Nanotechnology in the US: Leading in an Increasingly Competitive World

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International Institute for Nanotechnology

Northwestern University

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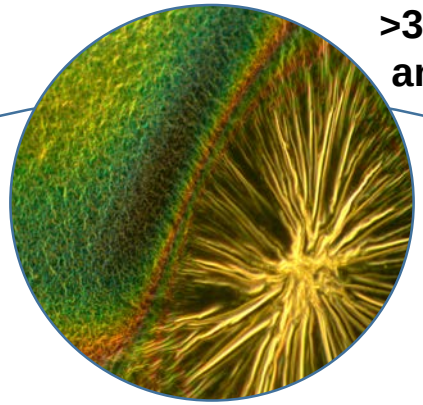
Northwestern University
Center for Nanofabrication and Molecular Self-Assembly

Northwestern University
Simpson Querrey Biomedical Research Center

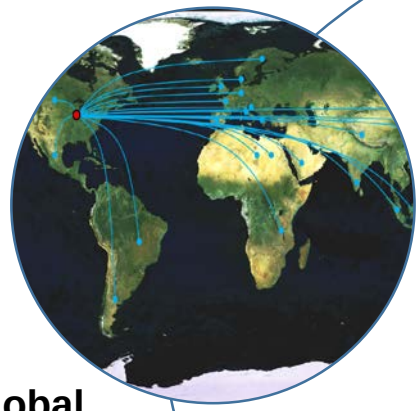
Argonne National Laboratory
Center for Nanoscale Materials

The first and the largest nanotechnology institute in the country

Uniting >$1 billion in Nanotechnology Research, Education, and Infrastructure



>36 Research centers and >20 shared/core facilities



Global Partnerships across six continents

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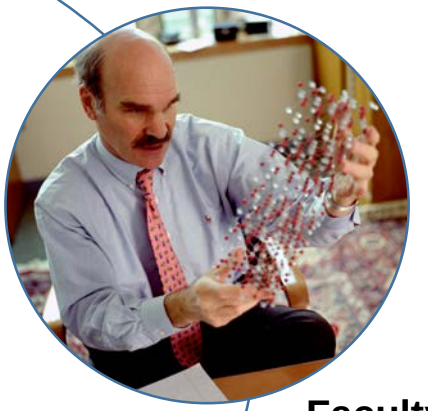
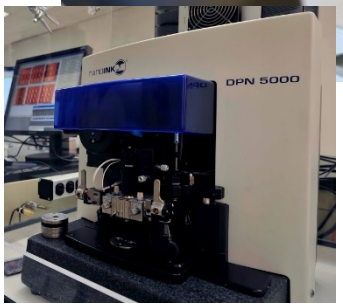


Faculty
>240 affiliated faculty members across 32 departments

Corporate Partners
>80 companies worldwide, including Baxter, GE, and Schlumberger

Students & Postdocs
>3,000, including NSF and NDSEG Fellows, and Fulbright, Rhodes, and Marshall Scholars

Translating Nanotechnology Innovations to the Marketplace



23 companies launched since inception

>2,000 commercial products

>$1 billion venture capital invested to-date

Nanosphere, Inc. (2000, Mirkin)
Integrated Microdevices (2001, Liu)
Ohmx Corporation (2003, Meade)
Nanodisc (2003, Sligar)
Acumen Pharmaceuticals, Inc. (2004, Klein)
Nanotope (2005, Stupp)
Polyera (2005, Marks)
SilenTech (2006, Sontheimer)
PreDx (2006, Meade)
NanoIntegris (2007, Hersam)
American Bio-Optics (2007, Backman)
SAMDITech (2007, Mrksich)
NanoSonix (2008, Dravid)
AuraSense (2009, Mirkin)
Citrics BioMedical (2009, Ameer)
iNfinitesimal (2010, Espinosa)
Exicure (XCUR, 2012, Mirkin)
PanaceaNano (2012, Stoddart)
NUMat Technologies (2013, Farha)
TERA-print (2015, Mirkin)
Azul 3D (2016, Mirkin)
Zylem Biosciences, Inc. (2018, Thaxton)
Vybyl Biopharma (2018, Gianneschi)

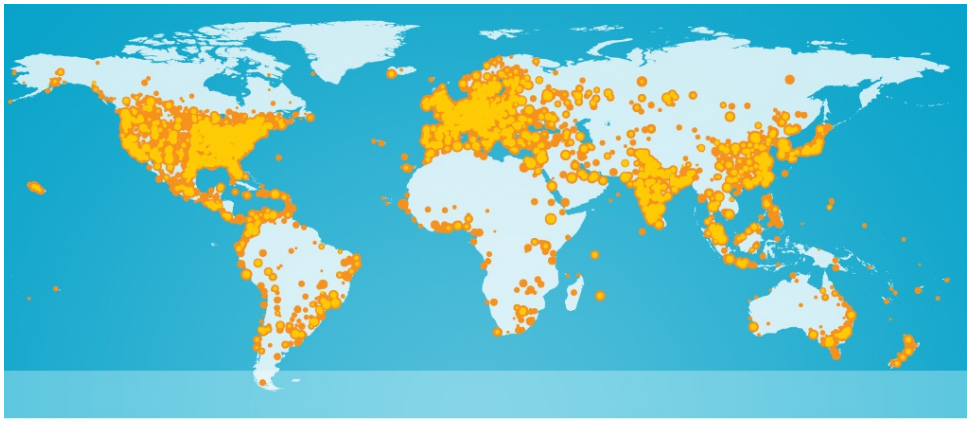
Outline

- **What is the current state** of nanoscience and nanotechnology resulting from the NNI as authorized in 2003?
- **How does the US compare** to other nations with respect to nanotechnology research and development?
- **Should the NNI continue** and **what should the NNI be doing?**
- **What are critical research areas** where the US should be the world leader to best achieve the goals of the NNI?

The NNI has Established World-Leading Academic Infrastructure

Academic research facilities

- NSF Nanoscale Science and Engineering Centers
- NSF Nanosystems Engineering Research Centers
- NCI: Centers of Cancer Nano. Excellence, Innovative Research in Cancer Nanotech., Cancer Nanotech. Training Centers
- EPA Centers for the Environmental Implications of Nanotechnology
- NSF's National Nanotechnology Coordinated Infrastructure
- Network for Computational Nanotechnology



Global reach of nanoHUB from the Network for Computational Nanotechnology (nanohub.org)

Graphic from National Nanotechnology Coordinated Infrastructure (nnci.net)

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The NNI has Established World-Leading Federal Infrastructure

Federal research facilities

- NCI's Nanotechnology Characterization Laboratory (Frederick, MD)
- NIST's Center for Nanoscale Science and Technology (Gaithersburg, MD)
- DoD Naval Research Lab.'s Institute for Nanoscience (Washington, DC)
- Five DoE Nanoscale Science Research Centers (NSRCs)

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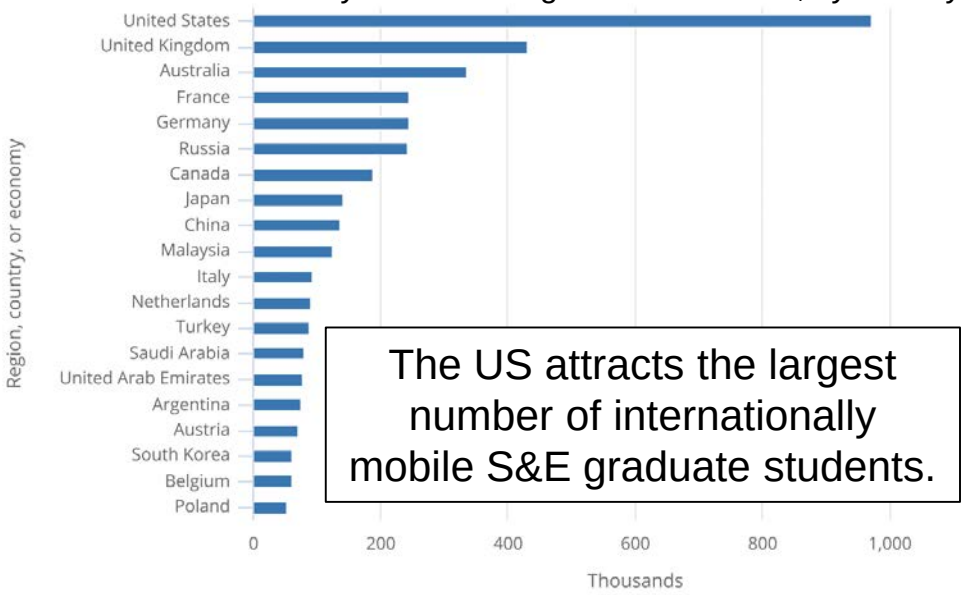
Graphic from Argonne National Laboratory (anl.gov)

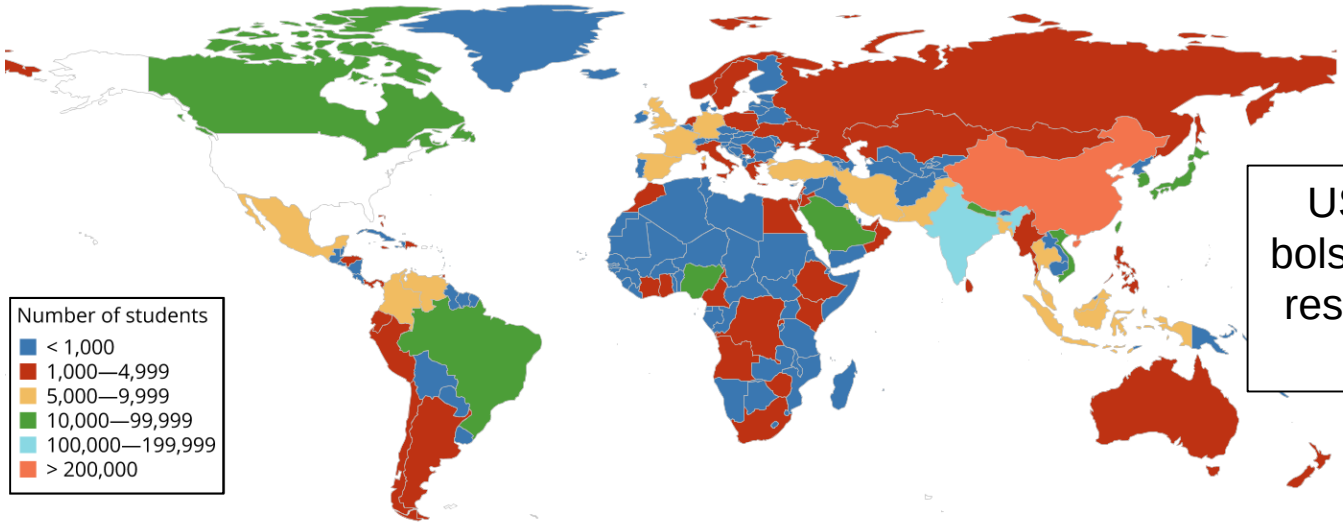
NNI-Supported Infrastructure Attracts World-Class Talent

Nanotechnology in the US leads by recruiting the best researchers from around the globe

Number of internationally mobile S&E graduate students, by country



The US attracts the largest number of internationally mobile S&E graduate students.



US nanotechnology is bolstered by the talents of researchers from almost every country

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National Science Board, Science & Engineering Indicators (2018): NSF Publication NSB20197.

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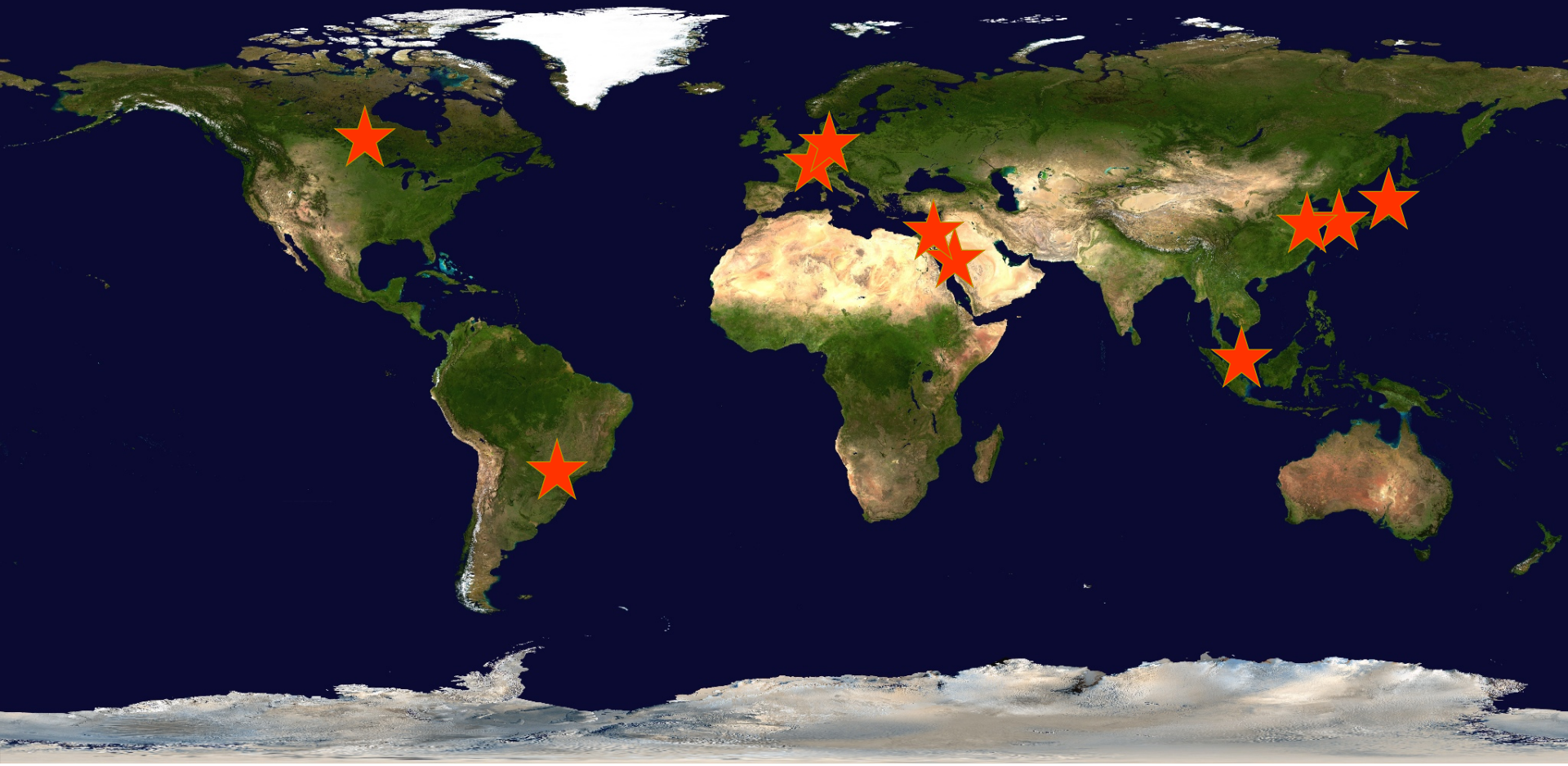
Where is the US Global Nanotechnology Competition?



China Singapore Saudi Arabia Canada Israel

Japan South Korea Switzerland Germany Brazil

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China is Developing Numerous Nanotechnology Centers

National Center for Nanoscience and Technology (NCNST) has co-founded 19 collaborative laboratories with Tsinghua University, Peking University, and Chinese Academy of Sciences (CAS).

Chinese institutes and research centers are growing and becoming world-renowned nanotechnology hubs:

- CAS, Suzhou Institute of Nano-Tech and Nano-Bionics
- CAS, Beijing Institute of Nanoenergy and Nanosystems
- Shanghai Jiao Tong University, National Engineering Research Center for Nanotechnology
- Hunan University, Institute of Chemical Biology and Nanomedicine (ICBN)

Singapore and South Korea Continue to Develop their Research Programs in Nanotechnology

Institute of Bioengineering and Nanotechnology (IBN), the world's first bioengineering and nanotechnology research institute

Nanyang Technological University (NTU)-wide network of research centers with shared facilities for nanofabrication, nanocharacterization and nanotechnology applications, called ***NanoCluster***

Korea Advanced Institute for Science and Technology (KAIST) Graduate School of Nanoscience and Technology acts independently to house experts pursuing nanoscience technology.

Korea Advanced Nano Fab Center (affiliated with KAIST) establishes country-wide support for nanodevices

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US is Losing Top Talent and Research Output

Top talent is moving overseas due to improving foreign infrastructure

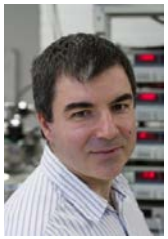
Dr. Weihong Tan
Professor, Hunan University

Dr. Michael Sheetz
Professor, National University of Singapore

Dr. Steve Granick
Founding Director, Center for Soft and Living Matter, Korean Institute for Basic Science

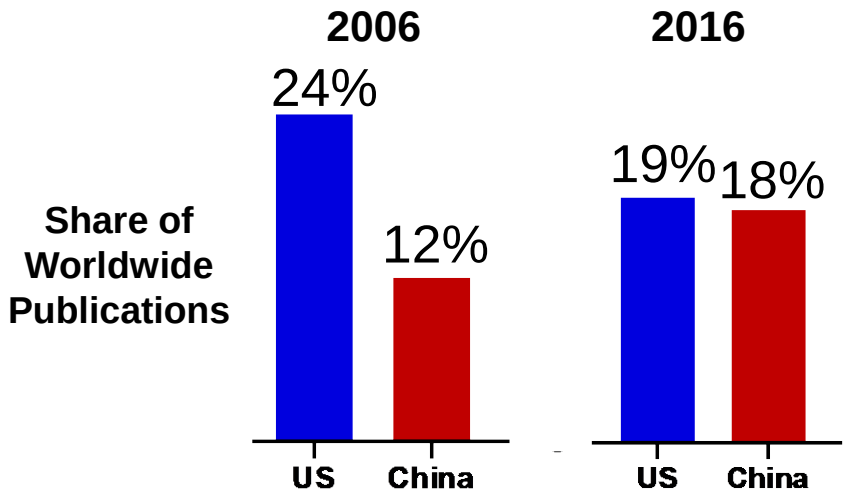
Dr. Dean Ho
Professor, National University of Singapore

Dr. Xiaoliang Sunney Xie
Professor, Peking University



Professor Sir Konstantin Novoselov
Professor, National University of Singapore

The consequences of losing top talent…



US is ranked 5th in scientific nanotechnology article output per million population (behind Switzerland, Republic of Korea, Germany, and France)

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National Science Board, Science & Engineering Indicators.
Thomson Reuters' data cited by the UNESCO Science Report.

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The NNI Must Continue and Grow to Further Accelerate Progress in Nanotechnology in the US

Compare drug discovery…

1960s
Cholesterol synthesis enzyme (HGMR) identified

1970s
Lovastatin discovered as an inhibitor of HGMR

1996
Atorvastatin receives FDA approval for medical use

LIPITOR

35 years

…to the NNI's investment in nanotechnology

$23 billion investment
>60 world-class facilities
thousands of researchers
only 16 years

*The inter-agency **collaborative** approach of the NNI is uniquely placed to rapidly build nanotechnology expertise in the US*

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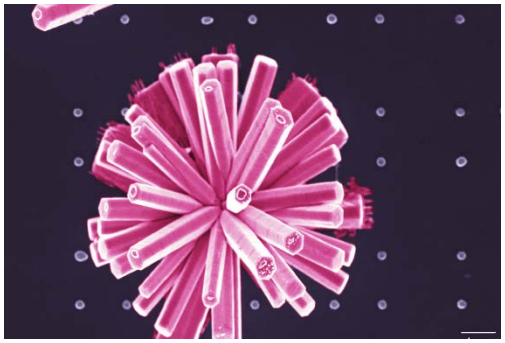
Images show SHyNE, an NSF-NNCI facility located at Northwestern University

Priorities for the NNI over the Next Four Years



Continue to develop fundamental knowledge towards new discoveries

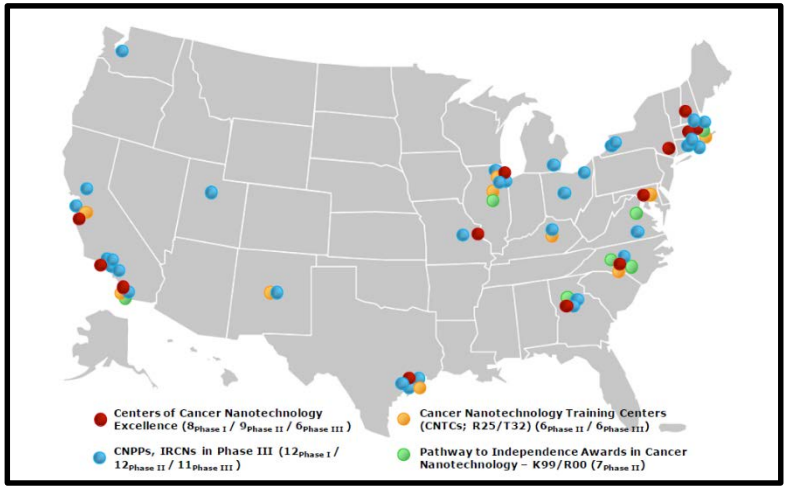
Support engineering of discoveries into new technologies and their translation to market

Recruit and retain top talent from across the globe and invest in their success in the US

The Best Infrastructure Attracts The Best Talent

The NNI cannot be complacent; infrastructure needs to have continuing support (centers, facilities) to retain the best researchers

Northwestern University Center for Nanofabrication and Molecular Self-Assembly



NIH-Sponsored Centers for Cancer Nanotechnology Excellence (CCNEs)

Argonne National Laboratory Center for Nanoscale Materials

Losing Talent is Not a Winning Proposition

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In Terms of Approach, NNI Support Must be Directed Both to Centers and Individuals

Centers

- Focal point for some research fields
- Foster interactions between disciplines
- Enhanced researcher mobility to access facilities
- Stronger federal-academic-industrial collaborations

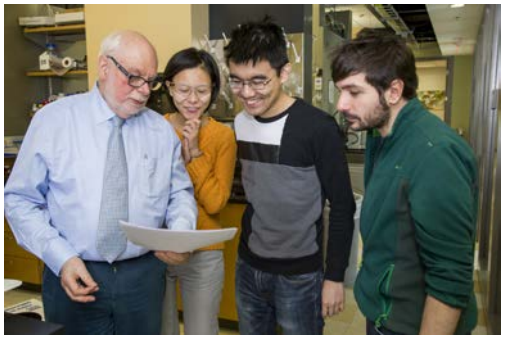
Individuals

- Commitment to top talent
- Longer-term funding to enable high-reward explorative research
- Larger individual grants to allow institutions and individual research groups to reach a critical mass for innovation

The NNI Must Make Science Relevant and Interesting to the Public

Enhance the visibility of science by engaging and educating the general public

Encourage translation of new knowledge into products on the market to improve lives



Foster a welcoming environment for all, including foreign scientists

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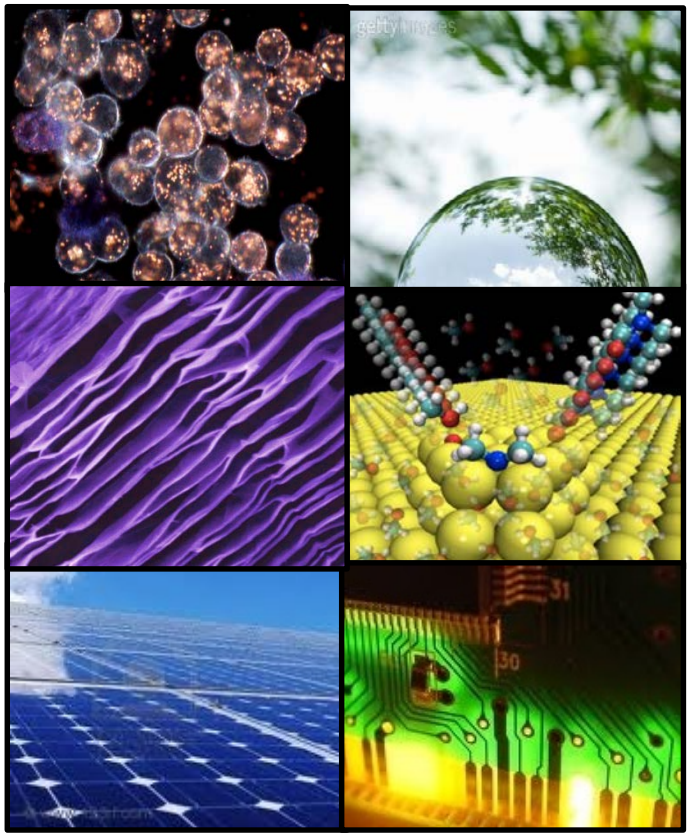
Critical Research Areas

Medicine

Materials & Devices

Energy Solutions



Clean Environment Solutions

Catalysis

Security & Defense

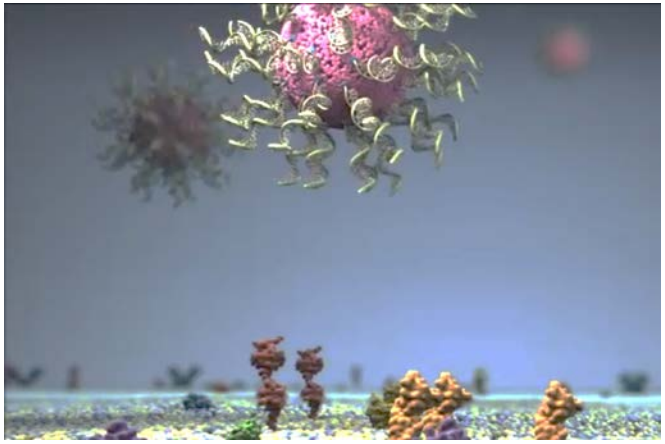
To achieve the goals of the NNI, the US must be a world leader in these areas

Future Research Priorities: Medicine

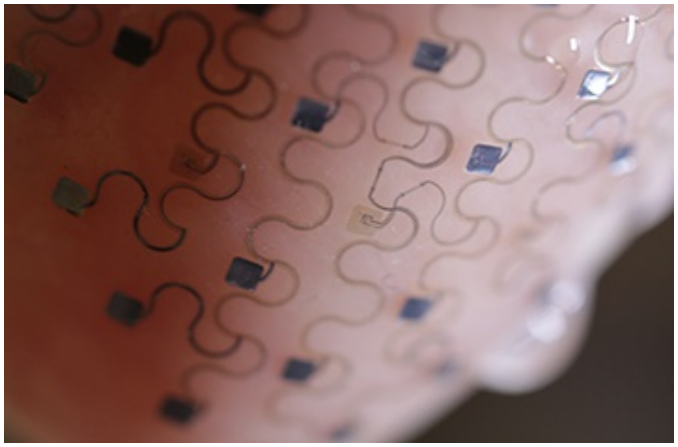
Nanomedicine has the greatest chance to make the largest impact, not only to **treat** disease, but to **cure** it.

Engineered immunity

Gene regulation



Targeted drug delivery



Injectable and wearable electronics

Future Research Priorities: Energy and Environment

Reduced dependence on fossil fuels

Clean water

Food manufacture and processing

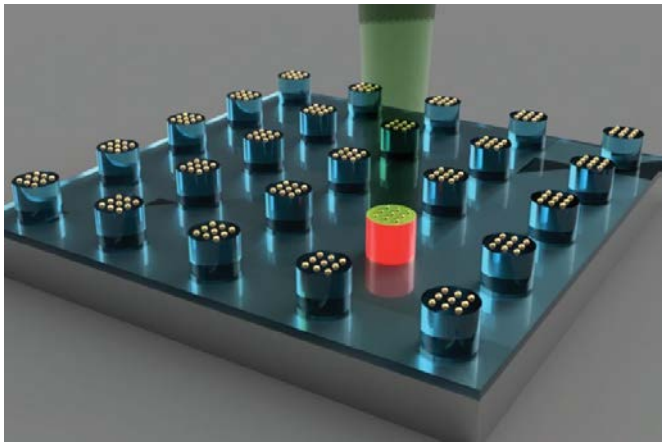
Chemical catalysis

Future Research Priorities: Defense

Nanoalloy materials

Lasers, photonics, and optics

Impact-resistant armor



High-throughput discovery

Conclusion: The US Needs the NNI to Remain Competitive

We must retain talent and pursue science at the highest levels to remain the world leader in nanoscience and nanotechnology

- Investment in centers, individuals, and partnerships
- Support for science at all levels, from K–12 to multi-PI centers
- Engagement with the general public to bolster trust in science
- Translation of knowledge to bring products to market