

2nd Annual National Academies Keck *Futures Initiative* Conference

Designing Nanostructures at the Interface between Biomedical and Physical Systems

Arnold & Mabel Beckman Center, Irvine, California

November 18-21, 2004

Conference Summary

National Academies Keck *Futures Initiative* Stimulates Advances in Nanoscience through Interdisciplinary Research

By Kiryn Haslinger

On a bus from the John Wayne Airport in Orange County to the Newport Beach hotel where I was staying, the driver asked the gentleman in the front seat, "Are you here for the nano-conference." I, and several others seated near me, perked up, since we all were indeed there for just that reason. "Nano? What's that?" replied the man, who evidently was not one of the 155 researchers, policy makers, and writers who were invited for a four-day conference to discuss the latest advances in nanoscience and brainstorm about the most pressing big problems to which nanotechnology could be applied. "I don't really know," said the bus driver, "but I think it's really, really small."

Later that night at the kick-off reception, some of the best scientists, engineers, and medical researchers in the U.S. couldn't put it any more eloquently. The buzzing prefix that has taken the scientific world by storm refers to the size of structures, which are about a billionth of a meter: small objects with big potential. As objects shrink down to the scale of atoms and molecules, they are subject to the laws of quantum mechanics and do not behave according to the physics that governs the objects we encounter in our macro-sized consciousness. Though quantum mechanics is celebrating a centennial this year (Einstein's paper describing a quantum mechanical phenomenon, the photoelectric effect, was published in 1905) humans still do not fully understand the laws that govern the world's most basic constituents. But harnessing the power of the nanoscale could mean more efficient electronics, significantly faster computers, effective environmentally friendly energy sources, and a possible revolution in the field of medicine.

These goals inspired the National Academies Keck *Futures Initiative* to host a conference on *Designing Nanostructures at the Interface of Biomedical and Physical Systems*. Launched in 2003, the National Academies Keck *Futures Initiative* (NAKFI) seeks to stimulate new modes of scientific inquiry and break down the conceptual and institutional barriers to interdisciplinary research. NAKFI is supported by a 15-year, \$40 million grant from the W.M. Keck Foundation. Underlying the initiative is the conviction that interdisciplinary research and clear scientific communication are the cornerstones of modern scientific achievement. The *Futures Initiative* includes three primary components: seeding interdisciplinary research with competitive grants in emerging fields, rewarding first-rate scientific communication, and sponsoring conferences for a select group of the nation's brightest researchers. The conferences are intended to bring talented scientists, engineers, and medical researchers from diverse backgrounds together, to discuss a single topic, and determine the big questions that will define the great discoveries of the future.

Articulating questions is an accurate description of the format of this year's NAKFI conference. Indeed, throughout the four-day *Designing Nanostructures* conference, researchers continually struggled to state the problems that exist in attacking the exciting but ill-defined field of nanoscience. Richard Foster, a member of the W.M. Keck Foundation's board, kicked off the meeting in an introductory speech about the challenges of discovery by asserting this very idea. "The questions, at this stage, are more important than the answers," he said.

The conference's planning committee decided early on to develop an inquiry-based meeting centered on focus groups. Over the next few months, the organizers identified ten questions for the groups to

address. Given this format, the committee also decided to hold a “pre-conference,” in which seven researchers presented broad overviews geared toward an interdisciplinary audience – *The Future of Medicine*, *Optical Nanoimaging*, and *Nanotechnology Ethics*, to name a few. These tutorials were designed to help bridge the language gaps between disciplines and provide the focus groups with common ground on which to explore their questions. At the *Designing Nanostructure* Pre-conference, on September 18-19, 2004, some 130 individuals from academia, industry, national labs, research foundations, government agencies, and the media gathered to prepare for the larger November meeting at the Arnold and Mabel Beckman Center of the National Academies in Irvine, California.

The conference, held November 18-21, 2004, was marked by a unique and innovative format. Instead of having several researchers communicate their work in formal detailed presentations, two scientists continued the set of broad tutorials begun at the pre-conference. Conference attendees were then divided into ten focus groups, each of which spent a total of eight hours exploring diverse challenges at the interface between physical science, biomedical science, engineering, and technology, interspersed with several hours of informal networking and in-depth technical poster presentations.

Cherry Murray, the conference’s chair and Deputy Director for Science and Technology at the Lawrence Livermore National Laboratory, stressed the importance of the tutorials. Unlike most scientific meetings, where speakers can assume the collective understanding of particular fundamentals of their fields, interdisciplinary research requires a greater level of orientation and translation. Researchers must orient their collaborators to the basic principles in their fields, and articulate the open, exciting questions in their areas of research. They must also communicate clearly, demystifying the language of their disciplines and minimizing jargon.

Much of today’s research requires expertise in more than one field, which is very difficult for a single person to master. Interdisciplinary research seeks to combine the skill sets of various researchers so that science can move forward through the creative collective efforts of collaborators. Highlighting NAKFI’s mission, the opening session of the conference featured the release of the National Academies report on *Facilitating Interdisciplinary Research* commissioned by the Keck Foundation as part of the *Futures Initiative*. The report examines the current state of scientific research and support in the U.S., with a particular focus on how future generations of scientists should be trained. Covering all levels of scientific education, the report recommends ways for students and researchers to seek out interdisciplinary experiences and broaden their expertise by learning about other research fields. It encourages academic institutions to remove barriers to interdisciplinary research by developing joint programs and collaborating with industry and government organizations. Two of the major barriers to interdisciplinary research are funding and the tenure process. How should collaborative groups share funding for a joint project? Will young researchers in academia risk their careers by taking the time to learn about other fields and work on interdisciplinary problems that cross the boundaries of traditional academic departments, in which decisions about promotion and tenure are made? The report suggests ways that the structures and goals of funding agencies and academic institutions could be revised to mitigate these challenges and encourage scientists to tackle the world’s biggest scientific problems collaboratively.

In the spirit of the report’s recommendations, NAKFI conference focus groups were dispatched to their first of several brainstorming sessions to discuss major challenges at the crossroads between nanotechnology and biomedical and physical systems. The membership of each focus group was intentionally diverse, in order to apply a broad range of skills to each problem. The groups included researchers from science, engineering, and medicine, as well as representatives from private and public funding agencies, universities, businesses, and the science media. Researchers represented a wide range of experience – from postdoctoral fellows to well-established career scientists – from a variety of disciplines that included chemistry, biology, physics, engineering, bioinformatics, medicine, toxicology, and applied anthropology. The group members were expected to pool their insights and creativity to provide a concise statement of their problem, outline a structure for its solution, identify the most important gaps in science and technology, and make recommendations about how to bridge those gaps. They were also charged with considering the potential benefits to society and ethical risks that solving the problem might present.

The focus groups were not expected to solve their problems, but several of them learned through the process that a concise, elegant statement of a problem leads naturally to an innovative solution. After a total of eight hours of group discussion, three groups thought they had developed potentially patentable ideas, and the conference organizers were challenged to develop mechanisms by which groups could publicly announce their solutions without losing their intellectual property protection.

The NAKFI conference was a proof in principle that when great minds come together, to focus on specific problems, they can accomplish amazing feats. At focus group report-outs on the last day of the conference, each group presented its problem and findings. As the appointed group members spoke, the prevailing feeling was a sense that anything is possible. A hand-held environmental DNA detector can be built for quick and easy self-diagnosis of disease, or to determine the concentration of toxins in the air. A bio-battery, which would safely fuel implantation devices helping the blind to see, can be engineered to modulate output. Individualized medicine may be realized in the form of synthetic biofactories that can be engineered to monitor an individual's organs and produce enzymes that are dangerously lacking. You just have to ask the right questions. In a room full of people who don't speak the same scientific language, you must ask those questions very carefully, defining each and every term. The traditional hypothesis-driven scientific method is changing to reflect the method employed by the NAKFI conference focus groups.

Traditional disciplinary research also had a prominent role at the conference. Between focus group meetings, conference participants presented poster sessions of the current research being conducted in their labs. These sessions provided an opportunity for scientists to network and learn about advances in research from other scientists in one-on-one conversations.

Another major component of the *Futures Initiative* is the National Academies award for communicating science. Each year, three \$20,000 Communication Awards are presented – one each for a book author; a newspaper, magazine, or online journalist; and TV/radio correspondent or producer – to recognize excellence in reporting and communicating science, engineering, and medicine to the public. Without talented writers and broadcasters, who bring details of the exciting potential of science and technology to nonscientists, the public's only exposure to what's happening in the lab may be through sensationalist science fiction novels and movies. To properly educate policy makers, businesspeople, and young future scientists, and to present a realistic platform on which to discuss the real ethical issues surrounding research, science communicators must carefully construct articles, books, and broadcasts that are scientifically accurate and, at the same time, accessible and interesting to those not trained in science. Matt Ridley was awarded a 2004 Communication Award for his book, *The Agile Gene: How Nature Turns on Nurture*, an insightful synthesis of how modern genetics has illuminated the age-old nature-nurture debate. Robert Lee Hotz was honored with an award for his gripping narrative on the space shuttle Columbia accident, "Butterfly on a Bullet." And Sue Norton and David Clark were honored for presenting the importance of engineering in scientific exploration in their stunning film, "Science of the Deep: Mid-Water Mysteries," broadcast on *The Science Channel*. In addition, as part of NAKFI's commitment to science communication, ten graduate student science writers were invited to attend the conference. Each writer joined a focus group and was responsible for writing a report of the group's work.

The NAKFI ideal of enhancing communication among researchers, funding agencies, universities, and the public while stimulating interdisciplinary research at the frontiers of science was realized through the creative teamwork of the *Designing Nanostructures* meeting participants. Nanoscience and its application to biomedicine are at the cutting edge of research, and the partnerships formed at the conference are likely to have a significant impact on future research applying nanotechnology to biomedical problems.

On December 29, 1959, at the annual meeting of the American Physical Society, the great physicist Richard Feynman conceived of manipulating materials on the atomic scale. Though he did not use the word "nanoscience," he generated excitement in the idea that controlling particles to advance technology and enhance human existence would one day be possible. "In the year 2000, when they look back at this age," Feynman predicted, "they will wonder why it was not until the year 1960 that anybody began seriously to move in this direction." After 100 years of quantum mechanics and 55 years of nanoscience, researchers are making great leaps forward in harnessing the potential of nanotechnology. The Keck

Futures Initiative conference was an important step forward in the progress of this exciting field.