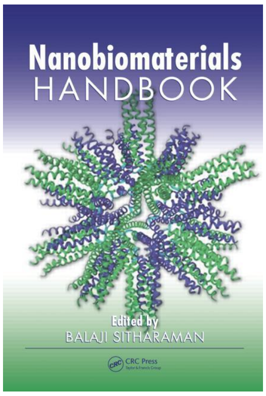

Nanobiomaterials Handbook

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Breaking the Carbon Barrier

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Breaking the Carbon Barrier: Nanobiomaterials and Communal Ethics

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Technologies produce environmental footprints of all sorts from climate change to toxic chemical effluents. While sorting through ways to solve crises, we are given two solutions across a long continuum. On one hand, we can prevent the problem from occurring and, on the other hand, we can solve the problem once it has occurred. Ethicists have wrestled with this concept on many levels. The following discussion examines how the promises associated with advances in nanobiotechnology may denigrate the concept of stewardship for quick fixes at the cost of grander environmental goals.

32.1 Introduction

There are many ways to solve a problem. We can redefine the problem so it is no longer a problem. For example, a case can be made that global warming leads to longer growing seasons in Canada and Northern Asia. Unfortunately, redefinition tends to trade off one problem with another by shifting its purview to another population or another place in time and space. We can solve the problem by reducing its effects. Automobile catalytic converters reduce the troubling content of exhaust. This reductive approach to a problem tends to mitigate at some level. However, it has an awful tendency to generate additional concerns, such as pollution from platinum mining. Another option is to reduce the power of the antecedent to produce the effect. Prevention is strategically interesting for many reasons, not the least of which is the range of opportunities prevention provides that are foreclosed by the other two strategies mentioned above. By implementing positive incentives to develop geothermal, wind, and solar power as alternatives to fossil fuels, we leave the fossil fuels for other uses and provide opportunities for management strategies to be developed by future generations. Conservation leads to better management in the present and future.

This chapter does not catalogue the potential applications of nanobiotechnology (enough of that is found herein). It does not suggest that nanobiotechnology is an infeasible solution to reduce tragic effects associated with food, energy, and the environment. It does not tell stories about overachieving nanobiotechnology doing heinous things to Earth. Rather it calls upon all of us to reconsider nanobiotechnology for what it is: a technological fix. We challenge the reader to consider whether the philosophies and ethics of technological magic bullets are the preferred way to engage the world in which we live. In addition, we are not totalistic is our prognostications. This chapter is not a carte blanche indictment of the impact based solution strategy; there are instances wherein the impacts are too menacing to ignore and academic arguments on philosophy and ethics may need to take a proverbial back seat to questions of survival and compassion. On the other hand, it is unwise to ignore the alternatives to the technological fix. Indeed, a rich tradition in conservation ethics and stewardship seems a wiser approach in some instances and deserves its place in arguments over advanced technologies.

32.2 On Nanobiotechnology: The Present

On definitions: nanobiotechnology is the convergence of nanotechnology and biotechnology. It employs biological structures on the nanoscale or designs nanostructures inspired by nature. For some, the terms are indistinguishable from each other referring to any application of nanotechnology to living systems. Major efforts in nanobiotechnology involve building up of new architectures from individual biomolecules and biomacromolecules. Within the dimensional ranges associated with nanobiotechnology we witness novel functions and properties.

> This rapidly evolving field uses the same building blocks exploited by nature for structural and catalytic functions and as engineering materials for construction of new materials systems. Biological macromolecules, especially polypeptides, RNA, and DNA, can be reinvented by in vitro evolution and rational design to self-assemble into desired structures, organize other materials, and provide nanoscale motions and switching
>
> **(VLAG 2006).**

Nanobiotechnology and bionanotechnology are bantered in some media as a technology with broad applications. While applications in medicine and drug design have dominated the reportage on nanobiotechnology, we examined three other areas: food, energy, and environmental remediation.

32.2.1 Food

Food companies are investigating nanotechnology for various “nanofood” applications such as production, packaging, additives, and safety. Nanobiotechnology opens whole new worlds for the food industry. India’s Minister for Food and Agriculture Sharad Pawar claimed: “Bio-nanotechnology takes agriculture from the era of genetically modified (GM) crops to the brave new world of atomically modified organisms” yet touted it as “going a long way in helping India’s food security” (India News 2007).

Example 32.1: National Agriculture and Food Research Institute/Organization—Japan

Japan’s National Agriculture and Food Research Organization and its institutes are using their nanobiotechnology laboratory to develop technologies for analyzing the nanolevel structures/properties of foods and biomaterials, as well as technologies to evaluate food quality/function based on the information obtained by such analysis technologies. They are trying to analyze the nanometer-scale structures and functions of food materials (e.g., starch granule) and biomaterials, ranging from DNA to proteins and chromosomes (yeast, barley, etc.). Using scanning probe microscopy to detect ultra-weak force and to manipulate an object with nanometer resolution, they are attempting to detect trace substances in foods (allergens, etc.) and developing a new genome analyzing related technology (National Agriculture and Food Research Organization 2009).

Example 32.2: University of Wageningen Bionanotechnology Center for Food and Health Innovations—BioNT (Germany)

One of their projects involves using shells containing functional food additives. While much of their work involves micro-channeling technologies they are pushing their work into the nano range. The aim of one of their projects is to design and test possible shell materials that can be surfactant or organogelator stabilized oils, or food-grade (bio)polymers. Another project supported by MicroNed and industrial partners is exploring the use of nano-engineered membranes in co-flow-assisted emulsification. As well they are exploring the lower limits in droplet sizes that can be produced with this mode of operation necessary for the production of primary emulsions. Another examines the use of probiotic capsules within oil shells (BioNT Wageningen 2007).

32.2.2 Energy

One of the latest uses of nanobiotechnology is through producing new technologies that focus on new, more efficient energy sources. Energy consumption is set to increase 20% by 2020. Nanobiotechnology has been touted as promising for the development of new fuel cells, batteries, and solar energy production and for energy conservation in conjunction with insulation products.

Example 32.3: MIT Belcher Research Team—USA

Massachusetts Institute of Technology material science and engineering researchers Yun Jung Lee and Hyunjung Yi published research findings in *Science* (Lee et al. 2009) regarding the use of nanobiotechnology in battery life. "The team manipulated two genes from a common virus used in nanotechnology research (M13) to attach iron phosphate, an excellent conductor, to carbon nanotube networks to create a structure for more efficient electrodes" (Maize 2009). According to MIT Tech Talk, MIT President Susan Hockfield took the prototype battery to the White House where she and U.S. President Barack Obama spoke about the need for federal funding to advance clean-energy technologies. "Now that the researchers have demonstrated they can wire virus batteries at the nanoscale, they intend to pursue even better batteries using materials with higher voltage and capacitance" (Trafton 2009).

Example 32.4: CMU Research Corporation—USA

Bio-Nano Power a Central Michigan University—Research Corporation tenant led by Nathan Long, resident and CEO, and his team of researchers filed a comprehensive patent, "Bio-Nano Power Cells and Their Uses," which ties together more than 2 years of intense biotechnology and nanotechnology research to develop power cells that generate efficient, high density power and emit lower CO_2 pollutants (Nanotechnology Now 2009). Long foresees a range of applications from miniaturized self-powered glucose monitors and large-scale machines such as personal computers and even automobiles.

32.2.3 Environmental Remediation

Educational institutions, corporations, and government agencies are researching nanobiotechnology for bioremediation activities. By combining nanosize technology with biology, they mimic how nature itself would clean and remove harmful waste and toxins.

Example 32.5: Lawrence Berkeley National Lab—U.S. Department of Energy

A research team led by John Moreau and Jill Banfield examined a biofilm rich in zinc sulfide collected from a flooded mine and noted it readily combined with zinc to form nanosized biominerals. The metal sulfide formations aggregated and were especially dense measuring several microns in diameter. In addition, they discovered proteins and polypeptides with the zinc sulfide nanoparticles. The researchers are attempting to better understand the mechanisms whereby proteins promote nanoparticle aggregation. These findings suggest that microbially derived extracellular proteins can limit the dispersal of nanoparticulate metal-bearing phases, such as the mineral products of bioremediation, which may otherwise be transported away from their source by subsurface fluid flow. Their research was reported in *Science* (Moreau et al. 2007).

Example 32.6: Cornell University—USA

Cornell University researchers from horticultural sciences and entomology have used biodegradable nanofibers with pesticides to improve efficiencies. Chunhui Zhang presented these findings at the 2009 ACS meeting in Salt Lake City. Encapsulating the pesticide within nanofibers, "the new technology also extends how long the pesticides remain effective and improves the safety of applications. As the fiber biodegrades, the chemicals are slowly released into the soil" (Hall 2009).

There are many examples: some more speculative than others, some transitioning from the micro-level to the nanolevel, and still others that are mischaracterizations of microlevel research as nanolevel research. None of these reservations withstanding, what these examples share in common will be examined in detail below. Before we move to that part of this chapter, we must examine how this commonality will be criticized.

32.3 On Environmental Stewardship

Environmental stewardship is associated with conservation and conservation ethics. This field has a broad meaning. There is a hard interpretation involving intrinsic value (e.g., animals and other species rights) as well as a softer version involving extrinsic value to humanity (e.g., conserving rain forests to mine for chemical formulae for pharmaceuticals).

Many conservationists and environmentalists affected the perspective of contemporary environmental ethics. White (1967) argued how humans situate themselves in response to ecological challenges affects the range of likely solutions. Hardin (1968) warned individuals acting in their own self-interest tend to deplete limited resources almost without exception. Leopold (1949) offered a land ethic premised on an obligation to preserve the environment for its own sake. Carson (1962) launched the environmental movement by documenting the effects of pesticide mismanagement in *Silent Spring*. Each in their own way and voice made a case for ecological management and a conservation ethic that was highly suspicious of fixes.

Claims of nanobiotechnology are premised on technology as a fix, a solution at the impact level rather than the antecedent. For example, conservation and reduced demand are critical antecedent based solutions. Technological fixes tend to be situated at the impact level. Conservation ethicists find this world-view challenging. Some argue the resulting ethic continues environmental exploitation with the implicit assumption problems of all sorts are remediable. While a more balanced focus on antecedents as well as impacts makes eminent sense, rhetoric on the promises of nanobiotechnology seems to exaggerate impact solutions with minimal attention toward developing a simultaneous ethic of smart consumption.

Technological fixes have been subject to scrutiny not only by some environmental ethicists and conservationists but also by political and social scientists. Sarewicz and Nelson (2008), two social scientists, commented on technological fixes, such as vaccines, in a short piece in *Science*. They listed three rules suggesting fixes are limited in their efficacy. These rules are listed below in bold to help organize some of the shortcomings of technological fixes involving nanobiotechnology.

Rule 1: The Technology Must Largely Embody the Cause–Effect Relationship Connecting Problem to Solution

First and foremost, the fix should either impact the antecedent significantly or should interfere with the cause–effect relationship sufficiently to impact the effect. What the standards of embodiment might mean in this rule while left unclear opens ground to discuss whether focusing on antecedents rather than impacts should be preferred. In general, this rule argues a holism that treats both antecedent and impact to avoid recurrence or replication.

In cases where the antecedent is behavioral, resolving the capability of the antecedent to produce an impact can be especially daunting. There are many logical reasons why good people tolerate evil.

Once the effect is reduced to levels below easy detection, the motivation to prevent the recurrence of the effect falls and feeds a cycle whereby the fix becomes a necessary component of the cycle. If and when the fix becomes unable to impact the effect, the fix approach demands another round of technological research to generate the next fix, ad infinitum. The capacity to produce more and more fixes is built on a foundation of assumptions about expertise, willingness, and capacity. Secondly, fixes must be testable and falsifiable and most are fraught with overclaims and rhetorical flourishes. Most technological fixes are rhetorical in nature based on hyperbole rather than a lot of sound science and engineering.

While nanobiotechnology is not touted as a cure-all for the ills of society, many of the claims are hyperbolized. Suspicion of these claims is not necessarily driven by Luddites who believe technology is fundamentally dehumanizing and counterproductive, rather it is propagated by the concern that technology may hit "the wall" whereby the environmental challenges will outstrip our capacity to design and deploy a technological solution that fits the bill. These ethicists are apprehensive technology can design humanity out of all or most of the environmental challenges confronting us. In their view, those who see serial technological solutions to serial environmental problems are suffering from a form of hubris (excessive pride).

Rule 2: The Effects of the Technological Fix Must Be Assessable Using Relatively Unambiguous or Uncontroversial Criteria

One of the more challenging problems with a technological fix is assessment, especially when we are projecting success. Oftentimes, we have laboratory data that are transposed to a large-scale setting. Sometimes we have pilot data projected to global settings. As such, we are expected to evaluate highly speculative technological solutions to daunting issues. For example, consider the grand challenge of nutritious food. We must not only meet the caloric requirements of growing population but also their associated nutritional requirements. If a population has a special need, such as vitamin A to reduce blindness, we expect food producers, farmers, and corporations to consider supplementing foods with vitamin A and we get "Golden Rice." A single technological solution to a specific dietary deficiency might be desirable until we begin to examine other options crowded out by a technological fix, especially over a much longer time frame. Albrecht found in 2002:

> The problem with supplementation is that it should be a back-stop strategy for a limited period of time. Investing scarce resources in supplementation strategies that are not phased out and that are not complemented by other strategies that take away the need to supplement can have high opportunity costs that are often neglected. We therefore added a cost-effectiveness analysis for the combination of supplementation with other interventions. We found that the combination of supplementation with GR and with GR++ (super Golden Rice) did lead to the best results, followed by the combination of supplementation and fortification. The combination of supplementation and gardening proved to be the least cost-effective intervention (p. 45).

Albrecht's discussion suggests assessments should compare alternatives in combination against a period of time. The assessment difficulties uncovered by Albrecht regarding "Golden Rice" suggests technological fixes as solitary stop gap solutions may test positive, but when considered in a broader context, we find assessment more complex if not stupefying. There are simply too many unknown variables, and claims and counterclaims are inaccurate and exaggerated.

In addition, we assume the assessment models designed in the present are appropriate at some time in the future. Much like the presence of rabbits in the Australian continent, small changes can have ecologically devastating consequences. Introduced in the late 1700s as a food animal, rabbits have become the most significant known factor in Australian species loss. Introduced for all the right reasons, they stressed the ecosystem to the breaking point. Determining a priori the impacts of introducing an animal into a closed ecosystem or an enhanced seed variety to solve vitamin deficiencies involves data points outside the grasp of the best modeling and algorithmic formulae.

Rule 3: Research and Development Is Most Likely to Contribute Decisively to Solving a Social Problem When It Focuses on Improving a Standardized Technical Core That Already Exists

Incremental steps taken to enhance a process or procedure tend to be more productive than a fundamental shift in how things are done. Radical change, while paradigmatically significant, can appear to be the best option at hand, sometimes justifiably so. However presumption favors what we know and what we are accustomed to. On the other hand, a conservative approach to research and development (R&D) has vociferous opponents as well as proponents. Nonetheless, the argument made by Sarewicz and Nelson is grounded in the belief that what we know has higher levels of certainty than the unknown. The unknown involves speculations and prognostications about advantages and disadvantages. Many times promises and expectations on R&D go unfulfilled. Nuclear energy power generation and virtual reality are two technologies that fill this bill. Nuclear fission power generation is not too inexpensive to go unmetered (Strauss 1954) and virtual reality has not produced ubiquitous telepresence and virtual bodies (The Economist 2001).

Bred by efforts of researchers to associate broader societal implications as they attempt to solicit attention and grant money, hyperbole is endemic to claims associated with science and technology research and development. However, assessments seldom, if ever, hold a researcher to his rhetorical claims when decades later his research serves to function as little more than a historical artifact. More often, it will be debunked and contradicted by subsequent findings. While R&D may inform fields of research paths that should not be taken, methodologies that are not sufficient, and materials and applications that are not productive, R&D functions primarily to eliminate rather than instantiate new understanding. Given the time and energies that need to be dedicated to dis-validation, researchers are drawn to hyperbole as a rhetorical tool to garner the levels of attention, monetary and otherwise, that intrinsically reductive research efforts demand.

In open systems, hyperbole is less vulnerable to criticism. In closed systems hyperbole jockeys against other claims for time and space. Simply put, in a world of limited resources those captured by one claim or overclaim are foregone to others. Undoubtedly, this sensibility underlies some of the concerns associated with societal implications research about genomic decoding, bioscience, and nanotechnology.

In critical studies of media we note how media primes and frames discuss and debate. What has generally gone lacking has been any substantive research into the limits of the perceptual and attentive capacity of audiences of all sorts. It is hardly unrealistic to assume there are limits to public attentive capacities. Agendas set by media communication crowd out some subjects with the inclusion of others. This is a messy dynamic and tradeoffs are hardly one-to-one. However, crowding does occur when some news stories crowd out other news stories. This is true for science and technology as much as it is for political news stories such as the Obama administration's difficulty keeping a national health insurance plan on the public agenda while avoiding an economic freefall, fighting three wars in Iraq, Afghanistan, and Pakistan, and addressing nuclear proliferation concerns with North Korea and Iran. The public cannot focus on many agenda items and the media is well aware of this.

The aforementioned is evidence of the attentive capacity of the world around us is not limitless, founding our thesis that hyperbole about radical change should remain highly suspect. As such, incremental change premised on renovating rather than rebuilding should be privileged. As argued below, this standard should not be lost in claims associated with nanobiomaterials.

In addition, the impacts of paradigmatic shifts carry a high level of uncertainty, if not risk. While the present system or status quo may be imperfect, we know what those imperfections may be. This well-known argumentation theory privileges some claims over others based on whether some should be treated presumptively. Presumption as a concept makes legal jurisprudence possible privileging some testimony and evidence against others. The same is true for claims in science and technology. We witnessed this historically with Galileo's wrestle over heliocentricity and more recently when Pons and Fleishmann's careers were undercut by overclaims associated with cold fusion. Interestingly, in both these instances, the claims producing the most ire are not necessarily produced by those suffering the most ire.

Sarewicz and Nelson (2008) claim an entirely novel approach to a problem is presumptively suspicious.

> … R&D programs aimed at solving particular social problems should neither be expected to succeed, nor be advertised as having much promise of succeeding, at least in the short and medium term. They should be understood and described as aiming at the creation of fundamental knowledge and the exploration of new approaches, with success possible only over the long term, and with a significant chance of failure.

Technological fixes, including nanobiomaterials, are presumptively suspicious not only for the hyperbolic claims of their proponents but also their radical resolution of rather mundane social and ideological issues: how to feed the hungry safely, how to supply power for development, and how to clean up the ecosystem from excesses of all sorts.

32.4 Tech Fixes and Moral Absolution

Moral absolution may seem to be the raison d'etre of grief stricken members of the public who feel a sense of responsibility or loss for the state of the world around them. Fixing a problem may reduce impacts but preventing the antecedent from generating the problem in the first place carries higher moral value. Feeding the hungry, providing energy for development, and reducing environmental damage are laudable goals. Technological fixes are fine for what they are and what they do, but absolution is not the sine qua non of advanced technology.

> … [T]echnological fixes do not offer a path to moral absolution, but to technical resolution. Indeed, one of the key elements of a successful technological fix is that it helps to solve the problem while allowing people to maintain the diversity of values and interests that impede other paths to effective action. Recognizing when such opportunities for rapid progress are available should be a central part of innovation policy, and should guide investment choices (Sarewitz and Nelson 2008).

Absolution may not be prerequisite for pragmatists in handling global challenges. Much like the responder who devalues blameworthiness in order to focus on curatives, science and technology, including but not limited to nanobiotechnology and nanobiomaterials, focus on solutions without resolving cause. Their mantra is "if something else comes up, science and technology will rise to the occasion and come to the rescue." For the ethicist, this is a fool's goal and condemns humanity to a never-ending series of crises with collateral damage of all sorts. As a rule, crises are defined by damage. We know they are upon us by the devastation they inflict. For the ethicist, changing how we approach the world around us can forego the collaterals of crises. Focusing on impact-based solutions treats collaterals as means to define the onset of a crisis, denying them intrinsic value.

32.5 Lessons on Simultaneity

Some environmental ethicists are concerned if we do not learn stewardship and find ways to reduce, if not eliminate, the antecedents to problems, we are prone to learn nothing from our mistakes. Instead, we are dooming ourselves to stumble from one disaster into another until we reach a point when fixes are inappropriate or insufficient to deal with the crises at hand. The assumption human interests, intelligence, and intuitiveness will enable us to resolve whatever consequence we confront is simply unjustified. Predictions at this level involve too many unknowns to be anything but wishful thinking.

On the other hand, if the public comes to terms with ecological sustainability and conservation ethics, we are more likely to design solutions at the antecedent end of social and ecological problems rather than at the effects end. When we turn to impact based solutions like nanobiomaterials, we may need to address antecedents as well. Too often we defer to impact oriented solutions that can be affected effectively by reducing the antecedents, or devaluing antecedents that are difficult to minimize. For the ethicist evaluating technological fixes, sufficient justifications exist to concentrate comparable efforts at the antecedent end of a crisis. A purist would call for a conservation ethics at the antecedent end at the expense of impact-based solutions. A pragmatist would focus on impact based solutions because they work and do not carry the impediments of antecedent based efforts. The ethicist would argue simultaneity: attack impacts and antecedents simultaneously.

Why not serially? Once a strategy of impact solutions is emphasized, it tends to trade off with antecedent solutions. Once an impact solution is emphasized we are swept up in the hyperbole that is missing from antecedent efforts that are mundane and difficult—feed the poor, conserve electricity, recycle products, consume less. . . .

For the conservation ethicist, nanobiomaterials as technological fixes function as impact based solutions that trade off with antecedent based solutions. While there is no inherent reason for this to occur, it occurs nonetheless because that is the nature of the beast.

Societal implication researchers have surfaced to examine many emerging technologies. They are not solely concerned about human and environmental health and safety. The issues include questions of primacy, rich–poor divides, ownership of the commons, environmental conservation, and stewardship, and many more. For many social scientists and scholars in the humanities, technological fixes have dominated much of the hyperbolic discourse over emerging technologies. These discussions are valuable for many reasons; nevertheless we need to understand such a narrow focus on impact-based solutions is not without costs.

32.6 Conclusions

The authors do not advocate in this piece. I am merely constructing an argument to generate debate and discussion. To leave the weak and suffering behind as we attempt to change to motivations that function as antecedents is not our intent. Instead, we see roles for curatives and fixes but not with the exclusivity they have garnered.

I sense debate about simultaneity and effort at both the antecedent and impact ends of crises is worthy. Finally, I see space for discourse about environmental and conservation ethics as we approach emerging technologies, in this case nanobiotechnology, to solve the world crises that beset us with frightening regularity. We may suspend the trends only if the antecedents to crises receive as much attention as the impacts they have on all of us.

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