Testimony of Diandra L. Leslie-Pelecky, PhD
Director of the West Virginia Nano Initiative
Professor of Physics
West Virginia University
Submitted to the Senate Committee on Science, Commerce and Transportation
Subcommittee on Science and Space
July 14, 2011

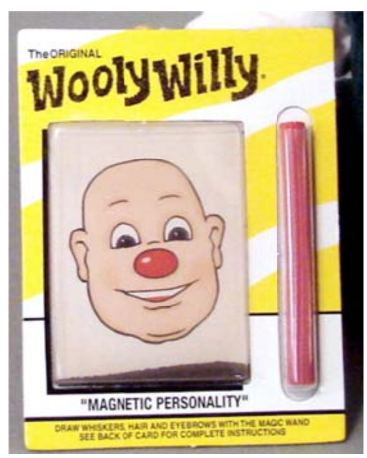
- The National Nanotechnology Initiative has had a tremendous impact in producing new materials for potential commercial applications, advancing fundamental knowledge, and developing a scientific and engineering workforce that has made the United States a global nanotechnology leader. Re-authorization of the NNI will ensure that the U.S. retains this leadership and will promote the transfer of basic knowledge to applications with important economic and societal impacts in energy, health and medicine, environmental monitoring and remediation, and homeland security.
- Nanotechnology is highly interdisciplinary and ranges from basic research to applications, making it critical for funding agencies to coordinate their efforts. Recent interagency calls for proposals in targeted areas involving nanotechnology must be continued and expanded upon to ensure that important research areas receive the necessary support.
- Realizing societal and economic benefits depends critically on establishing scientifically valid principles for responsibly developing and using nanotechnology.
  - We have much to learn about nanomaterial *bioactivity*: how a material interacts with biological organisms and the environment. In particular, we need to understand the relationships between physicochemical properties of nanomaterials and their bioactivity to enable "safety by design".
  - Regulation of nanomaterials is important to corporate and consumer adoption of this new technology. Companies need confidence that their products and manufacturing methods are safe for consumers and workers, while the development of new nanomaterials and nanotechnologies will benefit from being able to focus effort in the directions that are most likely to produce safe products.
  - Nanomaterials are a unique form of matter and we do not yet have all the knowledge we need to develop complete regulations for nanomaterials. Acquiring this knowledge must be a priority and nanomaterials regulation must remain flexible enough to adapt to our evolving understanding.
  - A potentially large market exists for products and services that determine nanomaterial bioactivity quickly and precisely. Sectors that would benefit include nanomanfacturing, homeland security, health and medicine, and a wide spectrum of basic and applied research.
- Nanotechnology research requires significant infrastructure for its continued development. Once-exotic instruments like electron microscopes are now basic tools for research and development. Funding opportunities to acquire these basic tools (some of which cost a half-million to a few million dollars) need to be developed. New state-of-the-art tools need to be invented and made available on a regional basis.
- Education is a priority to ensure our continuing world leadership in nanotechnology, to transfer basic discoveries to applications, and to ensure public acceptance of nanotechnology.
  - Educating the next generation of scientists and engineers requires new models at undergraduate and graduate levels that focus on integrating diverse fields without sacrificing depth of knowledge in core disciplines;
  - Lawyers, businesspersons, venture capitalists, elected officials, and government regulators need to acquire knowledge about specific nanomaterials and their applications to allow informed decision making;
  - Basic science and engineering education at the K-12 level is a pre-requisite for future scientists and engineers – but more importantly, it is critical for all citizens to develop fundamental scientific literacy so that they can make informed decisions about the roles nanomaterials will play in their lives.

Mr. Chairman and Members of the Subcommittee, my name is Diandra Leslie-Pelecky and I am the Director of the West Virginia Nano Initiative and Professor of Physics at West Virginia University. Thank you for the opportunity to testify today regarding the impact of the National Nanotechnology Initiative (NNI) and its reauthorization.

This is not an abstract thanks, as I am one of literally thousands of scientists and engineers who have had the opportunity to contribute in some small way to the huge advances in our understanding of nanomaterials because of the government's commitment to nanotechnology and its potential impact on our country's future through the NNI. Reauthorization of the NNI will further our basic understanding of nanomaterials, and help transform that knowledge into products and services that will benefit the people of the United State and our economy.

The idea that one can change the basic properties of a material simply by changing its size introduced a major paradigm shift in science and engineering. The possibilities for using nanomaterials to solve some of the country's most important problems – like more efficiently transforming and storing energy, or detecting diseases like cancer when there are only a few cancerous cells present – are moving ideas from the realm of science fiction to reality.

Despite having worked in nanomaterials my entire career, I had a very traditional preparation to become a physicist. I started out studying the fundamental properties of magnetic nanoparticles – particles about a thousandth the width of a human hair – trying to understand how their magnetism changes as their size varies. About eight years ago, I was inspired to consider how these magnetic nanoparticles might be applied.



You may remember a toy called Woolly Willy – a drawing of a man's face in a container that also contained iron filings. You use a magnet to move the iron filings around to create a beard or hair. I do something analogous with magnetic nanoparticles. I attach chemotherapy drugs to the nanoparticles, inject them, and then use magnets outside the body to hold the nanoparticles where I want them – which is at cancer tumors. This magnetic targeting approach allows us to concentrate the chemotherapy drugs near the tumor, increasing efficacy and decreasing side effects.

This is how I entered the field of nanomedicine, which uses the unique properties of nanomaterials to detect and treat disease. Like many of the hybrid fields that have evolved from nanomaterials research, nanomedicine sometimes finds itself at the edges of two or more funding agency mandates. Our work has been funded by the National Science Foundation and the National Institutes of Health, but we've also found that some aspects of the research are too disease focused for NSF, but not focused enough for NIH. Funding agencies have started to issue joint calls for proposals in the last few years, but more coordination is necessary to ensure that ideas that don't fit neatly in a funding 'box' can still move from the eureka moment to application. It is especially important to address the gap between the basic research pursued in most universities and the very applied work that immediately precedes commercialization.

As I continued working in nanomedicine, I've learned about a concept called 'bioactivity', which characterizes how nanomaterials interact with living organisms and the environment. My nanoparticles are designed to enter the body, locate near the tumor and release their chemotherapy drugs. After their mission is accomplished, the nanoparticles are metabolized by the body into oxygen and iron, both of which can be used or easily removed by the body. We do extensive tests to ensure that our nanoparticles' bioactivity is limited to cancer cells.

It might seem like the bioactivity of a material is something that we ought to be able to predict; however, the same surprising properties that we want to utilize to treat diseases and use energy more efficiently also sometimes surprise us when we look at how the materials interact with biological systems. Some materials have a threshold size, below which they start having undesired consequences. We can combine two materials that are fine on their own, but produce an undesired bioactivity when combined. Bioactivity has to be experimentally determined nanomaterial by nanomaterial.

We can create new nanomaterials in a matter of days; however, it takes several months for us to investigate and really understand the bioactivity of just one of those nanomaterials. Nanomaterials have turned the basic tenets of toxicology on their heads. We must support the basic research necessary to develop predictive capabilities for nanomaterials bioactivity. We have exceptional abilities in producing new nanomaterials of all kinds. Now, we need to advance our understanding of bioactivity to catch up with the rapid development of new nanomaterials.

I moved to West Virginia last year in part because of the proximity of West Virginia University to the National Institutes of Occupational Safety and Health (NIOSH). Collaborations between our organizations are producing some of the most exciting progress on understanding the bioactivity of naturally occurring and human-made nanomaterials. As the production of nanomaterials increases from lab quantities to nanomanufacturing-scale amounts, companies and regulatory agencies are going to need the type of information we collect on the intended and unintended environmental, health and safety impacts of nanomaterials.

Companies are uneasy about investing in new technologies that have so many unanswered questions. Companies need to know that their products are safe, and what steps they need to take to ensure that their workers have a safe environment. Even more importantly, companies developing new products would benefit significantly by being able to access a broad database of knowledge of environmental health and safety effects that could help predict the behavior of new nanomaterials and combinations of nanomaterials.

The ability to develop appropriate guidelines and regulations are hampered by lack of basic knowledge about nanomaterials bioactivity. Imagine being asked to referee a game for which you didn't know all the rules. The rules for nanomaterials are not likely to be simple, either. Nanomaterial bioactivity doesn't depend simply on size or shape or chemical composition. Nanomaterials must be regulated on a case-by-case basis according to their actual properties, not simple and possibly superfluous characteristics such as size. Regulatory agencies must be knowledgeable and nimble, willing to change as our knowledge increases.

There's an unfortunate perception that emphasis on understanding the environmental health and safety aspects of nanomaterials is a hindrance to using nanomaterials to drive the economy. Understanding nanomaterials bioactivity is a critical component of developing safe products and building consumer confidence in nanotechnology. It's also a potential business opportunity.

For example, researchers at West Virginia University and NIOSH are working on a microfluidic device that uses different types of cells as sensors to perform a real-time analysis of nanomaterials bioactivity. This device could allow a researcher or a company to learn within minutes how a new nanomaterial interacts with each different type of cell. There are industrial possibilities for developing sensors that monitor the presence of nanoparticles in the work environment or for homeland security purposes, and opportunities for companies capable of doing rapid, accurate bioactivity screening.

Realizing these opportunities requires advancing our basic understanding of nanomaterials bioactivity, which in turn requires infrastructure. The multifaceted nature of nanomaterials demands multiple characterization measurements, many of them pressing at the boundaries of what we are able to measure. The government has done an outstanding job making high-cost instrumentation available on a regional basis at national laboratories, such as the NSF-funded National Nanotechnology Infrastructure Network. These facilities make important contributions to research, but also provide unique educational opportunities for nanotechnology students.

Once-exotic instruments like electron microscopes are now basic tools that are required for nanomaterials research. There are a very limited number of funding opportunities for universities to acquire instruments in the half-million dollar to few million dollar range. These instruments do far more than facilitate research – they provide training opportunities for the next generations of nanotechnology researchers and developers.

Let me conclude by briefly addressing an aspect of nanotechnology that often gets lost: the need for education at many different levels. In graduate school, I studied physics and I worked with physicists. Now I study nanomedicine and I work with medical doctors, biologists, toxicologists, and pathologists – not to mention chemists, engineers and other physicists. I've learned almost an entirely new vocabulary in the last eight years. The undergraduate and graduate students working in my labs need to learn very different things than I learned when I went through school. Nanomaterials transcends disciplinary boundaries, requiring students to develop breadth of knowledge while still gaining expertise in their core discipline. Today's students won't be working in a small group of like-minded people in a single lab: they need to learn how to work with groups of people from very different backgrounds, on a wide spectrum of instrumentation. They need to learn about the importance of fundamental research, but they also need to learn about industrial applications of nanomaterials and entrepreneurship. This is a major departure from the discipline-based education most of us are used to and we need to invest in developing the most effective and efficient ways of educating the next generation of scientists and engineers.

Perhaps more importantly, we need to educate lawyers and businesspeople, elected officials, regulatory officers and venture capitalists about the realities of nanotechnology, especially as they pertain to specialized sectors of the economy like energy, health, and the environment. They need to utilize a principle of science that we often fail to communicate: cutting-edge scientific knowledge is dynamic and constantly evolving. Patent examiners, policy makers and the government scientists responsible for creating a stable and predictable regulatory climate will have learn how to adapt to our changing knowledge in a proactive and not reactive way.

Most importantly, in my view, is educating all citizens to make informed decisions about nanotechnology. This education starts in the K-12 system by building fundamental science and math literacy – something we are not doing very well at present. Our efforts need to be focused beyond developing curricula that define and explain nanomaterials. We need to emphasize the more fundamental objective of teaching people how to think critically. We need to switch the focus of education from memorizing information that any teenager can pull up in a microsecond from her phone to teaching that student how to synthesize and use that information to make valid decisions.

As the author of a science book written specifically for non-scientists, I have a lot more contact with the public than your average physics professor. What surprised me most was how hard the average person is willing to work to learn about science – if you can show them how it affects something they care about. Nanomaterials will eventually affect all facets of our lives, from our medical care to the cars we drive and the food we eat. Consumer understanding of nanomaterials is a pre-requisite to realizing the huge potential of nanotechnology to improve our country, our economy and our quality of life.

The National Nanotechnology Initiative has facilitated the growth and development of this very important field. Re-authorization of the NNI must include coordination of effort among multiple government agencies, increasing understanding of the environmental health and safety impacts of nanomaterials to facilitate their safe and responsible use in consumer products, and supporting the infrastructure necessary for future research and development. Finally, the NNI must promote education at all levels, from the future scientists and engineers that will enable us to maintain global leadership in nanotechnology, to developing the scientific literacy of the public so that they can make informed decisions about the role of nanotechnology in their lives. Thank you again for the opportunity to provide input on this very important issue.