Nanotechnology in the Age of Posthuman Engineering: Science Fiction as Science

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Now nanotechnology had made nearly anything possible, and so the cultural role in deciding what *should* be done with it had become far more important than imagining what *could* be done with it.

—Neal Stephenson, *The Diamond Age* (1995)

Long live the new flesh.

—David Cronenberg's *Videodrome* (1983)

The Technoscapes and Dreamscapes of Nanotechnology

K. Eric Drexler, pioneer and popularizer of the emerging science of nanotechnology, has summarized the ultimate goal of his field as "thorough and inexpensive control of the structure of matter."[1] Nanotechnology is the practical manipulation of atoms; it is engineering conducted on the molecular scale. Many scientists involved in this ambitious program envision building nanoscopic machines, often called "assemblers" or "nanobots," that will be used to construct objects on an atom-by-atom basis. Modeled largely after biological "machines" like enzymes, ribosomes, and mitochondria—even the cell—these nanomachines will have specific purposes such as binding two chemical elements together or taking certain compounds apart, and will also be designed to replicate themselves so that the speed and scale of molecular manufacturing may be increased. Several different

1. K. Eric Drexler, "Preface," in K. Eric Drexler, Chris Peterson, and Gayle Pergamit, *Unbounding the Future: The Nanotechnology Revolution* (New York: Morrow, 1991), p. 10.

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types of assemblers, or assemblers with multiple functions, will act together to engineer complex objects precise and reproducible down to every atomic variable. With its bold scheme to completely dominate materiality itself, nanotechnology has been prophesied to accomplish almost anything called for by human desires.

These prophecies have run the gamut from the mundane to the fantastic: Nanomachines will be able to disassemble any organic compound, such as wood, oil, or sewage, then restructure the constituent carbon atoms into diamond crystals of predetermined size and shape for numerous purposes, including structural materials of unprecedented strength. Nanomachines will be put into your carpet or clothing, programmed to constantly vaporize any dirt particles they encounter, keeping your house or your wardrobe perpetually clean. Nanomachines will quickly and cheaply fabricate furniture, or car engines, or nutritious food, from a soup of appropriate elements. Nanomachines will facilitate our exploration of space, synthesizing weightless lightsails to propel seamless spaceships throughout the universe. Nanomachines will repair damaged human cells on the molecular level, thus healing injury, curing disease, prolonging life, or perhaps annihilating death altogether.

Nanotechnology has been extensively discussed in these terms, but despite the fancifulness of certain nanoscenarios, it is a robust and active science. Many universities, laboratories, and companies around the world are investigating nanotech possibilities, constituting a dense discourse network—a technoscape—of individuals and institutions interested in the potential benefits of this nascent discipline.[2] The U.S. National Science Foundation supports a National Nanofabrication Users Network to coordinate efforts at numerous sites,[3] and the National Nanotechnology Initiative, proposed by the Clinton administration in 2000 and augmented by the Bush administration in 2001, offers funding and guidelines to promote nanotech breakthroughs.[4] Arguably at the center of the technoscape is the Foresight Institute, a nonprofit organization established in 1986 by Drexler and his wife, Christine Peterson, to foster thinking and research related to nanotechnology.[5] Hosting conferences, sponsoring

2. See the U.S. National Science Foundation's nanotechnology database, *www.wtec.org/loyola/nanobase/*, for a complete catalogue of nanotechnology research sites.

3. The National Nanofabrication Users Network, *www.nnun.org/*, "provides users with access to some of the most sophisticated nanofabrication technologies in the world with facilities open to all users from academia, government, and industry."

4. National Nanotechnology Initiative, *www.nano.gov*.

5. The Foresight Institute, *www.foresight.org*, is based in Palo Alto, Calif.

publications and awards, the Foresight Institute strives to be a nanotech mecca of sorts, anchoring the morass of nanotechnological endeavors currently spreading across the globe. Since Drexler first proposed a program for research in 1986 with the publication of his polemical *Engines of Creation: The Coming Era of Nanotechnology*,[6] nanotechnology has gained notoriety as a visionary science and the technoscape has burgeoned.

Offering intellectual and commercial attractions, career opportunities and research agendas, nanotechnology foresees a technocultural revolution that will, in a very short time, profoundly alter human life as we know it. The ability to perform molecular surgery on our bodies and our environment will have irrevocable social, economic, and epistemological effects; our relation to the world will change so utterly that even what it means to be human will be seriously challenged. But despite expanding interest in nanotech, despite proliferating ranks of researchers, despite international academic conferences, numerous doctoral dissertations, and hundreds of publications, the promise of a world violently restructured by nanotechnology has yet to become reality.

Scientific journal articles reporting experimental achievements in nanotech, or reviewing the field, frequently speak of the technical advances still required for "the full potential of nanotechnology to be realized,"[7] of steps needed toward fulfilling the "dream of creating useful machines the size of a virus,"[8] of efforts that, if they "pan out, . . . could help researchers make everything from tiny pumps that release lifesaving drugs when needed to futuristic materials that heal themselves when damaged."[9] These texts—representative of the genre of popular and professional writing about nanotech that I will call "nanowriting"—incorporate individual experiments and accomplishments in nanoscience into a teleological narrative of "the evolution of nanotechnology,"[10] a progressivist account of a scientific field in which the climax, the "full potential," the "dream" of a

6. K. Eric Drexler, *Engines of Creation: The Coming Era of Nanotechnology* (Garden City, N.Y.: Anchor Books/Doubleday, 1986); all references to this work are to the revised ed. (New York: Anchor Books/Doubleday, 1990).

7. Chad A. Mirkin, "Tweezers for the Nanotool Kit," *Science* 286 (1999): 2095.

8. Robert F. Service, "AFMs Wield Parts for Nanoconstruction," *Science* 282 (1998): 1620.

9. Robert F. Service, "Borrowing From Biology to Power the Petite," *Science* 283 (1999): 27.

10. James K. Gimzewski and Christian Joachim, "Nanoscale Science of Single Molecules Using Local Probes," *Science* 283 (1999): 1683.

nanotechnology capable of transforming garbage into gourmet meals and sending invisible surgeons through the bloodstream, is envisioned as *already inevitable*.

Nanowritings convey "a sense of inevitability that [future nanotech successes] will come in time," a sure faith that there "will come technologies that will be the best that they can ever be," and that "all manner of technologies will flow" from the current work of dedicated visionaries.[11] Because the "development of nanotechnology appears inevitable,"[12] nanowritings freely and ubiquitously import the nanofuture into the research of today, and the language used, as we will see, rewrites the advances of tomorrow into the present tense.[13] Nanowritings speculate on scientific and technological discoveries that have not yet occurred, but they nonetheless deploy such fictionalized events to describe and to encourage preparation for the wide-scale consequences of this "seemingly inevitable technological revolution."[14]

Even in the discipline's first recognized technical journal article—which both proposed a new technology and inaugurated a new professional field—Drexler writes that the incipient engineering science of molecular nanotechnology has dramatic "implications for the present" as well as the "the long-range future of humanity."[15] Re-

11. Richard Smalley, "Nanotech Growth," *Research and Development* 41:7 (1999): 34–37. Smalley, a Nobel Laureate, directs the Center for Nanoscale Science and Technology at Rice University.

12. Christine L. Peterson, "Nanotechnology: Evolution of the Concept," in *Prospects in Nanotechnology: Toward Molecular Manufacturing*, ed. Markus Krummenacker and James Lewis (New York: Wiley, 1995), pp. 173–186, quotation on p. 186. Indicative of nanowriting's teleological tendencies, Peterson's article absorbs the entire history of atomic theory, from Democritus to the present, to suggest the unavoidable rise of nanotechnology and our progression toward the nanofuture.

13. Nanowriting employs literary techniques common to speculative science writing in general. See Greg Myers, "Scientific Speculation and Literary Style in a Molecular Genetics Article," *Science in Context* 4 (1991): 321–346, on the linguistic peculiarities of scientific speculation that work to legitimate such claims. Nanowriting, however, goes beyond most scientific speculation in that its uses of the future tense and its visions of tomorrow are totalizing, bringing the future more firmly into the textual present—which is one reason, as we will see, why nanotechnology is so frequently characterized not as "speculative science" but as "fictional science."

14. B. C. Crandall, "Preface," in *Nanotechnology: Molecular Speculations on Global Abundance*, ed. idem (Cambridge, Mass.: MIT Press, 1996), p. ix. Crandall has founded three companies with investments in a nanotech future: Molecular Realities, Memetic Engineering, and Prime Arithmetics.

15. K. Eric Drexler, "Molecular Engineering: An Approach to the Development of General Capabilities for Molecular Manipulation," *Proceedings of the National Academy of Sciences* 78 (1981): 5278.

peated throughout the technoscape, this narrative telos of nanotechnology—described as already given—is a vision of the "long-range future of humanity" utterly transfigured by present scientific developments. In other words, embedded within nanowriting is the implicit assumption that, even though the nanodreams have yet to come to fruition, nanotechnology has *already* enacted the transformation of the world.

Due to the tendency of nanowriting to speculate on the far future and to prognosticate its role in the radical metamorphosis of human life (coupled with the fact that nanotech research has yet to produce material counterparts to its adventurous mathematical models and computer simulations), many critics have claimed that nanotechnology is less a science and more a science fiction. For instance, David E. H. Jones, chemist at the University of Newcastle upon Tyne, insinuates that nanotech is not a "realistic" science, and that, because its aspirations seem to violate certain natural limits of physics, "nanotechnology need not be taken seriously. It will remain just another exhibit in the freak-show that is the boundless-optimism school of technical forecasting."[16] Gary Stix, staff writer for *Scientific American* and a persistent critic of nanotech, has compared Drexler's writings to the scientific romances of Jules Verne and H. G. Wells, suggesting that "real nanotechnology" is not to be found in these science fiction stories.[17] Furthermore, Stix maintains that nanowriting, a "subgenre of science fiction," damages the legitimacy of nanoscience in the public eye, and that "[d]istinguishing between what's real and what's not" is essential for nanotech's prosperity.[18] Similarly, Stanford University biophysicist Steven M. Block has said that many nanoscientists, particularly Drexler and those involved with the Foresight Institute, have been too influenced by laughable "science fiction" expectations and have gotten ahead of themselves; he proposes that for "real science to proceed, nanotechnologists ought to distance themselves from the giggle factor."[19]

Several critics have stated that direct manipulation and engineering of atoms is not physically possible for thermodynamic or quantum mechanical reasons; others have suggested that, without experi-

16. David E. H. Jones, "Technical Boundless Optimism," *Nature* 374 (1995): 835, 837.

17. Gary Stix, "Trends in Nanotechnology: Waiting for Breakthroughs," *Scientific American* 274:4 (1996): 94–99, on p. 97.

18. Gary Stix, "Little Big Science," *Scientific American* 285:3 (2001): 37.

19. Steven M. Block, "What Is Nanotechnology," talk presented at the National Institutes of Health conference, "Nanoscience and Nanotechnology: Shaping Biomedical Research," Natcher Conference Center, Bethesda, Md., June 25, 2000.

mental verification for its outrageous notions and miraculous devices, nanotechnology is not scientifically valid; many more have dismissed the long-range predictions made by nanowriting on the grounds that such speculation obscures the reality of present-day research and the appreciable accomplishments within the field. These attacks have in common a strategic use of the term "real science" as opposed to "science fiction," and, whether rejecting the entire field as mere fantasy or attempting to extricate the scientific facts of nanotech from their science-fictional entanglements, charges of science-fictionality have repeatedly called the epistemological status of nanotechnology into question.[20]

Nanotechnology has responded to these attacks with various rhetorical strategies intended to distance its science from the negative associations of science fiction. However, I will be arguing that such strategies ultimately end up collapsing the distinction, reinforcing the science-fictional aspects of nanowriting in the process of rescuing its scientific legitimacy. I hope to make clear that the scientific achievements of nanotechnology have been and will continue to be extraordinarily significant; but, without contradiction, nanotechnology is thoroughly science-fictional in imagining its own future, and the future of the world, as the product of scientific advances that have not yet occurred.

Science fiction, in Darko Suvin's formalist account of the genre, is identified by the narratological deployment of a "novum"—a scientific or technological "cognitive innovation" as extrapolation or deviation from present-day realities—that becomes "'totalizing' in the sense that it [the novum] entails a change in the whole universe of the tale."[21] The diegesis of the science fiction story is an "alternate reality logically necessitated by and proceeding from the narrative kernel of the novum."[22] Succinctly, science fiction assumes an element of transgression from contemporary scientific thought that in itself brings about the transformation of the world. It follows that nanowriting, in positing the world turned upside down by the future advent of fully functional nanomachines, thereby falls into the domain of science fiction. Nanowriting performs radical ontological displacements within its texts and re-creates the world atom by atom

20. Many early critiques of nanotech's "science-fictionality" are described in Ed Regis's lively history, *Nano: The Emerging Science of Nanotechnology* (Boston: Little, Brown, 1995).

21. Darko Suvin, *Metamorphoses of Science Fiction: On the Poetics and History of a Literary Genre* (New Haven: Yale University Press, 1979), p. 64.

22. Ibid., p. 75.

as a crucial component of its extrapolative scientific method; but by employing this method, it becomes a postmodern genre that draws from and contributes to the fabulations of science fiction.[23] Science fiction is not a layer that can be stripped from nanoscience without loss, for it is the exclusive domain in which mature nanotechnology currently exists; it forms the horizon orienting the trajectory of much nanoscale research; and any eventual appearance of practical molecular manufacturing—transforming the world at a still-unknown point in the future—would surely constitute a tremendous materialization of the fantastic. Accordingly, I suggest that molecular nanotechnology should be viewed as simultaneously a science and a science fiction.

Jean Baudrillard has frequently written on the relationship of science to science fiction, contextualizing the dynamics of this relationship within his notion of hyperreality.[24] Mapping onto "three orders of simulacra"—the counterfeit, the reproduction, and the simulation—three orders of the speculative imaginary are described in his essay "Simulacra and Science Fiction." He writes: "To the first category [of simulacra] belongs the imagination of utopia. To the second corresponds science fiction, strictly speaking. To the third corresponds—is there an imaginary that might correspond to this order?"[25] The question is open because the third-order imaginary is still in the process of becoming and is as yet unnamed. But within this imaginary, the boundary between the real and its representation deteriorates, and Baudrillard writes that, in the postmodern moment, "There is no real, there is no imaginary except at a certain distance. What happens when this distance, including that between the real and imaginary, tends to abolish itself, to be reabsorbed on behalf of the model?"[26] The answer is the sedimentation of hyperreality, where the model becomes indistinguishable from the real, supplants the real, precedes the real, and finally is taken as more real than the real:

> The models no longer constitute either transcendence or projection, they no longer constitute the imaginary in relation to the real, they are themselves an

23. Science fiction and postmodernist writing regularly draw from one another to fabulate worlds and zones of radical otherness; see Brian McHale, *Postmodernist Fiction* (London/New York: Routledge, 1997), esp. pp. 59–72.

24. Jean Baudrillard, *Symbolic Exchange and Death*, trans. Iain Hamilton Grant (London/Thousand Oaks/New Delhi: Sage Publications, 1993), pp. 50–86. See also Baudrillard, "The Precession of Simulacra," in idem, *Simulacra and Simulation*, trans. Sheila Faria Glaser (Ann Arbor: University of Michigan Press, 1994), pp. 1–42.

25. Jean Baudrillard, "Simulacra and Science Fiction," in *Simulacra and Simulation* (n. 24), pp. 121–127, quotation on p. 121.

26. Ibid.

> anticipation of the real, and thus leave no room for any sort of fictional anticipation—they are immanent, and thus leave no room for any kind of imaginary transcendence. The field opened is that of simulation in the cybernetic sense, that is, of the manipulation of these models at every level (scenarios, the setting up of simulated situations, etc.) but then *nothing distinguishes this opera from the operation itself and the gestation of the real; there is no more fiction.*[27]

In the dichotomy of science versus science fiction, the advent of third-order simulacra or imaginaries announces that science and science fiction are no longer separable. The borderline between them is deconstructed. In Baudrillard's age of simulation, science and science fiction have become coterminous: "It is no longer possible to fabricate the unreal from the real, the imaginary from the givens of the real. The process will, rather, be the opposite: it will be to put decentered situations, models of simulation in place and to contrive to give them the feeling of the real, of the banal, of lived experience, to reinvent the real as fiction, precisely because it has disappeared from our life."[28] At the moment when science emerges from within science fiction and we can no longer tell the difference, the real has retreated and we are left with only the simulations of the hyperreal, where "there is neither fiction nor reality anymore" and "science fiction in this sense is no longer anywhere, and it is everywhere."[29]

The case of nanotechnology illustrates the hyperreal disappearance of the divide between science and science fiction. The terminology of "real science" versus "science fiction" consistently used in the debates surrounding nanotech depends upon the discursive logic of the real versus the simulacrum as analyzed by Baudrillard. Although each term may independently provide the illusion of having a positive referent—that is, "real science" might refer to a set of research and writing practices that adhere to and/or reveal facts of nature while being institutionally recognized as doing so, and "science fiction" might refer to a set of certain generically related fictional texts or writing practices that mimic such texts—when they are used to argue the cultural status of nanotechnology, real science and science fiction are nearly emptied of referential pretensions, becoming signifiers of unstable signifieds as they are forced into preestablished symbolic positions of "the real" and "the simulacrum." In this logic, science and science fiction negatively define each other, and though

27. Ibid., p. 122 (emphasis in original).

28. Ibid., p. 124.

29. Ibid., pp. 125, 126.

each is required for the other's structural existence, science fiction is the diminished and illegitimate term, the parasitical simulation of science.

To maintain that the categories of science and science fiction are supplemental constructs of each other is not to deny the political effects of discourse, for the fate of nanotechnology as a research field and the fates of real people working within it are strongly entwined with the language used. But I will show that the nanorhetoric mobilizing the logic of real science *opposed* to science fiction comes to undermine its own position, dissolving real science *into* science fiction and exemplifying what Baudrillard describes as the vanishing of the real, or the moment of hyperreal crisis when the real and "its" simulacrum are understood as semiotic fabrications, when "the real" (e.g., "real science") can be demonstrated as simulation and "the simulation" (e.g., "science fiction") can be demonstrated as real, when dichotomies must be abandoned in favor of hybrids. Although the strict categories of real science and science fiction must be used in order to accomplish their deconstruction (or are deconstructed because of their use), they should be read as under erasure, for the relationship of science to science fiction is not one of dichotomy but rather one of imbrication and symbiosis. Science fiction infuses science and vice versa, and vectors of influence point both ways. Inhabiting the liminal space traversed by these vectors are fields like nanotechnology that draw equally from the inscription practices of scientific research and science fiction narration, and only a more sutured concept—something like "science (fiction)"—adequately represents the technoscape of nanotechnology and its impact on the human future.

Nanotechnology is one particular example illustrating the complex interface where science and science fiction bleed into one another. Yet more significantly, nanotechnology is capable of engineering the future in its own hybrid image. Not only does the continued development of nanotechnology seemingly provide the means for making our material environments into the stuff of our wildest dreams, but nanotech's narratives of the "already inevitable" nanofuture ask us *even now* to reevaluate the foundations of our lived human realities and our expectations for the shape of things to come. Which is to say that the writing of nanotechnology, as much as or even more than any of its eagerly anticipated technological inventions, is already forging our conceptions of tomorrow. Unleashing its science fictions as science and thereby redrawing the contours of technoculture, nanotechnology instantiates the science-fictionizing of the world.

Donna Haraway has argued that the science-fictionizing of technoculture, or the postmodern revelation that "the boundary between science fiction and social reality is an optical illusion," gives rise to a "cyborg" epistemology threatening humanistic borders.[30] Similarly, Scott Bukatman sees the new subjectivity created by the science fictions of technoculture as a "terminal identity," writing that "[t]erminal identity is a form of speech, as an essential cyborg formation, and a potentially subversive reconception of the subject that situates the human and the technological as coextensive, codependent, and mutually defining."[31] Haraway and Bukatman suggest that cyborg fusions and science fiction technologies transfigure embodied experience, enabling the appearance of a posthuman subject that N. Katherine Hayles describes as "an amalgam, a collection of heterogeneous components, a material-informational entity whose boundaries undergo continuous construction and reconstruction."[32] I argue that nanotechnology is an active site of such cyborg boundary confusions and posthuman productivity, for within the technoscapes and dreamscapes of nanotechnology the biological and the technological interpenetrate, science and science fiction merge, and our lives are rewritten by the imaginative gaze—the new "nanological" way of seeing—resulting from the splice. The possible parameters of human subjectivities and human bodies, the limits of somatic existence, are transformed by the invisible machinations of nanotechnology—both the nanowriting of today and the nanoengineering of the future—facilitating the eclipse of man and the dawning of the posthuman condition.

Nanotechnology as Science, or, The Nanorhetoric

Nanotech is a vigorous scientific field anticipating a technological revolution of immense proportions in the near future, and Eric Drexler is right at the vanguard. Founder and chairman of the Foresight Institute as well as a research fellow at the Institute for Molecular Manufacturing, his scientific credentials (Ph.D. from MIT, a former visiting appointment at Stanford, numerous publications) are impressive. But Drexler's seminal and influential *Engines of Creation*,

30. Donna J. Haraway, "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century," in idem, *Simians, Cyborgs, and Women: The Reinvention of Nature* (New York: Routledge, 1991), pp. 149–181, on p. 149.

31. Scott Bukatman, *Terminal Identity: The Virtual Subject in Postmodern Science Fiction* (Durham, N.C.: Duke University Press, 1993), p. 22.

32. N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago: University of Chicago Press, 1999), p. 3.

outlining his program for nanotech research, is composed as a series of science-fictional vignettes. From spaceships to smart fabrics, from AI to immortality, *Engines of Creation* is a veritable checklist of science-fictional clichés—Drexler's insistence on scientificity notwithstanding—and the narrative structure of the book unfolds like a space opera: watch as brilliant nanoscientists seize control of the atom and lead humankind across the universe . . . and beyond!

The operatic excess of nanowriting—that genre of scientific text in which the already inevitable nanotech revolution can be glimpsed —characterizes even technical publications by Drexler, Ralph Merkle, Markus Krummenacker, Richard Smalley, Daniel Colbert, Robert Freitas, Jr., J. Storrs Hall, and other prophets of the nanofuture. Speculative and theoretical, these texts demonstrate what is possible but not what has been accomplished, what has been successfully simulated but not what has been realized (for example, Merkle writes that nanoscientists are working diligently to "transform nanotechnology from computer *models* into *reality*)."[33] These texts frame their scientific arguments with vivid tales of potential applications, which are firmly the stuff of the golden age of science fiction. Matter compilers, molecular surgeons, spaceships, space colonies, cryonics, smart utility fogs, extraterrestrial technological civilizations, and utopias abound in these papers, borrowing unabashedly from the repertoire of the twentieth-century science-fictional imagination.[34]

Consequently, the experimental evidence supporting the reality of nanotech has been marshaled into battle to divide the science from its "sci-fi" associations. Nanotechnology is a realistic science, many researches claim, because biological "nanomachines" like enzymes and viruses already exist in nature; there is no reason, then, why human engineers could not construct similar molecular de-

33. Ralph C. Merkle, "It's a Small, Small, Small, Small World," *Technology Review* 100:2 (1997): 25–32, on p. 26 (emphasis added).

34. These science-fictional images can be found in, but are not limited to, Drexler, "Molecular Engineering" (above, n. 15), pp. 5275–5278; K. Eric Drexler, "Molecular Manufacturing as a Path to Space," in Krummenacker and Lewis, *Prospects in Nanotechnology* (above, n. 12), pp. 197–205; Ralph C. Merkle, "Nanotechnology and Medicine," in *Advances in Anti-Aging Medicine*, vol. 1, ed. Ronald M. Klatz and Francis A. Kovarik (Larchmont, N.Y.: Liebert, 1996), pp. 277–286; Robert A. Freitas, Jr., *Nanomedicine,* vol. 1: *Basic Capabilities* (Georgetown, Tex.: Landes Bioscience, 1999); Markus Krummenacker, "Steps Towards Molecular Manufacturing," *Chemical Design Automation News* 9 (1994): 1, 29–39; Daniel T. Colbert and Richard E. Smalley, "Fullerine Nanotubes for Molecular Electronics," *Trends in Biotechnology* 17 (1999): 46–50; J. Storrs Hall, "Utility Fog: The Stuff That Dreams Are Made Of," in Crandall, *Nanotechnology* (above, n. 14), pp. 161–184.

vices.[35] Unfortunately, even with nature as a model, the tangible products of nanoresearch are extremely preliminary. The more celebrated experimental results, in no particular order, include: (1) Engineered proteins and synthetic molecules with protein-like capabilities (William DeGrado and colleagues accomplished the former in 1988; Donald Cram, Jean-Marie Lehn, and Charles Pederson shared a Nobel Prize in 1987 for the latter). (2) An organic molecule pinned to a surface with a scanning tunneling electron microscope (STM) (led by John Foster at IBM in 1988).[36] (3) The widely publicized construction of the IBM logo on a silicon chip by pushing individual xenon atoms with an STM (led by Donald Eigler at IBM in 1989).[37] (4) The production of fullerines (earning Richard Smalley, Robert Curl, and Sir Harold Kroto a Nobel Prize in 1996) and their applications, such as "nanopencils" that deposit molecular ink, and an increasingly precise manipulation of individual atoms.[38] (5) Invented nano-novelties, such as rotating molecular motors, a "nanoabacus," and a "nanotrain" (a large mobile molecule crawling along a molecular "track").[39] These technical accomplishments, as laudable and fascinating as they are, do not represent the successful arrival of molecular manufacturing; nonetheless, because they seem to suggest *progression* toward the "full potential" of nanotech, nanorhetoricians maintain that the "evolution of nanotechnology" is a scientifically valid expectation.

35. This argument is ubiquitous in nanowriting: Drexler, *Engines of Creation* (above, n. 6), pp. 5–11; Drexler, "Molecular Engineering" (above, n. 15), pp. 5575–5576; Ralph C. Merkle, "Molecular Manufacturing: Adding Positional Control to Chemical Synthesis," *Chemical Design Automation News* 8 (1993): 1, 55–61; idem, "Self-Replicating Systems and Molecular Manufacturing," *Journal of the British Interplanetary Society* 45 (1992): 407–413; Service, "Borrowing from Biology" (above, n. 9), p. 27.

36. J. S. Foster, J. E. Frommer, and P. C. Arnett, "Molecular Manipulation Using a Tunneling Microscope," *Nature* 331 (1988): 324–326.

37. D. M. Eigler and E. K. Schweizer, "Positioning Single Atoms with a Scanning Tunneling Microscope," *Nature* 344 (1990): 524–526.

38. Buckminsterfullerines, a.k.a. "buckyballs" or C_{60}, can potentially serve as robust structural or conductive materials, or as containers for individual atoms. Other fullerines called "nanotubes"—discovered by Sumio Iijima—can serve as probes or funnels for atomic positioning. See Hongjie Dai, Nathan Franklin, and Jie Han, "Exploiting the Properties of Carbon Nanotubes for Nanolithography," *Applied Physics Letters* 73 (1998): 1508–1510; Philip Kim and Charles M. Lieber, "Nanotube Nanotweezers," *Science* 286 (1999): 2148–2150. The hypothetical applications of fullerines are extraordinary—but remain to be realized in the future.

39. Anthony P. Davis, "Synthetic Molecular Motors," *Nature* 401 (1999): 120–121; Jonathan Knight, "The Engine of Creation," *New Scientist* 162:2191 (1999): 38–41.

Further evidence that nanotechnology is a real science, rather than a misguided fad, comes from its many signs of protodisciplinarity. The fact that professional scientists are actively working and staking their reputations on it is sociologically significant, and the visible confrontation between various nanotech research programs seeking to shape the field is symptomatic of the efforts of nanotechnology as a whole to attain the status of an acknowledged professional discipline.[40] These agonistic struggles within the technoscape have stabilized a field-specific lexicon as well as institutional structures—marked research funds, industrial conferences, and university programs—supporting nanotech research. Drexler taught an engineering course on nanotechnology at Stanford in 1989, and such curricular inclusion supposedly indicates the belated recognition of an already exciting field, for Drexler writes: "At Stanford, when I taught the first university course on nanotechnology, the room and hallway were packed on the first day, and the last entering student climbed through a window."[41] Pedagogical credibility stems from Drexler's textbook on nanotech engineering and design called *Nanosystems: Molecular Machinery, Manufacturing, and Computation* (1992).[42] A textbook is usually at the trailing end of a scientific discipline rather than the forefront, but Drexler composed this tome, filled with the differential equations, quantum mechanical calculations, and structural diagrams that had been missing from his earlier publications, seemingly with the intent of legitimating an increasingly maligned science. Since 1989, the Foresight Institute has sponsored annual international conferences on nanotechnology, bringing in researchers from all over the world. The first nanotech start-up company, Zyvex, appeared in Richardson, Texas, in 1997, intending to develop nanodevices like Drexler's assembler in less than a decade.[43] Zyvex has been followed by a boom in nanotech interest in Silicon Valley and other regions where industrial speculation and venture capital abundantly flow. There are even scholarly journals, such as *Nanotechnology* and *Nano Notes*, that publish exclusively the cutting-edge research in the field.

40. On confrontations within nanotechnology to capture outside credibility, see David Rotman, "Will the Real Nanotech Please Stand Up?" *Technology Review* 102:2 (1999): 47–53. For an excellent analysis of the social dynamics of scientific discipline formation, see Timothy Lenoir, *Instituting Science: The Cultural Production of Scientific Disciplines* (Stanford: Stanford University Press, 1997).

41. Drexler, *Engines of Creation* (above, n. 6), p. 241.

42. K. Eric Drexler, *Nanosystems: Molecular Machinery, Manufacturing, and Computation* (New York: Wiley, 1992).

43. Zyvex, *www.zyvex.com*.

So it certainly *looks* like a science, and the people promoting the field are really trying hard to show why it is not science fiction. The main argument enforcing this division emerges, again, from the logic of the real versus the simulacrum; specifically, nanowriters insist that their visions of the future are grounded in "real science," while the futures described in science fiction are not. Take, for example, Drexler's comments on science fiction in *Engines of Creation*:

> By now, most readers will have noted that this [nanotechnology] . . . sounds like science fiction. Some may be pleased, some dismayed that future possibilities do in fact have this quality. Some, though, may feel that "sounding like science fiction" is somehow grounds for dismissal. This feeling is common and deserves scrutiny.
>
> Technology and science fiction have long shared a curious relationship. In imagining future technologies, SF writers have been guided partly by science, partly by human longings, and partly by the market demand for bizarre stories. Some of their imaginings later become real, because ideas that seem plausible and interesting in fiction sometimes prove possible and attractive in actuality. What is more, when scientists and engineers foresee a dramatic possibility, such as rocket-powered spaceflight, SF writers commonly grab the idea and popularize it.
>
> Later, when engineering advances bring these possibilities closer to realization, other writers examine the facts and describe the prospects. These descriptions, unless they are quite abstract, then sound like science fiction. Future possibilities will often resemble today's fiction, just as robots, spaceships, and computers resemble yesterday's fiction. How could it be otherwise? Dramatic new technologies sound like science fiction because science fiction authors, despite their frequent fantasies, aren't blind and have a professional interest in the area.
>
> Science fiction authors often fictionalize (that is, counterfeit) the scientific content of their stories to "explain" dramatic technical advances, lump them together with this bogus science, and ignore the lot. This is unfortunate. When engineers project future abilities, they test their ideas, evolving them to fit our best understanding of the laws of nature. The resulting concepts must be distinguished from ideas evolved to fit the demands of paperback fiction. Our lives will depend upon it.[44]

I have quoted this passage at length because of its several remarkable qualities intended to rescue nanotechnology from the ghetto of science fiction. While the first paragraph begins the radical task of reconciling science and science fiction, juxtaposing the languages of "possibility" and "fact," Drexler quickly departs from this goal and

44. Drexler, *Engines of Creation* (above, n. 6), pp. 92–93.

instead firmly separates science, and particularly nanotechnology, from the "fantasies" of fiction. He clarifies the assumed directional flow of reality into fiction: when science fiction is "real" the writer either landed on reality by chance or "grabbed" the idea from science. Drexler thus distinguishes science fiction writers from "other writers" and "engineers" who "examine the facts" (presumably Drexler fits into this category). He employs the idea of the "counterfeit" to describe science fiction—not, of course, citing Baudrillard, but drawing on the same understanding of the counterfeit as similar to but distinct from reality. He divides "our best understanding of the laws of nature" (Drexler's writing) from "the demands of paperback fiction" (science fiction), concluding that, because of the dangerously real consequences made possible by nanotech, our very lives depend on maintaining this division! What further rationale for recognizing the barrier between science and science fiction could one need?

Thus Drexler seemingly secures his work as science, but another tactic deployed by defenders of nanotech is to exclude Drexler and his sympathizers from the technoscape entirely. This strategy acknowledges and foregrounds the intractable science-fictionalisms of Drexler's science and thereby pronounces him a pariah, in effect preserving the rest of nanotech as "real science."[45] For example, Donald Eigler (of the xenon IBM logo) has audaciously declared that "[Drexler] has had no influence on what goes on in nanoscience. Based on what little I've seen, Drexler's ideas are nanofanciful notions that are not very meaningful."[46] Mark Reed, the head of Yale's department of electrical engineering and researcher of nanoelectronics, has said: "There has been no experimental verification for any of Drexler's ideas. We're now starting to do the *real* measurements and demonstrations at that scale to get a *realistic* view of what can be fabricated and how things work. It's time for the *real* nanotech to stand up."[47] The force of this argument comes from the deluge of the "real," which, repeated ad nauseam, appears to drown Drexler and friends and engulf them in the irrationalities of their nanodreams. Again we see the rhetorical establishment of a powerful dichotomy of science versus science fiction, but this time constructed within the technoscape itself.

45. This strategy depends somewhat on a lack of definitional precision in the term "nanotechnology." Many researchers adopt the term for work in nanoelectronics, nanocomposition, or nanolithography that does not necessarily match Drexler's definition of nanotechnology as molecular manufacturing.

46. Eigler quoted in Rotman, "Will the Real Nanotech Please Stand Up?" (above, n. 40), p. 53.

47. Reed quoted in ibid., p. 48 (emphasis added).

A final tactic used by nanorhetoricians, both Drexlerians and Drexler-detractors, is the oft-repeated story about the genesis of nanotech. I will call this foundational narrative the "Feynman origin myth." The story goes (and it is told by nearly everyone researching in this field, posted on their web pages and repeated in their publications) that on December 29, 1959, Richard Feynman delivered a talk entitled "There's Plenty of Room at the Bottom" to the American Physical Society at the California Institute of Technology. Here, he suggested the possibility of engineering on the molecular level, arguing that the "principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done."[48] Feynman further asserted that something like nanotech is "a development which I think cannot be avoided." Quotations and paraphrases of these statements run rampant throughout the discourse network as arsenal in the war to legitimate nanotechnology.[49] Such recourse to Feynman's speech has given rise to the belief that he originated, author-ized, and established nanotechnology. Assertions like "This possibility [of nanotechnology] was first advanced by Richard Feynman in 1959"[50] and "Richard Feynman originated the idea of nanotechnology, or molecular machines, in the early 1960s"[51] are commonplace and have taken on the status of truisms. Feynman's talk is continually invoked to prove that nanotechnology is a real science, but not because of the talk's theoretical, mathematical, or experimental sophistication; indeed, judging from the language used—the frequent appearance of "possibility," "in

48. Richard Feynman, "There's Plenty of Room at the Bottom," in *Miniaturization*, ed. H. D. Gilbert (New York: Reinhold, 1961), pp. 282–296, 295; all further references to Feynman's 1959 talk are to this transcript. The talk was originally published in *Engineering and Science* 23 (February 1960): 22–36; a shorter version was published as "The Wonders That Await a Micro-microscope," *Saturday Review* 43 (1960): 45–47. Also available on the Web at *www.zyvex.com/nanotech/feynman.html*. These several incarnations of Feynman's talk, each with independent legacies of citation, suggest the influence of the speech within the technoscape.

49. A few examples among many: Drexler, "Molecular Engineering" (above, n. 15), p. 5275; Drexler, *Engines of Creation* (above, n. 6), pp. 40–41; Davis, "Synthetic Molecular Motors" (above, n. 39), p. 120; Gimzewski and Joachim, "Nanoscale Science" (above, n. 10), p. 1683; Merkle, "Nanotechnology and Medicine" (above, n. 34), pp. 277–286; Ralph C. Merkle, "Letter to the Editor," *Technology Review* 102:3 (1999): 15–16. See also Regis, *Nano* (above, n. 20), pp. 10–12, 63–94, for a history of this talk and its sociological function.

50. J. Storrs Hall, "An Overview of Nanotechnology," *www.geocities.com/Area51/Shadowlands/6583/project207.html*.

51. "Richard Feynman," *www.photosynthesis.com/RICHARD_F.html*.

principle," "I think," and the telling "it would be, in principle, possible (I think)"—it is clear that the talk was just as speculative as (if not more than) any article penned by Drexler, Merkle, or their associates.

The Feynman origin myth is resurrected over and over again as a cheap way of garnering scientific authority. How better to assure that your science is valid than to have one of the most famous physicists of all time pronouncing on the "possibility" of your field? It is not uncommon for nanorhetoricians, when referencing the talk, to remind their audience that Feynman won the 1965 Nobel Prize in physics. Merkle candidly recognizes that name recognition and cultural capital are the main values of this tactic when he writes: "One of the arguments in favor of nanotechnology is that Richard Feynman, in a remarkable talk given in 1959, said that, 'The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom.'"[52] The argument clearly is not *what* Feynman said, but "is that" *he* said it. The argument hinges on his unique vision, what he "can see," something special about his scientific ability that transforms a speculative statement into a description of reality. A frank example of fetishizing the author and the origin (the Foresight Institute even offers a "Feynman Prize"), Feynman's talk grounds nanotechnology not in the real but in discourse. Nevertheless, the Feynman origin myth is perceived as dissociating nanotechnology from science fiction.

To its credit, nanotech has been fairly successful in the battle to vindicate itself as a real science, as something very different from science fiction despite how much it may seem like science fiction. The anti-SF rhetoric has even made its nanodreams appear more like inevitabilities to a larger audience. From 1992, when Drexler and company unveiled a wonderful nanofuture to the U.S. government and achieved the allocation of special NSF funds for nanoscale research, to the implementation of the 2001 National Nanotechnology Initiative (the foundations for which grew out of Congressional testimonies by Smalley, Merkle, and other key figures in the field), nanorhetoric triumphed in transforming science fiction visions into manifest and lucrative national ventures.[53] Even President Clinton,

52. Ralph C. Merkle, "A Response to *Scientific American*'s News Story *Trends in Nanotechnology*," *www.islandone.org/Foresight/SciAmDebate/SciAmResponse.html*.

53. The nanotechnologists' 1992 testimonies are found in *New Technologies for a Sustainable World: Hearing Before the Subcommittee on Commerce, Science and Transportation, United States Senate, One Hundred Second Congress, Second Session, June 26, 1992* (Washington, D.C.: U.S. Government Printing Office, 1993). The 1999 testimonies are found in *Nanotechnology: The State of Nanoscience and Its Prospects for the Next Decade: Hearing*

announcing the National Nanotechnology Initiative at Caltech on January 21, 2000, demonstrated his absorption of nanorhetoric by citing not only several frequently imagined miracles of the nanofuture, but also the Feynman origin myth. Thus despite many determined critics, nanotech managed to secure its professional future by combining fantastic speculation with concerted attacks on science fiction. Indeed, considering nanotech's rapid expansion in academia and industry, the reputable scientists involved, and its current high profile, there appears little doubt that nanotech is real science.

However, the "sci-fi" anxieties haunting the defenders of nanotechnology disclose its scandalous proximity to science fiction, and, I argue, only rhetoric is maintaining the separation. Furthermore, I will show that this rhetoric thoroughly deconstructs itself in a futile struggle for boundary articulation that has already been lost.

Nanotechnology as Science Fiction, or, Deconstructing the Nanorhetoric

Recall Drexler's arguments regarding science fiction. Drexler must explicitly distinguish his science from paperback fiction because his nanonarratives borrow extensively from preexisting genre conventions. His stories—like those found throughout nanowriting—describe the world transformed by imagined feats of science and engineering relegated to the unspecified future, and even when denying the science-fictionality of his vignettes by emphasizing that they are "scientifically sound," he cannot avoid drawing attention to the fact that they do, after all, "sound like science fiction." Although he confirms the conventional assumption that science is the real, science fiction its imaginary simulacrum, when he says that his science "sounds *like*" fiction, he reverses the assumed order. Science fiction has preceded science, and the ensuing science is not ultimately delineated from science fiction by Drexler's arguments.

Though Drexler distinguishes science fiction writing from his kind of writing through the criterion of mimesis, science fiction writers who "grab the idea [from science] and popularize it" are not logically different from writers who "examine the facts" of science and popularize them, as *Engines of Creation* is intended to do. Along the same lines, the criterion that Drexler's stories are scientifically sound while science fiction stories are (presumably) not is chal-

Before the Subcommittee on Science, House of Representatives, One Hundred Sixth Congress, First Session, June 22, 1999 (Washington, D.C.: U.S. Government Printing Office, 2000). Federal documentation for the National Nanotechnology Initiative is compiled by the National Science and Technology Council in *National Nanotechnology Initiative: Leading the Next Industrial Revolution* (Washington, D.C.: Office of Science and Technology Policy, 2000).

lenged when he acknowledges that science fiction "imaginings" frequently "become real" (again reversing the assumed order). Science and science fiction dynamically and frequently shift structural positions in Drexler's writing, both suggested to be inhabited by "the real" at the same time as each paradoxically appears to simulate the other. That is to say, the real has become simulation and the simulation has become real.

None of these inconsistencies means that Drexler is not writing good science; they do mean that the boundary between science fiction writers and writers of what Drexler calls "theoretical applied science," like himself, is hopelessly blurred. Tellingly, Drexler has personally forayed into the production of genre science fiction texts, writing an introduction to the short story collection *Nanodreams* (1995), where he discusses the importance of science fiction in assessing future technologies.[54] The final failure of the dichotomy between science and science fiction occurs when Drexler, having apparently given up the endeavor, calls the scenarios described in *Engines of Creation* "science fiction dreams."[55]

Thus the division between writers of science fiction and writers of "theoretical applied science" or "exploratory engineering" is destabilized and confused. "Scientifically sound," according to Drexler, can be a quality of both kinds of writing—destroying the criterion, erasing the division. Ultimately, Drexler's nanowriting indicates that science fiction precedes and supersedes "its" science, echoing Baudrillard's "precession of simulacra": the simulacra coming before, displacing, and supplanting, making the real seem to be the not-real, the scientific to be the science-fictional.[56]

Determining that Drexler's version of nanotechnology is inseparable from its science-fictionalisms would apparently make the nanotactic of excluding him from the field more effective. After all, if his writing is indeed science-fictional, then he is not, according to Reed, part of "the real nanotech." However, attempts to banish Drexler from the field he established actually have the ironic effect of highlighting the science-fictionality of nanotech. When Eigler states that Drexler "has had no influence on what goes on in nanoscience," he

54. Elton Elliott, ed., *Nanodreams* (New York: Baen Books, 1995). Drexler's argument is similar to that of Arthur C. Clarke's *Profiles of the Future: An Inquiry into the Limits of the Possible* (New York: Harper and Row, 1958). Frequently cited in Drexler's publications, Clarke's text aggressively foregrounds the science-fictional foundations of scientific extrapolation.

55. Drexler, *Engines of Creation* (above, n. 6), pp. 234–235.

56. Baudrillard, "Precession of Simulacra" (above, n. 24), pp. 1–42.

is disregarding Drexler's seminal technical publications and the considerable contributions of his Foresight Institute; furthermore, Eigler is in flat contradiction to the vast expanses of the technoscape recognizing Drexler's inspiring influence[57]—including Smalley, who says that Drexler "has had tremendous effect on the field through his books."[58] When Reed says that Drexler's ideas have not been experimentally verified and therefore are not part of the "real" nanotech, he is disregarding the validity of all theoretical science—clearly a problematic move. Consequently, Drexler cannot be so simply exiled: he has persuaded not only individual nanoscientists but also governmental funding boards about the inevitable nanofuture,[59] and accordingly, nanotechnology should acknowledge the heavy speculation that remains fundamental for its own development as a research field. After all, having proclaimed that Drexler is "science-fictional" and "not real," yet ultimately obliged to recognize his influence, this tactic to expel science fiction from science backfires on itself.

Even Merkle's *response* to these exclusionary efforts eventually backfires. In a letter to the editor of *Technology Review*, he writes:

> While I am happy to see the increasing interest in nanotechnology, I was disappointed by your special report on this important subject. Mark Reed summarized one common thread of the articles when he said "There has been no experimental verification for any of (Eric) Drexler's ideas." Presumably this includes the proposal to use self-replication to reduce manufacturing costs. The fact that the planet is covered by self-replicating systems is at odds with Reed's claim.
>
> Self-replicating programmable molecular manufacturing systems, a.k.a. assemblers, are not living systems. This difference lets Reed argue that they have never before been built and their feasibility has not been experimentally verified. Of course, this statement applies to anything we have not built. Reed has discovered the universal criticism. Proposals for a lunar landing in 1960? Heavier-than-air flight before the Wright brothers? Babbage's proposal to build a computer before 1850? No experimental verification. Case closed.[60]

57. Not the least of which are the technology companies founded in the 1990s to pursue some aspect of Drexler's vision, such as Zyvex, Nanogen, Molecular Manufacturing Enterprises, NanoTechnology Development Corporation, and NanoLogic.

58. Smalley quoted in David Voss, "Moses of the Nanoworld," *Technology Review* 102:2 (1999): 62. Smalley nevertheless states that Drexlerian self-replicating assemblers are "not possible," and believes that nanotech will develop along different lines: see Richard Smalley, "Of Chemistry, Love, and Nanobots," *Scientific American* 285:3 (2001): 76–77.

59. See Regis, *Nano* (above, n. 20), pp. 3–18.

60. Merkle, "Letter to the Editor" (above, n. 49), p. 15.

Merkle musters a "fact" (i.e., that self-replicating systems abound in nature) in support of Drexler and builds an argument for the validity of scientific speculation, successfully countering Reed's implication that Drexler's science is not "real." Drexler is salvaged, put back on the secure ground of reality. But while accomplishing Drexler's reassimilation into the field, Merkle also equates nanotechnology with science fiction. He suggests that nanotechnology is a real science, even though it lacks experimental verification, because proposals for a lunar landing in 1960, considerations of heavier-than-air flight before the Wright brothers, and Babbage's idea for a computer had no experimental verification, and yet these ideas eventually found verification after time. "Case closed," he writes. But, of course, speculations for a moon voyage, for heavier-than-air flight, and for computers of various sorts had existed long before their "real" incarnations—think of the stories of Jules Verne, H. G. Wells, Hugo Gernsbeck, Isaac Asimov, Robert Heinlein, Arthur C. Clarke, and countless others—all of which were and still are clearly marked as science fiction. Thus in recuperating the speculations of nanowriting, Merkle solidifies the relay between nanotechnology and science fiction. Before moon voyages, air flight, and computers there was science fiction; before nanotechnology (future) there is nanotechnology (now). Nanotechnology is science fiction. Case closed?

This dissolving boundary between science and science fiction in nanowriting elsewhere occurs as intertextuality, in the sense that loci of meaning within nanowritings are frequently dependent upon a larger web of texts, in both science and science fiction, that enable their signification. In this respect, nanowritings are what Jonathan Culler describes as "intertextual constructs" that "can be read only in relation to other texts, and [they are] made possible by the codes which animate the discursive spaces of a culture."[61] For example, the concept of the "Diamond Age"—describing how the nanotechnology era will be historicized relative to the Stone Age, the Bronze Age, the Silicon Age, etc.,—appears in science fiction, particularly Neal Stephenson's nanotech novel, *The Diamond Age* (1995), and also in Merkle's *Technology Review* survey article, "It's a Small, Small, Small, Small World" (1997).[62] Each text, science and science fiction, assumes reader familiarity with the terminology deployed by the other.

61. Jonathan Culler, *The Pursuit of Signs: Semiotics, Literature, Deconstruction* (London: Routledge and Kegan Paul, 1981), p. 38.

62. Neal Stephenson, *The Diamond Age* (New York: Bantam Books, 1995); Merkle, "It's a Small . . . World" (above, n. 33), pp. 27, 29–31.

Stephenson's novel, furthermore, describes a "Merkle Hall" located within the nanotech corporation, Design Works, whose ceiling, reminiscent of Michelangelo's Sistine Chapel, is covered with a fresco depicting the pantheon of nanotech, wherein Feynman, Merkle, and Drexler mingle with more fictional personalities.[63] Fact and fiction merge in the blender of nanowriting where allusions are creatively drawn from both technical reports and popular novels.

The issue of science-fictional allusion arises even more strikingly in J. Storrs Hall's theoretical elaboration of a nanotech "utility fog"—an engineered, pervasive substance for complete environmental control and universal human-machine interface.[64] Hall's essay in exploratory engineering, diffusely impregnated with science fiction tropes, is structured around witty references to many canonical science fiction texts, including *Forbidden Planet* (1956), Robert Heinlein's "The Roads Must Roll" (1940), Jules Verne's *From the Earth to the Moon* (1865), H. G. Wells's *The Shape of Things to Come* (1933), and Karl Capek's *R.U.R. (Rossum's Universal Robots)* (1920), to mention just a handful. Within nanowriting, the facile permeability of these worlds of science and fiction, the ease with which concepts and signs traffic between them, challenges any stringent boundrification. The tactics of separating nanotech from the science fiction with which it is complicit fail on every level.

As a final bit of evidence, let's return to the Feynman origin myth. Despite nanorhetoricians' frequent citations of the talk to support the realness of their discipline, the talk itself sits awkwardly with such a purpose. We have seen the indeterminacy and speculative nature of the language Feynman uses, and strikingly, the talk is composed as a series of science fiction stories, just like Drexler's *Engines of Creation*. Feynman tells stories about tiny writing, tiny computers, the actual visualization of an atom, human surgery accomplished by "swallow[ing] the surgeon," and "completely automatic factories"—certainly not impossibilities, but still the conceits of numerous genre science fiction narratives long before Feynman stepped up to the podium. Thoroughly penetrated by the science-fictional imaginary, it is no coincidence that Feynman's nanotech looks just like Drexler's nanotech, fabricated from the same "science fiction dreams."

The Feynman origin myth thus contains in itself the deconstruction of the nanotech/science fiction dichotomy. The ease with which the myth is used by both Drexlerians and those who challenge Drexler's vision of nanotech is a further indication of its deconstruc-

63. Stephenson, *Diamond Age*, pp. 41–42.

64. Hall, "Utility Fog" (above, n. 34), pp. 161–184.

tive ability. Consider, for example, the response of Thomas N. Thetis (IBM Research Division) to the *Technology Review* article where Reed implies that Drexler's nanotech is not real: "Your writers clearly distinguished hype from hard science and vision from reality. I was reminded of Richard Feynman's famous 1959 after-dinner talk. . . . Feynman managed to foreshadow decades of advances. . . . I know that his vision influenced at least a few of the individuals who have made these [hard science] things happen."[65] That Thetis can speak of "vision" opposed to "reality" in one sentence and of Feynman's "vision" that *contributed* to hard (i.e., real) science in another reveals the ease of appropriating such a myth for one's own purposes, the impossibility of simply excluding Drexler's "vision" from the field, and the blurring of science and science fiction within the Feynman talk. After all, if vision is opposed to reality, then Feynman's talk abandoned reality entirely.

Even as a genesis story, the Feynman myth succeeds only in making a science fiction of nanotechnology. Nanotechnology is supposedly a real science *because* it was founded and authorized by the great Richard Feynman. But this origin is not an origin, and its displacement unravels the structure of its legacy. The Feynman myth would work only if it clearly had no precedents, if it was truly an "original" event in intellectual history, if Feynman had offered a unique, programmatic conception of how nanotechnology was to be accomplished. Yet this is not the case: Feynman merely depicted a speculative vision of a possible technology, and science fiction writers, as they have done with so many things, had already beaten him there. Technologies and concepts that are identifiably similar to current visions of nanotechnology appear in Theodore Sturgeon's "Microcosmic God" (1941), Robert Heinlein's "Waldo" (1942), Eric Frank Russell's "Hobbyist" (1947), James Blish's "Surface Tension" (1952), and Philip K. Dick's "Autofac" (1954)—all well before Feynman gave his now-mythical talk.

Although there is no evidence that Feynman personally read any of these science fiction stories, his friend Albert R. Hibbs (senior staff scientist at the Jet Propulsion Laboratory) did read "Waldo" and described it to him in the period just before Feynman composed his talk.[66] And indeed, Heinlein's influence haunts Feynman's depiction of nanotechnology. In Heinlein's novella, the eponymous genius, Waldo, has invented devices—known as "waldoes"—which are mechanical hands of varying sizes, slaved to a set of master hands

65. Thomas N. Thetis, "Letter to the Editor," *Technology Review* 102:2 (1999): 15.

66. See Regis, *Nano* (above, n. 20), pp. 152–154.

attached to a human operator. Heinlein writes that the "secondary waldoes, whose actions could be controlled by Waldo himself by means of his primaries," are used to make smaller and smaller copies of themselves ("[Waldo] used the tiny waldoes to create tinier ones"), ultimately permitting Waldo to directly manipulate microscopic materials by means of his own human hands.[67] Heinlein thus hypothesizes a method for molecular engineering that Feynman in his talk, without crediting his source, offers as a means to "arrange the atoms one by one the way we want them." Feynman describes his proposed system:

> [It would be based on] a set of master and slave hands, so that by operating a set of levers here, you control the "hands" there. . . . I want to build . . . a master-slave system which operates electrically. But I want the slaves to be made especially carefully by modern large-scale machinists so that they are one-fourth the scale of the "hands" that you ordinarily maneuver. So you have a scheme by which you can do things at one-quarter scale anyway—the little servo motors with little hands play with little nuts and bolts; they drill little holes; they are four times smaller. Aha! So I manufacture [with these hands] . . . still another set of hands again relatively one-quarter size! . . . Thus I can now manipulate the one-sixteenth size hands. Well, you get the principle from there on.[68]

The originality of the Feynman myth crumbles, for we can see that his talk emerges from genre science fiction. His method of molecular manipulation is borrowed from Heinlein. Even the proposition for internal nanoscopic surgery—a notion that Feynman credits to Al Hibbs—was already proclaimed as an "original" idea by Heinlein in the "Waldo" novella, where he writes that microscopic surgery via microscopic machines "had never been seen before, but Waldo gave that aspect little thought; no one had told him that such surgery was unheard-of."[69] The mythologized order of precedence is therefore reversed, for it becomes evident that speculations of nanotech were freely circulating in the discourse of science fiction long before science "grabbed the idea." If we really want to locate an origin to nanotechnology, it is not to Feynman that we must look, but to science fiction.

Consequently, I reiterate that in the case of nanotech we have a situation where simulation has preceded and enveloped "real" science, where the line between science and science fiction is blurred,

67. Robert A. Heinlein, "Waldo" (1942), in idem, *Waldo & Magic, Inc.* (New York: Dell Rey, Ballantine Books, 1986), pp. 29, 133.

68. Feyman, "There's Plenty of Room" (above, n. 48), p. 292.

69. Heinlein, "Waldo" (above, n. 67), p. 133.

made porous, and effaced. It even seems likely that hybridity has been responsible for nanotech's recent financial success; companies have been founded and government officials have been awed less by nanotech's real accomplishments—for there are few—but rather by its dream of the future, its promise of a world reborn: its science fiction indistinguishable from its science. Rapidly becoming a major actor in the science-fictionizing of technoculture—along with certain other interstitial sciences and technologies, such as virtual reality, cybernetics, cloning, exobiology, artificial intelligence, and artificial life—nanotechnology exerts strong symbolic influence over the way we conceptualize the world and ourselves. In other words, as a science (fiction) with enormous cultural resources and increasing historical significance, nanotechnology claims for itself a powerful role in the human future and the future of the human.

Posthuman Engineering

The birth of nanotechnology as a scientific discipline provokes the hyperreal collapse of humanistic discourse, puncturing the fragile membrane between real and simulation, science and science fiction, organism and machine, and heralding metamorphic futures and cyborganic discontinuities. In both its speculative-theoretical and applied-engineering modes, nanotechnology unbuilds those constructions of human thought, as well as those forms of human embodiment, based on the security of presence and stability—terrorizing presentist humanism from the vantage point of an already inevitable future. As Jacques Derrida has repeatedly suggested, the deconstruction of metaphysical structures allows us to "pass beyond man and humanism, the name of man being the name of that being who, throughout the history of metaphysics or of ontotheology—in other words, throughout his entire history—has dreamed of full presence, the reassuring foundation, the origin and the end of play."[70] Critiquing humanism from within while simultaneously stepping radically outside the domain defined by humanism opens a subject position other than that implanted between essence and eschatology—which is the position of the human, for the "name of man has always been inscribed in metaphysics between these two ends."[71] With a similar agenda, Michel Foucault has argued for the historic boundaries of humanism, depicting an epistemic closure

70. Jacques Derrida, "Structure, Sign, and Play in the Discourse of the Human Sciences," in idem, *Writing and Difference*, trans. Alan Bass (Chicago: University of Chicago Press, 1978), p. 292.

71. Jacques Derrida, "The Ends of Man," in idem, *Margins of Philosophy*, trans. Alan Bass (Chicago: University of Chicago Press, 1982), p. 123.

marking the end of man as an entity: "As the archaeology of our thought easily shows, man is an invention of recent date. And one perhaps nearing its end."[72] The intellectual breakdown of humanism is advanced through the collision between human flesh and postmodern technologies, where the relational interface mediates the emergence of new posthuman haptic spaces—machinic, virtual, material, and meaty—as Paul Virilio, Brian Massumi, N. Katherine Hayles, and the contributors to this volume have suggested.[73] I argue that nanotechnology participates in the techno-de(con)struction of humanism, forcing us to think otherwise through its ambiguous hyperreal status and its narratives of corporeal reconfiguration from beyond the temporal horizon, fabricating new fields of embodiment and facilitating our becoming posthuman by envisioning a future where the world and the body have been made into the stuff of science fiction dreams.

Kelly Hurley has written that posthuman narratives of "bodily ambiguation" and "speculations on alternate logics of identity that rupture and exceed the ones we know" restructure our somatic experiences, for these posthuman narratives work to "disallow human specificity on every level, to evacuate the 'human subject' in terms of bodily, species, sexual, and psychological identity," supporting the "generation of posthuman embodiments both horrific and sublime."[74] Nanotechnology produces such narratives of bodily ambiguation and articulates an alternative logic of identity—a subversive technoscientific gaze that I will term "nanologic"—in the stories of nanofutures circulating within the technoscape and beyond. (Indeed, nanoscientists seem to align with Hurley on the immediate tangible impact of posthuman narratives in their suspicion that the world has already been remade by nanotech, that nanowriting's extrapolation of

72. Michel Foucault, *The Order of Things: An Archaeology of the Human Sciences* (New York: Vintage Books, 1973), p. 387. It is worth noting that Derrida, "without naming names," critiques Foucault's claim for the end of man as a reinscription of humanist eschatology. Although ultimately affirming the necessity of Foucault's move outside the boundaries of humanism, Derrida suggests that this strategy must be accompanied by deconstruction from within in order to become other than another sedimented humanism (see Derrida, "Ends of Man," pp. 114–123, 134–136).

73. See Paul Virilio, *The Art of the Motor*, trans. Julie Rose (Minneapolis: University of Minnesota Press, 1995); Brian Massumi, *Parables for the Virtual: Movement, Affect, Sensation* (Durham, N.C.: Duke University Press, 2002); Hayles, *How We Became Posthuman* (above, n. 32), and the other articles in this volume.

74. Kelly Hurley, "Reading Like an Alien: Posthuman Identity in Ridley Scott's *Alien* and David Cronenberg's *Rabid*," in *Posthuman Bodies*, ed. Judith Halberstam and Ira Livingston (Bloomington: Indiana University Press, 1995), pp. 205, 220, 220, 205.

possible posthuman futures necessitates the "foresight" that Drexler and others have been advocating since their earliest publications.)[75]

Whether utopian visions or catastrophic nightmares, nanonarratives resist traditional humanist interpretations by repeatedly depicting the future in terms that disequilibrate the human body. From the eroticized collective consciousness of the Drummers in Stephenson's *The Diamond Age* (1995), to the lycanthropic transformations of Dean Koontz's *Midnight* (1989), to the permeability of "enlivened" city-structures and body-structures in Kathleen Ann Goonan's *Queen City Jazz* (1994), to the metamorphosis of the entire human population into billowing sheets of sentient brown sludge in Greg Bear's *Blood Music* (1985), posthuman bodies in nanonarratives are never stable, never idealized, never normative, never confined; the limits of posthuman corporeality are as wide as the nanological imagination. Nanologic disrupts the boundaries and the configurations of the human body, rebuilding the body without commitment to the forms given by nature or culture; and thus nanotechnology, as both a contemporary discourse and a future material science, is an instrument of posthuman engineering.

Rather than purveying a posthumanism in which the subject is in danger of losing the body—an imagined fate that Hayles has extensively critiqued[76]—nanonarratives articulate posthuman subjectivities resulting from embodied transformations. Embodiment is fundamental to nanonarratives because, in the science of nanotechnology, *matter* profoundly *matters*. Nanotech respects no unitary construct above the atom and reduces everything to pure materiality, demolishing metaphysical categories of identity. Accordingly, nanologic does not support any sort of abstracted, theoretical construction of the body because nanotech unbounds the body, puts its surfaces and interiors into constant flux. The posthuman bodies conditioned by nanologic are therefore always individuated experiences of embodiment in an endless array of possible bodily conformations, where all borders are fair game.

75. This alignment is strengthened by the commitment of several nanoscientists to the ideology of extropianism, which maintains that human life is evolving through the mediation of technosciences and the active pursuit of science fiction scenarios. Max More, president of the Extropy Institute, writes that extropians "advocate using science to accelerate our move from human to a transhuman or posthuman condition," and that nanotechnology is a significant vehicle in bringing about the posthuman future (Max More, "The Extropian Principles 3.0," *www.extropy.com/ideas/principles.html*). Merkle and Drexler have lectured at several extropian conferences, and Hall is nanotechnology editor of *Extropy: The Journal of Transhumanist Solutions*.

76. Hayles, *How We Became Posthuman* (above, n. 32), esp. pp. 1–24.

Nanologic is a cyborg logic, imploding the separation between the biological and the technological, the body and the machine. As we have seen, one of the arguments legitimating nanotechnology is that biological machines like ribosomes and enzymes and cells are real, and consequently there is nothing impossible about engineering such nanomachines. But the very ease in describing biological objects as machines indicates the cyborgism of nanotech, its logic of prosthesis, its construction of bodies and machines as mutually constitutive. Nanotechnology envisions the components of the body and mechanical objects as indistinguishable and, subsequently, utilizes the biological machine *as the model* for the nanomachine, achieving a terminal circularity. Nanologic removes all intellectual boundaries between organism and technology—as Drexler puts it, nanologic causes "the distinction between hardware and life . . . to blur"[77]—and human bodies become posthuman cyborgs, inextricably entwined, interpenetrant, and merged with the mechanical nanodevices *already inside them*.

Having become cyborganic machines, bodies in the grasp of nanologic can be reassembled or reproduced with engineering specificity. Unlike genomic cloning, which provides genotypic but not necessarily phenotypic identity, the copying fidelity of nanotechnology is so exact that copies would have precise identity down to the atomic level. Feynman (following Heinlein) foresaw this in his talk: "all of our devices can be mass produced so that they are absolutely perfect copies of one another."[78] The ability of nanodevices to produce exact copies—copies of themselves, copies of their constructions—is fundamental to nanologic, and it is not, perhaps, entirely a coincidence that for more than a decade Merkle directed the groundbreaking Computational Nanotechnology Project for Xerox.[79] The potential for nanotechnology to reproduce anything exactly, accurate in every atomic detail, or to reconstruct anything into an identical copy of anything else, leads to posthuman nanonarratives that, undermining our conceptions of identity and origin(ality), need not become literalized to have transformed the architectures of our somatic experience. As Hurley suggests, posthuman narratives ask us "to imagine otherwise, outside the parameters of

77. Drexler, *Engines of Creation* (above, n. 6), p. 38.

78. Feyman, "There's Plenty of Room" (above, n. 48), p. 295.

79. Merkle, who left Xerox in 1999 to become principal fellow of Zyvex, jokes about copy culture's impact on nanotech in Ralph C. Merkle, "Design-Ahead for Nanotechnology," in Krummenacker and Lewis, *Prospects in Nanotechnology* (above, n. 12), pp. 23–52, p. 35.

'the human,'" thereby opening up new possibilities of corporeality that change the way we conceive ourselves.[80] Such possibilities are illustrated by the following series of nanoscenarios:

- A wooden chair, subjected to a herd of nanobots, can be transformed into a table, its "chairness" subtly and efficiently morphed into "tableness." Nanologic undermines essentialism, insisting that every thing is simply a temporary arrangement of atoms that can be endlessly restructured.
- A wooden chair can be transformed into a living fish. There is no magic here, merely a precise rearrangement of molecules. Life instantly arises from dead material; as Drexler writes, nanologic reveals that "nature draws no line between living and nonliving."[81]
- A wooden chair can be transformed into a human (i.e., Homo sapiens). The same process for the fish now challenges humanist metaphysics a little more forcefully. The resulting human could even be a specific person like Sigourney Weaver (posthuman icon from the *Alien* films), identical to the movie star in every respect: DNA, proteins, phospholipids, neurotransmitters, memories.
- A fish can be transformed into a human. The fish does not die, does not stop being, it merely becomes human.
- A human, subjected to a herd of nanobots carrying the data set for another human, can suddenly become someone else. Human *A* and Human *B* share the same matter, the same coordinates in space-time; although they have different identities, although they are different people, they are the same being.
- A woman can be metamorphosed into a man, or vice versa, or in various partial combinations. Mono-, inter-, and transsexuality can be manifested in a single figure. Tissues, hormones, and chromosomes can be refabricated. The posthuman body is thus queered: sex and sexuality made infinitely malleable, sexual difference slipping into sexual indeterminacy, or deferral.
- A human body can become the copy of an already existing human body. Say, for example, Harrison Ford (posthuman icon from *Blade Runner*) transforms into Sigourney Weaver. Then there are two Sigourneys, identical down to the memories, even down to the belief that each is Sigourney Weaver and the other is the copy. There is no possible way of telling them

80. Hurley, "Reading Like an Alien" (above, n. 74), p. 205.

81. Drexler, *Engines of Creation*, p. 103.

apart, no possible way of telling which was the "original." Someone might ask, "Will the real Sigourney please stand up," but inevitably they both will. More disturbing than the replicants in *Blade Runner*, which merely mimic, these nanocopies actually *are*. Nanologic again destroys the difference between real and simulacrum.

- Nanotechnology can devise a matter-transporter to facilitate human travel across great distances of space.[82] At one end, nanobots dismantle the human traveler atom by atom, recording the location of each molecule, until the traveler is just a pile of disorganized material. The nanomachines feed data into a computer system, which instructs another group of nanobots at the terminal end of the transporter, working from a feed of appropriate elements, to reassemble the human traveler exactly as she or he had been at the proximal end. The traveler will have no memory of the trip but will emerge precisely as she or he was when the process began; though made from different atoms, the traveler is still the same person. Embodiment has been distributed across a spatial divide and between separate accumulations of matter. Furthermore, the data can be reused to construct multiple, identical copies of the traveler. Personhood can be duplicated, flesh xeroxed, minds mimeographed.
- Human bodies can be modified well beyond the confines of experience, becoming alien formations or improbable mélanges. Nanotechnology empowers posthuman imaginations to achieve outlandish physical alterations. (How many tentacles would you like to have?)
- Finally, nanologic enables us to think beyond human boundaries in a tragic sense, for nanotechnology can also bring about a post-human future where all of humanity has ceased to exist and nothing new emerges from the wreckage. This fate is made possible by insidious nanoweapons of mass destruction, or the nanocalyptic hypothesis of out-of-control nanobots turning the entire biosphere into "grey goo."[83] While providing a

82. The fantasy of "telegraphing a human" appears frequently within posthuman science (fiction): for example, Norbert Weiner, *The Human Use of Human Beings: Cybernetics and Society* (Boston: Houghton Mifflin, 1954), pp. 95–104; Hans Moravec, *Mind Children: The Future of Robot and Human Intelligence* (Cambridge, Mass.: Harvard University Press, 1988), pp. 116–122.

83. The "grey goo" hypothesis imagines the entire organic world dismantled into disorganized material: Drexler, *Engines of Creation*, pp. 172–173; Regis, *Nano* (above, n. 20), pp. 121–124. This horrifying possibility has so disturbed Bill Joy, cofounder and chief scientist of Sun Microsystems (and certainly no technophobe), that he questions

means to engineer new posthuman embodiment, nanotech also provides a means to engineer posthuman extinction.

As these scenarios suggest, nanotechnology has unprecedented effects on the way we are able to conceptualize our bodies, our biologies, our subjectivities, our technologies, and the world we share with other organisms. Whether positing the liberation of human potential or the total annihilation of organic life on this planet, nanologic demands that we think outside the realms of the human and humanism. Nanologic makes our bodies cyborg and redefines our material experiences, redraws our conceptual borders, and reimagines our future. Accordingly, even before the full potential of a working nanotechnology has been realized, we have already become posthuman. Indeed, posthuman subjects abound in the nanoliterature, and although science fiction novels like Ian McDonald's *Necroville* (1994), James L. Halperin's *The First Immortal* (1998), or Michael Flynn's *The Nanotech Chronicles* (1991) imagine posthuman nano-modified bodies as appearing at some ambiguous point in the future, other "nonfictional" posthuman beings exist already, right now, within the popular and professional writings of nanoscientists. As real, embodied, material entities, enmeshed in the semiotics of nanologic, these posthumans are found at nanotechnology's intersection with cryonics.

Drexler, Merkle, and other nanoscientists are deeply involved in the idea of freezing and preserving human bodies, or parts of human bodies, until the proper nanotechnology has been developed in the future that can revive and heal them. Freeze the body now and eventually nanotechnology will resurrect the subject, reversing not only the cellular damage caused by the freezing process, but also the damage that had originally caused the person to die, maybe even building an entirely new body for the cryonaut. Cryonic science is not simply tangentially related to nanotechnology, but has become a principal extension of nanologic—evidenced by the ubiquitous discussions of cryonics at all levels of nanodiscourse, from fanzines to university conferences.[84] Furthermore, Merkle is a director of the Alcor Life Extension Foundation, a cryonics institute based in River-

the wisdom of pursuing nanoresearch, suggesting that the future would perhaps be a better place if we did not follow our nanodreams: see Bill Joy, "Why the Future Doesn't Need Us," *Wired* 8:4 (2000): 238–263.

84. For a sustained discussion of nanotechnology's significance for and commitment to cryonics, see Wesley M. Du Charme, *Becoming Immortal: Nanotechnology, You, and the Demise of Death* (Evergreen, Colo.: Blue Creek Ventures, 1995). In Du Charme's account—typical of nanowriting—"you" are already a posthuman subject of the future.

side, California, and also hosts a cryonics web page; Drexler is on the scientific advisory board of the Alcor Foundation and has written extensively about cryonics in his books and scientific journal articles.[85]

Even in Drexler's first nanotech publication, cryonic resuscitation is evoked when he writes that the "eventual development of the ability [of nanotechnology] to repair freezing damage [to cells] (and to circumvent cold damage during thawing) has consequences for the preservation of biological materials today, provided a sufficiently long-range perspective is taken."[86] Drexler thus implies that projected technologies of the future determine how we should deal with human tissues and human bodies in the present. Again nanowriting uses the language of the "already inevitable" and assumes that the full potential of nanotech has essentially been realized, temporal distance notwithstanding. Consequently, as deployed within the discourse of nanotechnology, the fact that cryonic techniques are currently in use means that nano-modified bodies are among us even now. Those who are dead but cryonically frozen have been encoded by nanologic as already revived, as already outside the humanistic dichotomy of dead/alive, as already voyagers into a brave new world of nanotech splendor . . . as already posthuman.

This nanological encoding of the cryonaut is evident when Drexler writes of cryonic resurrection in the science-fictional present tense, collapsing present and future, medical reality and technological fantasy, human death and posthuman revivification, into a single syntagmatic episode of *Engines of Creation*. Drexler tells of a hypothetical contemporary patient who

> has expired because of a heart attack. . . . [T]he patient is soon placed in biostasis to prevent irreversible dissolution. . . . Years pass. . . . [During this time, physicians learn to] use cell repair technology to resuscitate patients in biostasis. . . . Cell repair machines are pumped through the blood vessels [of the pa-

85. The Alcor Foundation, founded in 1972, promotes public awareness of cryonic possibilities and assists its members in arranging for cryonic suspension after their deaths. Alcor cites fully functional nanotechnology as the fundamental scientific development still needed in order to repair and resurrect suspended patients. See the Alcor Life Extension Foundation, *www.alcor.org*. The Extropy Institute, in which many nanoscientists are involved (see n. 75, above), traces its historical origins to the Alcor Foundation, signaling the deeply complicit nature of posthuman discourse and cryo-nanotechnology. For more on the interlinkage of cryonics, nanotechnology, and posthuman immortality, see Ed Regis, *Great Mambo Chicken and the Transhuman Condition: Science Slightly over the Edge* (New York: Addison-Wesley, 1990), pp. 1–9, 76–143. See also Merkle's cryonics web site, *www.merkle.com/cryo.html*.

86. Drexler, "Molecular Engineering" (above, n. 15), p. 5278.

> tient] and enter the cells. Repairs commence. . . . At last, the sleeper wakes refreshed to the light of a new day—and to the sight of old friends.[87]

By way of alluding to H. G. Wells's *When the Sleeper Wakes* (1899), a canonic science-fictional depiction of sleeping into the future, Drexler validates and necessitates present-day acts of cryonic freezing within his prophecy of the coming nanoera. While indicative of nanowriting's dependence on the conventions of genre science fiction, this passage more significantly indicates how nanowriting's implosion of science into science fiction transmutes formerly human subjects into posthuman entities, amalgams of discourse and corporeality, biology and technology. For Drexler's cryonaut becomes posthuman at the moment of being incorporated into nanonarrative, thereby surviving its human death and becoming reborn through its cyborg interpenetration with nanomachines. And though the cryonaut in this story is hypothetical, other more specific cryonauts are made posthuman through the same mangle of nanologic.

Take, for example, Walt Disney—perhaps the world's most famous cryonically preserved character. In a wonderful semiotic tangle, the discourses of nanotechnology, cryonics, hyperreality, and posthumanism all converge under the sign of Disney. Baudrillard has frequently written on the viral expansion of Disneyism, the "disnifying" of postmodern culture, the hyperreality of which Walt's own cryonic suspension is a telling symptom.[88] Bukatman expands on Baudrillard's depiction of the pervasive hyperreality of Disneyism, arguing that the "hypercinematic" architectures of Disneyesque spaces literally incorporate human bodies into their cybernetic systems, begetting cyborg terminal identities.[89] The Disney posthuman factory described by Baudrillard and Bukatman is dramatically improved by the advent of nanotechnology, for nanoscientist and aerospace engineer Tom McKendree suggests that the "simulations" at Disneyland and other heightened realities will become even more of "a total experience" through nanotech's ability to "make the fantasies real."[90] Disneyism, already complicit with the reproduction of

87. Drexler, *Engines of Creation*, pp. 136–138.

88. Jean Baudrillard, *Écran Total* (Paris: Éditions Galilée, 1997), pp. 169–173; Baudrillard, "Precession of Simulacra" (above, n. 24), pp. 12–14.

89. See Bukatman, *Terminal Identity* (above, n. 31), pp. 227–229; Scott Bukatman, "There's Always Tomorrowland: Disney and the Hypercinematic Experience," *October* 57 (1991): 55–78.

90. Tom McKendree, "Nanotech Hobbies," in Crandall, *Nanotechnology* (above, n. 14), p. 143.

hyperreality and posthumanity, is simply attenuated by the imagineering capabilities of nanotechnology—so it is no mere coincidence that Disney "the man" becomes manifested at the point where nanologic merges with cryonics.

Consider Merkle's "It's a Small, Small, Small, Small World" essay: the title refers to the small world of atoms and assemblers purveyed by nanotechnology and, simultaneously, to the "It's a Small World" ride at Disneyland and Disneyworld whose infectious song ("It's a small world, after all! It's a small, small world!") metonymically stands for the Disneyscape as a whole. Disneyism is thus imported into nanowriting as metaphor for the nanoworld itself, and appropriately so—for not only does this figural resonance reveal the embeddedness of nanologic in the plane of hyperreality, where science and science fiction are one and the same, but furthermore, Walt's crystallized body is thereby absorbed into the Tomorrowland-like nanofuture that enables its return from the dead. Merkle details the coming "Diamond Age" of nanotechnology where the "ability to build molecule by molecule could also give us surgical instruments of such precision that they could operate on the cells and even the molecules from which we are made,"[91] and, as many nanowriters have explained, such surgical precision will surely bring about cryonic resurrection.[92] Although Disney is presently on ice, waiting to be reborn through the advances of nanotechnology, within nanowriting—where a "small world" of quotidian miracles is deemed already accomplished, where "nanotechnology will inevitably appear regardless of what we do or don't do"[93]—Disney the sleeper already wakes. The future is now, and through the textual machinations of nanowriting that enable preserved human bodies to surmount their own deaths, Walt Disney himself has been transmuted into a posthuman creature of flesh, machines, and hypersigns.

If nanologic's symbolic reprocessing of cryonauts like Walt Disney is any indication, then the transformation of the world envisioned by nanowriting is highly performative, and posthuman evolution has already begun. Accordingly, if nanotech is turning us posthuman, a critical scrutiny of the direction that nanotechnology takes

91. Merkle, "It's a Small . . . World" (above, n. 33), p. 26.

92. Regis, *Great Mambo Chicken* (above, n. 85), pp. 2, 126–130.

93. Merkle, "It's a Small . . . World," p. 32. Merkle actually cautions that nanotech will not develop on its own, but then strangely implies that even if we do not strive for the nanofuture, if "we ignore it, or simply hope that someone will stumble over it," the evolution of nanotech will still proceed—it is still inevitable—but it just "will take much longer."

and an engaged involvement in the corresponding changes to our lives and our bodies are required to ensure that becoming posthuman is accomplished on our own terms. In *The Diamond Age*, Stephenson issues a note of caution as his novel replicates the narrative of nanotech inevitability: "nanotechnology had made nearly anything possible, and so the cultural role in deciding what *should* be done with it had become far more important than imagining what *could* be done with it."[94] Nanotechnology empowers us to write our own posthuman future, but considering the massive biological, ecological, corporeal, and cultural changes heralded by nanologic (be they utopic or apocalyptic), as voyagers into the future we must exercise the necessary foresight.

Indeed, foresight is a note that echoes throughout the technoscapes and dreamscapes of nanotechnology, from popular novels to experimental reports, as both a warning and an enticement. Haraway has similarly called for active intervention into the cyborg metamorphoses of our posthuman futures, writing that as "[a]nthropologists of possible selves, we are technicians of realizable futures."[95] Nanotechnology and all of its implications are on the horizon, bodied forth by the speculations of science and of fiction. With the nanofuture in sight, we must prepare for our posthuman condition . . . for it may be a small world, after all.

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94. Stephenson, *Diamond Age* (above, n. 62), p. 31.

95. Donna J. Haraway, "The Biopolitics of Postmodern Bodies: Constitutions of Self in Immune System Discourse," in idem, *Simians* (above, n. 30), p. 230. Chris Hables Gray persuasively reiterates this need for "participatory cyborg evolution" in his recent political mapping of posthumanism, *Cyborg Citizen: Politics in the Posthuman Age* (London/New York: Routledge, 2001).