Abstract:

Nano Transformations: A Future of Our Making[1]

By Joseph Bordogna[2]

"Nano" denotes the very small in scale, but there is nothing diminutive about the expectations generated by nanotech—the application of fundamental research at the nanoscale.

Some call it "the next industrial revolution," anticipating an economic bonanza that dollar for dollar, and job for job, will outstrip the introduction of electricity, the automobile, or the new information and communications technologies. Others forecast a nearly utopian future in which new materials, manufacturing processes, and applications in energy, health, agriculture and environment banish the age-old scourges of hunger, poverty and disease, and substantially expand human intellectual and physical capabilities, all at diminished cost to resources and the environment.

These changes may well be unlike any that have come before. Nanoscience and engineering already provide new knowledge that gives us the capability to design and build materials one atom or molecule at a time. At the nano scale, ordinary matter often displays surprising properties that can be exploited to boost computer speed and memory capacity, and make materials that are stronger, lighter, and smarter by orders of magnitude.

Nano is also the dimension where living and non-living worlds meet—where molecules that form the basis of life interact with the physical environment to spin the complex threads that link life at all levels with the planet. The possibilities at this interface are staggering—new ways to deliver drugs or repair DNA, and the development of artificial tissue, to name only two. Understanding life and its interaction with the physical and cyber world at the nano level is likely to open vistas that have not yet been imagined.

The expectations raised by nano have inspired governments worldwide to increase support for nano research and education and sparked international competition to bring nano from the bench to the boardroom. They have also stimulated dialogue on the human, social, and environmental implications of the new technology.

Whatever our particular vision of the future, those of us who track progress in nanoscale science and engineering probably agree on one thing: Nanotech has the potential to engender colossal transformation—with pervasive consequences for our economies, our societies, and our everyday lives.

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Many questions arise as we contemplate a nano-enabled future. I will mention just three: How can we advance nano efficiently and rapidly? How can we do this benignly? And finally, how can we do it equitably?

The first question addresses the productivity and quality of our research, education, and industrial systems: How do we design the research, education and development environment so that new knowledge emerges rapidly and is transformed effectively into technological innovations that deliver social and economic benefits? This is the customary nexus that we constantly try to improve, through better practice and policies.

Fortunately, the recent explosion of new knowledge and technologies—particularly in information and communications and the life sciences—has already given us some useful experience. The character of research is changing, and several answers that will help us move the frontier of nano forward are beginning to emerge.

International Cooperation in Fundamental Research

As we have learned from other emerging fields of science and engineering, international collaboration in frontier research can increase the momentum needed to speed us on the way toward rationally framing and solving common problems. In the case of nano, international collaboration in frontier nanoscience and engineering research and education is essential. Many challenges—in medicine, agriculture, in climate and environmental science, and engineering, for example—are global in nature, and require global research and education platforms. Many nations have already made substantial investments in nano, and progress in research and education is occurring worldwide. Potential applications are so all-encompassing that no one country is ever likely to have exclusive claim.

National Support for Nanoscale Science and Engineering

Sustained public funding and support for nano research and education is equally important. Nano's potential to deliver large-scale benefits to society without harm, the basic rationale for public support, would be sufficient to justify national investment. But another feature of nano reinforces its claim. Nano has been called a "general purpose technology" to capture the expectation that—like electricity—nanotechnology will enable and reconfigure a wide range of technologies, touching most sectors of the economy. The creation of new jobs and wealth, leading to improvements in standards of living, is part of nano's exceptional promise. It should not surprise anyone that competition in this emerging field is intense. In the U.S., these considerations led to the establishment of the National Nanotechnology Initiative, a federally funded program to advance nano research and development. Funding for this initiative reached $770 million in fiscal year 2003. The National Science Foundation, the federal agency that I serve, has the interagency lead in this coordinated effort. Similarly, national programs are underway in the EU, Japan and a host of other nations.

It is important for us to recognize that these national programs are compatible with international cooperation in nanoscience and engineering. Collaboration and competition are not mutually exclusive, and rapid progress in discovery may well depend upon achieving a healthy balance between them.

Multidisciplinary Collaborations and Partnerships Across Sectors

Over the past two decades, the interface between disciplines has often provided the most fertile ground for advances at the frontier of knowledge. We have learned that multidisciplinary collaboration can lead to path-breaking advances that would simply be beyond the scope of a single field or an individual. Partnerships are equally important in facilitating the transfer of research results to industry. Building these partnerships early in the research and education process speeds discovery and innovation, and has the added bonus of providing learning environments for researchers, producers and students.

Innovation in Education

If nanotech drives the pervasive transformations foreseen by many, a workforce with new knowledge and skills will be required. The integration of education and research—educating students in consonance with every step of the discovery process—can produce the savvy workforce needed to make the leap from new knowledge to technological innovation. We will need to design new learning environments that meet this challenge.

Integration of the Social, Behavioral, Cognitive and Economic Sciences into Nano Research and Education

If nano offers us vastly more options, then we need a foundation for understanding the consequences of choosing among them. Discovery in the social, behavioral, cognitive and economic sciences can be integrated into nano research and education from the get-go. Exploring how nano may affect human and social development, and teasing out how it may change individuals, societies, cultures and institutions can give us a way of anticipating and shaping the future.

A better understanding of the interplay among human and social dynamics and the transformations that nanotechnology may set in motion can help us shape answers to the second and third questions posed earlier: How can we develop and deploy nanotech benignly and equitably? To the extent possible, we need to develop new knowledge and engage in dialogue to anticipate and guard against unintended consequences that could harm individuals or the environmental systems that sustain life. Likewise, we need to focus our attention on questions of justice and fairness: Who receives the benefits of nano, and who gets a vote in determining how they are distributed?

These considerations are no longer ancillary to the science, engineering, and technology enterprise. We need to anticipate and guide change in order to design a nano future of our choice, not just one of our making. Future generations may well judge our success—and our wisdom—by how well we realize the potential of nano while avoiding the pitfalls.