Topic Page: Nanotechnology

Definition: **nanotechnology** from *Philip's Encyclopedia*

Range of technologies whose dimensions are on the nanometre scale. The term is used both for the materials science of nano-scale particles, and for the more advanced idea of entire machines a few nanometres across. The former technologies are now beginning to enter practical use, while the latter are still largely theoretical. If nano-machines prove possible, they would be able to perform sophisticated chemical manipulations directly at a molecular level.

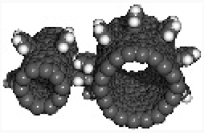

Image from: **Simulation of fullerene gear train. [Source:...** in *Encyclopedia of 20th Century Technology*

Summary Article: **Nanotechnology**
From *Encyclopedia of Global Studies*

Nanotechnology is a term referring to a range of new technological innovations that are global both in their potential impact and in the transnational composition of the research teams working to develop them. It involves innovations that result from working directly with materials at the scale of less than 100 nanometers, roughly the size of complex molecules. (A nanometer is a billionth of a meter; by way of comparison, a human hair is roughly 80,000 nanometers wide.) At this scale, materials exhibit unique mechanical, optical, magnetic, and electronic properties—a world in which the laws of classical physics (which apply to large bodies) and quantum mechanics (which apply at the atomic level) interact in complex and novel ways. Nanotechnology has benefited from the development of new instruments—such as the Nobel Prize-winning scanning tunneling microscope, which creates images of surfaces at the atomic level— enabling researchers to visualize atomic structures as well as manipulate materials at the atomic level.

Nanotechnology is widely believed to hold great promise in a wide variety of applications, from ultrafast computing to miraculous cures for cancer and other diseases, while at the same time generating substantial economic returns. Yet nanotechnology is a new (“emerging”) technology; as a consequence, these promised returns remain years in the future.

Governments around the world are investing billions of dollars in support of basic research and development, in hopes that their countries will become leading players in what has been predicted to be a multitrillion-dollar market. Some governments even provide support for commercialization, in hopes of giving their country's high-tech firms a competitive advantage in the global marketplace.

Because nanotechnology has emerged at a time when science and technology are increasingly globalized—thanks to the ease with which knowledge can be shared across borders—many emerging economies are hopeful of developing nanotech breakthroughs that will enable them to compete effectively with more economically and technologically advanced countries. Yet despite high levels of public and private investment, skeptics argue that nanotechnology is more hype than real: that it is a relabeling of work that has been done in materials science for years—perhaps even centuries—and that funds would be better spent on specific applications such as energy or biotechnology rather than on a general, all-embracing area that is defined largely by scale.

Nanotechnology: Promise or Hype?

Nanotechnology offers a seemingly endless list of promised benefits. This list names but a few:

- Solar cells based partly on carbon (an organic element) rather than exclusively on silicon (an inorganic element), making them cheaper and far more efficient sources of energy
- Carbon-based nanofibers far stronger (and lighter) than existing materials
- Targeted drug delivery, affording noninvasive cancer treatment without the toxic side effects of radiation and chemotherapy
- “Labs-on-a-chip,” providing instant diagnosis of numerous diseases in remote field settings in developing countries
- Powerful filters capable of removing the tiniest pathogens from water or air
- Ultra high-speed computing based on nanoscale storage devices with data densities far greater than those currently available

The U.S. National Science Foundation estimates that by 2015, some 7 million workers—mostly in the United States, Europe, and Japan—will be engaged in jobs directly or indirectly resulting from nanotechnology. One U.S. government-sponsored workshop on nanotechnology forecast that by 2013, nanotechnology could be used in almost half of all products, including computers, disease control instruments, renewal energy, lightweight equipment in cars and airplanes, and filters that would remove water-based contaminants for entire cities.

Yet notwithstanding such impressive claims, nanotechnology has yet to realize its potential as a source of innovative products, much less as an engine of growth for developing countries. One 2007 study for the U.S. Department of Commerce Technology Administration concluded that there were as yet no “home runs” in the commercialization of nanotechnology. The Washington-based Woodrow Wilson International Center for Scholars, through its Project on Emerging Nanotechnologies, has identified more than a thousand consumer products that employ “firstgeneration” nanomaterials, such as titanium dioxide or zinc oxide in sunscreens and cosmetics; carbon nanotubes in bike frames, golf clubs, and tennis rackets; nanoscale coatings that filter out odors in refrigerators; and membranes that filter pollutants from water and air. By far the largest number of products (nearly two thirds) fell into the category of health and fitness, a catchall that includes cosmetics, clothing, personal care, sporting goods, sunscreens, and filters of various types. For the most part, these are products in which nanoscale compounds are added to existing products—allegedly as enhancements (e.g., nanoscale titanium and zinc are effective ultraviolet filters) but sometimes mainly as marketing tools. (Many products marketed as “nano” are so in name only.) More than half of all nano-enhanced products originated in the United States; about a quarter came from East Asia, with most of the rest from Europe.

It is important to note that nano-enhanced products result from inputs involving global supply chains, in which the raw materials (which in this case include nanopowders derived from carbon, silicon, titanium, gold, silver, and zinc) typically originate in developing countries. China, for example, is a major exporter of carbon nanotubes, which are increasingly used in lightweight bicycle frames—frames that are primarily designed and sold in the United States, Europe, or Japan, then made and assembled in lower cost East Asian countries. The nanoscale raw materials at the bottom end of the supply chain are generally the least profitable (and most hazardous) activities in the supply chain. Thus, although nanotechnology may well contribute to billions of dollars' worth of products, at its present stage of development, the value added by basic nanomaterials—which are usually manufactured in low-wage countries—is minimal.

Production of nanomaterials, such as carbon nanotubes, is also potentially dangerous, although little is currently known about their actual toxicity. Because of their small size, there is concern that such materials could easily penetrate cells and tissues, much as viruses do (they are roughly the same size), where they could theoretically cause significant damage. While this has led to some concern about the use of nanomaterials in sunscreens and cosmetics, the current thinking is that by the time they are agglomerated into creams and lotions, they are no longer at the nanoscale and therefore most likely no longer toxic. But at the bottom end of the supply chain, where nanopowders are manufactured in factories in developing countries with lax environmental standards, toxicity may be a greater concern. Unfortunately, relatively little is scientifically known about nanotoxicity, and no set of international standards has been developed to govern their manufacture.

Does Public Investment Pay Off?

In the last year for which comparable data were available (2007), the governments of roughly 80 countries were collectively investing nearly $7 billion in nanotechnology. Global private investment was slightly higher. The United States is the world's biggest spender on nanotechnology. Federal funding under the National Nanotechnology Initiative (NNI), launched in 2000, reached $1.7 billion in 2011, one of the largest government investments in technology since the Apollo program. The NNI, which has proven to be a model for other countries, encompasses 13 federal agencies; although it is aimed at enhancing U.S. industrial competitiveness, the bulk funding goes to universities and government labs, with relatively little directly to the private sector.

One key barrier to successfully commercializing nanotechnology is that funding usually favors basic research rather than the development and commercialization of actual products. This is less the case in those emerging economies that are willing to adopt industrial policies that offer the promise of rapid economic growth. Governmental support for nanotechnology is therefore especially strong in emerging economies, which hope to "leapfrog development" through promoting hightech efforts. China, India, Taiwan, and South Korea, for example, are all investing in nanotechnology. China in particular is spending as much as $250 million annually on nanotechnology, which—when adjusted for purchasing power—would likely make China second only to the United States in terms of public investment. The Chinese government at all levels—not only primarily the central government in Beijing but also a number of provincial and even city-level governments—has funded training facilities for scientists, university-based research centers, large-scale science and technology industrial parks, and incubators designed to help promising nanotech applications find their way to market. China, which has a strong tradition of central planning (one of its remaining communist legacies), is in the beginning stages of its Long and Medium Term Scientific and Technological Development Plan

(MLP) for the period of 2006 through 2020, which called for China to become an "innovation-oriented society" by 2020 and a world leader in science and technology by 2050. Nanotechnology was one of four "science megaprojects" singled out as key areas for funding (the other three are development and reproductive biology, protein science, and quantum research). With an estimated $2.3 trillion in export-generated foreign exchange reserves as of 2010, China has ample funds to invest in the creation of a national system that will result in what it terms "indigenous innovation" in science and technology, now seen as the key to national prosperity. Both the 11th (2006-2010) and 12th (2011-2015) Five-Year Plans view innovation as the key to addressing the country's significant social, environmental, global competitive, and national security challenges. While it is difficult to draw comparisons between the American and Chinese approaches to supporting nanotechnology, research currently suggests that if one looks at all levels of government combined, China has a stronger industrial policy than the United States, in that while the United States emphasizes support for basic research, China provides greater support for commercialization as well. China is well positioned to become a major world player in nanotechnology: It now rivals the United States in numbers of nano-related publications in indexed scientific journals and is rapidly increasing the number of nano-related patents taken out in the United States and Europe. Although the quality of Chinese research is not yet the equal of that done in the United States, Europe, and Japan, its trajectory is steeply upward.

Nanotechnology Draws on a Global Talent Pool

The communications revolution, along with the relatively low cost of international travel, has contributed to the globalization of science generally; nanotechnology is no exception. Whether it is basic research in universities or product development in firms, teams of nanoscientists and engineers often span national borders. International conferences, formal partnerships between universities, and international collaborations among individual scholars all contribute to a global talent pool. Furthermore, because it is defined by scale, nanotechnology is often interdisciplinary as well, bringing chemists, physicists, biologists, and material scientists—sometimes from different countries—into laboratories offering the specialized instruments required by work at less than 100 nanometers.

China in particular has benefited from a global talent pool. Large numbers of Chinese scientists and engineers have earned advanced degrees and completed postdoctoral research in Europe, the United States, and Japan. Many are now returning to China, attracted by government programs that provide substantial funding for top returnees, the opportunities perceived in China's rapidly growing economy, and national pride. When they return, they bring with them their international networks, further contributing to cross-border collaborations.

To the extent that global problems can be solved, at least in part, by advances in sciences such as nanotechnology, the growth of a global talent pool is a hopeful sign.

See also:

Biohazards, Economic Development, Global Communications and Technology, Globalization, Phenomenon of, Industrialization, Technology Sector, Universities and Higher Learning

Further Readings

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