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Y a-t-il encore de la place en bas ?

Lessons from the Land of Atoms and Molecules

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Lessons from the Land of Atoms and Molecules

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Résumé : Lorsque les sciences humaines et sociales analysent les nanotechnologies, que révèlent-elles de ces disciplines ? Ici, je propose six éléments de réponse. Tout d'abord, nous pouvons nous demander si notre travail est issu de travaux antérieurs sur d'autres sujets scientifiques, tels que les organismes génétiquement modifiés ou le programme ELSI du projet du génome humain. Deuxièmement, comment jugeons-nous les promesses extravagantes associées à les nanotechnologies ? Troisièmement, que concluons-nous sur les origines des nanotechnologies ? Après cela, le problème de la définition des nanotechnologies. Ensuite, la question de savoir s'il aurait pu ou dû exister un consensus sur l'éthique en nanotechnologie. Et enfin, la responsabilité de communiquer nos découvertes et nos points de vue aux communautés scientifiques et d'ingénieurs qui créent les nanotechnologies.

Abstract: When the humanities and social sciences examine nanotechnology, what does this reveal about those disciplines? Here, I cover six topics. First, we can ask whether our work is derived from earlier work on other scientific topics like genetically modified organisms or the ELSI program of the Human Genome Project. Secondly, how do we judge the extravagant promises that were attached to nanotech? Third, what do we conclude about the origins of nanotech? After that, the problem of defining nanotechnology. Then the question whether there could have been, or should have been, a consensus on ethics in nanotech. And finally, a responsibility to communicate our findings and insights to the scientific and engineering communities that make nanotech happen.

1 Introduction

When I was a graduate student in anthropology many years ago, I tried to imagine how I might find my own place in the social sciences. One day I heard a story that taught me an important lesson about this part of academia. The story is doubtless apocryphal, and although I cannot guarantee its truth, it nevertheless reminds me that we need to have a sense of why we study nanotechnology.

The story dates from the late nineteenth or early twentieth century, and concerns a college in the United States which felt that it needed to enhance its teaching of the social sciences. Funds were raised and a building was erected to house sociology, psychology, and perhaps some other disciplines. The building now needed an epigram to be carved in stone above the entrance to remind its occupants of its mission with respect to both teaching and learning.

The social scientists suggested the second half of a couplet from Alexander Pope's 1734 *Essay on Man*:

Know Then Thyself, Presume not God to Scan. The Proper Study
of Mankind Is Man.

I like the way this justifies the social sciences, especially if "man" is taken to mean mankind, and not only one gender.

The Protestant trustees of the school did not approve of this idea, as to them the business of governing the school was a Christian mission. The couplet from Pope seemed to them irreligious, perhaps bordering on atheism. That would not do. So they reached into their own values and knowledge, with the result that they ordered a different epigram, namely, the question from the beginning of *Psalms* 8: 4-6:

What Is Man That Thou Art Mindful of Him?... For Thou Hast
Made Him a Little Lower Than the Angels, and Hast Crowned
Him with Glory and Honor...

The moral of this story is that you may have your own reasons for teaching sociology or any other subject, but your employers have their reasons, and theirs count more than yours.

From this story I infer that it is good for us to be aware of why we use the perspectives of the humanities and social sciences to study nanotechnology and other topics in science or technology. We should also consider how studying science and technology affects us. So here I offer a series of insights about the ways that we have investigated nanotech over the past seventeen years or so. I understand that my views are very much anchored in my own experiences, but my hope is that my insights will be helpful and relevant to all who have worked in this area. Perhaps my comments will have some value for those who examine other topics of science and technology as well, such as artificial

intelligence, synthetic biology, or environmental science, as they walk in the footsteps of those who have studied nanotech.

About two years after I arrived at the University of South Carolina in 2000, a group of faculty in the humanities received a generous grant from the U.S. National Science Foundation to study nanotechnology. When they first invited me to join the group, I declined because I was trying to launch a very different research project for myself. But the nanotech research slowly earned more and more of my curiosity. By the summer of 2003 I was wholeheartedly involved, and happily so.

Almost all of my research and writing since then has addressed societal and cultural issues in nanotech. I write a humanistic commentary on nanotech four times a year in the journal *Nature Nanotechnology*, plus peer-reviewed papers for journals, encyclopedias, and edited volumes. At this point I have had approximately ninety professional publications on nanotech.

So then, here is what I think:

2 Models for the ethics of nanotechnology (SEIN): ELSI or GMOs?

First, there is the question of how our work on nanotech derives from earlier work on other topics in science and technology. There are two principal accounts. Some say the relevant precedent was a series of controversies over genetically modified organisms, or GMO's, from the 1990s. Many in Western Europe rejected the idea of GMOs in the food supply out of hand, with the result that GMOs have been severely restricted in Europe. This suggested that the E.U. and some member states which felt optimistic about nanotech were concerned that nano might share the fate of GMOs. Supposedly they felt that investigations of nanotech by the humanities and social sciences would lubricate the friction between nanotech and its critics, that is, mitigate opposition to nanotech.

And there was a competing account on the other side of the Atlantic. I heard that the government-funded program of "ethical, legal and societal implications" (ELSI) from the Human Genome Project was the template for "societal and ethical implications of nanotechnology" (SEIN), as the National Science Foundation labeled that work. At a workshop on nanotech in Washington DC in April 2007, I asked a panel of three members of the U.S. Congress, plus an aide to the Chair of the House Science Committee, whether the inspiration for SEIN was ELSI or GMOs. All of them claimed that it was ELSI. It was known that the ELSI work was not perfect, but if SEIN was to be the child of ELSI, then it was intended that the child would be wiser than the parent.

I am saying that our interest in nanotech does not arise from nothing. It might well be that scholars in the humanities and social sciences on one side of the Atlantic wanted SEIN to be ELSI.2, while those on the other shore expected it to be GMO.2. There were conditions that preceded and informed the study of nanotechnology and they were not the same in the United States as in Western Europe. I believe that conferences and other venues eventually smoothed out those differences, but it is not a bad thing to be self-aware about our early motives—and our different motives—for examining a topic in science and technology.

Secondly, we would be wise to see that sometimes our career choices are steered by herd mentalities. Before we studied nanotech, many studied either ELSI or GMO's; after funding for SEIN started to dwindle, many migrated to studies of synthetic biology, also known as SynBio, or to examine Artificial Intelligence.

One can see these changes in the venues for disseminating our work. The journal *NanoEthics* focused closely on nanotech for several years, and then expanded to include synthetic biology and other topics. S.NET was originally the Society for the Study of Nanotechnology and Emerging Technologies; now its acronym means New and Emerging Technologies. The acronym is the same, but the topical interest is broader. Both the journal and the society continue to include the topic of nanotech, but no longer exclusively so.

It is not wrong for us to study any of these scientific topics, but we should bear in mind that our work is also a social-science phenomenon. Partly this is because we need to discover where we will find the next source of funding for our work, and partly it is because we share some visions of what is the next scientific topic worth studying.

There is no shame in seeing what our colleagues see, nor in caring about what our colleagues care about. But we need to see that when we move together from ELSI to SEIN to SynBio, we are doing this as a community and we are part of something bigger than our individual selves. This academic behaviour is not a result of totalitarian politics or of religious fanaticism, but it is still a group phenomenon.

3 The extravagant promises of nanotechnology

Next I have some ideas about the particulars of our work on nanotechnology. Early on we invested much of our interest in Eric Drexler's vision of nanotech. We felt that we needed to understand the science to the best of our abilities, and also that we ought to comprehend the popular visions of nanotech. Drexler's vision was the primary entry for nonscientists who became seriously interested in nanotech. We did not have to agree with Drexler, but we needed

to take him seriously to the extent that his ideas influenced a large population of nonscientists.

Subsequently it became clear that almost none of the scientific work actually being done in nanotechnology was in line with Drexler's vision. There was a wide gap between, on the one hand, Drexler's sense of nanotech and, on the other, the experiments, discoveries, publications, patents, and applications that have made nanotech so exciting. It appears that Drexler's vision has had a negligible influence on the scientists and engineers who make nanotechnology happen [Toumey 2014]. Some scientists in nanotech disagree with Drexler; some ignore him; some have simply never heard of him.

Eric Drexler continues to insist that he sees what one should see, and that those who see otherwise are misguided [Drexler 2013], [Drexler & Smalley 2003]. Even if his stance barely affects the science, if at all, those of us in the humanities and social sciences accept a continuing responsibility to consider how nonscientists know and judge nanotech. Whether we like it or not, Drexler's writing, especially his 1986 book, *Engines of Creation* [Drexler 1986], remains extremely influential among nonscientists who become curious about nanotech.

One might say that we wasted our time on a wide-eyed visionary who is largely ignored by the scientists and engineers in nanotech. But if there is a difference between Drexler's vision and the science that happens in working labs, and if the values and concerns of nonscientists constitute a legitimate research topic, then we need to recognize that the views of Eric Drexler are still the principal portal through which most nonscientists first encounter nanotech and gain a sense of what it might be.

A related point is that when nanotechnology started to receive a great deal of attention, respect and serious funding circa 2000, it benefited greatly from extravagant promises. This would be the next industrial revolution, it was said. Carbon nanotubes would displace everything made of steel because they are six times lighter and a hundred times stronger than steel. Nanomedicine would cure cancer and greatly extend the human lifespan. The predictions concerning the benefits of nanotech were grand enough to make sensible people become giddy.

And then the excessive expectations evaporated. Many good things have happened in nanotech, and many more are coming down the road, sooner or later. I believe that sometime in the future, nanomedicine is going to deliver some very effective therapeutics for cancer that will kill the tumors without harming non-cancerous cells: targeted drugs will displace chemotherapy with all its dreadful side effects. But this is still in the future.

There is a parallel story about extravagant expectations which is worth remembering. In 2003, the Director of the National Cancer Institute (a prominent part of the National Institutes of Health) predicted that suffering and death from cancer would be eliminated by the year 2015 [von Eschenbach 2003]. Nanomedicine was incorporated into that vision. It appears that the

Director's promise was increasingly ignored or forgotten as 2015 approached without achieving what was predicted, but some people learned the lesson that it was unwise to present an unrealistic expectation.

When nanotech failed to quickly deliver the amazing things it promised, policy makers and managers of government funding programs began to have second thoughts about investing so much so soon in this area. We learned another lesson here: extravagant promises might result in large amounts of dollars, euros, or pounds at first, but if you cannot produce the results you promise, then you discredit yourself, and it is likely that your sponsors will choose to invest their financial resources elsewhere.

This is a tricky situation. If your vision of a certain science or technology is modest because you want to be realistic, then your grant proposals may be less competitive than those that shine with glittering optimism. But if you promise too much and deliver too little, then that mistake will catch up with you sooner or later. This affected the study of nanotech by the humanities and social sciences as much as by the natural sciences.

4 The mythology of the origins of nanotechnology

Another lesson I learned was that there are competing narratives about the origin of nanotechnology. The premier origin myth says that nanotech began with Richard Feynman's 1959 talk "There's Plenty of Room at the Bottom" [Feynman 1959]. Indeed, the U.S. National Nanotechnology Initiative states on its website that Feynman is the father of nanotechnology. I found that certain persons in the CalTech (California Institute of Technology) community are especially devoted to this account, largely because Feynman spent most of his teaching career there. He was a brilliant Nobel Laureate and charismatic in a larger-than-life way.

I have no reason to dislike Richard Feynman or his remarkable genius, but I prefer a different account of what made nanotech happen. The group that I joined at the University of South Carolina was centered on faculty in the Department of Philosophy. One of their principal contributions was to examine epistemological issues in the relationship between nanoscale objects—especially atoms and molecules—and images of those objects produced by scanning probe microscopy. This included the Scanning Tunneling Microscope (STM) and the Atomic Force Microscope (AFM). I like to summarize those issues by saying that an image of an atom or a molecule cannot possibly look like a real atom or molecule.

Those epistemological questions point us to the invention of the Scanning Tunneling Microscope in 1981 and the invention of the Atomic Force Microscope in 1986 as the foundational moments in the field. Both of those

inventions came from IBM scientists, namely, Gerd Binnig and Heinrich Rohrer at IBM Zurich for the STM, and Binnig for the AFM. So then, if nanotech is made possible because of the STM and the AFM, then the Feynman/CalTech story is less compelling, and the IBM account is primary.

And on that point, I should mention that my own most prominent contribution to the study of nanotech was, in my opinion, my 2008 paper on the history of Richard Feynman's 1959 talk [Toumey 2008]. His talk was published six times in the following three years, which is truly impressive, but after this it was rarely cited in the twenty years between 1959 and 1979. I thought that in my paper I had shown that Feynman's talk was *not* the origin of nanotech. This science has multiple facets and multiple origins, and is not limited to that which Richard Feynman said in December 1959. Thus, without intending to endorse one narrative or another, I must admit that my view is more favorable to the IBM story than to the CalTech version.

But my account seems to have sunk without a trace. It happens again and again that the origin of nanotech—supposedly a singular origin—is said to be Feynman's talk. Chagrin, frustration, and bemusement: these are the feelings that course through me when I hear that nanotech began with Feynman.

This is not to say that scientists in nanotechnology spend their time choosing between the CalTech story and the IBM narrative. But if we are attentive to nuances in competing narratives—do not the humanities lovingly nurture narratives and their nuances?—then the story of the origin of nanotech becomes more interesting because we have two incommensurate accounts to weigh against each other.

I have my reasons for preferring the IBM version, partly because I learned from scholars who focused on issues of epistemology involving images produced by the STM and the AFM. It has been a great pleasure for me to learn about those issues at the feet of certain philosophers and artists. But I do not deny that my own perspective derives from my interactions with the team at the University of South Carolina. I understand that other scholars in other situations might have reasons to embrace different accounts of the origin of nanotechnology. This is not something that can easily be condensed into a simplistic linear history of this multidisciplinary field of study.

5 The problematic definition of nanotechnology

Next question: If we have committed ourselves to studying nanotechnology, then do we know what it is that we are going to study? What exactly is nanotech—this domain that apparently looms so large on our intellectual horizons? More specifically, what is nanotechnology as understood by those of us in the humanities and social sciences?

For this question we need to recognize three features built into nanotech that shape our knowledge and intentions. First, nanotechnology is not defined by a single product like a better smartphone or a singular process like the polymerase chain reaction. On the contrary, it embraces every scientific and engineering discipline and subdiscipline, plus certain technologies, for controlling matter that is measured at the scale of the nanometer. It includes atomic physics and subatomic physics; but not to the exclusion of organic chemistry and inorganic chemistry; and molecular biology; plus microelectronics; also materials science; in addition, scanning probe microscopy and electron beam microscopy; and many more fields.

At the University of South Carolina, our tutors for the science underlying nanotech were mostly from the Department of Chemistry. I hear that at other universities, the scholars in the humanities and social sciences get their scientific knowledge mostly from professors of physics. And in other cases, the focus is on microelectronics.

I do not mean to say that one science is a more legitimate purveyor of nanotech than another. But it could be that, in the early days of our work, some of us saw nanotech primarily as an exercise in chemistry, while others saw it as an extension of physics, and so on. In fact the person in organic chemistry could well have more in common with her counterpart in molecular biology than with the person down the hall doing inorganic chemistry in the same chemistry department.

This also means that a professor might describe his or her work in organic chemistry as such when there is a call for proposals in that field, but she might describe it as nanotech when the call for proposals is labelled as nanotechnology. The same work can be both chemistry and nanotech; or physics and nanotech; or molecular biology and nanotech; and so on. Likewise, scientists can publish their work on nanotech either in classic disciplinary journals or in recently founded nanotech journals.

Nanotech is a creature with multiple identities. When the funding agency or the journal says chemistry, then the scientist says I do chemistry; when they say nanotech, the scientist says I do nanotech. This is not intrinsically duplicitous. One's science ultimately speaks for itself, even if the label on the science changes. Nevertheless, this situation complicates the task of saying what nanotech is.

A second problem built into our investigations of nanotech concerns a sense of time. The earliest applications of nanotech were to relatively trivial products like golf clubs and tennis rackets reinforced with small quantities of carbon nanotubes. The truly impressive applications, like curing cancer or saving the environment, are to be found somewhere in the future. As a result, it is possible for anyone to project their hopes or fears onto the future state of nanotech. We can know what nanotech is like today, but it is not clear that nanotech will be the same in ten or twenty years.

A third condition is this: nanotechnology is an enabling technology, also known as a multipurpose technology platform. Consider the story of the assembly line. When it was invented to put automobiles together, it was not immediately obvious that it would have other purposes. But soon it served as a way to make sewing machines and almost any other product that needed many different parts to be put together in a particular order.

This means, again, that it is possible for anyone to project their own expectations onto nanotechnology, not limited by the current state of science and technology.

Perhaps this is just a bunch of silly daydreams to the scientists and engineers who make nanotech happen. I can understand this attitude. But if nanotech is going to change our material culture—medical diagnosis and therapeutics, microelectronics, materials science, and many other areas where technology touches us—then it is worth knowing what people hope for from nanotech, and what they fear about it. And the responsibility to discern these hopes and fears falls into the laps of those of us who toil in the humanities and social sciences.

6 A culture of collaboration and referencing in the ethics of nanotechnology

Next I'd like to comment on a way for us to make the best of each other's work. My example is the study of ethics in nanotechnology. I have in hand two hundred published papers on ethics in this area, and there could well be another hundred or so. My collection ranges chronologically from Weil [2001] to Hester, Mullins *et al.* [2015], and alphabetically from Allhoff [2007] to Wolfson [2003]. By one standard, this is very good. Many people have crafted thoughtful statements about ethics. And quantity of publications seems to be the principal metric by which the U.S. National Science Foundation judges the value of the research it funds.

It is regrettable, however, that few of the later papers build upon the earlier ones. For the most part, these publications on ethics cite each other very little. One would hope that all this work would result in a consensus, or at least a synthesis that highlights the main themes of these many publications. But if most authors ignore most others, then together these papers constitute a loose compendium of stand-alone statements.

We can observe the same phenomenon when we consider other topics in the study of nanotech: many excellent scholars have produced much superb work, and have published their findings, but have not shaped that work into a comprehensive vision of what we have learned and what we ought to do next. It is not possible to go back and start over again with our examinations of

nanotech, but perhaps this lesson will be useful for the next large-scale studies of science and technology. A consensus or synthesis of research related to a particular topic is worth having and worth doing.

7 The different publics for studies of nanoethics

I will conclude with one more observation, plus a recommendation to go with it. I mentioned earlier that each year I have four short humanistic commentaries in *Nature Nanotechnology*. This is my platform for showing the scientists and engineers who read this journal that the humanities and social sciences (not limited to my own work) can contribute to our understandings of nanotech.

Recently I completed a project, with valuable help from graduate research assistant Meagan Conway, aimed at discovering whether publications in SEIN actually reach the people who make nanotech happen. We conducted sixty interviews distributed among four populations: academic scientists and engineers in nanotech; persons involved in U.S. government policy for nanotech; persons in nanotech-related start-ups; and, intellectual property attorneys who steer nanotech products through patenting and regulatory processes.

We found that only a small fraction of all the SEIN work had come to the attention of persons in those four populations [Toumey & Conway 2017]. This brings us to a two-part question: when this community of ours studies nanotech from the perspectives of the humanities and social sciences, is our work trivial or nontrivial? If it is trivial, then there is no reason to communicate our work to the people who make nanotech happen, especially scientists, engineers and persons in government science policy. Or to anyone else for that matter. We can be entirely happy in our little bubble, enjoying our own little festival of the humanities.

But if we are really generating insights that help others to better understand nanotech, then it makes sense to communicate these insights to the people who make nanotech happen. Here I add that I am not the only one in the SEIN community who has had commentaries published in *Nature Nanotechnology*, which I appreciate. Furthermore, I am partly motivated by an ethos from my home discipline of cultural anthropology. If we benefit in our careers because certain communities permit us to study them, then we have a responsibility to share our results with those communities. For one anthropologist, the community might be a village on an island in the Pacific. For another, it might be a scientific community working in nanotech. The ethos of sharing the results with the community under study applies in both cases.

Now let us generalize to other STS topics. The Nature Publishing Group has approximately thirty monthly journals. Some address classic scientific

disciplines, e.g., *Nature Physics* and *Nature Chemistry*. Others are devoted to newer, more specialized topics, including biotechnology, nanotechnology, climate change, and sustainability. In this family of journals, there is a venue for writing commentaries for almost any topic of science or technology that one wants to study in STS.

In addition, there are trade publications read by scientists and engineers: *Technology Review* (from MIT); *Engineering & Science* (from CalTech); *Chemical & Engineering News*; *IEEE Science and Society*; and more.

I suspect that there are two reasons why many of us in STS hesitate to submit papers to those venues. First, their commentaries are not typically peer reviewed; second, there is much pressure to publish in the journals of one's home discipline, and neither scientific journals nor trade publications have any such value. These two considerations are especially acute for tenure-track assistant professors. Indeed, some fear that publishing a non-peer-reviewed article in a non-humanities journal can be the Kiss of Death when a committee considers whether one deserves tenure. What a rotten thing it is, if I am right, that a historian or a philosopher or an anthropologist has to choose either to communicate her work to the scientific community she studied, or to maximize her chances for tenure. But not both.

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