Beyond Truth: Pleasure of Nanofutures

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Introduction

Ever since Ludwik Fleck's analysis of the role of popularization in the genesis of scientific facts, scholars have sought to explain the relation between science and the public in terms of truth, or the negotiation of truth (*e.g.* Shapin & Schaffer 1985; Latour 1987; Collins & Pinch 1998; & Shapin 1994). However, prompted by changes in the funding structures for science, researchers have themselves been turning away from a concern with truth, as in a scientific theory that matches the deep structure of the material world, and towards a concern with research relevant to a market. Along with this turn, the role of scientific discourse in the public sphere has changed. This paper probes pleasure as an appropriate conceptual term in addition to truth.

We should not be surprised by changes in the public sphere; Jürgen Habermas has shown it to have changed for centuries (Habermas 1989). I will discuss the changes taking place in the last few decades only. Habermas thinks in terms of human beings with differing standpoints who reach some level of consensus in the public sphere by actually communicating content to each other. The public sphere is a kind of forum where consensus is somehow reached with the use of reason. Pleasure is a decidedly non-rationalist aspect of the public sphere.

The linear model that has held sway for a long time after World War II is perhaps the most simplistic of all. According to this model, truth is created in the sphere of pure science and passed on to applied science and technology. Ludwik Fleck (1979) provided the first critique of this scheme involving a notion of feedback. Fleck used the terminology of the exoteric and the esoteric sphere, where the exoteric sphere is more public understanding of science than engineering—the point being that the esoteric sphere is not isolated. Fleck concerned himself only with this one boundary: between the inner sanctum of science and the outer lay world. However, Fleck was ignored until the 1970s when the linear model came under scrutiny. In Shapin's discussion of the public sphere, it was just this boundary of the expert and the layperson that was at issue (Shapin 1990). Since then Shinn and Whitley (1985) have denoted a more complex flow of information between various groups with various degrees of expertise that Bucchi (1998) has visualized. The funnel shape denotes theories and results being strengthened as they move towards the 'popular stage'—in Richard Whitley's terms:

> The more removed the context of research is from the context of reception in terms of language, intellectual prestige and skill levels, the easier it is for scientists to present their work as certain, decontextualised from the conditions of its production, and authoritative (Bucchi 1998, 12).

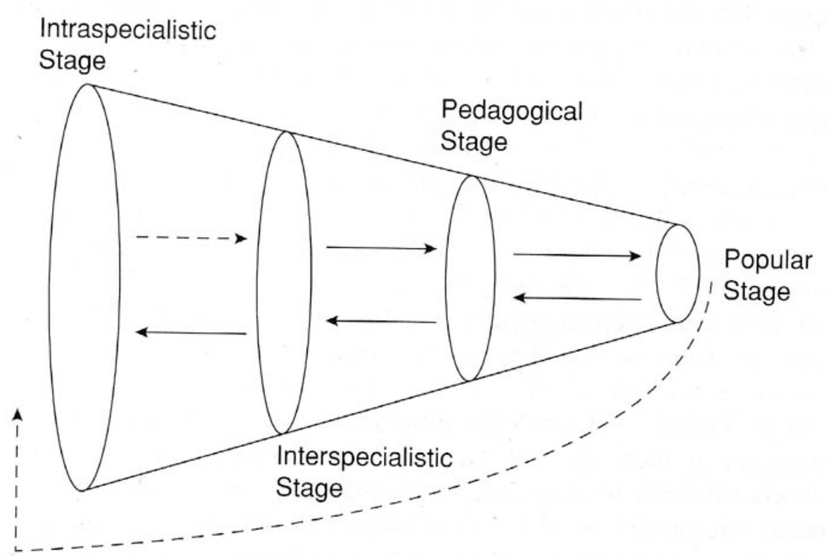

Figure 1: Bucchi's visualization of the public sphere

The intraspecialistic stage refers to specialist journals, such as *Physical Review*. The interspecialistic stage refers to journals intended for scientists from all disciplines, such *Nature* or *Science*. Textbooks constitute the pedagogical stage, and the popular stage might be thought of as TV programs, for example on the Discovery channel. Bucchi's main focus is on cases such as cold fusion, in which two researchers at the University of Utah held a press conference to announce their discovery, thus bypassing the intermediary stages (and thus also peer review) altogether. His focus is visualized with the bypassing large arrow.

Facts, truths, or knowledge is produced and passed around in this realm. It is clearly not just a one-way street going from the expert to the layperson. There is another large body of work that analyzes the way in which the expert's trustworthiness and credibility is built up, focusing on such issues as objectivity and authority. This was a major point of Shapin and Schaffer's *Leviathan* and it was taken up, for example, by Ted Porter's configuration of quantitative analysis as a technology of trust—a means of fortifying claims fending off charges of subjectivity or vested interest (Porter 1995). Daston and Galison (1992) have proposed a taxonomy of objectivity along with a periodization based on it. Hilgartner has focused on the important role of staging for the establishment of trustworthiness, in the process bringing together an increasing amount of literature on staging science. He analyzes science advisors' self-presentation and convincingly argues that "the theatrical perspective offers a means to examine how credibility is produced in social action, rather than treating it as a pre-existing property of an advisory body" (Hilgartner 2000, 7). This is a topic that Iwan Morus has devoted much attention to (Morus 1998). It is important for such experts to convey a good impression of their integrity and moral character in order to persuade.

All these studies are indispensable for our understanding of the role of science and the public sphere. It may well be that in the post-war period when the linear model held sway and professionals were generally revered, there was no need to consider other questions than the truth, and the trustworthiness of those who speak authoritatively about it. But in the last few decades the emphasis in science funding has moved away from a concern with filling in gaps of knowledge to the production of knowledge that is worthwhile or serviceable (the latter is Sheila Jasanoff's term). Knowledge has become more of a means to an end and less of an end in itself. This has put much more pressure on accountability. How does one ascribe value to research when the value only becomes visible at the end of a 20-year long commercialization process subject to the vagaries of the market?

Adapting to such funding realities, some scientists have turned to hype. The tremendous amount of hype surrounding nano or genomics is at least as important a part of science and the public sphere as the truth discourse is. None of the above authors pay attention to hype. I will argue that in addition to persuasion, and even suasion, science in the public sphere features also the feeling of exhilaration. This is not an indictment of scientists engaged in hype—after all they are only playing their cards well in the new game of science funding—it is merely an argument that while the truth discourse may have been appropriate at the time of the linear model, it is now wide of the mark.

Barthes' discussion of "writerly" and "readerly" texts may serve as a heuristic. Barthes discusses both texts for passive consumption and texts that stimulate the reader's active participation. The former may prompt pleasure (*plaisir*) and the latter a form of exuberant joy (*jouissance*). *Jouissance* calls up a violent, climactic bliss closer to loss, death, fragmentation, and the disruptive rapture experienced when transgressing limits, whereas *plaisir* simply hints at an easygoing enjoyment, more stable in its reenactment of cultural codes (Barthes 1975, esp. page 4). Barthes' *jouissance* may well resemble the feeling of exhilaration prompted by nanohype. But my main point is that pleasure, in all its shades, may be found in scientific texts—and also in images—and that it matters for the topic of science and the public sphere. It is not just about the fact-truth-knowledge-authority-expertise-objectivity-disinterestedness-credibility complex, but emphatically also about exhilaration, pleasure, hopes and fears.

A Case Study: From Surface Physics via CAMP to inano

Scientific texts and images are intended for specific audiences. Some audiences are homogeneous, for example those addressed in a textbook or at a specialist conference. Other audiences are more heterogeneous. Scientists sometimes address newspaper readers that might include scientists in neighboring scientific disciplines, high school students contemplating a scientific career, decision makers in funding agencies and tax-payers.

I will analyze the publications of a scientific group in the Physics Department of the University of Aarhus, in Denmark. This Danish group is interesting because it exemplifies the changes of science in the public sphere in the last few decades—to the point where all of Bucchi's stages are involved. The main character in the plot is Flemming Besenbacher, an entrepreneurial professor of physics at the University of Aarhus. He sits on a great many committees and is generally very attentive to the political work that needs to be done to keep the funding for a lab coming. Ivan Steensgaard, a Besenbacher colleague, has worked at Bell Labs and is very experienced at generating publications in peer-reviewed scientific journals. In contrast to Besenbacher, he focuses on just this one task. Steensgaard is content to produce high quality science in a lab and leave the dealings with the outside world to others.[1]

The entrepreneurial Besenbacher has been very successful over the last two decades in creating an infrastructure within which research and many individuals thrive. It started in 1986: The entrepreneur and the more narrowly focused Steensgaard worked in surface science (the Danish term, *overfladefysik*, translates directly to the even narrower surface physics) and were fascinated with the possibilities of the newly invented instrument, the Scanning Tunneling Microscope. They teamed up with a colleague, Erik Lægsgaard, a talented radio amateur who managed to build a basic STM simply using stuff lying around in various labs. For quite a while they spun off publications investigating surfaces with an STM. "Pay dirt," Steensgaard calls it: it almost didn't matter what you did with the STM, all results were interesting and illuminating.

In Denmark there had been a tradition of spreading the tax kroners evenly among all university departments with little pressure to account for the money spent. By the late 1980s, privatization of government institutions generated capital that was to be spent in a more "elitist" (the critics' term) fashion, by funding research centers in mutual competition and subject to much increased accountability (For an overview of the most recent developments in Danish research policy, cf. Lundager Jensen [1996] and Grønbæk [2001]). The grant was to run for 5 years in the first instance and could then only be renewed once—the "sunset clause". Renewal was dependent upon the number of publications, weighted by the status of the journal, but also upon social relevance of the research. Besenbacher networked with a view to economic and environmental relevance. He located it in two prongs:

1. Work in collaboration with a Danish company providing catalysts for chemical industries. Catalysis is of great commercial interests; for example, a catalyst speeding up a desired chemical reaction might save millions of dollars for chemical industries.
2. Work on de-sulfurizing catalysts promising a reduction in acid rain and general environmental improvement.

The group managed to get an extension to their grant, and so the Center ran for an entire decade, from 1992 to 2002. The Center was a success in a number of ways. It became a high-status destination for graduate students and post-docs; it raised the profile of Aarhus University; it paid salaries and expenses for many individuals; it generated some interest amongst private enterprises; and it successfully reached out to secondary education by providing projects for high school students.

By 2001 Besenbacher was worried, though. His institutional creation was about to get the axe because of the sunset clause. He fulminated against the inequity in the discontinued funding for his successful enterprise, when other kinds of staid, old-fashioned research had steady funding by default (albeit at a low level). He worked diligently behind the scenes to have the sunset rule changed, but to no avail. He had no choice but to develop a new project and compete with others to set up a new Center. Having his ear to the ground he cultivated relationships in medicine and the life sciences, thrashing out a Center to work on, *inter alia*, biocompatible materials using scanning probe microscopy. He was successful again and now heads up a new Center. The old Center was called CAMP: Center for Atomic-scale Materials Physics, a descriptive term understandable to other scientists. The name of the new center is Interdisciplinary Nanoscience Center, or iNANO. The name of the Center now is a tag intended for a larger audience than physicists, chemists, biologists, and medical scientists. Atomic-scale materials science would have been much clearer, much less ambiguous, to the academic constituencies but incomprehensible to the many others that also matter, such as government officials, members of parliament, journalists, newspaper readers, and high school students. The iNANO Center's own organization underlines the fact that discourse has to take place in a great many venues—one might say in all of Bucchi's four stages simultaneously. The Center's own pamphlet makes the point with a Venn diagram of its organization: three mutually intersecting circles of iNANO, Nanoschool, and Bachelor and Master Studies (basically research and teaching) are ringed by the institutional support: University of Aarhus; Aalborg University; Danish Ministry of Science, Technology and Innovation; Danish National Research Foundation; Danish Research Agency; Danish Technical Research Council; EU Framework Programs; Danish Natural Science Research Council; Industrial Partners. This list reveals with great clarity the many different audiences that iNANO has to contend with, the many stages for which texts and images have to be crafted.

Besenbacher has developed a much more involved publication strategy than the one involving Steensgaard. The Center now issues press releases, starting with sentences such as this: "This week, a group of scientists at the University of Aarhus has published an article in the world-leading scientific journal, *Science* magazine. With the use of a powerful microscope capable of resolving single atoms (a scanning tunneling microscope), the Denmark-based research group has discovered a new phenomenon..."[2] They also publish in various glossy magazines in the science popularization genre. Graduate students, such as Jeppe Vang Lauritsen and Anne-Louise Stranne, have been inducted into this kind of publication early on. Vang Lauritsen had several such articles under his belt before graduating. Both themes of social relevance, mentioned above (improved efficiency of chemical industries, and environmentally improved technologies), are at the focus of these publications. Besenbacher writes reports for various political bodies, both the local university and municipal administrations, and the national parliament. He sits on the Danish Natural Science Research Council (DNSRC), an advisory committee to the national parliament, the Folketing. This council has a dual task: administering a block grant for research and advising the Parliament on science policy. The committee writes reports and strategic assessments which, I presume, is the single most important text for decisions of a budgetary nature. The 2003 strategic assessment for the next four years reads like a carbon copy of the entrepreneur's views: Elite centers are to be funded, the social relevance is pushed, and the importance of training the next generation for industrially relevant research is presented as the lifeblood of the Danish economy. The specter of declinism is deployed: the countries Denmark usually compares itself against (the US, Sweden, Finland, the UK, Germany) are investing money in research, and the Danish standard of living is at risk unless sufficient funding, and so on.

It is worth noticing that one of 6 special strategic areas of focus is nano and that authors' conflict of interest is not discussed.

The future benefit is stridently formulated in this DNSRC publication. The future tense is consistently used where one might have expected a subjunctive. Nanotechnology *will* thus offer: pharmaceuticals without side effects dosed using nanostructures; smaller and faster components for computers and communications technology; new and better building materials; new batteries and energy storage systems; new sensors; lab-on-a-chip systems; optical nanostructures for ultra fast communications; biological manufacturing of materials; and new catalytic converters for environmental purposes and for energy technology. The summary of all this takes on an almost prophetic tone: "Nanotechnology is an important area that will form the basis of the next industrial revolution."[3]

Locating the Pleasure

I will argue that pleasure may be found in much of this discourse, primarily due to the exhilaration felt by contemplating a technologically enhanced future. The communication of this exhilaration is at times explicit in the texts, and I will argue that it resonates also in the images.

I will suggest the presence of such pleasure in all genres. I will first discuss newspaper articles, several illustrations of which turn up also in an iNANO pamphlet. I will then turn to the CAMP and iNANO websites that prominently feature STM movies. Finally, I will discuss an article in a peer-reviewed journal which utilizes such movies. In the course of this section I generally move from the right to the left in Bucchi's diagram, although much is clearly intended for several of Bucchi's stages simultaneously.

Newspapers and Pamphlets

In an article in the daily *Jyllandsposten,* Besenbacher displays three molecules: ribosome, bacteriorhodopsin, and molybdenum disulfide. The legends help us understand their meaning (Besenbacher 2002):

> The living cells contain fascinating nanomachines. The ribosome here is the cell's protein factory. Ribosome's atomic structure has been determined recently, also with the participation of researchers from the iNANO center.
>
> Nature is a decisive source of inspiration within nanotechnology. The bacteriorhodopsin shown here is a protein regulated by light. It works as a nanoscale pump transporting protons across the membrane encompassing living cells.

These two molecules are being represented as a nanomachine and a nanoscale pump, which is precisely the language pioneered by Eric Drexler, a mechanical engineer by training. Drexler's vision of nanoscale machines built atom by atom gained tremendous credibility with Don Eigler's images of IBM and atomic corrals written with xenon atoms and imaged with an STM (Hessenbruch 2004). And indeed, Besenbacher uses just this corral in the same article with the following comment:

> this image has developed into a symbol of the promise of atomic-scale control that nanotechnology yields.

Drexler's vision caused excitement by opening up a vista of assembling any kind of molecule atom by atom, as long as the final molecule was energetically stable. The tremendous difference between pushing the chemically inert xenon atoms around on a surface and the assembly of large 3D molecules was elided, and appropriately so when the aim is to inspire and enthuse. And Drexler's vision gained in force by his comparison with the DNA-RNA-protein complex. He argued that nanotechnology could assemble molecules resembling the building blocks of life in that these new molecules themselves produce new molecules. In other words, we would design new life-like systems in real life, just as artificial life was being generated on computers (Drexler 1987).

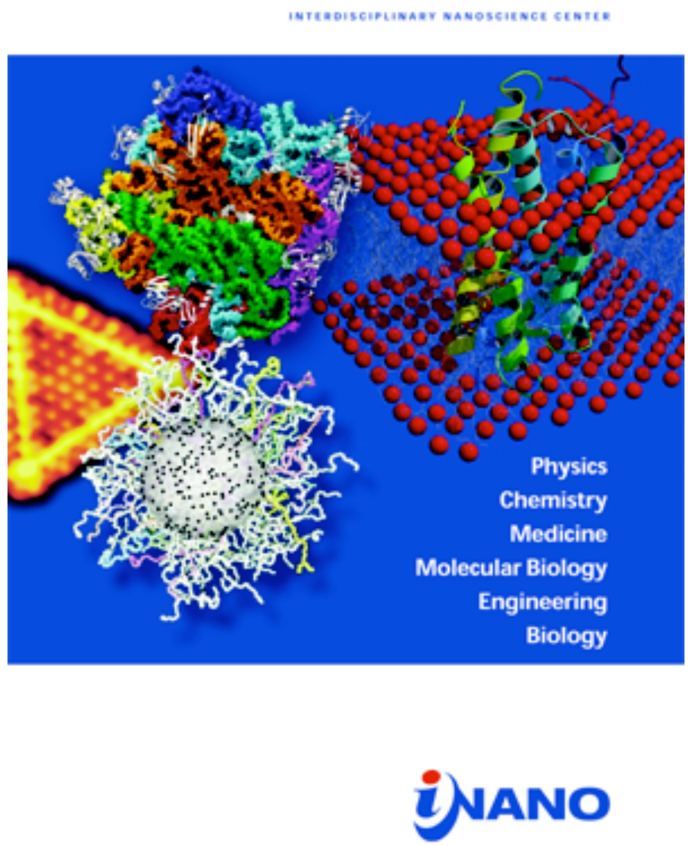

Figure 2: iNANO's 5 molecules

The same three molecules also grace pages 2 and 3 of a pamphlet introducing the center—and displayed on iNANO's website (Figure 2).[4] In large white letters the disciplines involved in the center are stated: physics, chemistry, medicine, molecular biology, engineering, and biology. In small letters on the left is a list of senior researchers and industrial partners.

The largest and most visible molecule is the bacteriorhodopsin which has also been incorporated into the banner of iNANO's website. Visually, it consists of two planes of red balls, connected by curled strands. The planes look more like the topic of surface science, whereas the curled strands show us that we are in the realm of biology. It is thus both appealing and eloquent about interdisciplinarity. To the left of it is the ribosome (below which is a molecule of less concern for the purposes of this paper), and further to the left the molybdenum disulfide molecule that the CAMP group had analyzed using an STM with a view to improvements in catalysis. These four molecules fill the right half of the image. On the left half and somewhat isolated from the other four we find a DNA strand. The intended audience for this pamphlet is wider than scientific colleagues. It is well suited for visitors to the lab, including high school students, or for distribution amongst journalists, administrators, and politicians. It is the kind of glossy genre that assumes a distracted reader. The coloring is striking, with a blue background and each of the five molecules consisting of a major color: red, green (and brown), white, orange, and purple; the prose is crisp and to the point, introducing the theme of nano, summarizing the funding structure and mission of the iNANO center along with its research and teaching activities.

The Sublime

The image fronting the US National Nanotechnology Initiative report issued in 1999, by comparison, is much more direct in its hype. It was also intended for a non-specific audience, also aiming to advertise nano, and also with a view to supporting funding for research. Here, we have an STM-produced image of a surface but set, not against a plain blue background but the starry sky with Earth, Moon, and a falling star. The report itself explains that: "The combination of a scanning tunneling microscope image of a silicon crystal's atomic surfacescape with cosmic imagery evokes the vastness of nanoscience's potential." Alfred Nordmann has made a number of interesting suggestions about this image that may aid also in the understanding of the Danish image (Nordmann 2004). First of all, the US image juxtaposes a macrocosm and microcosm, of outer space and inner space, suggesting a continuation of the frontier dream: going where no man has gone before. Secondly, the "mystical or forbidding presence of artefacts...floating through space, appear[s] to defy their origin in human social practice" (2004). Nordmann suggests that it inadvertently anticipates Bill Joy's worry that the nanotechnological future may not need us. While distracting attention away from the social nature of nanoscience, it focuses our attention on to our machine-enhanced sensory modalities: the perception of the very small and the very large; a point made almost ubiquitously in popularizing literature on nanoscience with a scale of images at powers of 10, for example at meters, millimeters, micrometers, and nanometers.

In the Danish image there are no vistas of outer space and inner space. The references to the vastness of nanotechnology's potential are more subtle because the original legends are now left out, but readers of the newspaper article will recognize the symbolic meaning intended for the molecules. And the molecules are certainly presented as divorced from human or social practice.

The DNA molecule in figure 2 is slightly off to one side, presumably because unlike the other four, it is not a molecule that the iNANO researchers have worked on. But its inclusion resonates with the promise of nanotechnology to design new molecular systems that are just as powerful as DNA and RNA—in fact the DNA molecule might be thought to be emphasized through its placement on page 2, one page before the other four. In the days of a shrinking physics budget and a growing life sciences budget, the one icon one wants to associate oneself with is the double helix of DNA (Nelkin & Lindee 1995).

And so while iNANO's visual language is subdued (just as Danish Lutheran churches are visually very restrained), it still encodes exhilaration. The phrases Besenbacher uses when addressing newspaper readers (Besenbacher 2002) and high school students[5] show us where the decoding is meant to take us: enormous potential, as yet unknown possibilities, fantastic possibilities, and the next industrial revolution.

One may pursue the question whether the promise or hype is justified, and whether the reader is being duped by the assertions (limiting oneself to the truth discourse). But this may be an inappropriate yardstick for the science hype genre. Instead, one might ponder the importance of a genre that invites revelry in an imagined future. Such revelries have a value all of their own. To get at this issue, I will take a short detour through audience studies that have developed alternative yardsticks in opposition to the “dominant” discourse of truth and falsity. Nick Stevenson has summarized John Fiske’s argument:

> What is important about the tabloid press is not whether the articles and features it runs are actually true, but its oppositional stance to official regimes of truth. Fiske illustrates this argument by referring to a story concerning aliens landing from outer space, which he claims to be a recurrent one within tabloid journalism. The point about such stories is that they subversively blur the distinction between facts and fiction, thereby disrupting the dominant language game disseminated by the power bloc. Further, while official news attempts to ideologically mask the contradictions evident within its discourse, the tabloid press deliberately seeks to exaggerate certain norms, hereby *abnormalising* them. Fiske’s argument here is that the sensationalised stories characteristic of the tabloid press produce a writerly text in that they openly invite the interpretive participation of their readers. The tabloids, like other popular texts such as Madonna and soap operas, maintain their popularity by informing the people about the world in a way that is open to the tactics of the weak (Stevenson 2002, 94).

The prophetic prose and visual language of nanohype may resemble tabloid journalism in this sense (not in the sense of being true or false). Whereas technical texts tell readers what is the case, leaving little room for interpretation, especially without substantial technical training, the playful suggestions of nanohype enable the reader to imagine and to enjoy imagining. Thus Besenbacher, in addressing high school students and the general public, wisely refrains from technical detail and instead invites revelries that for many readers will be pleasurable. The readers are expected to be distracted, maybe thumbing through the pamphlet during a spare moment, or reading the newspaper during breakfast. The reader is not expected to commit any facts to memory (connoting tedium) but rather to daydream.

As Colin Milburn has convincingly shown, science fiction is in the background of much nanoresearch. The Drexlerian vision has clearly taken elements from science fiction, as did Richard Feynman who gave a lecture entitled “There is Plenty of Room at the Bottom” in 1959, a lecture which is now often (paradoxically) referred to with a view to establishing nanotechnology's scientific origins (Milburn 2002). And science fiction has this same characteristic: it invites playful revelries of the future; it prompts pleasure.

It has been suggested that a core element of science fiction is its delight in the sense of wonder, sometimes referred to as sensawunda or as the sublime. Science fiction editor David Hartwell has summarized it thus:

> A sense of wonder, awe at the vastness of space and time, is at the root of the excitement of science fiction. Any child who has looked up at the stars at night and thought about how far away they are, how there is no end or outer edge to this place, this universe—any child who has felt the thrill of fear and excitement at such thoughts stands a very good chance of becoming a science fiction reader.
>
> To say that science fiction is in essence a religious literature is an overstatement, but one that contains truth. SF is a uniquely modern incarnation of an ancient tradition: the tale of wonder. Tales of miracles, tales of great powers and consequences beyond the experience of people in your neighborhood, tales of the gods who inhabit other worlds and sometimes descend to visit ours, tales of humans traveling to the abode of the gods, tales of the uncanny: all exist now as science fiction.
>
> Science fiction's appeal lies in its combination of the rational, the believable, with the miraculous. It is an appeal to the sense of wonder (Quoted in James 1994, 105).

It is this sense of wonder that resonates in Besenbacher's use of words such as "dizzying," "unbelievably small," "undreamt-of," "fantastic," "visions," "unimaginable," "as yet undefined," and "ground-breaking" (Lindberg 2001; Besenbacher 2002).[6] And the images encode some of the same sense of wonder. As an aside, it would seem that science fiction is turning away from the original general trope of exploring empty space and alien worlds. Cyberpunk, one of the more recent genres of science fiction is more concerned with communication technologies, cyborgs, and technologically altered minds (*e.g.* Gibson [1984] & Goonan [1994]). The NNI is clued in to this development: its current mantra is

NBIC (nano-bio-info-cogno) convergence. The mantra certainly refers to interdisciplinarity, but also to the sense of hype in the latest science fiction literature. This is an aside because I haven't found an instance of the Besenbacher group referring to NBIC.

But the pleasurable reading of possible futures is being constantly challenged by the discourse of truth and falsity. Just as science fiction as a genre has historically been marginalized and science fiction fandom ridiculed, so the nanovisions are under attack. Largely, this is prompted by the desire to have transparency in a political process that earmarks millions of dollars in pursuit of a vague future. But it is driven even more by the dual nature of new technology: the theme of the wizard's apprentice. Media reports on nano have picked up the Drexler vision, accelerating greatly with the publication of *Prey* by Michael Crichton, the author of Jurassic Park (Anderson *et al* 2004. Cf. also Stephens 2004). In *Prey*, we have nanorobots instead of dinosaurs, but the theme is the same: they escape and wreak havoc upon humanity. With this publication, the pleasurable revelries of the future are turning into nightmares, thus threatening to undermine the political will for nanotechnology funding. The response in the nano-community has been to emphasize differences between actual nanoresearch and the research featured in *Prey*. Drexler himself has expressed frustration that his vision is being tarred with the brush of *Prey* (Drexler 2004).

Faced with similar hostility to nano in Danish newspapers, Besenbacher also has emphasized the need to distinguish science from "mere science fiction" (Besenbacher, quoted in Holm 2004). The blurring of the boundary between truth and fiction is desirable when that blurring leads to exhilaration, but not if it leads to fear. Phrased thus, Besenbacher's stance appears inconsistent, but in strategic terms it is clearly not.

Movies

I will now turn to the webpages and to the STM movies. They were created during the CAMP project that ran from 1992 to 2002 and prominently displayed on the CAMP website. They are still present on the iNANO website but not with top billing. Thus, in a snese, we are moving to the left in Bucchi's diagram.

Erik Lægsgaard, the designer and builder of the Aarhus STM, thinks explicitly in terms of adapting scientific instrumentation to the human senses. For example, we humans are very good at noticing a duck waddling across a lawn. We sense immediately that the background is staying fairly stable and the real change in front of us is the movement of the duck. Trees may sway, and waves in a pond may constitute movement too, but we recognize with ease that these movements always return to the original position and so we can block them out of our attention. Similarly, we can recognize diffusing single atoms against a fairly stable surface. Scientific instrumentation and computer programs have a much harder time with such recognition. Hence, Lægsgaard argues, it makes sense to make movies and use the human senses for just this kind of research. Similarly, during the development of the STM in the 1980s, Lægsgaard, a passionate radio amateur, decided to use sound in the tuning of the STM. Lægsgaard argues that it is much harder to generate a visual image of similar utility, and that the human ear is especially well suited to recognizing the kind of sound that signals a properly functioning instrument.

These movies were used in research and so the first audience was the CAMP/iNANO researchers themselves, trying to get a grip on the nanoworld. They were displayed at conferences as well, making the scientific colleagues the second audience. The websites configure a third, larger, audience. I will address pleasure in the larger audience first and get back to pleasure amongst scientific colleagues. A member of the lab, Anne-Louise Stranne has presented just such a movie with the help of 6 stills in a glossy science-popularizing journal. The article is structured to make the point that:

> nanotechnology is based on complete control of atoms' behavior. With complete control, a whole new world will open up providing opportunities for constructing and using materials. Individual atoms may be used as small machines moving other atoms, and it will be possible to generate electrical components from a small set of atoms. And that's just the beginning.

But to reach this promised land of technology, one must be sure that the atoms don't move or react in an uncontrolled fashion. It is here that research of atoms on surfaces enters the picture (Stranne 1999).

The movies are placed most prominently on the CAMP website, just under the banner. (They are also accessible from the iNANO website, as is Stranne's article). The movies are in yellow-orange-red, brown colors and consist of points moving along a background pattern that remains comparatively stable. We are informed in the legend and surrounding text that these are atoms diffusing along surfaces. Each still of the movie is an STM scan of the surface, and we are actually watching 30 minutes of action compressed into a few seconds, so that the motion of the diffusing atoms becomes easily recognizable. The newspaper article mentioned repeatedly above (in *Jyllandsposten*) is placed on that website and with a feedback link to its author (Flemming Besenbacher) along with one to the movies.[7]

What may the intention of placing movies on the website be? For one thing, they allow something like a voyeuristic sense of control of the nanoscale: Take a peep at the hitherto unseen world! A world that humanity has wanted to access for centuries—a world thematized in the mid-20th century by George Gamow's *Mr. Tompkins* and other sf authors, and more recently on US National Public Television by *The Magic School Bus*. And comprehension is easy: any viewer can discern the atom moving across the surface—quite unlike most visual scientific material. In other words, a part of the fascination with the movie consists of visual access to atomic scale: from being able to see individual atoms move to controlling such atoms seems but a small step! As in Eigler's experiment with xenon atoms, it evokes control of the nanoworld and the pleasurable revelry of revolutionary future technologies. The pleasurable revelry is available with one click—it may reach a distracted audience such as high school students searching for something cool.

It deserves mention also that these movies were up already in 2000 when the appearance of the internet was still largely static. I remember watching these movies then, being fascinated simply because they were on my computer screen, not on the TV. With time, the pleasure of watching just any movie on the web has obviously waned.

The Intraspecialistic Stage

I will now turn to pleasure among scientists, by examining an article in *Physical Review Letters* analyzing a movie. This audience is not presumed to be distracted, quite the opposite. Hence visuals are in plain black and white, and the mode of discourse around them is matter-of-fact without any overt references to futuristic revelries. Instead, the arguments attempt to leave as little as possible for the audience's imagination to play with. In fact, readers of scientific publications may be presumed to be on the prowl: looking for resources that they can use in their own research. Attendees at scientific conferences may also be looking to score points with the audience by asking penetrating questions. In either case, the audience is highly focused and critical of any ambiguity.

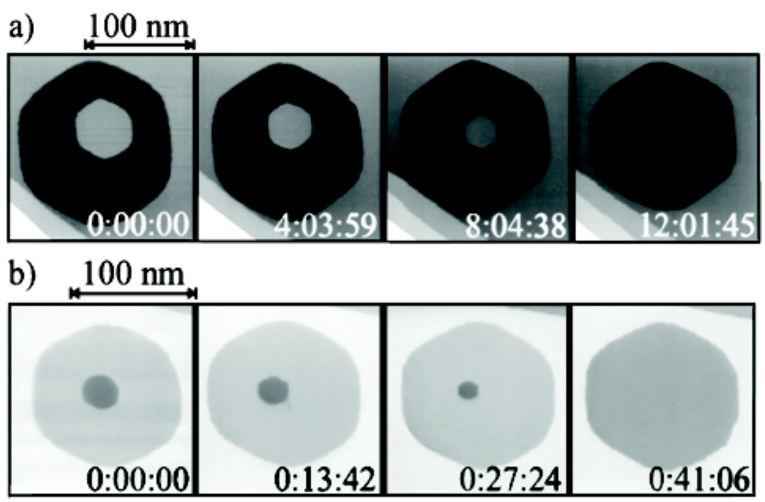

Figure 3: Four stills from a movie

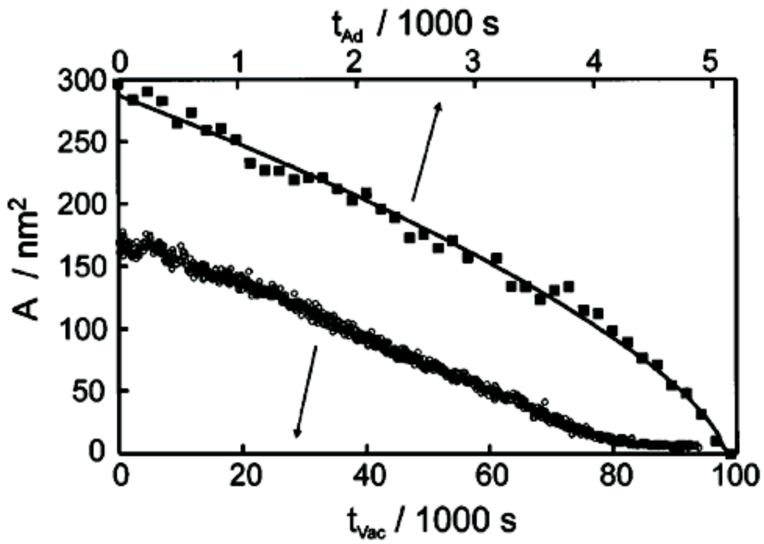

Figure 4: Graph of decay

The graphs (Figure 4) are derived from the movies (Figure 3). One movie is of hexagonal assemblies of atoms upon the surface of a silver crystal.[8] The movie shows the gradual decay of these nanostructures, as the authors call them. The publication using this movie treats the movie as a means to an end (Morgenstern *et al* 1998). The display of a set of four stills gives the reader a general sense of the appearance of the movie and highlights the decay. This information is transformed into a more succinct, graphical representation of the decay. For each still of the movie (many more than the four used earlier on in their publication) the area of the nanostructure is measured. The measurements are displayed on a graph, the axes being area and time. The resulting graph contains a continuous curve falling off to zero, symbolizing the degradation of the structure. (The same experiment is done with “vacancy island decay”, a flat hole on the surface which is then gradually filled up; hence the graph has two lines.) The point that the authors want to get to is the kinetics that causes these decays, and here they engage with the so-called Ostwald ripening model. They discuss what the measurements tell us about the model, that is to say to what extent the measurements support the model and to what extent the model assures the experimenters that their results are sensible, as opposed to, say, an artifact of the STM.

In other words, the movies need to be summarized into a conspectual view, most often a graph, from which even more succinct information (numbers) about the decay may be formed, such as the linearity of the decay and the gradient of the line. These numbers can then be fed into a quantitative model and the implications for the trustworthiness of each discussed. Of course, much scientific work is of this kind: a cascade of representations, summarizing information to ever-higher degrees of abstraction, the highest level of which is theory—or models (Latour 1987).

As mentioned, the audience is configured as attentive and interested. There is no color and little fireworks. The reader is expected to understand the jargon of surface physics and know how to read graphs. The Ostwald ripening theory is explained in some detail, but to follow the argument the reader must know, say, differential equations and Arrhenius plots. Some level of scientific literacy is required. The majority of the population will have no interest in this paper and would not be able to make any sense of it.

Even here the initiated may experience pleasure. There may be pleasure in deciphering highly abstract codes, in communicating at a very abstract level, and in figuring out the consequences for one's own research. And there may be pleasure in belonging to a select group of individuals that is thus enabled—especially if this group can see itself as superior in some way, such as more rational than the rest of the population. In other words, just as maps are capable of solidifying national identities, so graphs may be capable of solidifying disciplinary identities.

And there may be at least two further sources of pleasure in this publication. The authors frame the importance of the paper thus:

> The control of kinetic parameters in thin metal film growth is of utmost importance for the ability to design novel nanoscale structures.

> As many nanoscale surface structures are only metastable, it is important to know on what time scale material rearranges and whether these processes can be used for modifying nanostructures on surfaces.

This is indeed the nanohype theme so prominent in the popularizing literature. The Drexler dream requires control at the nanoscale, and this paper will inform you of an aspect of just that.

The second additional source of pleasure lies in the power of the STM to produce images and movies. As I have argued elsewhere (Hessenbruch 2004), the early source of surface scientists' fascination with the STM was three-fold: atomic resolution, and the imaging in real-space, and real-time. Getting images of individual atoms had been something of a holy grail in science throughout the 20th century—overlaid with the mystique of the uncertainty principle. Most people, including many scientists, understood the uncertainty principle to rule out the possibility of the imaging of individual atoms. Hence scientists also felt the pleasure of voyeurism, when seeing the first STM images. Until the 1980s, scientists had their information from such techniques as x-ray diffraction, which is powerful but sums over many atoms at a time. The information about, say, the structure of DNA was encoded in a space that differed from real space, and one space could be mapped on to the other with Fourier transforms—a mathematical technique.[9] Generations of crystallographers learnt to think in Fourier space, and the intriguing nature of STM images was that they provided images directly in real space—no need for a Fourier transform. Finally, x-ray images require the summing over longer periods of time. One cannot do snapshots of crystals using x-rays and then see how the crystal changes over time. STM movies are precisely this: they show you developments in real time. All these three factors must have rendered STM movies "cool" to scientists, adding pleasure to the publication under discussion.

Conclusion

Pleasure may thus be found in all of Bucchi's stages and it should be clear that the question of truth and consensus cannot encompass all the goings-on in the public sphere. Also, the existence of esoteric texts, textbooks, popularizations and TV shows made us think of a fragmented discourse so that certain texts and images address certain audiences only, depending on their level of expertise. By contrast, I have shown that the audiences addressed are heterogeneous.

The textual and visual language is writerly, in Barthes' sense. This is quite obvious in the newspaper articles, but writerly language may even be detected in the *Physical Review Letters*. Just as Benedict Anderson has argued that maps have "penetrated deep into the popular imagination" (Anderson 1983) and contributed to the making of national identities, so a similar group identity may be enhanced by images of molecules as machines, and images of inner and outer space. Certainly, Besenbacher's PR-work is intended to tie together networks of support. Constant maintenance work is required lest parts of the network disengage, constant work is required to establish new contacts.

Latour's talk of heterogenous networks seems apposite here: Besenbacher enrolls actants (humans and adatoms). In 1987, Latour still talked of trials of strength: the stronger network would sustain a stronger claim on truth. But the networks discussed in this article primarily sustain funding, not truth. And indeed Latour's recent work (*e.g.* Latour 2004) has shifted towards the politics of sustaining heterogeneous networks in general—not just in order to win a struggle among versions of truth. As such, this paper is in accord with that aspect of Latour's trajectory.

Bucchi's diagram is static in time. It doesn't allow for changes in the public sphere, a change that Habermas has documented in the long term. The development from surface physics through CAMP to iNANO indicates further changes. But to what extent is the story described here representative? Besenbacher is an exception within the Physics Department of Aarhus University. Other professors there, such as Steensgaard, do not publish popularizing articles, sit on government committees, commission nicely designed websites, or devise and write new grant proposals. They write scientific papers and communicate with their peers. These professors still live science as they did 30 years ago. However, the next generation is being trained to behave like Besenbacher. In other institutions, such as MIT or Stanford, and in other departments, such as the life and medical sciences, the practice of interdisciplinary, networking science with a view simultaneously to the market and to 'pure science' is much more common. Gibbons *et al* have argued that science has been gradually shifting in this sense for a few decades, and this paper adds to the evidence (Gibbons *et al* 1994).

The same group of authors has more recently pointed to current science's similarity with derivatives in financial markets, such as "futures." Here "economic activity derived from first-order operations rooted in material production and exchange is displaced onto a second-order level where abstraction and speculation predominate…Innovation has acquired an urgent, even quasi-moral, stridency" (Nowotny *et al* 2001, 67). "Collusions of interest…tread a thin line between authentic belief in the future potential and mere rhetoric of 'selling' a particular line of research to politicians and the public. Promises come first…in order to instill and stimulate demand which later will underpin a market" (Nowotny *et al* 2001, 37-8). Potentiality tends to take precedence over actuality. This fits nano to a tee. Nano is full of promises based upon a potential, the assessment of which is difficult, but which are elaborated upon and amplified in the media. These promises excite the imagination of industry, the public, and members of parliament, and influence research funding decisions. They also help establish new disciplinary boundaries (Guice 1999; Hedgecoe 2003). That such a centripetal force is indeed taking place under the banner of nano has been clearly demonstrated by Schummer 2004).

Now, the effect of expectations is not new. A part of Colin Milburn's argument (Milburn 2002) is that science fiction played a role in Feynman's argument about "plenty of room at the bottom." But this doesn't mean that science fiction has always played the same role. With the changes in funding structures, more and more scientists are urged or encouraged to behave like Besenbacher. The role of science fiction and exhilaration is increasing.

The policing of hype needs to change accordingly. Why insist that fears instilled by science fiction (*Prey*) must be marginalized as fiction when at the same time hopes are classified as possible fact? This opens up the question of accountability of hype. Research is supposed to be more accountable now when commercialization has replaced filling in a gap of knowledge as the yardstick, but when research gambles on future markets accountability seems hard to achieve. Can we account for some of the value of nano in the pleasure of expectation it gives, regardless of whether the promise actually comes to fruition?

At any rate, Bucchi's diagram falls short for two reasons: it is simplistic in focusing only on truth and not on the circulation of money and the selling of dreams[10]; and it ignores historical changes in science and the public sphere. Fitting the role of pleasure into Bucchi's diagram will, however, pose severe problems. The important category is not expertise but the politics of funding. Besenbacher's newspaper articles address simultaneously several of Bucchi's stages, and a politician might read it with a view to voters' interests at the next election. An investor might read it thinking of where to put his or her high risk investments. The manager of an industrial company might read it thinking of investors wanting to invest in nanorelated research. Think tanks and government bodies deciding upon funding structures use a managerial cost-benefit language shorn of hype. Nonetheless, the very reason for funding nano is the uncertain promise that no private company is prepared to bet on. The whole discourse of fact-truth-knowledge-authority-expertise-objectivity-disinterestedness-credibility concerns itself with what is the case, neither with what might be the case nor with revelries of what might be influencing what is.

Should we therefore abandon attempts to map science in the public sphere? I think not. Bucchi's diagram has great heuristic value. It has to be more complex to fit the realities on the ground, and it needs to incorporate temporality. In fact, the very complexity of the resulting map will likely defy its original purpose: to provide a conspectual view. But there will be pleasure in the attempt.

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Endnotes

1 Interviews with four members of this Danish group (Besenbacher, Steensgaard, Lægsgaard, and Vang Lauritsen) may be found on http://hrst.mit.edu. Hard copies of these interviews will be deposited in the Burndy Library.

2 http://www.phys.au.dk/camp/pdf/science-uk-press-release.pdf

3 http://www.forsk.dk/snf/publ/stratplan/strategi_03_07eng.pdf

4 http://www.inano.dk/graphics/iNANO-system/File-links/inano_final.pdf

5 http://www.destination-fremtiden.dk/nanoart.asp. The name of this website translates as "destination: the future"; using the English word for destination connotes something other than the mundane.

6 Also iNANO pamphlet: http://www.inano.dk/graphics/iNANO-system/File-links/inano_final.pdf.

7 The site is constantly being reorganized and since April 1, 2004, some of these links have disappeared—but the links to the movies have always remained intact.

8 Adatoms on a Ag(111) surface.

9 For brevity's sake the phase problem is ignored here.

10 It ignores also activities such as political lobbying and the legal discourse of intellectual property or regulation; the relevance of all of which have been demonstrated at the *Imaging and Imagining* conference in Columbia, South Carolina, March 2004.