One more Thing to Think About: The Ethics of Nanotechnology in Bio-Medical Engineering Research and Development

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Introduction

When the National Science and Technology Council, the Committee on Technology, and the Interagency Working Group on Nanoscience, Engineering and Technology put their ideas together in the brochure, *Nanotechnology: Shaping the World Atom by Atom*, they told the lay public that nanotechnology promises to fundamentally transform human life. This publication lists 'major improvements to human health and to the practice of medicine' as among the areas of change to come with the emerging capacity to manipulate atoms and otherwise work at the nanoscale. It also states that nanotechnology will lead to a new generation of prosthetic and medical implants "whose surfaces are molecularly designed to interact with the body." And, that those nanoscale devices will be able to attract and assemble raw materials in bodily fluids to regenerate bone, or other missing or damaged tissues. Other amazing possibilities offered in the report are that nanostructured vaccines could eliminate hazards of conventional vaccines that rely on viruses and bacteria, and that nanotubules in the body could conceivably take up drug molecules and release them slowly over time. Chips sized home diagnostic devices with nanoscale detection and processing components that could fundamentally alter then management of illnesses and medical care, are highlighted as another potential outcome of the development of nanotechnology.

These are exciting possibilities, which place a lot of pressure on those basic researchers who are funded to explore the domains of nanoscience and on those who are funded to then develop the devices which will be needed, if we are to make good on those and other promises; promises and hopes for improving our health and environment, and for enhancing the qualities of our lives. External sources of pressure to rapidly publish research results, and to produce new devices of unprecedented capacities, seem to only be increasing in the professions of science and engineering. So are the pressures to go beyond basic science questions and to take heed of the social and ethical dimensions of the work. Policy makers, financial investors, special interest groups, and the general public, are actively interested in the social and ethical implications of bio and nanotechnology. And to some degree, they are relying on scientists and engineers to understand and predict where this is all leading, what it means, and what kinds of results are to be expected with the appropriation of these new technological developments.

Nanoscale science and engineering, specifically implemented in the application of biotechnology, does come with a host of social-ethical questions, which beg the attention not just of philosophers of technology, but of the practitioners themselves. At stake is the long-term well-being of our entire society. And therefore, it behooves us to infuse the design of basic research, and of actual devices, with ongoing social-ethical conscientiousness. This intended focus can help assure that we direct limited resources and energies proactively and preventatively, attentive to broad social needs. To do so can also minimize those social-ethical horrors down the road, assured us by the law of unintended consequences. But isn't the commitment to consider and reflect upon social-ethical issues in bioengineering just one more thing to have to be concerned about, in an already pressured profession that places huge expectations on its practitioners? In fact, isn't it also a distraction from the intensive focus needed for good basic science? And shouldn't larger social and ethical questions be left up the society and our governing bodies to be sorted out? Yes, these are valid assertions. But given the potential outcomes of radical change to our bodies and the way we treat them, to our family lives, our economic systems, to our social structure and even our basic belief systems, what choice do we have?

"Hold on there!" you say? "What is all this stuff about fundamental and social radical change?" "What has all that got to do with the work of my group and my laboratory?" The answer is 'nothing, and everything.' Alone, individual researchers can make a huge difference in the broader knowledge base, or only a minor contribution. But collectively, individual knowledge and technologies will eventually find their way into broad applications. This is inevitable, in part, because of the magnetism of economics. The drive to cure cancer is stimulated not only by the drive to lessen human suffering, but also by ego, money, and political pressure. It is precisely because there are so many other factors in the bio- and nanotechnology initiatives than the simple intention of serving the greatest good for humanity; we must become cognizant of the social and ethical implications of our practices. If we were to actually find a biological mechanism which allowed us to use technology to cure cancer, we may also step into critical questions of who has access to those treatments, who will pay for those treatments, what rights do we have to die, and what will the power to cure disease do to our faith and belief in a Creator? If we develop new tissues so that we can replace organs, and bones, and joints and if we actually do cure cancer, and AIDS, and heart disease, and neurological disorders, and birth defects, and so on, there is no question that we will have to change our notions of mortality, and of the fundamental purposes of our lives. Maybe there is a way to think about those things questions while we are moving full steam ahead on our science.

<u>Nano scaled Science and Engineering</u>

Nanoscience is a form of research which is distinguished from other sciences not by its intent, but rather, by its scale. Biochemists, physical and molecular chemists, and physicists will explain that it is not a new science, as they and others have been working at nanometer scales for over two decades. What is novel and exciting are the interconnections forming between otherwise unrelated fields of science. And, the tools it uses to see, study, manipulate and control phenomenon at the nanoscale. The NIH working definition of bioengineering reads,

> Bioengineering integrates physical, chemical, mathematical, and computational sciences and engineering principles to study biology, medicine, behavior, and health. It advances fundamental concepts; creates knowledge from the molecular to the organ systems levels; and develops innovative biologics, materials, processes, implants, devices, and informatics approaches for the prevention, diagnosis, and treatment of disease, for patient rehabilitation, and for improving health.

As nano and bioengineering join forces, the possibilities of new discoveries, capabilities and applications become astounding. Already we have such developments as the design of smart micro particles and nanoparticles for advanced medicine, high-density biomedical nanosensors, silicon nano-particles used as fluorescent tags and photo-sensitizers. According to Tejdal Desai of the Biomedical Engineering Society,

> "Nanotechnology is changing the way we view the biological world. With recent developments in the synthesis, characterization, and application of nanostructures, we have significantly advanced our understanding of biology and medicine. Nanoscale features can mimic the biological world, giving us unprecedented control and manipulation over our environment. From biomimetic materials and biomolecular surface modification to single molecule imaging and drug delivery systems, nanotechnology will pave the way towards a new biotechnological frontier."

<u>The Domain of Public Discourse</u>

Public discourse and scholarship have just begun to address questions of "what ought to be done?" with regard to our ability to work at the nanoscale. Nanoscience is still a laboratory pursuit, with no apparent ethical guidelines. There are very exciting understandings and findings emerging on a regular basis. However, there remains a vast amount of understanding yet to be acquired. The moral questions of right and wrong, good and harm, justice and duty are highly speculative. Most researchers aspire for the results of their work to improve the quality of human life. But projections about how the development of nanotechnology may evolve are varied, and various individuals carry differing notions and ideals about how nanotechnology might and should be used.

Whenever a new technology is perceived to have a potentially significant impact on society, whether for benefit or for harm, public debate emerges over the meaning and significance of that new technology. For example, new science and technology developments such as in-vitro fertilization, recombinant DNA/genetic engineering, mapping of the human genome, and human cloning have all been subject to intense and critical public discussion. Such public debates over the social impact of technology are made most apparent in the media. This is where the disparate and competing interests are made most explicit. As new technologies emerge, so do the disparate and varied voices of talk show hosts, television personalities and news anchors, science-fiction authors, science journalists, politicians, commentators, scientists and others, all competing, through discourse, to establish the meanings and direction of those technologies. In turn, the public responds with conflicting expressions of enthusiasm, fear, expectation, and mistrust, in the effort to control and direct the uses of those seemingly powerful, or threatening technologies. Questions and responses are levied about the effects of particular technologies on the human condition, and the ability of those technologies to address social, environmental, bodily and other ills. Perceptions of technology's role in improving the human condition are pitted against expressions of concern about whether the forces of technology may represent potential harm to the individual and to the society. Debate also addresses questions of who will have access or be denied access to these technologies. Public discourse in general, provides society with a forum from which to form policy. It also gives private individuals access to the making of meaning and belief about important issues of technology ethics and utility. This is good. As technology moves faster and more intensely into our individual and collective lives, excitement and ambivalence run up against outcries of technological doom, and public debate in an open society, provides a critical forum for exchange and understanding which may other wise not be possible. What is not good is when beliefs, meanings, and policies are formed from relative ignorance, hearsay, mistrust, or fear.

Whenever a strong and controversial public statement is made by a scientist about a newly emerging technology of potentially significant impact, that statement, in turn causes a sharp response in the public debate. And this too, is good. For example, when Bill Joy wrote "Why the Future Doesn't Need Us," it stimulated the public debate into an emotive, provocative and far reaching discourse on nanotechnology, genetic engineering and robotics. Unfortunately, the voices of other laboratory scientists and engineers, speaking from their roles as such, or even as private individuals, are relatively mute in most public dialogues about nanotechnology. And yet those same voices represent the knowledge and wisdom of those who are most instrumental in the conceptualization and birth of nanotechnology. Without them, the public debate is becomes mired down in battles over conflicting ideologies and opinions.

This can be understood in light of the emergence of information technology, which in its developmental phase, moved rapidly through the process of public discourse to be appropriated as a pervasive, widely accepted, dominant presence in the material and social fabric of our lives. Despite its legal and ethical complexities, and the radical changes it has brought to our ways of working and communicating, information technology has come to be seen not just as a social good, but also as a material necessity. It remains to be seen how society will respond to the rapid emergence of nanotechnology. There is not yet a well-informed, public agreement on the meaning and significance of nanotechnology. And it may never come. Perhaps, after nanoscience has been appropriated as new technologies, and gradually come into use, then in very subtle ways gradual acceptance may unfold, just like with information technology. And like the emergence of information technology, it may be consumed so voraciously, and so ubiquitously, that its dramatic social-cultural and ethical impacts will barely be noticed. But if bio and nanotechnology emerge as even a remote threat to human and environmental health, then the debate over its meaning and significance will rage. A wise and well-informed public discourse, which has the power to guide and direct the development of nanoscience, depends on the active participation of scientists and engineers. In fact, the research scientists and engineers who stand at the forefront of nanoscience are the only source of reliable information, and wisdom, on which to base a healthy, well informed public discourse.

At one extreme in any discourse about new technology, there are those voices that hold an almost mythical place for that technology, as the solution to the social and material problems that face us. New technological developments promise to bring solutions to problems otherwise unattainable. These extreme, utopian voices tout the claim: the more technology, the better. And they argue that there should be no harnesses placed on the pursuit of new mechanisms, understandings, devices, or systems which offer the potential to address our material desires, needs and challenges. These voices suggest that technological ingenuity is the answer to such problems and challenges as environmental devastation, hunger, disease, and want of material goods, which bring increased comfort to daily living. Yes, they admit, technology has sometimes failed us, but only because we had not quite gotten it right. With enough resources of time, intelligence and financing, we will eventually get it right, and make good on the promises of technology.

On the far other end of the debate, voices tout the claim that technological growth ultimately generates more socio/cultural, and material problems than it eliminates. It interferes with the development and maintenance of community; it reduces human awareness of, and sensitivity to the natural world. And, technology alienates the individual from one's own body, senses, and awareness of self. These voices also raise concerns about uncontrollable and toxic biological/synthetic new substances, the proliferation of war, poverty, ecological demise, and social isolation, as a result of new technological developments. The two opposing perspectives on newly emerging technologies mark the outer edges of the debate that emerges, and can become particularly contentious, inside the development of any new technology. Nanotechnology will be no exception. However, if that debate can take heed of the perspectives of scientists and engineers, then those two extremes are more likely to approach the center, and the embattled search for meaning and understanding may resolve itself on common ground.

Public debate about the development of nanotechnology is just beginning. Like the recent debates over human cloning, recombinant DNA and genetic engineering, and earlier debates over the space program, and the uses of nuclear power, disparate voices are emerging with critical questions about the goods and harms which may emerge as the result of our ability to manipulate and control matter at the nanoscale. Science fictional accounts, such as Michael Creighton's book Prey portrays nanotechnology as an ominous, life threatening scientific endeavor. The novel puts into words very particular kinds of perceptions, meanings, understandings and beliefs about nanoscience and nanotechnology. Because the public discourse absorbs this type of material, as well as the ideas and beliefs of other interested parties, listening to the voices of actual laboratory scientists and engineers who are working with nanotechnology, is critical. Without those voices, discourse on nanotechnology is subject to relative ignorance and unfounded fear, as much as to unbridled enthusiasm and blind trust. Scientists and engineers working at the frontier of this research (pioneers on our journey through this amazing and novel forest) can serve as voices of comfort, understanding, expertise, and reason, as those voices in turn, respond to humanity's needs. It is to them that we must look for leadership towards the responsible and ethical pursuit of nanotechnology.

<u>Questions of Ethics in Newly Emerging Technologies</u>

All scientific research and engineering, including nanoscience and biotechnology, is governed by recognized and well-established ethics. It is built on a foundation of trust, to assure that results are valid, and that the observable world is being described without bias. Great care is given to the use of human subjects, to inform those subjects, and to minimize any known harms that could come to them as a result of the research. Likewise, authenticity of authorship, honest documentation, respect for intellectual property, accurate reporting of findings, proper detailing of protocol and allocation of credit are standards of ethics in the professions of scientific research and development.

Engineers who work as researchers, taking the results of science into the development of new devices, machines and techniques for human use, are also guided by detailed, well-developed professional codes. These codes govern issues such as integrity and safety of design, with the intention of anticipating and then minimizing potential harms to humans and their environment. As a group, engineers are entrusted by the public to design, build and assemble products and materials, which will serve and benefit the best interests of the common good, while rigorously testing against known harms, and communicating all known risks.

Other than those formulated by the Foresight Institute, there are no established ethics particular to the rapidly developing fields of bio and nanotechnology, the way that there are recognized principles that govern the practice of civil engineering, for example, Given the many potential breakthroughs represented by these emerging fields, the challenge is to formulate and agree upon an ethics that can guide the development and articulate the intentions of those technologies now, while they are still developing.

What would it mean to have an ethical pursuit of nanotechnology? It would begin with genuinely seeking answers to questions such as these: Do we know enough of the basic science to proceed towards a safe and responsible development of nanoscale devices and applications? Does nanotechnology represent a progressive technological force? Will it lead to decreases in human suffering and will it address yet unmet humans needs? Might it be capable of supporting our spiritual and mental well being? Could it unintentionally contribute to the degradation of our societies, the environment and the sense of cultural meaning and human connections? It is no longer a matter of dispute whether technology has a profound influence in shaping the social, cultural and material elements of the modern world. This is an accepted and recognized premise outside and inside of the science and engineering communities. One very important question yet to be answered is how nanotechnology may impact tomorrow's world. And conversely, how the social, political, economic and institutional environments in which a nanotechnology is forming, and from which it emerges, in turn may have an influence on the technologies themselves. In other words, nanotechnology will shape and mold society to its possibilities, from within the culture and institution of science and engineering. That culture and institution is largely made up of individual researchers. In order to fully and wisely understand, and direct the nanotechnology towards social-ethical responsibility, its potential impact upon the human community must be considered. Such consideration must hold paramount the beliefs and understandings of those experts whose work it is to study, innovate, and develop the workings and products of nanotechnology.

The Leadership Role of Engineers and Scientists

Scientists (and with them, research engineers) are categorized in the cultural domain as a voice of authority. Our public discourse reflects that positioning in the language we use to talk about the work of scientists. "They say," "There's a study that proves," "According to science," "Science says," are preambles to claims of proof, objectivity, knowledge, and expertise. We base our beliefs and even our personal decisions on the faith that "science" knows. "They" (scientists) are talked about as if they function as one entity, privy to knowledge and abilities no else has. This authoritarian ethos gives initial credibility and power to those invested in the development of novel-appearing endeavors such as nanoscience. It gives them a public trust that their work is worthy and good.

The institution of science arose from its early, European roots in the Royal Society, which determined that science would most successfully accomplish its goals of discovery, if insulated from larger social concerns. The social contract held that science would be insulated from social concerns in exchange for the promise that its fruits would address social needs and bring benefit to the society at large. For many years, it functioned relatively free of public scrutiny and criticism, and was held in the highest cultural esteem, based on the implicit trust born of that initial promise. But the protective shroud of expertise has been increasingly difficult to maintain, and science is being asked to justify its practices. Given recent science and engineering history, the public hesitates to assume that its social interests are foundational in technological development. The development of nuclear technology was one outcome of science that brought all of that into question. Today, "science" is being called on to participate in the public discourse, and to be accountable, predictable, and responsible in its endeavors.

Of course there are scientists who are actively engaged in that process of reflection. For example, Richard Mathies of Berkeley University knows very well that his research has huge social implications. And he is talking and thinking about them. Regarding his work in applying high sensitivity confocal fluorescence scanning to DNA sequencing and diagnostics Mathies says,

> There are social as well as technical issues to be overcome. On the technical side, the big challenge is the integration of the plethora of micro fluidic technologies that have been developed into robust analysis systems. Although this challenge is significant, I think that great progress will be made on the integration issues in the next five years. On the more challenging social side we must address the ethical, legal and social issues that will arise from the wide application of micro fluidic technologies. Microtechnologies such as point-of-care genetic analysis and portable forensic analyzers raise issues about privacy, insurance discrimination and so on. Also, the Human Genome Project is often erroneously associated in

> the press with human cloning technology, thereby raising concerns among the public. The difficult legal and legislative issues need to be resolved and the public needs to be educated about what these new measurements and technologies mean what they don't mean. Education will also be important in the medical community; doctors need to understand and trust the new technology before they can advise and inform their patients about it. Educational issues could take up to 10 years or more to resolve so this is a big obstacle in getting our micro fluidic analysis devices into every day use."[1]

Research scientists and engineers have a direct influence on the material realities of our social/cultural existence. From the very formulation of a hypothesis, to the interpretation of their data, scientists apply their ideas and understandings to craft the blueprints for what is materially possible. Engineers then put their imaginations to the task of translating those creative possibilities into working systems and devices, on which society relies and depends. It is simple denial, to see such pivotal and fundamental roles as in a way distinctive from the social-cultural milieu in which they function. The concept of determinism and illusion of neutrality, are apparent in some of these narratives. They appear as a claim of innocence and social insignificance, in asserting that what an individual scientist does, someone else will do inevitably, because science is about the discovery of what already exists. But what if science is also about the social creation of knowledge? Then, this expressed naivety about the very direct impacts of their work on society serves to function as a myth. Perhaps science does not simply function was an isolated enclave of masterful minds, busy at work in discovering what there is to be known about the physical universe. Maybe, science is also a cultural mirror. It appears to materialize a truth that is otherwise hidden from view. It reflects what we perceive ourselves to be. It challenges our previously held perceptions of physical realities. And ultimately, while it can reveal what's true and real, it can still be no more or less than our very self. Hughes (1983) challenged the view that technology is self-determinant and pre-given as it unfolds over time to respond to society's needs. Rather, he said, a technology has many possible futures, reflecting different social interests that ground its development. The myth of neutrality, of science as an entity independent from society, may serve a very important purpose of self-protection against the unwarranted scrutiny and interference of outside interest groups. Unfortunately, one result of perpetuating that myth may be a conceptual roadblock to the formulation of sound ethical principles for the development of bio and nanotechnology. What does it mean to put trust in society? Does it mean that what we do in research and what we develop in laboratories doesn't matter, because society will take care of its applications? Is it possible that this so-called society actually has a direct relationship with so-called, science? And that distinguishing the two is a fundamental false dichotomy?

So where do we begin? Let me suggest we begin with the initial use of three "moral markers;" indicators and signs used to guide and to support the enterprise of bio and nanoscience as it forms, develops, and evolves into specific devices and applications. Moral markers such as these can help scientists, as well as the general public, to keep its

[1] Profile-Richard A. Mathies, Trends in Biotechnology, pg. 44--45

bearings clear, while holding onto compasses that can be used to determine ethical orientation along the way.

1. *Acknowledging feelings of discomfort, fear or anxiety can lead us to the awareness of, and respect for, being in entirely unfamiliar terrain. These valid but often ignored feelings can warn us to look closely and see what is giving rise to the agitation. Sometimes, it means that old belief systems are being challenged, and must be abandoned. Other times, it means that important belief systems are being challenged, and need to be reinforced. Which is correct is sometimes a matter of social agreement and culturally established norms. At other times, it is a matter of principle, such as the principle of avoiding direct and intentional harm to human life. Surprising physical or emotional responses to particular facets of research or development could mean that not enough is understood to navigate carefully. Likewise, unexpected physical and emotional improvements to human well-being may be seen as a sign of encouragement, and to the inability to hypothesize about or reasonably predict what lies just ahead, thereby justifying reconsideration of the basic premises and assumptions made.*

2. *Recognizing intolerance of established norms and beliefs also marks a potential moral problem. The unwillingness of financial investors, research scientists, laypersons, policy makers or the press to respect and value the purpose and function of well-established social norms and beliefs, can be a sign of aggression and towards the untempered promotion of rapid technological change. It takes time for a society to appropriate its new technologies in meaningful and acceptable ways. The evolutionary synchronicity of technological development and new knowledge with expressions of human meaning, needs and capacities always follows behind and adapts to new technological opportunities. But this process must happen at such a pace and in such a way, which assures that those new technologies are incorporated in life-enhancing, morally acceptable ways. Established social/moral norms and beliefs must be honored, as they serve to keep this process in check.*

3. *Upholding liberty and autonomy in research, fair and equitable distribution of knowledge, and justice in the availability of technology assures the development of nanoscience into usable new products for the common good. When this is not the end goal of technological development, it marks a significant moral challenge to be overcome. The usual balance in the use of intellectual property – limiting early disclosure in order to obtain rights and then making invention available (perhaps for a fee) – will continue to apply in the bio-tech/ nanoworld. The possibility of profit from such IP is one factor driving invention and discovery. And yet, when the profit motive guides scientific research and development, it is especially important, in terms of ethics, to ultimately include consideration of all stakeholders, not just of stockholders.*

What would it mean if through the means of bio and nanotechnology, humans no longer have to succumb to bodily aging and malfunctions that result from disease and deterioration of living tissue? Or, if our minds were less limited by the materiality of the body? Aren't these among the goals of current research? Such breakthroughs of science could, perhaps, point towards the ultimate of freedom and human expression. And, they could also mean the radical destruction of human meaning and purpose. Either way, reconstruction of a fundamental sense of self would emerge as a result. And along the way, issues of human and environmental safety, justice and privacy will be challenged. As will be questions of the allocation of resources, military applications, and threats of uncontrollable, new biological and material forms. As we project ourselves out through the chronicles of scientific ingenuity, excited and encouraged about the vast new possibilities at our finger tips, engage reflection about ethics, and carry along moral markers to remind us of who we are, and who we wish to become, as a result of the fine work we do.

Sources

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