Nanoethics (2007) 1:57–68
DOI 10.1007/s11569-007-0008-5

ORIGINAL PAPER

Revolutionary and Familiar, Inevitable and Precarious: Rhetorical Contradictions in Enthusiasm for Nanotechnology

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Received: 28 February 2007 / Accepted: 28 February 2007 / Published online: 23 March 2007

Abstract This paper analyses rhetorics of scientific and corporate enthusiasm surrounding nanotechnology. I argue that enthusiasts for nanotechnologies often try to have it both ways on questions concerning the nature and possible impact of these technologies, and the inevitability of their development and use. In arguments about their nature and impact we are simultaneously informed that these are revolutionary technologies with the potential to profoundly change the world and that they merely represent the extension of existing technologies. They are revolutionary *and* familiar. In debates surrounding possible regulation of these technologies it is claimed both that their development is inevitable, so that regulation would be fruitless, and that increased research funding and legislative changes are necessary in order that we can enjoy their benefits. That is, they are inevitable *and* precarious. An increased awareness of these rhetorical contradictions may allow us better to assess the likely impact and future of nanotechnology.

Keywords Ethics · Funding · Nanotechnology · Public opinion · Science · Rhetoric · Technology

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Introduction

As we enter the new millennium, powerful new technologies for engineering matter at the nanoscale are poised to transform our natural, social, economic, political, and moral environment. According to many writers, technologists, and government reports nanotechnology (or nanotechnologies) promises, or perhaps threatens, to change the world in ways in which we can as yet only partially imagine [9, 10, pp. 1–47; 14, 16–18, 28, 31, 32, 35, 46, 48, 56, 58, pp. 262–272; 77, pp. 25–32].[1]

Public debate about a nanotechnological future is shaped by two pairs of contradictory narratives. The first two narratives concern the historical significance of nanotechnologies, their nature and likely impact, and their relation to what has gone before. The second pair of narratives concern the extent to which the development of these technologies is inevitable and

[1]Whether it is appropriate to refer to the capacity to manipulate matter at the nanoscale as a product of nanotechnolog*y* or nanotechnologies is a vexed question in the literature about the social and environmental impacts and ethical issues associated with this capacity [60, pp. 5–6; 74, pp. 4–7]. I believe that either may be appropriate depending on context. In what follows, when I am discussing this capacity itself I will usually identify it with nanotechnology. However, when it is appropriate to draw attention to the multiplicity of different technologies which rely on, or realise, this capacity, I will refer to nanotechnologies.

the extent of human agency in the matter. Enthusiasts for nanotechnology often try to have it both ways on these questions. In arguments about the nature and impact of nanotechnologies, we are simultaneously informed that these are revolutionary technologies with the potential to profoundly change the world *and* that they merely represent the extension of existing technologies with which we are familiar. They are revolutionary *and* familiar. In debates surrounding possible regulation of these technologies, it is claimed both that their development is inevitable, so that any attempt to regulate or resist it would be fruitless, *and* that increased research funding, legislative changes, and changes in public attitudes are necessary in order that we can enjoy their benefits. That is, they are inevitable *and* precarious. An increased awareness of these rhetorical contradictions may allow us better to assess the likely impact and future of nanotechnology.

By "narratives," in what follows, I mean a set of resources, characters, settings, and plots through which we make sense of a situation. Narratives assert and presuppose certain basic factual claims but also include a set of speculations about possible futures. They structure the way in which we describe and relate events, in the past and — more importantly for current purposes — in the future. These narratives are sometimes deployed quite consciously in response to political and institutional challenges facing those with vested interests in these new technologies but they also have a force that shapes the way these parties understand their interests and the challenges they face.[2] In so far as they shape both the public debate about the future of nanotechnology and the intentions and self-understandings of participants in these debates, they are likely to play an important role in determining how these technologies are received and adopted [9, 10, p. 47; 43].

[2]It would also be a mistake to think that contradictory claims about nanotechnology are made only by its defenders. They also appear in criticism of nanotechnology, especially from the environmental movement. The pressures and incentives to use these narratives differ, however, if one is hostile to nanotechnology and thus they are typically deployed in different circumstances. As we shall see below, the temptation is to use them in roughly the reverse way as they are used by enthusiasts for nanotechnology. For reasons of space and because my aim is critical, my central concern here is with enthusiasm for nanotechnologies and I shall treat the rhetoric of critics of these technologies largely in footnotes.

Of course, there are multiple factors shaping and driving the development of nanotechnologies, not least powerful economic and corporate interests in them. I cannot hope here to resolve the debate as to how much economic forces, technical constraints, or social understandings drive technological development. I will merely insist that the narratives through which we understand technology play enough of a role to justify my attention to them here.

I should also emphasise that for the most part here I will not be concerned with the truth or falsity of the claims made by these narratives, or even with the question as to which of them is the "best" narrative. My primary purpose here is to draw our attention to the structures of these narratives and the contradictions and tensions that exist between them.

The four narratives with which I am concerned here are all very easy to discern in debates around nanotechnology. Occasionally one will come across a source or speaker who will draw upon all of these narratives in one presentation but most contributions to debates about these new technologies will draw on only one narrative from each pair. I do not want to suggest that these are the only narratives concerning nanotechnology, nor that those who draw upon them are always implicated in the contradictions I identify. I describe them as contradictory and there is a clear sense in which the claims of one are in tension with the claims of the other, in each pair. However, I do not wish to hold that it is impossible to construct versions of these narratives that are compatible. All I hope to establish here is that it will usually require some care to do so.

Revolutionary and Familiar

The first pair of narratives that I wish to discuss treat the relationship between nanotechnologies and what has gone before.

Revolutionary?

The first of these narratives – and perhaps the most pervasive – emphasises the revolutionary nature of nanotechnology [9, 10, pp. 1–47; 28, 43, 58, pp. 262–272; 77, pp. 25–32]. This narrative holds that nanotechnologies are revolutionary in two senses: firstly, that they represent a radical break from previous human efforts in the area; secondly, that they will change the world. The first of these claims has some force in struggles for status within the academy and in appeals for funding for research, but it is primarily a historical rather than a political claim. It is the second of these claims that is emphasised in public debate and that I am mainly concerned with here.

The idea that the development of nanotechnology heralds a technological revolution with widespread social, economic, and political implications is perhaps the most common claim made in discussions of nanotechnology [9, 10, pp. 1–47]. This idea appears in its most dramatic form in the writings of those who believe that a mature nanotechnology will consist in a "molecular manufacturing" technology, based either on "molecular assemblers" or on self replicating nanobots [14, 16–18, 35, 46]. Thus Eric Drexler notoriously claimed that,

> ... as advances in computer-aided design speed the development of molecular tools, the advance toward assemblers will quicken.... They promise to bring changes as profound as the industrial revolution, antibiotics, and nuclear weapons all rolled up in one massive breakthrough – [16, p. 20].

In a similar vein, the Center for Responsible Nanotechnology, suggests that,

> The next Industrial Revolution is right around the corner. Fourth generation nanotechnology – molecular manufacturing – will radically transform the world, and the people, of the early 21st century – Center for Responsible Nanotechnology, http://www.crnano.org/, 21.9.06.

Of course, the literature surrounding the idea of "molecular manufacturing" abounds with fantastic claims. According to some of its proponents, nanotechnology will cure cancer and heart disease, reverse pollution, feed the world and provide cheap – even free – consumer goods for all [14, 16–18]. Indeed, the claims made for nanotechnology by these authors are so far in advance of the existing reality that it sometimes seems as though there is almost nothing that it cannot do [21, p. 8; 69, 74, p. 3].

However, it would be a mistake to think that the claim that nanotechnology is revolutionary is made only by those who believe that a "molecular manufacturing" technology is just around the corner. This claim also appears regularly in the more "mainstream" literature around nanotechnology. Thus, the introduction to a significant contemporary collection of papers about the prospects for nanotechnology claims that,

> Nanotechnology holds the promise of advances that exceed those achieved in recent decades in computers and biotechnology. Its applications will have dramatic infrastructural impacts, such as building tremendously faster computers, constructing lighter aircraft, finding cancerous tumours still invisible to the human eye, or generating vast amounts of energy from highly efficient solar cells – [24, p. xiii].

Importantly, the revolutionary nature of nanotechnology is emphasised in various documents associated with the US Government's National Nanotechnology Initiative (NNI). The report that announced and described this initiative was entitled "National Nanotechnology Initiative – Leading towards the Next Industrial Revolution" [31][3] and included the statement that,

> ... nanoscience and technology will change the nature of almost every human-made object in the next century – [31, p. 16].

The NNI website homepage currently has the slogan "Leading to a Revolution in Technology and Industry" in a prominent position across the top of the page (http://www.nano.gov/, at 15.2.07). The anticipated size and impact of this revolution is conveyed by several oft-cited dramatic comparisons in documents that were instrumental in cohering industry and US government support for the initiative.

> As the twenty-first century unfolds, nanotechnology's impact on the health, wealth and security of the world's people is expected to be at least as significant as the combined influences in this century of antibiotics, the integrated circuit, and human-made polymers – [59, p. iii].

Given the impact of antibiotics on health care, and computers and plastics on manufacturing and engineering, this is no small claim! Alternatively, and

[3] The NNI has also (presumably as a publicity exercise) arrange to have this title inscribed in letters 50 nanometers wide [54, p. 5].

even more dramatically (given the inclusion of running water and electricity),

> ... nanoscience and nanoengineering will become as socially transforming as the development of running water, electricity, antibiotics, and microelectronics – [48, p. 1].

Or, without the benefit of these by now, perhaps, over-laboured comparisons,

> A revolution is occurring in science and technology, based on the recently developed ability to measure, manipulate and organise matter on the nanoscale... As a result, progress in nanoscience will have a very far reaching impact. ... There is little doubt that the broader implications of this nanoscience and nanotechnology revolution for society at large will be profound – [58, p. 1].

Nor is this claim about the revolutionary nature of nanotechnology made only by the authors (or editors) of these documents. Pages 262 to 272 of Roco and Bainbridge's (eds) [58], *Societal Implications of Nanoscience and Nanotechnology* consist of a number of testimonials by various authorities as to the significance of the collection's topic, several of which also emphasise the revolutionary impact of nanotechnology.

> Nanotechnology, the science of developing tools and machines as small as one molecule, will have as big an impact on our lives as transistors and chips did in the past 40 years. Imagine highly specialized machines you ingest, systems for security smaller than a piece of dust and collectively intelligent household appliances and cars. The implications for defense, public safety and health are astounding – Newt Gingrich, former Speaker of the U.S. House of Representatives (*Washington Post*, October 18, 1999, "We Must Fund the Scientific Revolution"), in [58, p. 270].

> The gathering nanotechnology revolution will eventually make possible a huge leap in computing power, faster stronger yet much lighter materials, advances in medical technologies, as well as devices and processors with much lower energy and environmental costs. Nanotechnology may well rival the development of the transistor or telecommunications in its ultimate impact – Charles M. Vest, President, Massachusetts Institute of Technology, in [58, at p. 263].

> The ability to control materials near the atomic level to alter properties, tailor their behaviour, and to build unseen devices will bring about a revolution that is currently unimaginable – Harry A. Atwater, President, Materials Research Society, in [58, at p. 266].

The affect of the editors listing the positions of these various authorities is to imply that these are not "fringe" opinions; these are people who should know what they are talking about!

Furthermore, the claim that nanotechnology heralds a revolution also appears in the writing of authors who explicitly repudiate Drexler's vision of "molecular manufacturing." For instance, Richard Smalley, one of the most outspoken critics of the idea of "molecular manufacturing" [7, 68] is nevertheless, in the course of his written testimony to the US Congress, prepared to quote approvingly Mike Roco's claim that,

> The impact of NT on health, wealth, and the standard of living for people will be a least the equivalent of the combined influences of microelectronics, medical imaging, computer aided engineering, and man-made polymers in this century – Roco quoted in [67].[4]

A popular account of nanotechnology, which explicitly disassociates itself from Drexler's vision (p. 6–9), similiarly claims of nanoscale science and technology that,

> It will not content itself with revolutionising the grand things: economy and culture and democracy. It will alter, from the inside out, the myriad small details that affect us – how we stay healthy, how we spend leisure time, how we raise our children. The nanocosm that supports these widespread changes may not always be apparent, but perceived or not, it will be the agent of revolution – [3, p. 12].

[4]This quotation is sometimes attributed to Smalley himself (see, for example, Mnyusiwalla et al. [45]) but by my reading of this source, he was actually quoting Roco (though with some variation of the passage in [59, at p. iii], cited above).

In short, the claim that nanotechnology is revolutionary occurs throughout the popular, scientific and academic literature on nanotechnology and is by no means confined to those who associate nanotechnology with molecular manufacturing.

Familiar?

When enthusiasts for nanotechnology trumpet its revolutionary nature, it is presumably because they expect their audience to respond with similar enthusiasm. Who wouldn't rush to embrace technologies that will provide the marvelous benefits outlined above? However, awareness of the revolutionary and world shaping potential of nanotechnology may also provoke another set of responses: uncertainty, fear and suspicion [21, 22, 32, 36, 77].[5]

When fears about the nature and impact of these technologies arise, another – contradictory – narrative is often deployed. This narrative emphasises the continuity of the new nanotechnologies with what has gone before. There is on this account nothing to be afraid of because the new technologies are just more of the same. What was touted as revolutionary turns out to be familiar [43, 64].[6]

Perhaps the most blunt way of asserting this is to insist that nanotechnology is already "here" by emphasising the continuities between some nanotechnologies and existing chemical, engineering and manufacturing technologies [43, 59, p. xxvi; 64, p. 219]. Thus,

> In some senses, nanoscience and nanotechnologies are not new. Chemists have been making polymers, which are large molecules made up of nanoscale subunits, for many decades and nanotechnologies have been used to create the tiny features on computer chips for the past 20 years – [60, p. 5].

And,

> "In one sense we've had nanotechnology for decades. A car tyre is black because it contains trillions of nanoscale carbon particles" – Doug Perovic, quoted in [3, p. 33].

Or, more ambitiously:

> ... seen this way, mainstream nanotechnology isn't really new; we've been unwitting nanotechnologists for centuries – [34, p. 20].

One scientific textbook on nanotechnology, even goes so far as to imply that nanotechnology has been used since the fourth century!

> It is known that in the fourth century AD Roman glassmakers were fabricating glasses containing nanosize metals. An artefact from this period called the Lycurgus cup resides in the British Museum in London. The cup... is made from soda lime glass containing silver and gold nanoparticles – [53, p. 1].

Alternatively, perhaps because it may be too deflationary to deny the novelty of nanotechnology in the world of engineering and manufacturing, it may be claimed that nanotechnology is already present in the natural world, in biological catalysts, in the cells and molecular structures involved in photosynthesis, and in the lustre of abalone [3, 48, 53, p. 1; 60, p. 5–6; 61, 67]. Or, as one researcher puts it,

> ... molecular manufacturing? Self assembly? Designer materials? Nature, my friend, has been doing all that for billions of years – Doug Perovic, quoted in [3, p. 33].

Thus, again, in stark contrast to the previous narrative of revolution, here we have a rhetorical strategy for rendering nanotechnologies familiar and therefore (hopefully) harmless.[7]

[5] Somewhat cynically, it is in the service of these emotions that critics of these technologies are most likely to emphasise their revolutionary nature.

[6] This strategy of legitimation is, of course, not unique to nanotechnology [9, p. 628]. For a good discussion of its role in promoting biotechnologies see [8, p. 63–72].

[7] The suggestion that the possible hazards associated with nanotechnology are lessened because it is familiar occurs with striking regularity in discussions of the likely environmental affects of nanoparticles wherein it is often pointed out that we are all already often exposed to nanoparticles in the form of the exhaust products from diesel combustion engines, soot from forest fires, and salt in sea air [56, p. 185; 60, pp. 51–57; 71, p. 13; 74, p. 14]. What this observation neglects (besides, bizarrely, the fact that some of these particles are known to be responsible for thousands of deaths each year in modern cities) is that the nanoparticles that have been produced by human activity to this point have been accidental products with large distributions of particle size and shape. Engineered nanoparticles will have uniform distributions and particular structures. They are therefore likely to behave very differently.

In contexts where the revolutionary implications of nanotechnology seem all too obvious, the claim that it should be regarded merely as an extension of what has gone before is sometimes advanced by asserting a continuity at a more profound level. We are, it is sometimes insisted, tool using animals [35, pp. 15–18; 38, pp. 1–2]. Alternatively, it may be suggested that curiosity is natural to mankind; we are creatures with a desire always to know more about the world. Occasionally, but less often in contemporary debate, the existence of a drive to dominate and control nature is postulated [39, p. 209]. Regardless of the particular nature of the drive that is postulated, the affect of postulating it is to assimilate the new (nano) technology to the old, as being just another product of this familiar human urge. In an unexpected – but not unwelcome – turnaround it is the critics of technological progress who are denying and transcending nature.

The idea that nanotechnologies are simply familiar extensions of existing technologies is one of the points where the two narrative pairs which interest me here intersect. If these new technologies are no more than incremental extensions of familiar existing technologies and/or if they are the products of innate human drives, it is more plausible to claim that their development is inevitable.

Inevitable and Precarious

The second pair of narratives that I wish to examine contest the extent of human agency with regards to the future of nanotechnology. One – perhaps the dominant – narrative insists that the development of nanotechnology is inevitable. The other, on the contrary, implies that it is precarious.

The Inevitability of Technological "Progress"

The idea that technological progress is inevitable is also a familiar one [8, p. 19]. Indeed, it is one of the most remarkable features of debates about nanotechnologies, just how little agency most people think we have in relation to their development. As Cyrus Mody [43] has observed, the literature around nanotechnology is suffused with an implicit technological determinism.

Again, this narrative is perhaps most explicit in the writings of those who believe that a mature nanotechnology will take the form of a "molecular manufacturing" technology. Tellingly, according to Bill Joy [32], Eric Drexler started the Foresight Institute "to help prepare society for anticipated advanced technologies." For his part, Ray Kurzweil [35] heads successive sections of his futurist opus, *The Age of Spiritual Machines*, "Preparing the present" (Part II) "To face the future" (Part III). The introduction to a collection which includes some of the most fantastic (and far-fetched) meditations on the impact of advanced nanotechnology suggests that,

> Nanotechnology poses a difficult question: what will we human primates do when some of us learn to manipulate matter as finely as the DNA and RNA molecules that encode our own material structure? This book speculates on the outcome of this surprising and yet seemingly inevitable technological revolution – [14, p. ix].

However, this claim about the inevitability of nanotechnology also appears in the writing of authors who think that molecular manufacturing *a la* Drexler is at most a distant likelihood. A recent primer on the implications of nanotechnology for the business community insists that,

> The science behind nanotechnology is real; it is here now; it is constantly evolving, expanding, and improving; and it *will* change the way we live – (emphasis in the original) [73, p. 12].

and that,

> ... the question is not *if* nanotechnology is going to happen but *when* – (emphasis in the original) [73, p. 188].

The narrative of inevitability also informs the National Science and Technology Council's [48] report on nanotechnology. The concluding words of this report are,

> It no longer seems a question of whether nanotechnology will become a reality. The big question is how important and transformative nanotechnology will become, will it become affordable, who will be the leaders, and how can it be used to make the world better place? – questions that will, in time, be answered.

The use of the passive voice in the final clause of this passage is striking. These "big questions" "will be answered" – all those of us who are going to experience the nanotechnology revolution need to do is wait to see how!

The prevailing view amongst enthusiasts for nanotechnology can, therefore, perhaps best be summed up as "The future is coming, we'd better get ready for it." A full explanation of just why the future development of these technologies is inevitable is less common. One suspects that any argument to this conclusion might rely on empirical, political, and historical premises that are more controversial than is generally recognised [43].

In fact there seem to be a number of different strands of argument made in the service of this narrative of inevitability.

The first presents a kind of "techno-optimism" which rests on the premise that technological development is self-evidently a good – or at least that the steps required to halt it are self-evidently bad [15, p. 51; 35, p. 130; 52, p. 289]. Sometimes this is because the free development of technology is seen as a condition, or perhaps a consequence, of a free market. As free markets are good and regulating them is bad, so too is unfettered technological development good, and any attempt to regulate it bad. Alternatively, it may draw upon the arguments discussed above, which hold that technological development stems from an innate human drive. Realising our nature is good, whereas thwarting it is clearly a bad thing. In either version, technological development is seen primarily as progressive, and consequently inevitable, because of a faith that human history tends towards progress [11, 20, p. 233; 38, p. 174].[8]

The second strand takes no position on the question of whether the development of these technologies would be a good or a bad thing, but relies on an empirical claim about the impossibility of regulating technological development. It is often argued that it is impossible to prevent a technology being realised once it is a technical possibility. Once we *can* do something, then it is inevitable that someone, somewhere, *will* do it [14, p. 194; 25, pp. 187–188]. This is especially true if there is some obvious incentive to do so, no matter how short sighted this might be. Again, one reason for believing this refers to the nature of free markets. A free market economy creates powerful incentives for economic actors within it to resist, avoid, or thwart regulation, where a profit can be made [34]. Market societies have arguably had little success historically in regulating technologies. The difficulties involved in regulating technology are greatly exacerbated by the fact that, in a world where goods and ideas move with ease across national borders, halting or regulating technological development would require action at an international level [16, p. 20; 25, pp. 187–188; 32, 75]. Because competing nation states may also each have incentives to develop these technologies, for instance because they have military application, or because they offer possible economic benefits, this requirement is especially daunting.

The third strand, affirms the possibility of regulating technology and indeed the desirability of doing so, but argues that there is currently no conceivable social movement that could in fact force their regulation [34]. This strand sometimes takes the form of a resigned "techno pessimism," wherein it is allowed that these technologies may in fact be dangerous and destructive [14, p. 194; 25, p. 187; 46, pp. 311–314; 75]. Even though it is possible for governments to regulate technological development, it requires substantial political will for them to do so. Governments are unlikely to possess this will unless they are responding to an active and powerful pressure group. In the last decade or so, progressive and social movements have been on the retreat from a concerted onslaught by conservative governments and free market idealogues. After so many successive defeats, it is difficult to imagine any existing social movement overcoming the powerful corporate interests that oppose the regulation of these technologies. According to this line of thought, our inability to halt the march of technology is an unfortunate reality of our contingent political circumstances.

All of these strands contribute to the narrative of the inevitability of technological "progress". Typically, those opposed to regulation start with the first strand, retreat to the second, and then insist on the third. That is, they first hold that the development of these technologies is a good, then that it can't be stopped, and finally that we can't stop it.

The Precariousness of Progress

However, the fact that the argument is occurring at all suggests that the development of these technologies is

[8] Of particular interest in this context is the discussion of "Moore's Law" in the literature surrounding nanotechnology which often treats an empirical historical claim about manufacturing capabilities as though it were a natural law.

not inevitable. Claims about the inevitability of technological change sit alongside an often slightly hysterical insistence that the future of nanotechnology is in fact precarious. It is often suggested that unless we take action now, we will miss out on the (potential) benefits of nanotechnologies [31, 47, 59].

The first reason why, it is sometimes suggested, this might be the case is that the development of these technologies is dependent on government investment in research into the basic science that underpins them [2, pp. 18–19; 29, 41, 55, 76]. Many basic questions about the science which will underpin these new technologies remain unanswered, and which research projects are likely to answer these remains unclear. Pure and "blue sky" research is therefore essential to the development of these new technologies. Yet, with a few notable exceptions [50, 62], private corporations are unwilling to invest large amounts into basic research, because of the high risks involved [31, p. 23]. Most basic research fails to yield any profitable results. Progress in basic science is therefore heavily dependent on government funding [31, 50, 58, p. 10; 59].[9]

Even when funding for research is provided by the private sector, the research being done typically relies upon and presupposes research being done or previously carried out, in the public sector [12, 42]. Sometimes this is obvious, as when researchers employed in publicly funded institutions devote their expertise and skills to particular research projects funded by private corporations. However, more subtly – and, I think, more importantly – the education of these scientists relies on universities and other research institutes, such as government laboratories and teaching hospitals, that could not exist without state support [31, p. 23; 58, p. iv; 13, 57, pp. xi–xii; 76]. Thus even much private sector and commercial research and development is ultimately reliant on adequate levels of public funding for research [26, pp. 6–27; 29, 55, 59, 72, 76].

Insisting that the development of these new technologies is precarious is therefore an important strategy in winning more government funding for research [2, p. 6].

However, public funding for research is actually the lesser of the two things that techno-enthusiasts require from the state. More important, is a legal – but also a moral – context which enables research (and product development) to proceed.

The law may impact directly on research and/or manufacturing by rendering it, or procedures involved in it, illegal. Thus, for instance, some stem-cell researchers ordinarily based in the US have had to work overseas to pursue lines of research prohibited by law in the United States. As yet, as far as I am aware, nanotechnology has not fallen foul of this kind of direct legal sanction, however, as I will discuss below, the prospect that it might be so affected (should calls for a global moratorium be heeded by governments) looms large in discussions of social attitudes to nanotechnology.

In any case, indirect effects of the law are more common and typically more important in shaping the development of new technologies. The law may affect the prospects of research by shaping the motivational structures of those involved in it. The most obvious way in which this may happen is the result of the interaction between commercial interest in a technology and the law of intellectual property. Corporations are unlikely to be willing to invest in nanotechnology research unless they can foresee making a profit from owning and selling the product of their research [21, 33, p. 49; 50, 51]. However, the commercial risks involved in bringing a technology to market are also in part a product of the regulatory environment in which research and commercialisation are pursued [20, p. 165; 71]. Thus, laws relating to material standards, occupational health and safety, privacy, the environmental release of nanoparticles, liability for damages associated with exposure to nanomaterials, and the sale and transfer of "sensitive" technology may all play a role in determining how (and whether) a technology develops [1, 6, 23, 30, 40, 47, 60, pp. 13–15; 63, p. 101; 71, 74, p. 12 & 16; 77, pp. 35–37].

Thus one of the reasons it is sometimes suggested that the development of new technologies is precarious is an "outdated" legislative context [60, pp. 76–78]. Unless we change the laws then the technology will not develop. The precarious nature of our fabulous nano-future is therefore emphasised whenever changes are sought to legislation in order to protect, facilitate or encourage research.

While the law is explicit and its impact obvious, the moral or social context in which research occurs

[9] An important source of funding for research into basic and even applied science is the military. Many existing technologies have their origins in research conducted by the military, or alternatively to the fact that military applications provide a guaranteed sources of profits in the early stages of the development of a commercial technology.

can have similar effects [5, 60, pp. 81–82]. If a technology or research program is widely believed to be profoundly immoral, it may be difficult to find reputable and competent scientists who are willing to work on it. Popular opposition may threaten the laboratories in which it occurs, as happens today in the United Kingdom with research involving live animals. Alternatively, even if research succeeds, commercial vendors may be unable to persuade the population that they desire its benefits [73, pp. 181–186]. The lack of a viable market for a product, due to consumer fears or hostility, may in turn jeopardise commercial interest in funding research in an area [74, p. 6]. This possibility haunts much of the literature about the social and ethical implications of nanotechnology, which often cites consumer and public hostility to genetically modified foods and/or organisms, as an illustration of how public attitudes can derail a technology [2, 6, 13, 30, 37, 44, 49, 60, pp. 81–82].

For these reasons, significant changes in public attitudes may be necessary before research and development of a technology can proceed. Sometimes the plea for change is directed towards public ears; unless "we" overcome our fears about nanotechnology, for instance, we will not reap its benefits [16, pp. 237–9].[10] More often the plea is made for the government, or scientists themselves, or science communicators, to "educate" the public [45, 47, 48, p. 8; 49, 57, p. x; 70]. Either way, the fact that the plea is made highlights the concern that the development of these technologies is precarious.

So if *this* narrative is to be believed, the development of these technologies is not inevitable at all.

Enthusiasts for these new technologies typically try to avoid this embarrassing admission, by insisting that the development of whichever technology is under discussion *is* inevitable, what concerns them is simply whether *we* are the ones who will develop it or – more importantly – whether we are the ones who will profit from it. That is, they embrace the narrative of inevitability in relation to its development, but emphasise the precarious nature of our own profit from this fact. This usually takes the form of arguing that "if we don't do the research, someone else will." What's more there's a – insert large number here – million dollar export industry that we will not be able to compete in unless we develop the technology ourselves.[11] The literature around nanotechnology abounds with dramatic claims about what nanotechnology will be "worth" at some date in the future [56, 58, pp. 182–4; 72] in the context of an implicit threat that governments that fail to invest in and facilitate nanotechnology research will miss out on these spoils [19, 27, 64, p. 217].

However it is not clear that this attempt to reconcile the narratives of inevitability and precariousness succeeds. To begin with, the narrative of the inevitability of their development typically purports to include their future locally as well as globally. However, as those who embrace the narrative of precariousness at the local level admit, circumstances in Australia are sufficient to render their development here uncertain. Of course, if it is true that the development of these technologies is inevitable at the global level, then this will undoubtedly have implications for their arrival and impact locally. Yet, the relation between their global and local future seems unlikely to hold only in one direction. The development of these technologies in any nation is part of their development globally. There is no reason why the government policies, legal restrictions, and social attitudes that might halt the development of these technologies locally should be confined to one nation. Indeed, some of the circumstances that allegedly render the development of these technologies precarious are already global. The legal contexts, and especially the intellectual property regimes, that partially determine commercial interest in these technologies are increasingly the product of international agreements. Similarly, social attitudes towards nanotechnology are increasingly constituted and contested at a global level by governments, corporations, and non-government organisations [21, 66, p. 150]. In all of these matters what happens in Australia may influence events elsewhere around the world. If their future here is precarious then this makes their future globally (more) precarious. Ultimately, however, it is not my intention here to try to settle whether or not these narratives can be

[10] Again, it is worth remembering here the Foresight Institute's stated aim to "help prepare society" for the coming technological revolution.

[11] In passing we should note that this is an odd form of argument to adopt in relation to a moral, or even a social, issue. It amounts to saying "bother the ethics, there's money to be made." It would in fact license any immorality, as long as there's a profit to be made, and other parties unscrupulous enough to try to make it. It would justify arms sales to Third World dictatorships, or growing opium to sell to drug cartels, for instance.

reconciled; it may well be that they can. My purpose here has merely been to question whether doing so is as simple a matter as distinguishing between their development at a local and a global level.

Implications

I have deliberately avoided engaging in a debate about the relative merits of the claims made within the various narratives that I have identified. A thorough evaluation of the relative significance of these competing narratives in relation to the future of nanotechnology would require entering into the debates in which they have their currency, a task well beyond the scope of this paper. Nonetheless, simply becoming clear on the structure of these narratives, and the contradictions and tensions between them, has a number of important consequences.

Firstly, the existence of flourishing but contradictory narratives around these issues highlights the fact that there are genuine and unresolved questions here. It seems likely that none of these narratives tells the whole story. Nanotechnologies are in some senses unlike anything that has gone before and as such open up radical new possibilities for transforming the world around us; in other ways, they build on and resemble existing technologies and pose many of the same problems. There are powerful incentives and social forces propelling their development, but also social and political choices being made to promote it [43]. Until we have a better sense of how much each of these things is true, discussions of the future of these technologies are likely to suffer from being too easily captured by one or other of these narratives. It is important that we study the history and politics of technology if we wish to be able to think productively about its future [4, 65].

Secondly, the fact that the same narratives are so widely used to describe and understand nanotechnology also suggests that they are to some extent "all purpose" means whereby to understand new technologies. The tools we have to understand the future of these new technologies turn out to be old ones. As the narrative of "familiarity" reminds us, this may not be entirely inappropriate. Many of the issues raised by these technologies are old and familiar ones such as environmental risks, social impacts, and political questions. However, these technologies may also raise new issues and these issues are likely to be different for different nanotechnologies. We should therefore be careful about thinking about the future of these technologies through the same set of narratives. We need to develop new, more complex, narratives which are sensitive to the specificities of the particular technologies, through which to understand each of them.

Thirdly, identifying these different narratives and the contradictions between them, empowers those who – like myself – would prefer that we were cautious in embracing the supposed benefits of nanotechnology. We can point our the embarrassing contradictions in the rhetoric of enthusiasts for nanotechnologies; they should not be allowed to have it both ways on these questions. If these technologies are revolutionary, then we are right to be concerned about them. If they are familiar, then we know all too well the problems they may bring with them. If the development of these technologies is inevitable, then why should we go out of our way to make it possible? If it is precarious, then that means that we have a choice to refuse it. Recognising the tensions between the narratives that are used to promote these new technologies opens up a conceptual and rhetorical space in which to question and interrogate claims made about nanotechnology.

Finally, and perhaps most importantly, an examination of the range of narratives drawn upon in these debates draws our attention to the less popular narrative of the precarious nature of technological development. This narrative implies that we do have substantial agency in relation to the future of technologies. It therefore holds open the possibility that we could reject particular technologies if we wished [66, pp. 131–150]. If nanotechnologies won't develop unless we change our policies, laws and minds about them, then by resisting these changes we could, if we wished, resist the development of these technologies. In a period in which we are continually being informed that our lives will, in the near future, be revolutionised by technological changes beyond our control, it is vitally necessary to remind ourselves that we may have a choice in this matter [37]. While advocates for these technologies demand that we change to accommodate them, a political struggle to control our own future remains an open possibility.

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