Ira Flatow *Present at the Future*

It all started with physicist and Nobel laureate Richard Feynman. In 1959, Feynman gave a talk at California Institute of Technology entitled “There’s Plenty of Room at the Bottom,” in which he challenged his fellow scientists to come up with tiny, molecule-sized machines that can do surgery, libraries that can be stored on the head of a pin (the entire 24-volume Encyclopaedia Britannica), minuscule computers. Why? Because small machines could work more efficiently, using a lot less power, and manufacturing them would be much cheaper. But to realize Feynman’s vision, researchers needed new tools.

1990-atomic force microscope

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Some nanotechnologists are experimenting with nanowires, incredibly tiny wires that could become part of minuscule transistors and electronic circuitry because they have optical and electronic properties. At Harvard, chemist Charles Lieber has combined them with nanoscale lasers for use in photonics, the process by which silicon-chip circuitry is now made, on a tiny scale. Lieber cofounded Nanosys, a nanotech startup company with, he says, “the modest goal of revolutionizing chemical and biological sensing, computing, photonics, and information storage.”

Lieber thinks that nanowires could be very useful in medicine. He says that one of his nanowires is made of silicon, and its dimensions are similar to carbon nanotubes. In other words, incredibly tiny! He says that “this very small wire acts as sort of a switch, and then when a biological molecule binds to it, it can change the resistance or conductivity of that wire, either turning it on or off. That provides us with the selectivity to recognize one virus out of a whole soup of many different biological species. The virus binds to an antibody in your blood, and by using chemistry, we have linked antibodies to the surface of the nanowire.

“We’ve been able to demonstrate unambiguously that when a particular virus binds to the wire’s surface, the electrical signal changed. If you could detect a virus at this early stage, when your body’s immune system might be still holding it in check, you could then be treated effectively before the virus began replicating rapidly and became highly infectious.”

Lieber looks forward to “detecting a virus in real time,” or even many viruses simultaneously. That would mean you’d visit your doctor, give a blood or saliva sample—and get your diagnosis right there. You wouldn’t have to wait several days for test results to come back from the lab before you could find out why you haven’t been feeling well. If you turned out to have a serious illness, such as cancer, that early diagnosis could make a huge difference in your prognosis and treatment. On-the-spot diagnosis could save your life—or the life of a soldier who’s been exposed to a chemical weapon or bioweapon on the battlefield, or the health of a swamp or river at risk of pollution.

Nanotechnologists such as Lieber and Brinker have succeeded in making us safer by developing supersensitive sensors to detect anthrax or other biological or chemical warfare agents. One of these supersmart “noses” that Brinker worked on is already in public places, such as airports and public transit systems. Another kind of sensor, called “smart dust,” glitters like a disco ball from the 1970s, and turns from green to red when it detects a pollutant in the environment.

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While Sivan is working with DNA, Dr. Angela Belcher, professor of materials science and engineering and biological engineering at MIT, believes that she might be able to force nature to work with materials not normally found in the wild and convince organisms, such as viruses, to build devices that are foreign to them. She is working to manipulate “three different parts of a virus simultaneously to start building” the basic parts of a transistor. “What we’re doing is mimicking nature, like how an abalone grows calcium carbonate to grow a shell. We’re using viruses to grow any kind of material we’re interested in, and one kind of material [is] semiconductor materials.”

It’s a tedious process that starts with sifting through countless numbers of viruses, weeding out only those that have the right talent for the job of, say, building a wire. “We take a billion viruses and allow them to interact with the semiconductor material, and then only keep a couple of them that interact very well, and we throw the rest of them away. And any one that does interact, we keep evolving it to have better and better interaction. Then we can make billions and billions of viruses that can now grow that particular semiconductor wire. We breed them to make a wire that we’re interested in.”

So to create a wire, the virus would bridge two different metals. “We can actually manipulate many different proteins and many different genes on a single virus, so we can have one end of a virus grow one kind of material and another end of a virus grow or attach to another kind of material, all through this genetic selection and amplification. We pour in precursors and grow wire—it can be a metal wire or a semiconductor wire or a magnetic wire—just by throwing in precursor salts.

What happens to the virus once the wire is completed? “We can either burn off the virus at that point, just by increasing the temperature, or we can keep the virus around and recycle it and use it again.”

Why use viruses? Belche says she can use many different organisms—she also uses yeast to grow materials—but she focuses on viruses because they “have this nice shape. They’re very long and thin.”

Letting nature self-assemble devices results in electronic devices with fewer errors, since the wires can form only in the right places. It also allows you to customize the exact dimensions of what you are trying to make, by manipulating the genetic code of the virus. You want it this long? This thick? This wide? How about this strong? Just jiggle the genetic code. As Belcher told OpenDOOR, the MIT alumni magazine, “My dream is to have a material that’s genetically controllable and genetically tunable. I’d like to have a DNA sequence that codes for the production of any kind of material you want. You want a solar cell, here’s the DNA sequence for it. You want a battery, here’s the DNA sequence for it.”

NOT TO FORGET BACTERIA

Not only can viruses be coaxed into building microscopic electrical parts; so can bacteria. The press release said it all: “A microbiologist discovers our planet is hardwired with electricity-producing bacteria.” In other words, scientists have found that under certain conditions, some common bacteria can sprout nanowires that conduct electricity. And with the Earth populated with more microbes than any other form of life, that’s a lot of nanonetworking.

“Earth appears to be hardwired,” is how Yuri Gorby, staff scientist at the U.S. Department of Energy’s Pacific Northwest National Laboratory put it. Gorby and his colleagues discovered that they could coax some microbes to transform toxic metals into sprouting microwires, called pilli, as small as 10 nanometers in diameter. These wires could be formed into bundles as wide as 150 nanometers. And many other bacteria, not in the toxic metals business, can also form these wires, such as microbes involved in photosynthesis and fermentation. But what they all have in common is the ability to reach out and touch ther bacteria by growing these wires from their cell 168 THE NEW SMALL IS BIG membranes that find the other microbes and “form an electrically integrated community,” says Gorby.

Being electrically conductive means that the bacteria hold the potential (pun intended) to be the power sources for fuel cells and bacteria-powered batteries.

Why would nature make such bacteria that can produce and conduct electricity and have the power to clean up toxic metals? Gorby can only speculate.

“The effect is suggestive of a highly organized form of energy distribution among members of the oldest and most sustainable life forms on the planet.”

SAFETY

One question often asked is “How safe is nanotechnology?” What if all those tiny nanoparticles spill into our water supply? Or what if we were to breathe them in as they came out of an aerosol spray can or sprayer in the workplace? Right now, we don’t know, although we’re sure that self-replicating nanobots will never take over the Earth and reduce every living thing to “gray goo,” as computer scientist-entrepreneur Bill Joy has warned. Nor will we ever be stalked by intelligent, predatory nanobots, as hapless scientists were in Michael Crichton’s scary thriller, Prey. But many people, including some in the federal government, are concerned about the potential health hazards posed by these tiny particles that can easily get into the blood and be captured by the lungs.

“Major efforts are underway in both industry and government to realize the amazing promise of this technology. However, very little attention is devoted to assessment of health risks to humans or to the ecosystem,” says the National Institute of Environmental Health Sciences, part of the National Institutes of Health, in a 2003 report. “The toxicology of nanoparticles is poorly understood, as there is no regulatory requirement to test nanoparticles for health, safety, and environmental impacts. More research is urgently needed, as there are many indications that ultrafine particles could pose a human 169 NANOTECHNOLOGY health hazard. Research is now showing that when harmless bulk materials are made into ultrafine particles, they tend to become toxic. Generally, the smaller the particles, the more reactive and toxic are their effects.”

An animal study, reported in 2004 by the Society of Toxicology, compared the effects of different, common pollutants on the lungs of lab rats. It found that “if carbon nanotubes reach the lungs, they are much more toxic than carbon black and can be more toxic than quartz, which is considered a serious occupational health hazard in chronic inhalation exposures.” (Scientists were from NASA’s Johnson Space Center, Wyle Laboratories in Houston, and the University of Texas Medical School at Houston.)

“I don’t know that we can say that nanoparticles are inherently risky,” says Dr. Kristen Kulinowski, executive director of education and public policy at the Center for Biological and Environmental Nanotechnology and director of the International Council on Nanotechnology at Rice University in Houston, Texas. “What I would say is that the size and surface chemistry of nanoparticles raises concerns that they might have unique toxicological profiles that we don’t see in particles that are larger of the same chemical composition.”

In April 2006, the RAND Corporation released a report exploring health risks associated with the use of nanomaterials in the workplace. The report said that the U.S. government is providing insufficient funding to understand and manage risks that nanomaterials pose to the health of workers in the rapidly growing nanotechnology industry. The RAND report said that the government has directed more than a billion dollars annually to the development of nanotechnology, but just 1 percent of that, $10 million, to studying research understanding and managing the risks involved. Basically, that says there’s not enough money going into researching the health effects of nanotechnology. This is an issue that bears close watching.

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