Fast Facts about
Nanotechnology & Nanotoxicology

What is nanotechnology?

Nanotechnology is the understanding and manipulation of matter at the nanoscale, which means at least one dimension measures between 1-100 nanometers. This is the scale of atoms and molecules. Materials at the nanoscale have unusual properties that are different from conventionally-scaled materials. Many kinds of research and technologies are included in nanotechnology. What they have in common is their size.

Nanoparticles have been used as far back as the late Bronze Age (1200-1000 BCE) when red glass was colored with copper nanoparticles. The fields of computing, communications, engineering and medicine are using nanotechnology to create new products, sometimes with amazing properties.

How small is the nanoscale?

"Nano" is a Greek prefix meaning "dwarf". A nanometer (nm) equals one billionth, or 10^{-9}, of a meter. To give some sense of scale, the diameter of the DNA helix is 2 nm. Some of the smallest life forms (Mycoplasma bacteria, for example) are 200 nm long. The diameter of an average human hair is 100,000 nm and the length of a comma in 12-point font is 500,000 nm.

Your fingernails grow a nanometer per second. A man's beard grows a nanometer in the time it takes to raise the razor to his face. Comparing the size of a nanometer to a meter is like comparing a marble to the earth.

What are the properties of materials at the nanoscale?

Familiar materials can develop odd properties at the nanoscale. Properties such as melting point, fluorescence, electrical conductivity, magnetic permeability, and chemical reactivity can change. Nanoscale materials have a much larger surface area than the same mass of larger-scale materials, so more of the substance comes in contact with materials around it. This increases reactivity.

Nanoscale aluminum can explode. Nanoscale gold is red or purple, not yellow, and the particles react differently with light. Nanoscale gold can be made to accumulate in cancerous tumors, enabling precise imaging and targeted laser destruction that avoids harm to healthy cells.

Nanoscale materials have been used to create better catalysts, for example the car's catalytic converter that reduces the toxicity of engine fumes. Nano-engineered batteries and fuel cells can potentially provide cleaner, safer, more affordable ways to produce and store energy. The large surface area of nanoscale membranes makes them useful for water treatment and desalination.

Nanoscale materials are used in cosmetics, clothing, bandages, and many other consumer products. Photo ©2013 clipart.com.

The promise of nanotechnology

Nanotechnology is expected to lead to new medical treatments and tools; more efficient energy production, storage and transmission; better access to clean water; more effective pollution reduction and prevention; and stronger, lighter materials for cars and airplanes. Nanotechnology has enormous potential.

What are some uses of nanotechnology?

Nanoscale materials are used in many consumer products including automotive, electronic, household, sports, clothing, cosmetic and medical products. Here are a few examples:

- Nanoparticles in paint improve adhesion and prevent mildew.
- Nanoscale titanium dioxide in glass prevents streaks; the glass never needs washing.
- Carbon nanotubes strengthen high-end tennis rackets and balls, golf clubs, bowling balls and bicycle frames.
- Nano-coated fabric makes clothing stain-resistant.
- Nanoscale zinc oxide makes sunscreen transparent.
- Cosmetics with alumina powder diffuse light and make wrinkles hard to see.
- Nanoscale silver has antibacterial properties and is used in washing machine drums, kitchen tableware, anti-odor socks, sheets and towels, and adhesive bandages.
- Molecular nanodrops in a brand of canola oil inhibit cholesterol from entering the bloodstream.

Nanoparticles help detect and treat cancer

Researchers at the University of Washington, Fred Hutchinson Cancer Research Center and Seattle Children's Hospital are using nanotechnology to develop a drug called tumor paint that attaches to cancer cells in brain tumors.

The scientists developed tumor paint by attaching a fluorescent molecule to a small protein from the toxin produced by the Israeli deathstalker scorpion. Tumor paint is injected into the bloodstream and finds its way into the brain where it attaches to and lights up cancer cells. The surgeon can then see and remove the cancer cells without damaging healthy brain cells.

Semiconductor quantum dots (Qdots) are nanoparticles that emit light. Although not yet approved for use in humans, Qdots show promise for targeting and illuminating cancerous tumors, leading to earlier diagnosis. Dr. Xiaohu Gao's lab in the UW Dept. of Bioengineering is researching a specialized use of Qdots with the potential to treat conditions ranging from breast cancer to deteriorating eyesight. The UW Nanotoxicology Center is studying the composition, toxicity, and environmental impact of Qdots and other engineered nanomaterials. The Center tests the behavior of Qdots in both human and mouse cells.

What are the risks and uncertainties of nanomaterials?

In addition to the beneficial possibilities of nanotechnology, nanoparticles may have unexpected and unintended consequences that must be studied and understood.

Researchers have found that silver nanoparticles used in socks to reduce foot odor are being released in the wash; the particles are flushed into the waste stream where they may kill bacteria that are critical to natural ecosystems and water treatment.

A wide variety of adverse effects have been found in different strains of rats and mice exposed to engineered nanoparticles. Research has shown that, when rats breathe nanoparticles, the particles settle in their brains and lungs and lead to inflammation and stress response. Engineered nanoparticles have caused DNA damage to a degree linked to cancer, lung disease, heart and neurological disease, and aging. Engineered carbon nanotubes can be as harmful to the lungs as asbestos if inhaled in sufficient quantities.

Public agencies such as the National Institute for Occupational Safety and Health (NIOSH) are conducting research on the potential health effects of workplace exposures to nanoparticles. Many researchers are calling for tighter regulation of nanotechnology. Andrew Maynard, science advisor to the Wilson Center's Project on Emerging Nanotechnologies, claims there is insufficient funding for human health and safety research, and that better understanding is needed of the risks associated with nanotechnology.

Federal investment in nanotechnology research

From 2006-2013 the US invested $13 billion in nanotechnology through the 27 federal departments and agencies that are part of the National Nanotechnology Initiative (NNI). The NNI budget for nanotechnology research in 2014 is $1.7 billion. These agencies are making the greatest investment in nanotechnology research: US Departments of Energy, Defense, Commerce, and Homeland Security, Environmental Protection Agency (EPA), Federal Drug Administration (FDA) and the National Institutes of Health (NIH).

The NNI is also committed to environmental health and safety (EHS) research related to nanotechnology. In 2014, the budget for EHS research is $120 million. Recognizing the importance of health and safety research, the percent of the total NNI budget devoted to environmental health and safety research has gradually increased from 3% in 2006 to 7% in 2013 and 2014.

The National Institute of Environmental Health Sciences (NIEHS) sponsors the NIEHS Centers for Nanotechnology Health Implications Research (NCNHIR) Consortium and a Nano-EHS program. The NCNHIR Consortium involves 9 University Cooperative Centers which conduct research on the toxicity of engineered nanomaterials (ENMs) to gain fundamental understanding on how their physical and chemical properties influence interactions with biological systems and to better understand potential health risks associated with ENM exposure. The UW Nanotoxicology Center, a member of this Consortium, is investigating the toxicity of Qdots, nanosilver and multiwall carbon nanotubes, in order to develop predictive models for the risks of adverse health outcomes caused by exposure to these and other ENMs.

Who is regulating nanomaterials?

The EPA, FDA, Occupational Safety and Health Administration, Department of Transportation, Consumer Product Safety Commission, and Department of Agriculture are the US regulatory agencies responsible for implementing policies to protect public health, safety, and the environment. The framework for regulating nanomaterials and applications of nanotechnology builds on existing laws and authorities and the risk-based approaches already used by these agencies. Manufacturers are responsible for the safety of their products.

Federal regulatory agencies are expected to base regulations on scientific evidence and to avoid actions that unjustifiably characterize nanomaterials as either hazardous or harmless.

Where to go to learn more

The National Nanotechnology Initiative (NNI). Federal research and development (R&D) initiative of 27 federal departments and agencies, working to promote nanotechnology http://www.nano.gov.

The NIEHS Centers for Nanotechnology Health Implications Research http://www.niehs.nih.gov/research/supported/dert/programs/nanotech/index.cfm

University of Washington Nanotoxicology Center http://depts.washington.edu/nanotox/.

The Nanotechnology Project. Dedicated to minimizing the risks of nanotechnologies while maximizing potential benefits and engaging consumers. Includes an inventory of consumer products. http://www.nanotechproject.org.

Nanotechnology. Jennifer Kahn (2006). National Geographic Magazine. http://ngm.nationalgeographic.com/2006/06/nanotechnology/kahn-text

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