Health Forum Journal Interviews Dr. Canton

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Dr. Canton Interviewed by Health Forum Journal

Nanomedicine: The Next Little Thing

By David Ollier Weber
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Nanomedicine is a blockbuster, with huge implications for health care (not to mention human life). Realize it or not, you are living in the Century of Nanomedicine. Nothing is going to be the same.

Disease? An obsolescent concept, at least as conventionally defined.

Already, notes the man who has literally written the book on nanomedicine, theoretician Robert Freitas Jr., of Zyvex Corporation, in Richardson, Texas, scientists are rapidly filling in the map of the human genome and dissecting the proteome. It is not unreasonable to expect that before mid-century we will possess "a complete catalog of all human proteins, lipids, carbohydrates, nucleoproteins and other molecules, including full sequence, structure and much functional information," he writes. This will be accomplished in large measure thanks to the chemists, materials scientists, and nanotechnology engineers at university laboratories and start-up commercial enterprises who are gaining astonishing dexterity in the fabrication of complex microscopic tools and "machines" assembled by positioning nanobits of matter with atomic-level precision.

(The prefix nano- comes from the Greek word for dwarf, Freitas explains, and is used to designate one-billionth of a standard measurement–a nanometer, for example, is one billionth of a meter, or about the width of six carbon atoms. Nanotechnology and nanomedicine refer to deployment of instruments built, sized, and operating on a scale of less than 100 nanometers–"the scale of biology," points out chemist Chad Mirkin, director of the Institute for Nanotechnology at Northwestern University. A virus, for example, measures 60 to 100 nanometers, an antibody 2 to 20, a protein under 10.)

"The comprehensive knowledge of human molecular structure so painstakingly acquired during the 20th and early 21st centuries will be used in the 21st century to design medically active microscopic machines," asserts Freitas in Nanomedicine, the densely annotated, intricately reasoned 500-page survey of possibilities he published in 1999. (He is now at work at Zyvex on volumes two and three. All quotes that follow, except those indicated, are from the first book.) "These machines," he continues, "rather than being tasked primarily with voyages of pure discovery, will instead most often be sent on missions of cellular inspection, repair and reconstruction." Nanometer-scaled medical "robots" armed with detectors and antibiotic or antiviral payloads that can seek out invaders inside individual cells, or gobble and neutralize microbes circulating in the bloodstream, or link and assemble tissue structures to accomplish major reconstructive and restorative procedures will be capable within a few decades, Freitas is confident, of "revers[ing] all pathological effects of disease or injury, with a minimum of pain, discomfort, side effects, intrusiveness and time, and with a maximum of effectiveness, efficiency and likelihood of success."

Medical Evolution

Just how nutty is this guy? We're not all zipping around in flying cars as was predicted in the 1950s, or commuting to the moon à la Stanley Kubrick's 2001: A Space Odyssey. How likely is it that infinitesimal medical robots will be bustling about inside our bodies, keeping us hale and virtually immortal in 2101? Freitas points to the trajectory of science history. As does James Canton, president of the Institute for Global Futures, in San Francisco. "Right now, in terms of time lines and the development of Western medicine, we're just a few notches away from leeches and bloodletting," observes Canton. And yet, he acknowledges, those notches include the groundbreaking biological insights that, since the mid-19th century, have transformed medical diagnosis and therapy from a magical art into a modern, evidence-based science. It was in the late 17th century that scholars introduced the term molecula. By 1869 the chemistry-book definition of a "molecule" was "the smallest particle of an element in the free state . . . , a group of atoms mechanically indivisible." A dawning appreciation of the biological function of molecules by Louis Pasteur (seeking a treatment for anthrax), Paul Ehrlich, Alexander Fleming, Rene Dubos, and others culminated in the development of penicillin (in 1939) and successor antibiotics–agents of unprecedented potency against pathogens because of their deadly molecular aim.

Refinements in microscopy enabled biologists in the 1850s to descry the dye-absorbing rods in cell nuclei they labeled chromosomes, and to recognize by the early 20th century that these were the repositories of genes. By mid-century James Watson, Francis Crick, and Maurice Wilkins, interpreting the remarkable X-ray crystallographic images and brilliant clues supplied by Rosalind Franklin (she would die of cancer at 37), had earned Nobel Prizes for their elucidation of the double-helical nature of the molecule that encodes an organism's genetic heritage: deoxyribonucleic acid, or DNA. In 1990, amplification of this knowledge, hitched to other scientific advances–including the use of viruses as vectors to insert desirable genes into living cells, and the polymerase chain reaction (PCR) technique for rapidly reading and replicating the chemical base pairs of DNA strands–made possible the first "gene therapy" for a child born with a hereditary disorder, adenosine deaminase deficiency. It worked.

In the late 1950s, physicist Richard Feynman predicted that the ability to arrange atoms "one by one the way we want them" would be an inevitable step along the path of scientific advance. And indeed, by 1982 IBM researchers had built the scanning tunneling microscope that enabled them to shuffle 35 xenon atoms to spell out the corporate logo. A refinement, the atomic force microscope, offered even more precision and versatility in working with living systems. In 1985, Rice University researcher Richard Smalley created a new form of carbon whose 60 atoms form a geodesic sphere with walls only one atom thick. (He called it Buckminsterfullerene after the architect of the geodesic dome, a name later shortened to fullerene. It was in this period that the term nanotechnology was also introduced.) Used as the tip on an atomic force microscope probe, a tubular variant of the carbon-60 molecule now gives researchers the ability to scrutinize the composition and operation of single proteins–for example, beta amyloid, the source of the plaque that accumulates in the brain to produce Alzheimer's disease.

Genie's Box

More than any other time in history, mankind faces a crossroads: One path leads to despair and hopelessness, and the other to total extinction. Let us pray we have the wisdom to choose correctly. – Woody Allen

B Not everyone is ecstatic about the prospects of a nanotechnology-enhanced world. Sun Microsystems cofounder and chief scientist Bill Joy is a notable Cassandra who fears that comedian Allen may have got it right. In a 2000 interview with the online magazine Salon, Joy explained his fears:

"We understand biology and we understand machines, but these things [nanotechnology, genetic engineering, and robotics] are different. . . . These things are so powerful [that when we use them] we really can't foresee what the outcome will be."

Joy thinks some kind of consensus on regulation must be reached, but he's not expecting it anytime soon. "We would have to deal with the scientific community's enormous desire for lack of interference, and businesses' enormous desire for lack of interference, and government's desire to not do anything," he opined joylessly. "Everybody's pretty happy with the status quo at this point. It's going to take some real leadership, and it's going to take time to develop."

Futurist Canton shares Freitas's certainty that "we have now unlocked the genie's box. This is the last generation of folks who will not have access to a deep palette of understanding of our genetic destiny. There won't even be a field in 10 years called 'nanomedicine'–it'll simply be 'medicine.' And the transformation will be profound. Manipulation of matter at the atomic level means manipulation of our entire reality. It will challenge the whole notion of human evolution."

Thus Canton shares Joy's deep trepidations as well.

"We'll make every mistake we can possibly make," Canton predicts, "up to the point of damaging the gene pool. We don't know enough to know the potential risks to our evolutionary foundation this technology could produce. We're talking about how our consciousness and behavior may be altered by the most powerful set of tools any civilization has ever dealt with in the history of mankind. So. Do I think we ought to move cautiously? Yes. But I also believe we will move forward."

No doubt about it. Certainly not among the nanotechnologists. Gazing at the manmade molecules of nanoscale bone-seed he's synthesized at Rensselaer Polytechnic Institute in Troy, New York [see sidebar], chemist Richard Siegel exclaims: "We're living in a very exciting world right now!"

Welcome to the Century of Nanomedicine. Nothing is going to be the same.

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