NANOTECHNOLOGY FOR A BETTER FUTURE

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What is the nanoscale?

Practically speaking, the nanoscale ranges from about 1 nanometer (nm) to 100 nanometers. A nanometer is one billionth of a meter. (A meter is about 10% longer than a yard.) The prefix "nano" means "one billionth", or 10-9, in the international system for units of weights and measure.

A sheet of paper is about 100,000 nanometers thick; a single gold atom is about a third of a nanometer in diameter. **Nanotechnology is different from older technologies** because unusual physical, chemical, and biological properties can emerge in materials at the nanoscale.

What is nanotechnology?

Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale.

These properties may differ in important ways from the properties of bulk materials and single atoms or molecules. **Researchers who try to understand the fundamentals of these size-dependent properties call their work *nanoscience*, while those focusing on how to effectively use the properties call their work *nanoengineering*.**

Is nanotechnology new? Where did it come from?

Yes and no. There are isolated examples of discoveries that we might now call nanotechnology going back 50 years or even more. We know that nanoscale gold was used in stained glass and ceramics as far back as the 10th Century, but it took 10 more centuries before high-powered microscopes were invented that allowed us to see things at the nanoscale and begin to work with materials at that level.

Nanotechnology as we now know it began about twenty years ago, when science and engineering extended into the nanoscale from both above and below. Around the turn of the millennium, research managers in the U.S. and other countries observed that physicists, biologists, chemists, electrical engineers, optical engineers, and materials scientists were working on the nanoscale. Realizing that these researchers could benefit from each other's insights, they set up a coordinated program called the U.S. National Nanotechnology Initiative (NNI).

What are nanomaterials? Are they new? Do they exist in nature?

Nanomaterials is a term that includes all nanosized materials, including engineered nanoparticles, incidental nanoparticles and other nano-objects, like those that exist in nature.

When particles are purposefully manufactured with nanoscale dimensions, we call them *engineered nanoparticles*. There are two other ways nanoparticles are formed. Nanoparticles can occur as a byproduct of combustion, industrial manufacturing, and other human activities; these are known as *incidental nanoparticles*. Natural processes, such as sea spray and erosion, can also create nanoparticles.

Many important functions of living organisms take place at the nanoscale. The human body uses natural nanoscale materials, such as proteins and other molecules, to control the body's many systems and processes. A typical protein such as hemoglobin, which carries oxygen through the bloodstream, is 5 nms in diameter.

What are nanoparticles, nanotubes, and nanofilms?

These are different types of nanomaterials, named for their individual shapes and dimensions. Think of these simply as particles, tubes, and films that have one or more nanosized dimension. Nanoparticles are bits of a material at least one of the I three dimensions of the particle are within the nanoscale. Nanotubes have a diameter that's nanosize, but can be several hundred nanometers (nm) long or even longer. Nanofilms or nanoplates have a thickness that's nanosize, but their other two dimensions can be quite large.

What is a nanostructured material?

A nanostructured material has *internal* structure that is within the 1 to100 nanometer (nm) range, while the pieces of material themselves are larger than 100 nm.

Where is nanotechnology used today?

Nanotechnology is used in many commercial products and processes. Nanomaterials are used to add strength to composite materials used to make lightweight tennis rackets, baseball bats, and bicycles. Nanostructured catalysts are used to make chemical manufacturing processes more efficient, saving energy and reducing the waste products. A few pharmaceutical products have been reformulated with nanosized particles to improve their absorption and make them easier to administer. Opticians apply nanocoatings to eyeglasses to make them easier to keep clean and harder to scratch. Nanomaterials are applied as coatings on fabrics to make clothing stain resistant and easy to care for. Several companies make nanostructured products using space-saving insulators that are useful when size and weight is at a premium—for example, when insulating long pipelines in remote places, or trying to reduce heating losses in a leaky old house. Nanoceramics are used in some dental implants, or to fill holes in bones after removing a bone tumor, because their mechanical and chemical properties can be tuned to match those of the surrounding tissue. Almost all electronic devices manufactured in the last decade use some nanomaterials. Nanotechnology is used much more extensively to build new transistor structures and interconnects for the fastest, most advanced computing chips, introduced in 2007 and 2008.

Where else will nanotechnology be used in the future?

Some exciting new nanotechnology-based medicines are now in clinical trials. Some use nanoparticles to deliver toxic drugs directly to tumors, while minimizing the amount of drug damages healthy tissue. Others are used to make medical imaging tools, like MRIs and CAT scans, work better and more safely. Nanotechnology is enabling scientists to find ways to make our home, cars, and businesses more energy efficient through new fuel cells, batteries, and solar panels. They are also finding ways to purify drinking water and to detect and clean up environmental waste and damage. Nanosensors in packaging may soon be able to detect food borne pathogens. New nanomaterials will be stronger, lighter and more durable than the materials we use today in buildings, bridges, automobiles, and more. Scientists have experimented with nanomaterials that bend light and may one day be able to create an "invisibility cloak." The possibilities seem limitless and the future of nanotechnology holds great potential.

How many researchers are working in nanotechnology today?

The current estimate is about 20,000 worldwide.

What are future workforce needs?

The National Science Foundation,USA has estimated that 2 million workers will be needed to support nanotechnology industries worldwide within 15 years.

Nanotechnology, like any other branch of science, is primarily concerned with understanding how nature works. We have discussed how our efforts to produce devices and manipulate matter are still at a very primitive stage compared to nature. Nature has the ability to design highly energy efficient systems that operate precisely and without waste, fix only that which needs fixing, do only that which needs doing, and no more. One day our understanding of nanoscale phenomena may allow us to replicate at least part of what nature accomplishes with ease.