Introduction to Nanoscience

Study Guide

Chapter 2 - Societal Implications

This chapter is a science-nonintensive chapter that provides a broader perspective about nanoscience and nanotechnology. NS and NT do not exist in a vacuum. They exist within our culture, quite a global one at that. A multitude of societal factors are influenced by science and technology, and we are quite familiar with them. Conversely, society also exerts influence on the science and technology. They are integrally joined and continually exert influence on one another. In many ways, to neglect one is to neglect the other; to develop a technology without considering the social ramifications is, to put it bluntly, irresponsible. The National Science Foundation (NSF) and the National Nanotechnology Initiative (NNI), working together, have elevated the importance of societal issues like never before. Never has there been such focus on the societal implications of a certain technology, with the exception perhaps of nuclear energy. Programs originating from federal agencies and departments and from the private sector all agree that nanotechnology, in order for its commercialization to proceed in a responsible way, must be viewed from the broadest perspective. Hopefully this chapter 2 of the text provides an inkling of that perspective.

You as a student are on the threshold of what may become a lifetime career, perhaps a passion– albeit one that you most likely will reinvent every five to ten years. If NS and/or NT are in your stars, you must, as a conscientious citizen of this globe, consider the ramifications of your work, your discoveries and your applications. NT has the capability to interface intimately with nature, and the consequences, good, bad or indifferent, should never be underestimated. NT has the capability to make and break jobs, cure and cause diseases, increase or decrease security, render folks rich or poor, extend life or shorten it. It has the capability to enhance and enable all products and services.

In order to understand, predict and plan for NS and NT, we need to study the various aspects of our society and environment that are most sensitive to a new technology. In a case where this was not done properly is the case of GMOs (genetically modified organisms), better know as "Frankenfoods". Most consider the GMO experience as one without much forethought. The consequences of such ramrod technology is self-evident around the globe (e.g. people aren't buyin' it).

Societal Implications of Nano Societal implications of nanoscience and nanotechnology include every aspect of our society that can be impacted by NS and NT. Although somewhat redundantly stated, we need to drive home the point that technology affects society and society affects technology. A short list of societal components is provided below:

- Ethics
- Intellectual property
- Technology transfer
- Education K-12
- Education community college level
- Education college level
- Labor and workforce development - technician workforce (The gold collar worker)
- Labor and workforce development - engineers, scientists, professors
- Business practices
- Investment
- Environmental issues
- National security and defense
- Medicine and therapeutics
- Products (electronics, telecom, information, construction, biotech, aerospace, transportation, recreation, agriculture,
- Public policy
- Public perception
- Science policy
- Nanotechnology and religion
- Nanotechnology and philosophy
- Industry profiles (aerospace, defense, security, telecom, information, construction, recreation, pharma, medicine, biotech, transportation, electronics, energy, water supply, agriculture and many more)
- The future of nanotechnology
- Economical aspects
- The global imperative
- Regulation
- Government policy
- International policy and nano
- Clean water
- Economic development
- Space exploration
- ...... and so many more

Discussion topic: In what order would your group prioritize the elements of the above list? Since not all the topics are independent, how would your group assemble similar topics into supergroups? Are there other categories? Please list them.

Links: There are several excellent links. Two of the most useful documents are available for free from the National Nanotechnology Initiative (www.nano.gov → resources → publications).

Societal Implications of Nanoscience and Nanotechnology
http://www.wtec.org/loyola/nano/NSET.Societal.Implications/

Nanotechnology: Societal Implications– Maximizing Benefit for Humanity
http://www.nano.gov/html/res/pubs.html Nanotechnology: Societal Implications

Center for Responsible Nanotechnology
http://www.crnano.org/

Louis, There are better and far more current reports from the European Union. This stuff is pretty old.

We include excerpts from a whitepaper created by the Colorado Nanotechnology Initiative Task Force on Nano-Ethics and Societal Impacts. Please read if you have some time.

Welcoming the Nano Age

Social and Ethical Considerations of Nanotechnology

Prepared by the Colorado Nanotechnology Initiative
Global Task Force on Nano-Ethics and Societal Impacts
September 4, 2003

Prologue

Nanotechnology is a global phenomenon. It is a technology that will eventually impact most products we make– here in Denver, Colorado, the Nation and on the international landscape. We gather here at this workshop to place on paper a few aspects of this new technology– one that transcends the laboratory and the manufacturing line– and into our lives, our computers, our local, national and international activities and projected impacts.

Introduction: From Evolution to Revolution

Dr. Geoff Gorsuch, Executive Director, Men's Ministry, Singapore, The Navigators

We are on the verge of a nano-tech revolution. According to experts on science policy Michael Crow and Daniel Sarewitz of Columbia University, literature produced by the government, futurists, and techno-pundits alike indicates that "the promise of nanotechnology to remake our world seems virtually infinite."[1]

Peter Singer of the University of Toronto reports that "[t]here have been major scientific and technological advances in microscopy, material science, molecular level manipulation, and scientific understanding at the borderline between classical and

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[1] Crow, M., and Sarewitz, D. Nanotechnology and Societal Transformation,

quantum physics." As a result, says Singer, "all of society, not just scientists, needs to take nano-tech seriously."[2]

Besides the breakthroughs mentioned above, nanotechnology (NT) has already started to change our lives in an evolutionary manner in other fields. For instance, existing products and services have already been improved by the "control of matter on the nanometer scale and the exploitation of novel phenomena and properties at that length."[2] Additionally, NT has begun to fundamentally change electronics, medicine and materials. With a few notable exceptions, most scientific and social commentators agree these changes are very promising for the future.

While the promise is great, any significant shift in human technology warrants careful scrutiny. The problem is that relatively invisible, scientific evolution eventually reaches a "tipping point" and becomes a visible, technological revolution. At that point, production, business and education, the engines of culture, go into upheavals that cannot be accurately predicted. History teaches us that along with progress, there is also pain. As the new displaces the old, the man in the street feels destabilized and ill prepared for the future. But, he is not alone. Those who should be most prepared are most likely not. During the evolutionary phase of innovation and change, scientists, educators, industry, doctors, lawyers, philosophers and ethicists—those in the know—should be carefully thinking about the coming revolution and putting systems in place to prepare the culture for its impact. But are they?

Again, according to Singer, "[d]espite the potential impact of NT…there is a paucity of serious published research into the ethical, legal and social implications of NT. As science leaps ahead, ethics lags behind."[2] At this rate, when the revolution comes, the culture will not be ready to adapt to it. While some say we can cross that bridge only when we come to it, others are calling for a full moratorium on all nano-research until the study of its social implications reaches the speed of progress of this new science, itself.

Whenever there is a lack of clear thought and communication, alarmist tendencies can emerge. Predictably, the media are making the most of them, whether in discussion of "gray goo" in a popular science journal[3] or on the silver screen. Imagine this scene playing out in your local theater:

> She screamed…Her swollen face and body blew away from her in streams of particles, like sand blown off of a sand dune…I felt her body growing lighter and lighter in my arms. Still the particles continued to flow away with a kind of

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[2] Mnyusiwalla1, A., Singer, P., and Daar1, A. "Mind the gap': science and ethics in nanotechnology," *Nanotechnology* 14 (2003). Institute of Physics Publishing. Available: stacks.iop.org/Nano/14/R9

[3] Joy, B. *Wired News.*

> whooshing sound…She looked as if she was dying of cancer…I leaned in and turned my ear to her mouth to hear… 'Jack,' she whispered, 'It's eating me.'[4]

What was "it?" According to author Michael Crichton, "it" was a swarm of nanoparticles! In his novel, *PREY*, we see how the dream of nanotechnology can, in the minds of some, be easily turned into a nightmare. Though the scientific community will laugh at such science fiction, seeing it as "an illogical extrapolation of current research"[5], the lay community may not. With Hollywood going "nano," we can only imagine what the impression on the public will be over time. In point of fact, technology has often emerged as a double-edged sword, wreaking some level of societal havoc whether through socially or environmentally irresponsible applications, unintended consequences, or the failure of public policy and the legal system to keep pace.

So, where does that leave us? Can a sober-minded scientific, educational and business community effectively assure a wary public that the dreams of miracle cures and longer, healthier lives, among other wonders, will safely happen through prudently planned and executed nano-innovation? Or, will alarmists have the final say?

Apparently, the question we need to address is: *Will NT serve us or enslave us?* More specifically, to insure that NT will serve the best short and long-term interests of humankind, we must ask, *How must this particular revolution be managed? What principles and standards must be put into play to guide it? What laws and institutions must be legislated not only to foster its development, but to regulate its impact as well?* And, finally, *what methods and tools can be developed to assist in addressing these questions in a timely, thoughtful and effective manner?*

These questions cannot be relegated to an afterthought or a nagging intrusion on the domain of pure scientific research. According to Crow and Sarewitz, "[t]he ongoing experience of public opposition to…prospective technologies…needs to be viewed as integral to the relationship between innovation and societal transformation."[1]

As a result of the massive efforts of government and industry alike, NT applications will soon be entering the market place in volumes. Sarewitz and Crow give three reasons for why rapid technological change is potentially disruptive: it is usually not consensual, it usually creates both winners and losers, and it "can threaten the social structure, economic stability and spiritual meaning that people strive in their lives to achieve."[1]

The role of this task force is to explore the potential impacts of NT and recommend approaches that respect the "human context for technological change"[1] and ensure that a balance of the common good is realized. Our goal is to assist stakeholders in Colorado

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[4] Crichton, M. *PREY*, Harper Collins, NY, New York, 2003, pg, 337-338

[5] [Reference Needed]

[6] *American Heritage Dictionary*, William Morris, Ed., Houghton Mifflin Co., 1969.

in implementing this evolutionary phase of primitive yet fundamental breakthroughs in the realms of chemistry, biology and physics such that it will evolve into a revolutionary blessing for humankind.

This white paper endeavors to accomplish the following:

- Define nanotechnology
- Discuss briefly its possible applications and societal impacts
- Examine the role of public dialogue and possible responses to concerns that are raised
- Propose minimal necessary ethical guidelines and institutional safeguards to help science, academia, government and business steer the NT revolution to safe and sane public service

Outline specific research objectives that can be applied to science policy formation.

Responsible Nanotechnology Development: A Platform for Dialogue

Erik Fisher, Ph.D., Asst. Research Professor, NSF Center for Nanotechnology in Society, Consortium for Science, Policy & Outcomes, Arizona State University

Industry standards, design guidelines, and ethical codes to inform the ethical development of NT have been developed by several groups. Most of these focus on short-term areas of concern for which there are immediate potential impacts. Such concerns may range from environmental impact, military and surveillance uses, and biomedical applications, to human enhancement and social justice. For instance, in the summer of 2003, the Center for Responsible Nanotechnology[18] had created seven development principles and six specific design guidelines; the Foresight Institute listed four policy goals; and Nanotechnology Now[16] offered eight ethical guidelines.

Developing such guidelines is a necessary step; but implementing them involves an entirely different set of considerations. To be effective, efforts aimed at foreseeing and addressing the negative consequences of NT must take into account realistic and practical considerations that apply to specific decision spaces and application contexts, if they are to lead to wise management and policy practices. Implementation ought, therefore, to take into account both the context and process of NT research and development. This means that regular assessment—whether expert or lay—should be integrated within the actual fabric of technological development itself, rather than merely be imposed from the outside. This "internal" assessment needs to start at the very beginning of the process that eventually culminates in publicly embedded NT products. This starting point needs to include basic science and early product research and development. Assessment can then be expanded to encompass policy decisions, regulations, and public dialogue.

The integration of regular self-assessment by those conducting research and development at the nanoscale serves a separate function from external oversight. In addition to

[18] http://crnano.org/index.html

external mechanisms, a set of internal mechanisms is needed to facilitate informed reflection *by scientists and engineers* upon the ethical dimensions and societal consequences of their technical work. As NT development matures and applications emerge, external oversight will become more and more feasible and prominent, and informed reflection by scientists and engineers will provide an additional layer of assurance. Moreover, it will continue to carry further benefits, such as allowing researchers to do due diligence. It can also make good economic sense, in that end use considerations will be factored into technical decision making at an earlier stage.

In this light, the CNTI ethics task force proposes the development and testing of an enhancement model to the product design process that introduces key decision points. The proposed self-assessment model, applicable especially to design processes in basic research and technology development, will guide design teams through a series of questions and considerations, allowing scientists and engineers to recognize and address potential sensitivities regarding potential unintended consequences of their technical decisions. Ultimately, such a tool may be usefully extended to similar decision processes in product marketing and the development of public policy.

Any tool designed to encourage self-critical ethical assessment must take into account the technology development process to avoid unnecessarily hampering it, and to increase the likelihood of its actual implementation by scientists and engineers. The typical way in which this process is conceived can be represented by the three-stage RDI process of Research, Development, and Implementation.[19] Traditionally, ethical considerations tend to arise towards the end of the development phase, if at all; often, they do not receive consideration until after commercialization. Economically, however, it can be counter productive to introduce ethical considerations and regulatory measures after significant funds and resources have been invested in specific design platforms and product areas. Instead, the ability to examine societal and ethical questions at early stages of research and development—in addition to asking questions of technical feasibility—could save valuable resources by addressing both potential design flaws and potential controversies that could arise later on.

Ideally, simply following well-conceived standards, regulations, and guidelines would eliminate the need for the kind of reflective tool proposed here. Such guidelines, however, because they need to be very general, are not always easy to interpret or useful to apply to specific situations. Part of the difficulty of applying general rules to specific research and development projects arises from the fact that most technical and design decisions seem to involve purely technical trade offs, so that considering broader dimensions at early stages may seem superfluous, and a key decision point with ethical

[19] Figure created by Anil Rao, Ph.D., MSCD Biology, Metro State College

implications may be easily overlooked. Additionally, it is unlikely that framers of guidelines could comprehensively identify all potentially unethical scenarios associated with a given technology. In both cases, mitigating unforeseeable and unintended consequences has to involve envisioning them in relation to the decisions that culminate in specific designs, as well as specific applications of those designs.

Being conscious of tacit decisions, technical alternatives, and potential consequences involves seeing what is otherwise invisible to the non-scientist and the scientist alike: the lay person is unaware of technical considerations and procedures, while the scientist takes most of them for granted. Hence, it can be useful for scienctists and non-scientists to collaborate during the technology development process to ask and consider salient questions at key junctures in order to "tease out" potential consequences and scenarios. In addition to asking prescribed questions, nano-scientists and engineers should also be encouraged to formulate their own "authentic" queries, since drawing upon one's own knowledge base and value sets is necessary (though not sufficient) to engender a culture of accountability.

Unconstrained and regular dialogue (such as the brainstorming that occurs in the early stages of engineering product design) will not always lead to clear sets of consequences; in such cases, observations, speculations, and information deemed relevant can be documented and passed on to others to bear in mind, monitor, and re-assess during later stages of the development process. Thus, pressing but uncertain considerations can be tagged for future tracking and discussion as application contexts become more defined. In general, the same basic questions, as well as unique ones, can be asked again and again at each stage of the continuum and by any agent who is part of the overall process since new contexts, developments, and individual roles all can potentially give rise to new insights.

Clearly, codes of conduct and professional guidelines are not enough: ethical lapses in scientific research as well as in industry are still all too common. Likewise, personal efforts at ethical reflection can lack the training and consistency that semi-structured multidisciplinary dialogue can offer. To be effective, guidelines would ideally be implemented and "enacted" on all levels, with a framework and common language that affords effective dialogue and reflection and that actually informs technical decision making. What then constitutes the parameters and content of such a framework and method?

Challenges and Opportunities of Applied Nanotechnology

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Until quite recently, people have assumed that the human condition on earth could not help but get better. One could easily look back and say that our species is living longer, healthier lives and is enjoying a plethora of products that make life easier and more enjoyable. However, a growing number of people in contemporary society is beginning to question this assumption and are concerned about global oil reserves that have predictable dates for depletion, the steady decline of biodiversity, and continued proliferation of weapons that are ever more deadly and massive in scope. Some predict a future where children will be worse off than their parents. World tensions will mount as entities squabble over ever diminishing resources of energy, clean water, land for farming and wildlife, and so on.

New technologies have served to improve the human condition in the past, and the new technology of nanomaterials is poised to improve the human condition in the future. NT's endless possibilities are rekindling excitement and hope about the future. While not a panacea, this technology will positively impact many areas of concern and perhaps even turn the tide on a number of global negative trends. Many people are inspired by NT's potential to put the human condition back on a positive track. They are invigorated by the process of exploration, dialogue, and more hopeful visions of the future. What do these visions include?

NT research is already occurring in the areas of biotechnology, consumer goods, defense, energy, the environment, information technology, telecommunications and transportation. Large corporations, such as Hewlett-Packard (HP), already have large portfolios of NT patents. HP is currently running a prime-time commercial that lists amazing products such as tiny chips that could contain the contents of all the books ever written. HP and the University of California were granted a U.S. patent last year that may be a foundation for such a product. Mr. Keukes of HP is quoted as saying, "imagine computers so small, they are everywhere, even in the fibers of your clothing."[14]

NT promises a range of positive applications including improvements in national defense, generally healthier lives for people, and a range of entertaining and fun gadgets. For example, the Nanotechnology Now[15] lists the following potential benefits likely to be realized from NT research and development:

- Reduce the amount of water traditionally used in manufacturing and agriculture
- Enable the manufacture of cheap greenhouses that could save water, land and food
- Make solar energy more economically feasible
- Improve living spaces
- Provide cheaper computers
- Solve environmental problems
- Improve medicines and their widespread distribution

However, not all applications may be positive. The products of NT can be categorized into three general areas: the first and the largest are those that simply enhance existing technologies to make a good product more cost effective, higher performing, less environmentally taxing, or more accessible to greater numbers of people. This category would include products such as nanotube-based sensors for detecting gasoline vapors.

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[14] Foremskin, T. "HP given nanotechnology U.S. Patent, San Francisco 1-23-02,"
[15] http://nanotech-now.com

Technology of this nature is already in use and accepted by society with the new nanoproduct simply replacing the older product, and utilizing fewer resources in the process.

These are non-controversial products. Few, if any, would argue that the business community should not produce electronically enhanced, high tech wheelchairs or temperature sensing implanted microchips for pets. In the field of energy, products are being designed that will provide cleaner, more efficient and affordable fuel. Infrastructure investment in older proven technologies may be the only thing holding back wide scale manufacturing and distribution of these types of products.

A second category includes nanoproducts that may not integrate well with natural environmental systems. They are likely to fall into the same category as plastics, which have great functionality but also have disposal and recyclability issues. Just as the lid to a plastic container must be removed and discarded prior to recycling, nanomaterials may also be combined with existing materials so that all or part of the end product is not recyclable. Brand new materials such as carbon nanotubes, gold clusters and "Buckyballs, are being created in laboratories. If large quantities of such materials are introduced into the natural environment or ingested, we will have consequences that are currently difficult to predict. Byproducts from the production of nanomaterials also have environmental consequences that may prove challenging. Each newly produced nanomaterial should be evaluated within the context of how it fits into a sustainable system of human and ecological health.

The third category involves nanoproducts that will directly challenge our concepts of human control and security. For example, the same nano-eye that could help us better kill a cancer cell could be used against us in some application of espionage. Artificial intelligence systems may be created that are considered superior to the human brain. Small, very powerful technologies may fall into the hands of extremists who could use them to forward their own agenda at the expense of the majority. Many products will be created that will offer double-edged swords. The same product may be applied defensively or offensively, for health promotion or destruction.

Finally, the impact of NT goes beyond the products themselves. The history of technology suggests that the large-scale acquisition of NT and nano-capabilities may shift global political and economic power bases to the point of instability. Whether flooding the market with a vast array of new or improved products or creating powerful governmental/military complexes of enhanced surveillance methods and weapons, NT will, at least initially, create potentially new boundaries between the haves and have-nots. And, the speed with which this might happen is evidenced in the current global race of governments around the globe to be the first to harness the power of NT.

The combination of the process of technology acquisition and dissemination and the products themselves gives rise to an array of legitimate concerns regarding the development of NT. For example, Meyer, in a summary paper prepared for the National

Science Foundation (NSF) in the late 1990's,[16] notes the following potential detrimental effects of NT:

- Risks related to enhanced capabilities in genetic manipulation of plants, animals and humans
- Unanticipated effects of failed devices such as implanted medication delivery systems
- Violations of human privacy including bodily invasion without the knowledge of the host
- Security risks associated with difficulties in detecting nano-sized artifacts
- Environmental degradation due to the uncontrolled spread of nano waste and difficulties in recycling composite materials
- Increased feasibility of effective delivery systems for biological and chemical weapons
- Replacement of manufacturing jobs with small numbers of highly skilled workers.

Despite the potentially negative consequences of nano-development, the vast majority of nano-products is likely to fall into the realm of what is acceptable, desirable and considered a positive contribution to human progress. Together, many of these applications could contribute globally towards removing causes of distress and reducing social unrest. Used wisely, NT holds some potential for a more hopeful future. However, how the balance of challenges and opportunities plays out in the NT revolution will, in large part, be influenced by both public acceptance and the response of public institutions to the implications of the technologies. Let's examine those factors influencing the manner in which this dialogue and response is likely to evolve.

Meeting the Ethical Imperative of Nanotechnology

Deb Bennett-Woods, Assoc. Professor, Health Care Ethics & Director of the Center for Ethics and Leadership in Health Professions, Regis University

All new technology carries with it potential social, cultural, economic, political and environmental implications that require careful thought throughout the process. These considerations take on an ethical dimension when they either threaten to violate basic moral tenets or principles, or when such principles suggest an obligation in support of the technology (e.g., reduce suffering or eliminate an existing harm). When ethical considerations are both positive and negative, we are faced with an ethical dilemma. Because the potential consequences of a new technology can be significant and complex, the ethical dialogue can also be complex. Witness the ongoing controversies surrounding aspects of genetic engineering such as GMO foods or human cloning for embryonic stem cell research. However, the very complexity of the dialogue can render it insignificant in its impact on decision-making. This has proven particularly true with respect to the development and dissemination of new technologies.

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[16] Meyer, M. (2001) Socio-economic research on nanoscale science and technology: A European overview and illustration. In *Societal Implications of Nanoscience and Nanotechnology* (Final Report). pp. 217-241.

Ethical discussions generally take one of two forms. The first is scholarly debate, often substantive but inaccessible, mired in academic jargon and buried deep in scholarly journals or books of limited circulation. The second form of ethical discussion is the highly public debate carried on in the media by politicians and investigative reporters. This debate tends to be reactionary, divisive, shrill, and focused on limited and superficial information. Somewhere in the middle of these two extremes reside the scientists, engineers, regulators, corporate executives, investors and consumers who really drive the forward progress or delay of the technology as it moves toward and into the marketplace.

The result of this dichotomy in dialogue is that the most common basis of ethical analysis becomes an overly simplified, utilitarian cost/benefit analysis, with one side arguing narrowly that the new technology will benefit the greatest number of people, while the other side argues narrowly on the basis of some slippery slope consequence down which the technology is likely to slide. For example, medical applications of nanotechnology may provide the key to treating diseases of all kinds, versus, the indiscriminate use of nanoparticles in medicine may result in a dangerous accumulation of biologically active nanomaterials in the body and human waste stream, as well as the possibility of unanticipated genetic mutations and unexpected toxicities. Neither argument fully reflects the true complexity or range of ethical dimensions embedded in the issue.

The magnitude of possible applications and complex consequences associated with NT, as introduced earlier in this paper, demands a higher standard of ethical analysis and dialogue than we are accustomed to conducting. The challenge becomes finding a model and the common ground on which such dialogue can proceed. Think of it as an infrastructure for ethical analysis on behalf of society. Four general recommendations are offered for the establishment of such an infrastructure.

1. Use a combination of brainstorming, scenario development and other strategic tools to identify and prioritize those aspects of NT, and its likely applications and outcomes, requiring deep, ethical analysis and consideration. Identify a few key issues likely to be foundational to the broader impact of NT, and around which ethical dialogue needs to generate consistent definitions and assumptions. These might include public acceptance, nanotoxicity and environmental impact, economic and workforce disruptions, etc.

2. Establish a common language, easy to learn and apply, that can be shared among stakeholders at all levels in order to facilitate meaningful dialogue. For example, the use of common ethical principles and standards could easily serve this purpose. In the same way the Belmont Report[20] interpreted the principles of respect for persons, beneficence and justice as central to any ethical considerations related to human subjects research, an expanded set of principles, straightforwardly defined, could provide a common language for the analysis of

[20] National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research (1979). The Belmont report: Ethical principles and guidelines for the protection of human subjects research. Available: http://ohsr.od.nih.gov/mpa/belmont.php3

NT. These might include analogous principles such as respect for communities, the common good, and social justice.

3. Establish a model of decision-making that systematically poses ethical dilemmas from a variety of perspectives. One of the great contributions of ethical theory is the ability for differing perspectives to force the analysis into different vantage points or lenses. This renders it more difficult for one perspective, such as short-term utilitarian considerations, to dominate the process. Again, because ethical theory is often rendered inaccessible by philosophers, the model must concisely apply theory to the development of a systematic process of exploration that is readily understood by scientists, engineers, corporate executives, public policymakers and the general public alike.

4. Test the model with particular attention to its use in the NT research grant and proposal writing and selection process. Once developed, make the model widely available through web-based training, advocating its use at all levels of decision-making from basic science, to applied research and development, to product marketing and sales, to policy-making and regulation.

We have entered a crossroads beyond which we are potentially faced with the next great revolution in human evolution. It may be wise to begin considering all research as human subjects research, and to discover mechanisms that can effectively promote knowledge while also avoiding rapid and poorly considered technological progress conducted at the risk of human safety and dignity.

Welcoming the Nano Age: The Challenge Restated

The history of modern society can be traced through a long line of event milestones such as the invention of the wheel, the printing press, the electric light bulb, radio, television and now the Internet. Each of these events has helped drive and has in turn been driven by a myriad of responses that reshaped human society and culture. Similarly, human history is often described in various taxonomies of time including the Stone, Copper, Bronze and Iron Ages as well as the more recent Industrial and Information Ages. Each age can be characterized by a collection of technological events and human responses that, taken together, constitute a significant shift in the human condition. Social, cultural, political and economic systems are upended and reconstituted in response. Established geographic and cultural boundaries dissolve and realign, political and economic power is redistributed, and social institutions evolve or adapt to the new realities.

Two observations might be made of this historical charting of the patterns of human progress. First, the pace at which milestones are introduced and the human response to them is rapidly accelerating. The amount of new knowledge generated in the last 100 years exceeds the sum total of all knowledge accumulated throughout the whole of human history before that. On the scale of human time, one "age" has now barely arrived before the next one is upon us.

This leads to the second observation. Never has there been a plan for exactly how to embark on a new age in human evolutionary progress. Inherent natural barriers have moderated the magnitude and pace of change so that even large-scale changes required time to overcome the natural human suspicion of and resistance to change. Nonetheless, change happens, filled with unexpected and untoward consequences. We do our best to learn and adapt; however, as the pace of change accelerates, the available time to adapt is shrinking. We no longer have the luxury of a few centuries to sort out the effects of new knowledge and its requisite technological impacts. As a result, today the pace of our technological progress well outstrips our ability to predict and assess its adverse consequences, or to complete the learning curve that allows us to adapt broadly and minimize those negative effects in favor of more uniformly positive outcomes. Disruptions in the social, economic, political and cultural fabrics of societies across the globe remain unresolved as questions of environmental impact and long-term sustainability of the human population are raised with ever-increasing concern.

The coming together at the nanoscale of chemistry, biology, physics, engineering, electronics and computer science to create a new scientific discipline opens the door for the type of human leap in innovation that rightly constitutes a new age. NT has vast potential for impacts across the entire spectrum of human endeavor– from research and development to the legal system to real estate and marketing. What if this time, we do have a plan? What if we use the accumulated wisdom of both the natural and the human sciences, in a truly multidisciplinary partnership, to anticipate and plan for the manner in which the next stage of technological development is introduced? Throughout history, humankind has been both beneficiary and victim of our curiosity, creativity and self-interested motivation for progress. NT presents a truly unique opportunity to revolutionize not only our technological capabilities, but also our human capacity for self-aware and self-regulated evolution.

Where will nanotechnology take us? How many countries already have nanotechnology initiatives? As it turns out, all countries in Europe, Asia, Africa and North and South America have some level on nano-engagement. How do we spread the word about nanotechnology to all nations in the world? How do we spread the word about responsible development of nanotechnology to all nations in the world?