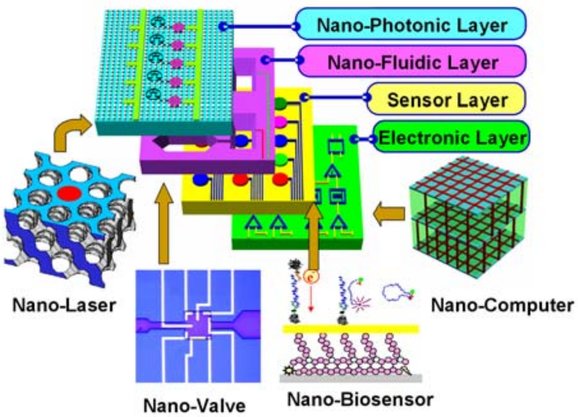
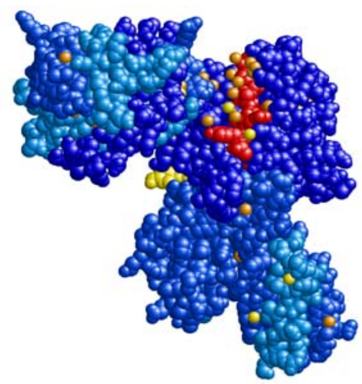
SYSTEMS NANOTECHNOLOGY

NSF leads the nation in fundamental nanoscale science and engineering research. This leadership is both in NSF's launching and subsequent support of the interagency National Nanotechnology Initiative (NNI), and through its own investments in nanoscale research. Support for nanotechnology research and education is a central component of the National Competitiveness Initiative.

The rudimentary capabilities of nanotechnology today for systematic control and manufacture at the nanoscale are evolving into four overlapping generations of nanotechnology products: passive nanostructures, active nanostructures, systems of nanosystems with three-dimensional features, and heterogeneous molecular nanosystems. Understanding interactions among nanostructures and their collective behavior in systems will become a central research topic for discoveries and innovation toward new industrial and medical applications.



Conceptual schematic of a manufactured nanosystem
(X. Zhang, UCLA)



Conceptual schematic of a biosystem

Systems nanotechnology deals with understanding, control and use of interdependent nanoscale components linked in a network, interacting at their nanoscale interfaces, and collectively leading to new functionalities. The following areas are recommended for increased research and education:

- Understanding mechanisms and patterns of system behavior as a function of components, interaction forces and networks at the nanoscale. Emerging behavior of systems with large number of nano-components is of special interest. Several priorities are understanding and use of quantum phenomena, selfassembling and evolutionary dynamics in nanosystems. An example is connecting quantum predictively across length and time scales with the macro properties of molecules and materials. Another example is system dynamics of catalysts, proteins (the smallest class of biological machines with emerging behavior), cells, tissues, and nervous systems.
- Tools for measuring, simulation and restructuring matter with atomic precision, time resolution of chemical reactions, and for domains of relevance to systems engineering and systems biology. A focus will be on new tools for characterization of nanoscale phenomena in biological systems, including mechanical properties at the cellular and sub-cellular levels.
- Study of typical applications of systems nanotechnology with a focus on new system architectures for various functionalities and applications:
  (1) nanoelectronics with research targets such as replacing electron as carrier of information in logic and storage devices, and new circuits and architectures for developing computing platforms with nano-scale devices;
  (2) nanomanufacturing of large systems, with a special focus on "just-in-place, just-in-time" production;
  (3) hybrid nanobiosystems;
  (4) new sensors with nanoscale features for use in medicine, agriculture and basic biological research;
  (5) energy conversion and storage systems; and
  (6) water filtration systems.
- Nano-informatics for better communication and nanosystem design, including defining the ontology of terms, interconnecting databases, using specific informatics tools, and connecting to bioinformatics.

Analysis of environmental, health, societal, ethical, and policy implications of nanotechnology for active nanosystems. Development of a new framework for risk management that can address evolving nanostructures and emerging functions of nanosystems with potential use in consumer products, medical treatments, food industry and other areas. *(NSF NNI priorities in FY 2009, NSE Group - M. Roco)*

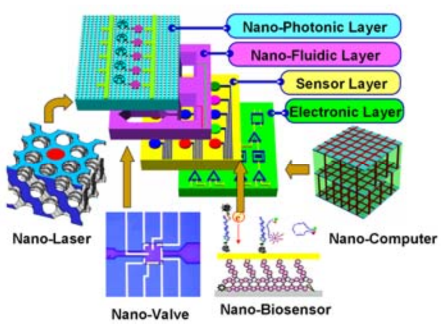
Toward the next generation of systems nanotechnology

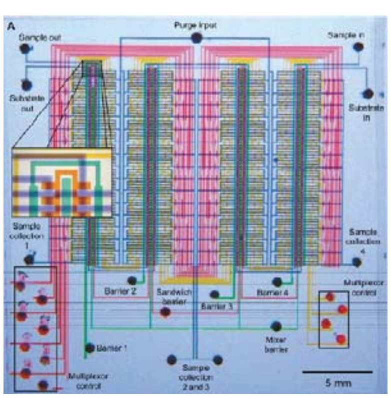
The potential of successfully manipulating matter at the nanoscale is only beginning to be realized. The next frontier in nanotechnology is to create controllable systems built from nanoscale components. Understanding interactions among nanostructures and their collective behavior in systems will become a central research topic for discoveries and innovation toward new industrial and medical applications.

Currently, nanotechnology research has applications mainly in passive nanostructures and devices, such as coatings and sensors. The next step is to bring nanoscience and nanoengineering to a new level, in which nanoscale building blocks are parts of larger systems that are designed to perform specific tasks. Complex nanosystems with emerging behavior are included. The field of systems nanotechnology aims to understand, control and use interdependent nanoscale components linked in a network, interacting at their nanoscale interfaces, and collectively leading to new functionalities. It also aims to integrate nano and micro structures and new molecular design.

Such systems will support crucial applications, such as petascale computing; designing-in properties by manufacturing materials from the nanoscale; regenerating human tissue and organs from the nanoscale; designing systems of nano-sized sensors for use in medicine, agriculture, biological research, or national security; selectively filtering harmful particles from water; and manufacturing devices, such as solar cells, that efficiently convert and store renewable energy.

Conceptual schematic of a manufactured nanosystem. The hope for this device is its use to identify the molecular signature of breast tumors. ***X Zhang, 0725886***





Integrated circuits that are smaller and faster are possible with microfluidics systems built from or incorporating nanocomponents. At right is a microfluidic chip incorporating 2056 integrated valves in an area of one square inch (image courtesy of Thorsen et al.). NSF funding: ***Ferreira, 0328162,*** **for the Center for Nano-Chemical-Electrical-Mechanical Manufacturing Systems.**