The Lessons Of Living Things

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Natural Computing

By Dennis Shasha and Cathy Lazere
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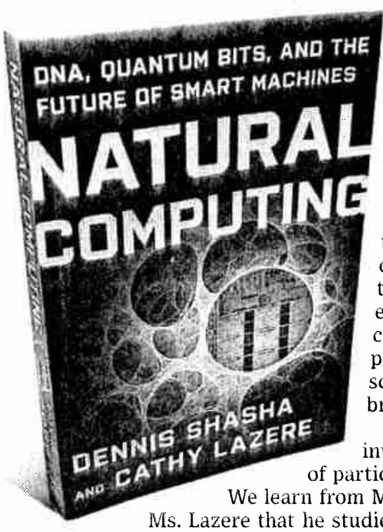
David E. Shaw has made billions of dollars on Wall Street—as head of the investment firm D.E. Shaw & Co.—but his real dream is to watch proteins unfold. It sounds tedious, but it is in fact one of the deepest secrets in biology. Imagine that you could build a house by simply squeezing building materials out of giant tubes and letting the strings of goo fold themselves into useful architectural structures. That's roughly the way a DNA blueprint gets turned into a body, and Mr. Shaw's goal is to make computers fast enough to capture the details of this process and, eventually, to apply the process itself to the creation of new medicines.

In "Natural Computing," Dennis Shasha and Cathy Lazere profile Mr. Shaw and 14 other scientists who are pushing computer science beyond traditional boundaries. In particular, the scientists are trespassing into the realms of biology and physics and attempting to create computer designs and functions that will imitate organic reality. The authors look at both the research and the researchers themselves, providing basic background to the ideas under investigation and profiling the scientists, often tracing their paths from eccentric childhood passions to scientific breakthroughs.



Mr. Shaw's investigations are of particular interest. We learn from Mr. Shasha and Ms. Lazere that he studied physics in college and did his doctoral studies in artificial intelligence, eventually assembling the prototype of a machine that integrated logic and memory on the same chip. He thereby "avoided the so-called *von Neumann bottleneck*—the time required to communicate data between processor and memory," a breakthrough in the early 1980s with applications to Wall Street trading and quantitative investing.

For years, we are told, Mr. Shaw pondered leaving the financial world and returning to basic research, and he finally did in 2001. "Shaw thought protein dynamics problems provided a good fit for his interests and his background in developing novel machine architectures," the authors write. "He had a personal reason as well: his mother, father, and sister had all died of cancer." Mr. Shaw hoped that he could design a computational tool that would "someday be used to develop life-saving drugs."

His "Anton machine," named for the inventive early scientist Anton van Leeuwenhoek, creates simulations of protein development and operates at astounding computational rates, executing certain aspects of molecular dynamics "at an effective peak speed of more than 650 trillion operations per second." For the moment, the Anton machine is seen as a means of investigating biological processes. Whether it will eventually make life-saving drugs possible is anyone's guess. Mr. Shaw's goal, at any rate, is "to advance the state of scientific knowledge."

How the processes of biology are guiding computer design and purpose.

The Anton machine applies computer models to a biological problem, but biology often plays a role as a designer in Mr. Shasha and Ms. Lazere's narrative. The scientist Rodney Brooks, for instance, used the mechanics of insect movement to build robots that now explore the surface of the moon and of Mars. When he first began designing such machines, in the early 1990s, he believed (and has since been proved right) that "an intelligent system had to have its representations grounded in the physical world."

More such biological inspiration is needed, the authors say, in the field of computer science generally, now overly focused on brittle algorithms. The authors compare algorithms to the interchangeable parts of bricks-and-mortar mass manufacture. In the future, they argue, computers will have to avoid a static, fixed condition and find ways of evolving without direct supervision, even learning to heal themselves without a visit from a repairman.

Louis Qualls, another of the scientists profiled in "Natural Computing," needs such capabilities to design nuclear power plants for use on the surface of the moon, a task that challenges designers to create a safe, reliable reactor for an unfamiliar environment. He works at Oak Ridge National Laboratory using "genetic" algorithms to help put together complicated systems that are very difficult to design manually. He starts with basic design possibilities and lets the computer explore a myriad of possible tweaks, probing over and over again, say, how best to model radiation damage in metals, until a solution is reached—without human intervention. Such programs are implemented with traditional hardware, but the inspiration for the techniques comes from the world of living things.

Biology's role can be even more direct. The authors argue that the silicon in our familiar computers may be replaced, over time, with biological materials like bacteria and DNA. Scientists can already create origami out of DNA and make viruses in various designed shapes. Similar approaches to making a biochemical-hardware interface could be used to control biological processes with computers or make peripheral devices, like a "printer" that would output a new vaccine.

No one has yet built a computer based on quantum mechanics, but algorithms have been designed that slash the complexity of current approaches to imitating quantum processes. Some problems that are effectively impossible to solve on current machines will take only seconds on quantum computers. The boon to mankind will be great, though such computers will render useless current encryption techniques, affecting the utility of government security programs and the privacy of Web shopping sites. There is a downside to everything.

Mr. Hamilton is founder of Categorical Technology, LLC, a start-up that applies natural computing techniques to problems in Web publishing.