced to and discussed nanotechnology in the context of their experience of other technologies. The authors identify key themes of enthusiasm and ambivalence and gradually evolving concerns around risks, but also with questions of control, power, inequality and the kind of 'utopian' futures being promised. As with most other studies, participants had little knowledge of what nanotechnology was. The authors note that "when pressed, people tended to define it as something that was scientific, clever, small, possibly medical, futuristic and associated with science fiction" (pp. 47–48). A further paper suggests, from the focus group data, that there are several broad areas of concern which are key in shaping lay responses to nanotechnology. These patterns of concern are as follows (see Macnaghten 2010): (1) Their potential for harm, mishap and potential irretrievability; (2) The inevitability of technological innovation as being double-edged; (3) The likelihood that the technology would reduce autonomy, choice and personal control; (4) The ability of technology to transgress limits and to 'play God'; and (5) The speed of technological innovation as beyond the control of governance.

The most recent UK-based deliberative process was a citizen's jury-style event funded by the consumer organisation "Which?" designed to look at how

nanotechnology would "affect consumers" (Opinion Leader 2008). Again, the jury identified key opportunities: medical applications, increased consumer choice, the potential to help the environment and developing countries. The process brought up safety as a key concern, along with the current lack of effective regulation and labelling. The dangers of military or surveillance applications and questions about inequality and impacts on the environment were also raised. Recommendations focussed around the need for better regulation and information. While this process might be considered problematic in its strong focus on participants as consumers and corresponding emphasis on risk (the report's introduction notes that the organisers were "keen that consumers should be able to make educated choices about the extent to which they use nanotechnologies… being aware of the areas in which uncertainty remains"; Opinion Leader 2008, 3), it is striking that despite these framings broader issues still emerged. The report notes, for example, that some participants were concerned about relying on 'high-tech' rather than currently available 'low-tech' solutions, or about whether nanotechnology was simply a money-making opportunity for big business.

Public engagement activity in the United States has been more limited although the investment of a NSF funded Centre for Nanotechnology in Society has created a context for deliberative research which is rapidly being translated into initiatives, the most notable of which is an integrated set of consensus conferences set within a National Citizens' Technology Forum. Loosely based on the Danish Consensus Conference practice, and conducted across six sites in the United States (in New Hampshire, Georgia, Wisconsin, Colorado, Arizona, and California), the research was set up to present the informed, deliberative opinions of ordinary, non-expert people for the consideration of policy makers who are responsible for managing these technologies before those technologies are deployed. The process itself was extensive, involving parallel panels of approximately 15 individuals undertaking a guided process of learning and deliberating in order to create a set of recommendations arrived upon by consensus. The final reports generated by the individual Citizens' Technology Forums show common themes around: the call for regulation, the need for a new and dedicated policy commission, concerns over access and equity, the need to prioritise remediation over enhancement, and the requirement for wise and judicious oversight (see http://www4.ncsu.edu/~pwhmds/final_reports.html).

11.5 Other Perspectives on the Public and Public Discourse

A final category of literature is related to the role of the media and other mediating sources in the public reception of nanotechnology. There is, for example, a small literature examining media coverage of nanotechnology (for a brief review, see Kjølberg and Wickson 2007; also Anderson et al. 2005; Faber 2006; Gaskell et al. 2005; Kulinowski 2004; Stephens 2005). Toumey's work more explicitly relates media coverage to public perceptions. As well as tracking nanotechnology's 'creation myth' through the scientific and popular press (Toumey 2005), he has argued

that the narratives surrounding nanotechnology will help anticipate public reactions to it (Toumey 2004). Drawing on the histories of recombinant DNA and cold fusion research, he suggests that if certain conditions are met – including polarised and hyperbolic discourse and exacerbated differences in power and wealth – then negative stories about nanotechnology may rapidly become dominant. As he notes, a "little bit of recklessness or disdain will easily be magnified and transmuted into a compelling story about amoral scientists arrogantly producing terribly dangerous threats to our health and our environment" (2004, 108). Somewhat similarly, Schummer (2005) attempts to understand public interactions with nanotechnology through examining patterns of book buying. Using a complex network analysis based on data from Amazon.com, he argues that there is high public interest in nanotechnology, with many purchasers of 'nanobooks' being new to science and technology literature, and that this interest is focussed in books about forecasting and investment. He also suggests that interest in fiction and non-fiction about nanotechnology remains mostly separate, but that links between them are growing – as are connections to the business world – through 'border-crossing' authors.

A related literature has focused on the visions or imaginaries that are manifest in nanotechnology policy and discourse and their role in constructing future-oriented promises and expectations. Informed by wider social science interest on the role expectations in constructing socio-technical futures (Selin 2007; van Lente 1993; Brown and Michael 2003), and on the master narratives of technoscience that drive and frame current science and technology policy (Felt and Wynne 2007), research has begun to explore the multiple ways in which scenarios, foresight or vision assessment techniques can be deployed to help anticipate the likely social and ethical implications of nanotechnology. For example, van Merkerk and van Lente explored the concept of 'emerging irreversibilities' to help underlying the dynamics of on-going technological development in the case of nanotubes with the aim of rendering the technology more socially accountable (van Merkerk and van Lente 2005); the European Framework 6 project Nanologue has developed three scenarios aimed at setting out three possible futures in the development of nanotechnology with the aim of structuring the debate around 'responsible innovation' (Nanologue 2007); while scenarios have been incorporated into research projects around upstream public engagement (Kearnes et al. 2006), green technology foresight (Joergensen et al. 2006), a CNS-ASU project that used scenarios to frame debates about the societal implications of nanotechnology, and a project commissioned by the UK Economic and Social Research Council to create scenarios about converging technologies. Using more literary cultural studies are studies that have examined the role of science fiction in the development of nanotechnology policy (Milburn 2004) and a project based on conversations with scientists and engineers about the role of science fiction in shaping the moral imagination of practitioners (Berne 2006).

Finally, there are at least two agenda-setting papers which seek to shape the emerging field. Bainbridge (2004) discusses six methodologies which he believes will be useful for social scientists seeking to examine the "socio-cultural meaning of nanotechnology" (p. 285). The six include web-based questionnaires, vignette

experiments, and quantitative content analysis: of the six, only one – textual analysis of science fiction novels – is a qualitative method. Bainbridge writes with a concern for examining and setting right – through "remedial action such as educational reform or public information campaigns" (p. 285) – cultural perceptions of nanotechnology. His agenda – driven by the assumption that the technology unproblematically has "vast potential" (p. 298) – may therefore be viewed as somewhat limited. Writing from a different perspective, Macnaghten et al. (2005) similarly seek to outline a research programme for real-time social science analysis of nanotechnology. They describe five areas (Imaginaries, Public Engagement, Governance, Globalisation, and Emergence) which social science could productively investigate: all touch upon public negotiations of nanotechnology in some way. This research agenda is, as Bainbridge's is, explicitly linked to action. In this case, however, the emphasis is not on educating publics but on "rendering scientific cultures more self-aware of their own taken-for-granted expectations, visions, and imaginations of the ultimate ends of knowledge, and rendering these more articulated, and thus more socially accountable and resilient" (p. 278). Within this programme it is therefore science and its governance which are seen as the focus for action. Social science is viewed as part of an interdisciplinary collaboration whereby nanotechnology is robustly managed and lay inputs are included 'upstream' in its development (Wilsdon and Willis 2004).

11.6 Conclusion

The problematic nature of studying public perceptions of technologies that frequently don't exist yet can perhaps explain the structure of this body of literature: it is split between (generally) crude survey research and descriptions of deliberative policy processes. While many of the studies I have discussed might be questioned in terms of their framing, it is possible to draw out some key points. In sum, the key points are as follows.

Firstly, both quantitative and qualitative studies indicate that there is considerable optimism for (certain) nanotechnologies, particularly those which will deliver social benefits such as helping poor people or delivering new medical technologies or helping the environment. The question of motivation is a key variable in structuring public responses. However, in this regard, most survey research and many deliberative processes uncover distrust and cynicism of industry, science and government motivations, not simply in terms of their sensed ability to manage nanotechnologies and provide reassuring forms of oversight, but also with regards to the forces that are seen to be driving nanotechnology R&D. When acquainted with considerations of political economy, including the sizeable budgets allocated to research by both private and public institutions, people tend to question the likelihood that such research will be devoted to good purposes such as improving the environment or helping the poor. The associated promise that nanotechnology will be the 'next industrial revolution' simply accentuates this dynamic.

Secondly, most studies indicate that there remain some areas of concern. Survey work tends to deliver findings on concerns about risks, regulation, and uncertainty. These also emerge in more deliberative processes, alongside broader questions about control, inequality, power, and whether we really need or want these technologies. What this means is that public perceptions of nanotechnology can not be dislocated from wider perceptions of technology and its role – both good and bad – in constituting the good life. Nanotechnology, including its promises to 'control the structure of matter' and associated claims for precision and intervention on nature 'at its core', thus acts as a symbol that both galvanises concern and excitement about advanced science and its relationship to society. Understanding this symbolic role is a topic for future research.

Thirdly, most research indicates that lay publics would like more information and openness about nanotechnology, and that they feel it's important that they have the opportunity to be involved in shaping science policy in this area. Again this points to the widespread aspiration for closer involvement in nanotechnology research and policy decisions at a stage when there remain real opportunities for influence and modulation. Understanding how to operationalise such 'upstream' engagement in ways that are both meaningful and resonant to both public and private actors is a final issue for future inquiry.

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Chapter 12
Unlocking the Futures of Nanotechology. Future-Oriented Narratives and Access to the Public Discourse on Nanoscale

Simone Arnaldi

12.1 Introduction

Futuristic visions have accompanied the development of nanotechnology since Eric K. Drexler popularized the word with his 1986 book *Engines of creation*. Future-oriented narratives about expectations and promises of nanoscale technologies have a centre stage in the public discourse, but their statute is anything but controversial. Both prospected innovations and the discourse on anticipated innovations have garnered attention by scholars and commentators: on the one hand, literature focused on the transformative and disruptive power of nanoscale technologies, discussing their potential ethical, social, economic impacts (e.g. HLEG 2005; Ott and Papilloud 2007; Roco and Bainbridge 2001, 2002; Whitman 2007); on the other hand, the disrupting impacts of the underlying values and assumptions of visions and future-oriented narratives on our current ethical and cultural system have been examined (Cameron 2006; Grunwald 2007; Khushf 2005; Schummer 2007).

In both cases, the focus of attention has been on transformation, on the revolutionary impacts of this emerging field, on the dramatic social change possibly induced, and on the consequent disarticulation of the present socio-technical order. Accordingly, scholars have pleaded for a renewed configuration of the relationships between technoscience, government, and society, advocating the engagement of stakeholders and the public in nanotechnology development (e.g. HLEG 2005; Roco and Bainbridge 2001, 2002; Renn and Roco 2006), and public consultation and engagement projects have been organized in many countries.

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If literature has indeed analyzed the impacts of nanotechnology and their discourse in terms of transforming socio-technical order, less attention has been paid instead to the possible role of nanotechnology discourse in *stabilizing* socio-technical networks and, in particular, in *producing* specific configurations of the division of social labour and of the relationships between technoscience, government, and society.

Rather than discussing the merits of these arrangements that future-oriented narratives of nanotechnology contribute to create, this chapter indicates the problem of unequal access to these future-oriented debates as an ethical and social problem, as it reduces the plurality of perspectives about alternative future developments and choices that are available in the public discussion, and as it creates the conditions for the persistence of this exclusion in the future.

A first section of the chapter briefly introduces the richness and relevance of anticipations, expectations, visions, promises and other forms of anticipatory claims in nanotechnology discourse. A second section of the chapter will provide a minimal interpretive framework for the reader about the influence of future-oriented narratives on developmental trajectories of technologies and about the ways in which this influence manifests itself. A third section will discuss how these ordering processes fostered by this future-oriented communication are a potential element impeding access to the public debate on (nano)technology. A closing section claims the importance of opening up future-oriented communication to a variety of social actors in order to move beyond the technocratic logic of science-society relations that appears still predominant.

12.2 What Futures?

In nanotechnology discourse, the future is rich of expectations and promises. The enabling character of this emerging technological field extended the supposed transformative reach of nanoscale science and technology to almost countless application areas. “Nanotechnologists Project That Their Work Will Leave No Stone Unturned”, says the US National Science and Technology Council Brochure *Shaping the world atom by atom* (NSTC 1999, p. 10). Policy documents, opinions of ethical advisory boards as well as outreach notes have often translated this projection into a careful mapping of the scientific, technical, economic, and social areas that nanotechnology is supposed to revolutionize (e.g. National Research Council 2006; European Commission 2004; Commission de l’éthique de la science et de la technologie 2006; Comitato Nazionale di Bioetica 2006). Nanotechnology’s capacities have been even amplified when considering its potential for convergence with other emerging technologies. For instance, in its examination of the social implications of nano-, bio-, info-, and cogno-convergence, the High Level Expert Group on Foresighting the New Technology Wave appointed by the European

Commission has suggested that nanotechnology enables these Converging Technologies (CT) to have an "unlimited reach" on the material world:

> As the convergence draws in other technologies and technology-enabling sciences, it would appear that nothing can escape the reach of CTs and that the mind, social interactions, communication, and emotional states can all be engineered. […] One can expect that for every problem, someone may propose a more or less creative, viable or desirable technological fix (HLEG 2005, p. 3).

In the utsnaturs on converging technologies, nanotechnology is expected to transform "the way almost everything – from vaccines to computers to automobile tires to objects not yet imagined – is designed and made" (White House 2000). Human nature and our self-perception as human beings are expected to change, given "[t]he potential of nanotechnology, biotechnology, and cognitive science to bring about basic shifts in human nature" (Cameron 2006, p. 286), along with the possibility that "wholly new ethical principles will govern in areas of radical technological advance, such as the acceptance of brain implants, the role of robots in human society, and the ambiguity of death in an era of increasing experimentation with cloning" (Roco and Bainbridge 2002, p. 31). There is no reason to refer only to what Gordijn called 'utopian dreams' (Gordijn 2005) for finding other examples of the expected, sweeping changes brought by nanotechnology. Also more mundane instances and opinions converge in attributing to nanotechnology the potential "to change medical science dramatically" (EGE 2007; ETP 2006), "to help reduce the human footprint on the environment" (Azonano 2007), to contribute to address successfully a significant number of problems affecting developing countries (Salamanca-Buentello et al. 2005).

In general, nanotechnology discourse is characterized by an emphasis on the transformative impacts of nanotechnologies, on the dramatic social change that they can possibly induce, and on the radical modification of the present sociotechnical order and social cohesion they can consequently cause (for an overview, cf. the collection of articles edited by Tyshenko 2010). As noted by Grunwald (2007), this emphasis on change reflects the power of science and technology to reduce human dependency on the natural and social given, thus expanding the options available for action. This increased capacity of technical manipulation augments contingency in the *conditio humana*, thus challenging shared beliefs, values, and norms, as well as stable behavioural patterns, societal interdependencies, and division of social labour. The 'limitlessness' of nanotechnology's promised reach shifts this contingency to an increased level.

Existing research has illustrated that this potential impact of nanotechnology is not deployed only through technical novelties and their applications, i.e. on a *factual dimension*. Rather, this transformative power is performed also on the *discursive level*. On this level, visionary communication and future-oriented narratives call into question social order, by discussing present certitudes and collective convictions and by suggesting alternative courses of action, which are fostered by technology, even before the prospected technical options are in place. As Armin

Grunwald clearly explains in his discussion of the rhetoric of converging technologies for human enhancement:

> Previously unquestioned certitudes (for example, the abilities of a healthy human eye and its limits) are already dissipated by the fact that future technical possibilities for improvement are discussed throughout society. Independent of the question, whether and when these possibilities could be realized, the possible alternatives and, with them, the possible choices come into view through the visionary communication on the future itself. Traditional certitudes are eliminated, and new contingencies are created without their technical preconditions having been established— in this manner, visions often march far in advance of scientific and technical research (Grunwald 2007, p. 384).

In his appraisal of what he calls 'speculative ethics', Alfred Nordmann unveils the underlying rhetorical mechanism that grant this persuasive force of these future-oriented narratives: the 'foreshortening of the conditional'.

> An if-and-then statement opens by suggesting a possible technological development and continues with a consequence that demands immediate attention. What looks like an improbable, merely possible future in the first half of the sentence, appears in the second half as something inevitable. And as the hypothetical gets displaced by a supposed actual, an imagined future overwhelms the present (Nordmann 2007, p. 32).

This mechanism produces

> a curious reversal of the burden of proof to promote the displacement of the present by a hypothetical future. […] Those who refuse to prepare for an unknown and unknowable future […] are required to justify their stance, if only by demonstrating that they do not suffer from status-quo-bias" (Nordmann 2007, p. 38).

In visionary and future-oriented communication on nanotechnology, epistemic uncertainty and normative orientation interact and they mutually reinforce one another: from anticipatory claims about future technical options, advice follows for shifting present policy priorities and choices; from uncertain premises, social mandates are renewed and allocated; from hypotheses, social change is demanded (cf. van Lente 1993). In Grunwald's work, anticipatory and visionary technological narratives perform therefore an orientation function as well: they are both an expression and a cause of the increased contingencies, but, on the other hand, they reduce contingency and uncertainty as they suggest, select, and make salient alternative courses of action that are considered consistent in the newly anticipated future socio-technical scenarios, whether their technical preconditions are actually in place or not (Grunwald 2007, pp. 384–385).

Despite its ambivalence, future-oriented communication has thus a role in shaping the socio-technical configurations that are associated to nanotechnologies and their discourses. The second section of this chapter will briefly illustrate how future-oriented narratives perform this role.

12.3 Why Futures?

Though a comprehensive assessment of the influence of anticipations on the governance of innovation and on science-society relationships exceeds by far the scope of this chapter (for an overview, cf. Brown et al. 2000 and Borup et al. 2006),

the following paragraphs are aimed to provide a minimal interpretive framework for the reader about the influence of future-oriented narratives on developmental trajectories of technologies and about the ways in which this influence appears.

In their appraisal of the governance of innovation in the European Union, Felt et al. (2007) suggested that these future-oriented, anticipatory narratives are the beacon of the currently dominant governance regime, which they call the "regime of the economics of technoscientific promises". In this regime, the promised benefits to be delivered by science and technology legitimate present decisions and socio-technical configurations. The power of such a regime relies on two characteristics, which are apparently contradictory. On the one hand, future-oriented narratives on technology are based on the assumption by the promoters of an emerging technology that

> the emerging technology (biotechnology in the 80s, nanotechnology now) 'will solve human problems' (health, sustainability, etc.) through a wide range of applications[. On the other,] the credibility and the force of this statement are paradoxically based on an uncertain future, and the source of its persuasive power force relies exactly from these uncertainties: promises do refer by their very nature to an uncertain future, but they require support by believing immediately in them, before they exist; it is belief, and subsequent action, that are assumed as the conditions for fulfilling a promise (Felt et al. 2007, p. 24).

In sum, this future-oriented communication outlines goals, promises, expectations, bearing mandates for action. As noticed by the literature on 'promising technologies',

> [promises] function as a yardstick for the present and as a signpost for the future. The implication for the dynamics of concrete developments is that what starts as an "option" can be labelled a technical "promise," and may subsequently function as a "requirement" to be achieved, and a "necessity" for technologists to work on, and for others to support (Rip and van Lente 1998, p. 216).

Once they are shared within and between social groups and are considered acceptable, legitimated and worth of being pursued, they acquire an independent force and require action: promising possibilities are translated into requirements to be met to deliver promises themselves, tasks are assigned to achieve these goals, and various activities are performed to respond to requirements and to the imperatives born by promising expectations (van Lente 1993; Rip and van Lente 1998; van Lente 2000). The interlocking and the mutual stabilization of agendas ends up acquiring a structural character and it becomes "forceful due to the perceived implications of the projected futures" (Rip and van Lente 1998, p. 206). These structural configurations are a result of actors discussing, negotiating, and supporting particular anticipations, and of interweaving different anticipatory claims, the (current and future) roles to actors and artefacts they assign, the mutual positions, tasks, and activities they outline, the prospected consequences of present and future actions they prospect according to these narratives.

Though these transitions are subject to debate and conflict and, therefore, they can be reversed, the configuration of the relationships of roles and agendas can become a 'natural', or better a 'naturalized', framework for actors' activities. The notion of "irreversibility" of socio-technical trajectories has been used to describe this process: the more investments and activities deployed to fulfil technological promises, the more change, delay, or arrest will meet greater resistance,

till trajectories become gradually irreversible. As van Merkerk and Robinson (2006, p. 413) explain:

> Emerging irreversibilities facilitate specific technological paths (make it easier to act and interact) and constrain others (make it more difficult to do something else). A key notion here is that emerging irreversibilities enable and constrain actors in the sense that actors encounter more or less resistance for the different options they try to explore and develop (this can be hidden behind the backs of the actors). When actors try to act against irreversibilities, this requires effort. The converse is true when actors try to achieve things in line with irreversibilities. Actors can then rely on some predictability and therefore improve the success of their strategies. The greater the degree of irreversibility, the more difficult it becomes for actors to go against it.

Through future-oriented narratives, therefore, actors, artefacts, sites and meanings are selected, ordered, and coordinated. Berkhout summarises the normative power of anticipatory statements as they describe and validate the relationship between three elements of future socio-technical scenarios: "*objectives*, the qualitative or quantitative expression of novel future outcomes; *orders*, a set of social and institutional relationships in which these objectives can be met; and *technologies*, the means for achieving objectives" (Berkhout 2006, p. 302). Emerging irreversibilities subsequent to the stabilization of actors' agendas define, affirm, and stabilize specific configurations of these relationships, reducing the possible alternatives and making salient the complex meanings and the specific technical trajectories that are associated to them.

The next section will present some remarks about the relevance of future-oriented communication for what Berkhout calls 'orders', i.e. for the (present and future) social and institutional arrangements that accompany the prospected technological trajectories of nanotechnology.

12.4 Whose Futures?

Where are expectations, anticipations, promises, etc. formulated and debated? Who contributes to the subsequent stabilization of agendas? As we have introduced, the existing relationship between future-oriented communication and the regime of innovation makes the former a crucial factor in shaping science-society relations, and, therefore, it would be wrong to consider these anticipatory narrative as something separated from the broader techno-scientific discourse, subject to different dynamics, and with different characteristics.

In particular, different but converging notions recognized the diversification and multiplication of the arenas and of sites where innovation is produced and debated. For example, the acknowledgement that politics of innovation is displaced (Nahuis and van Lente 2008, p. 559), the recognition of the hybrid nature of the public debates on technologies and their social implications (Callon et al. 2001), the multi-site and inter-textual nature of 'issue cultures' in technoscience (O'Mahony and Schaefer 2005), the transitionary quality of heterogeneous assemblages of coalitions and communities supporting different views of technological artefacts (Irwin and

Michael 2003), all these concepts share the view that technology is produced, debated, contested between various interrelated settings ranging from the context of design to the context of use.

As mentioned in the previous section, expectations, promises, and visions communicated by future-oriented narratives, and emerging prospective structures define and consolidate specific socio-technical configurations, relationships and boundaries among meanings, actors, and sites, thus reducing, ordering, and coordinating this heterogeneity. Regarding nanotechnology, different commentators have shed light on the role of future-communication in shaping the coalitions defining the different meanings associated to nanoscale research and technology. Milburn, for instance, observed how fictional representations made possible that nanotechnology managed to secure its professional future by enabling the unusual combination of scientists, fiction writers, and government officials (Milburn 2002). Schummer noticed that the definition of the ethical, legal and social impacts of nanotechnologies has been oriented by an alliance between science fiction writers, business, transhumanist organizations and visionary engineers, which is prominent among different "groups of interest" (Schummer 2007).

As briefly illustrated in the previous section, the coordination of heterogeneity has, however, its price. The division of labour and the allocation of social mandates create insiders and outsiders. The former are privileged in their mission of developing technologies; the latter are allowed to support and in no case to interfere, if one wants promises to be fulfilled. Insiders acquire the right not only work to pursue technical novelty, but also to discuss their conditions of existence and their hypothetical consequences. For instance, shaping the dominant meanings of the social implications of nanotechnology, the semantic alliances mapped by Schummer simultaneously exclude other actors and interpretive perspectives, like social scientists and their views of the issue (Schummer 2007). The so-called Drexler-Smalley controversy on the boundaries and prospects of nanotechnology invites a similar reading (Baum 2003): discussing whether nanotechnology is other than molecular manufacturing and atomic precision assembling (Drexler), whether this is either an impossible pretence (Smalley) or a strategic objective (Drexler), ends in defining the mutual positions, roles, and legitimacy of different programmes of investigation, scientists, research institutions, and disciplinary cultures (cf. Bueno 2004; Bensaude-Vincent 2004; Ferrari 2009), and in granting, or failing to grant, access of actors and groups to established arenas.

In general, as noted by Treyer (2007), the future-oriented debates include the diverse images, actors, scales, loci produced in and contributing to a lasting discussion on the futures of a common topic. These debates are the result of "the co-evolution along time of: – a corpus of representations of the futures on a specific field (be they curves, scenarios, modelling exercises, images, visions, …), each one constructed and elaborated with reference to the others; – a community of persons and institutions associated to the elaboration and discussion of these representations of the future." (Treyer 2007, p. 3). These dimensions interact: on the one hand, diverse actors introduce different perspectives on alternative future developments of a common topic. On the other hand, specific futures select and make salient

particular actors, configurations of relationships, and sites of discussion, thus selecting progressively the elements of the future-oriented debate.

12.5 Opening Futures: Access to Futures as an Ethical Problem

The features of the public debate on nanotechnologies reveal a great deal of ambiguity regarding the set of social actors entitled to enter the discussion about this emerging field. On the one hand, public authorities (e.g. European Commission 2008) and the scientific literature (e.g. Macnaghten et al. 2005; Wisdon and Willis 2004) emphasise the importance of public participation to political decisions on nanotechnology. On the other hand, some authoritative commentators lament the inappropriate reduction of these engagement exercises to forms of risk assessment, rather than opportunities to discuss the framework of innovation governance (Felt et al. 2007), while some empirical evidence show that nanotechnology discourse and practice are still largely informed by a technocratic model (Arnaldi 2010; Vinck 2010; Wolbring 2010), in a context where the public is generally diverted and uninformed (Neresini 2006).

While most of the attention has been focused on the cognitive and normative evaluation of future-oriented communication about nanotechnology in terms of the plausibility of the prospected scenarios and in terms of the social and ethical issues they raise, this chapter suggests the relevance of parallely considering the problem of access to the production of future-oriented narratives as equally important.

Actions for observing whose nanotechnology futures are, and for appraising the conditions for actors to shape these future-oriented narratives are therefore needed to promote engagement, diversity, and alternative views in future-oriented debates, as opportunities to build narratives opening futures beyond the technocratic logic of science-society relations that we are still experiencing.

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Chapter 13
Nanotechnology and Ethics – European Public Policies

Henk ten Have

13.1 Introduction

The global dissemination of science and technology is transforming bioethics increasingly into a global intellectual and practical activity. Research projects are undertaken in multiple international centres with more and more research subjects being recruited in developing countries. Medication is distributed all over the globe. Healthcare practices are increasingly standardised although guidelines and legislative frameworks may differ or even be absent. This globalisation of science and healthcare makes the benefits of scientific and technological progress, at least theoretically, available to all citizens of the world. However, we know that in practise the benefits and burdens of scientific development are not equally distributed. Poorer countries are often excluded from the benefits of biomedical progress. Vaccination programmes for infectious diseases, for example, are frequently not used in the least developed countries because of lack of resources. There is also the risk that different legal and moral standards are applied in different regions of the world. While in western countries detailed legislation regulates the conduct of clinical trials, less developed countries have experiences of 'unauthorized' research since they do not have appropriate legislation or ethical review committees. Scientific development, technological innovation and environmental protection are often the focus of close attention of policy-makers in more developed countries. One of the effects can be that research consortia and pharmaceutical companies are transferring their activities to less developed countries where legal frameworks and public oversight are less extensive. Especially Africa is sometimes regarded as the dustbin of the world. This danger is illustrated by the recent scandal over toxic waste in the Ivory Coast as well as the movie *The Constant Gardene*r.

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The globalisation of bioethics discourse and practices is therefore a necessity since similar issues and problems in relation to science and technology are arising everywhere. But it is also a challenge for at least two reasons. First, if bioethics wants to be more than descriptive, it needs to take into account the heterogeneity of moral views but also at the same time determine and defend the principles and values that are of equal importance to all citizens of the world, wherever they live. Second, if bioethics wants to be relevant in a global perspective, it needs to broaden its agenda and scope, and take into account the concerns especially of citizens in the least developed countries since their voices are hardly heard in the bioethical debate.

An important reason for the United Nations Educational, Scientific and Cultural Organization (UNESCO) to start its ethics programme in 1993 has been to make sure that in all countries due regard is given to basic values such as the freedom, dignity and rights of the human person. But an equally significant motivation was the need to ensure that all countries can participate in the advances of science and technology and the resultant benefits. Member States have since then identified basic principles and shared values in connection to the human genome and human genetic data, and they have adopted fundamental principles in bioethics in the *Universal Declaration on Bioethics and Human Rights* (UNESCO 2005). They have also initiated activities to build capacities and bioethics infrastructures in order to deal with challenges of science and technology (Ten Have 2006).

What has been true one decade ago for the international concerns in regard to genetics and life sciences is also valid for the development of nanotechnology today. As many previous emerging technologies, nanotechnology is raising many promises. Enormous benefits are expected in a wide range of areas. At the same time concerns are expressed about current and future developments. Since we are now in a relatively early stage of the development of the technology, there is an opportunity to engage in prospective ethical reflection. In assessing new and emerging technologies, the scope of ethical questions can be twofold (Ten Have 2007). On the one hand, there are moral questions arising within the framework of the technology. They concern for example, the possible adverse impact of nanotechnologies on health, safety and the environment. On the other hand, moral questions can be raised concerning the significance and value of the technology itself. An important issue is the long-term impact of nanotechnology on a global level. This is not a matter of risk assessment but it addresses the concerns of global justice and the goals of technological progress. It is unclear who will benefit and who might lose out. There is also the danger that nanotechnology will widen the gap between rich and poor countries, creating a 'nano-divide'. These concerns are realistic. The world market for nanotechnology products in 2015 is estimated between 1 and 2.6 trillion US dollars (Hullmann 2006). But the overwhelming majority of these products will be produced and sold in the US, Europe and Asia. At this stage it will be important to develop international policies in order to direct the development of nanotechnology towards social and environmental goals that are important for all citizens of the world. Many governments have now started to develop such policies, although there are significant differences among countries. In this chapter, the focus will be on the development of policies within the European Union. The Member States of this

Union have developed explicit policies in regard to nanotechnologies, on the one hand out of fear that Europe may lag behind the United States and emerging countries such as China and India, on the other hand out of concern about the possible ethical implications of these new technologies.

13.2 Interrelation of Economic and Ethical Concerns

The European Commission has in May 2004 published "Towards a European Strategy for Nanotechnology". The Commission subsequently adopted (in June 2005) after an extensive, open consultation an Action Plan for the immediate implementation of a safe, integrated and responsible strategy for nanosciences and nanotechnologies ("Nanosciences and nanotechnologies; an action plan for Europe 2005–2009"). Since then, two implementation reports have been published (European Commission 2007, 2009).
These documents are specifically motivated by two different type of concern:

1. Economic concerns. Concerted efforts are necessary in the field of nanosciences and nanotechnologies in order to address the needs of citizens in specified areas (public health, energy, transport, sustainable development) and in order to contribute to the EU's economic growth, competitiveness and productivity. Europe is worried that it is lagging behind, in particular, the United States. Global spending on R&D in the field of nanoscience and nanotechnology shows that in 2004 37 % is spent in the US, 28 % in Japan and 24 % in Europe. The per capita investment in the 25 member states of the European Union (in 2004) was 3 euros, compared to 4.5 euros in the US and 6 euros in Japan. Private investment in Europe is even lower with approximately 1.5 euros per capita, compared to 6 euros in the US and more then 12 euros in Japan. Future spending will not significantly change this picture even when total expenditures are increasing. The European Research program (6th EU Framework Programme for Research) has invested during 2002–2006 1.4 billion euros in nanotechnology, while in the new programme for 2007–2013 (7th Framework Programme) about 3.5 billion euros have been allocated for this research area.
2. Ethical concerns. In research policy it will be important to ensure that ethical principles are respected, that social considerations are integrated in the R&D process at an early stage and that a dialogue with citizens is encouraged in order to safeguard that citizen's concerns and expectations are taken into account.

To make sure that these concerns are properly addressed, the European Commission announced that it will ask the European Group on Ethics in Science and New Technologies to carry out an ethical analysis of nanomedicine. This analysis will "identify the primary ethical concerns and enable future ethical review of proposed nanoscience and nanotechnology Research and Development (R&D) projects to be carried out appropriately" (European Commission 2005, p. 9). In the first report on the implementation of the Action Plan 2 years later the Commission

announced that it intended to adopt a Code of Conduct for Responsible Nanosciences and Nanotechnologies Research (European Commission 2007). After rounds of consultation during 2007, the Code has been adopted by the Commission in February 2008 (European Commission 2008). The Code formulates seven general principles, such as 'meaning' (research activities should be comprehensible to the public and respect fundamental rights) and 'precaution' (research activities should be conducted in accordance with the precautionary principle). However, most of the principles are managerial rather than ethical, for example 'inclusiveness' (research activities should be guided by the principles of openness to all stakeholders), 'excellence' (research activities should meet the best scientific standards) and 'innovation' (research activities should encourage maximum creativity, flexibility and planning ability for innovation and growth). The Code is voluntary. The Commission hopes that it will be adopted by Members States and relevant authorities, and used in quality assurance mechanisms and as criteria for funding research activities. There is no enforcement mechanism. The Commission will only regularly monitor the Code.

In the last few years, reports on the social and ethical implications of nanotechnologies have been published in several European countries. An influential role is played by the comprehensive report published in 2004 by the UK Royal Society and Royal Academy of Engineering, including separate chapters on Social and Ethical Issues and Public dialogue. It argues that most of the ethical issues arising from applications of nanotechnologies will not be new or unique; nevertheless when these issues arise, they need to be addressed seriously and timely. It recommends to fund interdisciplinary research of the social and ethical issues and to introduce formal training on these issues for all research students and staff working in the area of nanotechnologies.

The report of the Health Council of the Netherlands (2006) emphasizes mechanisms of risk governance and public dialogue. It advocates establishing a special national commission with representatives of science, industry and civil society in order to identify and communicate risks at the earliest possible stage.

The Federal Ministry of Education and Research in Germany published the *Nano-Initiative – Action Plan 2010* in 2007. The emphasis is primarily on economic interests. Germany is number one in nanotechnologies in Europe. About half of the nanotech firms in Europe are German firms. Ethics is only mentioned very briefly. What is needed is an intensive societal dialogue to inform the public about the potential benefits and risks of nanotechnologies.

In France, the report of the ethics committee of CNRS (2006), the national research organisation, is primarily focused on ethics, but the emphasis is on the responsibility of the scientific community itself. What is necessary is "vigilance éthique" (this can be translated as 'ethical awareness' but it has a stronger undertone, referring to 'alertness'). The report recommends concertation of all relevant stakeholders, an orientation on ethics in all stages of the scientific career, the development of ethics guidebooks and the establishment of "espaces éthiques" in research centers. The recent report of the National Ethics Committee in France (CCNE 2007)

has a more philosophical approach in the elaboration of ethical issues. It argues that the dynamics of nanosciences and nanotechnologies are driven by the interplay of two approaches, in fact two different models of rationality:

1. the desire to intervene, to rearrange and to reconstruct matter (mastery through analytical decomposition); this is the classical dream of engineering ("la maitrise de l'ingenieur", "désir de contrôle")
2. the desire to synthesize and to make molecular objects capable of self-assemblage and self-replication ("l'emergence de l'imprevisible"; "désir d'emergence").

It is remarkable that in the United States policy-making in regard to ethical issues of nanotechnology is relatively lacking. The former President's Council on Bioethics has begun to examine the ethics of nanotechnology. After several sessions on the subject, the Council concluded that a moral assessment of nanotechnology is premature. Nanotechnology is of course associated with ethical problems (for example the analysis of benefit and risk) but there is not the conviction that these are novel problems. If the development of nanotechnology would make it possible to alter human beings themselves, the ethical predicament will be radically different. Since it is uncertain in what direction the technology is developing, also the ethical implications of potential nanotechnologies are unclear (PCBE 2008).

13.3 European Opinion on Ethics

The European Group on Ethics in Science and New Technologies is a neutral, independent, pluralist and multidisciplinary body, composed of 15 experts appointed by the European Commission for their expertise and personal qualities. The task of the Group is to examine ethical questions arising from science and new technologies. It issues Opinions to the European Commission in connection with the preparation and implementation of Community legislation or policies. For every full Opinion to be issued, a roundtable is held before the Opinion is adopted. Representatives of the Institutions of the European Union, experts of the fields, parties representing different interests, including NGOs, patients and consumer organisations and industrial stakeholders, are invited to participate in the debate.

The European Group published its Opinion on the ethical aspects of nanomedicine in January 2007 (EGE 2007). The focus is, as indicated in the title, on nanomedicine. The fundamental starting point of the ethical considerations is that the interests of science are legitimate and justified insofar as they are compatible with human dignity and human rights. Protection of human rights is fundamentally articulated in various European documents: the Charter of Fundamental Rights, the European Convention on Human Rights, and the Oviedo Convention which deals explicitly with biomedicine and bioethics. Human rights are rooted in the principle of human dignity. Together they "shed light", as it is said in the Opinion, on core European values: integrity, autonomy, privacy, equity, fairness, pluralism and solidarity.

The Opinion, however, also introduces a broader perspective. It refers to the United Nations Millennium Development Goals, arguing that there is a moral duty to make affordable health care and biomedical technologies available to all who need them on a fair and equitable basis.

13.4 Ethical Considerations

The European Group distinguishes several ethical issues. Similar distinctions are made in the national reports but with sometimes different emphases.

13.4.1 Safety

In fact in all reports, it is pointed out that concern for safety is of vital importance. There is a lack of data on possible risks. The European Group makes a distinction between direct risks and indirect risks. Direct risks can emerge when patients are undergoing an application of nanomedicine, for example in a clinical trial or a medical treatment. Indirect risks are associated with the possible harmful impact of free nanoparticles on public health and the environment (nano-pollution) and they can be harmful for all individuals. In practise, it is impossible to draw a precise borderline between the two kinds of risk.

The European Group argues that risk assessment should be a top priority. The lack of data is a cause of concern. There are considerable difficulties because there are uncertainties and knowledge gaps; there is also a difference between short-term and long-term risks. There is a more substantial difficulty because it is uncertain whether the current mechanisms to identify, estimate and manage risks are adequate for these new technologies. In the report of the French National Ethics Committee (CCNE 2007) it is stressed that enthusiasm among scientists to examine risks is rather low until now. In 2005, only 0.4 % of the total R&D expenditures for nanosciences and nanotechnologies have been used for research on risks. It means according to the Committee that there is first of all the temptation to produce, sell and disseminate the objects, rather than to study and understand them.

It is important to note that for the European Group risk assessment is not only a technical issue. Safe governance of nanotechnology is a key factor for the protection of human dignity and autonomy of persons directly or indirectly at risk. This means that assessing risks should take into consideration specific values. Here, the Group argues, like both French and Dutch reports that the Precautionary Principle as a general risk management tool should play a role. In assessing the relevancy of the Precautionary Principle an important cultural difference is noteworthy. The principle is not much appreciated in the U.S.A. In a session of the former President's Council on Bioethics it has been called the "Prince Charles approach", advocating a moratorium on nano-research until we are certain about the risks (PCBE 2008). However, the Precautionary Principle does not imply that scientific research should

stop. The Principle applies whenever three conditions are occurring: the existence of a risk, the possibility of harm, and scientific uncertainty concerning the actual occurrence of this harm. In these conditions, the Principle requires to identify the "acceptable risk" threshold (not "zero risk") and to balance the potential benefits as well as potential harms respecting the values at stake (e.g. human dignity). It is obvious that value judgments play a role already in the determination what is a risk itself.

In this perspective, a broader approach to technology assessment is advocated. In addition to the usual retrospective assessment there should be a prospective technology assessment at national and European level. This prospective assessment should focus on safety (agrofood, public health, environment), security (dual use, impact of bioterrorism and military research), and societal issues (impact on social, economic and institutional structures, with concern for justice and fair distribution of goods). This view has been endorsed by a Resolution of the European Parliament recognising that a responsible strategy in this field does integrate social, ethical, health and safety aspects into the technological development of nanosciences and nanotechnologies (European Parliament 2006).

13.4.2 Research Ethics

Nanosciences and nanotechnologies will give rise to special ethical concerns in the field of research. The European Group identifies the following areas where problems can emerge.

13.4.2.1 Research Priorities

Nanomedicine can create new opportunities to meet the needs of patients. But, as the European Group argues, "the overall goals of health-related research must be seen in the context of fair distribution and the overall goal of alleviation of the global health status" (EGE 2007, p. 59). Ethical questions should therefore be raised concerning the criteria used in priority setting. Patenting and private gain derived from research funded by public money raises the issue of the fair sharing of burdens and benefits. There is a need to clarify the ways in which public investments in this area will benefit the citizens of Europe. The Group again refers to the UN Millennium Development Goals, invoking the global perspective, as is also done in the Dutch report.

13.4.2.2 Clinical Medicine

Several ethical questions concern clinical research and practice. Given the lack of knowledge and uncertainties it is difficult to provide adequate information and to obtain informed consent. It will be necessary to develop new methods of providing

information, but the Group does not provide any suggestions here. Ethical review may also be problematic. Researchers have the responsibility to make sure that adequate ethical review processes are carried through for studies of nanomedical devices on human beings. In this context it is also recommended to create better information exchange between research ethics committees in the Member States.

Privacy is a concern discussed in all reports because information obtained by new diagnostic methods can be used by third parties such as insurance companies and employers.

Possible solutions to these clinical and research problems require serious interdisciplinary research. Like has been done in the context of the Human Genome project, a considerable amount (the Group suggests 3 %) of the budget for research should be reserved for research on the Ethical, Legal and Social Implications of nanomedicine (NELSI). This research need better coordination and cooperation. Hence, the European Group proposes to establish a European Network on Nanotechnology Ethics.

Such research should have a broader perspective. Studies should also focus on more fundamental issues, in particular on the philosophical and anthropological questions raised, e.g. concerning individual responsibility, concept of the self, personal identity, societal goals and global health care. One of the basic questions for example is how our concepts of human being will change under the influence of nanotechnological developments.

At the same time the French National Ethics Committee, although it extensively addresses philosophical questions, gives a warning. The philosophical questions of 'l'homme-machine', even if important, should not be used to cover up or to hid the more urgent ethical issues related to the "subterranean intrusion" of nanoparticles which is mainly driven by technological performance and commercial interests (CCNE 2007).

13.4.3 Public Participation

All European reports so far agree on the need for more and better involvement of civil society. The European Group explains that there are two reasons for this focus on public participation: First, Europe is characterised by pluralism with a tradition of mutual respect and tolerance. Deliberative democracy requires a culture of debate and communication. Second, nowadays there is a need for trust and confidence building between the scientific community and the public.

It is important that the involvement of the public in the debate on nanosciences and nanotechnologies is focusing on uncertainties and knowledge gaps, not only on safety issues but also for example on policy choices such as the funding of research and development. The involvement should go beyond informing the public as if this is a prerequisite for effective marketing of commercial products. The European Group also advocates transparency and openness not only on the possible benefits but also on the harms and risks, even if unknown or uncertain. In order to create

more realistic views of the prospects of the new technologies the challenge is to find a middle road between hype and pessimism. That a subtle and differentiated approach will be indispensable was demonstrated by the first 'nano-panic', an incident in March 2006 in Germany. Approximately hundred people reported severe respiratory problems, some with fluid in their lungs, after they had used the 'Magic Nano' cleaning product for bathrooms. There was immediate suspicion that the spray contained harmful nanoparticles. But detailed examination revealed that, despite of the name, the spray did not contain any nanomaterials at all. The widely publicized incident, however, reinforced the call for more stringent guidelines in order to make sure that nanoproducts when they arrive on the market are extensively tested and proven safe for human use.

Several models of public dialogue have already been developed and tested, such as the Nano Jury in the United Kingdom and Nano Trucks in Germany. But there is also a need for developing new methods of engaging the general public about issues raised by new technologies. The European Group makes several proposals:

1. prepare surveys of public perception of the benefits and risks of the applications of nanotechnologies
2. create an EU website on ethics and nanomedicine
3. organise academic and public debates on problems and possibilities
4. give attention to the question of labelling of nanomedical products.

The European Parliament has supported the proposal of the European Commission to set up ethical committees. They can provide independent scientific advice and will help ensure that the public is properly informed, thereby creating a climate of trust. But it is not clear whether these are separate ethics committees focused on nanotechnology or that the mandate of existing committees should be expanded. Anyway, it is important to note that ethics committees are assigned, as mechanisms of deliberative democracy, an important role in initiating public debate.

The emphasis on public involvement is not without problems, however. The French National Ethics Committee (CCNE 2007) discusses the disconnection between the discourse and the reality of nanotechnologies. In France, the concept of nanotechnology is usually taken in a more radical sense: it will transform our existence and life-world in creating a new 'nano-world' or 'nano-cosmos' ('le nanomonde'). In this new world computers will be more powerful, communication faster, daily life more agreeable. There is also much talk about the revolutionary development of nanosciences for the treatment of diseases that are incurable today. Nonetheless for the moment there is only new paint, textiles, cosmetics produced. It seems that the public discussion about nanotechnology is mainly focussed on future promises and hypothetical benefits, especially in the domain of health and medicine, while the actual development is driven by commercial interests and consumer products. This situation resembles that of the development of GMOs and genefood: ideologically, the discourse was very much focused on eradicating hunger in the world but the actual products were marketed in the interests of the agro-industrial companies of the rich countries. The disconnection between discourse and reality is furthermore encouraged by distinguishing 'generations' of nanotechnology products, as promoted

by the International Risk Governance Council (IRGC 2007). Identifying the current products and applications of nanotechnology as 'first generation' is somewhat preposterous, as if the development of second (active nanostructures), third (integrated nanosystems) and fourth generations (heterogeneous molecular nanosystems) will be unavoidable. It justifies in fact the down-to-earth approach of the former President's Council on Bioethics when it argues that at the moment we only have nanotechnologies that enhance currently existing technologies and consumer products (PCBE 2008). Involving and engaging the public will require balanced and factual information, without ideologies, biases, and value-judgments.

The Dutch report elaborates the point that scientific research can only prosper if there is trust within society (Health Council of the Netherlands 2006). However this is not only a matter of informing the public. It is vital that science subjects itself and its own performance to continual critical reflection. What is true for science is also true for institutions such as government agencies, policy making bodies, research organisations, companies. Again it is reiterated that lessons should be learned from the problematic introduction of genetically modified food in Europe. It is clear that many misperceptions about public opinion exist. Scientific and technological knowledge among the general public is indeed limited. This does not mean that concerns about technology are due to lack of knowledge or incorrect information. Concerns cannot be removed through scientific education and information. On the contrary, there are indications that more knowledge and information promote scepticism and polarisation.

Of prime importance is free choice, transparency and personalised information. The public knows very well that it is necessary to balance harms and benefits. But at the same time it has the impression that they never hear how this is done and that their views are taken into account. They therefore are suspicious that in the end economic interests are more important in policy-making and risk management than health and environment. Affairs like BSE and dioxine intoxication have not so much illustrated lack of knowledge and information about biological processes but rather failing institutions, carelessness, incompetence, lack of resources and even fraud. Expert declarations denying or downgrading risks create more confusion and are in the eyes of many citizens disturbing and unreliable.

Instead of strategies to make the population "more rational", institutions should pay more attention to their own conduct. Trust must be earned by expertise, performance, integrity, openness, accountability. A basic precondition of public engagement in nanotechnologies therefore is openness and honesty. Encouraging public understanding for the purpose of acceptance of these technologies is, as Kyle and Dodds have argued, "an improper reason for public engagement and is unlikely to cultivate public trust" (O.c., 2009, p. 86).

The Eurobarometer of 2006, a survey of citizen's views in all EU member states, confirms this (Gaskell et al. 2006). When asked whether nanotechnology will improve our way of life in 20 years, 40 % of respondents replied positive, 5 % negative, but 42 % did not know how to answer. Support for nanotechnology (whether the technology should be encouraged) however totals 55 % (varying between 33 % in Ireland and 72 % in Finland). The majority view (66 %) is positive and without

concern that the technology is risky. In comparison to surveys in the US and Canada, Europeans consider nanotechnology as more useful for society and have greater confidence in current regulatory arrangements.

13.4.4 Responsibility of the Scientific Community

The French CNRS report in particular emphasizes that a fundamental transformation is required of the mentality of researchers (CNRS 2006). In the area of research, ignorance or reluctance can often prevail in relation to ethics. The awakening of ethical reflection on science and technology is not a one time, incidental event introduced by ethics specialists but a long-term effort focused on and sustained by all researchers. This is what is called "vigilance éthique". It demonstrates the responsibility of the scientific community itself. This is the counterpart of transparency, the clarification of information towards the public. Transparency as well as responsibility is required because nanosciences and nanotechnologies are developing within a social context that is sensitive to problems emerging from scientific and technological progress. Again, this is not only a matter of researchers explaining the results of their research, but of showing that researchers themselves take into account, are aware, and sometimes worried about the possible implications for the life of citizens and society in general. The scientific community is therefore faced with three challenges:

1. Rethinking the 'ethos' of research. The changing conditions and social structure of science makes it necessary to redevelop codes of conduct and to promote ethics education.
2. Prevention and precaution. Reflection on the possible consequences of research results should pay more attention to prevention of risks; this is not only limited to nanoparticles but should also consider the possible impact on the individual and society. The same responsibility requires precaution in the face of uncertainties.
3. Reflection on values and ends. Given the political and commercial contexts in which nanotechnology programs are stimulated, it is difficult to maintain, according to the CNRS report, the neutrality of science. Scientists themselves should therefore reflect on the values underlying their work. Nanotechnologies in particular transcend fundamental cultural values such as the distinctions between natural and artificial and between natural and cultural. There are also important questions of meaning that every researcher should address: Why this research? What is its purpose? Who will benefit from it?

In order to take this responsibility of the scientific community seriously, a sustained effort is needed to inculcate ethics throughout the careers of researchers. This should start in their early education and continue in their training, the formulation of projects, the laboratory work and the evaluation. The aim is to make scientists more reflective and to create spaces for ethics within the daily business of research.

13.4.5 Social-Ethical Issues

In many European reports it is stated that nanotechnologies are not only significant for individuals but have consequences for society as a whole. Nanotechnologies will furthermore have global consequences. They will influence the use of natural resources and the distribution of wealth. They can potentially contribute to the creation of a more sustainable society and promote the health of future generations, and therefore help to realize the Millennium Development Goals.

However, as is particularly pointed out in the Dutch report (Health Council of the Netherlands 2006), without consistent efforts to translate technological developments towards the circumstances of developing countries, it is unclear whether these countries will enjoy the benefits of technological progress.
The European Group distinguishes two aspects in the issue of equal distribution:

1. Intergenerational questions: they concern the distribution between current and future generations. Particularly the problem of sustainability is relevant here. Applications of nanotechnology can promote better use of natural resources and energy, water purification systems, and removal of waste. This would be important for future generations, but at the same time more knowledge is necessary concerning the environmental impact of nanomaterials themselves.
2. Intragenerational questions: they concern the distribution among present generations. This is the problem with the possible use of nanotechnologies to address the needs of the developing world. It is unclear whether developing countries will really benefit. At present, for example vaccination is available and relatively inexpensive but nonetheless infrequently used. Because the driving forces of technological development are primarily focused on developed countries, the materials and objects produced are first of all of interest to people in these countries.

13.5 Global Perspectives: The Role of UNESCO

From a global perspective, ethical reflection needs to address the potential benefits and harms of nanotechnologies but even more important is assessing and publicly discussing the goals for which these technologies will be used, now that science and technology can be harnessed to solve the most pressing needs of humankind.

In early 2004, UNESCO's World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) decided that nanotechnology was a subject meriting UNESCO's attention due to its enormous potential benefits, but also its considerable challenges to regulators, scientists and, ultimately, to society at large. Therefore, as one of the first UN agencies, UNESCO started anticipatory studies regarding ethical and social impacts of nanotechnology and its applications. The subject was first explored during the COMEST meeting in Rio de Janeiro in 2003. It was further discussed in the next COMEST meeting in Bangkok in 2005. With the

aim of mapping the ethical dimensions of nanotechnology from a global perspective and exploring the respective implications for all member states (whether or not they are carrying out research in nanotechnologies), as well as possible and feasible international actions in this area, a multidisciplinary group on ethics and nanotechnology was established later that year with the participation of ten experts from nine countries (Brazil, Canada, China, Germany, Japan, Netherlands, New Zealand, South Korea, and the Sultanate of Oman).

The expert group set up a twofold working strategy. The first phase involves the preparation of a "state-of-the-art" study on ethics and nanotechnology. The aim of this study is to explain what kind of ethical issues are related to the development of nanosciences and nanotechnologies, so that policy-makers, especially in developing countries, will have a better idea of the challenges. In order to raise awareness concerning ethical issues of nanotechnology, and to inform non-expert persons. UNESCO has published in 2006 the informative brochure *The Ethics and Politics of Nanotechnology*, which describes nanotechnology and its likely future development both in terms of research, its potential applications and the vast range of products that it does and could support. It also presents some of the ethical, legal and political issues that will face the international community in the near future. The purpose is to provide information regarding nanotechnologies and the ethical and social issues they might raise. The brochure has also been translated in the Arabic, Chinese, French, Russian and Spanish languages (UNESCO 2006).

The purpose of the "state of the art" study of the experts is to explore the ethical as well as the policy issues more in depth. The expert group met in UNESCO, Paris, on 5–6 July and 6–7 December 2005, and reports of both meetings can be found in the Ethics of Science and Technology webpage. They prepared papers that have been reviewed and discussed. The contributions have been published in the book *Nanotechnologies: science, ethics and policy issues* in the "Ethics of science and technology" series of UNESCO, and translations in the other official languages are currently in process (Ten Have 2007).

The second phase consisted in producing material and reflections for a UNESCO Policy Document indicating what kind of international actions should be undertaken. An "Outline of a Policy Advice on Nanotechnologies and Ethics" was elaborated, comprising four kinds of actions to be undertaken by UNESCO: awareness raising, education, research and policy. This draft document has been discussed in the Extraordinary meeting of COMEST in Paris in June 2006. After further consultations with international experts in November 2006 in Paris, additional recommendations were taken into consideration during the COMEST meeting in Dakar in December 2006. The result was the finalisation of the COMEST Policy Recommendations which have now been published as *Nanotechnologies and Ethics – Policies and Actions* (COMEST 2007).

The COMEST document is the first substantial proposal for a global guidance in this field. The document begins with a brief characterization of central features of nanotechnology by its interdisciplinary and cross disciplinary dimensions, emphasizing its enabling aspect. Four kinds of actions were proposed by the experts: articulating the ethical framework, awareness-raising, education,

research and policy. Each of these actions poses a different set of issues. Further reflection on the ethical principles that could guide the development of nanotechnologies will be required to articulate the ethical framework. In this connection there is also a need for capacity building for Member States and the general public to deal with ethical issues, as well as for media outreach on the ethical issues of nanotechnologies. COMEST also advocated the establishment of an International Commission for Nanotechnologies and Ethics, in order to create a standing platform to guarantee continuous ethical debate. In the area of awareness-raising, several specific issues have been emphasized: environmental impact and health issues, privacy and confidentiality, and intellectual property. In the area of education, it is argued that there is a general need for education, not only in regard to nanotechnologies (since public knowledge is rather limited in this field) but also in regard to ethics. In the area of research and policies COMEST recommends that more scientific and technical knowledge is necessary, more social sciences research should guide policy, as well as more ethical and legal research is needed. It is also argued that nanotechnologies should be more focused on development. It is necessary to identify those technologies that are most appropriate and relevant for development.

13.6 Final Remarks and Conclusion

Nowadays, the possible benefits and harms deriving from nanotechnology are increasingly discussed, as well as its implications for international relations in science and technology policies. It is clear that the European Union plays a leading role in the international debates concerning the ethical and social implications of nanotechnologies. Many initiatives are being carried out at the international level in order to provide an early, informed, interdisciplinary and public debate. It is expected that these activities be able to preserve or even restore trust in science and technology. This is particularly relevant for nanotechnology in order to maximize the benefits that can be expected from it, as well to anticipate and to minimize eventual risks. Academic researchers, developers, potential users and other important actors are actively involved in this trust building exercises in order to ensure the inclusion of an adequate representation of societal forces that ultimately shape the future of nanotechnology. The failure to have such broad and inclusive public debate and involvement is to a large extent, at least in Europe, the cause of the criticism and public mistrust encountered in other areas of scientific advancement. At the same time, there is increasing concern that all countries should be able to benefit from scientific and technological progress, especially those developing countries that are at the moment not involved in the nanotechnology revolution. Rather than emphasising the particular European perspective, policy reports in Europe seem to raise the question how Europe can contribute to make nanosciences and nanotechnologies relevant and beneficial for humankind in general. This global perspective offers opportunities for international organisations such as UNESCO. As the only UN organisation with a mandate in the area of the sciences, UNESCO can take up the

challenge and should be able to assist Member States and policy-makers in making the development of nanosciences and nanotechnologies contributing to reach the Millennium Development Goals. It is evident that this global challenge, despite the many initiatives currently going on in Europe, is not really addressed at the moment, and that the international community is only in the very early stages of formulating appropriate responses.

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Index

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