

*Program of Dialogue on Science, Ethics and Religion*

**Summary**

**Nanoscience and Nanotechnology: The next big idea is really small**

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The next big thing in science is so small that scientists will be working at a molecular level that is fifty-thousand times smaller than the width of a human hair. Yet the implications are so huge that without proper regulation, some ethicists fear a societal division unseen since the Industrial Revolution.

Dr. Mark Ratner discussed the growing field of nanoscience and the potential applications of that science in a December 4, 2003 speech sponsored by the Dialogue on Science, Ethics and Religion. Dr. Ratner is Morrison Professor in the Department of Chemistry and a member of the Institute for Nanotechnology at Northwestern University where he also earned his Ph.D. He is a recipient of the 2001 Feynman Prize for major advances in molecular nanotechnology.

To illustrate the scale at which scientists will be working, Ratner showed a photograph of Florida taken by satellite. He gradually reduced the size of the photograph until it showed a single cell of a single leaf on a tree in the state of Florida. That is a relative demonstration of the reduction of scale at which scientists will be working when they move their inquiry and technological development to the nano-level. "It's not only small," he said, "it's a special kind of small." When scaled to nanosize, anything from the flu virus to gold particles can be studied at the molecular level. If scientists can reduce structures to their molecular level, we can begin to understand how they work.

"Why do we care?" Ratner asked. "Big deal. Things are little." It matters, he explained, partly because of something called "Moore's Law." Moore's Law is based on the observation that the number of transistors per square inch on integrated circuits had doubled every eighteen months since the integrated circuit was invented and states that this rate will continue for the foreseeable future. Technology has been concentrating on smaller, not bigger, for some time now. Computers, for example, that used to be so huge they could fill an entire building, are now small, cheap and readily available. Cell phones, portable radios, personal digital assistants and other personal electronics have all benefited from technology that has decreased the size (and increased the usefulness and reliability) of the chip needed to store information.

Nanotechnology comes in, Ratner explained, because the cost of developing new microchips using current technology is increasing at such a rate that seven years from now the cost of building a plant to build new computers will be \$50 billion. "It isn't gonna happen," Ratner said, "because people are going to move on to other things, and what they're going to move on to is nanostructures."

"Now what's involved in nanotechnology?" Ratner asked. "You have to make something, you have to observe it-and remember you can't possibly see it-and then you

have to try to understand how it works.” Scientists are going to be working at the level of individual atoms and molecules. Though these are almost too small to be observed even with a powerful microscope, they can be manipulated.

This manipulation is accomplished with something called a scanning tunneling microscope. This instrument cannot “see” the atoms, but it can allow scientists to “sense” the structure of the material at the atomic level and to manipulate the molecules using nanotips on the microscope itself.

Nanotechnology has been around for many centuries; and early use was in stained glass artwork. The smaller things become approaching molecular size, the more their characteristics become size-dependent. Color changes with molecular size give stained glass its brilliant colors.

The science of nanotechnology was relatively unexplored until the 1960’s, when Richard Feynman gave what Ratner called the “founding speech of nanotechnology.” Quoting from Feynman’s speech, Ratner read, “People tell me about miniaturization and how far it has progressed today. They tell me about electric motors the size of the nail on your small finger. And there is a device on the market they tell me that can write the Lord’s Prayer on the head of a pin. But that’s nothing, that’s the most primitive halting step in the direction I intend to discuss. There is a staggering small world that is below and in the year 2000, when they look back at this age they will wonder why it was not until 1960 that anybody began seriously to think about it.”

To demonstrate how far nanotechnology has progressed since Feynman delivered his speech in the 1960’s, Ratner explained that the speech, which he displayed onscreen, was written using a writing method (dip-pen nanolithography, developed by Chad Mirkin’s group) so small that using the same scale, 10,000 editions of the Encyclopedia Britannica could be written on one 8 ½ by 11 piece of paper. The ability to store information on this scale will allow scientists to collect and store unprecedented amounts of information – for example, to better predict weather patterns.

“What’s interesting is that we’re fabricating at the scale that nature fabricates.” Scientists have accomplished this using a fountain pen that is 100,000 times smaller than a normal pen. Another technique for fabrication is “nanospraypainting,” using nano-sized balls. These balls are packed together on a surface, leaving triangular spaces between the nano-balls. The balls are spray painted, and then removed. What is left is the triangular dots between the balls. This technique is used to make nanostructures.

Applications of nanoscience, however, go beyond information storage. Using nanotechnology, researcher Sam Stupp is developing a method of human repair. Stupp has developed a molecule that will assemble itself into a log-like structure. That structure be very long with a small cross-section, and can be chosen to bind with particular proteins in the body. Once in the body it can assemble itself and proteins will build themselves onto the molecule. This method could be used for spinal chord regeneration and creating artificial bones.

Nanoscience can have applications that will be useful for the general public as well. Nanomolecules react very sensitively and quickly, allowing scientists to quickly detect toxins in the air. After 9/11, for example, there was concern about any biochemical agents that may have been in the air. Nanotechnology would allow scientists to quickly ascertain air and water safety. Nanotechnology can detect botulism, anthrax and cholera. On a more commercial level, nanotechnology is now used to create windshields that won't freeze, and grease-less sunscreen; it will be used for solar energy capture, for efficient lighting and for corrosion control.

With technological power comes a need for responsibility and a duty to the ethical and moral codes formed thus far by humanity, Laurie Zoloth argued in her response to Ratner. Debates that really matter do not address regulations, they address human dignity.

Dr. Zoloth is a professor of Ethics and Humanities, and of Medicine, and of Religion at Northwestern University's Feinberg School of Medicine, (Chicago) in the Program in Medical Ethics and the Humanities. Her response outlined the potential ethical problems posed by nanoscience, and proposed solutions.

"It is so powerful it may well create a two-tiered system in which people who can obtain and use the new technology will have wealth and power that will be unavailable to the have-nots."

Zoloth argued for a national and international code of ethics and regulations to control the new science. She urged the formation of two boards at the national level to govern nanotechnology, one to regulate use and the other to oversee research.

Citing several articles written about the possibilities and implications of nanotechnology, Zoloth asserted that nanoscience is advancing at a rate far faster than ethicists and governments have been able to form regulations. Nanoscience has already taken hold of the public imagination, spurring fears and hopes for the future.

"We've opened the Pandora's Box (of science) and we're watching in horror at each new thing. Nano is just the last thing out and when it comes out, it's framed by the very way we have of seeing. Shaped by cloning and genetic enhancement, and of course, bioterrorism."

Nanoscience brings an unprecedented ability to control and manipulate nature. This power, Zoloth argued, has the ability to bring untold good to humanity, but it also has the power to bring untold danger. With nanoscience comes a fear of technology itself.

But, she argued, we should not shy away from the new science out of fear. She asked if any ethicists would have argued against the invention of the steam engine knowing all the problems that came with the benefits of technology during the Industrial Revolution.

“We learn to negotiate with and then restrain technology. It is the essential principles...that frame the relationship between ethics and science. When we come together to think about all the wonders of medicine, we have learned to raise the questions in a deliberative way. It’s just the latest thing out of Pandora’s box. Is it ethical in principle, or is there some principle in which the research is inherently wrong?”

It is too late, she declared, to debate whether nanotechnology should be explored. What ethicists must do now is decide how to best apply the technology for the benefit of society. Zoloth urged for public education about nanoscience and all the ethical questions that accompany it. She argued that scientists should obtain the consent of not just the subjects of their tests, but the consent of society-at-large.

“We need scrutiny and public education, we need to plan new economies, regulation of new groups, open industry meetings and government meetings. Intellectual patent laws need to be addressed. Privacy and civil liberty concerns need to be addressed. We need vigilance and responsibility by the science community.”

Nanoscience could change the way humans view the world and themselves. It challenges the notion of naturally seen and observable limits and creates a blurring of categories between what is alive and what is not alive. Referring to the (fantasized and improbable) use of nanotechnology to create self-replicating molecules for use in human repair, Zoloth said, “The fear of replication plays on this problem of what is alive and what is not.”

“By the middle of the last century mankind had the ability to extinguish life on earth, by the middle of next century, mankind will have the ability to create it. It’s hard to say which of the two places the larger burden of responsibility on our shoulders.”