Chapter 1
On the Autonomy and Justification of Nanoethics*†

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Abstract In this paper, I take a critical stance on the emerging field of nanoethics. After an introductory section, Section 1.2 considers the conceptual foundations of nanotechnology, arguing that nanoethics can only be as coherent as nanotechnology itself and then discussing concerns with this latter concept; the conceptual foundations of nanoethics are then explicitly addressed in Section 1.3. Section 1.4 considers ethical issues that will be raised through nanotechnology and, in Section 1.5, it is argued that none of these issues is unique to nanotechnology. In Section 1.6, I express skepticism about arguments which hold that, while the issues themselves might not be unique, they nevertheless are instantiated to such a degree that extant moral frameworks will be ill-equipped to handle them. In Section 1.7, I draw plausible distinctions between nanoethics and other applied ethics, arguing that these latter might well identify unique moral issues and, as such, distinguish themselves from nanoethics. Finally, in Section 1.8, I explore the conclusions of this result, ultimately arguing that, while nanoethics may fail to identify novel ethical concerns, it is at least the case that nanotechnology is deserving of ethical attention, if not a new associative applied ethic.

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1.1 Introduction

Nanotechnology has been hailed as the “next Industrial Revolution” (National Science and Technology Council’s Committee on Technology, 2000), and promises to have substantial impacts into many areas of our lives. These impacts will be manifest through many of the novel applications that nanotechnology will enable; these applications will take advantage of features that are only realized through nanoscale manipulations. And, through these technological advances, many ethical and social questions will, or have been, raised (Allhoff et al., 2007). These questions have given rise to the emergent field of nanoethics, which has been characterized by substantial research funding and an explosion of publication outlets (including this one).

What has yet to happen, though, is any sort of sustained and critical meta-discussion regarding the field of nanoethics itself: what *is* this field? What delimits it? What is *special* about it? These questions can be answered by any number of platitudes—such as “nanoethics is the study of the ethical and social dimensions of nanotechnology”—but these answers are extremely limited in their elucidation. First, they seem to *presuppose* that there are such dimensions, and that is precisely one of the issues at stake. Second, and less obviously, they presuppose that the notion of nanotechnology itself is a coherent one: for nanoethics to be related in some way to nanotechnology, the former concept can only be as sensible as the latter.

In this paper, I want to try to see what legitimacy can be conferred upon nanoethics. In particular, I will be interested in whether there are any ethical issues that are unique to nanotechnology and, if not, what implications that has for the field itself. Ultimately I will argue that, while there are *not* substantially novel ethical implications raised by nanotechnology, this fact does not undermine the need for ethical *attention* to nanotechnology, as well as the need for associative public and political forums. In other words, I think that nanoethics lacks any metaphysical autonomy (from other areas of applied ethics), but I nevertheless think that the field can receive a pragmatic justification. I take this pragmatic justification to be weaker than a metaphysical one, but a justification nonetheless.

1.2 Conceptual Foundations of Nanotechnology

As I mentioned above, I take it that nanoethics can only be conceptually coherent as nanotechnology itself. The reason is that the former has to, at least in some sense, be predicated upon the latter. Most intuitively, “nanotechnology” must be used in the definition of “nanoethics” as, for example, the above conception that “nanoethics is the study of the ethical and social dimensions of nanotechnology”. But of course, if we said that “bachelors are unmarried males” and “males” or “married” were nonsensical concepts, then “bachelors” would be nonsensical as well. So, insofar as nanoethics could (and, usually, is) defined by reference to nanotechnology, the former only makes as much sense as the latter.

So, what is nanotechnology? This is a question that has already been addressed elsewhere, so I will not linger too long (Allhoff and Lin, 2006). But, while there might be independent reasons for coming up with some specific conception of nanotechnology, the point of the question in this paper is that the question bears directly on the cohesiveness of nanoethics.

A common definition, and one that is good enough for these purposes, comes from the National Nanotechnology Initiative (US) "nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications." (National Nanotechnology Initiative, n.d.).[1] This definition, then, seems to suggest two necessary (and jointly sufficient) conditions for nanotechnology. The first is an issue of *scale*: nanotechnology is concerned with things of a certain size. "Nano-" (from Greek *nannos*, "very short man") means one billionth, and, in nanotechnology, the relevant billionth is that of a meter. Nanometers are the relevant scales for the size of atoms; for example, a hydrogen atom is 7.874×10^{-10} ft in diameter, which is an unwieldy scale to use since we could rather describe the same dimension as about a quarter of a nanometer. The second issue has to do with that of *novelty*: nanotechnology does not *just* deal with small things, but rather must deal with them in a way that takes advantage of some properties that are manifest *because* of the nanoscale (Allhoff et al., 2009).

Either one of these conditions raises conceptual difficulties for nanotechnology. Regarding the issue of scale, there are simple boundary issues that are already well-trod among philosophers: imagine that some nanostructure has some dimension of 110 nm. Or 150 nm. Or 230 nm. Are there principled reasons for excluding some of these structures from the realm of nanotechnology? At least one point is that the 100 nm upper-bound for nanotechnology is more conventional than "real", and that conventions have their limits. In deciding whether some structures that lie just outside this range are therefore impervious to any dialogue about nanoethics, we need not to take such stipulative definitions too seriously.

Also regarding the issue of scale, it is an odd feature of the NNI definition that it is silent as to the issue of dimensionality. Our world is comprised of three spatial dimensions, and the nanoscale might be appropriate to some of these dimensions, but not others. For example, nanoscientists distinguish between zero-dimensional

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[1] As an anonymous reviewer pointed out, this definition is ambiguous between two readings: whether the novelty attaches to the matter at 1–100 nanometers or whether it attaches to nanotechnology itself. Ultimately, the interpretation hinges on the semantics of the clause following the comma, which could be read either restrictively or non-restrictively. Consider, for example, "marsupials are mammals who lay eggs." In this case, "who lay eggs" is a restrictive clause used to distinguish egg-laying mammals from non-egg-laying mammals. Alternatively, consider "marsupials are mammals, who lay eggs." In this case, the more natural reading of "who lay eggs" is as a non-restrictive clause which suggests that all mammals lay eggs. If the comma makes the difference, then, the novelty attaches to the matter at the nanoscale, and not (necessarily) to nanotechnology itself. But this then falsely suggests that *all* matter at that scale manifests such novelty given the scope of the non-restrictive clause. Rather, it seems that *nanotechnology* should manifest the novelty, and the semantics of this definition are therefore misleading. I thank the reviewer for these insights, as well as the linguist that she/he consulted in providing them.

nanostructures, one-dimensional nanostructures, and two dimensional nanostructures. For reasons completely beyond my comprehension, the nomenclature here is to identify the number of dimensions that are *not* confined to the nanoscale: zero-dimensional nanostructures (e.g., quantum dots) are confined to the nanoscale in all three dimensions; one-dimensional nanostructures (e.g., nanowires) are confined to the nanoscale in two dimensions; and two dimensional nanostructures (e.g., nano-films) are confined to the nanoscale in one dimension (Allhoff et al., 2009). On the NNI definition, it is not clear whether, for example, nanowires count as nanotechnology since they have one dimension that exceeds 100 nm. Maybe the idea is that nanotechnology has *at least one* dimension that is on the nanoscale but, first, this is rarely made explicit and, second, it is not immediately clear why one, as opposed to two or three, is the relevant number of dimensions.

Second, as the NNI definition intimates, any serious definition of nanotechnology has to transcend mere scale: simply because a few atoms have been isolated, it hardly follows that there is nanotechnology. Rather, the point has to be that such technology requires the demonstration of phenomena that are manifest *because* of their occurrent scale and, furthermore, these phenomena have to be harnessed in some relevant way such as to be productive. Intuitively, then, the NNI definition seems to be headed in the right direction, but there is no easy way to resolve much of the ambiguity that it invites. In particular, what are "phenomena"? What does "novel" mean? How about "application"? There are at least some straightforward cases. For example, nanotechnology enables previously impossible surface to volume ratios and, insofar as the surface of materials is the most reactive, novel applications are indeed possible.[2] A washing machine that uses silver nanoparticles to kill bacteria (Silver Institute, 2003) works precisely because there is simply more silver surface put into contact with more bacteria, so this application takes advantage of a straightforward feature of nanoparticles and, undoubtedly, produces a novel application. And, in addition to surface to volume ratios, nanotechnology can take advantage of other features, such as quantum effects, unique bonding patterns and lattice arrangements, and so on.

But, while there might be cases that obviously satisfy the requirement that "unique phenomena enable novel applications", there are other cases where this is far less clear. For example, some baseball bats are now fortified with carbon nanotubes, which make the bats stronger. The strength/density ratios of the nanotubes clearly take advantage of nano-properties, but it is less clear what the "novel application" is. Certainly it is novel to embed the nanotubes into a *baseball bat*, but the *application* (that of hitting a ball) is hardly novel at all. Even if the ball goes a little further.

The point of this discussion is not to nitpick the definition offered by the NNI which, again, is very standard and, I think, as good as any other. Rather, the point is supposed to be that these sorts of definitions necessarily draw arbitrary lines and

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[2] The surface of a sphere is given by $A = 4\pi r^2$ (where r is the radius of the sphere) and the volume is given by $V = 4\pi r^3/3$. The surface to volume ratio, then, is $3/r$ so, as the radius gets smaller, the surface to volume ratio goes up.

invoke vague concepts which, when pushed on, might be susceptible to challenge or confusion. Maybe there are other ways to offer the definitions than the philosophically preferred method of offering necessary and sufficient conditions,[3] but I do not see any of them as being completely unproblematic.

1.3 Conceptual Foundations of Nanoethics

So, for now, let us assume that we have a handle on what nanotechnology is and then try to figure out what we are talking about when we talk about nanoethics. As I said above, it might be fairly common to understand this as pertaining to the ethical and social implications of nanotechnology. It is worth noting, though, that even this conception seems oddly incongruent with nano*ethics*, which does not make any obvious reference to social implications (at least those that do not have ethical upshots). Sometimes the social and ethical implications are grouped together as SEIN (social and ethical interactions with nanotechnology)[4], but the territory is littered with all sorts of other acronyms as well, such as NELSI (nanotechnology's version of ELSI—ethical, social, and legal implications—that was first associated with the Human Genome Project) or NE^{3}LS (nano-ethical, environmental, economic, legal, and social issues) (Keiper, 2007). I think that many of these acronyms are generated to enjoin some sort of self-importance that plays well to funding bodies, but they betray a lack of conceptual unity. Are environmental issues part of nanoethics? Legal issues? Or, as already mentioned, social issues? As the field seeks an identity, it has to be clear about what is part of it and what is not, and the proliferation of disparate acronyms challenges such a conception.

It has to be the case that ethics cuts across various other inquiries, among them social, legal, environmental, and economic. Furthermore, it is probably the case that many of these other inquires have non-ethical components. For example, figuring out how extant patent law applies to nanotechnologies is not a simple issue (Harris, 2008), but it is not obviously an ethical issue either, particularly if we just

[3] See, for example, Schummer (2008), Section 2. Schummer identifies, in addition to the traditional "nominal" definitions, both "real" and "teleological" definitions for nanotechnologies. Real definitions refer to a list of particular research topics, though it still seems to me that there will be vagueness as to what is or is not on this list. Or else that the list is so fluid across time as to not be of much use in the first place. Teleological approaches define nanotechnology in terms of its future goals, but then it seems that there are the obvious problems of *whose* goals should count in such an analysis, and different constituencies would obviously have different goals. Furthermore, those goals are, again, fluid across time, so this would not lead to stable definitions. Regarding this last point, which was again made against "real" definitions, I take it that one desideratum of definitions is that they should be (at least mostly) persistent; it would not make much sense to say that, today, bachelors were unmarried males but, tomorrow, they were something else altogether.

[4] Baird and Vogt (2004). Some understand "SEIN" as "social and ethical implications of nanotechnology", but I do not see this as a relevant difference.

refer to the issues of legal interpretation (which might be normative, if not ethical) and not to what *fair* laws should be. Similarly, there are issues about how nanotechnology will affect the environment (Myhr and Dalmo, 2007). Some of this is just going to be basic science, and that is not (immediately) ethical in nature, but there are ethical questions about what sort of environmental practices are morally permissible (or obligatory). Nano-economics will be an issue, particularly with the implications that nanoscience has for the developing world (both in terms of what it offers and in terms of what the latter might not be able to afford) (Schummer, 2007b). Again, there are probably two ways to analyses for these impacts, which can be ethical and non-ethical. Regarding the latter, it is an open question what the economic impacts *will be*, and this is just a factual question. But there are also ethical questions that those facts will raise, particularly as pertain to issues of distributive justice.

The point, then, is supposed to be that some of these ethical questions are very proximate to, if not inextricably bound up with, some of the non-ethical questions that will be raised by various other (viz., non-ethical) questions into nanotechnology's impacts. In developing our conception of nanoethics, it certainly becomes complicated as we try to delimit a field that is so closely interrelated to various other ones; many of these boundaries will be blurred or attenuated at best. It is not clear to me, then, how separable the social, legal, economic, and environmental issues are from the ethical ones, as many of these acronyms seem to suggest. I think that, as we move forward, these complexities are important to recognize.

Nonetheless, what seems more important to me than what we *call* the field (i.e., which acronym we favor) is what the field amounts to.[5] And, insofar as some of the ethical issues will have social upshots, or else will involve legislation, the environment, or economic policy, we might just end up with a fairly broad nano*ethics*. What remains to be seen, though, is precisely what these ethical issues are, as well as the implications that those issues have for circumscribing an autonomous applied ethic. In Section 1.4, I will deal with the first issue and, in Section 1.5, the latter.

1.4 Issues in Nanoethics

Regardless of how we define nanoethics and how we draw its boundaries, it must, at the end of the day, be the sort of discipline that is constituted by various ethical issues. Whether those issues are sufficient to confer autonomy upon the field remains to be seen, but certainly the existence of relevant ethical issues is a necessary—if not necessarily sufficient—condition for delimiting an applied ethic. In this section, I want to present briefly some of the ethical issues that nanotechnology allegedly raises. The point here is not to do this in tremendous detail, which is both

[5] In this, I am sympathetic to the "real" approach discussed by Schummer. See footnote 3 above, where I mention some misgiving about it but, practically (if not theoretically), it has some advantages.

inappropriate for the task in hand and, regardless, has already been done elsewhere.[6] Rather, the idea is to get some ideas on the table that will be useful for the remainder of this discussion.[7]

1.4.1 Legal and Regulatory Issues

Nanotechnology will pose challenges to extant legal and regulatory schemes, some of which will be strained or compromised by technological advancement.[8] Consider, for example, patent law, which will have to accommodate developments in nanotechnology. Taking carbon nanotubes in particular, there are four patent law doctrines which could be used to challenge their patenting. These doctrines (from the U.S. Patent Act) include whether the new product is: patentable (35 U.S.C. §101); anticipated by prior art (§102); obvious given prior art (§103); and "enabled" (for production, given the patent; §112) (Harris, 2008). And, in this particular case, meeting any of those criteria is going to be a challenge (Harris, 2008).

Regarding regulations, some of the current frameworks are inadequate to deal with nanotechnology (Lin, 2007). For example, regulations exist to secure the safety of substances that exist either in the workplace or in public; these regulations mandate the creation of materials safety data sheets (MSDS) which contain information regarding the properties of those materials, including the potential hazards that they present. At present, MSDSs for carbon nanotubes and fullerenes are identical to those used for graphite. While these are all carbon allotropes, they have very different physical and chemical properties (and, presumably, hazardous properties as well) (Baird and Vogt, 2004).

Another example is Samsung's "Silver Wash" washing machine, which uses silver nanoparticles to kill bacteria. There are worries that the nanoparticles could be discharged and concentrate in water treatment plants, where they might kill bacteria that are supposed to be detoxifying wastewater. The Environmental Protection Agency (US) has now classified this washing machine as a pesticide and subjected it to appropriate legislation (Royal Society of Chemistry, 2006). The producers of the washing machine, however, can avoid this legislation by simply removing claims that their washing machine kills bacteria. Whatever else we want to say about this case, the classification of a washing machine as a pesticide seems forced, and the "opting out" conditions for the regulation seem too lax. As nanotechnology

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[6] In addition to this book, see Allhoff et al. (2007).

[7] The following list is becoming more or less standard, but there are two sources that I have paid especially close attention to in drafting it. See Baird and Vogt (2004). See also Robert (2008), especially Section 2.

[8] While I will have nothing specific to say about intellectual property, this is closely related—if nevertheless orthogonal in some respects—to legal and regulatory issues. See Robert (2008) for brief mention therein. The following discussion of patents, though, reveals some of the issues that attach to intellectual property as well.

enables either non-traditional applications of traditional products or else allows novel products altogether, it will be imperative to decide whether extant frameworks are adapted to accommodate these developments or whether those frameworks are jettisoned in favor of new ones altogether.

1.4.2 Research Funding and Priorities

Nanotechnology research commands huge sums of money, and that investment is growing rapidly. In the United States, research commitments have risen from $116M in 1997 (Roco, n.d.) to over a billion dollars in 2005 (National Nanotechnology Initiative, n.d.). By some measures, this might not seem like a tremendous amount of money. For example, the United States allocated $439B to the Department of Defense in FY2007 (Office of the US President, n.d.), which is two orders of magnitude greater than its investment in nanotechnology. Nevertheless, this is still a lot of money that could have been put to some other purpose. Is this too much money to invest in nanotechnology? As with all issues in federal funding, there are a multitude of projects competing for a limited number of dollars, and some determinations must be made as to how to spend it. If funding into nanotechnology comes at the expense of other projects to which governments bear ethical obligations—e.g., security, health care, retirement, etc.—then that funding needs to be justified.

In addition to the funding that nanotechnology commands—or, more precisely, *because* of the funding that it commands—it exerts an influence on the entire scientific community. This influence is manifest in various ways. Examples include: personnel (as scientists who research something else turn to nanotechnology); institutions (as Centers and Institutes are developed for nanotechnology's pursuit); cultures (as nanotechnology becomes trendy, develops journals, conferences, societies, etc.), and so on. In all of these cases, we can ask whether the influence is good or bad. While neither nanotechnology nor its funding is going to go away, it is surely the case that we can substantively ask whether the investment *levels* for nanotechnology—including the non-monetary ones just mentioned—are appropriate or whether they should be reconsidered.

1.4.3 Equity

As mentioned above, nanotechnology will raise issues regarding fair distribution; issues regarding nanotechnology and the developing world will be particularly acute (Schummer, 2007b; Schummer, 2008). While I have already mentioned water purification as a potential environmental application for nanotechnology, it is worth emphasizing that 1.1 billion people lack access to safe drinking water, and that this leads to millions of deaths a year, especially among children in poor Asian and African countries (World Health Organization, 2004; quoted in Schummer, 2007b). Nanotechnology may very well offer the potential to mitigate many of these problems, but the countries most in need will be those most unable to afford the new technologies.

Second, nanotechnology may be used in solar energy production, particularly through applications in photovoltaics. If solar power becomes available, this will bear substantial impact on rural communities since those communities will lack access to central power plants and grids (Schummer, 2007b). Many of these communities may be under- or unpowered, and the application of nanotechnology to cheap and widely available solar energy could have substantial impacts.

Third, there are medical applications of nanotechnology that will be of primary importance to the developing world. For example, consider HIV/AIDS, which generated 4.1 million new infections in 2005, and 2.8 million deaths; these infections and deaths were borne disproportionately by the developing world (UNAIDS, 2006). Against this backdrop, consider an Australian company which has a developed a dendrimer, SPL7013, which might be used in a vaginal microbial gel to prevent HIV infection during intercourse.[9] Because dendrimers fall under the purview of nanotechnology, this means that nanotechnology has the potential to play a serious role in HIV/AIDS prevention.

These examples, of which there are others, show that nanotechnology could provide substantial benefits to the developing world. Again, though, the developing world is going to be unable to afford many of the technological interventions that would be so valuable. Questions are then raised about equity and distributive justice: the developed world will have access to technologies that the developing world will not, and then we must ask—*especially* in light of the tremendous benefits that the developing world could receive from these technologies—whether this is morally acceptable.[10]

1.4.4 Environment, Health, and Safety[11]

As Baird and Vogt (2004) succinctly write: "[n]anotechnology's promise is that it will provide new means for pollution remediation and less toxic ways to manufacture goods. However, latent toxicity is the flipside: nanosize materials are interesting because their physical and chemical properties differ so radically from

[9] Schummer (2007b), p. 298. For an associated scientific study, see Jiang et al. (2005).

[10] It is also worth pointing out that, though the discussion herein has been framed in terms of the developed versus developing world, issues of equity can cut against different axes as well: rural/non-rural; carbon-based/non-carbon-based economies; oil and non-oil producing regions, etc. This nanodivide, therefore, can be far more insidious than merely trans-continental. See Baird and Vogt (2004), p. 393. I follow Schummer (2007b), though, in thinking that the questions regarding the developing world are the most perspicuous, which is not to say that others might not be profitably explored.

[11] Environmental impacts are sometimes treated separately from health and safety ones, though they are often treated together as well. For present purposes, I think that they can be properly consolidated. Generally, my view is that a sufficiently broad conception of "environment" covers the health and safety issues as well, though I will use the more standard "environment, health, and safety (EHS)" locution.

bulk amounts of chemically the same compounds. Some of these differences are useful and wanted, but others have the potential to be less desirable."

In the way of specifics, nanotechnology is likely to enable more efficient and effective water filtration, options for cleaning up oil spills, various coatings (to protect against the environment) and, potentially, artificial photosynthesis (Allhoff et al., 2007). But these applications carry risks with them as well. For example, one study has linked buckyballs (i.e., synthetic carbon molecules of a specific orientation) to brain damage in fish.[12] Also, studies have indicated that carbon nanotubes can lead to toxic effects in mice (Lam et al., 2004). Certainly there are issues worth discussing in these studies—in particular, the delivery mechanism in the mice study is unlikely to be naturally occurrent—but they at least highlight some of the potential impacts that nanotechnology could have on the biological world.[13] And, of course, the environmental implications of nanotechnology could (directly) affect humans as well (Myhr and Dalmo, 2007). Particularly at risk could be those who work in factories where production might lead to the liberation of nanoparticles into the air; worker safety is surely a legitimate ethical concern.

In addition to toxicity, there are other ethical issues that pertain to nanotechnology and the environment. For example, as water purification becomes more efficient and effective, it might be the case that we then incur duties to apply these technologies (as against inefficient and ineffective previous generations thereof). Furthermore, the availability of environmentally positive nanotechnologies may change the moral status the developed world bears to the less-developed (and, in particular, the environmentally compromised) world; for more on equity issues, see Section 1.4.3 above.

Most basically, then, there will be questions about whether we *can* use these technologies (given toxicity and other risks), whether we *have* to use these technologies (given obligations of environmental stewardship), and whether we have to *share* them (given obligations to international distributive justice).

1.4.5 Privacy[14]

Another area in which nanotechnology will have an impact is in terms of monitoring and surveillance (Khushf, 2004; see also Gutierrez, 2007). New sensor and surveillance technology is being enabled by the rapid development of submicron technologies and nanotechnology. Many nanotechnologies, from lithography to molecular electronics are helping to make computing devices smaller and faster; these developments will continue into the foreseeable future. Devices for signal

[12] See Oberdörster (2004). For a follow-up study, see Zhu et al. (2006).

[13] For a discussion of some of the interpretive issues, see Berube (2008).

[14] The following section is excerpted and adapted from Allhoff et al. (under review).

detection, solar energy collection and a variety of mechanical, electrical and chemical operations are being miniaturized at the micrometer level, and all of these technologies together provide the means for such devices as Radio Frequency Identity Chips (RFIDs) (Schummer, 2007a).

RFIDs are already widely used for tracking and tracing various items (Jules et al., 2005). An RFID chip or tag consists of a small integrated circuit attached to a tiny radio antenna, which can receive and transmit a radio signal. RFID tags are now also being used to trace and track consumer products and everyday objects as a replacement of barcodes (Kardasiadou and Talidou, 2006). Governments and the global business world are preparing for a large-scale implementation of RFID technology in the first decades of the twenty-first century for these purposes (van den Hoven, 2006). As RFIDs become smaller, they may well become too small to be seen by the naked eye or otherwise be undetectable given extant or (widely) available technologies.

Monitoring and surveillance capabilities are not the only areas that will be enhanced by the kinds of tracking and sensing devices already discussed: allied health fields—and, in particular, their use of medical records—deserve much discussion in this regard. Lab-on-a-chip technologies, for example, will facilitate very rapid, economical, and comprehensive medical diagnosis and screening, and the rapid decoding of genetic dispositions could become possible in normal clinical work. But as with the concern raised in the Human Genome Project, employers or insurance companies could pressure individuals to make this information available, and the data could be monitored by the employer (Schmid et al., 2006). This clearly raises worries about privacy and data protection.

In all of these applications, questions can be raised about the relevant (moral) benefits and costs. The benefits will be manifest through increased safety and security or, in medical applications, through improved outcomes. The costs will be impingement upon individuals' rights and liberties, particularly those that pertain to privacy (whether in general or with medical records in particular). A corollary of these costs will be *who* might have access to the information: presumably many—though perhaps not all—of the costs might be mitigated by delimiting proper custodianship of personal information. However, protecting the custodianship will be non-trivial, and there will surely be disagreements as to which custodianships (and of what) should be constituted in the first place.

1.4.6 Medicine

Nanotechnology will have applications to medicine—often called nanomedicine or, more broadly, bionanotechnology—and these applications will raise ethical questions (European Commission Group on Ethics in Science and New Technologies, 2007). For present purposes, let us focus on three such applications: treatment, diagnostics, and delivery (Ebbesen and Jensen,2006; see also Bawa and Johnson, 2008).

Nanotechnology enables surgical techniques that are more precise and less damaging than traditional ones. For example, a Japanese group has performed surgery on living cells using atomic force microscopy with a nanoneedle (6–8 μm in length and 200–300 nm in diameter) (Obataya et al., 2005; quoted in Ebbesen and Jensen, 2006). This needle was able to penetrate both cellular and nuclear membranes, and the thinness of the needle prevented fatal damage to those cells. In addition to ultra-precise and safe surgical needles, laser surgery at the nanoscale is also possible: femtosecond near-infrared (NIR) laser pulses can be used to perform surgery on nanoscale structures inside living cells and tissues without damaging them (Tirlapur and König, 2003). Because the energy for these pulses is so high, they do not destroy the tissue by heat—as conventional lasers would—but rather vaporize the tissue, preventing necrosis of adjacent tissue (Ebbesen and Jenson, 2006).

There are also non-surgical treatment outcomes that will be facilitated by nanotechnology. For example, gold nanoparticles show potential for noninvasive cancer treatment (National Cancer Institute, 2005a). Many cancer cells have a protein, epidermal growth factor receptor (EGFR), distributed on the outside of their membranes; non-cancer cells have much less of this protein. By attaching gold nanoparticles to an antibody for EGFR (anti-EGFR), researchers have been able to get the nanoparticles to bind to the cancer cells (El-Sayed et al., 2006). Because the gold nanoparticles differentially absorb light, laser ablation can then be used to destroy the attached cancer cells without harming adjacent cells.

Similar strategies can also be used to effect improved diagnostic outcomes (National Cancer Institute, 2005b). Again, gold nanoparticles, by using anti-EGFR, can be used to bind to cancer cells. Once bound, the cancer cells manifest different light scattering and absorption spectra than benign cells (El-Sayed et al., 2005). Pathologists can thereafter use these results to identify malignant cells in biopsy samples. These results offer the promise of a generalization: nanoparticles can be differentially bound to something of interest—be it cancerous or whatever—then there will be potential for increased diagnostic power and, hopefully, better treatment outcomes.

Relatedly, delivery options can also be improved. Some therapeutic agent can be attached or adsorbed onto a nanocarrier which could then go on to deliver it to some precise location (again, by invoking various binding parameters) (Ebbesen and Jensen, 2006). This localized delivery will have the advantage of being more targeted (i.e., so that the agent gets where it needs to be) and minimizing side effects (i.e., so that the agent does not get anywhere other than where it is supposed to be).

Regarding ethical issues, toxicity will play a central role as we have limited information about the nanoparticles used in some of the treatment, diagnostic, and delivery applications mentioned above. How will these interact with the human body? How will they be processed after their use? While not mentioned above, these technologies could also be used for genetic interventions (by providing the delivery mechanisms), and there are ethical issues therein, including the traditional therapy/enhancement debate. There will also be issues of access, insurance, etc. as these technologies are not likely to be inexpensive (at least in the near term).

1.5 What's New?

In this section, I want to go through the social and ethical issues raised in the previous section and to argue that none of them is new or novel in any substantial way. As this part of my project has been addressed—if less systematically—elsewhere (Grunwald, 2005; Lewenstein, 2005; Litton, 2007), I will not belabor these points, but rather will try to quickly establish preliminary conclusions that will go on to form the basis for the rest of this paper.

1.5.1 Legal and Regulatory Issues

As mentioned in Section 1.4.1, there are questions about how to integrate nanotechnology into extant legal and regulatory frameworks, and some of those frameworks seem ill-equipped to accommodate these new technologies. This challenge, though, is surely not novel and rather continually presents itself with new technologies (or, in fact, just about anything that is substantially new). For example, consider cloning. After the cloning of Dolly in 1997, there was substantial confusion and discord about what should be done in legal and regulatory capacities; previous laws and regulations were predominantly silent about this technology.[15] The resolution in that case was various funding moratoria and public denouncements, though these have, to some extent, abated in more recent years (Cantrell, 1998–1999). Regardless of the details of that case, there were straightforward questions about what should be done given the advent of this new technology, and there were various outcomes effected. Nanotechnology is not going to be subject to similar outcomes—e.g., wholesale funding moratoria are off the table—but whatever process by which new technology is integrated into our laws and regulations can be applied, *mutatis mutandis*, to nanotechnology.

This is not to say that it is obvious what such a process is, or even that such a process is simple, either to conceive or to apply. But the point is that nanotechnology, as such, does not differ, in any relevant way, from other technologies that need to be accommodated. To be sure, nanotechnology is different from other technologies, and many of the empirical facts about nanotechnology will be relevant to its assimilation. For example, the precise details of carbon nanotubes are relevant to their patentability, and the toxicity specifications for various carbon allotropes are relevant to their regulation. But these facts are irrelevant to the frameworks by which we effect legal and regulatory reform, and nanotechnology does not raise any novel issues in such regards. The relevant questions there are such as the following: do the current laws make sense? Are they effective? Fair? Are the current regulations

[15] For a discussion of the legal issues following the cloning of Dolly and those surrounding the ban on human cloning in the US, see Swartz (2002). Also see the report from the UN Ad Hoc Committee (n.d.).

sufficient? Should they be strengthened or weakened? Do they provide a proper balance between autonomy and safety? And so on. These questions—or whatever the appropriate questions are—must be answered in the context of nanotechnology, but nanotechnology itself has nothing to say about what the questions are or the process by which we must answer them; the questions and the processes transcend nanotechnology completely.

1.5.2 Research Funding and Priorities

In Section 1.4.2, I discussed a worry that can be lodged against nanotechnology, which is that it commands funds (and other non-monetary resources) that are then diverted from other projects, some of which have ethical import. For example, investments in nanotechnology are not ones that are (directly) being made into feeding the poor, improving education, and so on. Again, though, this is just not a substantially new issue.

While various examples might serve to make this point, I think that one of the most appropriate has to do with the debate about bioterror defense funding (May, 2005; see also Allhoff, 2005a). There are at least three substantial parallels between bioterror and nanotechnology spending: both reflect fairly recent spending priorities; both display exponential funding growth in a short number of years (e.g., within the past decade); and both programs are challenged by somewhat to fairly limited knowledge about outcomes. These first two points about nanotechnology were made in Section 1.4.2, but it is worth emphasizing these parallels by noting that, in the United States, bioterror defense funding has increased from $305M in FY 2001 to $5.2B in FY 2004 (cf., investments in nanotechnology, which are roughly on the same order of magnitude) (May, 2005).

Regarding knowledge of the outcomes, a worry about investment in nanotechnology is that it might not deliver on its promise or else that it might end up leading to various hazards. Or, independently, that the money should just be more appropriately spent somewhere else. Bioterrorism has the same structural features: we do not know whether our investment will preclude attacks or, relatedly, whether it is either more money than we need to be spending to prevent such attacks or else not enough money to prevent those attacks. Or, independently of whether such attacks could be prevented, we could ask whether it would nevertheless be better to spend the money elsewhere (and perhaps either absorb the attacks or otherwise just hope that they do not occur). The similarities with the non-monetary considerations mentioned in Section 1.4.2 apply, *mutatis mutandis*, as well (e.g., what our researchers work on, what institutional structures and infrastructure we effect, etc.).

So, whatever concerns can legitimately be raised about nanotechnology research funding and priority, they are simply not new concerns; again, the bioterrorism example was chosen for structural similarity, but any range of other examples could work as well. To be clear, this is not to say that these discussions do not need to be held *about* nanotechnology, since the details (e.g., regarding expense, outcomes, etc.)

will be different in this case than they would be in any other. But no new ethical questions are raised by merely asking the old ones in a different context.

1.5.3 Equity

In Section 1.4.3, concerns were presented about how nanotechnology could lead to the nano-haves and the nano-have nots: the technologies will only be available to limited constituencies, at least in part because the formers' acquisition will take money and technical knowledge that will not be universally available. Against such a disparate allocation, we might worry about issues pertaining to fairness and distributive justice.

Again, this worry is not novel. Any range of examples might make this point, but an appropriate one might be the debate about various medical technologies and, in particular, genetic interventions (Allhoff, 2005b). Commentators in these debates have similarly worried that genetic interventions will only be available to a limited few; maybe this is especially worrisome in germ-line enhancements that will resonate through all future generations. Even in this case, it seems to me that the issue has nothing to do with the genetic technologies *themselves*, but rather with theories about distributive justice. Maybe such disparities are only justifiable if they benefit all of society.[16] Or else maybe those who can afford the technologies are entitled to create whatever disparities might thereafter result (Nozick, 1974).

The point is that whatever questions we want to ask about equity are ones that float free of the genetic technologies in particular. Rather, we have to figure out which account of distributive justice we want to adopt, and then we figure out whether that account would be violated by some extant (or forthcoming) practice regarding those technologies. Nanotechnology, then, would work the same way: nanotechnology *itself* is silent as to issues of fairness and justice, but rather must be applied and developed in ways that comport with our broader theoretical commitments regarding these issues. Regardless, the starting point has to be some debate about those issues in particular, and nanotechnology does not elucidate such a debate in any substantive way.[17]

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[16] See, for example, Rawls (1999). (Rawls advocates a "difference principle" by which inequalities are justified only if they make the least-well off class better off.)

[17] Having just mentioned Rawls (footnote 16 above), it should be acknowledged that a Rawlsian reflective equilibrium might benefit from having particular cases by which to consider these broader theoretical commitments. So, for example, we might imagine some disparity, and this disparity might violate our sense of justice; to the extent that this is true, any principles which license such a disparity might be revised to achieve equilibrium with our considered judgment in that particular case. But, while we might have considered judgments regarding distributions of nanotechnologies, I am extremely skeptical that there could be anything *special* about those technologies such that similar judgments could not be structurally replicated in multiple ways. If this is true, then the appeal to nanotechnology, while perhaps effective, would not be *necessary*; nanotechnology would then not play any essential role in the discourse.

1.5.4 Environment, Health, and Safety

As discussed in Section 1.4.4, nanotechnology has the potential for impacts upon the environment, health, and safety. Most succinctly, these concerns center around the following: relatively high surface areas, crystalline structures, and reactivity of nanoparticles and nanomaterials; the biological interactions of ultrafine nanoparticles; and the (in)visibility of some of these particles (Myhr and Dalmo, 2007).

As in Section 1.5.2, it might help to draw a specific analogy as well as to make some more general comments. In way of the analogy, consider asbestos, which manifests various of the health hazards that are concerns with nanotechnology (e.g., inhalation, lung problems, etc.) (U.S. Department of Health and Human Services, 2001). Despite recognition by the Greeks that asbestos caused damage to weavers, it achieved widespread usage during the 1860s as insulation, and deaths from asbestos were documented since the early 1900s (Mesothelioma Resource Center, n.d.). Nevertheless, a conclusive link between asbestos and mesothelioma—a specific form of cancer caused nearly-exclusively from asbestos exposure—was not recognized until 1960 (Keal, 1960). In the United States, approximately 10,000 people die each year from mesothelioma and other asbestos-related diseases (Environmental Working Group, n.d.).

As mentioned above, this case mirrors some of the concerns that attach to nanotechnology. In the latter, we do not know what the consequences will be, but we suspect, in at least certain scenarios, that there are risks (Lam et al., 2004). It is obvious that we need to make reasonable provisions to determine what those risks are, as well as develop effective measures to mitigate them (Myhr and Dalmo, 2007. As in the asbestos case, we may also have to consider some sort of legal remediation process for harms that are ultimately affected (American Bar Association, 2006).

More generally, though, philosophers (and others) have already developed accounts of how to think about risk.[18] Relatedly, there is a large literature on the so-called precautionary principle;[19] independently of its various formulations and controversies, this principle roughly says something about what remedies we should apply given the possibility that some practice will cause a harmful effect (Weckert and Moor, 2007). Whichever the approach, all accounts must at least evince the obvious commitments: to assess the costs and benefits for the relevant practice; to think about constraints or limitations that might apply to cost-benefit

[18] See, for example, Rescher (1983), Thompson (1986), Hansson (1996), Chicken (1998), and Hansson (1999a). A more comprehensive bibliography can be found at http://www.infra.kth.se/phil/riskpage/bib2.htm (accessed August 14, 2007).

[19] Bodansky (1991), O'Riordon and Cameron (1994), Cross (1996), Martin (1997), and Hansson (1999b). A more comprehensive bibliography can be found at http://www.infra.kth.se/phil/riskpage/bib3.htm (accessed August 14, 2007). This issue is discussed specifically as pertains to nanotechnology in Weckert and Moor (2007). See also Phoenix and Treder (2004). Available at http://www.crnano.org/precautionary.htm (accessed August 14, 2007).

analysis; to explore alternative practices that might mitigate negative effects (though perhaps lack some of the associative benefits); as well as to consider the relevance and proper handling of epistemic uncertainty. Whether such ideas are applied to the environment, marketing practices, a medical procedure, or anything else, the central framework should be invariant as all such applications share those same structural features. Nanotechnology, then, should be subjected to some relevant framework, but there is no good reason to think that it has any features which challenge such frameworks altogether or otherwise introduces any novel moral considerations into those frameworks.[20]

1.5.5 Privacy

As discussed in Section 1.4.5, nanotechnology can be applied in ways that challenge privacy. In some cases, this might be through RFIDs, which are used to increase surveillance and tracking capacity, though other applications will be possible as well. In the medical arena, tracking chips might provide ready access to a patient's information, at the prospective cost of being intercepted or otherwise accessed by unintended parties.

The question now is whether these implications for privacy raise any new worries, and, again, I think that they do not. Most fundamentally, the non-medical issues center around two competing values: privacy and security. It is not a dramatic oversimplification to say that, as privacy increases, security decreases, and vice versa: whatever information is reserved to individuals (through protections of their privacy) is, *ex hypothesi*, not information that can be put to other ends, such as security. Conversely, whatever information is annexed for security purposes is, *ex hypothesi*, no longer reserved to the individual. While this framework has many nuances that can be explored (Schoeman, 1984; Roessler, 2005), I nevertheless take it to be roughly correct. And, once this framework is generalized away from the particulars of nanotechnology, then we can see that it can be otherwise instantiated.

Consider, for example, the United States Patriot Act,[21] which was passed in the October, 2001, 45 days after the attacks on the World Trade Center in New York City. For present purposes, let us focus on Title II, "Enhanced Surveillance Procedures", which, among other things, gives the federal government the authority to intercept wire, oral, and electronic communications relating to terrorism (§201). While there are various philosophical issues that could be talked about in this context (Perrine, 2005; Brandt and Otter, 2005; Weldon, 2005), the simple point is that the Patriot Act increases surveillance at the expense of privacy: private communications are no longer reserved to individuals but can rather be accessed by the government.

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[20] Note that this conclusion is not challenged in Weckert and Moor (2007).

[21] H.R. 3162. Available at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname = 107_cong_bills&docid = f:h3162enr.txt.pdf (accessed August 15, 2007).

The debate, then, is whether these interventions are justified given individual rights as well as the likelihood that possible infringements would be productive.

The case of nanotechnology is structurally identical in this regard insofar as it manifests the same costs and benefits. The one potential difference—which I take to be morally insignificant—is that the locus of control lies with the government rather than outside of it.[22] For anyone who objects to the example, we might pick another one, such as privacy at the workplace, Internet privacy, and so on (Miller and Weckert, 2000; Weckert, 2002; Weckert, 2005); the same features are still on display. I do think it is worth noting that debates about privacy often take place in technological contexts (DeCew, 1997), though I see nothing inherently special about those contexts such that they change the moral landscape. Regardless, nanotechnology is just one technology among many (including those that would be applied to realize the goals of the Patriot Act as well), and I see no special challenges that it, *qua* nanotechnology, raises for privacy.[23]

1.5.6 Medicine

In Section 1.4.6, applications of nanotechnology to medicine were discussed. Particular focus was paid to three areas: treatment, diagnostics, and drug delivery. In each of these cases, nanomedicine has much to offer, though issues in toxicity/safety, insurance, and access will surely arise. In this section, let me take those three areas and draw connections to non-nanotechnological applications, showing that the issues in these regards are isomorphic with those in nanotechnology. I will draw on examples that focus on toxicity/safety, though examples could be generated that apply to other issues as well.

Starting with treatment, the principal worry is that some of these treatments could be damaging. To wit, the hope is that the treatments are less damaging than conventional treatments, but hazards loom regardless. Of particular concern is the toxicity from nanoparticles that might be used (e.g., in cancer treatment), as well as other safety concerns. Consider, for example, chemotherapy, which uses cytotoxic drugs to treat cancer. The downside of chemotherapy is that these drugs are toxic to the benign cells as well as the malignant ones, and there are side effects such as immunosuppression, nausea, vomiting, and so on. When physicians are prescribing

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[22] This is not to say that I take governments to be morally insignificant, just that the introduction of a government instead of some other entity does not alter the moral structure of the case.

[23] In the medical contexts, perhaps it is the case that the calculus shifts somewhat insofar as privacy is now no longer opposed by security *per se*, but rather by improved outcomes: as privacy increases, those outcomes become less likely, and vice versa. Again, though, this formal structure lacks any features endemic to nanotechnology; whatever debates need to be held can be executed within this framework—informed by empirical details of nanotechnology—without the framework itself being altered.

chemotherapy, they therefore have to think about these risks and whether the risks are justified. Whether the treatment option involves nanoparticles or not, this basic calculus is unchanged: physicians must choose the treatment option that offers the best prognosis. Toxicity or side effects count against these outcomes, and improved health counts in favor of them. Obviously, there are epistemic obstacles to such forecasting, and physicians must be appraised of the relevant toxicity and side effect data, but there is nothing endemic to nanotechnology that raises new issues for the process.

Diagnostically, the concerns with nanomedicine also center around toxicity. Conventional diagnostic mechanisms, however, manifest the same structural features as nano-diagnostics. Consider, for example, x-rays, which use electromagnetic radiation to generate images, and these images can be used for medical diagnostics. This radiation, absorbed in large dosages, can be carcinogenic,[24] so medical personnel have to be judicious in their application thereof. The radiation outputs for x-rays are reasonably well-understood, as are their toxicities in regards to human biology.[25] As when considering treatment options, medical personnel must consider these toxicities, as well as the benefits of this diagnostic mechanism (perhaps as contrasted with other options). Nano-diagnostics admits of a similar deliberative model.[26]

Finally, consider drug delivery. Nanotechnology has the potential for more targeted delivery, though there are again worries about toxicity. This concern, though, can be manifest about other delivery mechanisms. Consider, for example, the celebrated case of Jesse Gelsinger, who died in a gene therapy trial (Philipkowski, 1999). Gelsinger had ornithine transcarbamylase deficiency: he lacked a gene that would allow him to break down ammonia (a natural byproduct of protein metabolism). An attempt to deliver this gene through adenoviruses was made, and Gelsinger suffered an immunoreaction that led to multiple organ failure and brain death. Whether talking about vectors for genetic interventions or nanoparticles, we surely have to be worried about toxicity, immunoreactions, and other safety concerns. Nanotechnology does not change our thinking about these things in any substantive way. Again, we need to know what, for example, the toxicities *are* for nanoparticles, but this is an empirical issue and not a moral or a conceptual one.

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[24] Note that one of the pioneers of radioactivity, Marie Curie died from aplastic anemia, which was almost certainly caused by exposure to radiation. Rosalind Franklin, whose work on x-ray crystallography was critical to the discovery of the double helical structure of DNA contracted ovarian cancer at a relatively young age; again, her work was almost certainly responsible.

[25] There have been numerous studies of the effects of the use x-ray technology in diagnostic procedures. For a recent overview of data relating to risk of cancer see de Gonzalez and Darby (2004). Also, see Kereiakes and Rosenstein (1980); and National Research Council (1990).

[26] It is worth noting that part of the concern about nano-diagnostics is that the toxicities are patently *not* well-understood. While true, this is irrelevant to the formal deliberative model that is under discussion.

1.6 It's a Revolution!

In this section, I want to consider an argument which might be lodged against the argumentation of the previous section: the advocate of nanoethics could concede that it does not raise any numerically distinct issues, but nevertheless could maintain that those concerns are manifest to drastically different *degrees* through nanotechnology. In this regard, the advocate could maintain that such issues are transformative or revolutionary in some particular way and that, whatever other ethical frameworks we have already developed, those frameworks will be ill-equipped to deal with the force that nanotechnology represents. So, for example, maybe it is the case that we are already able to hold some informed discussion about the ethical significance of privacy, but it will be the case that nanotechnology will bring about such tremendous effects in this arena that only a radical reconception of privacy and its moral significance would do justice to these effects. If this is true, then it is certainly uncongenial to the overall line that I wish to be defending, so it is worth taking time to extend some consideration to this approach. I will not go through the different issues individually, but rather hope to abstract away the essential structure of this approach and to consider it in that regard.

To start, let us think more clearly about the notion of technological progress—or even progress more generally—that could plausibly undergird the claim that a revolution is at hand. For it to be the case that this is possible, it seems to me that at least the following structural features must obtain: first, there has to be some change in some metric across some amount of time; and, second, that change has to be sufficient to warrant a reconception of some basic premises, be they conceptual, normative, or otherwise. The first condition is often and easily met. Consider, for example, the following graph, which plots the world record times for the one mile run since the founding of the International Association of Athletics Federations:[27]

As this graph clearly shows, the world record times in the one mile run have been progressively falling over the past century. The evolution of those times, as with most real-world phenomena, is uneven, though the trend is unmistakable. Furthermore, the causes for the trend are fairly well-understood: improved training techniques, improved sports medicine, better dietary knowledge, and so on. Has running therefore been *revolutionized*? I think not, and the reason is that the gains are simply not substantial enough. From the first record (4:14.4 in 1913) to the current (3:43.1 in 1999), there is only a 31.3 second improvement, which is just over 12% faster. Even without a theory about how much improvement is actually needed for a revolution, it seems to me that this clearly cannot meet the threshold.

Another point worth making about this sort of trend. First, notice that I have plotted a linear regression on top of the data points, and extended that regression to 2008. It is not likely that anyone will run a 3:37 mile by then, and it is nearly impossible

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[27] Data taken from Wikipedia (2007). A fantastic book documents the quest to break the four minute mile—achieved when Britain's Roger Bannister ran 3:59.4 in May of 1954—as well as the subsequent history. See Bascomb (2004).

that anyone would run a 3:00 mile around 2100—if ever, given the limits of human biology—which is approximately when the regression would predict. The point, then, is that extrapolating into the future from some current or past trend has hazards if those trends will not continue. So, even to establish some future projections based on the above data, we have to have assumptions that transcend the data itself. If nanotechnology does effect some changes in the short- or mid-term, then, it hardly follows that we can extrapolate those changes into the indefinite future and then champion some pending revolution. But, as I have already said, I am otherwise skeptical as to the revolutionary force if the changes are on the above order of magnitude.

A more plausible case for a revolution comes when we consider exponential (rather than linear) change. Consider, for example, Moore's Law, named after Intel co-founder George Moore; this law states that the number of transistors that can fit on an integrated circuit doubles every 2 years.[28] When Intel's first processor, the 4004, was released in 1971, it had 2,300 transistors (Intel Museum, n.d.). As of 2007, its most recent processor, the Dual-Core Intel Itanium 2, has over 1.7 billion transistors (Shiveley, 2006). Those 36 years, then, accommodate just over 19 doublings in transistor capacity, which is extremely close to Moore's prognostication.[29] If this trend were idealized and plotted, it would look like this:[30]

In this case, the transistor capacity in 2007 is on the order of 100,000,000% greater than the transistor capacity in 1971 (cf., the 12% improvement in running times). So it seems obvious that there have been dramatic changes in computing since the early 1970s, and I suspect that anyone with experience of these older machines would certainly agree. Again, there are concerns about projecting these trends into the future; as pertains to Moore's Law alone, there is already concern that physical limits will derail the continued rate of increase, though multi-core chips will continue to allow for substantial improvements. Regardless, it seems reasonable to recognize a revolution in computing, as well as to recognize that this revolution will continue (indefinitely) into the future.

Returning to nanotechnology, consider the following graph, which takes a similar time span—otherwise chosen arbitrarily—to the processor revolution and shows the same increase during that period:

If this were the proper representation of nanotechnology's promise, then, *mutatis mutandis*, there would be no choice but to confer the same revolutionary status afforded to processors above. Nevertheless, I think that there are two pressing worries with this approach: empirical/epistemic and conceptual.

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[28] The doubling time is sometimes mentioned as 18 months, but Moore claimed that it was 2 years. The original paper is Moore (1965). See also Intel's web site at http://www.intel.com/technology/mooreslaw/ (accessed August 17, 2007).

[29] Mathematically, $2.300 \times 2^{19} = 1.2$ billion, which is reasonably close to 1.7 billion. Note that the transistors' capacity, on average, doubles slightly *faster* than Moore predicted.

[30] This representation roughly reflects the actual developments of transistor capacity for Intel processors in the intervening decades as well; the improvements have obviously not come at a constant rate, but are not far from it, either. That history is available at http://www.intel.com/technology/mooreslaw/index.htm (accessed August 17, 2007).

The empirical challenge is to show that, in fact, nanotechnology has the potential to increase something in some *dramatic* way. This challenge does not deny that nanotechnology will be used to make lighter and stronger materials, cleaner water, readily available solar energy, and so on. (In fact, it need not concede these claims, either, but certainly need complain about them.) Rather, it is completely consistent with these outcomes that the appropriate graph looks like this:

And, as I argued above, it is hardly obvious that this sort of illustration represents a revolution. In addition to these empirical claims, there are the related epistemic ones: to make a claim about the coming revolution requires that we disentangle the hype from the reality of nanotechnology as well as to make longitudinal predictions thereof. To be sure, any coming revolution's ontology is independent to our forecasting of it, but the present claims about any such revolution must be epistemically well-founded and defended.

Second, and perhaps more importantly, I have deep conceptual worries about Fig. 1.3. In particular, note that the y-axis is left undefined. *What* does the y-axis represent? It is simple to understand the axes in the first Figs. 1.1 and 1.2: they represent time and transistor capacity, respectively. These things are quantifiable—indeed, they are *quantities*—and can be easily measured. But when we talk about the transformative capacity for nanotechnology, it is far from clear what is being "transformed". Or at least, in the cases where it is clear what will be affected, it is far from clear that there is any sort of transformation. Consider the tensile strength of materials: nanotechnology will surely lead to improvement in this area. But that improvement undoubtedly has to be more accurately represented by Fig. 1.4 than by Fig. 1.3. For example, some materials fashioned from carbon nanotubes are 250 times stronger than steel, yet one tenth the weight (Johnson, 2005; Florida State University, 2005). This is only an increase in two orders of magnitude for strength

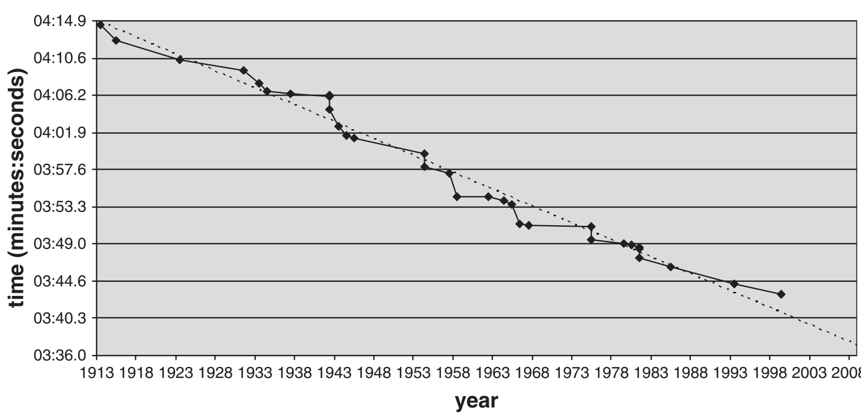

Fig. 1.1 One mile run world record

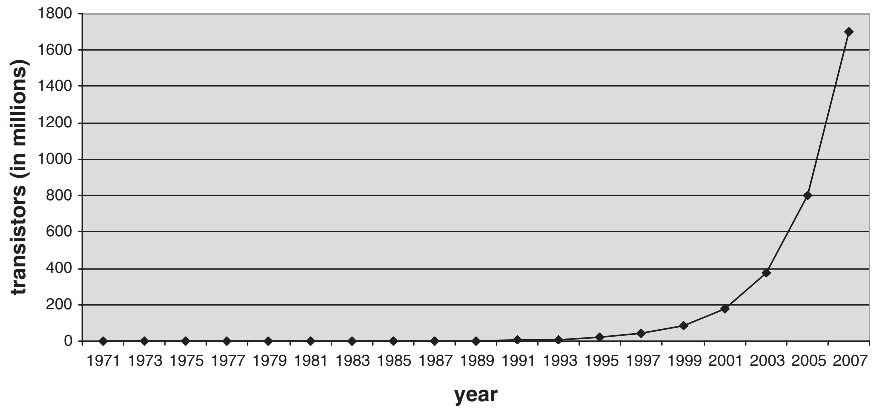

Fig. 1.2 Moore's law

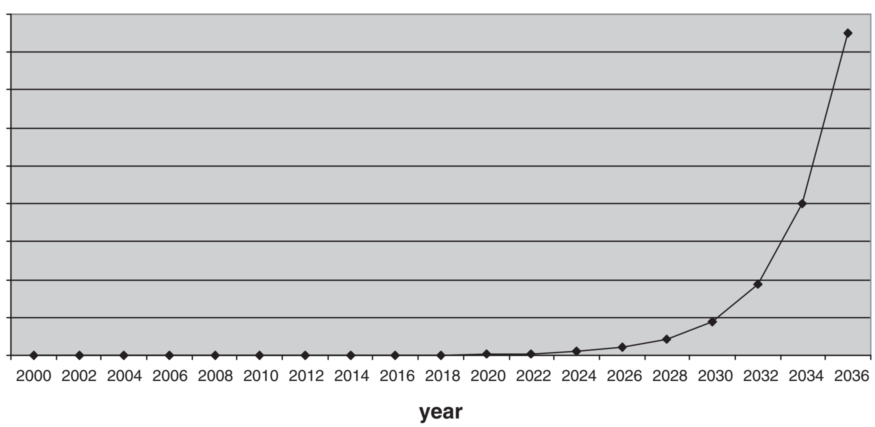

Fig. 1.3 The nanotechnology revolution

and one for weight, each of which is far from the *six*-fold increase in transistor capacitor for processors; even if there is nothing special about six-fold increases in particular, they are *far* greater than the increases in this case. And this example is probably one of the more dramatic that nanotechnology can offer (in terms of scales); other applications will yield substantially lower improvements.

As claims become more grand, it is less clear what they actually mean. Consider, for example, the first tenet of the "Transhumanist Declaration":

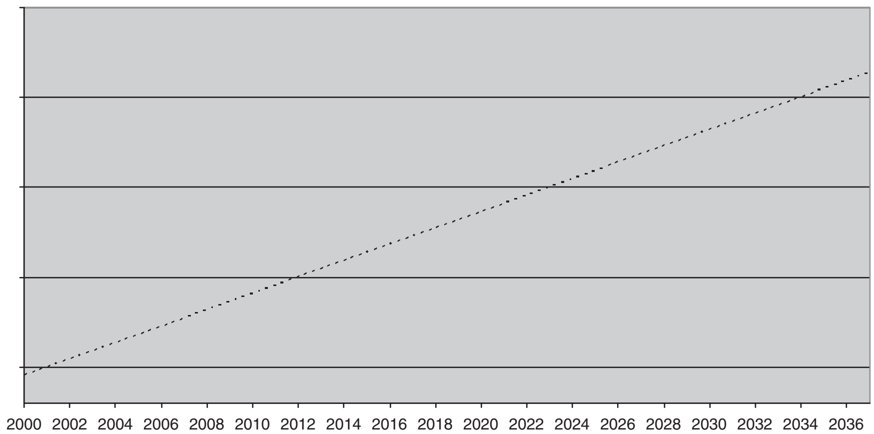

Fig. 1.4 The nanotechnology revolution?

> Humanity will be radically changed by technology in the future. We foresee the feasibility of redesigning the human condition, including such parameters as the inevitability of aging, limitations on human and artificial intellects, unchosen psychology, suffering, and our confinement to the planet earth. (World Transhumanist Association, 2002)

Returning to Fig. 1.3, how are we supposed to conceptualize such claims on the y-axis of our graph? To be sure, the transhumanist might reject the challenge, but I think it is a reasonable one: we are trying to show *what* is being transformed by technology.[31] Presumably this would be such a complex battery of goods as to make the aggregation impossible, or else it would be some concept—such as "human potential" (Bostrom, n.d.) or the "human transcendence of biology"[32]—that is barely intelligible. Relatedly, as the claims become more grand, they become less empirically plausible (or, at least, less popular). Consider, for example, claims that nanotechnology could offer the cure to aging (Sethe, 2007) or be the means by which to effect wide-scale space exploration (Toth-Fejel and Dodsworth, 2007); these are not ideas that are without their merits, but also not the ones that many talented research scientists are rushing to pursue.

At any rate, my present interest is not with any program in particular—indeed, many of the above are important projects pursued by friends—but rather with precise claims about *why* nanotechnology (or any other technology) deserves revolutionary status. As I laid out the challenge earlier in this section, it both must be the case that there is some change in some metric across some amount of time

[31] It is worth noticing that this sort of project does not afford a privileged status to nanotechnology, but rather to all technologies: nanotechnology, biotechnology, informational technologies, computer technologies and artificial intelligence, and so on. As the purview for the project broadens, nanotechnology's role with in it similarly diminishes.

[32] See, for example, Kurzweil (2006). Another ambitious project is Hughes (2004).

and that such change has to be sufficient to warrant a reconception of some basic premises, be they conceptual, normative, or otherwise. There is no doubt that nanotechnology satisfies this first requirement but, to my mind, there is sufficient doubt as to whether it satisfies the second.

As a final example, return to nanotechnology and aging and imagine that life expectancy doubled (note that doubling is far closer to Fig.1.4 than to Fig. 1.3). Now there would be many additional things to worry about, such as overpopulation and its effects on food, water, living space, economies, and so on. It would still be the case that happiness and autonomy matter, and no number of people in the world can change those basic ethical precepts. As I repeated throughout Section 1.5, we will continue to have new empirical inputs into our ethical frameworks, but those frameworks themselves will be left unaffected.

1.7 What's Different?

In Section 1.4, I presented many of the issues that are discussed under the aegis of nanoethics. Then, in Sections 1.5 and 1.6, I argued that none of these issues is novel in any substantive way or degree. Those issues need to be evaluated in the context of nanotechnology, but the moral issues are not unique to it. In this regard, I think that there is a plausible contrast between nanoethics and other disciplines within applied ethics: other applied ethics can reasonably be thought to instantiate novel ethical worries in ways that nanotechnology does not. I will explore the implications of this claim in Section 1.8 but, for now, I want to try to defend it. I should say, from the outset, that I think the claim is false, but I nevertheless find it at least plausible. My ultimate skepticism is not likely to be shared by many other people, though I will try to advance the strongest versions of the arguments that I expect they would make. Furthermore, for present purposes, the skepticism is irrelevant, though it otherwise ties into a broader project about the relationship among applied ethics. Finally, as we will see in Section 1.8, I think that such skepticism is less problematic than might otherwise be thought.

So, for now, the goal is to try to establish that other applied ethics might have distinguishing moral features and, if they do, then this sets them apart from nanotechnology. There are lots of different disciplines within applied ethics, and I cannot hope to cover them all. Nevertheless, let me comment on the following, which are either chosen for their traditions or else have other instructive features: biomedical ethics; business ethics; environmental ethics; and neuroethics. Again, the point is not to have comprehensive analyses of these disciplines, but rather to try to motivate a line which sets them apart from nanoethics.

1.7.1 Biomedical Ethics

In a seminal work, Edmund Pellegrino and David Thomasma (1993; see also Pellegrino, 1985) write this about medicine:

> Let us step back…for a moment and see why medicine cannot escape being a moral community. Three things about medicine as a human activity make it a moral enterprise that imposes collective responsibilities of great moment on its practitioners: (1) the nature of illness; (2) the nonproprietary nature of medical knowledge; and (3) the nature and circumstances of a professional oath.

Regarding the nature of illness, they think that the sick are in uniquely dependent, anxious, vulnerable, and exploitable states; they must "bare their weaknesses, compromise their dignity, and reveal intimacies of body and mind (Pellegrino and Thomasma, 1993)." Relatedly, trust is critical in the relationship between patient and physician. Regarding (2), the physician's knowledge is acquired "through the privilege of medical education…and is permitted free access to all of the world's medical knowledge" (Pellegrino and Thomasma, 1993, p.36). And, finally, physicians take oaths which bind them to their communities, to their patients, and which transcend self-interest and create moral duties.

Whether we agree with Pellegrino and Thomasma's vision of medicine is less important than the fact that they can even advance the claims that they do; such claims would not even seem coherent when talking about nanotechnology. Starting with (1), I am not sure that illness is necessarily as compromising as Pellegrino and Thomasma suggest, but it surely enjoys a different moral status than, say, nanocircuitry. The latter need not have anything to do with a moral agent at all, whereas the former analytically has to. Regarding (2), much of nanotechnology is precisely proprietary, and nanotechnologists are quite interested in ensuring that this stays the case. To be sure, there are non-proprietary aspects of nanotechnology (e.g., basic physics) and there are proprietary elements of medicine (e.g., patented drugs), but the former surely lacks the community and history of the latter. Regarding (3), there are no codes of ethics in nanotechnology, though there are various movements to create them (Shew, 2008; see also Institute for Food and Agricultural Standards, 2007). Such codes, though, speak more to safety of the technological processes than to moral obligations to help the sick or to serve any other community good.

I think that the case for medicine is overstated, particularly if we think of things like flu shots and sprained wrists: rich moral notions like vulnerability and sacred trust seem attenuated in these contexts.[33] Nevertheless, there is something compelling about this account, and the biomedical ethics literature clearly reflects a sense that there is something morally special about medicine. Other fields (e.g., law) might have some of these features (e.g., (3)), but, even if we do not offer some high privilege to illness, it is hard to see how they would have all three of the features. Granted, we could jettison this conception of medicine but, as I said in the introduction to this section, the idea is only to make *plausible* the idea that some applied ethics are ethically unique, and I think that medicine can readily sustain this weak aspiration.

[33] For a more sustained critique of some of these ideas, see Allhoff (2006) especially pp. 395–400.

1.7.2 Business Ethics

Consider a classic debate in business ethics, which positions Milton Friedman against R. Edward Freeman about corporate social responsibility. At stake is whether corporations have any obligations other than to increase their profits, whether social, environmental, or otherwise. Friedman argues that they do not, and that any attempt by corporations to do so, absent the will of the shareholders, is an unjust exercise of executive power and, furthermore, one that is not likely to be successful regardless (as such ventures fall outside the executives' expertise) (Friedman, 1970). Freeman, by contrast, argues that the corporation has duties to all of its stakeholders, among which he counts all those (including shareholders) that are affected by the activities of the corporation: employees, consumers, suppliers, community members, and so on (Freeman, 1994; see also Freeman, 1984).

Arguably, this disagreement forms the central debate in business ethics, from which other issues all follow (Allhoff and Vaidya, in press). Consider, for example, worker safety: absent any (direct) obligations to the worker, corporations might only provide for worker safety if, ultimately, it maximized profits (e.g., through the avoidance of lawsuits); similar stories could be told about whistleblowing (cf., duties to consumers), bluffing (cf., duties to suppliers), and so on. In this sense, business ethics is *unified* in such a way that nanoethics clearly is not. Furthermore, business ethics is then predicated upon a single ethical construct, which is rarely realized in other contexts: that of fiduciary obligation. To wit, the executive of the corporation has been entrusted to his post by a majority of the shareholders, and the principal question is whether his obligations are solely to them or rather whether those obligations extend elsewhere.

It seems to me that this issue has to be endemic to business ethics, at least insofar as, *a fortiori*, it is the only area in which we have executives. It turns up in some other guises elsewhere, such as law (or medicine [Allhoff, 2008]): consider whether the criminal defense attorney has obligations only to her client or whether she also has duties to the justice system (Freedman, 1966). Structurally, this might look the same but, to the extent that it does, it seems to me that the central features are being exported from the business ethics context rather than vice versa. Regardless, law (or medicine) is often treated as "professional ethics" closely aligned with business ethics (Allhoff and Vaidya, in press). Therefore, I do not think that the existence of these other applications challenge the independence of the shareholder/stakeholder debate in business ethics.

1.7.3 Environmental Ethics

Next, consider environmental ethics, which raises deep concerns about the limitations of economic cost-benefit analysis. In a seminal paper, Mark Sagoff writes about the outrage that the citizens of Lewiston, New York who live near the radioactive waste disposal that was borne from the Manhattan Project. Despite assurances from the local governments that there are no associative health risks, the citizens simply do not *want* to live near such waste because it conflicts with values that they have (Sagoff, 1981). Assuming for the moment that there really are no hazards from such waste, which seems a dubious assumption, it seems that traditional economic analysis cannot accommodate whatever considerations are due those citizens. The reason is that, *ex hypothesi*, there are *not* any (economic) costs; rather the costs have to do with senses of justice, propriety, and so on. To be sure, there are sophisticated approaches to cost-benefit analysis that try to accommodate these features (Shrader-Frechette, 1998), but there is at least a *prima facie* problem for the approach.

Another example might be the value of the redwoods in California (or any other sort of environmental preservation project); the cost-benefit analysis system would hold that those redwoods are worth whatever people are willing to pay to not have them cut down.[34] If the revenues from the Redwood National and State Parks are less than what Disney is willing to pay—by which there are obvious extensions to what *consumers* are willing to pay—for a theme park, then it is Pareto suboptimal to maintain the trees to the exclusion of a theme park.

In either of these cases, economic analyses seem to miss the point, which is that there are relevant extra-economic values. In their more extreme formulations, the economic approaches could unequivocally deny that any other such values matter and, in their less aggressive versions, they might try to cache out those "extra"-economic values economically. Regardless, environmental ethics stands at a pivotal place in this debate; much of resultant framework has been developed precisely in environmental contexts. To be sure, there are other contexts in which it might be investigated: consider torts liability reform in medicine where, despite economic inefficiency, some commentators nevertheless oppose such reform on the grounds that (extremely high) punitive damages are sometimes justified by the merits of evincing our moral disapprobation (Edwards and Cheney, 2004). But, again, this is a debate that was largely carried out in the environmental ethics literature, and which forms a cornerstone of that field. Nanotechnology lacks such a distinctive feature, whether in its own regard or whether one for which it has—or will, the former might be unfair given its incipience—catalyzed important investigations.

1.7.4 Neuroethics

Finally, consider neuroethics. This is a newer field, but one that is worth discussing because of various similarities that it has with nanoethics. Again, it is

[34] For a recent discussion of cost-benefit analysis in the US that contrasts its use with the "precautionary principle" of the UK, see Sunstein (2005).

new, like nanoethics. Also, it is heavily predicated upon technology, unlike the disciplines described above. While much of the current literature focuses on the ethical issues in functional neuroimaging, the field will surely expand to include brain implants (some of which will be enabled by nanotechnology), psychopharmacology, and so on.

Advocates of neuroethics certainly think that a lot is at stake with these new technologies. For example, Judy Illes and Eric Racine write that neurotechnology "will fundamentally alter the dynamic between personal identity, responsibility, and free will…Indeed, neurotechnologies as a whole are challenging our sense of personhood and providing new tools for society for judging it" (Illes and Racine, 2005). Some neuroscientists even think that neuroscience will annihilate the concept of personhood altogether (Illes and Racine, 2005). I think that there are lots of reasons to be skeptical about these claims (Buford and Allhoff, 2005; Buford and Allhoff, 2007), but, for now, let us take them seriously.

Personhood, given its associative relations to moral responsibility, is a foundational concept in ethics. Neuroscience, *ex hypothesi*, is the field that is most qualified to elucidate the workings of the brain and, with them, the psychological (if not conceptual) underpinnings for personhood.[35] If, for whatever reasons, neuroscience can cast doubt upon the coherence of this concept, then that would have deep ramifications for ethics. Relatedly, neuroscience might have something direct to say about moral responsibility: perhaps it can somehow vindicate determinism, or else provide evidence in favor of free will (Freeman et al., 2000). Again, I have deep skepticism about these projects; it seems to me that they are predominantly philosophical ones to which neuroscience is largely irrelevant. Nevertheless, there is a burgeoning enterprise in these topics, and I trust that there are at least some issues worth talking about, even if the conclusions turn out to be negative.

Regardless of whether the project fails or succeeds, neuroscience is the only (non-philosophical) discipline that can even hope to make headway on these questions which, again, are foundational to ethics. If neuroethics is understood to encompass the implications that neuroscience has for ethics or else the proper ethical stance to take on various practices within neuroscience—it seems to me that it could be understood in both these ways—then this discourse really does offer something new that is not already instantiated in different applied ethics. And, furthermore, this is not just to say that neuroethics is different in the trivial sense that it takes a unique target (viz., neuroscience), but rather that such a target really might concern itself with ethical and metaphysical issues for which it is specially positioned to render commentary.

[35] The link between personhood, personal identity, and psychological criteria invites a long tradition which extends, at least, to Locke (1994). More recently, see Parfit (1984). For a dissent—one which postulates biological, as opposed to psychological criteria—see Olson (1997).

1.8 What Now?

In this paper, I have taken a fairly negative line toward nanoethics. In Section 1.5, I argued that there are *not* new issues in nanoethics and, in Section 1.6, I argued that those issues are not manifest to dramatically different degrees. In Section 1.7, I argued that nanoethics therefore *failed* to demonstrate features which are (at least plausibly) instantiated in other disciplines within applied ethics. So if there is nothing new or dramatic in nanoethics, and if something new or dramatic is, in fact, what defines and individuates different applied ethics, what are we to make of nanoethics? I have already expressed skepticism about this latter criterion and, in this final section, I will press that skepticism. Absent such a requirement, there will still be a space for nanoethics, and it is that space that I want to articulate.

To motivate the line that I am going to take, consider an argument made by David Luban in a classic essay about the adversarial legal system (Luban, 1983). In this essay, Luban explores the ethical justification for the adversarial legal system (e.g., as it exists in the US) wherein plaintiffs and defendants are each afforded a legal team; these legal teams then compete against each other such that one wins and one loses. Ethically, the worry about such a system is that the priority is placed upon winning as opposed to reaching just outcomes (e.g., that the guilty are convicted and the innocent are exonerated). And, in the course of trying to win, lawyers might engage in behaviors that range from the morally contentious to the downright immoral (cf. Freedman, 1966). Luban wonders what sorts of considerations could justify this system, as against some alternative (e.g., the European inquisitorial system) that would avoid these hazards. Ultimately, his conclusion is that the best defense of the system that can be provided is a pragmatic one, which holds that the system is probably as good as any other (despite the hazards, it also has benefits, such as the double-edged zealous advocacy) and that changing systems would not be worth the trouble.

Whatever the merits of this analysis, I think that it introduces an interesting distinction which can be applied to present purposes, though the analogy is otherwise quite loose. In particular, there are two different sorts of (ethical) justifications that we might offer for something, be it an institution, practice, or discipline. The first is metaphysical, by which I mean that there is some moral feature that can be appealed to in order to make the appropriate justification. Furthermore, I take it that the metaphysical justification will only go through if the moral feature uniquely (or near-uniquely) attaches to the justificatory target. If it does not, then it is not that target which is being justified, but rather some broader one and the target then only becomes derivatively justified given its relation to the broader one. Alternatively, something might have a pragmatic justification which is weaker than the metaphysical justification; by this I mean that metaphysical justifications are necessary, whereas pragmatic justifications are contingent upon various empirical circumstances. So, for example, the adversary legal system would cease to be justified given its pragmatic justification if circumstances changed such that implementing a new system just was not that difficult. However, if such a system had a metaphysical justification—imagine that it were (necessarily) the morally best system—then that justification would persist independently of vagaries in circumstance.

Returning now to applied ethics, the disciplines discussed in Section 1.7 have plausible claims to metaphysical justifications. Biomedical ethics is uniquely concerned with illness and the associative vulnerabilities and anxieties that it engenders. Business ethics critically addresses the nature of fiduciary obligation, as well as the related ethical issues that therein follow. Environmental ethics challenges cost-benefit analyses and might generate alternative deliberative frameworks. Neuroethics aspires to various debates within personhood, moral responsibility, and free will. So I think that it is plausible to think that these fields are metaphysically justified insofar as they pick out ethical features that are endemic to them. To be sure, I expressed skepticism in that section about many of these claims, and it might turn out that none of these disciplines actually is metaphysically justified. Nothing hangs on that, though, as the point was just to show that nanotechnology cannot even plausibly make such claims; if it turns out there is only pragmatic justification to go around, my arguments would be no worse off. (In fact, I think that this is the case, but I will not further explore that line here.)

Coupling the notion of metaphysical justification with the argumentation of Section 1.5, it should now be clear that I do not think that nanoethics has such a justification. However, in light of the distinction between metaphysical and pragmatic justification, the lack of metaphysical justification need not be fatal for nanoethics. Rather, we can justify nanoethics pragmatically. Let me conclude this paper by characterizing that pragmatic justification. And, insodoing, I hope that we see what sort of response should be extended to nanoethics' skeptics (Keiper, 2007), even if this paper were largely conceived as a response to its advocates. My own stance, then, is therefore somewhere between these two poles.

The locus of the pragmatic justification centers around the impacts that nanotechnology will have on society. As discussed in Section 1.4, these impacts are likely to be multiple, and there are ethical issues (identified in that section and in Section 1.5) that must be addressed. As it turns out, those ethical issues are not tremendously novel, though they will have be addressed within a new context. But, just because they are not novel, it hardly follows that they do not need to be addressed *at all* and that we can just proceed with ethical disregard. Rather, the technologies must be evaluated along whatever ethical dimensions they manifest effects, whether well-being, rights and liberties, fairness, or whatever.

So, ultimately, I think that this is the right way to look at nanoethics. Nanotechnology deserves ethical *attention*. We need to be cognizant about the ethical impacts that nanotechnology will have, and we need to develop our empirical knowledge of the science such that those impacts can be well-understood. As I have argued in this paper, I do not think that we need an autonomous applied ethic to study these questions, but that, ultimately, makes the questions no less important.

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