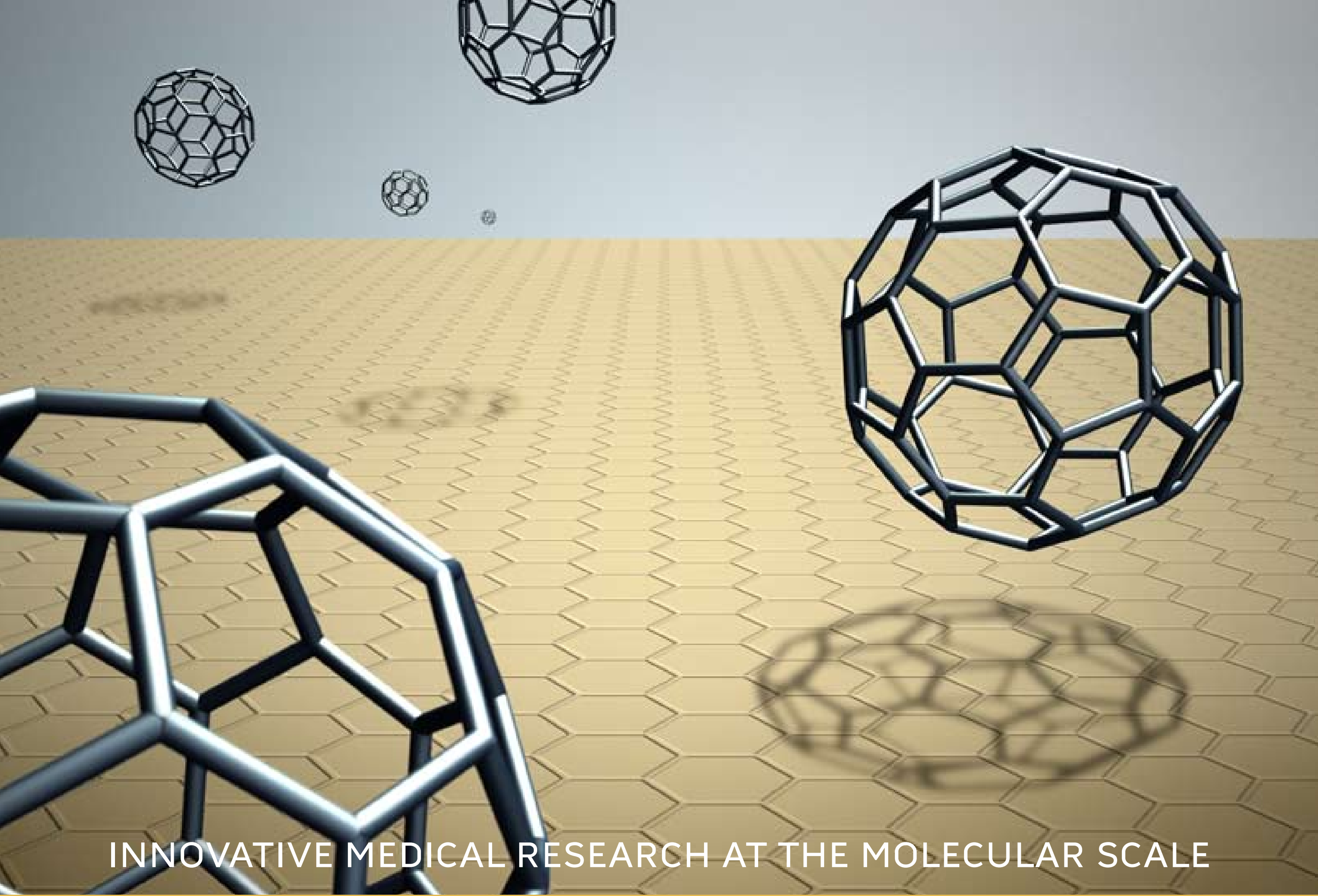
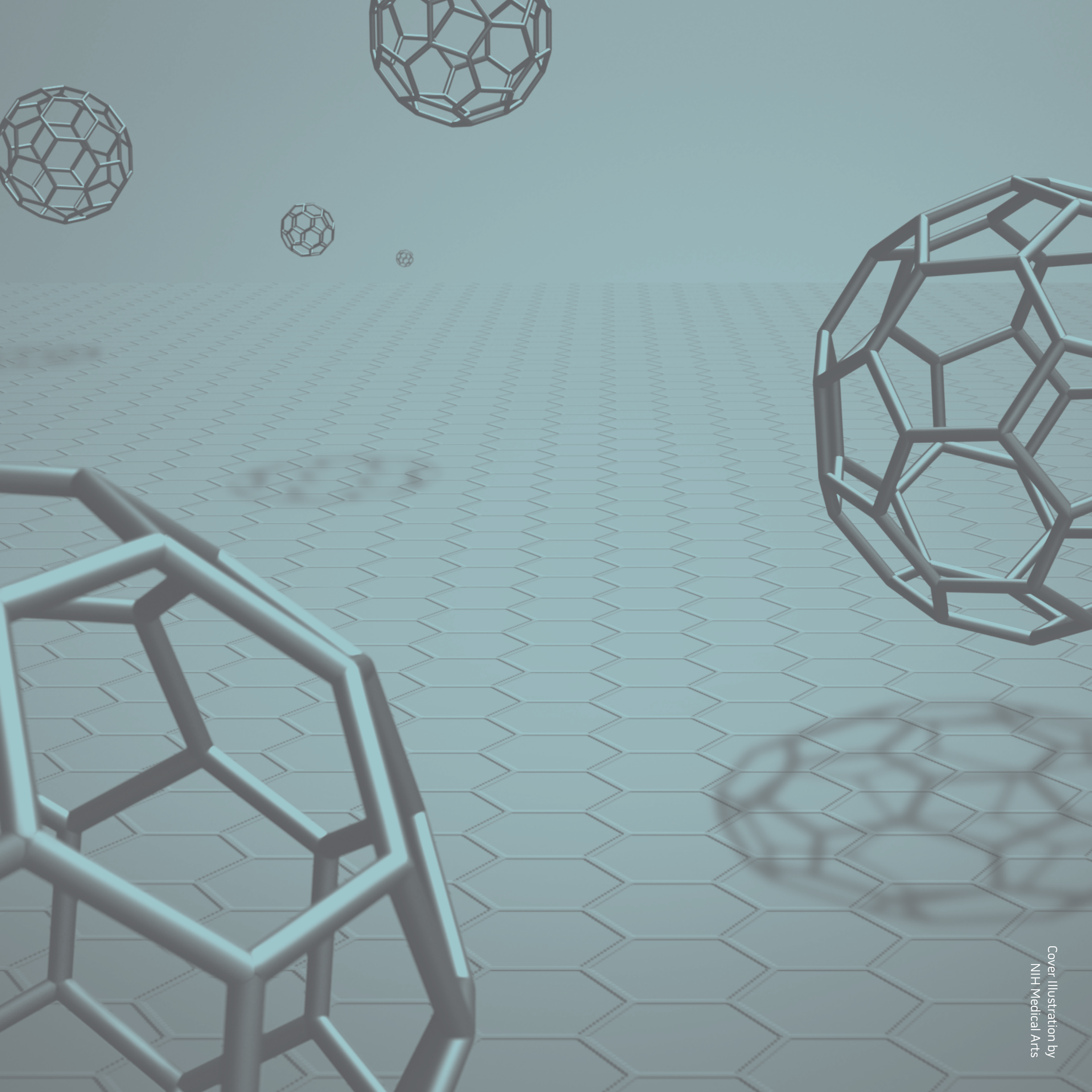


INNOVATIVE MEDICAL RESEARCH AT THE MOLECULAR SCALE

Nanotechnology

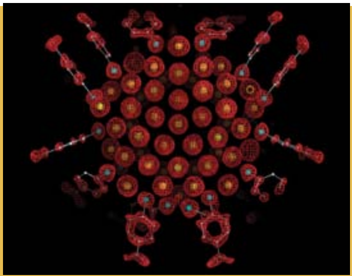
AT THE NATIONAL INSTITUTES OF HEALTH



Cover Illustration by
NIH Medical Arts

WHAT IS NANOTECHNOLOGY?

Nanotechnology is defined as the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, a scale at which unique properties of materials emerge that can be used to develop novel technologies and products. At the nanoscale, the physical, chemical, and biological properties of materials differ from the properties of matter either at smaller scales, such as atoms, or at larger scales that we use in everyday life such as millimeters or inches. Nanotechnology involves imaging, measuring, modeling, and manipulating matter only a few nanometers in size.



What is nanoscale?

A nanometer is a billionth of a meter.

A DNA molecule is 2 nanometers in diameter.

Protein molecules are about 10 nanometers in diameter.

A human hair is 100,000 nanometers in diameter.

Novel properties at the nanoscale

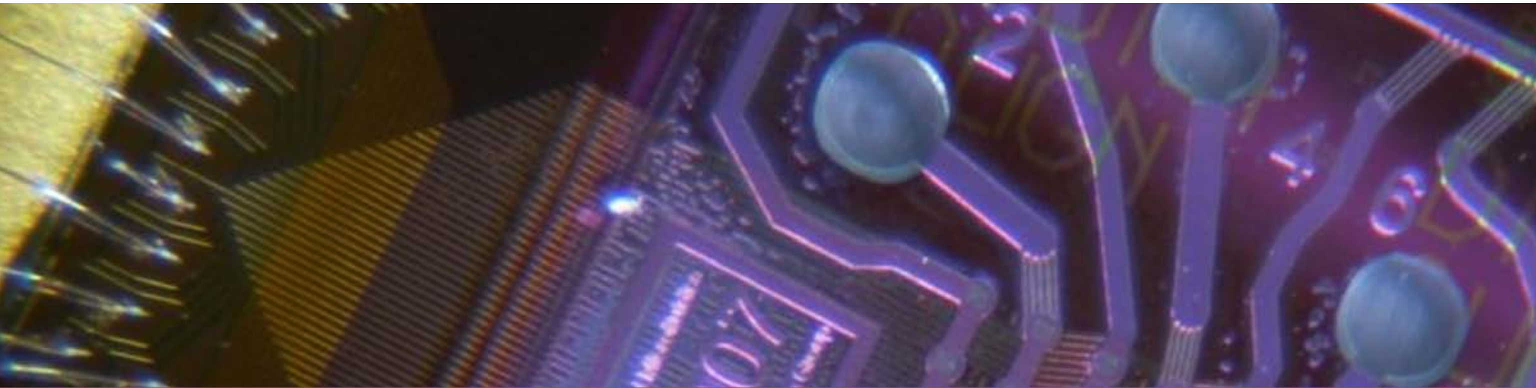
Many physical characteristics change dramatically as the size of a particle decreases to the nanoscale:

Carbon nanotubes are made of pure carbon, the same material that is found in pencil lead. But when the carbon atoms are arranged into tubes at the nanoscale, the material is stronger and stiffer than steel.

Gold nanoparticles are made of the same material as in jewelry. But when light interacts with nanoparticles of gold, different colors are reflected. The different colors can be used in simple medical tests to indicate infection or disease.

Metals such as copper become extremely rigid at the nanoscale, rather than bendable as in copper wires seen in everyday use.

Nanotechnology research calls upon a broad range of fields including engineering, physics, chemistry, materials science, biology, medicine, agriculture, environmental science, and manufacturing. In the future, nanomaterials will be used to improve energy usage and transmission, to form new modes of computing and computer storage devices, to improve and monitor the freshness of food, to construct lightweight, wear-resistant materials for the transportation and building industries, and to create safe and effective consumer products. Researchers are working on hundreds of other potential applications.



Researchers at the Center for Cancer Nanotechnology Excellence focused on Therapeutic Response (CCNE-TR) from Stanford University are working on developing rapid diagnostic assays based on detection of magnetic nanoparticle labels. Imaged here is a microfluidic magneto-nano chip with 8 by 8 sensors arrays and 8 microfluidic channels mounted on a chip carrier and an electronic test board. These chips are being developed to monitor protein profiles in blood samples from cancer patients to improve therapeutic effectiveness. The key to this technology is the use of magnetic nanoparticles to label protein molecules which are then accurately counted by the magneto-nano chip. Image courtesy of Professor Shan X. Wang, PhD, and Sebastian J. Osterfeld, PhD.

NANOTECHNOLOGY RESEARCH AT NIH

Currently, the National Institutes of Health (NIH) invests about $200 million each year in biomedical nanotechnology research. This research ranges from fundamental studies on the properties of nanomaterials to investigations of potential health and safety issues of nanotechnology products as they interact with the human body and our environment.

Novel materials are being developed for ultrasensitive identification and detection of important molecules that change in the body when a disease strikes. Measuring changes in these disease markers will enhance our ability to understand, diagnose, and treat many diseases. Other types of nanostructures are being designed to deliver medicines directly to diseased or damaged cells and tissues in the body to accelerate the healing process. New diagnostic methods and treatments are emerging as we learn to control the manufacture of nanomaterials and their actions in the body.

Nanotechnology Research for Better Health

Scientists are developing nanoscale diagnostic and therapeutic devices designed to improve health.

Medicine-coated nanoparticles for treating asthma
Nanoprobes for monitoring fatty plaques in blood vessels
Nanofibers for treating tooth decay
Nanoelectrodes for use in regaining brain function

This is an image of topoisomerase I wrapped around DNA, from the laboratory of Nynke Dekker, Kavli Institute of Nanoscience, Delft.

Health and Safety Issues

While nanotechnology holds much promise for the future, challenging issues exist related to health and safety. The NIH is funding research to understand the health effects of exposure to engineered nanoscale materials that have been designed to detect, prevent, and treat illnesses. The NIH plays an important role in carrying out essential research that paves the way to establishing the safety of nanoscale materials and products.

NIH Nano Task Force

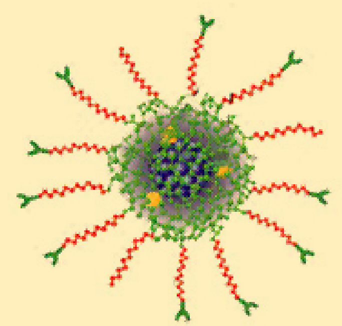
NIH comprises 27 institutes and centers that support research on most known diseases and tissues. Because nanotechnology has such widespread potential application, many individual institutes support nanotechnology research programs. Coordination of these efforts is accomplished by an NIH Nano Task Force that was established in 2006 to articulate a scientific vision for nanotechnology at the NIH; to inform the public and scientific communities about the NIH-supported research; to examine the need for health and safety research on the implications of nanomaterials; and to explore ethical, legal, and societal issues related to nanotechnology. Task force members also represent the NIH on federal interagency matters and at international meetings and activities related to nanotechnology.

NIH Nano Task Force Activities

Develop an overarching scientific vision for nanotechnology at the NIH

Develop strategies to communicate nanotechnology research breakthroughs to the public and scientific communities

Explore ethical, legal, and societal issues related to nanotechnology



The National Nanotechnology Initiative

The NIH participates in the National Nanotechnology Initiative (NNI), which coordinates the federal government's implementation of the 21st Century Nanotechnology Research and Development Act. Activities at the NIH represent about 15% of the $1.3 billion annual total government spending on nanotechnology research at more than two dozen federal agencies.

Researchers at the Northwestern University Center of Cancer Nanotechnology Excellence (NU CCNE) are using nanotechnology to develop highly sensitive diagnostic systems for cancer. The image above, taken with a transmission electron microscope, shows DNA-functionalized gold nanoparticles that have been assembled into a two-dimensional superlattice. DNA-functionalized gold nanoparticles are being used in a variety of high sensitivity biodiagnostic systems. Image courtesy of Professor Chad A. Mirkin, PhD, and Savka Stoeva, PhD.

NANOTECHNOLOGY RESOURCES

Information on many of the nanotechnology efforts across the NIH, as well as other federal agencies, can be found at the following websites:

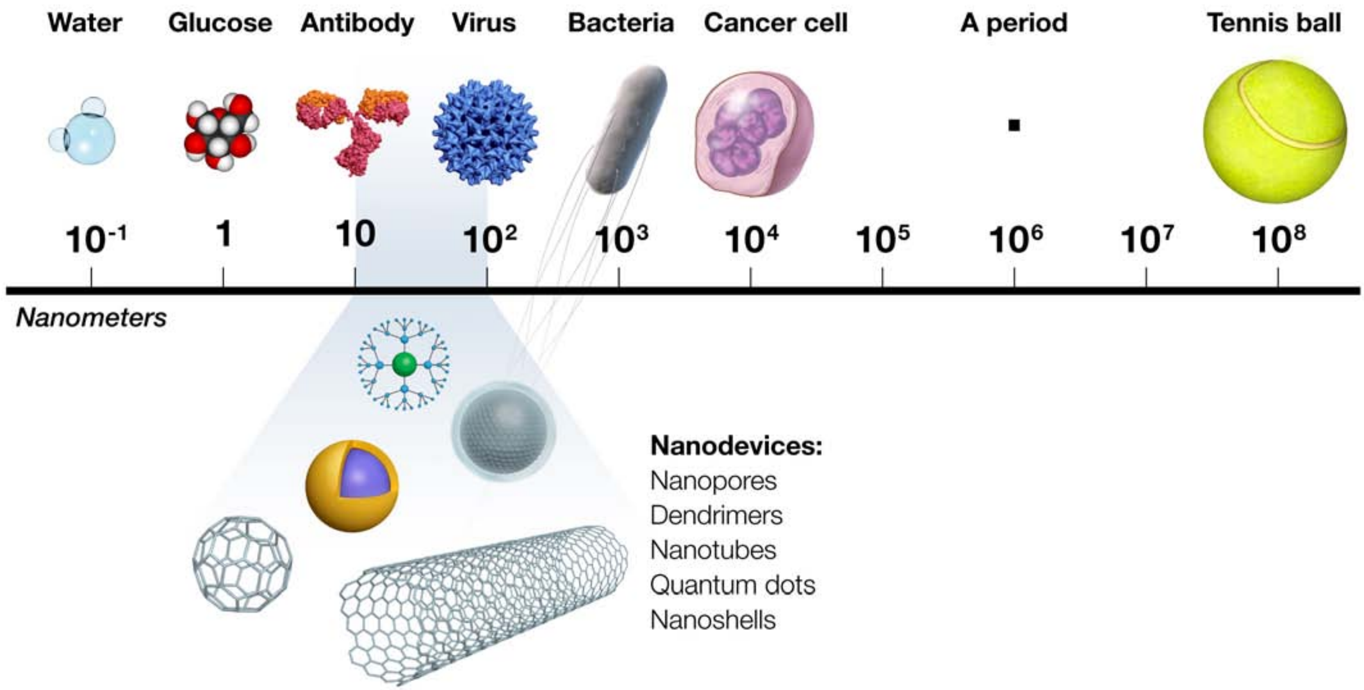
NIH Nano Task Force
A current roster of the representatives from NIH institutes and centers with nanotechnology portfolios
http://www.becon.nih.gov/nano_taskforce_010808.pdf

NIH Nanotechnology and Nanoscience Information
http://www.becon2.nih.gov/nano.htm

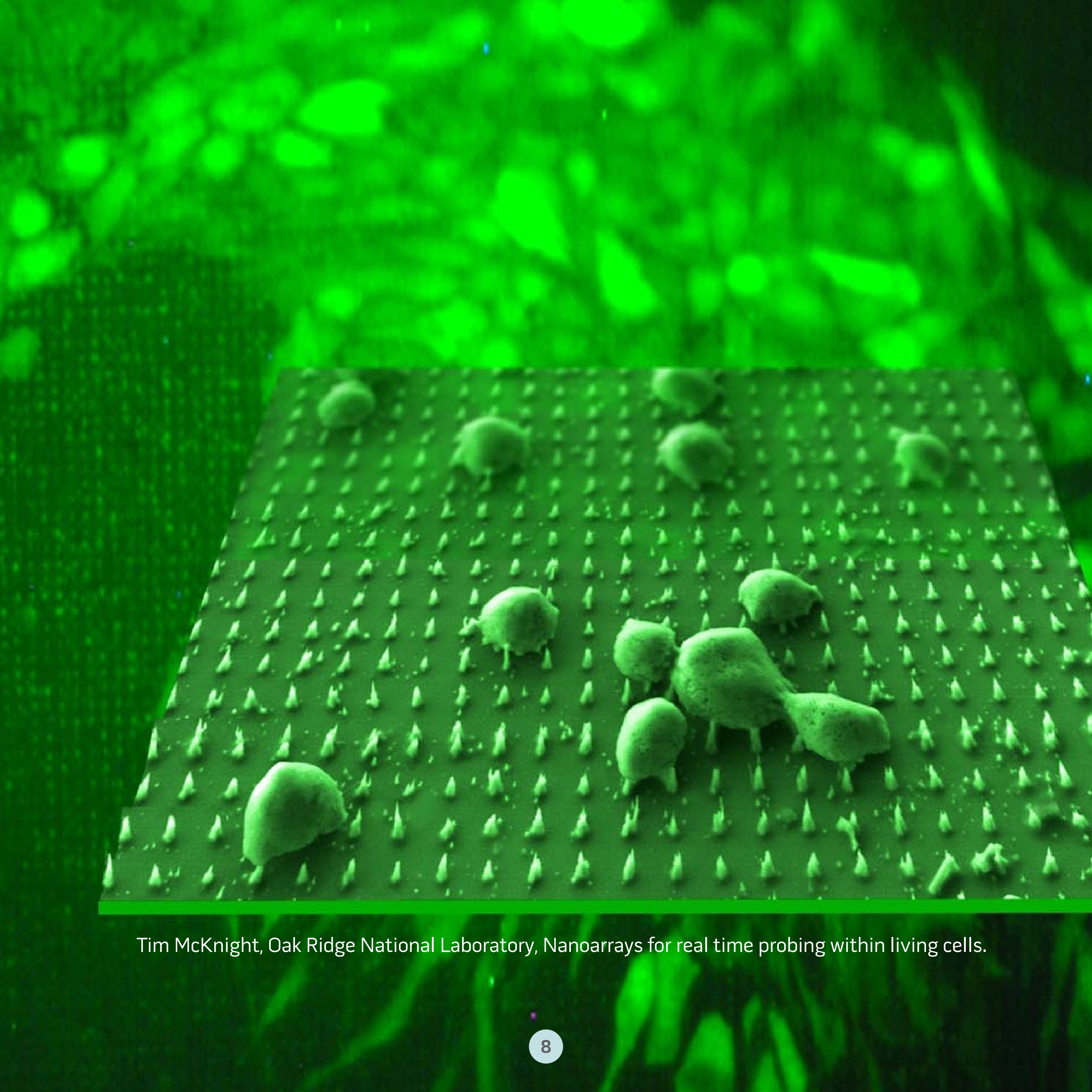
NIH Nano Health Enterprise
A public-private partnership initiative of government, industry, academia, and other sectors to facilitate research on the fundamental interactions of engineered nanomaterials with biological systems
http://www.niehs.nih.gov/research/supported/programs/nanohealth/index.cfm

NTP Nanotechnology Safety Initiative
The National Toxicology Program's Nanotechnology Safety Initiative to address potential health hazards created by the manufacture and use of nanomaterials
http://ntp.niehs.nih.gov/index.cfm?objectid=7E6B19D0-BDB5-82F8-FAE73011304F542A

NIH Nanotechnology Initiatives
The homepage of the NNI, which coordinates multi-agency federal nanotechnology efforts
http://www.nano.gov/



Nanoscale devices are one hundred to ten thousand times smaller than human cells. They are similar in size to large biological molecules ("biomolecules") such as enzymes and receptors. As an example, hemoglobin, the molecule that carries oxygen in red blood cells, is approximately 5 nanometers <http://nano.cancer.gov/resource center/nanotech glossary. asp#nanometer> in diameter. Nanoscale devices smaller than 50 nanometers can easily enter most cells, while those smaller than 20 nanometers can move out of blood vessels as they circulate through the body.



Tim McKnight, Oak Ridge National Laboratory, Nanoarrays for real time probing within living cells.

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