# NANOTECHNOLOGY

## What Is Nanotechnology?

Nanotechnology refers to the research and development of matter which is sized at the scale of between one and 100 nanometers. One nanometer is one-billionth of a meter – for comparison, a human hair is between 60,000 and 120,000 nanometers thick.[1] Given that many traditional branches of science already deal with molecules on a nanoscale, nanotechnology is not a completely new concept. However, over recent years, there has been rapid growth in the study and manipulation of molecules on the nanoscale with a view to developing new technologies. The government-run National Nanotechnology Initiative defines processes as nanotechnology if the following criteria are met:[2]

1. Research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometers,
2. Creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate sizes, and
3. Ability to be controlled or manipulated on the atomic scale.

At the nanoscale, the laws of quantum physics come into effect, and materials may take on new properties not observed in larger quantities of the same material. Such properties may include magnetic, electrical, optical, mechanical and structural characteristics, as well as increased surface area. It is such properties that make nanomaterials useful for new functions; however, these properties may also pose health and environmental risks.

## Applications of Nanotechnology

Nanotechnology can be applied to a wide range of different areas which impact our lives, including biology, engineering and design, green chemistry and consumer goods. Some uses of nanotechnology are described below.

- Microchips which allow laboratory experiments to be performed on a miniaturized scale will enable more efficient and more extensive research initiatives.[3]
- Nanoscale carriers can deliver drugs to specifically targeted parts of the body, leading to more effective disease treatment.[4]
- Some nanoparticles can assist chemical reactions which fulfill functions such as removing chemical contaminants from soil and water,[5] producing alternative energy sources to fossil fuels, and enabling less wasteful or polluting production processes.
- Nanofilters can be used to improve purification and desalinization of water.[6,7]
- Materials called nanostructured aerogels can be used to improve the strength and robustness of buildings in earthquake and hurricane-prone regions.[7]
- Nanotechnological innovations have enabled improvements in computing hardware with increased data storage and faster processing times.[8]
- Nanotechnology has also been applied to many consumer goods including tennis racquets (increased strength) and tennis balls (increased durability), eye glasses and cars (protective coatings) and sunscreen (reduced discoloration).[7,9]

## Potential Risks of Nanotechnology

While nanotechnology may have many exciting applications and uses, there is also concern regarding the potential toxicity of nanoparticles. Because of their extremely small size, there are

particular concerns about the ability of nanoparticles to penetrate and damage tissues and cells. Nanoparticles are often of a size similar to known air pollutants which can penetrate lung tissue and cause lung disease, and the inhalation of ultrafine nanoparticles has been associated with inflammation of lung tissue and toxicity in rodents.[10] Furthermore, the skin and the blood-brain barrier generally act as effective barriers to prevent unwanted particles from entering the body and the brain respectively, however there is evidence to indicate that some nanoparticles can also penetrate these normally protective layers.[11]

The potential toxicity of different nanoparticles is dependent not only on their size but also their chemical characteristics.[11] Therefore, some nanoparticles which can penetrate tissue and cells may nevertheless be relatively harmless, while other types of particles may pose specific risks related to their chemical reactivity and time taken to be released or broken down either in the body or in the outside environment. In general, relatively little is known about the particular health and environmental effects of different types of nanoparticles, and much more research is required to understand the full implications of nanotechnology and how it may be best applied usefully and safely.

## Useful Resources and Further Information

- Goldman L, Coussens C, eds. *Implications of Nanotechnology for Environmental Health Research, Roundtable on Environmental Health Sciences, Research, and Medicine*. Board on Health Sciences Policy, The National Academies Press, 2005. www.nap.edu/catalog/11248.html.
- Center for Responsible Nanotechnology: http://crnano.org/
- Environmental Protection Agency: http://es.epa.gov/ncer/nano/
- National Nanotechnology Initiative: www.nano.gov/
- Wikipedia: http://en.wikipedia.org/wiki/Nanotechnology

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[1] National Nanotechnology Initiative. www.nano.gov/html/facts/The_scale_of_things.html.
[2] US Environmental Protection Agency. http://es.epa.gov/ncer/nano/factsheet/.
[3] Thilmany J. Think small. *EMBO Report*. 2005 October; 6(10): 913–916.
[4] Moghimi SM, Hunter AC, Murray JC. Nanomedicine: current status and future prospects. *FASEB Journal*. 2005 Mar;19:311–330; Rawat M, Singh D, Saraf S, Saraf S. Nanocarriers: Promising vehicle for bioactive drugs. *Biological and Pharmacological Bulletin*. 2006; 29:1790-1798.
[5] Liu WT. Nanoparticles and their biological and environmental applications. *Journal of Bioscience and Bioengineering.* 2006 Jul;102(1):1-7.
[6] National Nanotechnology Initiative. www.nano.gov/html/facts/MoreProds.htm.
[7] Goldman L, Coussens C, eds. *Implications of Nanotechnology for Environmental Health Research, Roundtable on Environmental Health Sciences, Research, and Medicine.* Board on Health Sciences Policy, The National Academies Press, 2005.
[8] National Nanotechnology Initiative. www.nano.gov/html/facts/MoreProds.htm.
[9] National Nanotechnology Initiative. www.nano.gov/html/facts/appsprod.html.
[10] Lam CW, James JT, McCluskey R, Hunter RL. Pulmonary Toxicity of Single-Wall Carbon Nanotubes in Mice 7 and 90 Days After Intratracheal Instillation. *Toxicological Sciences.* 2004;77:126-134; Oberdorster G, Oberdorster E, Oberdorster J. Nanotoxicology: An emerging discipline evolving from studies of ultrafine particles. *Environmental Health Perspectives.* 2005;113:823–839.
[11] Maynard AD. Nanotechnology: The next big thing, or much ado about nothing?, 2006, *Annals of Occupational Hygiene* Advance Access. Hardman A. Toxicologic review of quantum dots: Toxicity depends on physicochemical and environmental factors. *Environmental Health Perspectives.* 2006;114:165-172.