Nanoethics (2008) 2:265–275
DOI 10.1007/s11569-008-0047-6

ORIGINAL PAPER

Nanotechnology: Considering the Complex Ethical, Legal, and Societal Issues with the Parameters of Human Performance

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Received: 29 October 2008 / Accepted: 29 October 2008 / Published online: 3 December 2008

Keywords Nanoethics · Enhancement · ELSI · Ethical · Legal · Social implications of nanotechnology

Introduction

Examining nanotechnology as a platform technology, as a technology that readily merges and converges with other technologies, allows us to contemplate the applications and implications of using these tiny devices to enhance or extend human capabilities. The contemplation of the intended and unintended consequences of human enhancement begs for striking a balance between opposing forces; and these forces are not static but dynamic and ever changing. The law is not static: it is constantly subject to change, extension and interpretation, and evolution, whether by legislation or judicial decisions. So, it is with this point of view in mind, that thus we examine both the positive and the negative aspects of the ethical, legal, and societal implications of using nanotechnology for human enhancement. First, we consider why nanotechnology is different from previous technologies, and then we explain why a subdivision of nanoethics within the broader discipline of bioethics is prudent. In sections three, four, and five, we consider the possible benefits, potential risks, and distinctions between therapy and enhancement. Finally in sections six and seven, we examine the status of current laws and make recommendatons for how to go about updating them.

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How Small is Nano-sized and Why Does Size Matter?

The term ‘nano’ has become part of everyday language, although it is often somewhat misused. From the IPod Nano (an illustration that the marketing industry is not above exploiting the term ‘nano’ for commercial gain) to the phrase ‘I’ll be there in a nano,’ the term has become a popular expression of tininess. And while the term ‘nanotechnology’ may encompass many different types of materials and applications, it does *not* refer to any specific materials or applications. ‘Nano’(whether used in science or technology) refers only to the *scale* of the object [1].

But just how small is something that is truly nano-sized? A “nanometer” (nm) equals one billionth of a meter. To give a more meaningful perspective on just how small something truly nano-sized is here is an illustration: A human hair measures between 50,000 and 100,000 nanometers wide. A red blood cell measures between 5,000–8,000 nm in diameter; a DNA molecule is about 2.5-nm wide. Ten atoms of hydrogen, side-by-side, equal one nanometer [1].

> According to the National Nanotechnology Initiative, nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nm, where *unique phenomena enable novel applications*. Encompassing nanoscale science, engineering and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale. *At the nanoscale, the physical, chemical, and biological properties of materials differ in fundamental and valuable ways from the properties of individual atoms and molecules or bulk matter.* Nanotechnology R&D is directed toward understanding and creating improved materials, devices, and systems that could use these new properties [21, 4].

At this level, at which things cannot be seen with the naked human eye, the emergent properties of the nanoparticles behave in an unexpected way; they are, at times, too small to obey the laws of classical physics**,** yet at other times, too large to apply the principles of quantum mechanics. The converse of this is that, at times, nanoparticles act in accordance with the laws of classical physics and that, at times, nanoparticles exhibit principles of quantum mechanics.

Why does this matter? Because in the world of quantum mechanics, the idea that we can locate objects precisely breaks down; that is, it is not possible to know both the position and the velocity of a particle precisely at the same time. In other words, in quantum mechanics, the position and momentum of particles do not have precise values, but have a probability distribution. There are no states in which a particle has both a definite position and a definite momentum [33]. This condition, labeled the Heisenberg Uncertainty Principle, reflects that we can only describe a *probability* to find a particle at X, as opposed to a *certainty.* The quantum mechanical (wavelike) properties of electrons inside matter are influenced by variations on the nanoscale. By nanoscale design of materials, it is possible to vary their micro-and macroscopic properties, such as charge capacity, magnetization and melting temperature, without changing their chemical composition [16]. It is this malleability of nanoparticles that allows to them to be a perfect platform for the convergence of other technologies, such as biotechnology, information technology, and cognitive technology [25].

Why Nanoethics?

While discussions of ethics of technology (likely starting with the discovery of fire) have been around for millennia, nanotechnology is a relatively young field of endeavor, getting its conceptual start with a speech in December 1959 by Richard Feynman [1]. In a speech called “There’s Plenty of Room at the Bottom: An Invitation to Enter a New Field of Physics,” Feynman discussed “the problem of manipulating and controlling things on a small scale” and offered two prizes: one to “the first guy who can take the information on the page of a book and put it on an area 1/25,000 smaller in linear scale in such manner that it can be read by an electron microscope” and the other “to the first guy who makes an operating electric motor—a rotating electric motor which can be controlled from the outside and, not counting the lead-in wires, is only 1/64 inch cube” [7]. Hence, the first funded research program in nanotechnology was established.

Philosopher Sheri Alpert [1] examines possible reasons why there has been a trend towards subdivisions in ethical inquiries, specifically referring to the development of ‘neuroethics’ and ‘nanoethics’:

1) Arguably it is more effective to address ethical issues in the specific contexts within which they occur. For instance, there are many types of ethical issues that arise within nanotechnology that will not arise within the neurosciences, e.g., issues of environmental impact, issues inherent to the nature of nanoscience, endeavors to create

new types of materials and devices by manipulating individual atoms and molecules, and the potential positive and negative economic impact nanotechnologies are predicted to have. Similarly, there are issues within the neurosciences that will not be relevant for nanotechnology—for instance, the ways in which fMRI images are interpreted and used (practically and methodologically).

2) It can also be argued that what is driving the separation of nano- and neuroethics is the fact that funding agencies (e.g., US federal agencies) are providing significant dollars for the contemplation of these issues within the context of a specific science or technology, such as nanotechnology or genetics. Pursuing sub-divided ethics, then, is a matter of it being pragmatic to do so. After all, it makes sense in the academic environment, which generally rewards grant acquisitions, for researchers who examine ethical issues to apply their skills to the questions that agencies are generously funding [27].

There is a third facet of nanotechnology that can viewed as either a good reason to create a subdivision of nanoethics, or a good reason to overlap the other areas of sciences that Alpert lays out in her Boolean diagram illustrating the relationship between nanotechnology and the other sciences, that is, that part of nanotechnology lives within the uncharted realm of the quantum physics universe, where the rules are unclear and based on probabilities. As mentioned in the previous sections, two aspects of quantum mechanics change how we consider nanoparticles differently than other macro-sized technologies: first, the superposition principle, which holds that a particle can simultaneously be in two places; and second, the Heisenberg Uncertainty Principle [27].

Both of these aspects of quantum mechanics have broad physical and profound philosophical implications; they reject the idea that physical phenomena are uniquely tied to deterministic causal laws, and that observable phenomena are independent of the observer [5]. They also imply that the very act of observation influences outcome [28]. This is an area that has yet to be explored thoroughly by scholarly bioethicists.

Engineers Kirsty Mills and Charles Fledderman argue that an interdisciplinary proactive approach would yield the best results:

> "What's so different about the ethics of nanotechnology? In one sense, nothing. We have the same obligation as ever to act responsibly and professionally, and many of the issues associated with nanotechnology need to be addressed for any technology. Previous technologies addressed these issues as they arose, with less than satisfactory results; asbestosis, toxic waste sites, non-biodegradable pollutants and the like are a poor legacy to leave. Also, the rapidly increasing rate of change of technological innovation—exemplified by the development of nanotechnology—means that we have even less time to "wait and see"; by the time a problem is detected, it may be too late to react effectively. The inherently multidisciplinary nature of nanotechnology complicates matters, as well. No single oversight body exists to set standards, and there is a risk of overlooking issues that aren't "in your field." *Only an integral approach to these issues will engender the required flexibility of approach*" [19; emphasis added].

To paraphrase Alpert, given these findings, it is seems more than an appropriate time to examine the types of ethical issues that may arise in nanotechnology and to see what the potential consequences of separation might be.

The Promise

The approaches taken to new technologies, including nanotechnology can be categorized into one of three outlooks: optimistic ("technology is good"), realistic ("technology is neutral, it depends on what it is used for") and skeptical ("be wary, approach technology with caution").

A review of the literature reveals the following eight nodes of societal discussion on nanotechnology:

1) technoscientists, especially those either working on or supervising some nanotechnological application who, almost invariably, tend to glorify nanotechnology;
2) leaders of business and industry who want to cash in on the projected benefits by developing a market for nanotechnology-driven products;
3) official or quasi-official bodies (e.g., special legislative commissions, think-tanks, etc.) that generate a significant amount of literature;
4) social science and humanities researchers who tend to focus on the social, economic, political,

legal, religious, philosophical, and ethical implications of nanotechnology;
5) fiction writers with imaginative scenarios, both utopian and dystopian;
6) political activists, particularly those with an environmental worldview, who tend to extend to nanotechnology the issues long raised by them with regard to biotechnology;
7) journalists and popular science writers who report on current events, perspectives, and funding regimes relating to the field; and
8) John Q. and Jane D. Public, who have yet to significantly grapple with or discuss nanotechnology in any depth [20].

Nanotechnology has been heralded as the next great hope for providing to solutions the problems such as:

- Clean, affordable, secure energy (e.g., nanosolar);
- Stronger, lighter, more durable materials (e.g., nanoceramics);
- Low-cost filters to provide clean drinking water (e.g., polymeric nanofiltration);
- Sensors/devices to detect/clean up harmful biological agents or hazardous chemicals in the environment;

and much more, but the most exciting promise of nanotechnology lies in the field of nanomedicine. It has been said that nanotechnology will help make medicine more "predictive, preemptive, personalized, and participatory (regenerative)" (Nanofrontiers Report 2006). And since so many medical items that started out as therapeutic and then moved into non-therapeutic use or enhancement (examples are given later under the section "Therapy vs. Enhancement"), an examination of the latest developments and potential uses of nanomedicine seems to be a good place to start. However, the categories of predictive, preemptive, personalized, and participatory are overlapping and not intended to delineate strict classes.

Predictive

From a "lab-on-a-chip"' that would perform a comprehensive analysis on a drop of blood, to molecular imaging systems to rapid DNA sequencing, this technology would help not only predict diseases, but serve as a preventive "early warning" system. For example, microarray-based diagnostics make it possible for the first time to correctly classify cancer types by identifying the mutations that cause them. If the type of cancer is known, predictions can be made about which anti-cancer drugs will be effective and thus spare patients from ineffective treatment [8].

At a more theoretical level, new frontiers opened by the integration of artificial life and nanobiotechnologies could lead to the development of "wetware." The following quotation illustrates potential applications for this new frontier:

> "…one of the materials at the nanobiomachine level used for building molecular computers is the cell, considering that the cell is one of the most sustainable autopoietic systems at the molecular level… provid[ing] us a strong tool for pioneering a new generation of computers… This implies the strong possibility of building an autonomous biomolecular computer using entire cells with conditional functions controlled by properly designed feedback guidance of kinases and phosphatases in the cells. We envision using this kind of system for proteomic analysis, i.e., for analyzing the information of the signaling pathways in cells by biomolecular computers in the form of nanobiomachines…Through evolution *in vitro* of a kind of evolutionary wetware, the transition from molecular computation to artificial life can be explained explicitly…This may lead to the emergence of new nanobiotechnologies for potential applications" [15].

Preemptive

Primarily in the diagnostic arena, the development of a new class of nanotechnology agents for tumor targeting and imaging has been very promising. For example, super paramagnetic iron oxide nanoparticles (SPIONs) have helped to achieve higher resolution and sensitivity for the clinical detection of cancer cells with Magnetic Resonance Imaging (MRI) [13]. This approach is superior to previous methods in detection because the SPIONS do not have any difficulty in crossing the blood-brain barrier. Also, the development of gold nanoparticles probes may hold key to earlier cancer detection; the gold nanoparticles are superior the previous quantum dots, which contained cadmium, a toxic heavy metal.

Other possible examples including monitoring nanobots that would act preemptively, for example, releasing clot-busting drugs at the onset of a heart attack or stroke, or steroids in the event of an allergy attack, providing instantaneous first aid.

Personalized

In a recent interview, Craig Venter [29] said, “Bio is the ultimate Nano,” meaning that nature had been creating nanoparticles long before humans had. With our understanding of the micro-world of viruses and *Mycoplasmagenitalium* (currently the smallest known organism capable of independent growth and reproduction, which Craig Venter’s scientific team hopes to recreate from scratch by the end of 2008) and DNA and RNA increasing, and with our attempts to build life molecule by molecule, we are fundamentally manipulating the building blocks of life. The hope is that nanotechnology may help overcome current limitations of gene therapy. By safely delivering therapeutic genes and other nucleic acid-based regulatory agents into malignant cells, personalized therapy becomes a reality [29].

Nanotechnology could also boost personalized medicine by real-time sensitive monitoring of drug therapies. For instance, a doctor could prescribe a combination of drugs in calculated proportions and nano-based monitoring devices could give the doctor the ability to adjust the proportions as needed. Which leads us to the fourth category, participatory or regenerative medicine, which is where most of the potential for non-therapeutic or enhancement purposes lies.

Participatory (or Regenerative)

There several ways that nanotechnology is radically advancing regenerative medicine: in tissue/organ engineering, the creation of replacement tissue, organs, or blood vessels, by infusing nanomaterial scaffolding with stem cells. Nanotechnologies provide the possibility to produce surfaces, structures and materials with nanoscale features that can mimic the natural environment of cells, to promote certain functions, such as cell adhesion, cell mobility and cell differentiation. Nanomaterials used in biomedical applications include nanoparticles for molecules delivery (drugs, growth factors, DNA), nanofibres for tissue scaffolds, surface modifications of implantable materials or nano devices, such as biosensors. The combination of these elements within tissue engineering (TE) is an excellent example of the great potential of nanotechnology applied to regenerative medicine. The ideal goal of regenerative medicine is the *in vivo* regeneration or, alternatively, the *in vitro* generation of a complex functional organ consisting of a scaffold made out of synthetic or natural materials that has been loaded with living cells [6].

Another example of regenerative nanomedicine would include restoring lost function of limbs, senses, and brain function by nano-enhanced devices that connect directly with the nervous system [23]. The treatment of mental illness and criminal behavior would be possible through neuronanotechology [30].

Once neural signals can be transmitted via nanowires, there is no reason that those signals could not go wireless. Imagine, neural signals controlling programs on the internet, remote sensing, space travel—the neuronally-connected interfaces might be able to receive signals for all five senses, smell, touch, taste, hearing, and even sight—from distant locations via a bi-directional link. We would quickly have the advantage of machine intelligence enhancing the human brain. We could enhance the senses, so that we might be able see multi-dimensionally, as a computer might, with infrared, ultrasonic, ultraviolet, etc. We currently have machine-brain interfaces such as cochlear implants and brain pacemakers for movement disorders, for Parkinson’s, for primary dystonia, for depression and even for Tourette’s syndrome. Bench research and animal trials are currently being conducted for nanochip replacement of the hippocampus and retinal prostheses [24].

One of the amazing lessons we are learning from the brain-machine interfaces, is the plasticity of the mind and sensory substitution. For example, recent experiments done with subjects using their tongues to ‘see’, remind us that it is the mind that does the seeing, not the eye itself—the mind interpreted the data as visual, which suggests that it does not matter which sense you use to gather data, it’s how the mind interprets it that counts [26, 2].

In similarly amazing discovery, we are at the brink of creating direct brain to brain communication, achieving technologically-assisted telepathy or “techlepathy” [24]. Cybernetics pioneer Kevin Warwick believes in the future of techlepathy; he’s actively trying to communicate in such a manner with his wife by creating an implant that connects his nervous system with hers, through microneurography [24]. The ability to communicate so directly could be a tremendous boon to humankind. Such a development would greatly enhance collaborative efforts for humans, whether it be for search and rescue teams, the development of life-saving treatments, or even artistic expressions.

Of course, the hope is that such advances would be used to share problem-solving and to benefit humankind, the world and all of its inhabitants. The danger lies in whether or not we share the same ideas about what would benefit whom.

The Perils

Like so many technological advances, that which has potential tremendous benefits also often brings with it the potential for tremendous risk. Instead of being used to enhance humans, the technology could be used for disenhancement. Two groups, The Nanoethics Group[1] and the Center for Responsible Nanotechnology,[2] both nonpartisan think tanks dedicated to explore issues in nanotechnology, have listed potential risks:

- Neuronano Warfare—The use of the technology to alter or disrupt perceptions and advance a destructive agenda.
- Weapons and surveillance devices could be made small, cheap, powerful, and very numerous, causing competing nations to enter a disruptive and unstable arms race.
- Cheap manufacturing and duplication of designs could lead to economic upheaval.
- Overuse of inexpensive products could cause widespread environmental damage.
- Privacy—as surveillance devices shrink in size, become more mobile and even implantable in our bodies, without our knowledge, what are the privacy issues at stake? A new method of identity authentication is burgeoning; ID cards and passwords are being replaced with Nanobiometrics.

In his article entitled "Why the Future Doesn't Need Us," Bill Joy [12], author and chief scientist at Sun Microsystems, said "I think it is no exaggeration to say we are on the cusp of the further perfection of extreme evil, an evil whose possibility spreads well beyond that which weapons of mass destruction bequeathed to the nation—states, on to a surprising and terrible empowerment of extreme individuals."

At the Singularity Summit in 2006 environmentalist Bill McKibben [18], a visiting scholar in environmental studies at Middlebury College who is the author of *Enough: Staying Human in an Engineered Age*, claims, "In societies where most of us need storage lockers more than we need nanotech miracle boxes, we need to declare that we have enough stuff. Enough intelligence. Enough capability. Enough."

In light of such dire possible consequences, do we limit nanotechnology research? Do we implement policies, federal, state, or international, that allow research "only for therapeutic purposes, but not for enhancement?"

Therapy vs. Enhancement

At first blush, the lines between what constitutes 'therapy' and what constitutes 'enhancement' may seem clear cut. Therapy is for healing the sick and relieving the suffering; enhancement is meant to augment or improve the "normal" workings of the human body and psyche (PBAC report).However, as the (US) President's Council on Bioethics (PBAC) recognized, the terms 'therapy' and 'enhancement' are frustrating and, at the same time, can be overlapping. Many therapeutic interventions can and are used later on for non-therapeutic purposes; for example, sildenafil citrate (popularly known as Viagra) may have started off as a therapy, but has quickly found a place in society as a drug to enhance romantic encounters. Or Minoxidil, originally used to treat high blood pressure, now advertised as the drug of choice for thinning hair or hair loss in men and women.

Some other examples of enhancements that could be seen as therapies and therapies that have enhancement aspects include:

- Vaccines—one gives a vaccine to a person that makes him/her immune to cholera or hepatitis B

[1] See [31].

[2] See [32].

or Human immunodeficiency virus (HIV), this would be a therapy, but it would also be an enhancement of the underlying immune system of the person.
- Anti-aging interventions—If we could gain an extra decade or two, by strengthening our immune system or improving tissue and cell repair and regeneration, this would clearly be a human enhancement; but because it would delay cardio-vascular disease, senile dementia, cancer, and other illnesses of aging, it would also be a preventive therapy.

Yet, PBAC came down squarely against enhancement, "citing appreciation of and respect for 'the naturally given,' threatened by hubris; the dignity of human activity, threatened by 'unnatural' means; the preservation of identity, threatened by efforts at self-transformation; and full human flourishing, threatened by spurious or shallow substitutes."

But banning enhancements is not something that is done easily; in a country where individual autonomy is highly valued, we, as a society, have not seen fit to ban enhancement technologies such as plastic surgery for purely cosmetic purposes. Nor have we banned the use of products for enhancement, as in the examples given previously. And banning nanotechnology research, as Bill Joy and Bill McKibben have suggested, will not work for at least two reasons. First, there is far too much money at stake; telling researchers and companies not to research and build nanotechnology when there are vast fortunes to be made, and glory to be won, and possibly national security interests at stake work is not likely to happen. For such a thing to happen would require the cooperation of state and federal lawmakers, all of whom would have too much to lose by trying to implement a ban. Secondly, even if such far reaching laws were passed, enacted and withstood court challenges, such a ban would push research underground where it could not be regulated. From an ethical perspective, it would be unreasonable to expect that any nation who actually obeys the ban would be deprived of the benefits nanotechnology would offer.

To turn a blind eye towards the potential risks certainly seems unwise. As Patrick Lin [14], research director of the Nanoethics Group has said, "If we had given foresight to how the invention or discovery of electricity, factories, automobiles, nuclear power and the Internet might affect people and society, we might have done a much better job in managing their negative consequences—such as economic disruption, urban sprawl, pollution, nuclear arms race and high-tech crimes" [31]. But a ban on such promising technology would result in a different type of harm, in terms of the economy and in terms of individual choices and freedoms. As Dr. Lin has also said, "we hope to strike a balance between business executives and others who are trying to brush aside ethical concerns and the other extreme of alarmists who predict gloom and doom. We think the truth is somewhere in the middle" [31].

At the same time it is important to note that it is also the application software that raises the ethical issues. Who programs the device? What boundaries are set on the software? What are the intentions of the software designer? Regardless of the size, how does the technology enhance or extend the capabilities of the individual? Does the software have the ability to do more than monitor but to influence the decision-making powers of the individuals? So, regulation of the technology (hardware, software, and wetware) seems prudent. What laws or regulations needed to be enacted to ensure this prudent course?

Dynamic Law: Past, Present, and Future

As we mentioned in the introduction, the law is not static: it is constantly subject to change, extension and reinterpretation, and evolution, whether by legislation or judicial decisions [see 10]. It has been described as a codified reflection of normative social practices, which purports to guide human behavior, giving rise to reasons for action [17]. Sometimes, the law is prescriptive, restricting human behavior. But providing sanctions is not the law's only function in society. Solving recurrent and multiple coordination problems, setting standards for desirable behavior, proclaiming symbolic expressions of communal values (such as autonomy and privacy), resolving disputes about facts, and such, are just some of the important functions which the law serves in our society.

In terms of nanotechnology, much of the focus in the legal arena has been on intellectual property, the preservation of property rights, patent law, and political implications, all with the focus on property issues. In an issue of the *Journal of Law, Medicine and Ethics* entirely dedicated to issues in nanotechnology, one article focused on the enhancement implications of nanotechnology. Bert Gordjin, focuses on the one area that has yet to be addressed in the law on nanoenhancement:

> "If emotional, as well as cognitive, enhancement systems were to become available for implantation, it might become increasingly difficult to determine the characteristics specific to an individual. If, in addition, many different people were to share the possibility of being permanently connected to databases, the exclusiveness of possessing particular information would become relative, which in turn would reduce the uniqueness of those people. Implantation of brain-to-brain communication systems—which would "wire up" different individuals to enable them to instantaneously exchange their conscious thoughts and experiences—could blur the borderline between the self and the cyberthink community. In the face of such mental wiring, how are one's own thoughts and experiences and life-history to be kept separate from those of others? And the borders between the real world and the virtual world would become increasingly blurred. As a result, it would become more and more difficult to determine one's own personal identity" [11].

In a similar vein, which Gordjin does not address, with the advent of so many enhancements, it is possible for persons to enhance or replace so much of themselves that they are no longer the same persons? That they no longer have the same identity? Traditionally, the law has divided entities into a clear cut dichotomy: either persons or property [9]. Our vocabulary is stuck in the old paradigm of something either being a person or a thing; the difficulty is that the notion of what a 'person' is has changed and shifted under the law. Legal (or juridical) 'persons' also include ships and corporations [3]. And the law is currently evolving to recognize that the dichotomy does not always work, that there may be a need to create a continuum rather than a dichotomy [9].

Surprisingly, the United States Supreme Court has already had a case that involves replacement of the parts of a 'person' and whether or not the replacements ended up creating a new identity; the 'person' was a shipping vessel. In the 1922 case of *New Bedford Dry Dock Company vs. Purdy, Claimant of the Steamer "Jack-O-Lantern"*, the question before the court was, "In rebuilding operations the test is whether the *identity* of the vessel has continued, or has been extinguished."[3] The appellee argued that because substantial portions of the vessel had been replaced and because the ship was now being used for amusement rather than as auto ferry the previous identity had been extinguished and a new identity formed. But the court stated in its opinion that "This court has not undertaken and will not now essay to announce rigid definitions of repairs and new construction; but we do not accept the suggestion that the two things can be accurately differentiated by consideration of the ultimate use to which the vessel is to be devoted" and held that as long as the hull and skeleton of the original vessel remained in intact, the original identity was retained.

Conceivably, one could make a similar argument when it comes to replacement parts for 'natural' persons, extrapolating the case law that has already created precedent for 'juridical' persons. If one were to argue by analogy, you could replace almost everything, so long as a skeleton and shell was left. But questions facing the courts would not just be about identity; it also would be about recognizing potential rights or liberties, and corresponding responsibilities. Whether using a property-personhood dichotomy or property-person continuum, the rights of the individual may change when the human performance of the individual is enhanced by machine or other technology. This raises issues about privacy, autonomy, and culpability [10]. It also raises the question of whether we can preserve human rights and human dignity despite that fact our 'humanness' and human nature is changing [9].

> In 2000, U.S. Supreme Court Justice Stephen Breyer wrote the following:
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> "In this Age of Science, science should expect to find a warm welcome, perhaps a permanent home, in our courtrooms. The reason is a simple one. The legal disputes before us increasingly

[3] See 258 U.S. 96; 42 S. Ct. 243; 66 L. Ed. 482 (1922) (emphasis added).

involve the principles and tools of science. Proper resolution of those disputes matters not just to the litigants, but also to the general public—those who live in our technologically complex society and whom the law must serve. Our decisions should reflect a proper scientific and technical understanding so that the law can respond to the needs of the public" [4].

Breyers' thoughts on the role of science in the law reflect a willingness to recognize, as we stated earlier in this paper, that the law is not static, that it evolves, and is subject to change, extension and interpretation, and evolution, whether by legislation or judicial decision. As our understanding of scientific information advances, we must be willing to revisit the law to consider what changes should be made to keep pace with our knowledge.

Summary and Recommendations

As nanotechnology continues to progress, the importance of a continued discussion and the monitoring and legal interpretation of the potential impacts are critical. In borrowing some approaches from Taoism, the search for the 'middle path' could benefit from attention to four areas:

1) Continuing dialogue—since nanotechnology is a highly interdisciplinary area, we would expect that collaboration among lawmakers, scientists, ethicists, economists (as well as the eight nodes of societal discussion mentioned earlier in Part 2 of this paper) would be needed to account for the complicated issues, positive and negative, arising from nanotechnology [14].
2) Come to terms that our creations can have unintended or unforeseen consequences and consider who will decide issues of regulation, liability. Should there be international oversight or federal government oversight or will individual jurisdictions be called upon to decide enact statutes or decide on a case-by-case basis?
3) An exploration and discussion of the property—personhood continuum, issues of personal identity, and whether current law is sufficient or will new laws be needed?
4) The possibility of legal reform and the creation of specialized "science courts," where the judges will have ongoing education and training to recognize and deal with these new legal issues and categories that arise from emerging technologies.

Legal institutions must try to avoid getting blinded by the hype and inappropriately sweeping in—and perhaps over-regulating—of both the novel and the mundane applications of this still relatively young technology [22]. As nanotechnology progresses, and both humans and nonhumans receive therapeutic benefits and enhancements, it will be up to the policy makers, courts, and legal profession to delineate societal guidelines for regulation and privacy, as well as to determine individual culpability and responsibility.

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