Out of Control:
The Rise of Neo-Biological Civilization
By Kevin Kelly.
Addison-Wesley, 1994. $28.00.

Melanie Mitchell

In *Technology Review*, October, 1995

For most of its history, science was encompassed within the catch-all of "natural philosophy"; it had no clear division into separate disciplines. Not until the seventeenth century or later did scientists identify themselves primarily as specialists in particular areas. But once started, the rise of scientific specialization was steep, and is now seen very clearly in the almost clean separation of university departments. In recent decades, however, movements back towards a more unified or "interdisciplinary" approach have been gaining steam. Computer scientists are finding that biology is a rich source of inspiration for building "adaptive" computer programs (programs that can automatically improve their performance over time); physicists, biologists, and neuroscientists are drawing on the theory of computation to understand information processing in natural systems; economists are using biological evolution as a source of metaphors for how economic change and innovation takes place.

Many of these new interdisciplinary approaches have roots in the cybernetics and information-theory movements of the 1940s, 50s, and 60s in which the harnessing of feedback in electronic systems, the formalization of "information" and "information processing", and, most important, the invention of the electronic computer gave rise to attempts to unify principles in diverse fields. Much of this interdisciplinary fervor subsided in the 1970s and early 80s, but recently there has been a renaissance of enthusiasm, engendering a spate of newly named fields including "cognitive science", "artificial life", "adaptive computation", "neural computation", and "complexity". These fields, of course, owe a great (though sometimes unacknowledged) debt to the earlier cybernetic era.

This recent renaissance is spurred by some momentous possibilities, such as capturing evolution and creating life in computers, engineering biological organisms, and, perhaps most ambitious, finding universal laws that govern all complex systems in nature. These ideas have caught the fancy of the general public, reflected in a proliferation of popular-audience books on these topics. Wired magazine editor Kevin Kelly's book, *Out of Control*, joins several others in celebrating the new "sciences of complexity".

Kelly's book is a broad-ranging survey of topics and personal musings on the theme of the merging of biology and technology. "The realm of the *born*—all that is nature—and the realm of the *made*—all that is humanly constructed—are becoming one. Machines are becoming biological and the biological is becoming engineered." In other words, we can now control biology with engineering techniques (e.g., genetic engineering or artificial ecologies) and we can borrow ideas from biology to create machines with life-like properties.

The book ranges over the spectrum of what's hot in today's computer science and biology. Kelly jumps from discussions of bee hives, to insect robots, to the formation of ecologies, to the coevolution of organisms. He covers the history of feedback and control, the engineering of coral reefs, Biosphere 2—a huge, glass-enclosed complex ecology in the desert of Arizona, "smart offices", electronic money, virtual reality, artificial evolution, and computer animation. He describes some of the more controversial theories in modern theoretical biology, and recounts attempts to predict the stock market using computers.

Kelly tells some wonderful stories, recounting, for example, the tale of how a crowd of 5,000 computer graphics experts succeeded in controlling a complicated flight simulator by individually "voting" on what to do at each moment. Then there is the history of the "Survival Research Labs," a San Francisco-based group of performance-artists, whose huge, life-like machines built out of found—or stolen—parts engage in street-theater robotics. The connection with the original theme is at times weak, but with help from Kelly, the topics maintain a vague family resemblance.

These descriptions of cutting-edge research and high-tech art are the strongest parts of the book—Kelly's excitement is contagious (although excitement is sometimes produced at the expense of scientific or historical accuracy, and occasionally lapses into outright hype). For technically minded readers the fun of reading the book will be mixed with a constant sense of frustration. The ideas described are tantalizing, but covered rather superficially. There are many intriguing "science sound-bites", but hardly ever enough detail to convey what is really meant.

The weakest parts of the book, to my mind, are Kelly's own philosophical musings about the themes of biological machines and mechanical biology. These sections dive head-first into some of the deepest of scientific questions, but often end up sounding vague, mystical, and at the edge of intelligible. Aphorisms like "Every self is an argument trying to prove its identity," or "Biology is an inevitability—almost a mathematical certainty—that all complexity will drift towards" have an aura of depth but not much content. There are also some very fuzzy views of logic and causality. Kelly creates a nice pun—"We now see that no logic except *bio*-logic can assemble a thinking device, or even a workable system of any magnitude"—but takes it too seriously, asserting many times that the "swarm logic" of biological systems is somehow different from "ordinary logic" and that the "lateral" or "nonlinear" causality in such systems is somehow different from ordinary causality. I almost know what he means, but this semi-mystical phrasing makes the idea sound more revolutionary than it really is.

Kelly's notions of "nonlinear" logic and causality in complex systems give way to a rather religious view of networks, parallelism, and the like. The "Net", always capitalized, is invoked as a mystical object:

> The Net is an emblem of multiples. Out of it comes swarm being—distributed being—spreading the self over the entire web so that no part can say 'I am the I.' It is irredeemably social, unabashedly of many minds. It conveys the logic both of Computer and of Nature—which in turn convey a power beyond understanding.

One can translate these sentiments into more pedestrian language ("Networks consist of many interconnected parts, over which information can be distributed. Networks can be used both for computation and for modeling natural systems. In general their behavior is difficult to analyze mathematically."), but I guess it's a lot more boring that way.

This mystical view of networks struck me as being, paradoxically, anti-scientific. Here, a book which is trying to explain the science behind complex systems gives the impression that when lots of simple parts are highly interconnected and get to act in a parallel "swarm", somehow, magically, in a way beyond understanding, phenomena such as "life" emerge. I deeply share Kelly's wonderment at the existence of decentralized collective behavior (such as that in insect colonies or in the brain), but the goal of science—to understand the *mechanisms* underlying such natural phenomena—is strangely left out of these musings.

Also worrisome is the power given to certain words such as "evolution". A great deal is made of "evolutionary computation", in which computer programs inspired by biological evolution evolve solutions to complex problems. Evolution is presented as the future of computation, and several research projects involving evolution by computers are described with great reverence. However, it seems that Kelly is seduced as much by these words and their air of mystery as by the actual computer programs. Of course, if sexy labels stir up excitement in science and help prod biologists and computationalists to work together, they have served a worthy purpose. But as one who believes strongly that biologically inspired approaches will indeed be the future of computation, I am nonetheless worried about their facile appeal. In the field of artificial intelligence, extreme early enthusiasm ("in 10 years we will have true thinking machines") gave way in some quarters to extreme disappointment and dismissal ("AI doesn't work at all"). Extremes of both sorts are unhealthy for the progress of science, and I am worried that the almost religious faith in evolution and other biological phenomena as the saviors of artificial intelligence, as exemplified by this and other treatments, will hinder real progress. These approaches are promising but not proven—establishing exactly what they can do for us will take time and hard work. There is still a long way to go before our human constructions become truly worthy of the richness of names like "evolution" and "life".

Kelly ends the book on two strangely conflicting notes. The first note is humility: he gives a list of excellent, difficult philosophical questions about the topics he has covered: "What is complexity, anyway?," "What, if anything, cannot be simulated?," "What, if any, are the distinctions between a simulation and a reality?," "Can evolution evolve its own teleological purpose?," and so on. Such questions illuminate how far science and philosophy still have to go in these areas.

The second note is hubris (some might say "chutzpah"): Kelly lists the "Nine Laws of God" which purport to explain everything he has discussed so far. "These nine principles underpin the awesome workings of prairies, flamingoes, cedar forests, eyeballs, natural selection in geological time, and the unfolding of a baby elephant from a tiny seed of elephant sperm and egg" (p. 471). A disquieting thought for scientists; has he done all our work for us? But not to worry: while his nine principles summarize some nice observations about complex systems in general ("control from the bottom up," "grow by chunking," "seek persistent disequilibrium"), they turn out to be the laws of a rather vague god, not the better-known god who is "in the details" where most of science lies. Kelly's god has, I'm glad to say, left all the details in the world for the scientists to figure out.

Melanie Mitchell is Research Professor and Director of the Adaptive Computation Program at the Santa Fe Institute.