УДК 539.2

HISTORY OF NANOTECHNOLOGY

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Today, in the young field of nanotechnology, scientists and engineers are taking control of atoms and molecules individually, manipulating them and putting them to use with an extraordinary degree of precision. Word of the promise of nanotechnology is spreading rapidly, and the air is thick with news of nanotech breakthroughs. Governments and businesses are investing billions of dollars in nanotechnology R&D, and political alliances and battle lines are starting to form. Public awareness of nanotech is clearly on the rise, too, partly because references to it are becoming more common in popular culture-with mentions in movies, books, video games, and television.

Yet there remains a great deal of confusion about just what nanotechnology is, both among the ordinary people whose lives will be changed by the new science, and among the policymakers who wittingly or unwittingly will help steer its course. Much of the confusion comes from the name “nanotechnology”, which is applied to two different things-that is, to two distinct but related fields of research, one with the potential to improve today’s world, the other with the potential to utterly remake or even destroy it. The meaning that nanotechnology holds for our future depends on which definition of the word “nanotechnology” pans out.

Although a few scientists had done related work earlier, nanotechnology didn’t really get going until the second half of the twentieth century. Credit for inspiring nanotechnology usually goes it Richard Feynman, brilliant Caltech physicist who later won a Nobel Prize for “fundamental work in quantum electrodynamics”. In an after-dinner lecture (“There’s Plenty of Room at the Bottom”) delivered on the evening of December 29, 1959, Feynman proposed work in a field “in little has been done, but in which an enormous amount can be done in principle”.

“What I want to talk about”, Feynman said, “is the problem of manipulating and controlling things on a small scale”. Feynman described how the entire Encyclopedia Britannica could be written on the head of a pin, and how all the world’s books could fit in a pamphlet. Such remarkable reductions could be done as “a simple reproduction of the original pictures, engravings, and everything else on a small scale without loss of resolution”. Yet it was possible to get smaller still if you converted all the world’s books into an efficient computer code instead of just reduced pictures, you could store “all the information that man has carefully accumulated in all the books in the world… in a cube of material one two-hundredth of an inch wide-which is the barest piece of dust that can be made out by the human eye. So there is plenty of room at the bottom!” He declared that “the principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom” – in fact, Feynman saw atomic manipulation as inevitable, “a development which I think cannot be avoided.”

Eric Drexler, who began to develop these theories even before he’d heard of Feynman’s lecture, first published his ideas in a 1981 journal article. Five years later, he brought the notion of molecular manufacturing to the general public with his book “Engines of Creation”. An astonishingly original work of futurism, “Engines of Creation” pointed out how molecular manufacturing would revolutionize other areas of science and technology-leading to breakthroughs in medicine, artificial intelligence, and the conquest of space.

Drexler refutes every technical objection he can anticipate, explaining how such phenomena as quantum uncertainty and thermal vibrations don't make molecular manufacturing impossible. It was also in Engines that Drexler introduced the term "nanotechnology"-a reference to the nanometer, one – billionth of a meter to describe this approach to molecular manufacturing, although the term is now also used the more mundane applications(cosmetics, tennis balls, etc.) described above.

"Engines of Creation" created much excitement. The term "nanotechnology" rapidly became popular, and almost immediately its meaning began to shift. By 1992, Drexler was using "molecular nanotechnology" or "molecular manufacturing" to distinguish his manufacturing ideas from the simpler product-focused research that was borrowing the word. This research, producing shorter-term results, came to define the field for observers, and has continued to claim the term " nanotechnology". To avoid confusion, this Press Kit refers to such research as "nanoscale technology".

To shore up his technical arguments for the feasibility of his vision, Drexler further expanded on his ideas in the world's first nanotechnology textbook. Nanosystems(1992), a dense volume that grew out of a class he taught at Stanford, is crammed with equations and diagrams, and designs for molecular machines, and it has gone far to put the theory of molecular manufacturing on sound technical footing-although scientific debate about the achievability and the best routes to developing nanotechnology has continued.

Meanwhile, a brief mention in "Engines of Creation" of the dangers of self-replicating systems was proving increasingly troublesome to the field of molecular manufacturing. The idea arose that any molecular manufacturing system would be only one "oops" away from eating the biosphere. The wired article "Why the Future Doesn't Need Us" by noted computer scientist Bill Joy publicized this concern. Nanoscale technology researchers, fearing-perhaps with justification-that "gray goo" would threaten their funding, increased their efforts to distance their work from molecular manufacturing. One of the easiest ways to do this was to claim that molecular manufacturing was impossible and unscientific. These claims gained force since molecular manufacturing research was (and remains) high technical, interdisciplinary, theoretical, and mostly undemonstrated.

Since 2000, awareness of nanotechnology among environmental activists, regulators, and lawmakers has been on the rise. Environmental organizations have expressed fears about the potential ecological and health consequences of mainstream nanotechnology, and have called for increased research into safety of nanoparticles.

The Drexler version of advanced nanotechnology has also been the subject of public fear, largely centered on the notion that nanotechnology could spiral out of control and convert all life on Earth into "gray goo." Drexler, who originally introduced this apocalyptic prospect in "Engines or Creation", has since repeatedly distanced himself from it-but gray goo retains its grip on the public imagination.

There are other serious reasons to be worried about the development of nanotechnology, including the risk of severe economic disruption; the possibly dehumanizing effects of using nanotechnology on ourselves; and the potential criminal, military, or terrorist use of advanced nanotechnology. A few organizations are paying full-time attention to these concerns, including the Foresight Institute (established in 1986) and the Center for Responsible Nanotechnology (established in 2002).

Public policy discussions have barely begun to reflect those long-term concerns. In 2000, the NNI was established to coordinate the government's work in nanotechnology; soon, federal spending on nanotechnology is scheduled to cross the $1 billion-per-year mark. Along with the increased funding has come a government commitment to investigate the "social, economic, health, and environmental implications" of nanotechnology. As public interest continues to grow, and as scientific progress make advanced nanotechnology seem ever more

attainable, policymakers are likely to increasingly turn their attentions to the promise and peril of nanotechnology.