CANADIAN INSTITUTE FOR ENVIRONMENTAL LAW AND POLICY

L'INSTITUT CANADIEN DU DROIT ET DE LA POLITIQUE DE L'ENVIRONNEMENT

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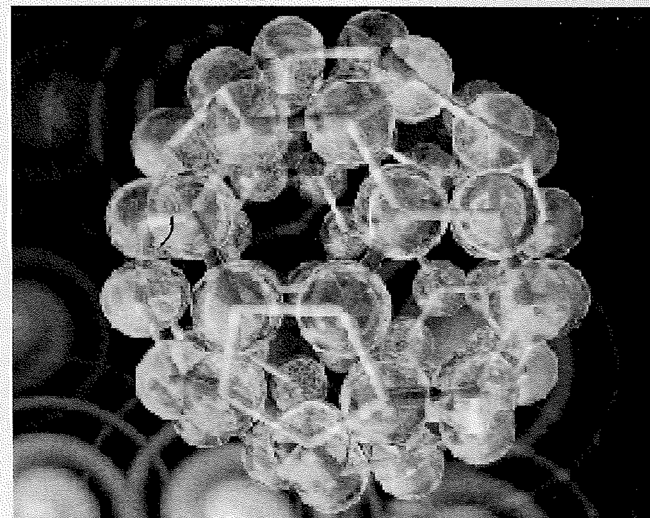
WHAT IS NANOTECHNOLOGY?

Nanotechnology includes a variety of techniques that are used to manipulate materials at the nanoscale, the scale of atoms and molecules. One nanometre (nm) equals one billionth of a metre, about the width of 10 hydrogen atoms; a DNA molecule is 2.5 nm wide, and a red blood cell is about 5,000 nm across. A human hair is about 80,000 nm in diameter.[1] "Atomic force" microscopes are needed to "see" material at this extremely small scale.

The building blocks for nanotechnology are simply the chemical elements and compounds which make up all materials. However, substances at the nanoscale (that is, 1 - 100 nm) have very different properties, such as changed colour, elasticity, strength, chemical reactivity, and electrical conductivity, from those they have in everyday human experience at the macroscale or even the microscale. Developing ways to use and control these novel properties is what nanotechnology is about.

For example, some molecules can be configured in unusual ways that give them attributes almost like comic book super-heroes. Buckyballs (also called fullerenes, and technically referred to as nano-C60) were discovered in 1985 and are hollow spheres of 60 carbon molecules. They can withstand enormous pressure and could be used as nano-containers, for instance for delivering drugs to highly specific sites in the body. Carbon nanotubes are like stretched-out buckyballs, with single- or multiple-sheeted walls; they are six times lighter and many times stronger than steel, and can be either semi-conductors or insulators. They may be used in energy-related applications, or added to materials to improve strength without increasing weight. Quantum dots are semiconductor nanoparticles that emit different colours depending on their size; they can be used to track or monitor various substances, such as biological materials in medical research.

[1] Shand, Hope, and Kathy Jo Wetter, "Shrinking Science: An Introduction to Nanotechnology," Ch.7 in *State of the World 2006* by Worldwatch Institute (New York: W.W.Norton & Company, Inc., 2006)



CLAIMED BENEFITS AND CONCERNS

WHAT POTENTIAL BENEFITS ARE CLAIMED FOR NANOTECHNOLOGY?

Coatings and powders containing nanoscale particles are now being used in consumer products to make fabrics stain-resistant or for ultraviolet protection in sunscreen and cosmetic creams. Nanoscale silver inhibits bacterial growth and is used to coat wound dressings.

Promoters are predicting huge future breakthroughs in many beneficial fields. There is an enormous and ever-growing number of potential applications in the near-term in medicine, electronics, energy and materials conservation and environmental clean-up. These include such things as highly targeted delivery of medications (for example, anticancer drugs going directly to the interior of cancer cells, killing those cells without the side effects associated with chemotherapy today), better water filtration, energy-saving improvements in batteries and fuel cells, and diagnostic sensors to detect pathogens and chemical contaminants.

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CLAIMED BENEFITS (contd.)

Further down the road, researchers are working on molecular nanotechnology, aiming to make self-assembling nanoscale molecules for creating devices like electronic circuitry actually manufactured at the molecular level. Nanobiotechnology takes the technology even further, and is about developing engineered organic-inorganic hybrids: DNA, living cells, viruses, or microbes that can be made to incorporate or utilize synthetic components to perform some human-directed function.

For example, researchers at MIT reported in the April 2006 on-line journal *Science* that they have used genetically modified viruses to assemble a positive electrode that works as a component of a conventional lithium-ion battery. However, this electrode can outperform those used in today's commercial batteries in that it can store up to three times the energy. To make the electrode, the researchers first engineered viruses, which are made of proteins, to incorporate some additional DNA sequences. These genetic sequences direct the viruses' proteins to form with a new amino acid that binds to cobalt ions. The genetically altered viruses then can, in a solution, coat themselves with cobalt ions. After reactions with water, cobalt oxide, an advanced battery material, can be produced. The MIT scientists hope to make negative electrodes as well, and eventually to have viruses actually assemble the positive and negative electrodes into a high-capacity battery.

WHAT SUSTAINABILITY CONCERNS ABOUT NANOTECHNOLOGY HAVE BEEN RAISED?

It should be noted that nanoscale particles can be found in the natural environment under certain conditions, such as salt nanocrystals in ocean air or nanoparticles that result from nearly all combustion. However, with the exploding growth in nanotechnology, exposures to synthetic nanomaterials for researchers, workers, and consumers will certainly increase, with unknown results.

Toxicity

Toxicity studies on engineered nanoparticles are now underway. In general, substances at the nanoscale are more reactive and toxic than at the micro- or macro-scale. Tissue damage to lungs, brains, and hearts has been found in animal species exposed to carbon nanotubes and buckyballs.

One concern is that nanoscale particles could be able to penetrate barriers in the body that exclude larger particles. A German product described as "nano" – Magic Nano, a protective sealant for glass and ceramics – was introduced as an aerosol spray for the first time in March 2006. It was withdrawn after two days when a number of consumers who used it reported coughing and breathing difficulties; six people were hospitalized with pulmonary edema, but all were released within a few days. The product had previously been marketed for four years in a pump container with no reported problems. However, aerosols alone can sometimes cause respiratory distress, and since the product's recipe is secret it is not proven that it actually contains nanomaterials or that they are the sole source of the problem.

Ecological

A 2004 report on nanoscience and nanotechnology by The Royal Society and The Royal Academy of Engineering in the U.K. stated that almost nothing is known about the behaviour of nanoparticles in environmental media, and recommended that until more is known, the release of manufactured nanoparticles and nanotubes into the environment be avoided as far as possible. Two years later, research has barely begun on ecological effects, but a 2005 study of buckyballs in the environment discovered that they are toxic to soil bacteria, and that in water they clump together, forming nanoparticles that are soluble, a strange property since buckyballs individually are insoluble.[2] The above-mentioned Royal Society report makes a distinction between nanoscale materials that are incorporated into parts of products like computer chips and the free release of nanoparticles and nanotubes. The latter seems potentially more risky, and even with the present limited production raises questions about nanomaterials in the waste streams from laboratories, industrial and medical facilities.

There is also concern about potential dangers of nanobiotechnology or synthetic biology if engineered "biological machines" are released into the environment – as they might be for environmental remediation or to mitigate climate change, for example. Possible hazards related to control or misuse of such synthetic life forms have not been addressed.

[2] Press release on website, Center for Biological and Environmental Nanotechnology (CBEN), Rice University, June 23, 2005

CONCERNS (contd.)

Equity and Social Issues

Many countries in the South are afraid that their traditional commodities or natural resource industries could become unnecessary, and that they will face massive industry disruption and worker displacement.

Military applications

In 2002, MIT established the Institute for Soldier Nanotechnologies. Battlesuits to improve "soldier survivability" are being designed to incorporate sensors and protective fibres and coatings to allow the suits to detect and neutralize chemical and biological agents.

WHAT IS THE STATUS OF NANOTECHNOLOGY IN TERMS OF COMMERCIALIZATION?

As noted above, consumer applications in cosmetics, sunscreens, paints, sports equipment such as tennis racquets, fabric treatments, and medicine are already in commercial use. The Project on Emerging Nanotechnologies (given below as an additional source of information) has an inventory of over 200 such products, and that is not considered an exhaustive list. The scale of R&D aimed toward near-future commercial use is enormous and growing rapidly; the rush to patent nanoscale products and processes has been likened to "biotechnology on steroids."

WHAT ABOUT GOVERNMENT OVERSIGHT AND POLICY?

Federal nanotechnology policy and support for research and development

In policy statements, Industry Canada and other agencies have stated that nanotechnology will be vitally important for Canada's future economic development. The National Research Council (NRC) in conjunction with the University of Alberta in Edmonton established the National Institute for Nanotechnology (NINT) in 2001. Because there is no single window for information and policy on this wide- reaching technology, it is difficult to discover just how much is being spent in total on research and development. Policy comments are almost entirely about research and business opportunities, with little or no official discussion of health, environment, or social issues.

Transparency & citizen engagement:

There is no formal ongoing mechanism for civil society input about nanotechnology policies in Canada.

Regulatory framework and labeling requirements

Canada and other governments have so far taken the position that a nano-scale material is still the same substance as at the micro- and macro-scales, and does not need any additional regulation beyond what is required for ordinary uses of that substance. (This is despite the fact that the novel properties exhibited at the nano-scale are precisely why these applications are useful.) Even cosmetics, which Canada has recently required for the first time to label all their ingredients, do not have to reveal that nano-scale particles of compounds are used. Neither do other products, including food. Some governments, however, have begun to consider possible approaches to potential regulatory or labeling initiatives; in 2005, for instance, the European Commission asked for public comment on nanotechnology risk assessment.

There is no legislated liability regimen in Canada. In Canada, nanotechnology issues are subject to the traditional common law rules of civil liability. If the use of nanotechnology causes damage to a person, their property or their economic interests, the producer or user of that biotechnology might or might not be held liable for that damage by a court. The common law, as it has developed in Canada, may not be flexible enough to meet the novel challenges raised by the potential for harm that nanotechnology applications may cause. These technologies bring up general policy issues that are better resolved by legislators rather than judges. A strict liability regime, entrenched in legislation, would hold producers of biotechnology responsible for damage to human or environmental health.

WHAT ARE THE INTERNATIONAL IMPLICATIONS?

There is a rush to control the burgeoning patent rights in what is likely the next "technology platform" – that is, an innovation like electricity, which is central to further developments in many diverse fields. Control over nanotechnology's fundamental tools and processes will be very important for shaping applications, having access to benefits, and avoiding and mitigating health, environmental, and other problems. China is already playing a very significant role in nanotechnology development, as is India. The poor and politically disadvantaged, both countries and individuals, should be concerned about being left out of this new knowledge- and technology-based revolution. Since nanoscale technologies also have the potential to revolutionize design and manufacturing of new materials across many sectors, developments could cause disruption and dislocation to workers and economies that depend on traditional commodities.

ADDITIONAL SOURCES OF INFORMATION

Specific to Nanotechnology:

- Worldwatch Institute's *State of the World 2006*, Chapter 5 (see **References,** endnote 1)
- The Massachusetts Institute of Technology (MIT) journal *Technology Review* in its online edition at frequently reports on nanotechnology developments.
- The Woodrow Wilson International Center for Scholars in partnership with the Pew Charitable Trusts launched the Project on Emerging Nanotechnologies in April 2005; its website is www.nanotechproject.org.
- The Royal Society and the Royal Academy of Engineering of the U.K. produced a major report in July, 2004, which is available online at www.nanotec.org.uk/finalReport.htm.

Concerned about Biotechnology

- **Union of Concerned Scientists** www.ucsusa.org/
- **Greenpeace Canada** www.greenpeace.ca

Pro-Biotechnology

- **Biotechnology – Good to Grow** www.biotechgoodtogrow.com/
- **BIOTECanada** – www.biotech.ca/
- **Council for Biotechnology Information** http://whybiotech.com/

Government of Canada

- **The Government of Canada's BioPortal** www.bioportal.gc.ca/
- **The Government of Canada's BioStrategy** http://biostrategy.gc.ca/
- **Canadian Biotechnology Advisory Committee** www.cbac-cccb.ca/

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