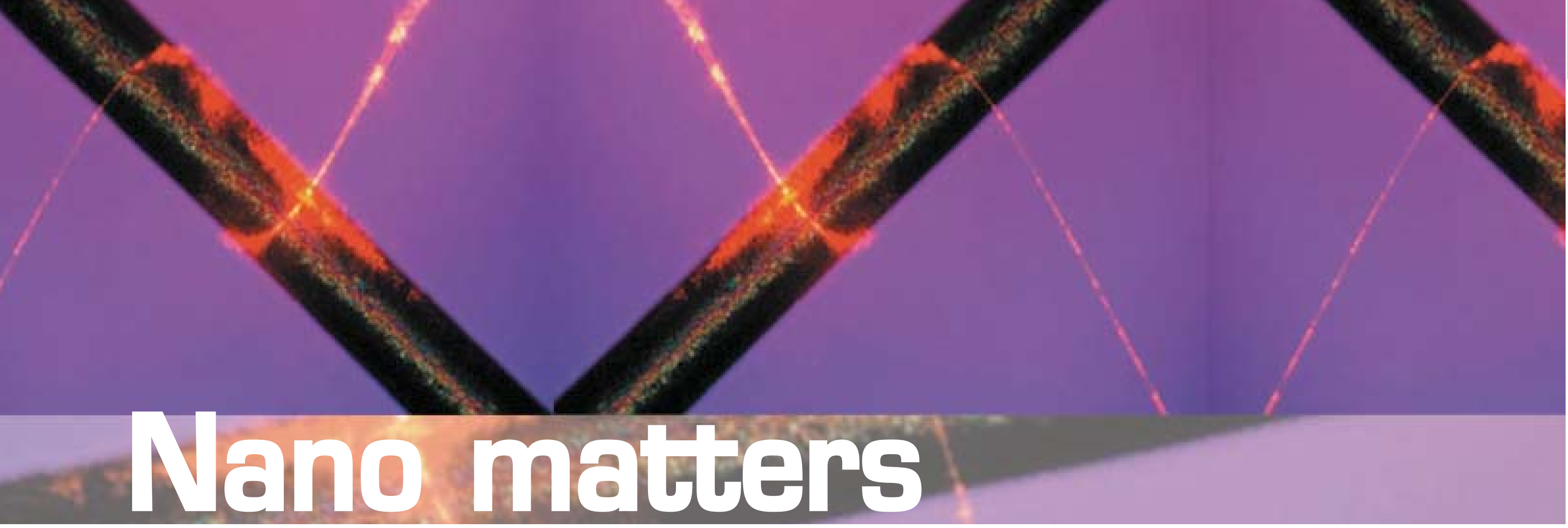

Nano matters

Should we care whether the next generation believes that nano is a compact place to carry a tune as opposed to an atomic-scale frontier for shaping new materials, medicines, and computing devices?

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(Image adapted from a photo by Eric Mazur, Harvard University.)

At the American Association for the Advancement of Science (AAAS) meeting this year, Anna Waldron, an education researcher developing a nanotech museum exhibit for 8-13 year-olds, briefed the audience on the results of a recent survey of young people. The good news: 17% more of the respondents were familiar with the term 'nano' than had been when she administered the survey back in 2004. The bad news: asked to say what 'nano' is, 17% referred to the iPod nano. And we have more for which to thank Steve Jobs, chief executive officer of Apple: while fewer kids confessed to having heard the term 'nanotechnology', those who did often explained it as the technology *inside* the iPod nano. (For further details of Waldron's research, see *Nano Today* (2006) 1 (2), 56)

Should we care whether the next generation believes that nano is a compact place to carry a tune as opposed to an atomic-scale frontier for shaping new materials, medicines, and computing devices? After all, the term 'nanotechnology' was only recently admitted to the scientific lexicon and is sufficiently vague and broad enough to tempt us into colloquial and creative license – even serious practitioners will admit that, at this point in time, the term connotes a glowing but somewhat indistinct future more than a rock-solid reality.

Materials scientists and chemists with whom I've spoken comment that they've been working with novel properties at the nanoscale for quite some time; physicists have been studying and characterizing quantum effects for years; biochemists have been engineering molecular drug delivery systems; electrical engineers regularly etch features on chips less than 100 nm across. Now, however, there are national initiatives, billions of dollars in investment, convention-sized events, and whole publications devoted to nanotechnology. Nano is indeed big: a rallying cry marshalling an all-out assault on the next frontier in research.

It is easy to be cynical and remember the vaunted promise of artificial intelligence, the dot.com boom and bust, the war on cancer, the genetic revolution, the prospect of clean unlimited nuclear energy, the end of infectious disease, and the solar energy revolution followed by the fuel cell revolution. It's also easy to remember that of all the heady prognostications, no one but *no one* predicted what has become, globally, the most transformative technology of the last decade – the worldwide web.

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But there *is* something fundamental and profound about nano. Something even more significant than its payload of promised whizzbang applications – the quantum computers, the self-healing materials, the elevator to space, the pinpoint-accurate tumor eradicators – something akin to a curtain rising on a grand new and even more sobering view of our universe, its mystery and its majesty.

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Grappling with scale: how to communicate the very concept of one-billionth of a meter? On the Current Science and Technology stage of Boston's Museum of Science (MOS), Daniel Davis makes use of an Eric Mazur image of a nanowire wrapped around a human hair. (Courtesy of MOS.)

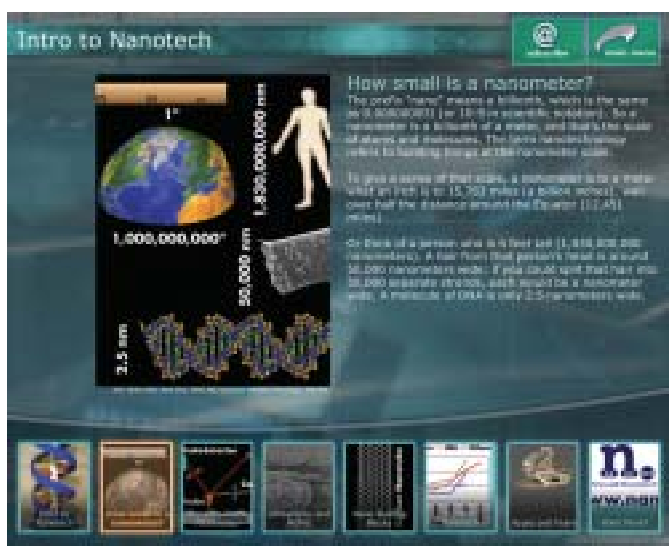
Nanoscience is a vision of a unity of knowledge, an integration of technique, and a bottom-up mastery of matter

In the past century, like the apocryphal blind men surrounding the elephant, each characterizing the whole creature quite differently based on the single part of it within their reach, we organized our institutions of higher learning into disciplines gathered around particular means of access to scientific evidence and tools of practice. Universities established great and distinct departments of evolutionary biology and geology, molecular biology and medicine, astronomy and astrophysics, high-energy physics, organic and inorganic chemistry, materials science and engineering, and so on and so forth.

Now, however, the blind men are strolling around the elephant and comparing notes. Even a science-attentive lay person can begin to connect the dots between disciplines and see how all these great human endeavors form one scalable continuum of knowledge, from the forces between atoms, to the cellular machinery for the synthesis of proteins, to the evolution of genomes, the dynamics of populations, the self-regulatory systems of the biosphere, and the life and death of stars. No longer can we draw a hard line between physics and chemistry, science and engineering, tools and techniques.

The vision of nanoscience is a vision of a unity of knowledge, an integration of technique, and a bottom-up mastery of matter. That this vision emerged by reaching beyond vision, beyond the wavelength of visible light, with tools that provide access to the force field of a single atom, is a reminder of just how many breakthroughs in human understanding have been triggered by engineering means of extending access to new realms: the telescope, the microscope, the particle collider, the great space-based observatories exploiting every electromagnetic wavelength, the functional magnetic resonance imaging spectrometer, the emergence of staggering parallel computing power.

The farther we look along the powers of ten in either direction, the more we realize how thin the slender slice of reality is that we can sense with the perceptual apparatus evolution provided, or intuit and explain with our Newtonian, Euclidian, and Baconian sensibilities. 95% of the universe is now understood to consist of 'dark matter', something we can neither perceive nor understand. Matter, forces, atoms, quarks – the deeper we look, the less intuitive and the more unnerving our so-called 'real world' seems. The real irony here is that as rapidly as we gain access into and mastery over new realms of space and matter, the more profound the mysteries at the further edges appear. We've solved the elephant; but can't explain the zoo.



A page from a multimedia touchscreen story produced by Joel Rosenberg at MOS. See www.mos.org/nano for other educational content produced by MOS in association with Harvard University's Nanoscale Science and Engineering Center (NSEC) and Northeastern University's Center for High-rate Nanomanufacturing NSEC.

Harvard physicist Charles Marcus introduces the notion of quantum computing to a public audience at MOS. (Courtesy of MOS.)

Now, all of this is far afield from wondering whether it is important that the public 'gets' that nanotechnology is about more than carrying 1000 songs in your shirt pocket. Of course it's important. While it's perhaps not as important as basic literacy, or understanding germ theory, aging, evolution, rules of evidence, ecological complexity, and climate change, nevertheless it would probably be beneficial to society if all of us could step back now and then and reflect a bit more on the fundamentals of existence and meaning. But, beyond these cultural considerations, we certainly do need a science-literate public, a technologically-adept workforce, and a flow of bright, young, ethically minded, and well-trained researchers into our laboratories.

Is it important that the public 'gets' nanotechnology? Of course it is

Much is at stake for our society and culture. Who will vote to fund the research? Who will own the patents on the new nanotechnologies? Who will ensure they are applied where we need them most? Who will program the 'smart' materials and 'sensible' environments and install the ubiquitous nanosensors? Who will sort and sift the realms of personal data? Who will build the 'killer' defense apps? Who will monitor the toxicity of tiny novel particles, their pathways through living tissues, and, if necessary, design the controls that regulate their release into the environment? Perhaps most importantly, who will design the schools of the future and the science curricula that will shape the skills and intellects and aspirations of the next generation on whom our hopes and dreams so depend?

Waldron is one of a host of creative informal science educators, museum exhibit designers, science media producers, and inquiry-based curricula development specialists currently pondering these questions. In addition, US federal, state, and local governments, along with technology-based industries, have begun to increase their investment in sectors of the 'free choice' education economy. Here, continuing adult education can be encouraged and leveraged and innovative science education practices can flourish on a proving ground before being targeted for implementation in schools district-by-district, campus-by-campus, and thereby embedded into the coming-of-age growth and development process for young people.

Our new Nanoscale Informal Science Education Network or NISE Net is one such comprehensive endeavor (see box). And none too soon. The *Science and Engineering Indicators 2006*, just published this February by the US National Science Board, show that only about half of Americans know which is smaller, an atom or an electron. Surely we can do better than flipping a coin. mt

About the NISE Net

How to foster public awareness of nanoscale science and engineering and introduce young people to research? The Nanoscale Informal Science Education Network, launched in October 2005, brings together scientists, educators, artists, exhibit designers, and multimedia producers to design and implement innovative programs, exhibits, fora, and media that can attract and engage families, young people, and adult audiences.

NISE Net's long-term objective is to build the capacity of the informal science education community to partner effectively with science research centers and community organizations and bridge the gap between research and public interest on an ongoing basis. Multidisciplinary teams will join together in collaborative workshops, rapid-prototyping design projects, research and evaluation, and production of nano education deliverables. A web-based professional resource center will link together the growing body of educational products, tools, materials, and knowledge produced by NISE Net partners.

NISE Net is led by the Museum of Science in Boston, the Exploratorium in San Francisco, and the Science Museum of Minnesota, and is funded by the US National Science Foundation (NSF). The Materials Research Society is playing an active role in NISE Net, as is the Association of Science-Technology Centers (ASTC). The network's 'thinking partners' include representatives from the NSF Nanoscale Science and Engineering Centers, the National Nanotechnology Infrastructure Network, the Nanotechnology in Society Network, Libraries for America, and several minority-serving science professional organizations. NISE Net's distinguished advisory panel is chaired by Robert Westervelt, head of Harvard's Nanoscale Science and Engineering Center, which began partnering with Boston's Museum of Science to produce nano public engagement activities five years ago.

Further information: www.nisenet.org