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# Narratives for Nanotech: Anticipating Public Reactions to Nanotechnology

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## Introduction

One of the ways people try to envision the future of nanotechnology is to tell stories about the past, expecting that the future will continue certain features of the *past*. If one tells stories which emphasize that the founders of nanotechnology past were heroic geniuses, for example, that kind of emphasis would bless nanotechnology *present* and *future* as a noble effort whose heroic qualities endure. Or so the storyteller would hope.

Public reactions to nanotechnology in the U.S. are more difficult to envision this way because there has been practically no history of public awareness, let alone public reaction to it (But see Bainbridge (2004) for some ideas about research on public awareness of nanotech). In lieu of such information, we need to turn to past episodes of the arrival of new forms of science and technology, and public reactions to them: atomic energy, space science, cold fusion, stem cell research, remediation of environmental disasters, genetically modified foods, and so on. American society has had many experiences with the arrival of new technologies, and perhaps comparisons and analogies with some of them will help us anticipate public reactions to nanotechnology.

This question is compelling because, in democratic societies, nonscientists have important roles to play and stakes in the arrival of a new technology. We make science policy through legislation, litigation, lobbying, appropriations, environmental regulations, public school curriculum guidelines, and other political mechanisms in which non-experts participate. Some of the actors are experts with the finest scientific credentials, but others are people with no credentials, and still others are in between those two positions. Those who have a stake in the formation of science policy can be scientists, engineers, technicians, would-be scientists, wouldn't be scientists, science teachers, science students, policy makers with and without knowledge of science, and so on.

In nanotechnology policy, some of the voices will be those of experts who work at the heart of nanotechnology. This is perfectly appropriate. But we must also take into account the voices of many other citizens. Nanotechnology is crafted by a relatively small population of experts, but public reactions to nanotech will be the work of many tens of millions.

So to anticipate those public reactions, we have to ask which histories of technology are relevant to nanotechnology, and why. How do we choose one story from the past over another for the purpose of projecting its features onto public reactions to nanotech? People may well hope that certain essential features will endure into the future, but different people will tell different stories from the past, depending on what they feel are the essential features for nanotechnology.

Furthermore, public reactions to a new technology are not necessarily determined only by the scientific merits of the technology. Extra-scientific considerations can be equally strong, including values, beliefs, symbolic communication, rhetorical tactics, and so on. We need to see that a case of a new technology can be, among other things, a drama of good versus evil, or hope versus fear, or fairness versus unfairness. Stories about nanotech too will be permeated with values, symbols, and rhetorical tactics.

To ask which stories are helpful and how, I turn to an insight from cultural anthropology, namely, Malinowski's theory of myths. I suggest that nanotechnology is likely to generate the conditions for myth-telling that Malinowski described. If so, we have to ask how we can draw insights about public reactions to nanotech from earlier cases of other technologies. Is our knowledge of other cases organized into reliable nomothetic principles, or must we match the case of nanotech to a small number of closely related case studies? The high level of hyperbole that characterizes many accounts of nanotech causes me to examine two earlier cases with similar features, namely, recombinant DNA and cold fusion. From this reasoning I extract some lessons about public reactions to nanotechnology.

## Malinowskian conditions and Malinowskian stories

Eighty years ago, Bronislaw Malinowski proposed a relationship between social conditions in the present and the telling of stories about the past. Malinowski taught that people tell myths, not because they need to empirically reconstruct a true record of past events, but rather because they need to retroactively justify certain conditions in the present. The telling of myths gives legitimacy to current circumstances by tracing them to a "primeval reality" (Malinowski 1948, p. 146), or by discovering precedent-"warrant of antiquity" (107)-for the way things are now. And so myths seem to be a record of past events, but they are really a reflection of the present situation (93-148).

Malinowski drew his illustrations from his ethnographic work in the Trobriand Islands of the Western Pacific. The Trobrianders prefer to justify their geographical situations by reference to a First Principle of autochthony: it is right and proper that we live where we do because this is where our ancestors emerged from underground. Indeed, a group which is satisfied with its location will point out the exact spots at which its first ancestors climbed up to the surface of the earth (111-14). But Trobriand clans and subclans sometimes occupy lands beyond their rightful territory, subduing or displacing other clans. When this happens, they violate the principle of autochthony by explaining that their own first ancestors behaved virtuously, while the other peoples' ancestors behaved improperly. Thus, a moral justification to occupy the lands of another clan (112-113). In still other circumstances, one group can justify its subjugation of another by marrying into the subjugated group, and then telling stories which exaggerate the rights that derive from those marriages (115). Myth-telling for the purpose of justifying the present situation is so open-ended that it is neither consistent nor reliable, even in respect to its own First Principle. "The logic of events is not very strictly observed in the reasoning of the myth," as Malinowski gently put it (113).

The sense of Malinowski's theory is that a myth is a living element which actively shapes current events, as opposed to being a record of what happened in the past (96-101). And so it makes sense that, ironically, "one of the most interesting phenomena connected with traditional precedent and charter is the adjustment of myth and mythological principle to cases in which the very foundation of such mythology is flagrantly violated" (117).

This kind of story-telling is more likely to arise in some circumstances than in others. When there are "certain inconsistencies created by historical events" (125); or when there are some "specially unpleasant or negative truths" (136); or when one group holds power over another; or when the credibility of a form of morality is less than secure (125-126): then we can expect that myths will be told because myth-telling enables people to resolve these anomalies and unpleasantries.

To summarize Malinowski's theory of myth-telling:

1. Myth-telling arises in certain tense circumstances, particularly when one group has to justify its treatment of another group, or when people suddenly experience profound historical changes, or when contemporary events seen especially disturbing;

2. Myth-telling need not answer to an accurate record of events in the past, even though it seems to be a convincing account of what happened before the present;

3. Instead, myth-telling reflects conditions and problems in the present, which is to say that the past is reconfigured to serve the present;

4. The result of myth-telling is to justify, legitimize, or rationalize the current circumstances in which people find themselves. Myth-telling is an exercise in coming to terms with present-day tensions.

That four-part formula is relevant and useful to public reactions to nanotechnology the near future if we imagine any of the following Malinowskian conditions:

> That the interests of the scientists and engineers who drive nanotechnology are placed in conflict with the interests of the public;
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> That the interests of some scientists are place in conflict with the interests of other scientists;
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> That one part of the public finds itself in serious conflict with another part in a controversy involving nanotechnology;
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> That various social or moral or political disagreements are rendered as controversies about nanotechnology, even if they have little or nothing to do with the scientific merits, or lack thereof, of research at the nanoscale;

That large parts of the public find the consequences of nanotechnology to be puzzling, disturbing, or downright frightening;

That large parts of the public feel that nanotechnology causes our lives to change too much too fast.

In other words, there are multiple possibilities for tension, unpleasantness and social conflict which could bring nanotechnology into the conditions that generate myth telling in a Malinowskian style. Those conditions will powerfully influence public reactions to nanotechnology. No doubt there will be multiple competing stories as various groups contest each other's interests. We can expect that people will tell stories about nanotech the way Trobrianders tell myths.

Now is a good time to think about this. Public awareness of nanotechnology has been minimal up to this point, so there has been very little public reaction. I see that reports on nanotech appear regularly in certain periodicals, including *Scientific American*, *Wired*, *Small Times*, *Technology Review*, and the *N.Y. Times*. I know that several million people read these publications. At the same time, however, several *hundred* million people do not read them, nor do they read other newspapers, magazines or web sites which report on nanotechnology. This condition will probably not last much longer. For a short time, we have the luxury of anticipating the possible forms of public reactions to nanotechnology.

## A nomothetic approach

What do we know about drawing comparisons and analogies in which past episodes stand in as surrogates for nanotech? I suggest that we have two strategies: (1) we can organize a large amount of information from many experiences by summarizing them as general insights, that is, nomothetic models which will predict our experiences with any new technology; or, (2) we can draw insights from a limited number of selectively chosen experiences which share important features with the case of nanotechnology.

The first strategy is a scientific approach in the sense that it seeks to summarize a large body of data in the form of regular laws. Its value depends heavily on the assumption that such laws have already been generated, and that the case of nanotechnology will faithfully conform to those laws. The second strategy has more modest intellectual features. It draws from a narrower base of information, and it depends strongly on which criteria are used to hypothesize that a given case study is germane to nanotechnology.

Let us begin ambitiously. The following general statements describe numerous episodes of the arrival of new technologies:

1A. When a new technology arrives, it will be so expensive that only the very wealthy can afford it, thereby exaggerating class differences. [Think of the initial days of cell phones, hand-held calculators, and air bags in cars, for example.]

1B. Shortly after a new technology arrives, mass production will great reduce the cost, thereby democratizing its availability. [Think of the second phase of cell phones, hand-held calculators, and air bags in cars.]

2A. If a new technology involves profound changes in health or medicine, some people will object that scientists and doctors are playing god. [Here one might recall organ transplants, tissue transplants and technology-assisted reproduction.]

2B. If a new technology involves profound changes in health or medicine, some people [including patients, their doctors, and their families, plus administrators, investors and manufacturers] will fervently advocate for its use, on the grounds that patients should not suffer or die needlessly. [Here one might recall organ transplants, tissue transplants and technology-assisted reproduction.]

3A. The best way to nurture an expensive new technology is to consign it to processes of proprietary capitalism, centered on patents and copyrights, because no one else besides proprietors and their investors will have the will or the resources to develop it, and because this will protect it from political interference. [Currently this argument is made on behalf of pharmaceutical research.]

3B. The best way to nurture an expensive new technology is through public funding and government regulation, so that potential dangers can be closely monitored, and the benefits of the new technology will become available to the largest possible number of people. [Here a good example is the Human Genome Project.]

4A. As Dorothy Nelkin pointed out, the media usually embrace a new technology enthusiastically and emphasize its promises and supposed advantages (Nelkin 1987). [Perhaps you can recall the initial accounts of cold fusion from 1988.]

4B. As Dorothy Nelkin pointed out, the media often denounce a new technology when it is seen to be imperfect, that is, when it fails to fulfill utopian expectations, even though the exact same media may have previously exaggerated its promises and supposed advantages (1987). [No doubt you can recall the later accounts of cold fusion.]

Notice that there is some truth in every one of these statements, but each of them can also be negated by another which is equally truthful. Furthermore, they tend to be extremely general. It is hard to say with much confidence that the case of nanotechnology will faithfully conform to any of these lessons. I surmise that these statements are not reliable general insights in a nomothetic style. On the contrary, they are platitudes: somewhat true, but too imprecise to specify the likely forms of public reactions to nanotechnology.

Like the Trobriand Islanders, we lack a consistent and reliable "logic of events," as Malinowski put it (1948, p. 113), for knowing the past for the purpose of coming to terms with the present. Instead, our visions of the past are somewhat arbitrary and unavoidably selective. A Trobriand myth-teller would find himself at home in our situation.

Then again, this is not unadulterated nihilism. Even though no case study from the past can be perfectly isomorphic with nanotechnology, a comparison can still have some real value if we confess a *priori* that it is somewhat arbitrary and selective, and then declare which features of nanotechnology we choose for selecting our comparisons.

## Landscapes of nanohyperbole

One feature seems to me to be especially salient to the question of public reactions to nanotechnology, namely, the climate of hyperbole which surrounds discussions of nanotech.

Vivid and exciting predictions begin with the Ur-text of nanotech, Richard Feynman's 1959 speech, "There's Plenty of Room at the Bottom." To cite but two examples, Feynman predicted an information technology in which "all of the information that man has carefully accumulated in all the books in the world can be written in this form in a cube of material one two-hundredth of an inch wide" (Feynman 1992, p. 61); and, there could be a "mechanical surgeon" so small that it can be swallowed, after which it would maneuver through to body to the site of a lesion, and then repair the lesion (64).

I emphasize that "Plenty of Room" is cherished for its value to nanophilic hyperbole. This may well be different from its value for guiding scientific work, particularly if many scientists had independent inspirations for their research at the nano scale. Furthermore, Colin Milburn argues emphatically that Feynman's vision of tiny tools was derived from earlier works of science fiction:

> Nanotechnology is supposedly a real science *because* it was founded and authorized by the great Richard Feynman. But this origin is not an origin, and its displacement unravels the structure of its legacy. The Feynman myth would work only if it clearly had no precedents, if it was truly an "original" event in intellectual history...Yet... science fiction writers had already beaten him there (Millburn 2002, p. 283 ).

Whether we call it history or science or myth, or even stealing stories from fiction writers, my point is that Feynman's talk is the principal historical reference for nanophilic hyperbole.

If that was *nanoGenesis*-in the beginning Feynman said let there be nano, and there was nano-then *nanoDeuteronomy* was Feynman's 1983 speech, "Infinitesimal Machinery." This one was distinctly more lighthearted than "Plenty of Room," and more precise concerning the process of arranging atoms into gadgets (Feynman 1993). As such, it did more than merely reiterate the original message. It confidently reinforced the author's vision of a world transformed by nanotechnology.

Walking in the footsteps of Feynman were the scientists who realized his vision with instruments and experiments. The Acts of the NanoApostles included Gerd Binnig's and Heinrich Rohrer's invention of the scanning tunneling microscope (Baro *et al*. 1984; Binnig and Rohrer 1985; 1986), and Eigler's and Schweizer's manipulation of xenon atoms to spell "IBM" (Eigler and Schweitzer 1990).

If we stipulate that Feynman established the original outlines for nanohyperbole, and that people like Binnig, Rohrer, Eigler and Schweizer gave it credibility, then the current landscape of values and ideologies reveals several genres of thought about the value of nanotechnology. Four such genres are particularly important. The first is extreme nanophilic hyperbole, that is, an uncritical embrace of nanotech which looks ahead several decades to the arrival of nanotechnology's most amazing promises. In the words of *The Economist*, "the nanoenthusiasts... are recklessly setting impossibly high expectations for the economic benefits of nanotechnology" (*Economist 2002*). This genre needed an apostle like Paul to carry the good news to the gentiles, and so there arrived K. Eric Drexler, whose 1986 book, *Engines of Creation*, popularized the vivid and exciting possibilities of "the coming era of nanotechnology" as his subtitle put it (Drexler 1986). Subsequently he institutionalized his enthusiasm in the form of the Foresight Institute in Palo Alto, California. In his book and elsewhere, Drexler has emphasized one form of nanotech more than any other, namely, nano-size machines, commonly called nanobots. It is generally agreed that if these devices are to be realized, they must be preceded by some kind of machines which can reliably manufacture nanobots in very large quantities. Thus the controversy that surrounds Drexler's vision is centered not on the desirability of nanobots *per se*, but rather on the feasibility of the process of producing them.

Extremely nanophilic hyperbole includes excitement about nanobots and the assemblers that make them, as anticipated by Eric Drexler and his supporters, and it also comprises a pair of contradictory theories about the interface of technology with human anatomy. One is the expectation that medical nanotechnology will cure diseases and repair human anatomy so quickly and successfully that the normal human lifespan will be extended indefinitely. The other is the hope that all human consciousness can be uploaded into machines, thus making human anatomy unnecessary. So our bodies can stay healthy for enormous lengths of time; but, our bodies are irrelevant to knowledge, thought,or spirituality. Extreme nanophilia is also represented in some works of science fiction, especially the novels of Kathleen Ann Goonan (e.g.,Goonan 1994; 1997; 2000).

The second family of positions on nanotechnology is a somewhat less fantastic form of optimism. As the Clinton administration gathered its various nanotech projects under the umbrella of the National Nanotechnology Initiative, it produced a series of documents that had a tone of childish enthusiasm. Invisible aircraft; computers millions of times faster than today's supercomputers; smokeless industry; and "nanoscale drugs or devices that might seek out and destroy malignant cells wherever they might be in the body": these were some of the expectations presented in the government's colorful booklet on nanotech (Amato 1999). In the detailed blueprint for the NNI, it was said that "developments in...(nanotechnology) are likely to change the way almost everything-from vaccines to computers to automobile tires to objects not yet imagined-is designed and made" (NSTC 2000, p. 13). That same document included President Bill Clinton in the team of cheerleaders. With a splash of Feynmanesque imagery, he said, "Imagine...shrinking all the information housed at the Library of Congress into a device the size of a sugar cube" ( NSTC 2000:13). The next major NNI text told us that "The effect of nanotechnology on the health, wealth, and standard of living for people in this century could be at least as significant as the combined influences of microelectronics, medical imaging, computer-aided engineering, and man-made polymers developed in the past century" (Roco and Bainbridge 2001, p. 2; see also Crandall 1996).

While this form of optimism has some affinities with the visionary nanophilia of Drexler and others, it is important to note the important distinctions. The U.S. government's optimism is much more concerned with immediate and near-future events, especially in materials science, medicine, information technology, and other areas in which commercial products can be delivered fairly soon. It distances itself from Drexler's agenda of nanobots and assemblers (Roco and Bainbridge 2001, p. 14), thereby insulating itself from accusations that it is merely indulging in preposterous fantasies at the taxpayer's expense.

My next category is that of measured skepticism. This genre comes from a group of science writers who recognize that important work is being done at the nanoscale, and that this work will generate profound consequences for science and society. But they also express disdain, almost contempt, for the hyperbole of extreme nanophilia. *Scientific American* is their principal venue, and the epitome of this kind of writing is Gary Stix's 1996 profile of Eric Drexler, wherein Drexler and his followers are comic eccentrics (Stix 1996). Stix's next article on nanotech was slightly kinder to Drexler, but still found ways to diminish him (Stix 2001). When *Scientific American* reported on carbon nanotubes (Mirsky 2000) and molecular computing (Reed and Tour 2000), it found it necessary to suggest that stories of "microscopic robots rearranging atoms on command" might be "moonshine." "The hype," said John Rennie, "outruns the reality" (Rennie 2000). The September 2001 special issue on nanotechnology gave Drexler a chance to present his vision of nanobots (Drexler 2001), but the following article by Richard E. Smalley explained why nanobots were preposterous (Smalley 2001). And a facetious opinion piece in the same issue by Michael Shermer ridiculed the idea that "nanocryonics" will banish death (Shermer 2001).

The genre of measured skepticism is continued by other authors as well. Peter Vettiger and Gerd Binnig clearly aspire to create nanoscale computers, but they emphasize how difficult it will be do so (Vettiger and Binnig 2003). Adam Keiper writes a lucid introduction to nanotech which bifurcates all the talk of a "nanotechnology revolution." On the one hand there are solid advances, incrementally achieved by hard-working scientists, and on the other there are the vivid fantasies of

Drexler and such (Keiper 2003). Military applications from nanotech will be remarkable, says Jurgen Altmann, but they involve so many risks that we need a series of preventive measures to prevent them from creating disasters (Altmann 2004).

I cannot prove that this position of measured skepticism resonates with the bench scientists who make nanotech real, but I have a strong instinct that they are much closer to this position than to extreme nanophilia. The enthusiasm and the funding of the NNI may please them very much, but they understand that their rewards and their careers are calibrated according to the tangible accomplishments they achieve, without reference to extraordinary predictions of great things in the distant future.

The fourth and final stance is an extreme nanophobic counter-hyperbole, approximately as intense as that of the visionary nanophiles. This last position follows the general outlines of the Frankenstein story to emphasize gloom-and-doom predictions that science is dangerous, that scientists are arrogant, and so on (see Feder 2002; Mills 2002). Its rhetorical style has several features: (1) considering that nanotech has yet to kill humans or devour the earth, its evils are projected into the future with the words would, might, possible, and possibly appearing regularly, in lieu of empirical experience of nanodangers; (2) scientists, usually unnamed, are routinely depicted as being both irresponsible and undemocratic; (3) the hypothetical horrors of nanotech are assumed to greatly exceed any possible benefits; (4) nanotech is guilty until proven innocent; and, (5) the proper response is a moratorium on research at the nanoscale.

Various combinations of these features are evident in recent articles by J. Smith and T. Wakeford (2003) and by L. Broadhead and S. Howard (2003), plus the comments by Prince Charles (Radford 2003). The most sustained commentary in this genre comes from the ETC Group of Winnipeg, Manitoba. Following several angry denunciations of the dangers of nanotech (ETC Group 2002; 2003a; 2003b), this organization called for a moratorium on commercial development of nanotech (ETC Group 2003c; 2003d; 2003e; see also Brown 2003), after which it published additional denunciations of nanotech (ETC Group 2003f; 2003g; see also Thomas 2003). The Greenpeace report on nanotech (Arnall 2003) relied very heavily on the ETC Group's position papers but, after briefly flirting with the idea of a moratorium, it recommended instead a balance of industrial self-restraint and government oversight (Arnall 2003,40-41). The Chemical Market Reporter expressed a sense of alarm in the business community that popular hostility to nanotech, regardless whether it had its basis in fact or in fiction, could poison the future of this kind of research (Lerner 2003).

The dark view of nanotech is also represented in a recent series of science fiction films, particularly *The Hulk*, *Agent Cody Banks*, *Jason X* and *Cowboy BeBop*. A group of novels, the best known of which is Michael Crichton's Prey (Crichton 2002), present visions of a world radically altered for the worse by nanotechnology. (For recent commentaries on nano in science fiction, see Collins 2001; Hayles 2004; Miksanek 2001; Milburn 2002).

Another form of dramatic nanophobia comes from Bill Joy (2000; 2001) and Bill McKibben (2003). This subgenre indicates that nanotech is the centerpiece of a so-called convergence of technologies which will diminish human nature so much, in relation to high-performance machines, that our human qualities will become irrelevant: the end of humanity, so to speak.

In reviewing extreme nanophobia, I do not suggest that concern about this technology is categorically equivalent to paranoia. Vicki Colvin and others have instigated good questions about nanorisk (Rotman 2003; Tenner 2001 ), while Doug Brown, Barnaby J. Feder and Candace Stuart have chronicled these discourses (Brown 2001; 2002a; 2002b; 2002c; Feder 2003a; 2003b; Stuart 2002; 2003a; 2003b). My point, rather, is that some of this concern, e.g., that of the ETC Group, is so shrill that it polarizes discussions of nanotech between extreme nanophilic and extreme nanophobic hyperbole, and thereby erases the more nuanced ideologies in between. *The Economist* has noted that, unfortunately, common images of nanotech tend to arrange themselves into a bipolar division of love-nano-or-hate-nano positions (Economist 2002).

### Malinowskian conditions and techno-hyperbole

If the public is going to be whipsawed between extreme forms of nanophilic and nanophobic hyperbole, we can look to past episodes of scientific or technological change which exhibited similar characteristics. I'd like to present two such cases; one without Malinowskian conditions, and one with. This contrast helps us see how hyperbole intersects with such conditions.

My case of techno-hyperbole without Malinowskian conditions is the story of cold fusion from 1988. Initial reports and speculations described a technological solution to our energy problems that would deliver abundant power at miniscule cost using the simplicity of old-time technology. We would have all the energy we wanted by virtue of a plain gadget, a simple electrolytic cell, that anyone could manage. No longer would we need legions of engineers, oil-producers, bureaucrats, and policy-makers to make our electricity hum. Instead, we could do it ourselves with batteries, beakers, and liquids from the neighborhood hardware store, like a teen-age Thomas Edison. A quick fix, a cheap fix, and the simplicity of kitchen-table technology: cold fusion would be all this (Toumey 1996a, p. 98-111; Toumey 1996b).

Another story from the following day amplified that excitement by starkly contrasting old energy with new: 24 March was the date when the world learned about the Exxon Valdez oil spill. As NOVA put it, "most of the time when we think about such disasters, we're reduced to despair. But perhaps this time, from the deserts of Utah (where Stanley Pons taught at the University of Utah), somebody was offering a real answer" (NOVA 1989, p. 1).

Thus the press had a story with "drama, heroes, wizardry, and the promise of unlimited energy," said Marcel LaFollette (Heylin 1990, pp. 24-25). The heroes, the two cold-fusion scientists, were "ordinary persons who had made extraordinary accomplishments, by being different" (24-25). The promise they offered us was that "a single cubic foot of sea water could produce as much energy as ten tons of coal" (Pool 1989), which is to say that "the top few feet of water in the world's oceans contain enough [cold fusion] energy to supply the world for 30 million years" (Peat 1989).

A vivid bit of rhetorical flourish arose when Chase Peterson, President of the University of Utah, went to Washington to request $25 million for a fusion research center to develop Pons's and Fleischmann's work. One of Peterson's consultants, Ira C. Magaziner, contrasted our national character with that of the Japanese. He explained to the U.S. Congress, not very subtly, that,

> As I speak to you now, it is almost midnight in Japan. At this very moment, there are large teams of Japanese scientists in university laboratories trying to verify this new fusion science. Even more significantly, dozens of engineering company laboratories are now working on commercializing it...(Money for cold fusion) says that America is prepared to fight to win this time...I have come here to ask you, for the sake of my children and all of America's next generation, to have America do it right this time (Crawford 1989, pp. 522-523; Huizenga 1992. pp. 50-51; Taubes 1993, p. 251).

The most succinct observation about this festival of hyperbole came from Moshe Gai, an Israeli physicist at Yale, who said, "I think cold fusion is the epitome of the American dream...It's the new world, it's a revolution overnight, getting rich overnight, and doing something against the understanding and against the consensus of what our scientific society is" (NOVA 1989, p. 8). Gai's insight came from a peculiar experience. He and his colleagues wanted to do a cold fusion experiment to falsify the Pons-Fleischmann hypothesis;

> And the reaction we got from the public was that...you scientists are...the only obstacle in the way of development of science. It's because of you that the dream of...cheap energy, will not come true. Like if we got rid of you scientists, we will have a good society...I was inundated by letters, telephone calls, people accusing me (of thwarting cold fusion) (7).

As Moshe Gai was a sharp voice for scientific skepticism, so Norman H. Bangerter spoke loud and clear for the opposite feeling. Said the Governor of Utah, "Knowing nothing about it, I am highly optimistic" (Taubes 1989, p. 115).

To my knowledge, there was no technophobic hostility to cold fusion. No one opposed it on the grounds that it was undesirable to produce energy through cheap and simple methods. Rather, the opposition stemmed from challenges to the veracity of the Pons-Fleischmann method for producing energy.

While hindsight shows that it was most unwise to embrace cold fusion uncritically, I emphasize here that these were not Malinowskian conditions. There were no great disparities of rank or power. The process of getting energy from cold fusion was believed to be so simple and so inexpensive that everyone would benefit in approximately equal proportion. And, when the Pons - Fleischmann hypothesis was discredited, it embarrassed some people and ruined the careers of a few, but it did not give any particular class of people great power over another class. Cold fusion was a fascinating story about science and technology, but it was no great rearrangement of our society or its economy.

## The case of recombinant DNA

My other episode of techno-hyperbole is the recombinant DNA controversy of the 1970s. This case demonstrates a very different set of conditions which led to serious consequences in public reactions to a new technology.

Recombinant DNA initially earned considerable technophilic hyperbole. An article in *Scientific American* announced that "Research with recombinant DNA may provide major new social benefits of uncertain magnitude: more effective and cheaper pharmaceutical products; better understanding of the causes of cancer; more abundant food crops; even new approaches to the energy problem" (Grobstein 1977, p. 22). Jeremy Rifkin, the well-known critic of new technologies, wrote that "With the unlocking of the secrets of DNA, we will eventually be able to change the cellular structure of living beings and to create entirely new species. Biologists are already doing it with microorganisms. The Nuclear Age was the age of the physicist; the Organic Age is the age of the biologist" (Rifkin 1977).

Language like that, however, was not always wise. "The scientific facts of recombinant-DNA are complex and readily susceptible to exaggeration" (Budrys 1977, p. 19), thereby permitting a cascade of technophobic hyperbole to counter the optimistic sentiments. It was feared that "Old bugs might learn dangerous new tricks and might, if the escaped from a laboratory, demolish the intricate genetic balance that keeps all our chips in play" (Bennett and Gurin 1977, p. 44). Rifkin charged that "NIH's own maximum-security DNA-research facility" was a trailer with leaky roof and poor external security ( Rifkin 1977). Jonathan King reminded others that at "the best microbiological containment facility ever build in the US, the Army Biological Warfare facility at Fort Detrick, Maryland...over a period of 20 years there were over 400 cases of lab workers getting serious infections from the organisms with which they worked" (King 1977, p. 635). New forms of life that might potentially be created in rDNA were called an "Armageddon virus" (Krimsky 1982, p. 309) and an "Andromeda-type virus" (Rifkin 1977). Rifkin warned that such an organism could "spread a deadly epidemic across the planet, killing hundreds of millions of people. They (i.e., certain scientists) also fear that a new, highly resistant plant might be developed that could wipe out all other vegetation and animal life in its path" (Rifkin 1977).

Much of this feeling stemmed from the use of *E. coli* as the best platform for reproducing new genetic combinations. Units of DNA were extracted from viruses and other sources, and then implanted in *E. coli* because that bacterium multiplied itself very rapidly. In one particularly notable instance from 1971, a cancer researcher isolated viral DNA which was believed to be carcinogenic, and then recombined that genetic information with the genome of a strain of *E. coli* (Budrys 1977, p. 20). Many varieties of *E. coli* live within the human intestinal tract. And so there was a tangible concern that evil new forms of *E. coli* would move from genetic labs to humans' bodies (Grobstein 1977, p. 26; King 1977, p. 635; Nader 1986, p. 144). "The worst that could be imagined was a cancer plague spread by E. coli" (Bennett and Gurin 1977, p. 46).

When these various individual concerns were summarized in general statements about the dangers of rDNA, the language could be extraordinarily dramatic:

> "The recombinant technology circumvents all the normal barriers to exchange of genetic material between species" (King 1977, p. 635).
>
> Some people imagined "worldwide epidemics caused by newly created pathogens; the triggering of catastrophic ecological imbalances; the power to dominate and control the human spirit" ( Grobstein 1977, p. 22).
>
> "There is a class of technologies that can do great, perhaps irreversible harm. Recombinant DNA is a member of that class" (Nader 1986, p. 140).
>
> "Only one accident is needed to endanger the future of mankind"; "The potential dangers [of rDNA] ... pose perhaps the single greatest challenge to life that humankind has ever faced"; "science fiction's most horrible scenarios become fact" (Rifkin 1977).

Many of the warnings about rDNA came from experienced biologists who knew the research very well, and who described both the benefits and the risks of this work. But lay persons' fears of risk tended to be more intense than those of the scientists. Nonscientists were apparently more influenced by critics of rDNA research than by its advocates, with the result that they focused more on the hazards than the benefits (Krimsky 1982, p. 310). It was often noted that the original guidelines for minimizing risk, composed at the Asilomar conference of 1975, were composed by scientists deeply committed to rDNA work, with no participation or voice for external critics from public health, lab workers, or environmentalists (Grobstein 1977, p. 31; King 1977, p. 634,; Nader 1982, p. 148). This enabled Rifkin to frame the rDNA debate as "a question of the public interest groups versus the scientists" (Budrys 1977, p. 21), and to capitalize on situations in which local officials in various cities and states were unaware of "secret research into recombinant DNA going on in laboratories in their communities" (Rifkin 1977). When it became known that some scientists had urged a moratorium on some forms of rDNA work in 1974, the popular interpretation of that was "if scientists were banning some research, they [the public] reasoned, then all of it must be extremely dangerous" (Bennett and Gurin 1977, p. 49).

Maxine Singer objected that "Statements implying that uncontrollable epidemic or environmental disaster is a certainty are as misleading and useless as statements implying that no possible hazard can come from the experiments" (Singer 1977, p. 632). Despite her judgment, public fears led to unpleasantness for working scientists. At Stanford Medical Center, Paul Berg had to terminate his experiment for inserting carcinogenic viral DNA into *E. coli* (Budrys 1977, p.20). From that event came a brief moratorium on some kinds of rDNA experiments (Grobstein 1977, p. 22), followed by the Asilomar Conference of February 1975 which ranked rDNA experiments according to their potential dangers. The Asilomar document then became the basis for the NIH Guidelines for

Research on Recombinant DNA (King 1977, p. 634; Singer 1977, p. 631).

This did not satisfy all lay persons. In Cambridge, Massachusetts, a City Councilwoman was distressed to learn that Harvard was building a P3 lab for rDNA. (P3 describes moderately risky experiments, and MIT was already running a P3 lab.) There had long been a "fragile relation" between the universities and the locals, which played out in real estate values, tax bases, and other acrimonious disagreements (Krimsky 1982, p. 298-99). The mayor of Cambridge initiated a series of hearings and investigations which emphasized the arrogance of the Harvard scientists in their dealing with the working-class residents of Cambridge. "Who the hell do the scientists think they are," asked Mayor Alfred Vellucci in June 1976, "that they can take federal tax dollars that are coming out of our tax returns and do research work that we then cannot come in and question?" (Nader 1982, p. 145,). When he framed the issue this way, "the self-governance of science was concretely and symbolically threatened" (Krimsky 1982, p. 300).

During a long process of ritually humiliating the Harvard scientists, the Cambridge City Council temporarily banned "all recombinant research within the city limits" (Budrys 1977. p. 21). Later it eased that ban, and permitted rDNA work with certain specific safeguards.

By 1981, there were similar laws regulating rDNA research six cities across three states (Nader 1982, p. 151), while additional local regulations were considered in a total of nine cities in seven states (Krimsky 1982, p. 294).

You might think that finally the scientists and their universities would have clearly understood the public's concerns, but Harvard soon found one more way to embarrass itself. NIH's Guidelines for rDNA research included a procedure for NIH to certify the safety of biological vectors ("plasmids," e.g., viruses) before an rDNA experiment could employ them. Charles A. Thomas, who had been on the NIH committee that composed the rDNA guidelines (and thus ought to have known better), had proceeded with not-yet-certified plasmids in his recombinant efforts to produce insulin at Harvard Medical School. He was required to terminate his experiments, and his research team was very publicly embarrassed (Wade 1977; 1978).

**Lessons from the case of rDNA**

When various elements of the public make sense of nanotechnology in their own terms, will that process include the telling of lurid horror stories about evil scientists and their dangerous technology? Will public reactions to nanotechnology be as unpleasant as some of the reactions to rDNA? I suggest that the story of recombinant DNA will be relevant to nanotechnology when the following three conditions are present:

1. ***Techno-hyperbole backfire:*** When some people praise nanotechnology in words and images of unrestrained nanophilic hyperbole, it would be wise to remember one of the ironic lessons from the experience of rDNA: techno*philic* hyperbole inspires the opposite reaction too, namely, techno*phobic* hyperbole. The positive predictions for rDNA frightened many people by telling them that a small group of elite experts unknown to the public would control an extraordinarily powerful method for manipulating life. This is exactly what nanotechnology might sound like too.

2. ***Malinowskian conditions:*** nanotechnology, like rDNA, is likely to affect different people in different ways, and particularly to exacerbate differences of power or wealth. Some people will control the research and development, while large numbers of other people will feel that they are powerless. Similarly, nanotechnology may create profound historical changes, and it might cause

people to feel that they cannot understand the existential situations in which they find themselves. And so, all three kinds of Malinowskian conditions might arise. In any of those circumstances, the stories people tell about nanotechnology will bear a burden of helping people come to terms with anomaly, conflict, inequality, and change. These pressures are not likely to engender a dispassionate appreciation of nanotechnology.

3. ***Disdain for public health and safety:*** if those who make nanotechnology real are as arrogant and inconsiderate as some of the people who brought us rDNA, then we can expect nanotechnology to be humanized as a stirring drama of virtuous lay persons versus dangerous scientists. This is especially true if the makers of nanotechnology ignore its risks to the public, or if they know those risks but underestimate them, or if they know those risks but dissemble when they ought to be candid about risks.

If all three conditions come together, I anticipate that many public reactions to nanotechnology will be at least as ugly as the initial public reaction to rDNA in Cambridge, Massachusetts. The first, techno-hyperbole backlash, is well under way. There is a large body of writing and speech which says repeatedly that nanotechnology is extremely exciting because it has great potential to rearrange our material world. I do not challenge such predictions, but I note that these visions, and the ways they are presented, can scare some people to the same degree that they thrill others. Indeed, the most frightening speculations about nanotech are the bread-and-butter of the ETC Group's rhetoric.

Next, nanotechnology is custom made for Malinowskian conditions. It is likely to create profound historical changes. And, even if it benefits everyone to some degree because of the consumer products it generates, its political economy of patents, copyrights and venture capital will give us a situation in which a limited number of people control those profound historical changes.

The third condition is yet undetermined. There has been too little public awareness of nanotechnology and its risks to craft a believable narrative of virtuous lay persons versus dangerous scientists. There have been a few extremely general warnings about the evils of nanotechnology, but no specific episodes of the makers of nanotechnology creating terrible risks to the public and then ignoring or concealing those risks, whether medical or environmental or otherwise.

Given that the first two conditions are here now, and have a momentum which is unlikely to be reversed, but that the third condition is not yet established, I suggest that the task of anticipating public reactions to nanotechnology should be focused on the last element: what risks will scientists and engineers create? How will they assume responsibility for those risks? How will they mitigate those risks? Will they candidly describe those risks and their own responsibilities for generating them? How will the public assess these risks and the experts who create them?

A little bit of recklessness or disdain will be easily magnified and transmuted into a compelling story about amoral scientists arrogantly producing terribly dangerous threats to our health and our environment. Perhaps the relevant scientific knowledge will be distorted, ignored, exaggerated or manipulated, thereby leaving scientists feeling exasperated and powerless. Perhaps that is very unfair. But the important lesson is that hyperbole and Malinowskian conditions have already intensified the values, hopes and fears that will be shaped into public reactions to nanotechnology in the near future. It would not take much disdain for public health and safety to complete a combination of circumstances that would cause much of the public to fear nanotechnology and hate it. And then the stories that people tell about nanotechnology will take the form of myth-telling in a Malinowskian style. These dramatic narratives of existential good and evil will be most unkind to nanotech and those who create it.

**Discussion: cultural dynamics of public reactions to a new technology**

When we see that a public controversy is an interaction between a given science and a given set of cultural values, as in the cases of cold fusion, rDNA, and probably nanotechnology, what will be the balance between the science and the cultural values? Will the quality of the science be so good and so obvious that most values, hopes and fears will be neutralized? Or do the pre-existing values set the terms of the debate, so that they neutralize the scientific content?

In an ideal world, scientists would communicate scientific knowledge clearly and effectively to lay persons, who would then understand the knowledge and use it to make sound judgments about science policy. After Hiroshima and Nagasaki, scientists made a great effort to explain the atom to the public, thereby preparing the public to accept nuclear plants to generate electricity. During the 1950s and '60s, NASA and the media presented the basics of space science in a friendly way which enabled millions to understand it, at least at a rudimentary level. Currently the Human Genome Project devotes at least 3% of its budget to ethical, legal and social issues, including public understanding. In these three examples, scientists and science teachers have aspired to an ideal model of communication and understanding.

In many other cases, however, the world is far from ideal. Charles Rosenberg (1966) and others have argued that science in general carries enormous secular authority, but that people often turn to science to reinforce pre-existing values and ideologies. Scientific authority is selectively appreciated and interpreted, depending on those pre-existing extra-scientific values. The sociologist Simon Locke notes that public understandings of science are not typically anchored in science as understood by scientists. On the contrary, public understanding in a scientific controversy is largely shaped by the rhetorical strategies of the competing parties, says Locke, with the result that pseudoscientific positions look much the same as scientific conclusions (Locke 1994; 1999*). In my own work, I have built upon Rosenberg's insights to identify cultural values that influence public understandings of science in the U.S. and the mechanisms by which those values displace scientific knowledge (Toumey 1996a; 1996b; 1997).

As the American public comes to terms with nanotechnology, I note that: (1) general scientific literacy in this country is very poor; (2) scientific literacy for nanotechnology is practically nonexistent; and (3) certain cultural values, including strong hopes and deep fears, are likely to shape public understanding of nanotechnology. To paraphrase Rosenberg, nanotechnology will be appreciated or feared, not because of its scientific merits, but because of pre-existing extra-scientific values. Nanophilic hopes and nanophobic fears will not wait until after scientific work is completed, assessed and disseminated. The tangible results of nanotech will be selectively appreciated and interpreted in accordance with those hopes and fears.

It is likely that public attitudes about nanotechnology, whether positive or negative or mixed, will become more intense, more coherent, and more prominent in the very near future, as nanotechnology's tangible implications become apparent to the public. Perhaps this would not matter much if the scientific research and its applications were entirely independent of social forces, cultural values and political decisions. But in a democratic society like ours, nonexperts have a voice in the research agenda, even if their voices affect the research indirectly. Our political system offers numerous ways for nonscientists to influence science policy, for better or for worse, and when they do they will incorporate their own cultural values into our nanotechnology policy.

**Conclusions**

Representations in the form of narratives are a way of arranging people and values into a moral order: we make sense of a new reality by putting it into stories set in the past. Those stories then enable us to say that one hero is better than another; or that one thing is the most important thing, and other things are less important; or that some features are good, while others features are evil; and so on.

Narrative representations compete with one another for credibility and historical authenticity. Different people will tell different stories about the past, depending on which features they selectively choose as the essential lessons that must be taught. For nanotechnology, the scientists and engineers who work at the heart of this research will contribute valuable stories, and perhaps will dispute each other's stories, while equally powerful narratives will come from other citizen participants who have other values to emphasize and other lessons to teach.

That nanotechnology is a blessing or a curse; that scientists can be trusted or should be feared; that all will enjoy its benefits, or that a few will control its powers: these kinds of pre-existing feelings about science will be at least as influential as the scientific merits of the research in shaping public reactions to nanotechnology. The same was true in the earlier cases of fluoridation, cold fusion, creationism-versus-evolution, embryonic stem cell research, and many more forms of science and technology.

Nanotechnology is important enough to have its own collection of histories, tales, legends, myths and anecdotes, but it is also new enough that it has to borrow information from comparisons and analogies until its own record of public reactions is established. As we anticipate those public reactions, let us recognize how they will be shaped by values and lessons that arise repeatedly in democratic societies, particularly if nanotechnology delivers Malinowskian conditions like inequalities of power and profound historical changes.

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