

## Building Scientific Progress without Borders: Nanobiology and Nanomedicine in China and the U.S.

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### Introduction

In recent years, growing numbers of nanomaterials and nanotechnology applications have been used as novel imaging, diagnostic, and therapeutic agents in the treatment of cancer and other diseases. The safe and effective development and use of these new nanotechnologies will require coordinated effort among diverse groups of international experts including basic scientists, toxicologists, clinical researchers, policymakers, and others. The first Joint China-U.S. Symposium on Nanobiotechnology and Nanomedicine was convened October 21 to 23, 2008, in Beijing, China, to address these and other emerging issues and opportunities (Supplementary Fig. S1). The goal of the symposium was to share experiences and exchange information pertaining to the development of nanotechnology for medical use including the prevention, detection, and treatment of disease, and ensuring the safety of the general public and of personnel working in the field. The symposium also provided a platform for exploring the development of new research collaborations among top Chinese and American scientists.

This symposium was organized in response to recent major investments in nanobiology and nanomedicine both in China and in the United States, respectively. Discussions focused on nanotechnology applications for cancer diagnostics and therapeutics, given the substantial advances in this field. The organization of the meeting was collaboratively developed by the National Center for Nanoscience and Technology of China, a leading nanotechnology research institution, and by the Chinese Academy of Sciences and Ministry of Science and Technology of China, as well as by the National Cancer Institute of the NIH and its Alliance for Nanotechnology in Cancer, and by the NIH's National Institute of Environmental Health Sciences. Additional key supporters included the NIH Office of the Director, and the Trans-NIH Nanotechnology Task Force. The meeting was initiated under the auspices of an agreement cosigned by Executive President, Dr. Chunli Bai

(Chinese Academy of Sciences, Beijing, China); Former Director, Dr. Elias A. Zerhouni (NIH, Bethesda, MD); Director, Dr. John E. Niederhuber (National Cancer Institute, Bethesda, MD); and by Former Acting Director, Dr. Samuel Wilson (National Institute of Environmental Health Services, Research Triangle Park, NC). The Symposium Organizing Committee included Dr. Yuliang Zhao (Institute of High Energy, Beijing, China), Dr. Xing-Jie Liang (National Center for Nanoscience and Technology of China, Beijing, China), Dr. Robert Blumenthal (National Cancer Institute, Bethesda, MD), Dr. Michael M. Gottesman (National Cancer Institute, Bethesda, MD), and Dr. Piotr Grodzinski (National Cancer Institute, Bethesda, MD), Dr. Sally Tinkle (National Institute of Environmental Health Services, Research Triangle Park, NC), Dr. Kuan Wang (National Institute of Arthritis and Musculoskeletal and Skin Diseases, Bethesda, MD), and Dr. Nancy E. Miller (National Cancer Institute, Bethesda, MD). Eighty scientists and research physicians attended the meeting. The U.S. delegation, composed of 30 invited leading scientists and policy experts, was led by Dr. Michael M. Gottesman, Chief, Laboratory of Cell Biology, National Cancer Institute (NCI), NIH, and Deputy Director for Intramural Research, NIH (Supplementary Fig. S2). Chinese attendees included participants from 30 universities and research institutes.

### Report

Six sessions of the symposium covered topics ranging from molecular investigations of nanoparticles for medical applications, the effect of engineered nanomaterials on human health and on the environment, to the development of nanoparticles for targeted delivery in cancer therapy and imaging, and the promises and challenges of using nanomaterials in clinical applications (Supplementary Table S1). The opening session reviewed nanomedicine programs and activities in China and the U.S. Dr. Yuliang Zhao (Institute of High Energy, Beijing, China) welcomed symposium attendees and provided a brief introduction and background regarding the meeting. Dr. Chen Wang (National Center for Nanoscience and Technology of China, Beijing, China) presented an overview of nanoscience and nanotechnology research in China, touching upon the current research framework, policy concerns, progress in nanostandardization, and potential societal effects of nanotechnology. He was followed by Dr. Xiaohan Liao (Ministry of Science and Technology of China, Beijing, China) and by Drs. Minghua Liu (Chinese Academy of Sciences, Beijing, China) and

**Note:** Supplementary data for this article are available at Cancer Research Online (<http://cancerres.aacrjournals.org/>).

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Zhifang Chai (Institute of High Energy, Beijing, China), who voiced the support of these important Chinese scientific organizations regarding the value of promoting new discoveries in nanobiology and nanomedicine.

The first session presented an overview of key NIH-supported nanomedicine activities and highlighted national and international nano policy concerns. NCI Alliance for Nanotechnology in Cancer was introduced as a major NCI program that supports extramural investigators and a Nanotechnology Characterization Laboratory at NCI-Frederick. Research themes and team-building strategies were described in eight NIH Nanomedicine Development Centers on behalf of the NIH Roadmap Nanomedicine Implementation Team. In addition, a talk on multidrug resistance in cancer highlighted the potential for nanotechnology to accelerate progress in this area. How metallofullerenes used as nanochemotherapeutics can potentially inhibit tumor growth was also illustrated. These presentations were followed by a panel discussion addressing similarities and differences between the U.S. and China both in the structure of the field and in the conceptual approach to research.

The second session focused on the molecular basis of nanomedicine, which included examples of both basic and mechanistic studies using nanomaterials in therapeutics and diagnostics. Key topics discussed in this session included results of investigations of cell processes at the nanoscale, and recent work in applying knowledge of molecular and cell biology to design and fabricate nanoparticles that are effective for biomedical applications.

The third session addressed the molecular basis for engineered nanomaterial interactions with human health and the environment. Some of the presenters in this session described specific studies of the safety and environmental effect of specific types of nanomaterials; however, an important overarching theme addressed in this session was the need to develop novel systematic approaches for evaluating and predicting potential toxic effects of large numbers of different nanomaterials.

The fourth session focused on the development of "smart" nanoparticles for cancer therapy and imaging. Presenters reviewed recent studies of specific nanoparticles in cancer imaging and therapy, including fluorescent semiconductor quantum dots, ferromagnetic nanoparticles, and integrin-targeted liquid perfluorocarbon nanoparticles. Other presenters described overall design criteria for developing new multifunctional nanoparticles, recent advances in the use of lithography for nanoparticle fabrication, and investigations of potential toxicologic adverse effects of nanoparticles of different sizes at the genomic and proteomic level.

The fifth session addressed biomarkers and targeted delivery. Several of the presentations in this session focused on studies that targeted different types of nanoparticles to tumor cells, including conjugation with ligands to improve targeting and performance. In addition, the importance of nanoparticle standardization and characterization was discussed.

The sixth session focused on the promise and hurdles of applying nanotechnology in the clinic. Several presenters reviewed studies of different types of nanoparticles such as nano C-60, carbon nanotubes, and polymeric micelles to improve drug delivery to cancer cells. Other talks focused on developing a detailed understanding of key cell processes and pathways that influence the uptake of different types of nanoparticles.

## Future Interactions

In addition to scientific presentations, members of the Symposium Steering Committee participated in two administrative meetings with representatives from the National Natural Science Foundation of China, a key Chinese scientific funding organization, and Chinese Academy of Sciences, to discuss mechanisms for encouraging future cooperation in nanobiology, nanomedicine, and other fields of biomedical research (Supplementary Fig. S3). Meeting participants discussed possible mechanisms for expanding China-U.S. cooperation, including the following: (a) developing joint research programs and grant solicitations, cooperative research agreements, and/or joint laboratories; (b) promoting additional training and exchange through predoctoral and postdoctoral fellowships, and short-term travel and training grants; and (c) supporting future joint workshops and conferences. In both administrative meetings, Chinese and U.S. representatives expressed a strong interest in developing new opportunities for cooperation, and agreed to identify research areas of mutual scientific interest based on the outcomes of the symposium.

## Prospects

During a discussion at the conclusion of the symposium, participants recommended developing a web or working site or other mechanisms to facilitate sharing of key resources and contacts to enable joint progress and collaboration. Such resources and contacts could include the following: specialized equipment, databases, tools, reagents and specimens, and clinical trial participation. The importance of recognizing intellectual property and export control issues in developing mechanisms for sharing information and resources between China and the U.S. in the field of nanobiology and nanomedicine was noted.

Additional key themes identified for future research included shared interests in implementing safe design for multifunctional nanoparticles; developing cost effective, nanotechnology-based diagnostics and interventions; and exploring cross-national cooperation in nanotechnology-related clinical trials. In addition to showcasing recent scientific progress in nanobiology and nanomedicine, the symposium helped build mutual understanding regarding one another's research enterprise. In coming months, symposium participants will actively explore the possibility in nanobiology and nanomedicine research and research training, to advance scientific discovery, enhance health and optimally identify, diagnose, and treat disease.

## Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

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