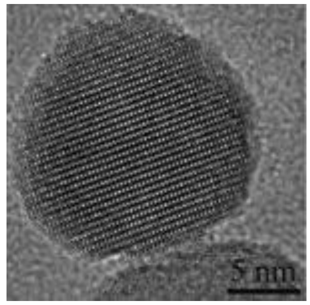
Nanoparticles



TEM image of Fe3O4 nanoparticle

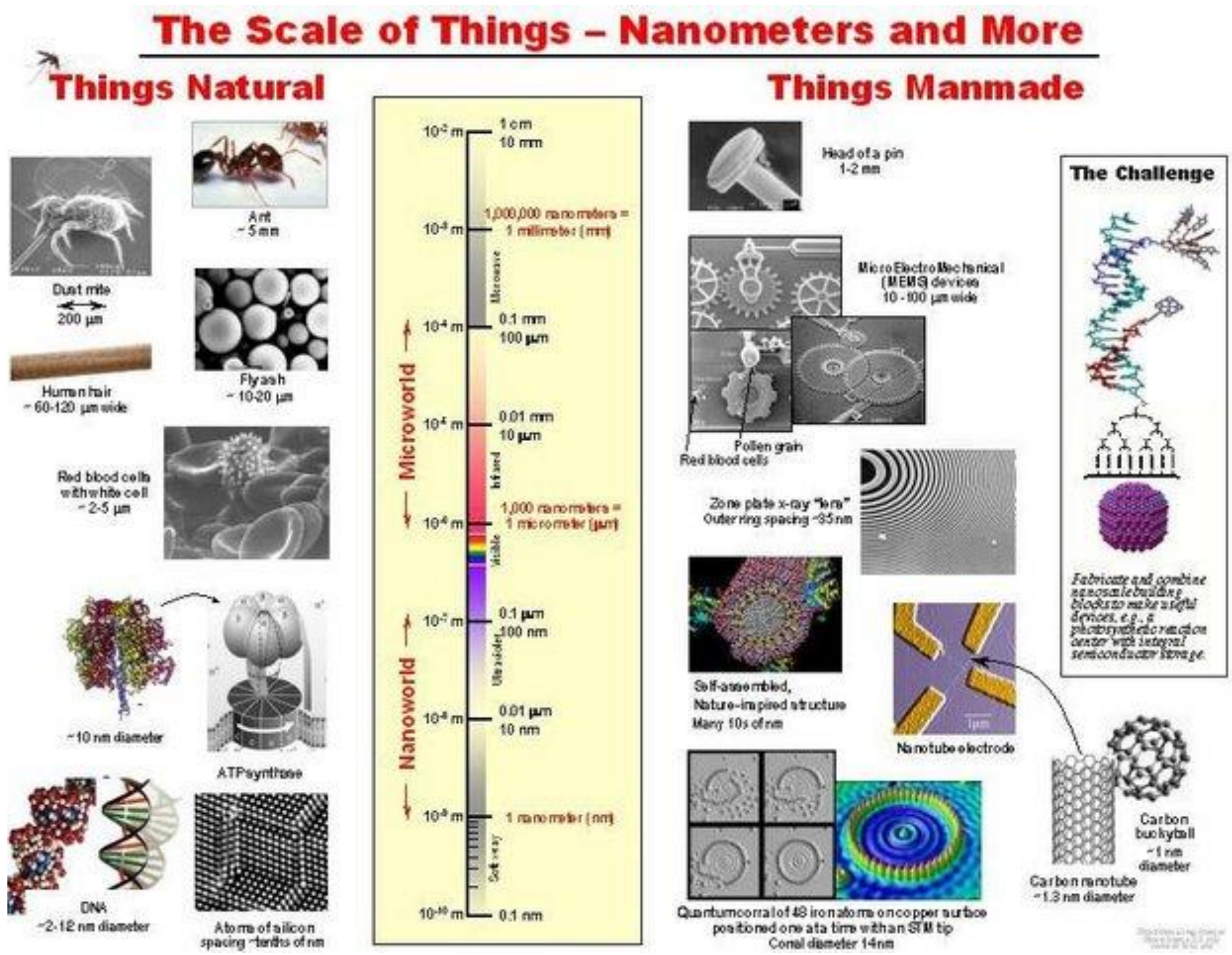
Nanoparticles are defined by an upper particle size limit of 100 nanometers (or up to 100 billionths of ameter). This definition may change as there are some scientists who that argue the designation of "nanoparticle" should apply to particles nearly half that size. Much of the interest in development of nanomaterials relates directly to the novel physical, chemical and biological properties associated with these materials in comparison to their larger (that is, bulk) or smaller (that is, single-atom) counterparts.

All particles (including nanoparticles) may differ in conductivity, strength and reflectivity—among other characteristics. For example titanium dioxide (TiO_2) a common ingredient in sunscreen products appears opaque white on the skin when in bulk form—as it reflects not only harmful ultraviolet rays but also visible light. Yet, nanosized TiO_2 in newer sunscreen formulations allows visible light to pass through (that is, appearing clear)—while still scattering harmful ultraviolet rays.

Dr. Richard Feynman, the Nobel Prize winning physicist, envisioned the technological potential of the *very small* in his 1959 speech, *There's Plenty of Room at the Bottom*. In it he foresaw a version of the*Encyclopedia Britannica* that could fit on the head of a pin. The necessary technological breakthrough followed twenty years later, when Eric Drexler pioneered “molecular manufacturing". He introduced the term nanotechnology to describe the act of engineering materials on a very small scale. Since then, nanotechnology, and the production of nanomaterials and nanoparticles has blossomed. By some estimates, nanotechnology is now a billion-dollar field globally, involving both government and industry dollars and it is growing. While the promise of nanotechnology includes both environmental and health applications including:

- more effective drug delivery;
- potential applications for solar-derived power;
- reduced use of industrial chemicals; and
- improved environmental cleanup methods.

Since such nanotechnology-based applications and formulations are so new, the potential toxicity of any specific nanomaterial in either humans or ecosystems is of concern to researchers, government, non-governmental organizations (NGOs), industry and consumers around the globe.While human manipulation of nanoparticles is considered a relatively new technology, nanoparticles or ultrafine particles have existed in our atmosphere for eons—produced in a number of ways including fires, volcanoes and sea spray. More recently, human-made sources including vehicular traffic and industrial emissions have added to the suite of nano-sized particles in all environmental media.



(Source: Office of Basic Energy Sciences, Office of Science, U.S. Department of Energy)

Types of Nanoparticles

To date, there are several categories of nanoparticles, including:

- Carbon-based nanomaterials including fullerenes (that is, cage-like carbon structures);
- single-walled carbon nanotubes (SWNT) in the shape of a tube (or they may be cage-like); and
- buckyballs (60 carbons in the shape of a sphere).

Metal-based nanomaterials include quantum dots, metal oxides and pure metal nanoparticles. Quantum dots are structures so small that their properties are susceptible to the removal of a single electron. Every living creature depends on a kind of quantum dot for energy production, as electrons are moved around by proteins so the cell can store or use energy. Manufactured quantum dots can contain a small number ofatoms, for example, from tens of atoms to a few hundred. Some manufactured quantum dots are nanosized crystals of various elements—(silicon and germanium or cadmium and selenium are examples), and they emit light when excited. What is most interesting about this is that the color of the light, based on its wavelength, will vary with the size of the nanosized crystal or the type of crystal. Smaller particles of a particular crystal emit light of shorter wavelengths (towards the blue end of the visible light spectrum) and larger particles emit light of longer wavelengths (towards the red end). Titanium dioxide is another example of a metal oxide now manufactured as a nano-metal oxide. Metals can also exist as single ions, or larger bulkier structures—gold or silver nanoparticles, for example. But, as with many nanomaterials, it seems that when metals occur as nanoparticles they may exhibit different properties than their larger counterparts. Nanoized silver (or silver ions), for example, is a potent antimicrobial agent; apparently aggregates of silver particles tend to lose their antimicrobial ability.Dendrimers are branched polymers. Polymers are made up of repeating units or monomers. Monomers are molecules that can combine—or polymerize—with similar or identical molecules. These can be manufactured so that they can carry other molecules within themselves—For example, certain drugs.Composites refer to combinations of nanomaterials with other materials. For example, DNA molecules may be combined with various nanomaterials to make a nanosized biocomposite.

Health and Environmental Impacts

While development of human-made nanomaterials is new, scientists have been aware of the potential dangers of very small particles, particularly airborne particulates. The most recent studies suggest that ultrafine particles, those that are 100nm or smaller, cause the greatest harm to the lungs. In general, as particle size gets smaller the toxicity increases, in part because of increased surface or reactive area, and in part because the behavior of the chemical in the environment or in living systems might change. For example, nano-sized forms of chemicals that normally would not be able to cross into the brain (blocked by what is know as the blood-brain-barrier,) might be able to penetrate and gain access more easily. Similarly nano-sized particles may act differently in the environment. Perhaps becoming more easily dispersed than their counterparts, or just the opposite, sinking into sediments or settling on soils, making them more likely to be ingested by marine creatures able to strip chemicals from sediment and soil particles. Scientists, regulators, and manufacturers around the globe are currently working to identify high-priority research goals that will enable health and environmental researchers to more efficiently measure, test and evaluate benefits and risks posed by these new materials. However, the U.S. Environmental Protection Agency(EPA) recently decided that for chemicals already registered under their Toxic Substances Control Act(TSCA) Chemical Substance Inventory (TSCA is the law enacted to protect humans and the environment from industrial pollution), nano-formulations of existing compounds (nanoized titanium dioxide for example) will not require new registration (or registration as a new chemical). Instead, they ask for voluntary submission of health and toxicity data by manufacturers and users of nanomatierals.

Further Reading

- Feynman, Richard P. 1960. There's Plenty of Room at the Bottom (PDF). *Engineering and Science magazine*, 23(5).
- Hardman, Ron. 2006. A Toxicologic Review of Quantum Dots: Toxicity Depends on Physicochemical and Environmental Factors (PDF). *Environmental Health Perspectives*, 114(2):165-172.
- National Nanotechnology Initiative. Nanotech facts.
- U.S. Environmental Protection Agency. 2007. White Paper (PDF).
- The Nanotechnology Project

Source:
http://www.eoearth.org/view/article/51cbee7c7896bb431f698319/?topic=51cbfc79f702fc2ba8129ed6