NANOTECHNOLOGY AND ETHICS:

A Short Guide to Ethical Responsibilities

of Nanotechnology Researchers

at NNIN Laboratories

by

Robert McGinn
Professor, Department of Management Science and Engineering
Director, Science, Technology, and Society Program
NNIN Ethics Investigator
Stanford University

September 10, 2008

TABLE OF CONTENTS

I. INTRODUCTION[1]

Consider the following 'data points' about nanotechnology (NT) and ethics:

- In 2000, Bill Joy, then Chief Scientist of Sun Microsystems, published an essay in which he termed the potential of nanoscale assemblers for destructive self-replication a threat to the biosphere.[2]
- In 2003, Michael Crichton's best-selling novel *Prey* depicted unpredictable swarms of programmed and learning-capable nanoparticles wreaking havoc on humans.
- Since 2003, when the National Science Foundation (NSF) published a request for proposals to establish a National Nanotechnology Infrastructure Network (NNIN), NSF has required that NT's "social and ethical implications" be a part of NNIN's research agenda.
- NSF has established two "Centers for Nanotechnology in Society" at U.S. universities to study societal – including ethical -- issues related to NT.
- In 2007, *Nanoethics*, a new scholarly journal about NT and ethics, was launched. The journal and its title indicate that some academics believe there are ethical issues related to NT that merit critical analysis.

Clearly, concern about ethical issues related to NT is in the air. The goal of this guide is to help NNIN researchers become better informed about the ethical dimension of NT. To that end, various ethical issues and responsibilities that can confront NT researchers in their work will be identified and discussed.[3]

However, before doing so, two important preliminary issues need attention: first, whether NT raises **unique** ethical issues and, if not, whether NT researchers should still concern themselves with "nanoethics"; second, whether ethical responsibility can be distilled into a **checklist** of specific ethical responsibilities.

First, many NT researchers acknowledge that there are significant ethical issues related to NT. However, some appear to believe that NT deserves their serious ethical attention only if at least some of these issues are **unique** to NT. While ethics experts have yet to identify any specific ethical issue unique to NT, and while there does not appear to be anything about the NT field *per se* that raises any **qualitatively new** ethical issues, neither point implies that NT is unworthy of ethical consideration by NT researchers. Intellectual property theft in the Internet era is not a less important ethical issue simply because the issue of theft is not

---

[1] Barbara Bernstein, Michael Deal, Douglas Kysar, and Paul Rissman read draft versions of this guide and provided helpful criticisms and suggestions.

[2] Bill Joy, "Why the Future Doesn't Need Us," *Wired*, Vol. 8, No. 4, April, 2000, http://www.wired.com/wired/archive/8.04/joy.html.

[3] Besides NT researchers, groups with NT-related ethical responsibilities include product designers, manufacturers, regulators, lawyers, judges, journalists, and educators.

unique to the IT field and has been around for ages. While the **kinds** of ethical issues and challenges discussed in this guide have arisen before and will probably arise again in future areas of research, old ethical wine in new technological bottles may still deserve careful attention. In fact, recognized ethical issues that appear in different guises in a new field of inquiry become **more**, not less, important for researchers in that field to consider if work in that field has substantial potential for changing society.

While NT seems not to raise any unique ethical issues, there **is** something unique, ethically speaking, about the NT enterprise. With the rapid growth of the NT field, an unprecedented ethics-related opportunity has emerged. Important government funding agencies that support NT research, e.g., the National Science Foundation in the United States and the *Centre Nationale pour la Recherche Scientifique* in France, want NT researchers to become more ethically well informed and reflective about their work in relation to the society that supports it. A belief has begun to emerge in the larger NT community that NT researchers can and should take a leading role in "improving the stewardship of the scientific enterprise,"[4] so that the latter will be able maintain the trust of the society whose funding makes it possible.

Second, a disclaimer about ethical responsibility is in order. This guide is **not** a comprehensive treatment of NT and ethics. Although a number of specific ethical responsibilities of NT researchers are identified below, taken as a group they should **not** be viewed as a "checklist" that offers the last word on ethical responsibility for NT researchers. Determining whether one has an ethical responsibility to do something is not like determining whether one can take a particular tax deduction by checking the relevant statutes of a tax code.

Ethical responsibility for researchers requires more than consulting a checklist of responsibilities, however extensive. It requires the researcher to develop the ability and inclination to determine for him/herself how actions, practices, and products are likely to impact the well-being of all affected parties. It also requires the researcher to commit to seeking new and more effective ways of combating harm to others, fostering social justice, and promoting public benefit through her/his professional work. While the responsibilities identified below are important, they do not provide a decision-making algorithm. They are guides or rules that are useful as far as they go. But the fact that a course of action is **not** ruled out by any of the stated responsibilities doesn't imply that there is no ethical responsibility to avoid it. Further empirical inquiry, additional critical reflection, and independent ethical judgment by the individual researcher may be required to make that determination. In short, while a list of specific ethical responsibilities is useful, it is not a substitute for thoughtful ethical judgment.

Let us now turn to the heart of this guide.

---

[4] I owe this phrase to Professor Douglas Kysar.

II. ETHICS

“Ethics” involves making judgments about whether particular actions and activities are right, wrong, or permissible – and why. Each ethical judgment in this guide hinges on whether the consequences of the action or activity in question enhance, diminish, or jeopardize the well-being of affected parties.

One important ethical value is that of justice. Justice has to do with whether a person or group gets its due, i.e., what it deserves. For example, justice is served to the extent that each party gets its due share of what is being allocated among members of a group, such as lab space, research funds, work time on a high-demand research instrument, or credit for a new discovery or theory.

In short, in this guide, ethics has to do with making judgments about whether actions are right, wrong, or permissible, including about whether people and social groups are treated justly, where those judgments are based at bottom on how the actions in question influence the well-being of impacted parties.

III. FOUR FUNDAMENTAL ETHICAL RESPONSIBILITIES OF SCIENTISTS AND ENGINEERS

A fundamental ethical responsibility of medical doctors is to “do no harm” to their patients. Scientists and engineers have an analogous fundamental ethical responsibility: to do no harm to *their* “patients,” i.e., their fellow workers, clients, employers, the users and consumers of their products, and, most generally, all who are or might be affected by their work.

This ethical responsibility to not harm can be unpacked into 3 **FUNDAMENTAL ETHICAL RESPONSIBILITIES OF SCIENTISTS AND ENGINEERS (FERSE**s):

> FERSE #1: to not do anything in her/his work that s/he knows (or should know) will **cause** (or create an unreasonable risk of causing) harm to others or to public welfare;
>
> FERSE #2: to try to **prevent** harm to parties likely to be affected by her/his work, perhaps also by the work of colleagues and by their organization;
>
> FERSE #3: to **alert** parties likely to be affected by such work that they are at risk of harm, even if the alerter is not its cause or is unable to prevent it.

A fourth fundamental ethical responsibility applies to scientists and engineers employed by an organization or engaged by a client:

> FERSE #4: to do the best s/he can in her/his work to **serve the legitimate interests** of her/his employer or client.

IV. ETHICAL RESPONSIBILITIES OF NT RESEARCHERS

A. Three domains

Ethical responsibilities related to the NT field arise in three domains.

1. Micro-social

The micro-social domain is the realm of NT R&D labs and manufacturing facilities. The leading micro-social ethical issue today in NT labs is **safety**. Since jeopardizing lab safety will cause (or create an unreasonable risk of causing) harm to lab members or facilities, it follows from FERSE #1 that…

ER1: NT researchers have an ethical responsibility to not do anything that they know (or should know) will undermine or pose a risk to safety in the NT lab.

This general ethical responsibility of NT researchers applies by implication to any kind of action that would indirectly compromise lab safety, e.g., actions related to new nanomaterials and to established laboratory procedures.

a. New nanomaterials

Regarding new nanomaterials, NT researchers must keep clearly in mind a basic fact about their field: **there is no guarantee that an element known to be safe at the macro- and microscales will also be safe at the nanoscale**. Because of "quantum effects," caused by the relatively high percentage of a nanomaterial's atoms that are on its surface compared with in its volume, an element's properties at the nanoscale can be quite different than those it exhibits at larger scales. Some novel nanoscale properties may even pose a threat to safety unless appropriate precautions are taken**.** Therefore,

ER2: NT researchers have an ethical responsibility to *always* take appropriate precautions when working with elements new at the nanoscale.

Similarly, product designers have an ethical responsibility to confirm that any nanomaterial they propose to use in a product has been shown to be safe, both individually and in combination with other elements.

b. Established lab procedures

In order to save time or money, be more productive, or reach a goal before a competitor, a NT researcher may be tempted to depart from established laboratory procedures and take a **prohibited shortcut** in his/ her work. Regardless of motive, NT researchers have an ethical responsibility to avoid taking prohibited shortcuts, because departing from established, time-tested lab procedures could create a significant risk to safety. Harm could result to people, machinery, or the lab's reputation, the latter jeopardizing its fund-raising ability or license to operate. Such possible harmful outcomes should be kept in mind by NT researchers tempted to take prohibited shortcuts. In short,

ER3: NT researchers have an ethical responsibility to not take prohibited shortcuts.

Suppose a NT researcher becomes aware that a fellow lab member is taking prohibited shortcuts in her/his work. Does the researcher have an ethical responsibility in such a situation? S/he should act in a way that s/he believes will deter or stop the shortcutter from further prohibited shortcutting, e.g., attempt to persuade her/him to stop, bring up the shortcutting for group discussion in the lab, or report the shortcutter to management. Given how critical safety is in and for NT facilities, reporting the shortcutter to lab management is not only ethically permissible, it becomes the researcher's ethical responsibility if less coercive deterrent actions fail to stop the shortcutting. If a NT researcher takes no action and the shortcutting persists, that researcher is not acting in accordance with FERSE #2's injunction to prevent harm. In short,

ER4: if less coercive options do not succeed in stopping prohibited shortcutting, NT researchers have an ethical responsibility to report such behavior to laboratory managers.

c. Laboratory culture

The phenomenon of prohibited shortcutting raises the important subject of **the culture of a NT laboratory**. To understand what this means, imagine two NT labs: L1 and L2. In L1, there are widely shared expectations that researchers will always put safety first, signs are prominently posted urging people to do just that, top management repeatedly emphasizes safety, actions that jeopardize lab safety are examined by an in-house safety committee and the perpetrators seriously penalized, and researchers care personally about preserving L1's reputation for safety, to the point of intervening if colleagues appear to be jeopardizing safety.

In L2, there is a "laid-back" attitude toward safety, talk of safety is widely regarded among researchers as mere rhetoric, management gives no indication of taking safety seriously, the only signs in the lab read "Do your own thing!", unsafe actions and practices are handled *ad hoc* and typically "winked at" or penalized with a "slap on the wrist," and individual researchers do not care about how other researchers conduct themselves as long as they are left alone to work as they want to.

Clearly, L1 and L2 clearly have radically different cultures. L1 has what might be termed a "safety culture" and L2 a "*laissez-faire* culture." The key point here is that **the existing culture of a NT lab may make it easier or harder for a researcher to act irresponsibly**, e.g., by taking prohibited shortcuts. This is why the culture of a laboratory is an important factor in lab safety, even though it is an intangible one that influences researcher behavior from 'behind the scene.'

Top managers have an ethical responsibility regarding the culture in their NT lab:

ER5: top managers in a NT lab have an ethical responsibility to actively promote a culture of safety in their facility.

But practicing researchers also have ethical responsibilities regarding lab culture:

ER6: researchers in NT labs have the ethical responsibility to help train and encourage newcomer researchers to do things in ways consistent with maintaining a strong safety culture in the lab.

ER7: researchers in NT labs have the ethical responsibility to combat any manifestations of *laissez-faire* lab culture in the actions and practices of their fellow researchers.

NT research is very likely to be launched in a number of less developed countries (LDCs) in the next few decades. This will involve transfers of NT equipment and knowledge from more developed countries (MDCs) to LDCs. Such transfers will give rise to an important, closely related ethical responsibility for MDC NT researchers and research managers involved in such processes.

ER8: NT researchers and managers have an ethical responsibility to explain in detail and to stress to LDC professionals in charge of new NT facilities the importance of establishing and maintaining a strong safety culture.

In December 2008, several NNIN faculty will teach a "short course" on NT in India to a group of Indian and U.S. students. Laudably, along with exposure to state-of-the-art NT technical knowledge and equipment, attention will also be given to ethical and social issues and responsibilities related to NT, including discussion of laboratory culture and its vital relationship to NT lab safety.

d. Other kinds of ethical issues

Besides safety, other kinds of ethical issues can and do arise in NT labs. Among them are intellectual property disputes -- who is entitled to what degree of credit for a particular idea, discovery, or innovation? -- and disputes over the integrity of the data cited to justify a technical claim. Such ethical issues are addressed in the literature on "research ethics."[5] The key point here is that such disputes can properly be evaluated in terms of **ethics**, for they are usually linkable to **harm or justice**. For example, fraudulent data can result in physical or financial harm to competitors, institutions, or users of materials or devices whose design properties depend on that data. Similarly, giving too little or too much credit in a publication to co-workers and to scholars whose ideas contributed to one's research work raises ethical issues of justice and intellectual property rights.

2. Meso-social

[5] See, for example, Marcel C. LaFollette, *Stealing Into Print: Fraud, Plagiarism, and Misconduct in Scientific Publishing* (University of California Press: Berkeley, 1992).

The meso-social domain is the intermediary realm of interactions between lab researchers and people from institutions representing or affecting society at large. Two kinds of such interactions deserve attention: those involved in public funding and media coverage.

a. Hype

A noteworthy ethical issue sometimes involved in public funding is **hype**[6] -- deliberately exaggerated claims intended to serve the exaggerator's interests. In research, hype can exist at two levels. *At the level of a particular research field as a whole*, hype would occur if in testimony before a key government funding agency NT researchers touted the NT field "the next Industrial Revolution" and asserted that it will "transform life as we know it." *At the level of an individual research proposal*, hype would occur if, in order to gain funding, a NT researcher exaggerated a project's feasibility, likely results, or significance. While hype may seem essential to researchers given the highly competitive nature of the research funding game, it *is* ethically irresponsible.

Hyping is ethically irresponsible for two reasons. Good science could go unfunded if a hyped field or project is funded or overfunded, and hype -- in the form of exaggerated claims about research payoffs to the public -- could erode public willingness to continue or increase funding for science and engineering.

Hyping one's application for funding might seem ethically worse than hyping one's field of specialization in hopes of gaining increased funding for it. However, *both* sorts of exaggeration are wrong. If successful in serving the hyping party's interests, each carries **significant opportunity costs**: potentially fruitful research on other projects or in another field may go unfunded because a hyped project is funded or a hyped field is overfunded. That outcome may effectively sustain harms that would have been diminished or overcome had the unfunded research been funded and succeeded. Just because hyping one's research field only *indirectly* benefits the hyper does not make such hype ethically permissible. In short,

ER9: NT researchers have an ethical responsibility to avoid hype.

b. Distortion

A noteworthy ethical issue involved in media coverage of science and engineering is **distortion**. For the sake of market share, mass media coverage of new technologies often incorporates a "gee whiz" approach.[7] Impressive visual effects and exciting predictions are emphasized. Since carefully qualified, balanced, or complex views do not attract viewers, views of boosters and opponents are transmitted superficially and uncritically. Electronic and print

[6] Instead of "hype," lawyers often use the expression "non-actionable puffery."
[7] In U.S. media coverage of science and engineering, the distinguished, long-running PBS program, "NOVA," devoted to improving public understanding of science, technology, and engineering, is a rare counterexample.

media accounts of new technologies often give short shrift to problems, hurdles, risks, cost overruns, and time frames for accomplishment. Such coverage can contribute to raising unrealistic public expectations of major payoffs and to fueling irrational public fears about new technologies. Nor is it conducive to making good decisions about allocating public resources to and within science and engineering. Over time, such participation can dilute public trust and foster public misunderstanding of science. That such harmful effects would be the aggregate results of many individual acts of participation, each seemingly harmless by itself, does not make each such act ethically neutral.

ER10: NT researchers have an ethical responsibility to not legitimize distorted media coverage of scientific or engineering developments by participating in programs that crudely simplify or sensationalize their costs, benefits, risks, problems, and time frames.

3. Macro-social

The "macro-social domain" refers to society at large.

The dominant view in the scientific research community has long been that researchers' major ethical responsibilities concern laboratory safety, data integrity, and publication proprieties, issues that arise in the micro- and meso-social domains. But do researchers have responsibilities for the social consequences of research? The traditional view has been that the fruits of research are neutral and can be put to benign or harmful uses by those who apply them. Since, according to this view, researchers do not select the goals that their work products are used to reach, they cannot reasonably be held ethically responsible for any negative consequences that result from pursuing those goals. Physicist Leon Lederman expressed the traditional view in these words:

> "Our lame but perhaps time-honored response is that scientific knowledge is not good or evil; it is enabling. Modern science, however abstract, is never safe. It can be used to raise mankind to new heights or literally to destroy the planet. As democratic government spreads, it is the people and their representatives who must use the power provided by science. We give you a powerful engine. You steer the ship."[8]

In the traditional view, then, society at large, not the individual researcher, is ethically responsible for what is done with the knowledge s/he produces. If, however, society played a role in enabling their research, some traditionalists would acknowledge that the researcher does have one responsibility to society at large:

[8] Leon M. Lederman, "The Responsibility of the Scientist," *New York Times*, July 24, 1999, p. A15

ER11: NT researchers have an ethical responsibility to society at large to do the best work they can to generate reliable new scientific knowledge, materials, devices, and systems.

For in so doing, they contribute indirectly to societal progress that supposedly results from individual contributions to technical progress. Such a responsibility, related to FERSE #4, is owed to society at large that makes the researcher's work possible.

While society, including private firms and public decision makers, is substantially responsible for what is done with technical knowledge produced by researchers, today's researchers, in NT and other fields, also bear some responsibility. They cannot always plead ignorance of the risks posed by the powerful 'engines' they make available to society. Researchers realize -- or should realize -- that the 'ships' these 'engines' may be used to power will be piloted by dominant social groups with track records, and will be given green lights by regulators and policy makers influenced by powerful forces with vested interests in proceeding apace. Contemporary researchers develop and facilitate the diffusion of their creations in *societies of known character.* While it is not always foreseeable that particular fruits of research will be turned into ethically troubling applications, in *some* cases it will be, e.g., when there are substantial military or economic advantages to be gained even if ethically problematic effects are foreseeable as a by-product. Hence, under FERSE #2,

ER12: if a NT researcher has reason to believe that her/his work (or work in her/his field) will be applied to society so as to create a risk of significant harm to humans, he or she has an ethical responsibility to alert appropriate authorities about the potential danger.

B. Two application areas

Some ethical issues and responsibilities that will confront NT researchers arise because NT knowledge and devices are incorporated into specific products introduced into society. We shall focus here on two important NT product areas.

1. Environment

Developments in NT offer hope for restoring some kinds of polluted environments. For example, water filtration membranes based on nanometric-sized materials of oxy-aluminum hydroxide or iron oxide are being developed. "These common and inexpensive materials and the use of synthetic processes that avoid organic solvents and polymers could be an ideal solution for certain southern countries where water is often unfit for consumption."[9] Given the potential such membranes would have for overcoming water quality problems in less developed countries, these NT products could significantly advance the cause of global distributive justice.

---

[9] Staff, "Nanos on All Fronts," Section 2 of "Riding the Nano Wave," *CNRS International Magazine*, Vol. 2, Spring 2006, http://www2.cnrs.fr/en/529.htm.

Regarding pollution prevention, nanoparticles of platinum and palladium increase the reactivity of catalysts, something that when used in automobile mufflers could better transform “highly polluting molecules” like CO, NOx, and unburned hydrogen into “better” molecules like CO_2, molecular nitrogen, and water vapor. Work is underway to determine the best metal or alloy at nanoscale and the combination of nanometric parameters that yields the most efficient catalyst.[10] Such work would be a form of harm prevention, as prescribed in FERSE #2.

However, it remains to be seen how rigorously government agencies regulate the environmental effects of nanoparticles and nanomaterial-treated products. Will toxic nanoparticles be released into the environment from the use of microbe-killing nano-silver ions in clothes washers, from rain runoff across solar panel cells coated with nanofilms or nano-inks, or from waste discharged by factories manufacturing nanoproducts? One would think not. After all, most developed countries have environmental protection agencies. However, for example, to date, U.S. regulatory agencies have been extremely reluctant to enact new regulations for new nanomaterials.[11] With large mounts of money being invested in nanotechnology product development, political-economic pressure for quick environmental regulatory approval of new nano-products is likely to be intense. The potential for decision-making in regulatory agencies, charged with protecting public health and safety, to be determined by *political-economic* considerations instead of by scientific evidence is troubling from an ethical point of view.

However, **NT-related regulatory decisions regarding the environment that are made on non-scientific grounds cannot be blamed on NT per se**. Rather they should be attributed to shortcomings in the procedures and processes that governments use to decide under what circumstances new knowledge, materials, and products are released into society at large. Nevertheless, since they are subject to FERSE #2, NT researchers should be alert to the possible influence of politics and economics on regulatory decision-making regarding NT materials and the environment.

ER13: if a NT researcher is in a position to make the public aware that regulatory decision-making regarding nanomaterials and the environment has been made on non-scientific grounds, and if doing so might help prevent harm to the public, then s/he has an ethical responsibility to bring that decision-making, with its costs and risks, to public attention.

2. Medicine

[10] *Ibid*.

[11] At a meeting of the U.S. House Science Committee in September 2006, Dr. Andrew Maynard, Chief Science Advisor for the Project on Emerging Nanotechnologies, stated, “The evidence before us strongly suggests that current federal research efforts are not adequate to address concerns arising about the environmental, health and safety impacts of nanotechnology. There are clear gaps in the research portfolio in determining potential hazard, evaluating exposure, controlling releases of nanomaterials, determining potential impact and managing risk.” U.S. House Science Committee, Press Release 109-323, September 21, 2006.

a. Nanomedications

The first nanomedications are likely to be introduced in the near future. Nanocapsules are being developed that, administered through the blood stream, would deliver therapeutic, active molecules right to targeted cells with greater efficacy and diminished side effects. Fatal hepatic diseases, such as cancer, are possible early targets of nanomedications.[12] The potential benefits of nanomedications are exciting, and researchers developing them deserve ethical praise for work that may prevent, cure, or lessen serious health problems.

b. Nanodevices

A more controversial category of projected medicine-related NT advances is that of human implantable nanodevices (**HINDs**). HINDs may offer the ability to monitor and wirelessly communicate the conditions or states of internal body organs or systems, e.g., body temperature, pulse, blood sugar, blood glucose, and heart activity.[13] The medical benefits of such innovations could prove enormous. HINDs are also being developed with the goal of restoring vision and correcting hearing dysfunctions.[14]

"NBIC" stands for "nano-bio-info-cogno," and "NBIC convergence" refers to the projected convergence of streams of research in four fields: nanotechnology, biotechnology, information science, and cognitive science. One expected result is a new type of HIND, one able to transmit and receive information about brain-related conditions and processes. The head of a neurological institute recently wrote this about NBIC work being pursued in his lab:

> "We have already begun…to create new nanotools to explore critical issues in synapse assembly, myelin formation, neuron outgrowth, and brain tumor cell migration. We are developing nanodevices that we can manipulate to positions within neurons, or on nerve fiber surfaces, or within the myelinating cell, to monitor cellular events under very precisely controlled conditions. The nanodevice can be engineered to report back to our scientists in a variety of ways; for example, by light emission that may be detected by the highly sophisticated imaging microscopes…We thus will have an unprecedented window into the inner workings of neural cells."[15]

c. Ethical issues

---

[12] Staff, "Nanos on All Fronts," *loc. cit.*
[13] Fabrice Jotterand, "Nanomedicine: How It Could Reshape Clinical Practice," *Nanomedicine*, Vol. 2, No. 4, 2007, 402.
[14] *Ibid*.
[15] David Colman , "Director's Corner," *Neuro News,* Montreal Neurological Institute, Montreal Canada, April 2004.

While the potential medical benefits of advances in NT are striking, these advances also raise **ethical issues** that deserve early and ongoing ethical reflection, including by NT researchers involved in achieving them.

i. Informed consent.

New medical nanomaterials and nanodevices will be tested on humans. The push to bring such products to market quickly could collide with the ethical responsibility to insure that human subjects give their informed consent to being tested. In light of FERSE #2, as such testing draws near, NT researchers have an ethical responsibility to oppose any plans to implant experimental nanodevices in patients without their knowledge, even for the patients' benefit.

ii. Justice

Should access to a new nanomedication be designated a moral right, or be allowed to hinge on ability to pay its current market price? Should the answer to that question depend on the gravity of the medical condition being treated or on the seriousness of the side-effects avoidable with the nanomedication? If access is allowed to depend on going market price, then people of modest means may have access only to conventional medications, likely with diminished efficacy and greater side effects. There is potential here for the emergence of a "nanomedical divide," analogous to but more ethically weighty than the current "IT divide."

iii. Liberty of choice

Political-economic circumstances could pressure humans to use implantable nanodevices preventively, to provide early warnings about medical problems. Such use could significantly decrease medical insurance payouts. Will people of modest means reluctantly agree to have such devices implanted – presumably at significant cost -- because they can't afford the higher insurance premiums likely to be set for those without the devices? If not, then their medical problems will only become known at more advanced stages when symptoms manifest themselves outwardly.

iv. Privacy

What kind of medical information obtainable from HINDs is it permissible to release to whom for what purpose? For example, should information about detected forerunner conditions for incurable diseases be given to insurance companies or employers? Do individuals have the ethical right to **not** be told what HINDs disclose about incurable medical conditions? Should the patient's family be informed about HIND-enabled diagnoses against the patient's wishes?

v. Enhancement

Early NBIC technologies are likely be **therapeutic** in intent, e.g., aimed at addressing problems in brain functioning. However, they could eventually be developed for purposes of cognitive **enhancement.** Since the human mind and human autonomy are extremely sensitive ethical concerns, it is not surprising that the U.S. public and NNIN researchers are deeply split about the ethical permissibility of cognitive enhancement. As with embryonic stem cell researchers, those working on NBIC HINDs for cognitive enhancement should be sensitive to and learn to discuss thoughtfully the ethical dimension of such work rather than leaving such discussion to politicians, regulators, and clerics.

vi. A new mode of human being

The likely development of a wide range of HINDs raises a provocative possibility: the emergence of a new hybrid mode of human-being. It could become *routine for people to have a range of nanodevices permanently implanted in them early in life, perhaps at birth.* This would be done so that early warning could be given of potentially dangerous medical conditions and suitable steps could be taken long before externally visible signs would reveal them downstream. This prospect, perhaps realizable in this century, raises profound philosophical and ethical concerns that NT researchers should bear in mind. For example, could a time come when a mode of human-being that is devoid of HINDs would deserve to be regarded as abnormal, inferior, and ethically indefensible?

V. Conclusion

As today's scientists and engineers probe new areas of inquiry that promise major social benefits but are also socially controversial, society needs and is beginning to demand researchers with a hybrid competence: state-of-the-art technical knowledge coupled with a sensitive ethical compass. To paraphrase Samuel Johnson, "while [ethical] integrity without [technical] knowledge is weak and useless, [technical] knowledge without [ethical] integrity is dangerous and dreadful."[16]

NT researchers must remember that the legitimate interests of the 'background client,' i.e., society at large, are paramount. They must prevail over pressing personal and organizational interests when giving priority to the latter would jeopardize public health, safety, or welfare. As Albert Einstein said to students at Cal Tech in 1931:

> "It is not enough that you should understand about applied science in order that your work may increase man's blessings. Concern for man himself must always be our goal, concern for the great unsolved problems of the distribution of goods and the division of labor, that the creations of your mind may be a blessing, and not a curse, to mankind. Never forget this in the midst of your diagrams and equations."[17]

---

[16] From Samuel Johnson's moral fable, *Rasselas*, 1759, Chapter 41 (bracketed words added), http://andromeda.rutgers.edu/~jlynch/Texts/rasselas.html.

[17] Albert Einstein, "Address Before Student Body," California Institute of Technology, February 16, 1931, http://www.hss.caltech.edu/~kcb/Ec121/EinsteinSpeech.html.