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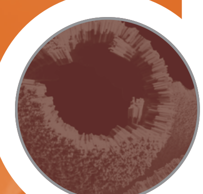
Project on Emerging Nanotechnologies

NANOTECHNOLOGY:

The Social and Ethical Issues

Ronald Sandler



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CONTENTS

PREFACE

Too often, discussions about the social and ethical issues surrounding new technologies are treated as afterthoughts, or worse still, as potential roadblocks to innovation. The ethical discussions are relegated to the end of scientific conferences, outsourced to social scientists, or generally marginalized in the policymaking process.

The goal of this paper by Ron Sandler of Northeastern University is to clearly place social and ethical issues within ongoing debates on the responsible development of nanotechnologies. The paper presents a broad framework to structure the analysis and discussion of ethical issues, which builds on improving our understanding of the social, cultural, and moral context of emerging technologies and assessing the status of these issues as the technologies evolve.

The author takes on some of the common misconceptions that undermine our ability to address social and ethical issues early and effectively, such as the "it's too early to discuss ethics" excuse and the tendency to frame new technologies in terms of their inevitability (and inevitable good). The paper highlights, through theory and research linked to case studies, a wide variety of possible social and ethical issues linked to emerging nanotechnologies, ranging from environmental justice to human enhancement and the myth of the techno-fix—our tendency to favor technological fixes to problems rather than behavioral changes or other major shifts. Indeed, the framework outlined in this paper can be applied to a wide variety of emerging technologies.

Every emerging technology offers us a new opportunity to engage stakeholders in a social and ethical debate. The nanotech revolution is still beginning and we still have time for an open and public discussion of its consequences, both intended and unintended. Hopefully, this paper will provide a framework for thinking through some of those impacts.

David Rejeski
Director, Project on Emerging Nanotechnologies

EXECUTIVE SUMMARY

Nanotechnology has tremendous potential to contribute to human flourishing in socially just and environmentally sustainable ways. However, nanotechnology is unlikely to realize its full potential unless its associated social and ethical issues are adequately attended. The purpose of this report is to raise the salience of social and ethical issues within ongoing responsible development discourses and efforts by:

- identifying the crucial roles of ethics in the responsible development of technology;
- dispelling common misconceptions about the social and ethical issues associated with emerging nanotechnologies;
- providing a typology of the social and ethical issues associated with emerging nanotechnologies and identifying several specific issues within each type; and
- emphasizing how social and ethical issues intersect with governmental functions and responsibilities.

Government and Ethics

Among the functions of government that intersect with the ethical and value dimensions of technology are the following:

- *Science and technology policy and funding* involve decisions about what ends should receive priority and about how resources should be allocated in pursuit of those ends. Justification of these decisions requires that some goals be valued more highly than others—i.e., it rests on comparative value judgments.
- *Regulation of science and technology* is intended to accomplish something that is thought to be worthwhile and that justifies any associated costs. Regulation also has power, control, oversight and responsibility dimensions, and often involves allocating burdens and benefits. All of these are characteristic of ethical issues and decisions.
- Government can *support research on, raise awareness of and promote responsiveness to social and ethical issues* associated with technology (as many believe to be the case with the Human Genome Project). It can also *obscure social and ethical issues* associated with technology (as many believe to be the case with genetically modified crops).

Ronald Sandler is an associate professor of philosophy in the Department of Philosophy and Religion, a researcher in the Nanotechnology and Society Research Group and Center for High-rate Nanomanufacturing, and a research associate in the Environmental Justice Research Collaborative at Northeastern University

Roles of Ethics in the Responsible Development of Technology

The goal for any emerging technology is to contribute to human flourishing in socially just and environmentally sustainable ways. Given this, the roles of ethics within responsible development of nanotechnology include:

- elucidating what constitutes justice, human flourishing and sustainability;
- identifying opportunities for nanotechnology to accomplish the goal and anticipating impediments to its doing so;
- developing standards for assessing prospective nanotechnologies;
- providing ethical capacity (i.e., tools and resources that assist individuals and organizations to make ethically informed decisions) to enable society to adapt effectively to emerging nanotechnologies; and
- identifying limits on how the goal ought to be pursued.

Three Misconceptions about Ethics and Emerging Nanotechnologies

Several common misconceptions about the social and ethical issues associated with emerging nanotechnologies have obscured their significance to responsible development and thereby hampered our responsiveness to them. Three of the most important of these misconceptions are as follows:

- *It is too soon to tell what the social and ethical issues are.* This misconception is fostered by a narrow focus on the technology itself when trying to identify social and ethical issues. When broader contextual factors, such as unequal access to technology, information insecurity and inadequate biodefense research oversight are considered, it becomes clear that it is not too early to identify and to begin to respond to social and ethical issues associated with emerging nanotechnologies.
- *The nanotechnology revolution is inevitably good.* This misconception results from a preoccupation with the crucial contributions that technology makes to the comfort, security, healthfulness and longevity of people's lives in industrialized nations. If one takes a more encompassing historical, global and ecological view of technology's development and impacts, it is clear that emerging technologies (including emerging nanotechnologies) are not inevitably good.
- *The point of the social and ethical issues is to secure public acceptance.* This misconception arises from the desire for smooth commercialization of emerging nanotechnologies coupled with the view that public opposition to them is primarily the result of misunderstandings or baseless concerns regarding them. In fact, people's concerns re-

garding emerging technologies are often neither the result of ignorance nor baseless. Moreover, as indicated above, there are robust roles for ethics in responsible development of nanotechnology other than securing public acceptance.

A Typology of Ethical Issues

This typology is intended to organize the social and ethical issues associated with emerging nanotechnologies in ways that are illuminating and productive.

1. *Social Context Issues*: Social context issues arise from the interaction of nanotechnologies with problematic features of the social or institutional contexts into which the nanotechnologies are emerging. Examples of social context issues include unequal access to health care, inequalities in education, unequal access to technology, inadequate information security/privacy protection, inefficiencies in intellectual property systems, unequal exposure to environmental hazards and inadequate consumer safety protection.
2. *Contested Moral Issues*: Contested moral issues arise from nanotechnology's interaction with or instantiation of morally controversial practices or activities—i.e., those that a substantial number of citizens believe should be prohibited. Examples of contested moral practices and activities in which nanoscale science and technology are, or are likely to be, involved include synthetic biology, construction of artificial organisms, biological weapons development, stem cell research and genetic modification of human beings.
3. *Technoculture Issues*: Technoculture issues arise from problematic aspects of the role of technology within the social systems and structures from which, and into which, nanotechnologies are emerging. Examples of technoculture issues include an overreliance on technological fixes to manage problematic effects (rather than addressing underlying causes of those effects), overestimation of our capacity to predict and control technologies (particularly within complex and dynamic biological systems) and technological mediation of our relationship with and experience of nature (and associated marginalization of natural values).
4. *Form of Life Issues*: Form of life issues arise from nanotechnology's synergistic impacts on aspects of the human situation on which social standards, practices and institutions are predicated. For example, if nanomedicine helps extend the average human life span even five or ten healthful years, norms of human flourishing will need to be reconsidered and there are likely to be significant impacts on family norms and structures (e.g., care responsibilities), life plans or trajectories (e.g., when people marry) and social and political institutions (e.g., Medicare).
5. *Transformational Issues*: Transformational issues arise from nanotechnology's potential (particularly in combination with other emerging technologies, such as biotechnology, information technology, computer science, cognitive science and robotics) to

transform aspects of the human situation. This might be accomplished by significantly altering the kind of creatures that we are, reconstituting our relationship to the natural environment or creating self-aware and autonomous artificial intelligences (i.e., artifactual persons). In such cases, some prominent aspect of our ethical landscape would need to be reconfigured—for example, what it means to be human, personal identity or the moral status of some artifacts.

The Status of the Social and Ethical Issues within Responsible Development

With the misconceptions resolved and the full range of issues elucidated, it is clear that the social and ethical issues associated with emerging nanotechnologies are:

- *Determinate*: It is possible to identify many of the social and ethical issues.
- *Immediate*: It is not too soon to begin considering many of the issues.
- *Distinct*: The issues are not reducible to other aspects of responsible development.
- *Significant*: Addressing the issues is crucial to the responsible development of emerging nanotechnologies.
- *Actionable*: In many cases, there are steps that can be taken now by actors, including those in government, to address the issues.

Consideration of and responsiveness to social and ethical issues are needed now in order to anticipate and proactively address, as far as possible, potential negative aspects of emerging nanotechnologies, as well as to identify and promote opportunities for nanotechnology to contribute to human flourishing in just and sustainable ways. The National Nanotechnology Initiative affords a unique opportunity to promote a broad, critical and constructive perspective on the relationships between technology, government, environment and society at the same time that emerging nanotechnologies offer enormous possibilities for making social (not just technological) progress through comprehensive, innovative, and forward-looking responsible development.

I. INTRODUCTION: TECHNOLOGY, ETHICS AND GOVERNMENT

Technology and Society

Technology is a thoroughly social phenomenon. Technologies emerge from society. They are made possible and encouraged by society—e.g., through social valuing, public funding and intellectual property policies. They are implemented in and disseminated through society; they are also sometimes prohibited, resisted or rejected by society. They alter society. Indeed, without technology it is difficult to conceive of society at all or, at least, to conceive of a society such as ours with complex and evolving cultures constituted by accumulated knowledge, traditions, practices, institutions and organizations. Technology shapes every aspect of our lives—the places we inhabit, the ways we interact, how we do our work (and the work that we do), our forms of recreation, our institutional arrangements and how we organize our days and our lives.

This understanding of the relationship between technology and society militates against the naïve view of technology as simply what we create to solve problems and overcome barriers i.e., that we find a need for it, create it, use it and control it (except, of course, for the occasional unanticipated side effects, which are best handled by further technological inventiveness). Not only is technology inseparable from society, it shapes us as much as we shape it. Thus, the relationship between technology and society is deeply value laden.

Ethics and the Functions of Government

Ethics, in its most basic sense, concerns how we ought (and ought not) to lead our lives. Because technology structures our experiences and shapes how we live, it has enormous ethical significance. The functions of government intersect with the ethical and value dimensions of technology in several ways:

- *Science and technology policy and funding* involve decisions about what ends should receive priority and how resources should be allocated in pursuit of those ends. This is evident in domains as diverse as energy policy (e.g., the balance of efficiency and production and the distribution of energy sources), intellectual property policy and research funding (from particle physics to entomology). In each case, the policy is intended to accomplish certain goals rather than some others. Its justification therefore depends on certain goals being valued more highly than their alternatives. Decisions about priorities are based on value judgments.

- *Regulation of science and technology* is intended to accomplish something that is thought to be worthwhile and that justifies any associated costs. Regulation has power, control, oversight and responsibility dimensions and often involves allocating burdens and benefits. All of these are characteristic of ethical issues and decisions. This is evident in domains as diverse as facilities permitting (e.g., nuclear power plants and waste-transfer stations), setting research limits (e.g., human subjects research and reproductive cloning), risk management (e.g., workplace safety and environmental pollution) and technology use (e.g., privacy protection and non-therapeutic use of human growth hormone). Regulation, like policy, has ineliminable value components.

- Government can *support research on, raise awareness of and promote responsiveness to social and ethical issues* associated with technology. The most prominent case of this in the United States has been the Ethical, Legal, and Societal Implications component of the Human Genome Project. Supported by 3–5 percent of the project's funding, this component catalyzed the field of bioethics by creating a cadre of professional ethicists and raising the salience of several ethical issues associated with genomics—e.g., the possibility of genetic screening by employers and insurance companies and protection of the confidentiality of genetic information. Government can also *obscure social and ethical issues* associated with technology. This has been the case with genetically modified crops, where inadequate government capacity (with respect to oversight, regulatory design and meaningful public participation in decision making, for example) has resulted in substantial economic, social and technological costs.

Although social and ethical issues associated with science and technology do not begin and end with government, government is not a neutral observer. Government functions and actors, from the local to the federal level and across all branches of government, respond to, engage with and act upon values and ethical issues associated with science and technology. This can be done effectively (as some have argued is the case with the Human Genome Project and embryonic stem cell research) or not (as some have argued is the case with genetically modified crops and nuclear power). How government engages these issues has substantial ethical, social, economic and technological implications.

The National Nanotechnology Initiative and the "Other" Social and Ethical Issues

The purpose of the National Nanotechnology Initiative (NNI) is to promote nanoscale science and technology in ways that, as far as possible, benefit U.S. citizens in particular and humanity in general. A crucial component to achieving this goal is supporting responsible development of nanotechnology, which, according to core NNI documents, is to be accomplished by addressing environmental, health and safety (EHS) concerns, engaging in public education and outreach and addressing other ethical, legal and social issues. To this end, the NNI has supported considerable work on EHS (e.g., characterizing the toxicity and mobility properties of nanoscale materials, assessing associated regulatory capacity and developing best research/workplace practices) and on education and outreach (e.g., preparing the workforce, educating the public about nanotechnology and encouraging public acceptance of nanotechnology). This is not to claim that current EHS and education efforts are adequate. As several independent assessments have indicated, there are serious concerns that current institutional capacities and efforts in these areas are not sufficiently organized or robust (Maynard 2006; National Research Council 2008). Nevertheless, in comparison with the attention afforded the other social and ethical issues, the NNI-supported work on EHS and education has been substantial.

References to the other social and ethical issues in core NNI documents are usually limited to a few sentences at the end of a section addressing the other aspects of responsible development. An example of this is in The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel: "Finally, there is an expanding need for activities that are focused on ethical, legal and other societal implications beyond just the environmental and health effects. The NNI should participate in appropriate dialogues with stakeholders, beyond the research and technical communities" (President's Council of Advisors on Science and Technology 2005, p. 43). The document does not indicate what the implications are, who the stakeholders and communities are, how dialogue might take place, what the dialogues are intended to accomplish or how attention to the implications or dialogues might inform the nanotechnology research and development program or otherwise contribute to shaping government policy, regulatory capacity or institutions.

This is standard treatment of the other social and ethical issues. They appear to be an afterthought. They are not considered to be directly relevant to the science and technology research program and are believed to be marginal to responsible development efforts, except when they intersect with public acceptance of nanotechnology.[1]

About this Report

If nanoscale science and engineering is going to be the platform for the next revolution in technology and industry (or if it even approaches this status), as many of its proponents claim, then it will be socially and ethically revolutionary as well. We cannot wait to address the ethical issues associated with emerging nanotechnologies until the dust has settled from innovation and commercialization. If our goal is to maximize nanotechnology as a social good—to have it contribute, as far as possible, to human flourishing in socially just and environmentally sustainable ways—then the social and ethical issues associated with emerging nanotechnologies must be identified. In addition, they must, as far as possible, be addressed concurrently with, and must mutually inform, technology development and commercialization.

The social and ethical issues associated with emerging technologies are *determinate*—i.e., it is possible to clearly identify

[1] The most thorough consideration of them within the NNI is Roco and Bainbridge (2005). See also Roco and Bainbridge (2001).

them. They are *immediate*—i.e., it is not too soon to begin considering them. They are *distinct*—i.e., not reducible to other aspects of responsible development. They are *significant*—i.e., crucial to responsible development of nanotechnology. And they are *actionable*—i.e., steps can be taken now by actors, including those in government, to address them. The purpose of this report is to describe the salience of these issues and to draw attention to them by articulating what they are, why they matter and what is involved in addressing them. To this end, the report:

- identifies the crucial roles of ethics in responsible development of technology;
- dispels common misconceptions about the social and ethical issues associated with emerging nanotechnologies;
- provides a typology of the social and ethical issues associated with emerging nanotechnologies and identifies several issues within each type;
- discusses in detail one paradigmatic issue of each type to illustrate significant features of the issues within the type; and
- emphasizes how social and ethical issues intersect with government functions and responsibilities.

II. ETHICS AND EMERGING NANOTECHNOLOGIES

Ethics as Restraint and Aspiration

Ethics, particularly as it relates to technology, is usually associated with prohibitions and restraints. This is unfortunate. Although part of its purview is proscription, ethics is also aspirational. It involves identifying how to make our way in the world well, what to strive for and the ideals that we set before ourselves, as individuals and as societies, and that we attempt to live up to and measure ourselves against. So while the ethics of nanotechnology does involve prohibitions and restraints, that is not nearly the whole, or even the most important part, of it. Nor is it where ethical reflection on nanotechnology is best begun. It should begin by reflecting on what we, as a society, should want from emerging nanotechnologies, namely, *that they contribute to human flourishing in socially just and environmentally sustainable ways.*

Roles of Ethics in Responsible Development

If this (or something close to it) is the appropriate goal, there are several roles for ethics in the development, application and dissemination of nanotechnology.

1. Ethical reflection and discourse can illuminate the goal by helping elucidate what justice, human flourishing and sustainability amount to. These concepts are neither obvious nor uncontested. They must be clarified and disambiguated and, to the extent possible, disagreements regarding them must be adjudicated (or common ground identified) if the goal for nanotechnology is to be well understood. Many ethicists are, and long have been, engaged in this project.

2. Ethical analysis and social science research on the relationship between society and technology, both in general and as it involves emerging nanotechnologies in particular, can not only identify opportunities for nanotechnology to accomplish the goal but also anticipate (and help resolve) impediments to its doing so. This can be accomplished by identifying societal and environmental problems that nanotechnological innovation might help address, identifying non-technical barriers that may prevent nanotechnology from achieving what it otherwise could and developing approaches to overcome these barriers in ways other than, but complementary to, technological innovation—e.g., involving institutional structures, public and private policies and individual and cultural practices. For example, nanotechnology has tremendous potential for helping the global poor—the approximately 2.5 billion people who live on less than $2 ppp/day. However, there are significant non-technological barriers to its doing so, including lack of research infrastructures in developing nations, lack of incentives for researchers in developed nations to work on pro-poor technologies, intellectual property restrictions, ineffective or inefficient distribution systems, incompatibility with the conditions and lifestyles of those whom the technologies are intended to benefit and inadequate

regulatory capacities. Identifying, analyzing and developing effective strategies for addressing these and other barriers requires the tools, resources and expertise of the social sciences and ethics.

3. Ethics can provide standards for assessing prospective nanotechnologies. Nanoscale science and technology includes diverse research areas and types of application—e.g., energy, agriculture, computing, medicine, weapons, textiles, building materials and environmental remediation. The ethical profiles of emerging nanotechnologies are therefore various. Some emerging fields or applications might be just, sustainable and compassionate; others might be reckless, shortsighted, unsustainable or unnecessary. Compare a synthetic biology research project situated within a biological defense program sited in an urban center with an industry-funded research project to develop carbon nanotube–enabled memory chips sited in a suburb. Both projects involve nanotechnology, but their ethical profiles differ along (at least) the following dimensions: objectives, risks, benefits and beneficiaries, control, oversight, regulation and degree to which they involve a 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. Case-by-case assessment is thus as important with respect to ethics as it is with respect to EHS. Social and ethical evaluations of nanotechnology must be research, technologyand application-specific. Such evaluations can contribute to more informed decision making regarding resource allocations and policy and regulatory designs, as well as help avoid public or regulatory reactions that might impede development or commercialization of desirable nanotechnologies.

4. Ethical capacity—i.e., tools and resources that assist individuals and organizations to make ethically informed decisions—is crucial to society's ability to adapt effectively to emerging nanotechnologies. Ethical capacity involves, for example, professional codes of conduct, ethical frameworks, well-developed case studies and historical precedents and individuals and organizations with expertise and experience identifying, analyzing and addressing relevant ethical issues. Governmental capacity (e.g., resources, expertise, commitment, institutional design, legal authority, public trust and access to information) and social capacity (e.g., educational institutions, media and communications, public interest/advocacy organizations, forums for public discourse and professional organizations) are critical to the responsible development of emerging nanotechnologies. Because of the limited domain of government activity and authority in comparison with the factors relevant to technological innovation and impacts, and because the exercise of ethical and social capacity often precedes, precipitates and guides government responsiveness, ethical capacity is critical as well. For example, the voluntary moratorium on certain forms of genetic research by members of the molecular biology community in the 1970s raised the salience of the issues, enabled further reflection and responsiveness to them by the research community and precipitated governmental action in the form of National Institutes of Health

(NIH) guidelines and efforts to develop expertise in identifying, analyzing and addressing issues as they arise (i.e., bioethics).

5. Ethics may help identify limits on how the goal ought to be pursued. Some means are not ethically acceptable, even if their ends are worthwhile. This is why medical research involving human subjects must be regulated, for example. Good intentions and a laudable goal are not sufficient to ensure ethically acceptable practice.

Ethical Issues vs. Ethical Implications

This is a report on the ethical *issues* associated with emerging nanotechnologies, broadly construed to include goals, opportunities, complications, barriers and limits. It is not a report on the ethical *implications* of nanotechnology (the preferred NNI terminology), which are not yet determined. The implications are what is at stake, and what those concerned with responsible development hope in some measure to shape by addressing the issues. Likewise this is not a report on the ethical *challenges* of nanotechnology, since emerging nanotechnologies present as much in social and ethical opportunities as in potential social and ethical problems, and ethics is as much aspirational as proscriptive.

III. THREE MISCONCEPTIONS ABOUT SOCIAL AND ETHICAL ISSUES

There are several common misconceptions regarding the social and ethical issues associated with emerging nanotechnologies that obscure their significance to responsible development. This section discusses three of the most influential and widespread of these issues.

Too Soon to Tell

A 2006 review of the NNI conducted by the National Research Council states that, "Currently, ethical considerations specific to nanotechnology have not come into focus.… Although near-term and tangible ethical concerns related to use of nanotechnology have yet to be determined, it is not too early now to think about how to inform, communicate with, and engage the public to ensure broad consideration of what responsible development of nanotechnology might entail from a societal perspective (National Research Council 2006, pp. 87-88).

This common "too soon to tell, but let's keep our eyes open" position is premised on two claims. The first is that there is nothing socially or ethically problematic about the capacity to characterize, control and construct on the nanoscale or the processes involved—i.e., the practice of nanoscale science and engineering. The second is that relatively few products containing engineered nanoscale particles, processes or devices have been developed, let alone produced in large volumes and widely disseminated.[2] If the practice of nanotechnology is socially and ethically innocuous (or at least no worse than what came before) and the nanotechnologies themselves largely do not yet exist (or at least have not been effectively commercialized), then the social and ethical considerations must remain indeterminate.

This line of reasoning is mistaken for two reasons. First, the social and ethical issues associated with emerging nanotechnologies need not be unique to nanotechnology in order to merit concern and attention. There may be issues that are familiar but that nonetheless need to be addressed because of their social and ethical significance. Indeed, because of the distinctive properties of nanoscale materials, the functionalities and products that nanoscale science and technology enable or the rate and volume of innovation associated with accelerating nanoscale science and engineering efforts, some of these issues may be exacerbated by nanotechnology. Second, there are resources for making reasonable predictions about what the social and ethical issues associated with nanotechnology are likely to be: experience with previous emerging technologies and the challenges they posed; information about the characteristic features of nanotechnology; information about the particular social, cultural and institutional contexts in which nanotechnologies are being developed, implemented, disseminated and regulated; and information about the time line for the application and commercialization of many types of products and devices incorporat-

[2] The number of products on the market that incorporate nanotechnology is steadily increasing (Project on Emerging Nanotechnologies 2008).

ing nanotechnology. These are, in fact, the same resources that are being drawn on to anticipate and respond to possible EHS and education challenges and opportunities associated with emerging nanotechnologies.

What these considerations have in common is that they involve reflecting on more than just the practice and products of nanotechnology. The social and ethical issues can be identified only by considering both the characteristic features of nanotechnologies and the features of the contexts into which they are emerging. When this is done, many of the social and ethical issues associated with nanotechnology come into focus.

The Inevitable Goodness of the Nanotechnology Revolution

A second misconception is premised on the view that technological innovation is inexorable—or even accelerating at an exponential rate—and so, too, are the benefits that accompany it. Given this, emphasizing the social and ethical issues (in this case identified with limits and restraints) associated with nanotechnology innovation is at best futile and at worst detrimental, since anything that might slow nanotechnology's inevitable arrival impedes its contribution to the social good. To promote the social good, it is best to promote innovation, application and dissemination in as unencumbered, unfettered and unregulated a way as possible, while also preparing for the coming technological upheaval. The role of responsible development, then, is to educate people about nanotechnology, promote public acceptance of it, facilitate commercialization of products and prepare people and institutions to adjust and identify, prevent, mitigate and remediate undesirable and unintended EHS effects.

The kernel of truth to this moralized variation of "science creates, industry applies and society adapts" is that people living in industrialized nations today live healthier, longer, more secure, more comfortable lives than did people at any other time in human history, and technology contributes enormously to this. Life expectancy in the United States for individuals born in 2005 is 78 years; in 1900, it was 47 (National Center for Health Statistics 2003, 2007). The majority of United States citizens have reliable access to basic resources—water, sanitation, electricity, shelter and food—and most have substantial additional economic resources (for example, in 2001 United States citizens spent U.S.$25 billion on recreational watercraft [Easterbrook 2003] and in 2002 United States citizens spent U.S. $180 billion at health and personal care stores [United States Census Bureau 2004]).

However, technological innovation is only part of the story. First, technology's potential as a social good (as opposed to an individual or class good) often has been realized only after significant social and ethical issues have been addressed. Moreover, addressing these issues has often been arduous. It has required novel laws and regulations (e.g., environmental and workplace-safety laws), the creation of government agencies (e.g., the Department of Labor [DOL] and the Environmental Protection Agency [EPA]) and whole new areas of ethics (e.g., environmental ethics, business ethics and medical ethics), as well as robust social movements to push for reforms (e.g., the environmental movement and the labor movement). It takes great social (not merely technological or industrial) effort and, often, sacrifice to maximize the good from technology while minimizing the bad. Moreover, technological innovation is not the only cause of longer life spans and increased material comfort. Innovations in political, economic and other social systems, institutions and arrangements have been significant, as have been changes in belief systems, values and worldviews (each which has often been intertwined with technological innovation).

Second, it is uncertain whether the benefits associated with the accelerated rate of technological innovation that has occurred since the industrial revolution are sustainable. Technology has enabled systems of production and patterns of consumption that have drawn down Earth's natural capital—i.e., natural resources, living systems, biodiversity and the capacity for them to be replenished—at an incredible rate. Moreover, associated ecological and agricultural problems have arisen with remarkable rapidity and on a global scale—e.g., pollution and toxics (in air, water, soil and products), climate change (which already is resulting in environmental refugees, agricultural disruptions and biodiversity loss) and food insecurities (Worldwatch Institute 2004, 2007; Millennium Ecosystem Assessment 2005; Intergovernmental Panel on Climate Change 2007). It may be, as many maintain, that further technological innovation will remedy these. But at this point, that conviction is rooted more in faith than in fact, since individual consumption levels continue to increase both domestically and globally, with associated decreases in natural capital and increases in pollution and greenhouse gas emissions (Worldwatch Institute 2007, 2004; Intergovernmental Panel on Climate Change 2007). Furthermore, even if these basic human-health and life challenges are met, there remain quality-of-life costs (e.g., fewer wilderness areas, diminished natural beauty and less biological and cultural diversity), as well as the detrimental effects on non-human animals and other organisms.

Third, from a global perspective, the period of rapid technological innovation beginning with the industrial revolution has not been nearly as beneficial: 1.1 billion people in less economically and technologically developed nations lack access to potable water; 2.6 billion lack access to basic sanitation; and 2.5 billion live on less than $2 ppp/day, with 980 million living on less than U.S. $1 ppp/day (United Nations 2006, 2007). In addition, the problems of pollution and toxic waste are acute in parts of the developing world, as industrialized nations have increasingly sought to pass environmental costs on to developing countries and as developing nations race to industrialize and exploit natural resources without adequate protection or regulatory structures. Moreover, those with the least resources (and thus the least means to respond to environmental hardship) tend to live in the most environmentally tenuous areas, e.g., polluted places and low ground. Particularly with respect to subsistence agriculture/aquaculture communities, when supporting environments are compromised—e.g., water tables drop, extended droughts occur, sea levels rise or coral reefs die—social systems can be undermined and environmental refugees created.

Finally, even if, from a general history of technology perspective, technological innovation accelerates over time, which technologies emerge at what time, how they are disseminated, and who has access to them are shaped by social and political features, e.g., funding priorities, funding availability, research constraints, programmatic decisions and intellectual property policies. Moreover, from the individual perspective, i.e., the perspective of a person's lived experience and his/her social situatedness, which is the perspective from which meaning and value are derived, the details of technological innovation and dissemination are significant, and these are responsive to social, institutional and political activities often motivated and justified by social and ethical considerations. Therefore, marginalizing attentiveness and responsiveness to nanotechnology's social and ethical dimensions is not justified, even if technological innovation is (in some sense) inevitable.

The Point Is to Secure Public Acceptance

A primary objective of the NNI's responsible development program is to promote public acceptance of nanotechnology:

> *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. Governments around the world must take a proactive stance to ensure that environmental, health and safety concerns are addressed as nanotechnology research and development moves forward in order to assure the public that nanotechnology products will be safe… 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* (President's Council of Advisors on Science and Technology 2005, pp. 42-3).

It is a common view, even among those who advocate strongly for social and ethical research, that its primary function is to help secure public acceptance of nanotechnologies and ensure nanotechnology's integration into the national and global economies by demonstrating that "societal concerns" are being addressed. However, this conception of the appropriate or primary role for attentiveness to social and ethical issues is belied by several of the considerations already discussed—e.g., their significance in the past and an inclusive conception of ethics. Research on social and ethical issues can identify opportunities for nanotechnologies to contribute to human flourishing in just and environmentally sustainable ways, anticipate potential barriers to its doing so, and suggest approaches (technological, social and institutional) for overcoming them.

There are significant social and ethical dimensions to public outreach, discourse and education. Their effectiveness depends in part on scientists and development researchers' ability to discuss nanotechnology accurately and in effectively framed ways. It is also important that such discussions be open, accessible, inclusive and fair. Moreover, as with EHS issues, public engagement and education in nanotechnology involve authority, responsibility, relative social influence, power and control, public policy and regulation (which always involve comparative value judgments), distributions of burdens and benefits (distributive justice), decision-making processes (procedural justice) and informed consent/voluntariness (autonomy). In these respects, social and ethical issues are implicated in and inseparable from the other aspects of responsible development. Nevertheless, as indicated above, the social and ethical issues are not exhausted by these factors or otherwise reducible to public education, addressing EHS concerns and promoting smooth commercialization of nanotechnology.

Furthermore, treating social and ethical research (and public engagement) as primarily an educational or public relations enterprise fails to appreciate the limits of science and industry. Although the scientific community has technical expertise and industry has economic expertise, neither necessarily has 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 empowered to make decisions about where we ought, or ought not, aim our material resources and technology in the future or about what limits we ought to place on our efforts to get there. Science and industry experts have an important role to play in discussions about these issues. 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. 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 what constraints should be placed on how those ends ought to be pursued are ethical and social 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 decisions to be worked out in boardrooms or laboratories. They depend on value judgments and conceptions of the good—areas in which business acumen and scientific knowledge afford no special privilege. So while scientists and industry leaders may be "elite" in their knowledge of the science and business of nanotechnology, they are not necessarily "elite" with respect to the social and ethical issues associated with nanotechnology, and it in no way justifies marginalizing the social and ethical issues raised by researchers and the concerned public by casting them primarily as barriers to be overcome in securing commercialization and public acceptance.

IV. TYPOLOGY OF THE ISSUES

Typologies divide and organize conceptual terrain. Most typologies are conventional and programmatic. This one is no different. It is *a* typology, not *the* typology, of the social and ethical issues.[3] The considerations that have guided its development are that it illuminate the full range of issues (inclusiveness), that the types are clear and distinguished by significant features (e.g., time line, familiarity, determinacy or regulatory relevance), that the types are neither too gross (and too few) nor too fine (and too many) to be helpful in organizing discourse on them and that it reflect ongoing discussions on the issues. The types are not mutually exclusive—a particular issue might fall within more than one type—and some aspects cut across all the types—e.g., evaluations of risks, power relations and societal (governmental, social and ethical) capacity.

THE TYPOLOGY

- SOCIAL CONTEXT ISSUES
- CONTESTED MORAL ISSUES
- TECHNOCULTURE ISSUES
- FORM OF LIFE ISSUES
- TRANSFORMATIONAL ISSUES

Social Context Issues

Social context issues arise from the interaction of nanotechnologies with problematic features of the social or institutional contexts into which they are emerging. With these issues, nanoscale science and technology is not responsible for the problem, in the sense that it is not the cause of the problematic feature of the social context that gives rise to them. Nevertheless, when nanotechnology is introduced into those contexts, it becomes implicated in them. In many cases, it can be reasonably expected that nanotechnology will exacerbate the problem because of the distinctive properties of nanoscale materials, the functionalities and products that nanoscale science and technology enable or the rate and volume of innovation associated with accelerating nanoscale science and engineering efforts. However, the problematic features sometimes also provide opportunities, insofar as nanotechnologies may contribute to addressing them.

Because nanotechnology is a general-use, enabling technology, and there are so many problematic features of the social contexts into which it is emerging, its associated social context issues are legion and their range is expansive. They include, for example, unequal access to health care, inequalities in education, unequal access to technology, inadequate information security/privacy protection, inefficiencies in intellectual property systems, inadequate protections of individual autonomy (in domains such as labeling and human subjects research), under-representation of women and minority groups in engineering and academia, shortsighted agricultural practices and policies, unfair tariffs and trade agreements, inadequate incentives and resources to develop pro-poor technologies, inadequate consumer-safety protection,

[3] The conceptual terrain covered by this typology does not include legal issues or workplace and professional ethics (e.g., lab ethics or publishing ethics).

conflicts of interests among regulators and researchers, inadequate research oversight (for example, with respect to biodefense labs), insufficient corporate accountability, externalization of pollution and health costs, unequal exposure to environmental burdens, lack of transparency and accountability in military research and diminishing public trust in industry and governmental institutions. These are social and ethical issues for nanotechnology because they are relevant to the extent to which nanotechnology will contribute to human flourishing in just and sustainable ways.

Contested Moral Issues

Contested moral issues arise from nanotechnology's interaction with or instantiation of morally controversial practices or activities—i.e., those that a substantial number of citizens believe should be prohibited. Contested moral issues can involve research and engineering practice (e.g., nanoscale science and engineering tools and techniques) or what nanoscale technologies enable in application (e.g., products and uses). Examples of contested moral practices and activities in which nanoscale science and technology are (or are likely to be) implicated include genetic modification of living organisms, the use of embryonic stem cells and chimeras in research, synthetic biology, constructing artificial organisms, weapons development (e.g., chemical and biological), gene patenting (and bioprospecting) and modification of human nature (e.g., genetically or pharmacologically). As with social context issues, contested moral issues often are not unique to nanotechnology, although in some cases nanotechnology might enable realizing particularly compelling or controversial instantiations of them.

Technoculture Issues

Technoculture issues arise from problematic aspects of the role of technology within the social systems and structures from which, and into which, nanotechnologies are emerging. Technology is not separable from society. Nevertheless, robust critiques of particular aspects of the relationship and particular roles afforded technology within modern industrialized society have been developed. These include, for example, overreliance on technological fixes to manage problematic effects (rather than addressing underlying causes of those effects), overestimation of our capacity to predict and control technologies (particularly within complex and dynamic biological systems), the tendency to favor control-oriented alternatives over less technologically sophisticated and accommodation alternatives, technological mediation of our relationship with and experience of nature (and associated marginalization of natural values), privileging elite-controlled quantitative risk assessment over more-inclusive and precautionary approaches to determining responsiveness to uncertainties associated with emerging technologies and overconfidence that technology will provide solutions to any problematic side effects associated with technological innovation.

As with social context and contested moral issues, technoculture issues are not unique to nanotechnology. However, nanoscale science and technology is distinctive because it involves the capacity to precisely characterize, design and control matter at the atomic and molecular levels. As a result, nanotechnology may be particularly susceptible to many technoculture issues.

Form of Life Issues

Form of life issues arise from nanotechnology's impacts on social standards, practices and institutions—e.g., family structures, social networks and life trajectories. Social norms are often predicated on facts about, or particular understandings of, the human situation—i.e., the human person, our relationships with each other and our relationships to the natural environment. Emerging nanotechnologies are likely to alter that situation.

As discussed earlier, technological innovation and dissemination has changed what reasonably can be considered a long, healthy, comfortable life. If nanotechnology (or nanomedicine, in particular) is able to deliver close to what has been promised, the norms associated with human flourishing will see further modification. Moreover, as in the past, increased longevity and expectations for healthfulness will have significant impacts on family norms and structures (e.g., care responsibilities), life plans or trajectories (e.g., when people get married) and social and political institutions (e.g., Social Security).

Nanotechnology might also have a significant impact on sociability. Information technologies have already altered forms and conceptions of social interaction. New types of forums have been created (e.g., online), and physical proximity has become less crucial. As nanoscale technologies increase memory and processing power and enable new modes of information exchange and interfacing, these trends are likely to continue and new possibilities are likely to emerge.

Form of life issues are likely to arise in environmental domains as well. Material sciences already have developed artificial alternatives (or artificial sources) for many resources and goods previously extracted from natural systems and organisms. This trend, too, is likely to accelerate given the capacity of nanoscale science and engineering to characterize materials and design and construct them at the atomic, molecular and macro-molecular level.

As the case of human health and longevity demonstrates, the disruption and reconfiguring of social norms can be beneficial. Nevertheless, it requires adaptation and response, which can be accomplished more or less smoothly and successfully. As with the issue types previously described, form of life issues are not new with nanotechnology, but nanotechnology is likely to realize novel and compelling versions of them.

Transformational Issues

Transformational issues arise from nanotechnology's potential (particularly in combination with other emerging technologies, such as biotechnology, information technology, computer science, cognitive science and robotics) to transform aspects of the human situation and not merely, as with form of life issues, modify some parameters. This might be accomplished by significantly altering the kind of creatures that we are, reconstituting our relationship to the natural environment, creating self-aware and autonomous artificial intelligences (i.e., artifactual persons) or developing robust alternative environments (e.g., virtual worlds that are as rich, immersive and socially complex as the physical world).

In such cases, novel ethical terrain would be introduced or some prominent aspect of our ethical landscape would need to be reconfigured or reconceived—e.g., what it means to be human (human nature), personal identity (psychological and metaphysical), the moral status of (some) artifacts, what constitutes embodiment and emplacement and the constituents of our flourishing (e.g., what is valuable or meaningful in life).

Examples of the types of technological accomplishment that would give rise to transformational issues, should they be realized, include genetic, pharmacological or biomachine enhancements of our physical, cognitive and psychological capabilities (or the introduction of novel capabilities) significantly beyond the range attainable by technologically unassisted people; direct integration of human and machine intelligences; artificial intelligences that pass the Turing test; and nanoassemblers or nanobots that would enable rapid molecular manufacture of macro-scale objects. These would also raise substantial social context issues (e.g., access to technology), form of life issues (e.g., effects on democratic institutions), technoculture issues (e.g., disaffection with our biological selves) and contested moral issues (e.g., the appropriateness of transcending biological "limits").

V. SOCIAL CONTEXT ISSUES

Social context issues arise from nanotechnology's interaction with problematic features of the social contexts into which it is emerging. After focusing on one illustrative social context issue—environmental justice—several significant features of social context issues in general are discussed.

Scenario: Manufacturing Nanotechnology

In order for the benefits of nanotechnology to be realized, nanomaterials and products containing nanotechnology must be manufactured at a high rate, in a high volume, with high reliability and at reasonable cost. Because of the distinctiveness of many of these materials and products, innovative nanoproduction and nanomanufacturing processes that are not easily (or inexpensively) incorporated into existing manufacturing and production facilities are required. As a result, a substantial new manufacturing infrastructure—one that includes everything from production of basic nanomaterials through finished products, as well as process and end-of-life waste disposal—must be established. Because of social, economic and institutional factors currently in place, the majority of the new facilities are sited in or near low-income and high-minority communities, ensuring that members of those communities are disproportionately exposed to the environmental (and attendant health) hazards associated with nanoscale particle releases into the environment. In addition, these communities, where traditional manufacturing and processing facilities also are disproportionately sited, experience less frequent and less thorough site reclamation and redevelopment than do other communities as out-of-date facilities cease operations.

Environmental Justice

Distributive environmental justice concerns the allocation of environmental burdens and benefits. Environmental burdens are land uses, facilities or activities that diminish the quality of a community's environment—e.g., agricultural waste streams, industrial pollution, toxic-waste sites, incinerators, waste transfer stations, refineries, transportation depots, mine tailings and sewage-treatment facilities. Environmental benefits are the goods associated with environmental burdens—i.e., commodities, experiences and wealth, the production of which generates the environmental burdens. Not all communities are equally exposed to environmental burdens. Low-income communities, which receive fewer of the environmental benefits, and high-minority communities are disproportionately exposed to undesirable land uses:

> *For 2000, neighborhoods within 3 kilometers of commercial hazardous waste facilities are 56 percent people of color whereas non-host areas are 30 percent people of color.*

> *Thus, percentages of people of color as a whole are 1.9 times greater in host neighborhoods than in non-host areas.… Poverty rates in the host neighborhoods are 1.5 times greater than non-host areas and mean annual household incomes and mean owner-occupied housing values in host neighborhoods are 15% lower* (Bullard et al. 2007).

The situation is starker in some places than in others. For example, in Massachusetts, low-income communities (median annual income less than $39,525) face a cumulative exposure rate to hazardous facilities and sites that is 2.5 to 4 times greater than that of higher-income communities, and communities with high minority populations (greater than 25 percent) face a cumulative exposure rate that is over 20 times greater than that of communities with low minority populations (less than 5 percent) (Faber and Krieg 2005, pp. 9-10). In Massachusetts, as in the nation, race is significant above and beyond class when it comes to exposure to environmental burdens.

The distribution of environmental burdens and benefits is not only unequal but also unjust. Nearly every theory or conception of justice would endorse the following principle of justice: "Justice increases when the benefits and burdens of social cooperation are born more equally, except when moral considerations or other values justify greater inequality" (Wenz 2007, p. 58). Theories and conceptions of justice differ in their accounts of what justifies inequality. Nevertheless, none endorses race, ethnicity or class as a basis for inequality or unequal treatment, which are the factors at issue in the case of unequal exposure to environmental burdens.

The Issue: Environmental Justice and Nanotechnology

What does the unequal and unjust distribution of environmental burdens have to do with nanotechnology? Nanotechnology is not the cause of the distribution of environmental burdens and benefits, and the capacity to design, control and construct on the nanoscale is not inherently unjust. When the features and practice of nanotechnology are considered, environmental justice does not appear to be a nanotechnology issue.

However, it is not possible to identify the social and ethical dimensions of nanotechnology by considering nanotechnology in itself, abstracted from its social context. Nanotechnology is emerging into a context in which inequalities in environmental burdens are allowed, and in many ways enabled and encouraged, by social institutions and practices. Moreover, it is clear that many nanotechnologies and nanomanufacturing processes will generate both environmental burdens and environmental benefits. Given the current social context, these are likely to perpetuate or exacerbate environmental injustice. Therefore, responsible development of nanotechnology is incomplete if it does not address the issue of environmental justice.

Addressing Environmental Injustice

Responsible development of nanotechnology requires addressing the causes of environmental injustice. Among the primary causes are pollution and its resultant health effects. Some nanotechnologies and nanomanufacturing processes *might* be developed and disseminated in forms or ways that could help mitigate these causes. Nanotechnologies *might* provide cleaner energies, reduce pollution and waste outputs associated with production of some types of consumer goods, provide highly efficient and effective environmental remediation, vastly improve environmental monitoring and data collection and dramatically improve prevention, detection and treatment of diseases, including "environmental illnesses" such as asthma and many cardiovascular diseases.

Whether nanotechnologies and nanomanufacturing processes exacerbate or alleviate environmental injustice depends upon, for example, which nanotechnologies and nanomanufacturing processes are realized, how they are implemented, disseminated and situated (and who or what factors determine these), who controls them and what sorts of oversight and regulations pertain to them (and how effectively these are enforced). These are not merely technology design or risk management issues, since policy, regulation, industry standards, education, social activism, social expectations, economics and the values and commitments of the people involved (among many other factors) are also relevant. So while nanotechnology *might* contribute to addressing environmental injustice, social context is crucial to whether it *in fact* does so.

Moreover, the causes of environmental injustice extend well beyond pollution and its health effects, which do not at all explain the unequal distribution. In the United States, these include the role of cost-benefit analysis in facility siting decisions, zoning and land-planning legacies from segregation, racism in job hiring and advancement, NIMBY ("not in my backyard") effects, differential political influence, redlining in insurance and lending practices, discriminatory use of restrictive covenants and corporate influence and the marginalization of local communities in land use decisions.

Nanotechnology (and science and engineering more generally) cannot address these factors. They require social and political response. For example, in 1994 President Clinton issued an executive order titled "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" that calls for "each Federal agency [to make] achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies and activities on minority populations and low-income populations in the United States" (Clinton 1994). Effective implementation of this order would significantly advance environmental justice efforts. However, according to the EPA's Office of Inspector General and the U.S. Commission on Civil Rights, the EPA has not yet integrated environmental justice into its core mission, and the relevant agencies and administrations have not developed a comprehensive strategic plan for implementing the order (Office of Inspector General 2004; United States Commission on Civil Rights 2003).

Efforts to address environmental injustice would also be advanced by implementing aggressive toxics reduction mandates (e.g., strict command-and-control limits; comprehensive toxics substitution programs or programs that require polluters to pay the health and ecosystem services costs of their pollution); shifting the burden of proof to industry to establish that chemicals used are safe (the "No data, no market" principle); establishing more comprehensive Toxics Release Inventory reporting requirements; increasing green chemistry research and implementation support at both the state and federal levels; adopting green procurement policies at the state and federal levels; standardizing life cycle analysis and end-of-life (or cradle-to-cradle) considerations in technology and production process designs (e.g., by incorporating them into industry and professional standards, as well as engineering curricula) and in regulatory and funding review (at state and federal agencies); encouraging participation of local communities in zoning and industrial permitting processes (e.g., by curbing the power of corporations associated with their personhood status); incentivizing community-oriented brownfields remediation and redevelopment; more effectively enforcing anti-discrimination laws in areas such as employment and lending (and requiring only disparate impact, rather than intent, to establish discrimination); improving collaboration among environmental justice and environmental organizations; and increasing private foundation funding for environmental justice initiatives.

The above is not a set of individually necessary or jointly sufficient conditions for ensuring that nanotechnology reduces, rather than exacerbates, environmental injustice. But it does indicate the scope of the challenge associated with developing nanotechnology in a responsible way with regards to environmental justice.

Beyond Environmental Justice

Environmental justice's intersection with nanotechnology is not anomalous. There are all manner of problematic features of obtaining social contexts that are relevant to the implementation, dissemination, control, oversight, responsibility for, access to, protection from, benefits and burdens of and decision making regarding nanotechnology. Moreover, the distinctive features of nanoscale science and technology, the functionalities and products they enable and the rate and volume of innovation are likely to exacerbate many of these. As a result, *the social context issues associated with nanotechnology are legion*. They include:

- differential access to medical care and medical technologies;
- educational inequalities;
- inadequate information security/privacy protections;
- inefficiencies in intellectual property systems;
- inadequate individual autonomy protections;
- under-representation of women and minority groups in engineering and academia;
- unsustainable agricultural policies and practices;
- unfair tariffs, subsidies and trade agreements;
- inadequate consumer safety protection;

- conflicts of interests for regulators or researchers;
- externalization of pollution and health costs;
- inadequate biodefense/military research oversight; and
- inadequate governmental capacity (e.g., resources, expertise, commitment, institutional design, legal authority, public trust, communication, access to information).

Comments on Social Context Issues

1. These issues are *determinate*. They arise from features of obtaining social contexts. Moreover, in many cases, such as environmental jutice, researchers have determined many of the factors (attitudinal, social, economic, institutional, legal, environmental and so on) that give rise to them. There is no need to wait until nanotechnology matures to identify social context issues.

2. These issues merit *immediate attention*. They are determinate and arise from problematic features of obtaining social contexts, so they ought to be attended to now, even independent from nanotechnology. However, their immediacy is amplified by nanotechnology, insofar as it might exacerbate them. They are opportunities for accomplishing anticipatory and proactive respon-sible development.

3. These issues are *significant to responsible development*. They are not minor or marginal issues. Addressing them is crucial in determining the extent to which nanotechnology will contribute to human flourishing in socially just and environmentally sustainable ways. Moreover, they are neither secondary to nor in the service of the other aspects of responsible development.

4. Responding to these issues *requires remedying the problematic features of the social contexts*. They cannot be addressed by technology design and risk management alone, although these sometimes can contribute to resolving them.

5. These issues are *actionable*. They are determinate, both in their content and, often, their causes. As a result, they frequently are determinate in their remedy as well, since researchers, practitioners and policy makers can develop well-informed (and often well-established) policies, programs, practices and other responses to address them.

6. These issues *intersect with government functions*. Social context issues do not always start and end with government. They involve non-governmental institutions, social practices and individual attitudes and behaviors as well. However, they often substantially involve state, federal or local government authority, activity and responsibility. As a result, they often cannot be adequately addressed without considerable government engagement and investment (e.g., awareness, commitment, personnel, resources, policy and regulation), well beyond current levels.

7. The *work of social scientists and ethicists is crucial* to identifying and studying these issues and in developing informed policies and other actions for addressing them. Moreover, because these issues extend beyond science and technology, comprehensive responsible development will require engaging researchers (inclusive of universities, public interest groups, government and professional organizations) who specialize in social research and ethical analysis in areas such as agriculture, environment, medicine, business, gender, race, public health, global health, education and government.

8. Addressing these issues requires that the *NNI substantially expand its "other social and ethical issues" efforts*. It is not just that more research (and researchers) are required than currently are involved. The scope of issues being studied and addressed, as well as the range of expertise of those involved in the research need considerable expansion. Moreover, mechanisms need to be established through which consideration of social and ethical issues can inform the science and technology research and development program or otherwise contribute to shaping government policy and regulatory capacity. At present, although social and ethical research on emerging nanotechnologies is supported by the NNI, it is not clear how (or whether) this research will have an impact on research or governmental activities.

One possible response to this expansive conception of responsible development might be that the problematic features that give rise to social context issues are too ubiquitous, too institutionally and culturally entrenched and too multifaceted to reasonably expect that they could be resolved. Many of these issues are difficult and recalcitrant. However, the scope and depth of the challenges involved demand that we do what we can to address them. To conclude that we ought not concern ourselves with them because they cannot be fully resolved would be to commit the perfectionist fallacy. As with EHS issues, the point of considering and responding to social and ethical issues is to make as much progress as possible, even as perfect responsible development is impossible.

VI. CONTESTED MORAL ISSUES

Scenario: Research at the Boundaries of Life Forms

As the tools and techniques of nanoscale science and technology continue to improve, research involving artificial organisms, synthetic biology, genetically modified organisms and chimeras (human-animal hybrids) accelerates. Just as awareness of this research is becoming more widespread, a group interested in pushing the boundaries of the science decides to introduce synthetic life forms into themselves. During the ensuing media coverage it is discovered that the Army has been introducing genetically modified bacteria into soldiers in an attempt to increase their resistance to illness when deployed. It is also learned that university researchers, supported by government funding, have synthesized novel strains of the polio virus. Several public interest groups and political constituencies begin to organize against this nearly entirely unregulated "life-meddling" research, arguing that this sort of research should not be done or, if it is done, that it should not take place near population centers or be introduced to humans, thereby exposing the public unknowingly and without their consent. Researchers in these fields find themselves on the defensive as efforts are made to restrict not only these research programs but all programs using the tools and techniques that made them possible. The political and regulatory uncertainty affects funding availability, as well as researchers' decisions about where to focus their work, and causes considerable resources (researchers, students, private funding) to be relocated to other countries. The result is a substantial deceleration of cutting-edge research in these areas, and a further diminishing of the United States' competitive advantage in emerging science and technology.

Research on Novel Life Forms

Research involving artificial organisms, synthetic biology, chimeras and genetic modification, each of which already employs nanoscale science and engineering tools and technologies, is advancing. Researchers at Los Alamos National Laboratory have reported creating "self-replicating cells assembled from nonliving organic and inorganic matter." These artificial organisms are nanoscale in size, around 1 million times smaller than bacteria, and do not contain any biomolecules found in living cells. The vision is to "engineer living technologies, which will be robust, autonomous, adaptive and even self-replicating, if necessary" (American Association for the Advancement of Science 2008).

Synthetic biology makes use of genetic (and other) materials from modern biological life forms to design and construct novel organisms. A prominent vision for synthetic biology is to develop an ever-expanding inventory of standard genomic parts and procedures that engineers can draw from to construct life forms with the desired functionalities. Among recent, and high-profile, events in the field are the genomic (or chromosomal) reconstruction of a Mycoplasma bacterium, accomplished by the J. Craig Venter Institute (Gibson et al. 2008), and the synthesis of a polio virus by State University of New York at Stony Brook researchers (Cello et al. 2002). As with artificial organisms, basic research in synthetic biology is not merely of scientific interest. The intent is to create organisms that can perform useful functions, such as "manufacturing" vaccines, chemicals and energy (e.g. hydrogen, biofuels, or oils), coding information, or supplementing our immune systems.

Genetically modified mice have been engineered with capacities well beyond those of non-genetically modified mice with respect to physical capabilities (e.g. strength [Lee 2007; Barre et al. 2007] and endurance [Wang et al. 2004]), cognitive capabilities (e.g. memory, learning, and problem solving [Tang et al. 1999; Routtenberg et al. 2000; Wang et al. 2004; Tan et al. 2006]), longevity (up to 65% longer lifespan [Conti 2006; Longo and Finch 2003]), and perception (e.g. trichromatism [Smallwood et al. 2003]). The last of these was accomplished by the replacement of a single mouse gene with a single human gene that encodes for a type of cone photoreceptor not normally possessed by mice (mice are usually bichromatic). Genetic alteration of non-human animals has not been restricted to mice and has included behavioral traits. For example, pair bonding male meadow voles (which normally are not pair bonding) were engineered by inserting into their genome a gene responsible for pair-bonding behavior in prairie voles. (The gene encodes for a receptor for the hormone vasopressin, which is not otherwise present in male meadow voles [Lim et al. 2004]).

With respect to chimera research, after a three month public consultation, the United Kingdom's Human Fertilisation and Embryology Authority is permitting research using cytoplasmic hybrids, which involves inserting human DNA into an empty non-human animal egg. These embryos must be destroyed within 14 days and are prohibited from being implanted in a womb. Other chimera research, such as that involving fertilizing a non-human egg with human sperm, has not been approved (Human Fertilisation and Embryology Authority, United Kingdom 2008). The United States, in contrast, does not have a comprehensive federal policy regarding such research, although the use of federal funding for it is prohibited, and President Bush, in his 2006 State of the Union Address, proposed making such research illegal (Bush 2006).

Tools, techniques, and applications of nanoscale science and engineering increasingly are employed in all of these research fields, enabling them and contributing substantially to their development. Without nanotechnology, much of the research being done would not be possible and their prospects for the future would not be nearly so bright.

The Issue: The Sanctity of Life Forms?

All these research programs push at the boundaries of life forms. They alter life forms at their most basic (i.e., genetic) level; they create novel life forms that would not otherwise exist; or they combine aspects of different life forms that would not otherwise be integrated. This is morally contested terrain. These activities involve human design, intention, purpose, control and property in a domain where many believe they do not belong. Objections to them are expressed in terms such as "unnatural," "disrespectful," "hubris," "domination," "profane" and "playing God." The bases of these objections are various; some are religious and some are not. They include, for example, conceptions of life forms (in general or instantiated in individual organisms) on which they are not materials to be manipulated for human ends, conceptions of stewardship toward living things that these practices breach and consequentialist concerns regarding possible detrimental effects—social, public health and environmental—of such research and the attitudes that countenance it.

Counterarguments to these concerns include emphasizing the prospective benefits of the technologies for humanity and, in many cases, for the environment, as well as highlighting respects in which the technologies are similar to (or only an extension of) other research programs and technologies that are now widely accepted—e.g., hybridization, in vitro fertilization and vaccinations. Appeals are also made to the value and rights of individual liberty and autonomy—e.g., that people ought to be able to engage in the activities of their own choosing, as long as they do not harm anyone else. In addition, objections to the research are criticized on the grounds that their bases are not scientific; that they are not informed by a proper understanding of the techniques and technologies involved or that the principles to which they appeal would render almost all technological innovations in medicine and agriculture unethical, thereby demonstrating the absurdity of the principles.

Beyond the Sanctity of Life Forms

Sanctity of life form issues are not the only contested moral issues associated with nanotechnology. Other contested research areas and applications in which nanoscale science and technology now play a role, or likely soon will, include:

- biological and chemical weapons;
- human embryonic stem cell research (and associated therapeutics);
- human enhancement; and
- gene patenting and bio-prospecting.

Comments on Contested Moral Issues

1. These issues *are not applicable to all nanotechnologies*. They apply to particular fields of research, types of research programs and applications. They do not apply, for example, to the use of nanoscale science and technology in paints, memory chips, textiles, tennis rackets, solar panels and water filters.

2. These issues are *determinate and immediate*. In most cases, these are ongoing issues into which emerging nanotechnologies have been introduced, although nanoscale science and engineering frequently enable or accelerate research programs or technologies that raise them.

3. These issues often *involve contrary worldviews*—i.e., sets of values and beliefs that

inform conceptions of the human situation, diagnoses of the challenges associated with that situation and prescriptions regarding appropriate responses to those challenges. They usually are not merely disagreements about facts that can be resolved through further research or education.

4. Concerns regarding morally contested research and applications *may have merit*. It is not the case that anything is permissible as long as it advances science and technology. This is why there is regulation and oversight of human subjects research, for example. It is *possible* that some controversial research programs and applications have morally problematic dimensions or pose unjustified and unacceptable risks.

5. Concerns regarding morally contested research and applications typically *are not based on ignorance or misunderstanding*. In the case of sanctity-of-life-form issues, what is found objectionable—i.e., creating, substantially altering or integrating different life forms at the genetic level—often is distinctive of the research. Moreover, understanding how cytoplasmic hybridization is accomplished or the tools involved in recombinant DNA techniques is not needed to determine whether these activities offend some moral commitment.

6. Concerns regarding controversial moral practices are *substantive*. They are not merely expressions of disapproval or repugnance. They often reflect beliefs about the proper use and limits of science and technology that are grounded in a robust worldview. They therefore involve value, empirical or metaphysical claims that can be articulated, engaged and evaluated. Consensus on these issues is not likely, and many advocates (on both sides) are dogmatic and entrenched. Nevertheless, the issues themselves are not intractable, ineffable or otherwise beyond the domain of productive inquiry and discourse.

7. Concerns regarding controversial moral practices *cannot justifiably be excluded from social and political discourse*. Among the fundamental principles of a liberal democratic society such as the United States is that ideas not be excluded from social and political domains on the basis of the worldviews from which they emerge. This is manifest in the protection of freedom of thought, speech, religion and assembly, as well as voting rights. That some worldviews are not "scientifically informed," as commonly understood in science and technology communities, is not justification for their being marginalized in public policy and regulatory discussions, even regarding science and technology.

8. These issues are *appropriately addressed in social and political domains*. They cannot be resolved in laboratories or boardrooms. The scientific community has technical expertise and industry has economic expertise. However, members of these communities do not, in virtue of that expertise, have special insight on contested moral issues or standing to represent the public's views about them.

9. These issues are *actionable*. They are immediate and identifiable, and several governmental bodies have author-

ity to set policy and develop regulations regarding them—e.g., Congress, the National Science Foundation (NSF), NIH, the U.S. Department of Agriculture, the Department of Energy (DOE) and DOD. Action is also possible by those in the research community. In the case of synthetic biology, some members of the research community are already advocating for standards and regulation.

The challenge regarding contested moral issues is how to proceed productively—i.e., in ways that, as far as possible, respect liberal democratic principles, encourage adjudication and identification of common ground, and do not unnecessarily or unjustifiably slow innovation, commercialization or realization of social and environmental goods. A cautionary precedent is genetically modified (GM) crops. Social and ethical concerns regarding GM crops themselves (e.g., sanctity of life forms) and their implementation (e.g., corporate control, absence of responsiveness to public input, lack of labeling/choice and inadequate regulatory oversight) have been, and largely continue to be, misunderstood or ignored by scientific and industry communities, who tend to mistakenly attribute public resistance almost exclusively to misinformation about the crops' environmental and human-health risks. Meanwhile, entrenched opponents of GM crops have failed to acknowledge that different GM crops, like different nanotechnologies, often have different ethical profiles in terms of, for example, objectives, benefits (and beneficiaries), risks (and who is exposed to them), control and oversight. The perpetual lack of recognition and engagement, from both sides, has contributed to substantial losses and delays in realizing social, environmental and economic opportunities.

The case of embryonic stem cell research perhaps provides a better model, one in which moral concerns were raised, widely considered and, through appropriate mechanisms and institutions, have informed research practice and public policy. Actions by the federal executive branch—in the form of restricting research funding to a limited number of stem cell lines—that were in part motivated by moral considerations have been an impetus for private (e.g., Harvard) and state (e.g., California) initiatives to make resources available for less-restricted embryonic stem cell research. It has led scientists to look for alternative methods for cultivating pluripotent stem cells or otherwise advancing stem cell research in ways that would avoid the moral concerns, and some significant successes toward that end have been reported (e.g., altering adult skin cells so that they exhibit some stem cell–like properties). The federal funding restriction might have slowed research and innovation involving embryonic stem cells, but it has not stymied it (or regenerative medicine more generally), and it might have resulted in some research capacity relocating overseas, but the United States maintains a competitive advantage. Moreover, it has precipitated widespread public dialogues regarding the issue across a wide range of forums—e.g., statewide campaigns around ballot initiatives, science museum forums, town hall discussions with congressional representatives, civic and religious group meetings and commentaries in professional journals. These have, in turn, prompted new policy and regulatory activities—for example, additional state initiatives (e.g., Massachusetts' biotech initiative) and congressional action to reverse the federal funding restriction.

This is not to endorse either the moral considerations that have been raised regarding embryonic stem cell research or the NIH's funding restrictions on the basis of those concerns. Rather, it is to highlight aspects of the experience that appear to have been constructive. In those respects, at least, the case suggests how contested moral issues can be productively addressed within a liberal, democratic, federalist system. Morally contested issues, including those associated with emerging nanotechnologies, need not result in intractable entrenchment that is contrary to realizing nanotechnology's potential as a social good.

VII. TECHNOCULTURE ISSUES

Technoculture issues arise from problematic aspects of the role of technology within the social systems and structures from which, and into which, nanotechnologies are emerging. Technology is not separable from society. Nevertheless, robust critiques of particular aspects of the relationship and particular roles afforded technology within modern industrialized societies have been developed. After focusing on one prominent technoculture issue—the techno-fix—several significant features of technoculture issues in general are discussed.

Scenario: Nanotechnology, Genomics and Asthma in Upper Manhattan

Twenty-five percent of children in Harlem and Washington Heights (upper Manhattan) suffer from asthma. In response, the NIH, through the National Institute for Environmental Health Sciences' (NIEHS) Genes, Environment and Health Initiative (GEI) and Environmental Genome Project (EGP), initiates an environmental health, genetics and toxicogenomics project. The project aims to identify any genetic variations, or polymorphisms, that contribute to asthma susceptibility among members of the community and thereby to elucidate the underlying genetic component of the elevated incidence. This information will then be used to develop effective prevention and treatment strategies particularized to those polymorphisms and to inform environmental regulations. Recent advances in nanoscale science and technology in the areas of genomics, toxicology and bio-monitoring are touted as enabling this sort of public health research to be done with unprecedented precision, efficiency and effectiveness. The NIH promote the initiative as an environmental justice project since the affected population is predominantly African American and Latino. Nevertheless, many environmental justice activists in the community are wary. They are concerned about possible stigmatization of individuals and communities when they are identified as possessing "faulty genes." They are concerned about the cost and availability of any resultant medical preventions or treatments, given the number of families in the neighborhoods who do not have comprehensive health insurance. They view the project, which was developed without substantive input from the communities, as being contrary to principles of environmental justice, which emphasize community-driven agendas. But most of all, they are concerned that the effort is misplaced. The problem is not primarily genetic; it is primarily environmental. It stems from the prevalence of a variety of asthma triggers in homes and schools, and, in particular, that 75 percent of the diesel bus depots in Manhattan are located in these neighborhoods, their exhaust resulting in elevated levels of fine particulate (including some nanoscale) exposures. In their view, addressing this obvious and well-established contributing environmental factor (e.g., through re-siting, cleaner vehicles or enforcement of existing regulations concerning exhaust levels and idling) would be easier, more cost-effective, more immediate and more likely to succeed in reducing asthma rates than the genomic approach.

The Techno-Fix

This scenario is an elaboration on an actual case. Three-quarters of Manhattan's bus depots are located in the high-minority communities of Harlem and Washington Heights, resulting in elevated diesel exhaust particulate levels in those areas. The high particulate levels are widely recognized as a major contributing factor to high childhood asthma rates in the communities. These rates average around 25 percent, which is well above the national and New York City norms (Nicholas et al. 2005). A New York City–based environmental justice advocacy group, West Harlem Environmental Action (WE ACT) has co-sponsored, with NIEHS and others, a Genes and Justice symposium series, intended to explore the possibilities and challenges involving community health, race and rights associated with genetic research in general and initiatives such as GEI and EGP in particular (West Harlem Environmental Action 2007). Each of the concerns described in the scenario are variations of concerns raised by activists who attended the initial symposium (DiChiro 2007). Moreover, nanoscale science and technology is expected to make significant contributions in the areas of genomics research, environmental monitoring, health monitoring and diagnosis and prevention and treatment of environmental diseases.

The environmental genomics program described in the scenario is a techno-fix. It prioritizes the development and use of emerging technologies (and technological innovation, generally) that address the detrimental effects associated with some practice (in this case, environmental pollution) over alternative responses (e.g., re-siting or enforcing existing regulations concerning exhaust levels and idling) that would address the underlying social, economic, policy, lifestyle or cultural causes that give rise to it. In industrial nations there is a widespread tendency to favor techno-fixes, particularly with respect to agricultural, environmental and human-health challenges. In agriculture, the herbicide and pesticide treadmill that enables perpetuation of industrial agriculture (with its attendant ecological and social costs—e.g., biodiversity loss, depletions of water resources, pollution of waterways and displacement of subsistence farmers in developing nations and family farmers in developed nations) is considered a paradigmatic techno-fix. With respect to environmental challenges, the tendency to pursue technological solutions to problems such as species population declines (e.g., captive breeding and assisted migration/relocation) and climate change (e.g., carbon sequestering and ocean iron seeding), rather than to alter lifestyles or modes of production (e.g., consumption, pollution and development patterns) exemplifies the favoring of techno-fixes. In medicine, prioritizing pharmacological intervention over lifestyle changes (e.g., with respect to high cholesterol and heart disease) illustrates the tendency towards techno-fixes, as do aspects of the current genomics preoccupation.

The objections raised to the genomics program in this scenario exemplify critiques of techno-fixes generally. Techno-fixes, because of their narrowness, are susceptible to unanticipated and undesirable ecological, agricultural and social consequences. They tend to focus on managing undesirable effects rather than on eliminating underlying causes. As a result, they often do not solve the problem, but rather enable perpetuation of the problematic practices. Moreover, they often depend for their success upon our ability to control the effects of 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. Furthermore, they often crowd out, draw resources from or are used as justification for not pursuing alternatives that, although less technologically sophisticated, may be more cost-effective, more immediate, more likely to succeed and less susceptible to unintended undesirable effects.

The Issue: Nanotechnology as Techno-Fix?

Many nanotechnologies are susceptible to being developed as techno-fixes. One reason for this is how nanotechnology is often conceptualized. With nanotechnology, it is often is intimated, we have accomplished control of matter at the basic, atomic level. We can design and construct with precision. We can collect and process increasingly 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 can be conceived and approached as engineering problems. This engineering-oriented conceptualization of environmental and social problems and confidence in our capacity to design, monitor, predict and control with detail and precision may encourage deploying nanotechnologies as techno-fixes.

The rhetoric around emerging nanotechnologies exacerbates this concern. Claims regarding how nanotechnology will reduce or eliminate pollution, solve world hunger and global health crises, remediate fresh water shortages, provide indefinite amounts of cheap, reliable, clean energy and enable longer, healthier lives are routine. One reason to be cautious about these claims is that many of these applications are in areas where techno-fixes are pervasive—e.g., agriculture, environment and medicine. Another reason for caution is that when claims about nanotechnology's potential for addressing social or environmental problems are made, the primary focus is the distinctive features of nanoscale science and engineering or the products they enable. The broader political, economic and cultural factors are rarely acknowledged, let alone addressed. Consider, for example, nanotechnology's often cited potential to contribute significantly to improving the lives of the global poor. 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 because of policy, infrastructure or cost constraints. How the technologies are deployed is also crucial. 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 or create problems, rather than resolve them. Finally, for many of the global poverty problems that nanotechnologies might address, there may be less technologically sophisticated, more cost-effective, more immediate and more likely to succeed alternatives.

This is not to claim that nanoscale science and technology is inherently problematic because it is a "deep," "reductive" or "control-oriented" technology. Nor is it to claim that nanotechnologies in these fields or with these applications are necessarily techno-fixes, that they should not be promoted or that they will not deliver on their potential to be social goods. Emerging nanotechnologies can be included as part of integrated approaches to responding to social, environmental and human health challenges that address as well the underlying social, institutional, cultural or economic causes. The problem of the techno-fix is not with emerging technologies (including emerging nanotechnologies) as such, but with the ways in which they are sometimes promoted and deployed—i.e., proffered as magic bullets or used to treat symptoms of some problematic practice, thereby enabling it to continue. When developed in these ways, they often are ineffectual and inefficient; they worsen the situation in the long run.

So while a techno-fix "advisory" is appropriate to nanotechnology, whether it is in fact developed and deployed as a techno-fix remains to be seen. It is not forgone, and awareness of its susceptibility, as well as the difficulties associated with techno-fixes on the part of researchers and policy makers, may contribute to its being developed and disseminated in alternative, more promising ways. This is a case, like many social context issues, where attentiveness to ethical issues is not a matter of prohibition, but of identifying how to maximize the potential of emerging nanotechnologies.

Beyond the Techno-Fix

Technoculture issues often are interrelated and manifest in combination, and many of the aspects of emerging nanotechnologies that render it susceptible to techno-fix concerns expose it to other technoculture concerns as well. Among the technoculture issues that *may be appropriate to nanotechnology* include:

- tendency to favor technological fixes over comprehensive solutions;
- tendency to treat problematic effects rather than address their underlying causes;
- techno-hubris, or overestimation of our ability to predict and control technology (particularly within complex systems);
- techno-determinism, or overstatement of the extent to which technology drives history;
- techno-optimism, or overconfidence in the inevitable goodness of technology and its capacity to solve social and environmental problems;
- alienation from nature—i.e., detrimental technological mediation of interactions and relationships between people and nature;

- commodification of nature and marginalization of non-economic values; and
- privileging elite-controlled risk assessment (rather than inclusive or precautionary approaches) to determining responsiveness to uncertainties associated with technology.

Comments on Technoculture Issues

1. These issues are *immediate and determinate.* They concern features of the relationship between technology and society. The issues are not new with nanotechnology, but in many cases emerging nanotechnologies may exacerbate them or realize them in particularly stark forms.

2. These issues demonstrate the *significance of individual and cultural attitudes or tendencies* to the extent to which emerging nanotechnologies promote human flourishing in just and sustainable ways.

3. Many of these issues substantially *intersect with social context issues*. The extent to which nanotechnology is developed and deployed as a techno-fix depends not only on the properties of the technologies themselves but also on strategies for implementation, who controls them and what oversight capacity is in place, for example.

4. Many of these issues *intersect with governmental functions and responsibilities*, since these are often relevant to the broader contextual factors that give rise to the issues. For example, government action could help overcome several of the barriers that prevent nanotechnology from realizing its potential to help address global poverty—e.g., through foreign aid programs (such as the U.S. Agency for International Development and the Millennium Challenge Corporation), changes in intellectual property systems (e.g., humanitarian exceptions or novel patent types) and funding priorities.

5. Many aspects of these issues are *actionable.* They are immediate and identifiable, and, as indicated above, several government bodies have authority to set policy and develop regulations relevant to them. Non-governmental action on many of them is also possible—e.g., incentivizing pro-poor research by providing funding (as the Bill and Melinda Gates Foundation has done), infusing science and engineering curricula with STS (science, technology and society) modules and refraining from enforcing patents with respect to humanitarian uses.

6. These issues are *not necessarily applicable to all nanotechnologies*. Whether they apply to particular fields of research, types of research programs and applications depends upon the particular features of the technologies, how they are implemented, what their objectives are, who controls them and what oversight measures are in place, for example.

Technoculture issues concern cultural orientations and individual attitudes and beliefs about technology and its relationship to society. With respect to these, others (including government) cannot and ought not directly intercede. As a result, while aspects of many technoculture issues are directly actionable, others are only indirectly so (through education, for example). This does not imply that they are intractable or inevitable. But it does suggest that some technoculture issues may be especially difficult to address, both in general and with respect to responsible development of emerging nanotechnologies in particular.

VIII. FORM OF LIFE ISSUES

Scenario: Virtual Socialization

Advances in nanoscale science and technology enable computing power to continue to grow exponentially, making possible increasingly robust, dynamic and complex virtual environments. In combination with other technologies, these advances also enable novel computer interfacing technologies that make the experience of virtual environments increasingly immersive. The expansion in the range and depth of social experiences and opportunities afforded by virtual reality results in more people shifting more of their interpersonal lives—e.g., recreation, friendship, romance, commerce, creative arts, education, and religious practice—into virtual environments. The impacts of this increase in virtual sociability are twofold. First, there is a diminishing effect on non-virtual social interaction. More time and resources expended in virtual environments is correlated with less time and resources expended on non-virtual social activities—e.g., civic groups, enrichment courses, volunteer activities, political involvement, church groups, cultural events and relaxation with friends and family. Second, there is a value-enhancing effect on virtual social interactions. The more time and resources one invests in virtual social relationships, affiliations and initiatives, the more meaningful these things become in one's life. As a result of these shifts, conceptions of what constitutes a socially rich human life—and the significance of physical proximities and relationships in it, in particular—begin to be reconsidered, as do other prominent aspects of human sociability, such as community, identity, embodiment and emplacement.

Virtual Reality

Virtual reality is a present and steadily expanding reality. The most prominent virtual world is Second Life, operated by Linden Lab. Second Life has more than 12 million residents or avatars (an avatar is a user's virtual self or persona), with thousands of new residents joining each day. There are over 15 million U.S. dollars' worth of Linden dollars in circulation in Second Life, and there was U.S. $22 million in economic activity in the fourth quarter of 2007. The virtual landscape of Second Life encompasses more than 65,000 acres (up from 64 acres in 2003), and new land is continually being added and developed (there is also an active resale market in virtual real estate) (Second Life 2008). The activities that take place in Second Life include everything from business meetings to dancing and community organizing to gaming; and the institutions established range from universities to fan clubs and newspapers to support groups. There are entrepreneurial, commercial, recreational, political, romantic, educational and professional opportunities and experiences on offer in Second Life. It is a socially diverse and rich environment.

Second Life is not the only virtual world. Others include There and Activeworlds, and, to a considerable extent, massively multiplayer online role-playing games such as The Sims Online and World of Warcraft. Moreover, architectures or platform types other than a single site or gateway maintained by a single entity (as is the case with Second Life and World of Warcraft) and to which an avatar is confined are being pursued. For example, a network of virtual worlds across which an avatar can travel could be established, or individuals could construct virtual reality just as individual websites (and the links between them) constitute the substantive content of the Internet.

The richness and complexity of virtual environments are limited by available computing (memory and processing) power. Because of heat and size constraints, conventional semiconductor chips are approaching their performance limits with today's processing speeds. Therefore, to extend Moore's law—that the number of transistors that can be placed on an integrated circuit doubles every two years (and that integrated circuits double in performance every 18 months)—researchers are increasingly looking to nanoscale technologies such as carbon nanotube transistors, molecular memory, magnetic computing, optical computing and, ultimately, quantum computing. There have been successes at many companies—e.g., Nanosys, Nantero, Intel, AMD and IBM—with feature sizes below 45 nanometers having been accomplished.

Research and innovation on interfacing technologies is also advancing. Already, Voice Over IP is available in many virtual worlds, including Second Life. Interfacing technologies in development that might be adopted by virtual reality users include optical lenses, visualization masks, whole-body-motion capture and direct brain-machine interfaces. Several of these are likely to incorporate nanoscale technologies—e.g., sensors and circuits—in their design.

The Issue: Virtual Reality and Sociability

The expansion of virtual reality already has precipitated normative issues both internal to virtual reality and at the interface between virtual and non-virtual (or physical) reality. Within virtual reality, issues of governance and authority associated with determining what activities are inappropriate or ought to be proscribed are increasingly common. For example, Linden Lab occasionally makes "unilateral" decisions regarding Second Life regulation and policy—e.g., eliminating gambling, shutting down banks (following a case of fraud) and eliminating particular avatars for disruptive or prohibited behavior. Many residents object to this model of governance as authoritarian and anti-democratic. Some would prefer a model on which governance (i.e., policy, regulation and enforcement) is accomplished though institutions (usually distributed, rather than centralized) designed and administered within Second Life by residents, while others have advocated for a third-party mediation model for dispute resolution. Issues of standards (with respect to operating platforms and economic policy, for example) and governance across virtual worlds have also been raised as some operators look to make avatars portable across virtual worlds. As these examples indicate, new norms concerning a broad range of relationships and activities within this novel social sphere are needed and being negotiated. There are social, political and ethical dimensions to these norms and negotiations, just as there are with their counterparts in physical reality.

At the intersection of virtual and non-virtual reality, questions are being raised regarding the extent to which norms and institutions of physical reality have authority in virtual reality and, if they do, how their authority applies. For example, do civil and criminal courts have jurisdiction in virtual reality? What constitutes a person's right of privacy, "bodily" integrity or personal autonomy in virtual reality? Does economic activity in virtual reality need to be reported to the Internal Revenue Service? Do intellectual property policies have force in virtual reality? Some of these questions have been introduced into the U.S. justice system. In one case, a former Second Life resident filed suit against Linden Lab claiming that it illegally confiscated thousands of U.S. dollars' worth of property that he had accumulated in Second Life (Bragg vs. Linden Research, Inc. and Philip Rosedale 2007). In another case, the plaintiff (a company that develops products for sale in Second Life) claims that the defendant (originally named in the case by his avatar and who has since defaulted) pirated and illegally sold unauthorized copies of a successful Second Life product (Eros LLC vs. Robert Leatherwood and John 1–10 Does 2007).

In addition to norms internal to virtual reality and at the interface between virtual and non-virtual reality, norms regarding interpersonal relationships in human life as such might be challenged as participation in virtual reality expands. Past technological innovations that structure forms of social interaction—e.g., telephone, television, e-mail and Facebook—have had a substantial impact on how people spend time together and communicate with each other, as well as relationship development (and durability), forms of intimacy and expectations, for example. There is no reason to believe that virtual reality will not also have such impacts, particularly given the novelty of the forms and conditions of social interaction it enables. Although it is difficult to identify in advance what the particular challenges and issues might be, given the distinctive features of the forms of sociability that virtual reality structures, the issues raised are likely to involve conceptions of social identity (including embodiment), the meaning of community (and of being a good citizen of it), the significance of physical familiarity and proximity to relationship quality and intimacy and the resources and skills that constitute social capability. More generally, if virtual reality enables forms of sociability that approach the fulfillment and meaningfulness of those in physical reality, what can reasonably be considered a socially rich human life will be considerably more diverse than it is now.

Beyond Virtual Reality and Sociability

Nanotechnology's possible impacts on the human situation and on the social and ethical norms predicated on it are not limited to those associated with virtual reality. Nanotechnology is a general-use technological platform, and its collective effects on the human person, our interpersonal relationships and our environmental relationship are likely to be significant, and the form of life issues that result are likely to be diverse. For example, if nanomedicine helps extend the normal human life span even five or ten healthful years, norms of human flourishing will need to be reconsidered and there will be significant impacts on family norms and structures (e.g., care responsibilities), life plans or trajectories (e.g., when people marry) and social and political institutions (e.g., Medicare). If nanoscale materials increasingly provide artificial alternatives to material goods formerly supplied by natural environments and devices containing nanoscale technologies further mediate our encounters with nature, norms predicated on our relationship with nature (e.g., regarding consumption and nature experience) will need to be reconsidered.

Comments on Form of Life Issues

1. Nanoscale science and engineering enable innovation across a wide range of fields and applications, including everything from communication to agriculture and medicine to sporting goods. Therefore, *the collective impacts of nanotechnology on the human situation are likely to be multifaceted and substantial.*

2. Technology structures and influences human activities, experiences, relationships and modes of thought. Therefore, *the form of life issues that arise from nanotechnology's impact on the human situation are likely to be diverse and, in some cases, profound.*

3. It will often be *difficult to identify in advance* the particular impacts on the human situation and resultant form of life issues. These issues do not concern obtaining features of nanotechnology or its cultural situatedness to the same extent as do social context issues, technoculture issues and contested moral issues.

4. Because they can be difficult to anticipate, *these issues often are less immediate, determinate or actionable* than social context or contested moral issues. Nevertheless, in some cases it will be possible to preemptively identify and take action on these issues—e.g., regarding the impacts of greater longevity and expectations about healthfulness on Social Security and Medicare.

5. *These issues are not always, or even usually, social problems.* The changes to the human situation brought about through nanotechnology will often be desirable or beneficial—e.g., longer, more healthful lives through nanomedicine. But even in cases where the impacts are desirable, adapting norms to them can be accomplished more or less effectively, and is thus a significant component of responsible development.

6. Many of these issues *intersect with government functions and responsibilities*, particularly where they have implications for public policy or programs. Medicare and Social Security are clear examples of this. These programs are predicated on the citizenry maintaining constant longevity and expectations of healthfulness. When the human situation changes, existing policies and programs may need to be adjusted to remain viable and to accomplish their

intended aims or new policies and programs may need to be developed.

Emerging nanotechnologies are likely to have a significant impact on the human situation and to contribute substantially to structuring human activities, relationships and experiences. Proactive responsible development of nanotechnology therefore requires, in cases where prediction is possible, identifying what the impacts are likely to be, evaluating whether or not they are desirable and determining how practice, policy and regulation might influence them. Doing so, in appropriately inclusive and democratic ways, is part of making informed decisions regarding adoption, policy and regulation, and is as much a part of responsible development as is effective adaptation as issues materialize.

IX. TRANSFORMATIONAL ISSUES

Transformational issues arise from nanotechnology's potential (particularly in combination with other emerging technologies, such as biotechnology, information technology, computer science, neuroscience, cognitive science and robotics) to transform aspects of the human situation (not merely, as with form of life issues, alter some of its parameters) in ways that introduce novel ethical terrain or require reconfiguring or reconceiving some prominent aspect of our ethical landscape (not merely modifying obtaining social and ethical norms).

Scenario: Cognitive Enhancement

As the U.S. population ages and life spans extend, research on diagnosing and treating cognitive degeneration accelerates. Enabled by nanoscale science and technology, several therapies are developed. Initially, these include pharmaceuticals, regenerative medicine and brain stimulation. Subsequently, as the genetic contributions to cognitive degeneration and the underlying biological mechanisms and pathways are increasingly elucidated, somatic and germline genetic therapies—e.g., modifying or introducing genes that encode for increases in brain-tissue growth, neural connectivity, neurochemicals or neurotransmitters—become possible. The Food and Drug Administration reviews several of these drugs, devices and therapies, finds them to be safe and effective and approves them for therapeutic purposes. However, because the new therapies also have an impact on underlying biological mechanisms associated with learning, memory and problem solving, many of them also have cognitive enhancement potentials. Although not developed, intended or approved for non-therapeutic purposes, they are prescribed and used off-label. Early adopters are seen as enjoying not only increased intrinsic goods associated with cognitive capacities (e.g., knowledge and understanding) but also as being advantaged with respect to many competitive and positional goods (e.g., employment and admissions to educational institutions). A competitive surge in the use of non-therapeutic cognitive enhancement technologies (including genetic interventions) ensues among those with access to them and resources to pay for them. The effects of this widespread, but differential adoption of cognitive enhancement technologies are multidimensional. On the biological dimension, evolved (or given) human biology—i.e., human nature—is being altered. On the capacity dimension, those who are enhanced have abilities others lack. On the social justice dimension, pre-existing economic and educational inequalities are exacerbated. On the social outlook dimension, no longer is everyone considered roughly equal in terms of cognitive capability. On the self-conception dimension, human biology is seen as involving constraints to be overcome rather than as enabling human goods. On the perspectival dimension, those who are cognitively enhanced experience the world differently.

On the Threshold of (Radical) Human Enhancement?

Enhancement of our cognitive, physical, perceptual or psychological capacities through technology is ubiquitous. Education technologies, computational devices, nutritional supplements, steroids, pharmaceuticals, communication systems and optical lenses are each a type of human enhancement technology. There is nothing about human enhancement technologies per se that makes them radical. What distinguishes radical enhancement from routine enhancement is that the former involves alteration of some system/process, or introduction of some novel system/process, that augments some core biological capability significantly beyond the range of capacity attainable by technologically unassisted human beings or introduces a capacity not had by technologically unassisted human beings. Radical enhancement technologies alter us in a way that gets at *the kind of creature that we are.*

Several considerations collectively suggest that it is not too soon to begin considering the social and ethical dimensions of radical human enhancement: successful attempts to radically enhance non-human species (often involving nanoscale science and technology); significant gains in advanced therapeutics that may have enhancement potentials (often involving nanoscale science and technology); ongoing research programs related to human enhancement (including those funded by the United States government); and the willingness of people to enhance themselves.

As previously discussed, radical enhancement of mice by means of genetic modification has been achieved across a broad range of capacities. They have been engineered to be physically high functioning (in terms of strength and endurance), cognitively high functioning (in terms of memory, learning and problem solving), long-lived (up to 65 percent longer life spans) and perceptually augmented (trichromatic rather than bichromatic). Moreover, radical enhancement has not been limited to mice. For example, male meadow voles, which typically are not pair bonding, have been made so by the insertion of the genes that are responsible for pair-bonding behavior in male prairie voles. Also, brain-machine interfaces have been accomplished with owl and rhesus macaque monkeys that enable them to control a robotic arm and a robot's walking (even over the Internet) by manipulating their brain states (Carmena 2003; Blakeslee 2008).

Similar brain-machine interface technologies have been used to enable tetraplegic humans to interface with computers to move a cursor, open e-mail, play a video game and draw figures (Hochberg et al. 2006). This is one type of advanced human therapeutic that *may* have radical enhancement applications, but it is not the only one. Nootropics, pharmaceuticals that increase the brain's supply of neurochemicals (e.g., neurotransmitters, enzymes or hormones), increase oxygen supply to the brain or stimulate nerve growth in the brain, are a promising therapeutic for cognitive disabilities and neural degradation, and may have cognitive enhancement potential. Regenerative medicine, therapeutics (e.g., involving stem cells) that generate new tissue to repair damaged, diseased or missing organs or new cells to treat degenerative diseases, may have longevity enhancement, as well as physical and cognitive enhancement, potential. Cochlear and retinal implants, therapeutics for deafness and retinal degeneration, could lead to perceptual enhancement possibilities as researchers better understand how to build devices that effectively integrate with those systems. Bionic limbs, currently used as replacements for lost limbs, have the potential to become bionic enhancements. Transcranial magnetic stimulation and electrical deep-brain stimulation, which have demonstrated some therapeutic potential for depression, psychological disorders, head trauma and semi-consciousness, may have psychological or cognitive augmentation potential as well. In addition, the sort of genetic enhancements that have already been realized in other species could also be realized in human beings. This is not an exhaustive review of advanced therapeutics with enhancement potentials, and it is not intended to serve as a set of predictions regarding which enhancement technologies will be realized or applied. It is a representative list of possibilities that collectively suggests that the technological capability for radical human enhancement is not science fiction, but science in the making.

This is further evidenced by claims by prominent and mainstream scientists and technologists. Mihail Roco, Senior Advisor for Nanotechnology at NSF and chair of the National Science and Technology Council's Subcommittee on Nanoscale Science, Engineering and Technology, has described the current state of the science as follows:

> *Accelerated improvement of human performance has become possible at the individual and collective levels. We have arrived at the moment when we can measure signals from and interact with human cells and the nervous system, begin to replace and regenerate body parts and build machines and other products with finesse suitable for direct interaction with human tissue and the nervous system* (Roco 2004, p. 3).

This assessment was made in the context of NSF's NBIC (nanotechnology, biotechnology, information technology and cognitive science) convergence program, which is a basic research and applied science program (with a societal implications component) that aims to employ "converging technologies integrated from the nanoscale [to] achieve tremendous improvements in human abilities, and enhance social achievement" (Roco and Montemagno 2004, p. vii). Among the "key visionary ideas" of the NBIC program are "expanding human cognition and communication" and "improving human health and physical capabilities" with technologies located both inside and outside the body (Roco and Bainbridge 2002, p. 17). According to Roco, "Converging technology products for improving human physical and mental performance (brain connectivity, sensory abilities, etc.)" should be realized in one generation and "evolution transcending human cell, body, and brain" will be realized in (a cautious) *n* generations (Roco 2004, p. 6).

NSF's NBIC program is not the only research program funded by the U.S. government with substantial human enhancement potential. The Defense Advanced Research Project Agency (DARPA) has an ongoing soldier enhancement research program. It aims to develop, for example, pharmaceuticals, device implants, exoskeletons and genetically engineered organisms that will enable soldiers that feel less pain, require less sleep, heal more quickly, have amplified physical abilities, are more thoroughly networked, are closely monitored both physiologically and psychologically in real time and have stronger intestinal fortitude.

In addition, there appears to be widespread interest in human enhancement, as well as willingness to take on risks, and even break rules, to attempt it. This is evidenced by the non-therapeutic use of technologies such as anabolic steroids, human growth hormones and modinafil (an anti-narcolepsy drug used to maintain wakefulness). These and other moderate enhancement technologies are prevalent not only among competitive athletes (from high school to the professional level) and other people who want to raise their performance levels (e.g., modinafil is reportedly used by United States Air Force pilots to maintain alertness) but also among ordinary citizens who want to feel a bit stronger or live a bit longer. Hundreds of thousands, and perhaps millions, of U.S. citizens, including between 1 and 2 percent of 10th and 12th graders, use anabolic steroids for non-therapeutic purposes each year (United States Sentencing Commission 2006). As the widespread use of elective (non-therapeutic) cosmetic surgery indicates—there were nearly 11 million cosmetic procedures in the United States in 2006—many people accept the risks associated with substantial technological interventions in return for the prospect of superficial benefits (American Society of Plastic Surgeons 2006).

These considerations collectively suggest that it is not premature to begin considering the social and ethical issues associated with radical human enhancement technologies.

Social and Ethical Dimensions of Radical Human Enhancement

Radical human enhancement raises an array of social context, social norm, contested moral and technoculture questions:

- For the person undergoing an enhancement, what are the risks associated with the process?
- Would it be beneficial or detrimental to become radically enhanced?
- Is there something problematic about the desire to become radically enhanced?
- Should parents have the legal right to radically enhance their children?
- Is it morally permissible for parents to radically enhance their children (and, if so, should they do so)?
- Should parents ever be required to radically enhance their children?
- How would radical human enhancement affect obtaining familial relationships, institutions and norms?
- How would radical human enhancement impact obtaining social norms, practices, organizations and institutions beyond the family?
- Overall, would widespread radical human enhancement have good or bad social consequences?
- Would radical human enhancement impair or promote justice?
- How would radical human enhancement alter our relationship to the environment

and non-human organisms?

- Does radical human enhancement violate reasonable moral constraints regarding appropriate use of technology?
- How should radical human enhancement be regarded or regulated in different competitive domains (e.g., sports, job market or education admissions)?
- Can the military require radical enhancement of soldiers?
- How should radical human enhancement research be funded?
- How should radical human enhancement research be regulated?
- Should attempts at radical human enhancement be regulated? If so, how?
- How should dual-use technologies (i.e., therapeutic technologies with enhancement potentials) be regulated in both the research and commercialization stages?
- How ought these issues be approached within a liberal democratic society?

Many of these issues (which are a representative sampling, not an exhaustive accounting) are interconnected. Moreover, each gives rise to a number of crucial sub-issues—e.g., regarding quantification and decision making about risks or resolving the conception and principles of justice operative in the relevant domains. In addition, as formulated, each concerns radical human enhancement in general; in practice, by contrast, these questions need to be raised regarding different types, modes and methods of radical human enhancement (and combinations thereof). This is because different radical human enhancements will have different social and ethical profiles (e.g., brain-machine interfacing through implantable devices vs. increased longevity through regenerative medicine vs. cognitive enhancement through germline genetic engineering).

These issues are complex, compelling and crucial to responsible development of emerging human enhancement technologies. Even so, they do not fully capture the ways in which radical human enhancement technologies are potentially transformational.

The Issue: Transformational Dimensions of Radical Human Enhancement

Technologies are transformational if their adoption would require reconfiguring some prominent aspect of our ethical landscape or would open novel ethical terrain. Radical human enhancement is transformational in both of these senses.

Ethics, at its most basic, concerns how creatures like us ought to go about a world like ours. There has been, and continues to be, considerable disagreement about the kind of creatures we are—from soul endowed and in the image of God to complex biomechanical systems to blank slates. These disagreements are ethically significant. Different accounts of the human person support different conceptions of the human ethical situation and, from there, different prescriptions for how we ought to live. Nevertheless, they are disagreements about how things are and about material that informs ethical reflection. They are not disagreements about how things ought to be. What is novel about the ethics of radical human enhancement is that the kind of creatures we are is not taken as a given, i.e., a stable backdrop against or a foundation on which ethics is done. It is itself the subject of ethical, not just descriptive (scientific or metaphysical), inquiry. *The ethics of radical human enhancement concerns the types of creatures that we ought (or want) to be*. Ethical capacity for radical human enhancement therefore requires developing frameworks for effectively evaluating candidate changes to human nature, as well as resources to help people and organizations navigate this novel terrain—e.g., individuals with expertise, professional codes, regulations, educational resources (such as courses and case studies) and consultation services.

In addition, the adoption (and even the prospect of adoption) of radical human enhancement technologies would compel rethinking familiar aspects of our ethical situation. In particular, it raises questions regarding conceptions of humanness (or what it means to be human) and personhood (or what it means to be an individual person):

- Is radical human enhancement contrary to or an expression of human nature?
- Would a radically enhanced person remain human?
- Would a radically enhanced person retain human dignity?
- Would personal identity (metaphysical and psychological) be retained through radical human enhancement?
- Does radical human enhancement render a person artifactual or biologically transcendent?

In these respects, radical human enhancement technologies are paradigmatic transformational technologies.

Beyond Radical Human Enhancement

Radical human enhancement technologies are not the only potentially transformative technologies in which nanoscale science and technology would play a crucial role. Others include:

- autonomous, self-aware artificial intelligences;
- nanobots or nanoassemblers that would enable rapid molecular manufacture of macroscale objects;
- integrating technologies that would effectively merge human and machine intelligence and/or virtual and non-virtual reality; and
- robust regenerative medicine or combinations of technologies that would enable perpetual (or nearly so) protection, repair and rejuvenation of the human body and brain.

Among the prominent aspects of our ethical situation that technologies such as these would reconfigure are:

- humanness or what it means to be human;
- personal identity or what constitutes the same person over time (psychologically and metaphysically);
- the moral status of some artifacts;
- the constituents of flourishing or what is good, valuable and meaningful in life; and
- mortality.

Comments on Transformational Issues

1. These issues are *less immediate and less determinate* than the other types of issues. The technologies that would give rise to them do not yet exist, even in cases where there are general research trajectories toward them. In some cases, it is contested whether the technologies are possible.

2. These issues *should not preoccupy research on, discussion about and responsiveness to other social and ethical issues*. Although less sensational in some respects, the other issue types—which in many cases are determinate, immediate and actionable—are nevertheless crucial to responsible development.

3. These issues *should not be dismissed*. The technologies that would realize them are, according to many researchers, possible. If they are realized, they will have considerable, indeed transformational, social and ethical impacts. Therefore, attentiveness to them is appropriate. If it appears that some may be realized in a reasonably short time (as has been suggested regarding radical human enhancement), an anticipatory response is needed within a similar timeframe.

Transformational issues are, in general, less actionable than the other issue types. This is a result of their relative indeterminacy and lack of immediacy. This is not to claim that they are not at all actionable. For example, even if regulatory or policy action regarding radical human enhancement would be premature, it is not too early to begin cultivating preliminary social, ethical and even government capacity. Some social and ethical capacity is, in fact, slowly developing—e.g., articles in the professional and public literatures, advocacy groups and think tanks, professional ethicists and relevant case studies and precedents (e.g., steroids and human growth hormones in sport). In addition, there is some demonstrated awareness of the possibility and significance of radical human enhancement within the federal government. The 21st Century Nanotechnology Research and Development Act requires attentiveness to radical human enhancement, noting that "the activities of the program shall include… ensuring that ethical, legal, environmental and other appropriate societal concerns, including the potential use of nanotechnology in enhancing human intelligence and in developing artificial intelligence which exceeds human capacity, are considered during the development of nanotechnology" (United States Congress 2003). Awareness within the Department of Defense is evidenced by DARPA's soldier enhancement program and awareness within NSF is evidenced by its NBIC program, both of which suggest some awareness within the executive branch. So while there does not appear to be significant attentiveness or engagement on the part of most potentially relevant regulatory bodies—e.g., the Food and Drug Administration and state medical boards—there is some engagement among many involved in emerging science and technology policy and research.

With respect to transformational issues that appear more distant, some preliminary capacity development is, perhaps, also possible—for example, through scenario work and discourse on whether particular transformations would be desirable or ought to be pursued.

X. CONCLUSION: THE OPPORTUNITY

Many of the social and ethical issues associated with emerging nanotechnologies are determinate, immediate, distinct, significant and actionable. Consideration of and responsiveness to them are needed now in order to anticipate and proactively address, as far as possible, potential negative aspects of emerging nanotechnologies, as well as to identify and promote opportunities for nanotechnology to contribute to human flourishing in just and sustainable ways. This is precisely the justification for including responsible development as an objective within the NNI.

However, the anticipatory model for responsible development sought by the NNI does not yet fully exist. As with nanoscale science and technology, there are some pieces in place, some resources from which to draw (e.g., experiences with previous emerging technologies and expertise in relevant areas), dedicated and capable researchers (in academia, government, nongovernmental organizations and elsewhere) and ambitious and laudable goals. This is true of all aspects of responsible development—education and outreach, EHS and other social, ethical and legal issues—and it is a reason why nanotechnology is as exciting and challenging from a humanities and social science perspective as it is from a science and engineering perspective. Thus far, the effort to develop effective responses to social and ethical issues associated with emerging nanotechnologies has been inadequate—stymied by misconception of what the issues are, why they are crucial to responsible development and how to proactively address them.

It is possible to do better, and the NNI affords as good an opportunity to address many of the issues as is likely to present itself. First, within the NNI there is a substantial and apparently genuine commitment to promoting nanotechnology as a social good, as well as recognition that considerable efforts in support of responsible development are necessary to do so. Second, there is some recognition within the NNI that there are significant social and ethical issues above and beyond public outreach, infrastructure and workforce development and EHS that need to be addressed. Social and ethical issues do at least find mention in core NNI documents, and there has been some effort within the NNI to identify them (Roco and Bainbridge 2001, 2005). Third, there is recognition within the NNI that significant policy and regulatory changes may be needed to build adequate government capacity for achieving responsible development. It is not often that the federal government openly encourages and supports rethinking the organization, authority, resources, mandates and approaches of its frontline regulatory and policy agencies, many of which intersect with or are implicated in social and ethical issues. Fourth, the NNI is a comprehensive research program along several dimensions—e.g., the number of government agencies involved, the number of disciplines involved and the types of research (basic, applied, social, scientific) being pursued. The NNI has already developed intraand interagency coordination (e.g., the Interagency Working Group on Nanotechnology Environmental and Health Implications) and coordinators (e.g., the

National Nanotechnology Coordination Office) to help avoid redundancy, define research needs and share data, for example.

Taken together, these factors suggest that the NNI affords a unique opportunity to take a broad, critical and constructive perspective on the relationship between technology, government, environment and society; while emerging nanotechnologies offer a unique opportunity to make social (not just technological) progress through broad, innovative, forward-looking responsible development. These are opportunities not to be missed.

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Woodrow Wilson International
Center for Scholars

One Woodrow Wilson Plaza
1300 Pennsylvania Ave., N.W.
Washington, DC 20004-3027

T 202.691.4000
F 202.691.4001
www.wilsoncenter.org/nano
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