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Setting an Agenda for the Social Studies of Nanotechnology

Citation for published version (APA):

Kaplan, S., Choi, H., Mody, C. C. M., & Roberts, J. (2008). *Setting an Agenda for the Social Studies of Nanotechnology*. Chemical Heritage Foundation.

Document status and date:
Published: 01/01/2008

Document Version:
Publisher's PDF, also known as Version of record

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

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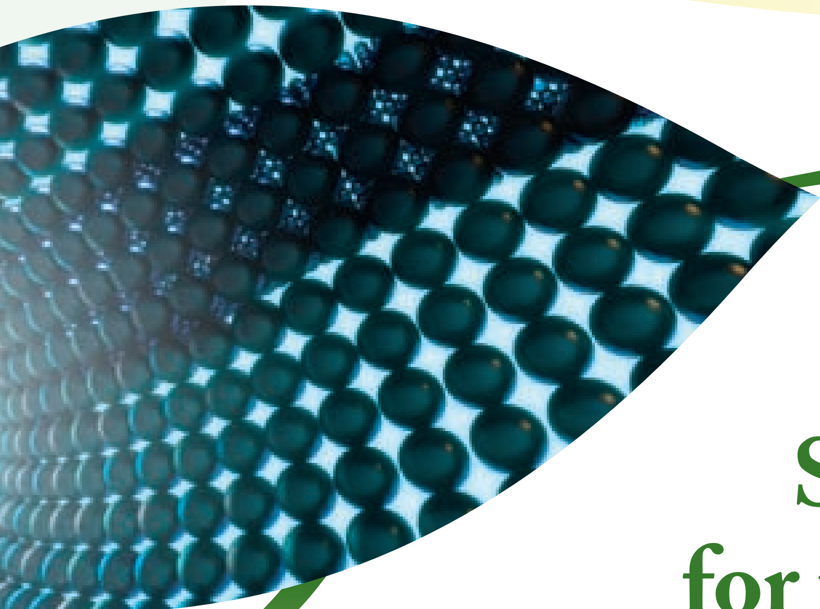

Setting an Agenda for the Social Studies of Nanotechnology

A Summary of the Joint Wharton–Chemical Heritage Foundation Symposium on the Social Studies of Nanotechnology

Hyungsub Choi
Sarah Kaplan
Cyrus C. M. Mody
Jody A. Roberts

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This document is a report on a symposium held on June 7-8, 2007 in Philadelphia, PA. The event was organized by Sarah Kaplan, Assistant Professor of Management at the Wharton School, University of Pennsylvania, and Cyrus Mody, Program Manager for Nanotechnology and Innovation Studies at the Chemical Heritage Foundation.

Funding was provided by the Gore Innovation Case Studies Program at the Chemical Heritage Foundation and the William & Phyllis Mack Center for Technological Innovation at the Wharton School.

This event also benefited from the participation of the University of Pennsylvania Nano/Bio Interface Center.

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Overview of Key Insights

Since President Clinton announced its creation in 2000, the National Nanotechnology Initiative (NNI) and its counterparts around the world have held countless conferences, built a dazzling array of nanocenters, and published a forest's worth of reports. Still a great many skeptics—scientists and nonscientists alike—say that nanotechnology is hype and branding with little substance. They have a point; fads are as much a fact of life in science and science policy as in pop music and travel destinations. But even the most ardent skeptic must acknowledge that institutions such as the University of Pennsylvania's Nano-Bio Interface Center, built with $11.4 million from the National Science Foundation (NSF), give nanotechnology a tangible social reality.

This report was prepared by Sarah Kaplan and Cyrus Mody along with Hyungsub Choi, Senior Program Manager for Innovation Studies, Chemical Heritage Foundation, and Jody Roberts, Program Manager for Environmental History and Policy, Chemical Heritage Foundation; with the assistance of Joanna Radin, doctoral student in the Department of History and Sociology of Science, University of Pennsylvania, and Michael Tomczyk, Managing Director of the Mack Center at ehe Wharton School, University of Pennsylvania.

Of course, developments in nanotechnology since 2000 have not been limited to new institutional infrastructures. The critical features of consumer microelectronics continue to shrink (to well below the NNI's one hundred-nanometer upper bound); the lengths of manufactured carbon nanotubes continue to grow (to the point where they can be spun into fibers hundreds of meters long); and the life spans of organic light-emitting diodes continue to extend (to the point that they can now be found in cell phones, digital camera displays and even cutting edge televisions).

The number of consumer goods said to contain nanotechnologies, as listed in the Woodrow Wilson Center's Nanotechnology Consumer Products Inventory, has climbed to over six hundred.

Exotic nanoelectronics, such as spintronics and molecular electronics, are now officially part of the microelectronics industry's road map for the next decade.

And, in what could be a persuasive "killer app," the first nanotechnology-based cancer therapies are undergoing U. S. Food and Drug Administration clinical trials.

Nanotechnology is increasingly a part of our material culture. It has set down deep roots in academia, in industry, and in government.

In the United States alone some twenty-three federal departments and agencies participate in the NNI. Yet public opinion surveys show that relatively few Americans have heard of nanotechnology or have a clear sense of what it encompasses.

Many of those who are acquainted with the term take their ideas from television shows such as Star Trek and The X-Files, where nanotechnology usually means tiny robots infecting bloodstreams and wreaking havoc—exactly the image the NNI and other nanotech proponents wish to avoid.

The disconnect between "official" and popular views of nanotechnology is hardly unexpected, nor is it necessarily a bad thing. But nanotech proponents worry that this misalignment could spin into a widespread public condemnation of their field. They point to a "wow-to-yuck" trajectory in public perceptions of previous high-tech areas, such as genetically-modified organisms (GMOs) and nuclear power.

The NNI is worried enough about public perception that it has mandated that 4 to 5 percent of federal nanotechnology funding be set aside for research on nano's "societal dimensions" (ethical, legal, and social issues, or ELSI). Much of this money goes to research on environmental and toxicological effects of nanoparticles, but there is still a sizeable residue for work in sociology, economics, history, anthropology, political science, rhetoric, communications, and philosophy.

Despite this stimulus, the community of social scientists (and fellow travelers) interested in nanotechnology has grown quite slowly. The few community-building efforts that have taken place have been funded mostly by the NSF.

This means that scholars whose expertise is relevant to understanding nanotechnology, such as historians of microelectronics or sociologists of biotechnology, have not connected to the nano-studies community unless they received NSF nano funding. The predominance of the NSF in setting the nano-studies agenda has also raised questions about the neutrality of research in this area.

To help build connections within the nano-studies community, and to bring in relevant expertise from outside that community, the Wharton School at the University of Pennsylvania and the Chemical Heritage Foundation (CHF) organized a two-day Symposium on the Social Studies of Nanotechnology.

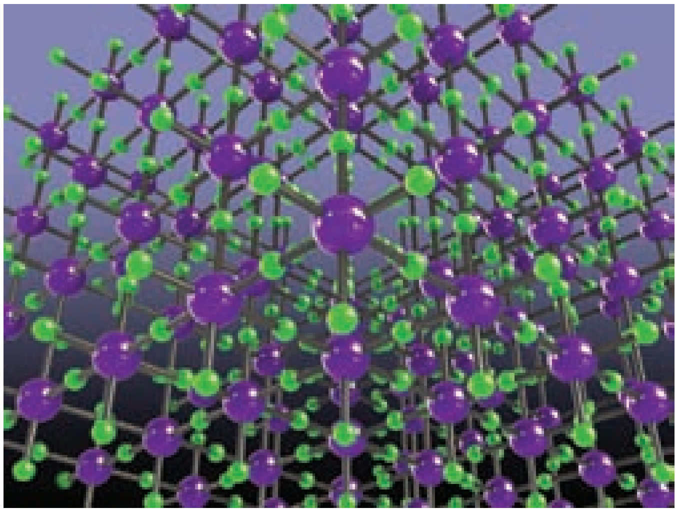
The first day, held at the Wharton School, offered an independent, closed forum where social scientists gathered to report their latest results and discuss future directions for research *[see Summary on Page 4]*.

The second day, held at CHF, was free and open to the public and offered social scientists a chance to make the case that their insights can shape nanotechnology to be more responsive to public needs. This public forum also allowed mixed panels of proponents and critics of nanotechnology, from industry, academia, government, and NGOs, to debate the place of social science in nano and answer questions from a large and inquisitive audience.

Two major questions confront the social scientist in dealing with nanotechnology. First, what is unique about nanotechnology such that it warrants attention from social scientists? Can the topic of nanotechnology be adequately dealt with using tools already developed by social scientists, or does the field require the development of new methods or theories?

Second, what can social scientists add to the conversation concerning nanotechnology? The social scientists gathered at the symposium represented a broad swath of the academy, including science studies, history, economics, anthropology, sociology, management, and media studies. Presenters and participants alike highlighted at least three themes in addressing why social scientists should be involved in nanotechnology.

Theme one: history matters. It is not always clear, however, which history is most appropriate. It has become commonplace to compare the development of nanotechnology to that of biotechnology. And indeed, as the participants noted, there are some striking similarities.



But telling the history of nanotechnology through the lens of biotechnology leads to a misunderstanding of the historical nuances that characterize nanotechnology, and it denies this budding field the autonomy to develop in a way that is distinctly not like biotechnology.

What are the alternative histories? One possible line traces the development of nanotechnology from silicon microelectronics as well as exotic offspring of silicon such as molecular electronics and spintronics. What can we gain from these alternative histories?

To begin with, we gain a better understanding of how nanotechnology came into being and the justifications offered for its existence. Clear-eyed history should be an integral part of nanotechnology's making itself transparent and credible to the public. But more importantly these perspectives on the past provide an opportunity to evaluate nanotech in its own right. Insights about what has worked and what hasn't can help direct the development of nanotechnology in the future.

Theme two: organization matters. Here, again, the analogy to biotech sometimes clarifies, sometimes obscures our understanding of nano. Like biotechnology, nanotechnology is taken to be at the forefront of a new wave of technologies that will alter the fabric of society. But the infrastructure of nanotechnology has many features that do not resemble biotechnology.

Unlike biotech, the formation of regional nanotech clusters is a purposeful, policy-driven process combining heavy government funding, venture capital, and already existing regional strengths.

Because nanotechnologies are an amorphous category—encompassing anything from drug delivery devices to sunscreens to textiles—sites of nanotechnology innovation and development have distinctly local flavors.

Old models of organizing research in this area, like road maps or clusters, are thus proving difficult to use and apply. In addition to the products and processes that nanotechnology enables, it may also be providing a new model for organizing research.

Theme three: relationships with the public matter. Perhaps the biggest reason nanotechnology is compared to biotechnology is the perceived risk of the wow-to-yuck phenomenon. Whether or not this transition actually occurred during the development of biotechnology is irrelevant: the concept has those working in nanotechnology (and those funding them) treading carefully and seeking ways to mitigate public concerns sooner rather than later. But for all the supposed attention, particularly in the form of ELSI funding opportunities, determining how and what and to whom to communicate continues to be a vexing set of problems.

Planning the Future. Three plans of action emerged from this discussion that suggest the role of social science scholarship in the ongoing evolution of nanotechnologies.

First, nano researchers need to discuss the real benefits and potential drawbacks of nanotechnology with the public.

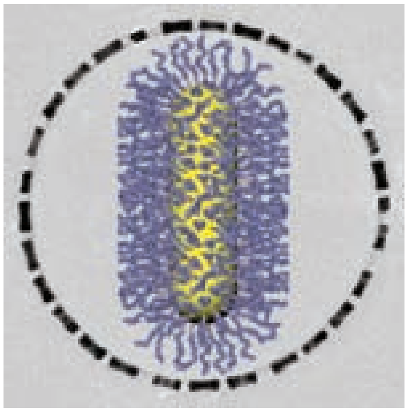
Second, rather than simply inundating a monolithic public with facts, scientists can attempt, via forums like science cafés, to allow different sectors of the public to push back and inform scientists' views.

And third, public policy, acting as a voice and vehicle for the people, can shape where and how nanotechnologies develop. Theoretically all three strategies are viable, and some are actively being pursued. But researchers in the field have not always been successful in the communications arena.

Engaged social science scholarship will prove crucial to the further development of nanotechnologies by examining why some members of the public may have anxieties, exploring the real and the possible consequences of nanotechnologies, and finding the best ways to communicate about those consequences.

This important—and perhaps critical—work in the social sciences can only happen, though, with funding to support independent research. In the United States, social studies of nanotechnology have largely been funded by the NSF and have largely focused on universities that have a nanotechnology center or institute.

Two main routes exist for this funding. First the NSF has tried to seed specialized groups of scholars interested in nano studies. Immediately after creation of the NNI in 2000, the NSF funded an interdisciplinary team of historians, philosophers, anthropologists, and artists at the University of South Carolina and a smaller group of economists and sociologists at the University of California, Los Angeles.



In 2005 the NSF funded a Network for Nanotechnology in Society with two dedicated centers: one at the University of California, Santa Barbara, focused on historical context, risk perception, and global diffusion of innovation; and one at Arizona State University focused on public perception and engagement and mapping nanotechnology research and development.

At that time the NSF also extended its support for the South Carolina and UCLA teams (the latter now partnered with Harvard University).

Each of these four nodes collaborates extensively with researchers at other universities, such as Duke University and the University of Wisconsin and at NGOs, such as the Woodrow Wilson Center.

In addition smaller groups of social scientists are increasingly teaming with engineers and natural scientists on grants sponsored by the NSF and, to a lesser extent, by the National Institutes of Health and the Department of Energy. These projects tend to focus on public outreach or measurement of public perceptions. Their findings are (in theory) coordinated and distributed through the National Nanotechnology Infrastructure Network, headquartered at Cornell University.

Finally, it should be noted that the field of nano studies is in many ways more advanced in Europe than in the United States. The European Union has given practicing social sciences and humanities scholars far more substantial opportunities to influence policy. For example, in 2004 the European Commission published a report on Converging Technologies—Shaping the Future of European Societies written by Alfred Nordmann, a philosopher of nanotechnology (summarizing the recommendations of a High Level Expert Group of social scientists and humanities scholars) to guide EU member states in crafting science policy. Several of those member states, including Britain, France, the Netherlands, Germany, Denmark, and Sweden, have funded important projects in both public engagement with nanotechnology and social science research on nanotechnology.

In general these projects have a more qualitative and participatory direction than equivalent efforts in the United States: a greater emphasis on citizen's juries, for instance, rather than opinion surveys and more focus on ethnography in place of scientometric mapping.

Summary of a conversation among social science scholars studying nanotechnology

The first day of the two-day symposium was a closed meeting of scholars sharing the latest developments in social science, history, and communications studies of nanotechnology. The goal of the dialogue was to understand what is unique about nanotechnology such that it warrants special attention from social scientists and what research on other technologies might be helpful in understanding the social, economic, and political dynamics associated with nanotechnology.

As Sarah Kaplan (University of Pennsylvania) pointed out, because of the substantial funding for Ethical, Social, and Legal Implications (ELSI) of nanotechnology included in National Nanotechnology Initiative (NNI) guidelines, social scientists are being involved in the development of nanotechnology in much earlier stages than was the case for many of its antecedents.

Therefore, social scientists need to be reflexive about their role. The nanotechnology field is presently unfolding, and social scientists are studying it as it emerges, without the benefit of the post hoc view. This has important methodological and political implications.

- In a discussion of the analogies and genealogies of nanotechnology, Hyungsub Choi and Cyrus Mody (both of the Chemical Heritage Foundation) traced the origins of nanotechnology to the institutional dynamics of the semiconductor industry. Marie Thursby (Georgia Institute of Technology) found that biotechnology may not be the perfect analogy for understanding patterns of innovation in nano.
- Evidence from the exploration of specific nanotechnologies shows that innovation pathways are shaped by social processes. Patrick McCray (University of California, Santa Barbara) noted that emerging fields of nanotechnology, such as spintronics, can radically change trajectories once incorporated into industry planning procedures such as the Semiconductor Roadmap. Michael Lounsbury (University of Alberta) showed how the patenting process and associated patent classification system shaped the ways technologies such as carbon nanotubes were understood and, therefore, how they evolved.
- Scholars are also examining the role of the government and various publics in shaping the evolution of nanotechnologies. Ann Johnson (University of South Carolina) argued that the federal NNI program is an attempt to force a top-down planning process on the development of nanotechnologies, the result of which is a new hybrid between top-down and bottom-up processes of innovation. In the meantime, as Dietram Scheufele (University of Wisconsin) made clear, this governmental funding is happening in the absence of much coherent understanding of nanotechnology on the part of the public.

The following discussants from the fields of history, economics, sociology, the social studies of science, communications, and materials science introduced provocative views from their studies of other technological fields: Dawn Bonnell (University of Pennsylvania), Ruth Schwartz Cowan (University of Pennsylvania), Rebecca Henderson (Massachusetts Institute of Technology), Tim Lenoir (Duke University), Bruce Lewenstein (Cornell University), Susan Lindee (University of Pennsylvania), David Mowery (University of California, Berkeley), Jason Owen-Smith (University of Michigan), and Trevor Pinch (Cornell University).

The day's discussion problematized a number of assumptions being made in nano science and technology. For example, scientists and firms speak of attempts to avoid the mistakes of GMOs (genetically modified organisms) or stem cells and apply the lessons of successful technologies such as the Semiconductor Roadmap. But it is not clear which analogies are useful, especially since nanotechnologies cut across so many technological fields.

It is also apparent from historical studies that the origin of nanotechnology is neither as new nor as singular as we think. The path can be traced back to technologies such as carbon black, which has been in use since the nineteenth century, and more recently to offshoots of microelectronics such as spintronics and molecular electronics. Social science can help us understand which versions of the past can help us think about the future.

Summary of the Public Symposium

The focal point of the public symposium was the interaction between social scientists (historians, sociologists, economists, rhetoricians, communications scholars, philosophers, and anthropologists) and stakeholders (federal funding and regulatory agencies, private foundations, NGOs, large corporations, small start-ups, venture capital firms, and regional development offices). This format allowed nano-studies scholars to interact with nano practitioners and with an audience of interested citizens.

The event began with a keynote address by Vicki Colvin, a distinguished nano scientist and director of the Center for Biological and Environmental Nanotechnology at Rice University. Colvin offered the natural scientist's perspective on the social implications of the development of nanotechnologies, including both potential risks and possible contributions to society. She observed that many key technological innovations involve both wow factors and yuck factors.

At this initial stage of nanotechnology, she emphasized, both natural scientists and social scientists are presented with a unique opportunity to shape future developments, mitigate potential risks, and seek to avoid yuck factors as the technology matures. Colvin's solution is open information, both in discussing potential risks and in considering the technical content that might solve critical social problems.

The remainder of the symposium was organized in panel discussions around three themes: risk and risk communication, interaction and communication with the public(s), and funding and economic development. The speakers came from a variety of backgrounds—academia, government, NGOs, and corporations—collectively covering a broad range of topics surrounding these themes.

The first panel (Risk and Risk Perception) explored the factors underlying public perceptions of nanotechnology risks. The character of nanotechnology as emerging technology poses both opportunity and challenge. The challenge is designing policy measures to mitigate risk when both the scientific knowledge and public awareness are frequently nascent. The second panel (Interaction and Communication with the Publics) was intimately linked with the first, since risk is the central concern in public engagement. An important hindrance in engaging the public with nanotechnology, according to the panelists, is the term nanotechnology itself. The gap between the precise definition of nanotechnology in technical circles (as codified by the NNI) and the more fluid notion in wide public circulation impedes policy making. The last panel (Funding and Economic Development) revolved around the hope (or hype?) that nanotechnology will open up new economic opportunities. Although the technology might be relatively new, the panelists generally agreed that past experiences in commercializing high technology, such as semiconductors and biotechnology, contain valuable lessons.

As all good discussions go, the Joint Wharton-CHF Symposium on the Social Studies of Nanotechnology yielded more questions than it could answer. How can the government and industry make policy for something about which the science is still uncertain and the public is still largely in the dark? What are the most effective means to engage the public in issues surrounding nanotechnology? What lessons can we learn from electronics and biotechnology clusters in Santa Clara, Boston, and San Diego? What would be the most effective model for innovation in nanotechnology? These questions require more extensive and focused scrutiny.

While the symposium's discussions only scratched the surface of this rich set of questions, they have hopefully provided a starting point for future conversations between natural scientists and social scientists over various issues surrounding nanotechnology. As Colvin's keynote address made clear, we are facing an opportunity of historic proportion. Continued conversations among stakeholders and scholars from diverse backgrounds will help shape the future direction of this emerging technology.

What follows is a summary of the discussions during the public symposium. We hope that the questions raised during the symposium will catalyze further explorations of the many issues surrounding nanotechnology.

Summary of Keynote Address

Eco-Nano: Can an Emerging Technology Develop Without the Yuck Factor?

Vicki Colvin, Director, Center for Biological and Environmental Nanotechnology and Professor of Chemistry and Chemical Engineering, Rice University

The twentieth century saw the marriage of science and industry, which significantly increased the rate of technological change. Throughout the century, dazzling new technological innovations brought many benefits to human society. For example, new pesticides contributed to the vast improvement in crop yields; semiconductor chips made possible more efficient communication; and deeper understanding of genetics allowed for the artificial production of insulin. It is this wow factor that drives scientists and engineers in their search for new knowledge.

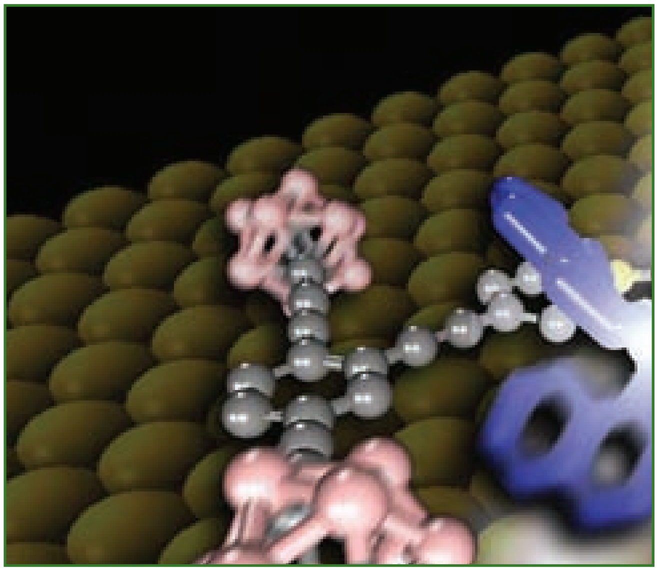
Not all technological innovations, however, have been embraced with unbridled enthusiasm. There are several reasons behind the resistance to new technology. Some technologies are resisted because they undermine vested interests: as economist Joseph A. Schumpeter pointed out, innovation inherently involves "creative destruction." Other technologies, such as synthetic chemistry and GMOs, have been the target of intense scrutiny and suspicion because of fears about their material and symbolic impacts on the human experience.

Many new technologies contain both the wow factor and the yuck factor. DDT, for example, helped fight mosquitoes during World War II, greatly reducing the spread of malaria, typhus, and other insect-borne diseases. On the other hand, this new synthetic pesticide has proven toxic to animals and humans.

Crops can be genetically engineered for drought resistance, but these techniques raise concerns about contamination of native species. Many new technologies of the twentieth century have made this transition from wow to yuck in their lifetimes, often triggered by a major crisis that in turn affects public perception.

Although nanotechnology is a new technology with tremendous promise, it has already garnered several perceived yuck factors. Michael Crichton's novel *Prey,* for example, introduced the public to a particularly dystopian nanotechnology scenario involving the proliferation of "grey goo." And in the real world journalists have begun to raise early-warning signals about engineered nanomaterials as potentially hazardous to human health.

It is important to note here that the yuck factor is not confined to the fear of unintended consequences of new substances. Control issues and social justice issues must be considered, too.



While it might be true, to quote Thomas Friedman, that the "world is flat," new technologies can be a potent force in perpetuating existing global inequalities and creating new ones.

Nanotechnology is still a nascent technology and has not yet experienced a major crisis, as some twentieth-century technologies have. Public perception of nano is still in its formative stages. These conditions present a unique opportunity for both natural scientists and social scientists to help nanotechnology develop without the yuck factor.

The key to this challenge is open information. In the last century, there was a tendency to avoid talking about the risk involved in the introduction of a new technology. Yet discussing known and potential risks in an open manner should be an integral part in the engineering and design of new nanomaterials, as well as in the use of naturally occurring nanomaterials. The latter are, in fact, surprisingly widespread.

Image Credit: T. Sasaki, Rice University

Sunscreens, for example, have long used nanoparticles of zinc oxide and nanoscale titanium to protect the skin from sun exposure and to prevent skin cancer.

Research has shown that some of these materials can have a striking biological impact. However, the existing regulatory framework does not mandate that manufacturers disclose the size of the materials used, making it virtually impossible to discern from ingredient labels whether a product contains nanomaterials.

It would be beneficial to inform the public of these facts, come up with new solutions that can remove potential risks, and try to engineer safe nanoparticles beginning with the design phase. We might call this principle "safety by design."

Open information is also critical for social and economic justice. For example, researchers at Rice University have been working on the use of nanoparticles to absorb arsenic from drinking water supplies.

Nanoscale iron oxide absorbs arsenic efficiently, but in many countries implementing the process is either too expensive or technically impossible. The Rice researchers realized they could use magnetic filtration for nanosorbents, which, at the small-size range, could pull out unsafe particles with a handheld magnet *(see accompanying image)*.

The "recipe" to make nanoscale magnetite can be posted on the Web, allowing the technique to be distributed to many villages and used by any individual with modest means in a regular kitchen setting.

This solution might be called "open-source nanotechnology," to quote anthropologist Christopher Kelty: the interaction between natural scientists and social scientists throughout the development process led to a sustainable and just outcome.

Public engagement with nanotechnology will be essential to avoiding the yuck factors related to toxicity and social justice. Natural scientists should provide the public with high-quality technical data. The design, implementation, and deployment of new nanomaterials, however, will benefit from close collaboration between natural scientists and social scientists.

The integration of social science and natural science for an emerging technology like nano in the twenty-first century should be done better and more extensively than for the emerging technologies of the twentieth century.

Panel 1

Risk and Risk Perception

Panelists:

Jaydee Hanson, Program Director, International Center for Technology Assessment

Evan Michelson, Research Associate, Project on Emerging Technologies, Woodrow Wilson International Center for Scholars

Clark Miller, Coprincipal Investigator, Center for Nanotechnology in Society, Arizona State University

Vladimir Murashov, Special Assistant to the Director, National Institute for Occupational Safety and Health

John Trumpbour, Research Director, Labor and Worklife Program, Harvard Law School

Moderator: Sarah Kaplan, Assistant Professor of Management, The Wharton School, University of Pennsylvania

Risk is usually cited as the issue most likely to stir public resistance to nanotechnology. Yet we know little about the underlying politics and economics that shape public perceptions of nanotech risks. This panel discussion highlighted the multifaceted nature of the potential risks associated with nanotechnologies and the complexity of managing and regulating them.

The most oft-cited concern is potential toxicity from ingestion or exposure to nanoparticles. We are still in the early stages of understanding such toxicological implications.

A lot of the discussion so far has been focused on the very small size of these particles and their potential ability to move through membranes and lodge in the body. However, some studies suggest that issues of solubility may be more important.

The challenge of understanding the risks of something that is hard to measure or characterize underlies these concerns. For instance, it is not known whether certain nanomaterials could compromise fetal development, and the tools and techniques needed to approach this issue are not yet available.

Another challenge is not knowing which products actually utilize nanotechnologies. Over 600 consumer products claiming to be based on nanotechnologies have been catalogued, but if manufacturers do not label their products then neither consumers nor regulators are aware of any nanotechnological content. This problem is likely exacerbated when it comes to industrial products not intended for direct use by consumers.

It is also made difficult by the fact that there is still little agreement about what counts as nanotechnology. It is important to point out that the problems of toxicity and exposure are not just of concern to the consumer but also to the scientist or worker involved in developing or manufacturing the products.

Many questions remain about which safety precautions might be necessary or if existing technologies to protect workers would be adequate when there is a potential for exposure to nanoparticles.

In addition to health and safety concerns, nanotechnologies may have other consequences for the public and for the workforce. For example, if nanotechnologies enable the development of a new type of house paint that lasts five times as long as other paints, the implications for people making their living painting houses is dire.

Therefore claims about job creation that could result from new nanotechnology industries should be viewed with caution. Nanotechnology may create some jobs and eliminate others.

The question is whether the workforce has or will have adequate training to take on the new jobs that will open up.

On the other hand, nanotechnologies may actually help manage other risks that exist today or might emerge in the future. For example, a nanodetector for avian influenza is currently under development, and the NIH is putting a lot of money into research and trials for nanotechnology-based cancer cures. The bottom line is that nanotechnologies come with benefits as well as risks. Therefore, regulation of these new technologies should be done with care so that society can claim the advantages while minimizing the disadvantages.

Regulatory or policy response to the emergence of this new technology is complicated by the fact that most consumers and workers have limited awareness of nanotechnologies. If the public is not engaged in the issue, there will not be enough support for the kinds of changes that might be required to regulate the risks. But awareness of technological risks often comes only after some kind of crisis (e.g., Love Canal and Three Mile Island).

Fortunately, the nanotechnology field has not had this kind of catalyzing event. The challenge is to understand how to create enough public interest in developing responsible policies before a crisis forces awareness.

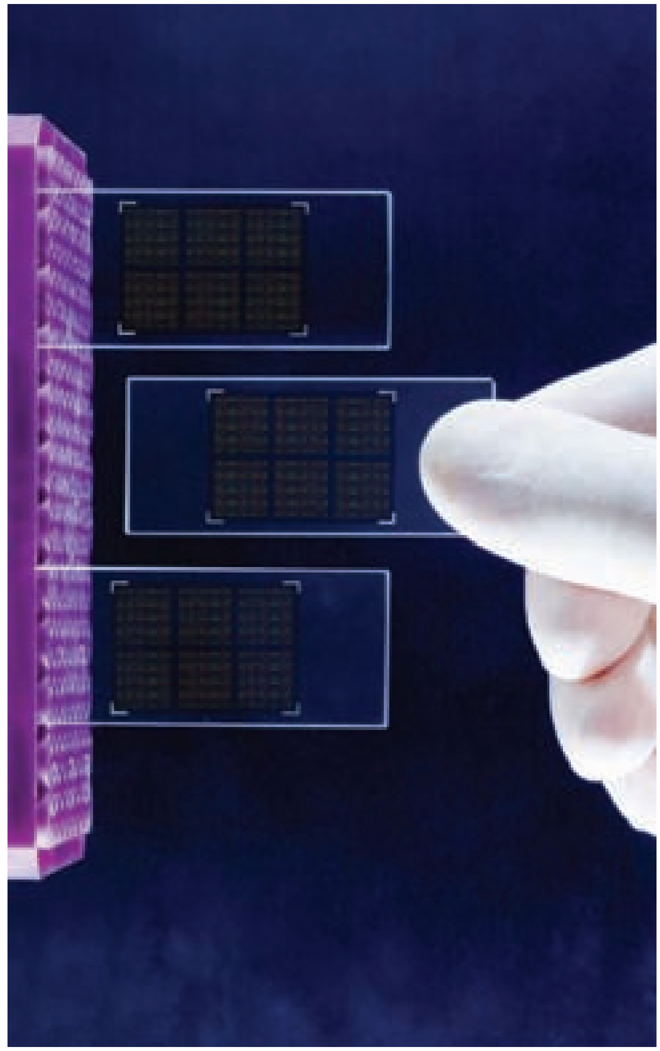
Because nanotechnologies cross many different kinds of technologies and industries, a regulatory response will also have to cross many different agencies and regulatory bodies. There will not be only one regulatory framework, and it is possible that the existing regulatory system may not be adequate for these new technologies. As a result, the regulatory framework for nanotechnologies is emerging much more slowly than the technologies themselves, and the mismatch may create problems.

The involvement of the activist community will be critical in shaping the response to nanotechnology risks. Examples of successful coping strategies used with other issues that affect public health and safety, such as the AIDS pandemic, indicate that change happens when activists protest and engage in dialogue with industry and governmental actors.

The lessons learned from these cases suggest that new models for working with industry may be most appropriate in highly uncertain settings such as emerging nanotechnologies. DuPont's recent partnership with Environmental Defense to develop a voluntary framework for production and disposal of nanomaterials may be a model for future approaches to risk in this arena.

The discussion during this segment of the symposium identified several challenges related to nanotechnology risks that require further inquiry amongst scientists, social scientists, managers, and policy makers, including:

- How can we think about the balance of benefits and risks of nanotechnologies? If something has important benefits, how to account for the risks that might also be entailed?



- How can the government and industry make policy about something about which the public is not very aware? Can we develop communication strategies that help the public and workers engage in a meaningful way in the dialogue about risks and regulation?
- How can the government and industry make policy about something when the science is still uncertain and the risks often cannot be measured or characterized?
- How can we understand whose interests are served by particular policies? How can these different interests be made visible to the public and policy makers in such a way as to ensure a balanced outcome?
- Can the existing regulatory framework (the agencies, law-making bodies, associations, and other actors) accommodate the risks posed by nanotechnologies? If not, what should new, innovative approaches look like?

These are a few of the thought-provoking, researchable issues that came from this panel discussion.

Panel 2

Interaction and Communication with the Public

Panelists:

Ivan Amato, Managing Editor, Chemical & Engineering News

Barbara Karn, Office of Research and Development, Environmental Protection Agency

Frederick Klaessig, Technical Director, Aerosil and Silanes, Degussa USA

Matthew Nisbet, Assistant Professor, Communication, American University

Chris Toumey, Research Associate Professor, University of South Carolina NanoCenter

Moderator: Cyrus Mody, Program Manager for Nanotechnology and Innovation Studies, Chemical Heritage Foundation

National and corporate policy makers are increasingly realizing that better, more transparent dialogue among government, industry, and the public is essential for building trust and inspiring a new generation of scientists and engineers. Issues of communication are intimately linked with those of risk and risk perception.

One of the greatest challenges associated with communicating about nanotechnology is the term nanotechnology itself. It is a monolithic and abstract term that covers a wide variety of technologies and ways of doing business. In addition, nanotechnology has become a convenient label for focusing funding (e.g., through the NNI) rather than for accurately representing the various technologies that receive that funding. Indeed the debate over the definition of nanotechnology continues unabated.

This lack of clarity impedes our ability to come to a decision about the level of caution we are comfortable with: it is difficult to formulate or communicate a notion of risk for a subject that is so amorphous. It also means that if one kind of nanotechnology experiences a safety crisis, the entire field might be adversely affected.

These factors are complicated by the fact that most nanotechnologies are in the very early stage of development. It is hard to communicate about technologies that are still at a nascent stage and therefore highly uncertain.

In addition, communication regarding a new technology such as nanotechnology involves multiple actors with a variety of agendas and many different audiences. So, for example, manufacturers want to communicate with policy makers to ensure favorable regulation, with consumers to assuage any concerns about risks or attract them to nanotechnology-based products, and with the workforce to attract them to build skills in this new arena.

Government departments, such as the Environmental Protection Agency, spend a large amount of time communicating with other agencies about opportunities and problems so that the appropriate bodies are making timely policies. They also develop communications to the general public (such as Web sites and white papers) to inform them of benefits and risks and to educators to prepare them to teach children about nanotechnology.

Scientists seek to communicate with policy makers in order to achieve favorable funding decisions. Journalists seek to uncover and explicate the hidden truths about the technology. Each case presents different communication challenges. The different actors engaged in communications bring different skill sets and motivations to the situation. Not all are trained in communication techniques, and most may not have time to learn these kinds of skills.

Perspectives on how ideas should be framed may differ. For example, scientists often want to be tentative or cautionary, but journalists, in an effort to attract a broad readership, may translate the ideas into a more active voice.

Scientists often do not want to talk to journalists because of this tendency; they are worried about how journalists translate what they say.

The field of science communications focuses on the need to communicate scientific ideas to the general public. The basic assumption is that public engagement with science is good, but in the case of complex and emerging nanotechnologies, the public may not be motivated to seek out or engage with information on the related benefits and risks.

Large-scale scientific literacy about nanotechnology may be unrealistic. Nanotechnology is not currently on people's minds in the same way that stem cells or global warming are. Most people do not have a sense of the ways that nanotechnology might affect them. It is often only crises that make people realize a technology is salient to their lives.

The question is how to achieve public awareness of nanotechnology without having a crisis. Better science and technology policy, established after due deliberation rather than in the crush of a crisis, can be accomplished only if the public (non-experts) are involved in working with the experts.

The difficulty lies in finding the right way to ensure public engagement. The University of South Carolina, among other institutions, is experimenting with a citizens' school for nanotechnology: a dialogue model of engagement, in which small group discussions are privileged over the use of mass media. Clear demand exists for such novel experiments in public engagement in nanotechnology.

While nanotech experts often complain about the large number of nanotechnology conferences, a show of hands at the Wharton-CHF symposium indicated that over half the audience were attending their first meeting on nanotechnology. This implies that even more efforts at communication must take place to begin to reach a broad cross-section of the public.

One potential solution would mimic Al Gore's strategy with regard to the environment. Following the success of his movie, *An Inconvenient Truth,* Gore is now training 1,000 "inconvenient truth ambassadors" to engage the public in dialogue on the issues. This "each one teach one" model may be more effective than broadcasting messages through mass media.

The NSF is also developing modules for use in K–12 education so that young people can begin learning about nanotechnology very early, a process which may prepare them for careers in the field and help them understand public health and safety issues. While it is certainly useful for nanotechnologists in government, industry, and academia to design improved Web pages and fund public relations efforts, the public-engagement and dialogue models may ultimately be more effective in getting the public to believe and approve what it hears about nano. On the other hand, mass media can be very powerful in shaping public perceptions. The example of *An Inconvenient Truth* shows how even an old-fashioned documentary can rapidly raise the visibility of an issue.

Most messages about nanotechnology have been communicated through popular fiction, such as Michael Crichton's *Prey.* These fantasies, while entertaining, may spread ideas about the technology that are not accurate. Many people who support nanotechnology (manufacturers, scientists, etc.) may regret that fictional works are a major source for popular beliefs about the potential of nanotechnology. Yet fiction may serve to sensitize the public to potential risks and may motivate citizens to engage with nanotechnology-related issues. Either way, the influence of fictional and nonfictional accounts in the mass media cannot be ignored in understanding how the public comes to see the benefits and risks of nanotechnology.

The discussion during this segment of the symposium identified several challenges related to communicating with the public about nanotechnology that require further inquiry amongst scientists, social scientists, managers, and policy makers. These include:

- What are the most effective means to engage the public in issues surrounding nanotechnology? While dialogue or educational models of interaction may be effective, can they be scaled-up to address a large enough group of people? How can we account for diversity of interests and views among groups? Will nanotechnology require new models for communication and interaction among scientists, government agencies, manufacturers and the public?
- Should scientists engage with the public? If so, how? Would it be useful or effective to train scientists in communication techniques?
- Can we understand how the motivations and interests of different actors may influence their communication goals and approaches?
- How can communication strategies be developed around a rapidly evolving and broadly defined set of technologies? Does the term nanotechnology help or hinder communication efforts?
- What is or could be the relationship between mass media transmission of ideas and more intimate models of communication through engagement? Under what conditions are these approaches either mutually reinforcing or at odds with each other?

Communication and interaction with a variety of publics pose a variety of challenges that would benefit from academic research and insight.

Panel 3

Funding and Economic Development

Panelists:

Martha J. Collins, Director, New Applications Research, Materials Research Center, Air Products and Chemicals

Roger Geiger, Distinguished Professor of Education, The Pennsylvania State University

Anthony Green, Vice President of Regional Technology Initiatives, Ben Franklin Technology Partners of Southeastern Pennsylvania

James Murday, Associate Director for Physical Sciences, Washington Office of Research Advancement, University of Southern California

Jan Youtie, Director, Program in Science, Technology, and Innovation Policy, and Principal Research Associate, Georgia Institute of Technology

Moderator: Nathan Ensmenger, Assistant Professor, History and Sociology of Science, University of Pennsylvania

Hopes run high that nanotechnology can create new economic opportunities, but many questions remain about the most effective models for innovation and the pathways to generating economic development and jobs.

It is important to note that the broad term nanotechnology does not hold any value; the value and the economic opportunities of nanotechnology will be linked to specific technologies and specific applications. Nanotechnologies will be used in many different industries (electronics, biotech, materials, etc.), and the patterns of economic development will be different according to the dynamics in each setting.

On the other hand, the term nanotechnology has been useful in focusing attention and resources from the federal and local government levels. Ideas about the potential benefits of nanotechnology have helped pique policy makers' interest in supporting funding efforts. Ideas about nanotechnology may also stimulate the public's interest in basic science and prepare a future workforce.

Nanotechnology initiatives have the potential to be like the United States' space program: a set of unifying ideas that can excite interest among many different stakeholders and thus spur investment in research, commercialization, and educational initiatives.

Indeed, the discourse surrounding the development of nanotechnology is similar to discourses surrounding the space program or the microelectronics industry: many see nanotechnology as an international race, with Brazil, Japan, Russia, Europe, South Korea, the United States, and many other countries or regions announcing big nanotechnology initiatives.

In the United States this battle is also being played out across states, with some states aggressively investing in nanotechnology and others making more modest commitments. In other high-tech industries, clusters or districts have proven to be productive of innovation and economic growth. Less is known about whether this pattern will hold true in the case of nanotechnology, though it appears that some clusters are already forming.

For example, in the United States, concentrated interests in nanotechnology exist in Silicon Valley and along Route 128 near Boston, and new geographic concentrations are emerging in the South and the Midwest, primarily around universities performing research in nanotechnologies.

One challenge in the development of nanotechnology is capital. Many observe a gap in capital available for small start-up companies.

The Small Business Innovation Research program can be helpful as a substitute for venture capital, but the program operates on the assumption of a linear model of technology transfer, which means more money is allocated for research than for commercialization. Other models may therefore be needed.

The role of large corporations in the development of nanotechnology should not, however, be neglected. Much of the research in the field is being done by well-established firms rather than start-ups. Big industry is not seen as needing funding, but corporations may need ways to share risk.

Some companies are beginning to experiment with approaches that would promote the development of nanotechnology through partnering. Many firms are increasingly using an open innovation model, bringing more ideas in from the outside through partnerships with universities, alliances with start-ups, and corporate-venture investing.

Another important challenge in the development of nanotechnology is the appropriate management of intellectual property (IP). Again, current models of obtaining and maintaining patents may not be useful in a multidisciplinary field like nanotechnology.

Some organizations are experimenting with new models for breaking down industry-institution barriers, such as starting an IP donation program (from large companies to small ones) and pooling patents from different institutions. The goal is to accelerate the rate of commercialization and to help firms avoid getting bogged down suing each other over IP.

Much of the economic development in nanotechnology will depend on the ability of the education system to train scientists to develop the technologies, workers to manufacture them, and consumers to understand and accept them.

The traditional disciplines of science are being blurred in the field of nanotechnology, which tends to be multidisciplinary. This has important implications for science education and worker training. For example, if engineering is a critical bridge between academic and industrial realms, then it may be the case that more attention to nanoscale factors should be built into education in engineering schools. Looking at nanotechnology through the lens of economic development may provide an opportunity to rethink science education.

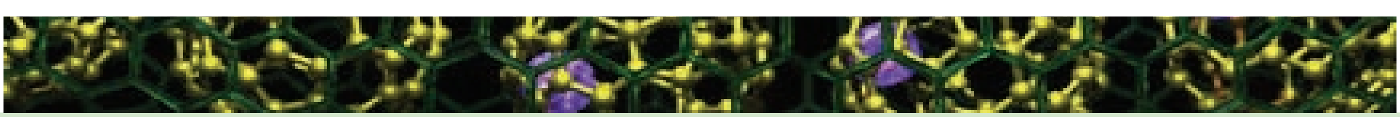
Finally, risk perceptions will affect what will be possible to commercialize and, ultimately, the trajectory of technical development in nanotechnology. If the challenges posed by risk perception and by communication with various publics are not met adequately, then economic development will be hindered.

The discussion during this segment of the symposium identified several challenges related to the role of nanotechnology in economic development that require further inquiry amongst scientists, social scientists, managers, and policy makers.

Fields of inquiry in the area of funding and economic development cover a broad range of issues:

- What is known about the national and regional benefits of past high-tech industries, and what lessons can they offer for nanotechnology? To what extent do the analogies from biotechnology or information technology apply in this new context?
- Will nanotechnology benefit from regional clusters or districts? And, if clusters form, will they work alongside clusters in other technical arenas, or will they form in new areas? To the extent that clusters are useful in nanotechnology, what is the best way to promote their formation?
- What are the most effective models for innovation? And how would these models affect incentives for innovation and commercialization? Is open innovation an approach that would be more applicable in nanotechnology? Is the linear model of innovation unhelpful in ensuring nanotechnologies are both developed and launched into the market?
- How can government policy most usefully support nanotechnology? What should be the role of government programs such as the Small Business Innovation Research program and other state or local funding initiatives?
- How can nanotechnology create jobs for local, regional, or national economic development? Is the education system preparing people for the kinds of jobs that will be created? If not, how should education be reconfigured to support nanotechnology-related economic growth?

The economic benefits and value from nanotechnology research and commercialization are just beginning to be realized. As nanotechnology continues its development, there will be intriguing opportunities for researchers to evaluate winning and losing strategies, and patterns of success and failure across industries.



Conclusion

The Wharton-CHF Symposium on the Social Studies of Nanotechnology showed that there is substantial interest in bringing social science perspectives into the nanotechnology enterprise. It was readily apparent to the academic researchers who met on the first day that the process of generating sound social scientific knowledge about nanotechnology is still in very early stages and that further community-building events are urgently needed.

There was also considerable agreement that many of the most useful and interesting insights of the day came from outside commentators who are not currently working on nanotechnology. Therefore any future events should be sure to include more of this non-nano expertise.

The public symposium on the second day demonstrated that a broad cross section of the public is hungry for information on nanotechnology as it relates to their lives. More than 150 people attended the event: real estate brokers, public transportation analysts, human resources consultants, freelance ethnographers, high school teachers—and, of course, representatives from government agencies, start-up companies, large chemical firms, environmental NGOs, and several universities.

What concerns most preoccupied this audience? In questions asked after each panel, and in follow-up e-mails and conversations, the audience most vocally expressed concern about nanoparticle toxicology. In different and sometimes contradictory ways, this concern was raised by ordinary consumers, practicing scientists, and industry representatives.

Even when panelists tried to raise awareness of nontoxicological risks from nanotechnology (e.g., economic disruptions), audience discussion still returned to the toxicological question, either raising concerns that nanotechnologies might be toxic or that the fear of toxicity might impede the further development of potentially beneficial technologies.

This observation highlights two key issues for future work in social studies of nanotechnology. First, social scientists need to contribute credibly to the debate about nano toxicology. Sociologically minded historians, for instance, need to offer detailed perspectives on past episodes of public skepticism about high-tech industries (e.g., GMOs, stem cells, nuclear power) that nanotech's proponents and critics gesture to in talking about nano toxicology.

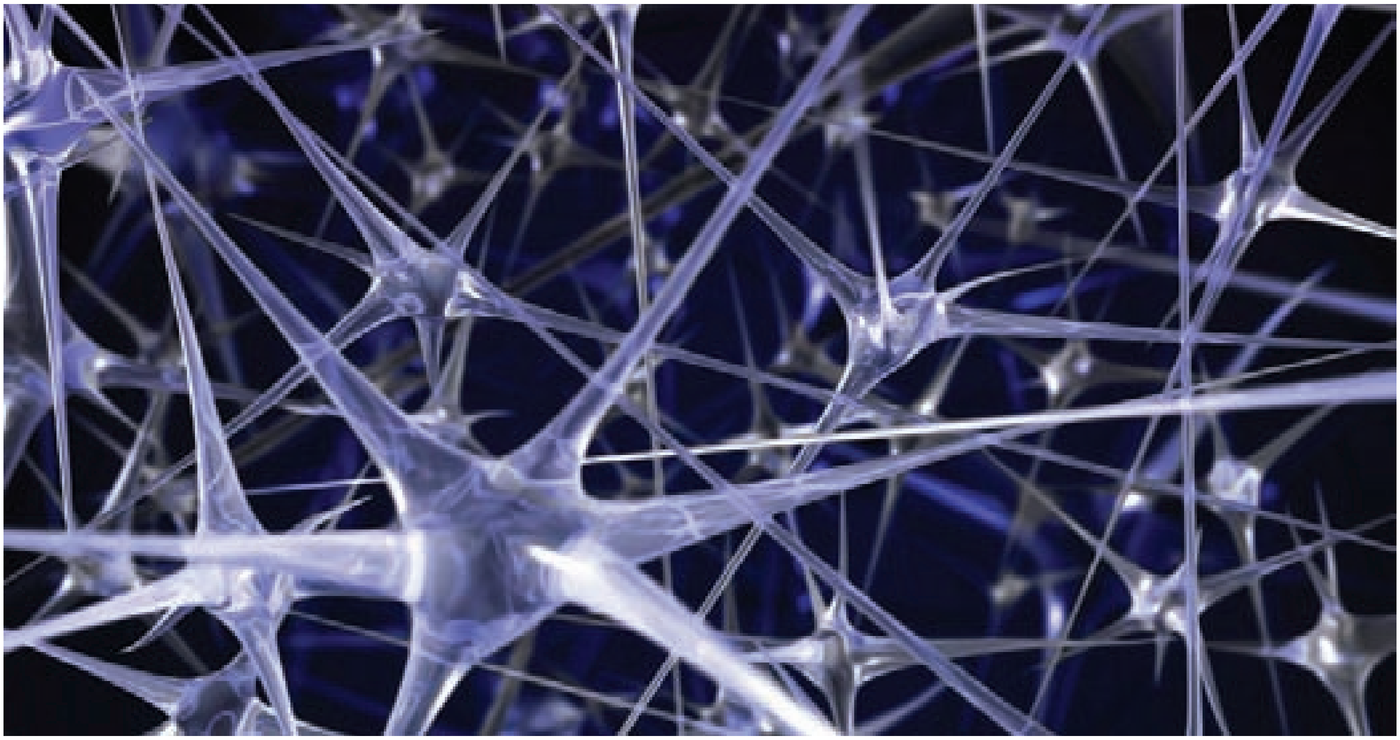
Was the GMO arc really one of wow to yuck? Was public skepticism about GMOs driven by toxicological and environmental risks or by underlying anxieties about globalization and economic concentration? What role did mistrust built up from previous episodes (e.g., hoof-and-mouth disease or mad cow disease) play?

Similarly richer quantitative studies of how the public perceives the toxicological risks and where they get those perceptions need to be developed. The majority of the surveys undertaken thus far have yielded unsurprising results: most members of the public know little about nanotechnology; knowing little they (quite reasonably) evaluate it in light of their attitudes toward high-tech fields they have heard of, or they evaluate nano blandly as medium risk, medium gain; background factors such as religion have an effect on public perceptions, but only a very small effect; and any negative reports on nano by journalists tend to be event driven (though the overwhelming majority of reports have been positive).

Social scientists, policy makers, and journalists have all tried to make recommendations based on these studies, but these recommendations seem premature. Further surveys that go beyond the obvious conclusions are called for.

What, for instance, is the role of class or race in shaping perceptions of nano? How do public perceptions vary by region or even locality? How, for instance, do people living in areas where old-line industries are dying or long gone feel about this new high-tech area? Both quantitative and qualitative data on how opinion makers shape public perceptions should be gathered.

Where do journalists' personal views come from? What constraints do they face in crafting stories? What are the actual conduits by which members of the public absorb information about nanotech from newspapers, science fiction novels and movies, and friends and neighbors?



Finally, rigorous economic analysis of the impact of public perception on industry is crucial. Nano proponents are clearly wary that a shift in public opinion will hurt commercialization of nanotech "just like with GMOs."

Of course, while the GMO controversy did hurt the European sales of companies like Monsanto, many GMO crops continued to thrive commercially in North America. If public opinion did shift against certain kinds of nano (nanoparticles in sunscreen, for instance) how would that actually affect commercialization of other kinds of nano (quantum dots for thermosurgery, for instance)?

But the conversation should not stop here. The second clear conclusion from these discussions is that social scientists need to argue more persuasively for the relevance of their expertise beyond the nanotoxicology issues.

Several panelists tried to introduce other issues in their remarks: economic disruptions from job losses due to nano (e.g., what do professional painters due when "smart paints" allow you to change the color of your walls with the flick of a switch); cultural shifts as nano opens up new practices and shuts down old ones (e.g., what do graffiti taggers do when nanocoatings prevent "defacement" of property); new pressures on long-held values (e.g., what happens to our universities as recipients of nanotech funding are under more and more pressure to commercialize their research); and new spins on old worries (e.g., how will nano-enabled gene chips affect the availability and use of personal medical information).

These issues matter, and there will likely come a point when they matter a lot. If the history of biotechnology has taught us anything, it is that public attention tends to shift from one facet of a high-tech field to another: from recombinant DNA to GMOs to stem cells to cloning. It is shortsighted to assume that the public will always be focused on nano toxicology. Moreover, it should be clear that such anxieties are never just about toxicology: underlying issues, such as corporate malfeasance or governmental transparency, must be addressed. Social scientists must cover the broad spectrum of nano issues, even—or perhaps especially—when their patrons or audiences would like them to focus on just one or two questions.

More than that, social scientists must find ways to study nanotechnology that benefit social science itself, instead of simply helping nanotechnologists check off boxes marked "societal dimensions" or "public engagement." And nanotechnologists must understand that social science research cannot simply be a means to promote their own scientific agendas.

Nano-social science must be good social science: it must be research that social scientists not interested in nanotechnology will find useful. It should also be social science that the researchers themselves are passionate about and find intrinsically interesting.

The cultivation of a vibrant and engaged community of social scientists is necessary for the development of sound research that can help to draw attention and understanding to the many questions still remaining in the world of nanotechnology.

* * *

Appendix I: Further Reading

Michael D. Cobb. 2005. "Framing Effects on Public Opinion about Nanotechnology." Science Communication, v27, n2, pp. 221-239.

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Arie Rip. 2006. "Folk Theories of Nanotechnologists. Science as Culture." Vol. 15, No. 4, pp.349-365.

Joachim Schummer. 2006. "Cultural Diversity in Nanotechnology Ethics." Interdisciplinary Science Reviews, v31, pp. 217-230.

John Trumpbour. 2007. "Technological Revolutions and the Limits of Ethics in an Age of Commercialization." In Nanotechnology: Societal Implications II, ed. Mihail C. Roco and William Sims Bainbridge (Dordrecht: Springer): pp. 113-121.

Appendix II: Agendas

Agendas for the Joint Wharton-Chemical Heritage Foundation Symposium on Social Studies of Nanotechnology

Included here are the detailed agendas for the Symposium including presentation topics and speakers for the academic session held at The Wharton School and the industry dialogue and panels held at The Chemical Heritage Foundation.

Symposium on the Social Studies ofNanotechnology - Academic Symposium

Agenda - June 7, 2007 (Hosted at the Wharton School, University of Pennsylvania)

Introduction to the Day

***Sarah Kaplan**, University of Pennsylvania*

Panel 1. Analogies and genealogies of nanotechnology (looking at microelectronics and biotechnology)

"Molecular Electronics and the Microelectronics Origins of Nanotechnology"

Hyungsub Choi** and **Cyrus C.M. Mody, Center for Contemporary History and Policy, Chemical Heritage Foundation*

"The Nanotech vs. the Biotech Revolution: Sources of Productivity in Incumbent Firm Research"

Frank Rothaermel** and **Marie Thursby, Georgia Institute of Technology*

Discussants:

***Tim Lenoir**, Duke University*
***Jason Owen-Smith**, University of Michigan*

Panel 2. Evolution of specific nanotechnologies (spintronics and carbon nanotubes)

"Following the Silicon Chip Road: Spintronics, Novelty, and Over-the-Horizon Technologies"

***Patrick McCray**, University of California, Santa Barbara*

"Structuring Intellectual Property: The Case of Carbon Nanotubes"

***Michael Lounsbury** and **P. Devereaux Jennings**, University of Alberta*

Discussants:

***Rebecca Henderson**, Massachusetts Institute of Technology*
***Trevor Pinch**, Cornell University*

Panel 3. Forces shaping nanotechnology evolution (the state, the publics)

"Top-Down Science: The Roles of Roadmaps in the Development of Nanotechnology"

***Ann Johnson**, University of South Carolina*

"Media, Science, and Policy: Examining Processes of Opinion Formation about Nanotechnology"

***Dominique Brossard, Eunkyung Kim, Dietram Scheufele**, University of Wisconsin and **Bruce Lewenstein**, Cornell University*

Discussants:

***Susan Lindee**, University of Pennsylvania*
***David Mowery**, University of California, Berkeley*

* presenter of the paper

Symposium on the Social Studies of Nanotechnology - Academic Symposium *(continued)*

Panel 4. Final panel: What Can the Social Sciences Bring to Nanotechnology? What Can Nanotechnology Bring to the Social Sciences?

Discussants:

Dawn Bonnell, *University of Pennsylvania*
Ruth Cowan, *University of Pennsylvania*
Bruce Lewenstein, *Cornell University*

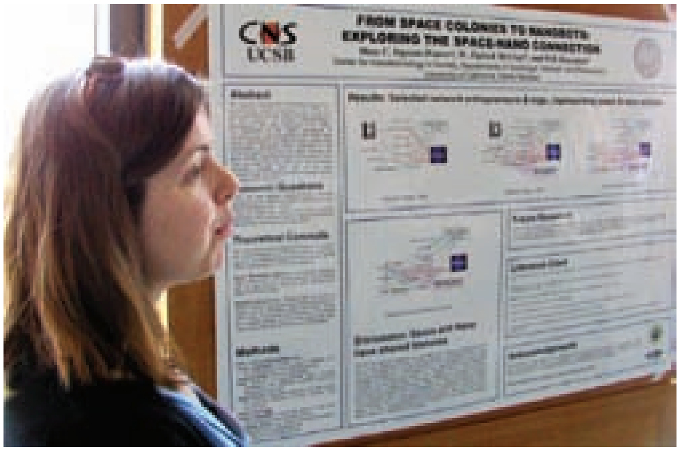
Poster Session

Poster presenters:

Augustin Cerveaux, *University of Strasbourg*
Nina Granqvist, *Helsinki School of Economics*
Mary Ingram-Waters, *University of California, Santa Barbara**
Byoungyoon Kim, *Rensselaer Polytechnic Institute*

Judges:

Hyungsub Choi, *Chemical Heritage Foundation*
Ken Colwell, *Drexel University*
Nathan Ensmenger, *University of Pennsylvania*



*Winner of Best Poster Award sponsored by the Nano-Bio Interface Center

Symposium on the Social Studies of Nanotechnology - Public Symposium

Agenda - June 8, 2007 (Hosted at the Chemical Heritage Foundation)

Keynote Address: "Eco-Nano: Can an Emerging Technology Develop Without the Yuck Factor?"

Speaker: ***Vicki Colvin***, *Director, Center for Biological and Environmental Nanotechnology, Professor of Chemistry and Professor of Chemical Engineering, Rice University*

Description: Nanoscientists have a unique opportunity to create the first technology that introduces a culture of social sensitivity and environmental awareness early in its life cycle. This can be accomplished if scientists and social scientists work together to continually query the ultimate value of nanotechnologies while actively collecting hard data on the impacts of nanomaterials.

Panel One: Risk and Risk Perception

Panelists:

Jaydee Hanson, *Program Director, International Center for Technology Assessment*
Evan Michelson, *Research Associate, Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars*
Clark Miller, *Coprincipal Investigator, Center for Nanotechnology in Society, Arizona State University*
Vladimir Murashov, *Special Assistant to the Director, National Institute for Occupational Safety and Health*
John Trumpbour, *Research Director, Labor and Worklife Program, Harvard Law School*
Moderator: Sarah Kaplan, *Assistant Professor of Management, The Wharton School, University of Pennsylvania*

Description: Toxicological risks from nanoparticles—and the public's perceptions of those risks—are usually cited as the issue most likely to stir public resistance to nanotechnology. Yet we know little about the underlying politics and economics that shape public perceptions of nanotech risks.

Panel Two: Interaction and Communication With the Public

Panelists:

Ivan Amato, *Managing Editor, Chemical & Engineering News*
Barbara Karn, *Office of Research and Development, Environmental Protection Agency*
Frederick Klaessig, *Technical Director, Aerosil and Silanes, Degussa USA*
Matthew Nisbet, *Assistant Professor, Communication, American University*
Chris Toumey, *Research Associate Professor, University of South Carolina NanoCenter*
Moderator: Cyrus Mody, *Assistant Program Manager for Nanotechnology and Innovation Studies, Chemical Heritage Foundation*

Description: National and corporate policy makers are increasingly realizing that better, more transparent dialogue among government, industry, and the public is essential for building trust and inspiring a new generation of scientists and engineers. Can social scientists facilitate that dialogue?

Panel Three: Funding and Economic Development

Panelists:

Martha J. Collins, *Director, New Applications Research, Materials Research Center, Air Products and Chemicals*
Roger Geiger, *Distinguished Professor of Education, The Pennsylvania State University*
Anthony Green, *Vice President of Regional Technology Initiatives, Ben Franklin Technology Partners of Southeastern Pennsylvania*
James Murday, *Associate Director for Physical Sciences, Washington Office of Research Advancement, University of Southern California*
Jan Youtie, *Director, Program in Science, Technology, and Innovation Policy, and Principal Research Associate, Georgia Institute of Technology*
Moderator: Nathan Ensmenger, *Assistant Professor, History and Sociology of Science, University of Pennsylvania*

Description: Hopes run high that nanotechnology can create new economic opportunities. What can social scientists tell us about the national and regional benefits of past high-tech industries, and what lessons can they offer for nanotechnology?

Sponsoring Organizations

Chemical Heritage Foundation

The Chemical Heritage Foundation (CHF) serves the community of chemical and molecular sciences, technologies, and industries, and the wider public, by treasuring the past, educating the present, and inspiring the future. Located in the Philadelphia historical district, CHF maintains world-class collections of historical instruments and apparatus, rare books, fine art, and personal papers of prominent scientists; encourages research in CHF collections; and carries out a program of outreach and interpretation in order to advance an understanding of the role of science and technology in shaping society.

Through its Center for Contemporary History and Policy (CCHP), CHF has worked to bring historical perspectives to pressing contemporary policy issues, exploring the complex interactions of science, technology, business regulation, and risk. Since its inception in 2004, CCHP has made efforts to integrate research on contemporary topics, policy studies, and long-range perspective in order to provide comprehensive and original approaches to policy-related topics. CCHP's current program areas include: biotechnology history and policy; environmental history and policy; chemical history of electronics; and innovation studies.

Activities of the CCHP Innovation Studies program include the annual Innovation Day and Warren G. Schlinger Symposium, co-hosted with the Society of Chemical Industry, America Section, which brings together chief technology officers and young industrial scientists from across the chemical sector to discuss diverse topics of interest; and the Gore Materials Innovation Case Study Project, which explores how the chemical and molecular industries have translated new ideas into marketable products during the past two decades. Through these initiatives, CCHP aims to provide an overarching bridge between theory and practice of contemporary technological innovation.

This symposium, presented jointly by the Gore Materials Innovation Case Study Project at the CHF and the Mack Center for Technological Innovation at the Wharton School, is designed to provide special insight in the field of science and technology, drawing upon the historical roots of chemical and molecular sciences, as well as in the emerging fields of today such as nanotechnology.

Mack Center for Technological Innovation

The William and Phyllis Mack Center for Technological Innovation provides research based guidance to firms in industries that are being created or transformed by radical innovation. The Center sponsors faculty research on patterns of success and failure across industries, as well as winning and losing strategies, and prospects for commercialization of emerging technologies such as biosciences.

The Mack Center is one of the Wharton School's leading research centers. Major research programs include the Emerging Technologies Management Research Program and BioSciences Crossroads Initiative.

Each year, the Mack Center sponsors ongoing research by Wharton faculty and Ph.D. students, and hosts insight-building events on cutting-edge topics involving technological innovation.

The research priorities of the Mack Center includes: Assessing New Technologies and Markets, Organizing for Technological Innovation, Managing Alliances and Acquisitions, Selecting and Valuing Innovation Systems and Portfolios, Technology-Enabled Business Transformation and Navigating the Unknown. Much of this research focuses on managing change under conditions of high uncertainty and risk.

Specific projects include the "Future of BioSciences" scenario project, which identifies critical factors that will influence commercialization of emerging life science and biomedical technologies. Wharton faculty sponsored by the Mack Center are also studying innovation ecosystems, metrics for tracking and analyzing innovation, and emerging global practices and strategies.

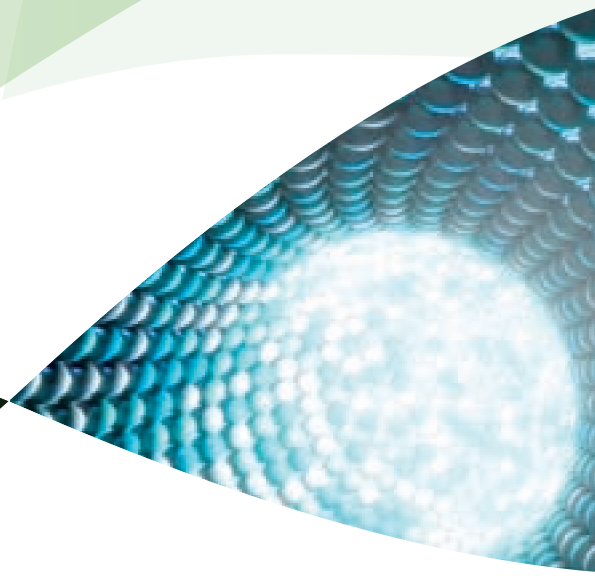
The insights developed from these activities help senior decision makers keep pace with rapid and ongoing innovation.

The Mack Center is guided by a core group of 12 senior faculty and staff, who work with our industry partners to identify topics of interest and concern to companies in many industries.

The Mack Center is a proud co-sponsor of this symposium, which has identified and explored a variety of critical issues in the emerging field of nanotechnology.

Chemical Heritage Foundation
315 Chestnut Street, Philadelphia, PA 19106
Phone: 215-925-2222 • Fax: 215-925-1954
www.chemheritage.org

William & Phyllis Mack Center for Technological Innovation
The Wharton School • University of Pennsylvania
3620 Locust Walk • 1050 SH-DH
Phone: 215-925-2222 • Fax: 215-925-1954
www.mackcenter.wharton.upenn.edu



CHEMICAL HERITAGE FOUNDATION

Gore Innovation
Case Studies Program

Wharton

William & Phyllis
Mack Center for
Technological
Innovation