Chapter 12
Nanoscience, Nanoscientists, and Controversy[1]

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12.1 Introduction

Contemporary life sciences and biotechnology research is controversial. Whether the topic is embryos, evolution, genetics, neuroimaging, pharmaceutical discovery, synthetic biology, or xenotransplantation, the research is subject to public, political, legal, regulatory, clinical, and/or scientific controversy. In some cases, the controversy may not be worth engaging, given the credibility (or, rather, lack thereof) of those who would object. Often, though, those who would object must be taken seriously—and even where the objectors lack credibility, any response to them must itself be serious. These are basic elements of civility in a pluralistic society, and yet they are widely ignored when science and scientists are the subjects of controversy.

As a scholar of the life sciences in society, I have tended to pay less attention to the question of generally whether research in chemistry, math, physics, or engineering is as widely deemed to be controversial as is research in biology and biotechnology—except, of course, where that research is oriented toward or undertaken in concert with the life sciences (as with engineering in relation to stem cell biology, or chemistry in relation to directed molecular evolution). But with advances in nanoscale science and engineering (NSE) research, it is hard to miss the fact that NSE is an exemplar of research in the natural and physical sciences that is controversial both in relation to the life sciences (as expected) but also in its own right. Whether because of the spatial or financial scale of the research, or because of the prospects for immense changes—good and bad—in science, industry, medicine, and society, or for a combination of these or other reasons, NSE research is paradigmatically controversial. So what?

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[1] I am grateful to two separate audiences, both in Chicagoland in August 2006 (NABIS) and October 2006 (International Institute for Nanotechnology, Northwestern University), as well as the editors of this volume, for their comments and thoughts on this work in progress. I am also grateful to members of my lab (especially Zach Pirtle and Jenny Brian) for ongoing, engaging discussions of science in society. My research is currently supported by the Center for Nanotechnology in Society, the Institute for Humanities Research, and the Center for Biology and Society, all at Arizona State University.

F. Allhoff, P. Lin (eds.) *Nanotechnology & Society: Current and Emerging Ethical Issues*,

I organize my claims as follows. First, I identify and briefly discuss a number of ethical and societal issues associated with NSE; second, I canvass a variety of scientists' and engineers' standard responses to claims that NSE (and science and engineering more generally) is controversial and assess their impropriety (as a cautionary tale, I discuss some recent events in stem cell biology in California and Canada); finally, I propose an alternative response and a strategy for implementing it. Throughout, my aim is to reflect critically on the roles and responsibilities of scientists, engineers, and ethicists in the face of controversial science and technology research and development. While my remarks are often general rather than specific to NSE, I hope to convince the reader that this as a strength rather than a limitation of my approach.

12.2 Societal and Ethical Implications of NSE

NSE research raises a large number of ethical, societal, and policy issues, from agenda-setting and funding through research, development, implementation, and use. As stipulated in the twenty-first Century Nanotechnology R&D Act of 2003 (PL 108–153), the United States Congress intended to ensure that: "ethical, legal, environmental, and other appropriate societal concerns, including the potential use of nanotechnology in enhancing human intelligence and in developing artificial intelligence which exceeds human capacity, are considered during the development of nanotechnology" (Section 2(b)(10)). This goal is to be accomplished by:

- Establishing a societal implications research program;
- Requiring that Nanoscale Science and Engineering Centers (NSECs) address societal implications;
- Integrating societal concerns with nanotechnology research and development for widespread benefit; and
- Providing for public input and engaging in public outreach activities through the National Nanotechnology Coordination Office (NNCO).

These activities are well underway. The NNCO is coordinating a wide range of efforts linking together nanoscale scientists and engineers with ethicists and policy decision-makers (http://www.nano.gov/html/about/nnco.html), NSECs have established Societal and Ethical Implications of Nanotechnology programs (e.g., at the International Institute for Nanotechnology at Northwestern University, http://www.nsec.northwestern.edu/SocialEthical.htm), and the National Science Foundation has funded a Nanoscale Informal Science Education network and two large NSECs focused on Nanotechnology in Society. The latter are based at Arizona State University (http://cns.asu.edu/) and at the University of California at Santa Barbara (http://www.cns.ucsb.edu/home/) and are part of a wider network of funded research centers and programs throughout the United States (http://www.nsf.gov/news/news_summ.jsp?cntn_id=104505&org=olpa&from=news).

Additionally, there is now a journal devoted specifically to NSE ethics (*Nanoethics*), forums for NSE ethics and policy articles in such journals as *Nature Nanotechnology*, and anthologies and yearbooks are either already published or are currently being planned. Table 12.1 presents some of the stock ethical, societal, and policy issues that form the core of this ongoing research.

Table 12.1 Stock ethical, societal, and policy issues associated with nanoscale science and engineering (NSE). Several issues are NSE-specific, several are intensified with NSE, and some arise generally in relation to emerging technological research and development. The table describes the source of the normative issue, but invokes no particular normative analysis

Issue	Description, source
1. Health and safety concerns	Spatial scale-dependent properties of nanoparticles raise concerns about their potential toxicity. Will it be possible to protect the health of laboratory workers, employees of manufacturing facilities, patients, and consumers?
2. Regulatory issues	Spatial scale-dependent properties of NSE raise concerns about the ability to identify, monitor, and moderate potential risks; will current national and international regulatory regimes suffice?
3. Range of potential impact issues	Financial and spatial scale-dependent properties of NSE raise the potential for "revolutionary" effects throughout society. Additionally, NSE is predicted to be part of a technological convergence with biotechnology, computing and information technology, and cognitive sciences, expected to profoundly alter the human condition. Will it be possible to anticipate, plan for, and cope with large-scale effects within and between societies? What are the opportunity costs associated with a significant focus on NSE, and how can these be moderated?
4. Research priorities, funding issues	There are industrial, military, medical, academic, and fundamental technological motivations for nanoscale science and engineering. What factors determine the research agenda for NSE? What factors *should* determine the research agenda?
5. Intellectual property (IP) issues	As with biotechnology, there are concerns about key patents for enabling technologies—who owns them, their breadth, their interrelationships, licensing considerations. Will the IP regime help or hinder research and commercial aspects of NSE? What IP strategies are being and should be pursued? (See also regulatory issues, range of potential impact considerations, and research priorities, funding issues.)
6. Equity and access considerations	As with technologies of all sorts, there is the potential for inequitable distribution of technologies within and between societies. Will NSE be different? (See also research priorities, funding issues, and intellectual property issues.)
7. Clinical translation concerns	In biomedicine, the path from bench to bedside is long and difficult. Will NSE be different? (See also health and safety concerns and regulatory issues.)
8. Privacy, confidentiality	Due to the spatial scale of NSE, nanotechnologies may enable unprecedented opportunities for detection, surveillance, and intervention into daily activities. Will it be possible to devise and enforce appropriate regulations? (See also regulatory issues.)

(continued)

Table 12.1 (continued)

Issue	Description, source
9. Potential dual-uses unintended consequences	As with technologies of all sorts, there is the potential for the "dual-use" of nanotechnologies: originally developed for one purpose, a technology is adopted for adapted for malevolent ends. Additionally, technologies engender unintended consequences of many kinds. Will it be possible to devise and enforce appropriate safeguards to minimize risks? (See also regulatory issues, and privacy, confidentiality.)

It is plainly evident that most of the issues highlighted in Table 12.1 are neither unique to nanoscale science and engineering, nor novel in this context. For instance, intellectual property concerns exist throughout the research enterprise, as do worries about military and corporate influence on the academic research agenda. Yet some concerns, especially about health and safety risks and about the suitability of regulatory regimes, are certainly intensified with NSE simply because of the spatial scale of the research. Moreover, the financial scale of the research—given the enormous investments in nanoscale science and engineering in the United States and elsewhere—serves to intensify the concerns about research agendas, equity, and opportunity costs. And the potential for widespread effects—particularly in industry (manufacturing, workforce) and medicine (drug discovery drug delivery, device engineering, health effects)—similarly serves to heighten the likelihood of dramatic societal fallouts from NSE, both good and bad.

So, from the perspective of ethics or policy, or in consideration of the societal dimensions of research and development, is nanoscale science and engineering unique in any interesting ways? *Not particularly*. Does that make it any less important to attend to societal, ethical, and policy concerns? *Absolutely not*. Indeed, just the opposite may be true: if NSE raises (even without intensifying) ethical, societal, and policy concerns that are raised by many other technologies, and that have not been adequately addressed in other quarters, then that suggests an even greater need for scrutiny of these considerations in the context of nanoscale science and engineering.

That said, given the interestingly different contexts of discovery and application and the diversity of fields and activities that comprise nanoscale science and engineering, the very idea of a distinct and homogeneous "nanoethics" is poorly conceived. Though there may be some ethical, societal, or policy issues that are best explored with regard to NSE as a whole, we have found it far more productive to narrow our attention to particular domains of research and development, and even to particular kinds of potential NSE-enabled technologies, in order more adequately to explore these issues. Within our group at the Center for Nanotechnology and Society at Arizona State University, one area of emphasis is the NSE-enabled development of and refinement of implantable neural prosthetic devices. One basic premise is that advances in NSE should yield solutions to a fundamental technological challenge in neural prosthetics design—the development of small, physically non-invasive, flexible, reliable, chronic, multielectrode recording and signalling methods for the cerebral neocortex. Such advances may for instance include miniaturization strategies or strategies for harnessing scale-dependent properties of nanomaterials as coatings for implantable devices or their components.

The design of neural prosthetics raises an enormous range of ethical, societal, and policy issues, from considerations about demonstrating the safety and efficacy of these devices in preclinical and clinical studies to determining the perspectives of intended consumers (especially people with disabilities—and especially given the controversy within Deaf communities about an early neural prosthetic, the cochlear implant), and from the allocation of scarce research dollars to such high-tech interventions with limited clinical usefulness to worries about potential misuses of neural implants for surveillance (mind reading) or even "substituted decisional authority" (mind control). To ask whether these issues are unique to nanoscale science and engineering is to miss the point that NSE contributes to technological advances that are, in their own right, worthy of ethical, societal and political scrutiny.

12.3 NSE and Controversy[2]

Nanoscale science and engineering is controversial in at least the ways canvassed above. So what? How should we respond to such claims? More generally, what are the roles of scientists, engineers, and ethicists in the face of claims that some area of science or engineering is morally, socially, or politically controversial?

At least three kinds of strategies have been widely adopted in the face of controversy. *Denial* is especially popular, and I have touched on it already. Also popular are *ignorance* and its converse, *dogmatism*. Table 12.2 summarizes these three responses. I will elaborate on them in turn.

Table 12.2 Three standard strategies for responding to claims that science or engineering research is controversial. See text for additional details

Strategy	*Modus operandi*
Denial	Deny the existence or severity of controversy, or deny that there is anything new about this particular controversy, so as to absolve any responsibility to engage critics.
Ignorance	Attempt to draw a firm line between the context of discovery and the context of application, and ignore the personal or professional responsibility of scientists and engineers for the applications (development, use, and implications) of their research.
Dogmatism	Dogmatically debate critics, all the while assuming that critics are simply wrong. This strategy usually entails paying lip service to the critics via public engagement exercises that are more aptly described as public relations exercises.

[2] In most of what follows, my emphasis is on science and scientists rather than engineering and engineers–even though most of what I say is generalizable. This is because the case for science and scientists is the much more difficult case to make.

Denial is an exceptionally popular strategy, involving either the denial of any controversy, the denial of severity of controversy, or the denial of the novelty of the controversy. The intent is to undercut the credibility of the critics and their objections, and to absolve scientists' and engineers' of any responsibility to engage critics. Some commentators use history as a tool of denial: such and such is just more of the same, and there is nothing new here. This is a very popular strategy within biotechnology ethics; for instance:

- humans have been engaged in biotechnology for 6000 years, at least since the invention of beer, and modern techniques of genetic engineering are *essentially the same*, so don't worry your pretty little head; and
- humans have been engaged in enhancement activities since the beginning of civilization—we seek out spiritual rituals and medical care for our kids, we send them to school (and not just any schools, but the best schools), and so on, simply in an effort to enhance their prospects for success; modern techniques of genetic engineering, coupled with cosmetic surgery and the use of pharmaceuticals are part of *essentially the same* project, so don't worry your pretty little head.

And so on. What is most interesting about these responses is that even though a kernel of content may be accurate—that biotechnology really is ancient and that biotechnological and biomedical enhancement really are in important ways similar to other enhancement techniques and part of overarching enhancement projects—there is no warrant for the injunction not to worry. The strategy of making a plausible descriptive claim about a state of affairs and then making a further normative claim is logically fraught and yet unfortunately rhetorically powerful.

A second standard strategy is best described as *ignorance*. This strategy involves actively ignoring or passively being ignorant of the social context of scientific discovery and the societal dimensions of scientific research. I suspect—indeed, I hope—that passive ignorance is more common than active ignorance, but passive ignorance becomes active when social issues are made salient and then willfully ignored. In this situation, ignorance involves a firm distinction between the *context of discovery* (what a scientist or engineer does in the lab, usually idealized, often romanticized) and the *context of application* (where the discovery is operationalized or applied, whether by being used as a gateway to further discovery, or turned into a product, or in some other way made useful). It also usually involves the claim that discovery is serendipitous and that it is impossible to predict the potential usefulness or applicability of scientific discoveries. And it usually involves a third claim that every discovery can be used in any number of ways, some good and some bad, such that worry about such uses is a waste of time and energy. So, in the end, either research is not controversial (but applications may be) or research may be controversial, and the claim is that it is just not scientists' or technologists' job to consider such concerns about controversial applications. Instead, let the ethicists lose sleep. These sorts of moves ignore the evidence that the context of discovery and the context of application are rarely entirely separate; further, they ignore the plain truth that the context of discovery is increasingly defined by the context of application (consider funding arrangements); instead, they pass the buck, whether actively or passively.

Dogmatism is the third standard strategy. The *modus operandi* is to welcome the charge that the research is controversial, and either to heavy-handedly dismiss all objections or to appear to open the door to public discussion and debate aimed at resolving the controversy presumably by persuasion one way or the other, or by compromise. The former is increasingly less common, replaced by what appears to be, on the surface, a much more acceptable strategy of promoting healthy discussion and debate. Except, unfortunately, that scratching the surface just a little reveals the charade: all that glitters is not gold. Too often, the putative openness is in fact just window-dressing, public relations rather than public engagement.

Consider stem cell research, and in particular the creation of part-human chimeras with human neural stem cells. When Stanford's Irving Weissman first pondered the creation of what has come to be known as the "human neuron mouse", he actively sought out guidance from a legal scholar at Stanford, Henry (Hank) Greely. Greely struck a committee to consider the morality of creating a mouse with a significant number of human neurons in its brain; Weissman awaited their report prior to undertaking the experiment. After some deliberation, Greely's committee issued a report recommending that Weissman proceed with caution. (Apparently, he never did the experiment; the reasons why remain unclear.) Throughout, Weissman maintained the public image of the thoughtful scientist, worried about the ethical propriety of his research, open to potential moral limitations on the research he is permitted to undertake. So far, so good. Except that Weissman had this to say, too: "Anybody who puts their own moral guidance in the way of this biomedical science, where they want to impose their will—not just be part of an argument—if that leads to a ban or moratorium. … they are stopping research that would save human lives" (as cited in Mott 2005, ellipsis in original). I am, of course, willing to grant that Weissman's words were taken out of context by the journalist (whose article is certainly careless on several fronts). But taken at face value, the quotation suggests the following dogmatic attitude: debate and argument are most welcome, so long as the outcome is a (foregone) conclusion in favor of permitting the research; anything else, any moral limitation on the research, would be unacceptable (and, indeed, in this case, sinful given the potential loss of human lives). So much for a nondogmatic response to moral concerns about scientific research.

Another, related kind of dogmatic response is to be on the cutting edge of the ethics debate[3]—but only for political reasons, not substantive scientific ones. It is becoming increasingly common for scientists (and, indeed, for corporations) either to find ethicists for hire or to take on the task of ethical reflection themselves. The ambition is always to go forward with the controversial research—and often to be first. The *modus operandi* is to take the offensive, and to position oneself as the thoughtful responsible scientist (or industry) who identifies ethical concerns (moral controversy about science) and who claims she/he would not go forward until the

[3] Françoise Baylis identified this important variant of a dogmatic response. I thank her for the suggestion and our ensuing discussion.

ethical issues are resolved. Then, s/he proceeds with the controversial research and, if challenged, points back to the prior ethical reflection as evidence that s/he has satisfactorily resolved the moral concerns—else she would not have proceeded. Logically, the reasoning is fallacious—the fallacy of *affirming the consequent*: If the ethical issues have been satisfactorily resolved (x), I will proceed with my controversial experiment (y); I am proceeding with my controversial experiment (y); therefore, the ethical issues must have been satisfactorily resolved (x)—if x, then y; y; therefore x. Despite the fallacy, the reasoning is eminently effective as a political strategy.[4]

Other strategies, such as equivocation and deflation (and especially the use of inapt analogies to explain away moral controversy) may be used on their own or in combination with denial, ignorance, or dogmatism regarding morally controversial science or engineering. But the three I have highlighted above appear to be most widely used. This is understandable—for instance, they are self-preserving, and so allow individuals and communities to protect themselves against charges of negligence while effectively permitting business as usual; moreover, each strategy may, on occasion, be locally appropriate, as when the complainant clearly refuses to engage in good faith. But despite these qualifications, such strategies are simply not suited to the task of defending good science and engineering in a civil society. And when particular science and engineering projects are deemed controversial, then that is indeed the task at hand.

Again, the case of stem cell biology affords an opportunity to probe these issues, and provides a cautionary tale for those of us engaging the controversial dimensions of nanoscale science and engineering. In December 2006, the Canadian government announced the Board of Directors of Assisted Human Reproduction Canada (AHRC). AHRC's mandate is to oversee technologies and practices of assisted human reproduction and related research in Canada (for details, see http://www.hc-sc.gc.ca/hl-vs/reprod/agenc/index_e.html). *Inter alia*, this agency is charged with making decisions regarding licenses for research and other activities deemed to require a license ("controlled activities") in the agency's enabling legislation, the 2004 Assisted Human Reproduction Act (http://laws.justice.gc.ca/en/A-13.4/index.html). Following the announcement of the Board of Directors, the media in Canada had a field day. The first report, in *The Globe and Mail* (Abraham 2006), set the tone, as it was picked up by many other newspapers (sometimes *verbatim*). Through quotations from two scientists and a health law professor, the journalist characterized the Board of Directors as handpicked expressly to stifle stem cell research and reproductive technologies in Canada. In particular, the article described four members of the Board in some detail, lumping them together as social conservatives who may influence the Board in ways harmful to the interests of

[4] Logically, two alternative constructions are valid: if x, then y; x; therefore y (by modus ponens) and if x, then y; not y; therefore not x (by modus tollens). See also Chapter 1 of Robert (2004) for an account of 'hedgeless hedging' that is rhetorically similarly effective but in a different context.

stem cell scientists. The other four members of the Board, as well as its Chairman and President, were mentioned only briefly.

There is no doubt that (embryonic) stem cell research is controversial. Quite apart from the *destruction* of human embryos required for deriving new embryonic stem cell lines, there are longstanding concerns about the *creation* of embryos specifically to be destroyed. For instance, there are concerns about the safety and wisdom of egg donation for creating new embryos (whether through *in vitro* fertilization or somatic cell nuclear transfer), and about the potential coercion of infertility patients to donate embryos (whether frozen or fresh) for research purposes. And, of course, stem cell research is only one of the topics to be covered by the AHRC—and not necessarily the most important one, since the Board deals with all aspects of assisted human reproduction. Even so, the media circus centered around stem cell research in particular, and around the potential for a conservative agenda to dominate the Board's deliberations.

In the article in *The Globe and Mail* and in another in the *Canadian Medical Association Journal (CMAJ)* (Eggertson 2007), the stem cell scientist quoted at most length is Michael Rudnicki, scientific director of the Stem Cell Network in Canada.[5] In his comments to journalists about the AHRC Board, Rudnicki put forward an image of science, scientists, and politics that is terrifically naïve—scientifically and politically. He complained in particular that the Board is stacked against stem cell science. The following passages from the *CMAJ* article include some of Rudnicki's remarks, as presented by the author of that article:

> "It was supposed to be an expert [board] and these are not experts. These are people who have agendas and opinions," Rudnicki says of those 4 board members. "If you wanted to see the legislation enacted in good faith, I would think that you would want to have people who did not have a clear stated position in opposition of what they're supposed to be regulating." The choices "raise the possibility of political interests at work," he added.
>
> "It's analogous to having a Jehovah's Witness who is totally opposed to transfusions being appointed to the board of the Canadian Blood Services."

In these passages, Rudnicki makes three movies: he offers an untenable analogy that can only be described as inflammatory; he effectively slanders the Board members (and especially those whom he personally deems to be socially conservative, regardless of whether they are in fact conservative); and he complains that the process was political (precisely because he fears that his own agenda will not be advanced).

Rudnicki's response (as constructed by the reporters) is entirely inappropriate on several counts. (This leaves open the possibility that Rudnicki was quoted out of context, though an extended report on the *Canadian Broadcasting Corporation* bears out my interpretation.) First, it fails to engage any specific concerns about

[5] I should disclose that from 2003–2005, I was a funded member of the Stem Cell Network, and withdrew from the Network when I moved from Canada to the United States. I was then, as now, critical of some of the Network's activities, particularly in relation to the commercialization of stem cell research and the apparent unwillingness to engage in thoughtful, open-ended debate about the ethics and politics of stem cell research.

stem cell biology while attempting to discredit those who raise concerns—the key ingredient of an *ad hominem* attack. Second, it pretends to advance an objective, scientific point of view as against the putatively conservative political point of view – without appreciating that advocating an agenda in favor of stem cell research is a political act, and without recognizing that a Board stacked in favor of stem cell research would have been equally political. Third, it ignores controversy and dogmatically endorses one amongst many reasonable points of view, all the while pretending that science is being inappropriately politicized.

Rudnicki's response is all too common amongst scientists and commentators—consider Chris Mooney's writings about the politicization of science in the United States according to which pure, objective science (a myth of epic proportions) is bastardized by Republicans (Mooney 2005; cf. Sarewitz 2006). But what Mooney and Rudnicki and others of their ilk fail to appreciate is that science today is always already political; there is no unequivocally pure science, and no unequivocally pure scientist, speaking truth to power. To advance science is to advance a political agenda. In many instances, it is an agenda worth advancing, not just because it is science, but because science is often good and worth advancing. Yet the good of science must always be demonstrated and not assumed. Alas, the myth of scientific purity remains ever-present, despite no enduring warrant for believing it.

At the heart of the standard, unacceptable responses to the diagnosis of controversy are two unacceptable images of science. One is an unacceptable image of science as value-neutral; the other is an unacceptable image of science in society, according to which science is the only epistemic game in town. But these images have been long since abandoned by everyone who thinks hard about science, and about science in society. Instead, we know full well that scientific knowledge is fallible, partial, and socially generated (the context of discovery is a social context, though not a particularly public one). And we know full well that scientific knowledge is enormously, but not exclusively, important. Accordingly, we must generate an alternative, and more appropriate response to scientific controversy, one more in line with this more reasonable view of science in society.

12.4 Controversy and Accountability

My argument—more accurately, my argument sketch—in this and the next section proceeds in three not entirely discrete steps. First, the moral permissibility of scientific research depends on its scientific and/ or social significance, which is an accountable enterprise. Second, accountability requires transparency, good will, an appropriate sense of obligation, and clear stopping rules. Finally, with accountability comes due respect. This particular route to addressing controversy via accountability at least stands a chance of building enduring support for science based on something other than myth alone.

Good science is ethical science. For scientific research to be morally warranted, it must be scientifically and/or socially significant. Whereas scientific *validity* is usually determined by peer-review, this may not be the most appropriate means for determining scientific *significance*. Consider that an insignificant experiment may be judged by an insular group of scientist-peers to be perfectly valid—because their insularity prevents them from questioning the assumptions that challenge the scientific significance of the experiment. As science aims at discovering significant truths (Kitcher 2001), it is important to assess scientific significance more appropriately. Prospects include considering the scientific significance of a research program alongside its social significance, and providing a publicly accessible account of scientific significance, in order to enable a fuller exploration and assessment of significance.

> Presumably, even though the results of particular experiments cannot be fully anticipated, scientists have good scientific reasons for conducting their experiments. That is, while scientists cannot predict exactly how experiments will turn out (else there would be no reason to perform the experiment), scientists surely do have reasons for performing one experiment and eschewing another. It is not too much to ask scientists to make these reasons transparent, such that a research program wears its logic on its sleeve, for anyone to see (Robert 2006, 843–844).

On this view, it is not enough for an experiment to be scientifically valid as judged by one's immediate peers who are themselves often already committed to a particular line of inquiry with all its assumptions and ambitions. Rather the experiment must be assessed on broader grounds whereby those assumptions and ambitions are themselves identified, elucidated, and justified. This is a kind of accountability—of requiring a publicly accessible justification, an account of one's proposed research and the transparent reasons one has for conducting it in this particular way at this particular time with these particular ends.

To this end, Kitcher (2001) has described the heuristic of *significance graphs*. Such graphs "reflect the concerns of the age", both scientific and social, and provide a kind of map for explaining and interpreting the importance of particular decisions within research programs. They are historicized and perhaps idealized, but they give an accessible sense of the logic of scientific research programs, and may thus serve to help justify the research. Justification is crucial:

> Well-articulated scientific justifications may help to dispel the appearance of hubris and irresponsibility. But to date scientists are partially responsible for generating this image, especially when they turn away from public justification of their research and demand to be left alone, unburdened by non-scientific rules and regulations. The problem with this response is that it fails to recognize the social context in which scientific research is deeply embedded; it fails to take seriously that scientific research, like all scholarly research, is a public enterprise – even where the research funds are not provided directly by the state, the research itself is undertaken in a civic context, bound by rules, regulations, and political mores (Robert 2006, 844).

This claim suggests a second dimension of accountability, namely the need to consider that science—even privately funded science—is a social enterprise. Scientists, after all, are people and, accordingly, are social beings with civic responsibilities and public obligations. The case is made most straightforwardly where scientists make promises about beneficial social outcomes specifically in order to get a grant. Where the research fails to deliver, the scientist should be help accountable – especially where the promises never should have been made in the first place. But even where there is no accountable promise to deliver a particular outcome from a scientific research program, this does not mean that scientists are off the hook, that there is no accountability.

Consider the claim that science, like art, should be thought of as an intrinsically valuable cultural activity. This view is distinct from two other popular views: one, that all scientific research has the potential for serendipitous deliverables, and so scientists should be left alone (and fully funded) to do whatever research they see fit (the serendipity view), and two, that all scientific research should have specific deliverables, and should be specifically and strategically guided toward those deliverables (the strategic view), The serendipity view has been popular since Vannevar Bush's report, *Science, The Endless Frontier* (Bush 1950) insisted on funding basic science as a means to deliver on the fullest potential of scientific inquiry. The strategic view is more recent, and emphasizes the need to demonstrate the value (usually, the economic value) of investment in scientific research; at its extreme, this view discounts the value of basic research in favor only of research that promises (and delivers) specific outcomes. By contrast, the cultural activity view holds that science is, like art, an intrinsically valuable cultural activity that may or may not yield specific outcomes but that is nonetheless undertaken within particular traditions and with particular customs and mores. Just as art is not quite undertaken simply for art's sake—but rather to express significant meaning through a medium—so too is science not quite undertaken just for science's sake; but just as art is not exclusively undertaken for expressly crass commercial reasons, so too is science similarly undertaken for other intrinsic and extrinsic reasons (of which commerce is but one). The governance of art and the governance of science are not quite analogous, and the metaphor must obviously be explored further. But the cultural activity view of science is, in practice, more difficult to defend than either the strategic or serendipity view, for it requires scientists to give up their privileged epistemic claim and the myth of scientific purity in favor of a more accurate depiction of science as an essential component of civilization, but not as the be all and end all of human inquiry. Were scientists to take on this particular challenge, a philosophical challenge, to be sure, I suspect they would dramatically improve their ability to grasp the nature of and adequately deal with charges of controversy at the intersection of science and society.

Taking seriously the moral and cultural justification of science and its significance is a critical first step. But note that better (scientific) justifications of scientific research will not entirely suffice to resolve controversies, for these disputes are more about (fact-related) values than about (value-laden) facts. How, then, to deal appropriately with divergent values at the heart of controversial science?

12.5 A Role for Ethicists

I am suggesting, in line with Kitcher (2001) and others (Wilsdon and Willis 2004), that understanding the scientific and social significance of science, let alone determining it, is a multidisciplinary, multi-sectoral task. It is too important to be left only to scientists, though scientists should be involved; it is similarly too important to be left only to ethicists, politicians, and other stakeholders—though, again, they should be involved. Understanding and determining significance is best described as a collaborative, performative enterprise to be undertaken publicly and deliberatively in spaces cultivated for this end.

Demos, a UK-based thinktank on the role of science in society, has advocated for "see-through science". As an alternative to public science-literacy programs based on the deficit view of public understanding, see-through science aims simultaneously to improve scientific literacy (Maienschein et al. 1998) while also promoting upstream engagement between scientists and publics to promote better science (Wilsdon and Willis 2004). See-through science is not easy to achieve. Opportunities for upstream engagement are scarce, and tools for talking are scarcer still (*cf.* Parens et al. 2005). Here, then, is a role for ethicists in the face of controversial science, a role much more appropriate than those standardly adopted.

Ethicists tend to respond poorly to controversial science. Ethicists too often gather at the extremes—deflation (denial, ignorance) on the one side, inflammation (many varieties of dogmatism) on the other—in attempts either to put out the flames or to fan them further. They end up either smothering important disagreements or generating more heat than light. These caricatures of practical ethicists as, alternately, firefighters and pyromaniacs are well-deserved; they are also images that many ethicists actively adopt. I prefer an alternative image, one initially introduced almost 15 years ago by Margaret Walker (Walker 1993) and recently extended in various helpful ways (Sherwin and Baylis 2003; Robert 2007). This is the image of practical ethicists (actually, ethics consultants in Walker's original piece) as architects of moral space—as those who create and maintain literal and figurative spaces for moral discussion and debate. As with medicine more generally, so too with practical ethics: it is better to prevent serious problems than to deal with them when they arise acutely. But, of course, there are better and worse ways of prevention. And so I envision bioethicists as those who should strive, with integrity and wisdom, to foster upstream conversation and collaboration between scientists and various publics (including ethicists but also politicians, industry representatives, and regular folks, *inter alia*) about the content, warrant, direction, governance, and implications of science as a cultural activity. The task of practical ethics, then, is the discovery and elucidation of moral and other values, the fostering of critical reflection on those values in context, and the cultivation of constructive moral discourse about conflicting values in a local or global decisional or policy context. Practical ethicists are thus gadfly-handmaiden-architects of moral space. (I am, of course, well aware that this romantic vision of bioethicists is not borne out in the discipline as we know it today. But I am hopeful [Robert et al. 2006; Robert 2007].)

Science, as a normative enterprise in a civil society, requires good will to proceed. Not just on the part of critics of science, but also of its proponents, good will engenders appropriate trust in the political deliberations that enable or disable scientific progress. Though I can only hint at the reasoning here, my view is that scientists and ethicists have obligations to be good citizens in this domain, and to take nothing for granted in establishing that science really is a good and valuable part of civilized society.

12.6 Conclusion

Where research is controversial, scientists may comport themselves in such a way as to mediate or moderate the controversy, or they can make things worse by themselves behaving in controversial ways. It is plainly evident that only the former option offers any prospect for maintaining public trust in science and scientists, and fostering the socially responsible advance of research and development in science and engineering.

My aim in this essay has been to motivate such collaborations in the context of nanoscale science and engineering. To date, too many scientists and engineers have proceeded from denying that NSE raises any new ethical issues (which may be true) to claiming that attending to and funding research on societal and ethical dimensions of nanoscale science and engineering is unnecessary (which is clearly false). In response, too many ethicists have bent over backwards to try to demonstrate the novelty of nanoethics (with terrifically limited success). The end result is a field ripe for ethical and societal analysis that is, alas, polarized and politicized in unproductive ways. My arguments in this essay are general but generalizable; efforts in nanoscale science and engineering afford an excellent opportunity for scientists, engineers, ethicists, and other stakeholders jointly to reinvent the social contract between science and society, and to break new ground for more productive interactions in the future.

References

Abraham, C. 2006. Critics troubled by new fertility panel. *The Globe and Mail* (23 December).

Bush, V. 1950. *Science, the Endless Frontier*. Washington, DC: National Science Foundation.

Eggertson, L. 2007. New reproductive technology board belies expert selection process. *Canadian Medical Association Journal* 176: 611–612.

Kitcher, P. 2001. *Science, Truth, and Democracy*. New York: Oxford University Press.

Maienschein, J et al. 1998. Scientific literacy. *Science* 281: 917.

Mooney, C. 2005. *The Republican War on Science*. New York: Basic Books.

Mott, M. 2005. Animal-human hybrids spark controversy. National Geographic News. 25 January. http://news.nationalgeographic.com/news/2005/01/ 0125_050125_chimeras.html. Cited 1 June 2007.

Parens, E et al., eds. 2005. *Wrestling with Behavioral Genetics: Science, Ethics, and Public Conversation*. Baltimore, MD: Johns Hopkins University Press.

Robert, J.S. 2004. *Embryology, Epigenesis, and Evolution: Taking Development Seriously*. New York: Cambridge University Press.

Robert, J.S. 2006. The science and ethics of making part-human animals in stem cell research. *FASEB Journal* 20: 838–845.

Robert, J.S. 2007. Systems bioethics. *The American Journal of Bioethics* 7.4: 80–82.

Robert, J.S et al. 2006. Systems bioethics and stem cell biology. *Journal of Bioethical Inquiry* 3: 19–31.

Sarewitz, D. 2006. Scientizing politics. *Issues in Science and Technology* 22.2 (Winter). http://www.issues.org/22.2/br_sarewitz.html. Cited 1 June 2007.

Sherwin, S. and F. Baylis. 2003. The feminist health care ethics consultant as architect and advocate. *Public Affairs Quarterly* 17: 141–158.
Walker, M.U. 1993. Keeping moral space open. *Hastings Center Report* 23.2: 33–40.
Wilsdon, J. and R. Willis. 2004. *See-through Science: Why Public Engagement Needs to Move Upstream*. London: Demos.