Nanotechnology: An Outsider's Perspective

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Many theorize what the future holds, complete with cliché flying cars and robotic maids, but what if those seemingly imaginary theories became real? Imagine a doctor planning your surgery using a microscopic robot to get into those hard-to-reach parts of your body, or better yet—eating a hamburger or hot dog made from your daily garbage. As crazy and futuristic as it may sound, nanotechnology may hold the key to advancing society into a whole new age of technology. Like most sciences, though, there is a flip side: science at such a tiny level, 10^{-9} meters to be exact, has as many potential dangers as it does advantages.

To put the small domain of nanotechnology into perspective, imagine 1/75,000 the width of a human hair—this is a nanometer.[1] At its basic level, nanotechnology seeks to manipulate and control objects at a molecular level in order to form macroscopic objects, what scientists call the "bottom-up" approach.[2] The nanotechnology community seems split between those who believe chemistry can be controlled and those who do not.[3]

Eric Drexler, the man whom most associate with nanotechnology, earned his Ph.D. in molecular nanotechnology from MIT in 1991.[4] In an article published by Chemical and Engineering News, Drexler has a heated letter of correspondence with Richard Smalley, who won the 1996 Nobel Prize for discovering fullerenes. Drexler says, "As you know, I introduced the term 'nanotechnology' in the mid-1980s to describe advanced capabilities based on molecular assemblers: proposed devices able to guide chemical reactions by positioning reactive molecules with atomic precision."[4] These proposed "molecular assemblers" position atoms and molecules to perform specific reactions in virtually any environment. Smalley, Drexler's primary opponent in the nanotechnology arena, supports the notion that nanotechnology can supply endless advantages to society, but he argues the practicality of molecular assemblers. The main catalyst in their heated debate stems from Smalley's "sticky fingers" and "fat fingers" argument. The "sticky-fingers" argument claims the atom on the end of an assembler's hand will stick to the atom being moved, thus making it virtually impossible to precisely release the atom in the desired spot. Similarly, the "fat fingers" argument claims there is simply not enough room to perform chemical tasks with multiple fingers at a microscopic level.[5] Imagine a person with big fingers trying to dial one number at a time on a telephone—they end up pushing surrounding buttons at the same time because the space on the phone is simply too small for their finger. Drexler tackles Smalley's proposed finger theories with his plan to use ribosomes and enzymes rather than fingers. The problem with this plan, according to Smalley, is that ribosomes and enzymes only function in water, greatly limiting their capabilities.[4] Drexler counters Smalley's accusations by explaining the application of nanofactories, which "use computers for digitally precise control, conveyors for parts transport, and positioning devices of assorted sizes to assemble small parts into larger parts, building macroscopic products."[4]

Beyond the Drexler-Smalley debates, the fundamentals of nanotechnology encompass various potential developments in fields such as medicine and the environment. Nanotechnology devices "can be designed to interact with cells and tissues at a molecular level with a high degree of functional specificity, thus allowing a degree of integration between technology and biological systems not previously attainable."[2] For instance, they could help the brain send controlled messages to prosthetic limbs in accident victims or perhaps even treat infected cells, such as cancer, directly.[6] Such devices could also help clean up natural disasters as well as recycle and reuse materials, helping alleviate natural resource waste. The question then surfaces: what sort of new contaminants will arise from nanotechnology?[7] While we may be able to clean up things such as oil spills, what will happen to the nanoparticles involved in the process? There are many questions still unanswered.

Figure 1. As conceived by Drexler, to deposit carbon, a device moves a vinylidenecarbene along a barrier-free path to insert into the strained alkene, twists 90 degrees to break a pi bond, and then pulls to cleave the remaining sigma bond. Courtesy of K. Eric Drexler.

Although nanotechnology may spur many beneficial developments, detrimental aspects, such as new contaminants, have bred a level of skepticism in society. Historically speaking, society has been making scientific developments for centuries—this is nothing new. Given people's ability to go beyond their boundaries, many question when, where, and how we draw the line on the technology we support and the technology we limit. In his article "The Question of Ethics," Donald Bruce postulates that ethical questions could surface if nanotechnology devices are applied to non-medical practices, such as extending an individual's sight into the infrared for stronger night vision. Because there is such an unknown factor in the human body, it becomes difficult to concretely define a healthy patient from an unhealthy patient. If during an annual check-up a doctor has the capacity to warn their patient of a group of malevolent cancer cells they know are incurable when the patient is simply there for a common cold, then this facet of nanotechnology may have revealed too much too soon.[6]

World War II proved no exception with testing human boundaries—though the refinement of the atom brought about nuclear power, it also brought about the nuclear bomb. Nanotechnology may help with military weapons' efficiency, but many fear unconstrained boundaries could lead to microscopic devices used to disassemble military weapons.[8] Similarly, devices having such control at a microscopic level could lead to surveillance invisible to the human eye. Nanotechnology treads a fine line between beneficial developments and developments with the potential to violate personal privacy, leading to gravely unfavorable legal issues. [8] The public paranoia surrounding this up-and-coming science seems to center primarily on its unrestrictive nature and prospective irreversibility. The Gray Goo Scenario, for instance, poses a setting in which a disassembler gets loose in the environment and begins disassembling everything—much like the episode of "Star Trek: The Next Generation" when Wesley's nanites get loose on the ship and destruct everything in their path.[8]

While the dangers of nanotechnology seem to make headlines over its positive developments, there is a level of skepticism in practically everything new and unknown—think back to the beginning phases of cars, planes, and medicine. The key to this developing science rests in establishing boundaries to avoid future misuse and potential disaster. Because there seems to be a lack of communication between scientists and society, public awareness of nanotechnology has become exaggerated and inaccurate. Ashley Shew brings up a good point in her paper "Codifying the Ethics of Nanotechnology" when she says there is a level of hypocrisy with nanotechnology in that it maintains a basic research level but insists on its capabilities to change the world.

Nanotechnology has great potential for success and great potential for failure. It could lead to a new era filled with innovative developments or an era filled with irreversible destruction. Scientists right now should keep in mind the long-term effects of their developments, even if it means going back to the old fashion list of 'good' and 'bad'—good, we can recycle and reuse waste products; bad, your neighbors could use microscopic devices to spy on you! There remains much ground for nanotechnology to explore–we are not yet in clear waters.

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Figure 2. The yellow and green solutions are suspensions of silver nano-particles, and the rest are suspensions of gold nano-particles. The nano-metal suspensions are under development for biological sensing applications and for contol of harmful bacteria. Courtesy of Guo-Quan Lu.

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