CURRENT BOOKS

After Chaos

ARTIFICIAL LIFE: The Quest for a New Creation. *By Steven Levy. Pantheon. 390 pp. $25*
COMPLEXITY: The Emerging Science at the Edge of Order and Chaos. *By M. Mitchell Waldrop. Simon & Schuster. 380 pp. $23*
COMPLEXITY: Life at the Edge of Chaos. *By Roger Lewin. Macmillan. 208 pp. $22*

We take our metaphors where we can find them. With every scientific revolution, failed or otherwise, new metaphors and images wedge themselves into the public mind. In the 19th century, "entropy" and "the Second Law of Thermodynamics" generated a perverse glee among those, including Protestant fundamentalists, who were taken with the idea that the universe is heading inevitably toward a state of complete disorder, a scientific version of the biblical fall. Earlier in this century, "relativity" and "the Heisenberg Uncertainty Principle" (i.e. there is no such thing as an immaculate perception) provided English majors and seminarians with offbeat dissertation topics. Then came successive waves of journal articles in the humanities whose keywords included one of the four C's—*cybernetics, catastrophe theory, chaos,* and now, the newest of them all, *complexity.*

Several years ago, James Gleick's *Chaos* (1987) popularized the notion that there is a new science of chaos. Tiny differences in the numbers plugged into seemingly simple equations, such as those used to model weather or the turbulent flow of water, Gleick showed, can lead to wild swings in the output. The behavior of these so-called chaotic nonlinear systems can be predicted only if we can be *infinitely* precise about the initial conditions; since that is impossible we are left with systems that, though completely deterministic, exhibit what to all appearances is random behavior.

Not all nonlinear systems are so badly behaved, and that is where complexity comes in. Once again simple systems turn out to be full of surprises, but instead of spiraling off into chaos they produce intricate patterns that seem to capture the essence of what we mean by complexity. In the jargon of this emerging field, complex adaptive systems—which might include cells, brains, organisms, ecosystems, and maybe even corporations and economies—exist on the "edge of chaos," in a regime not so ordered as to be rigid and dull but not so chaotic as to be meaningless. Like water turning from solid to liquid to vapor, the story goes, these systems go through "phase transitions" from order to chaos. And when they are poised on a cusp between these two extremes, such "complex systems" gain the ability to gather and process information, a flexibility that allows them to both alter and adapt to their worlds.

Whether this is more than an arresting metaphor is still anybody's guess. In the meantime, science journalists, hoping to replicate Gleick's success, have seized on complexity as the hot new topic. For the last few years they have been descending on an interdisciplinary research center called the Santa Fe Institute, which functions as the focus of the quest, to explain how complexity arises from simplicity—networks of genes giving rise to cells, networks of cells giving rise to organisms, networks of organisms giving rise to societies, all because of their ability to process information. The hope is that all of these webs are strung together according to general rules that have eluded mainstream science, that there is a science of complexity.

With all the sudden attention, scientists at the Santa Fe Institute must feel at times like the local Pueblo Indian communities being scrutinized by anthropologists. While some retreat into their offices for the more civilized company of computer screens, others have come to enjoy the limelight, repackaging their lives with the kinds of anecdotes they have learned that journalists like to hear. The result has been a

number of magazine articles and three recent books—Steven Levy's *Artificial Life*, M. Mitchell Waldrop's *Complexity*, and Roger Lewin's *Complexity*—in which we can read about the fomenters of this revolution. We hear, for example, three renditions of the life of Stuart Kauffman, a philosopher-turned-physician-turned-theoretical biologist, who is so sure that humanity must be more than a random fluke that he is trying to recast Darwinian evolution and uncover a grammar that leads inexorably to increasingly complex creatures. We also get the thrice-told tale of Christopher Langton, a Vietnam-era conscientious objector and blues guitarist who survived a horrible hang-gliding accident and went on to launch a new field called Artificial Life ("A-life," for short), which attempts to create self-reproducing computer programs so fluid and complex that it might someday seem smug and anthropocentric not to grant that they too are alive. Hovering in the background of all three books is Murray Gell-Mann, who is more gun-shy of journalists. Gell-Mann, who earned his Nobel Prize for the ultimate simplification, showing how hundreds of subatomic particles can be reduced to a handful of quarks, has come to Santa Fe to study the other side of the story: how nature goes from the simple to the complex.

These and the other scientists featured in these books are fascinating, brilliant people. Still, no one but a reviewer, who gets the books for free, is likely to read all three. But deciding among them is not an easy task.

First out of the chute was Levy, whose publisher ensured that his book came out in time to benefit from the publicity surrounding the biennial Artificial Life conference, which was held in Santa Fe last summer. Levy was there for a book-signing at a store just off the Plaza, where the first customers got free t-shirts with the legend "Get A-Life." Perhaps because it was first, *Artificial Life* feels rushed in places, but for the most part it is a solid piece of work. Levy showed in his first book, *Hackers: Heroes of the Computer Revolution* (1985), how good he is at capturing the excitement of quixotic seekers on the fringe of computer science. One of the best chapters of *Artificial Life*, called "Garage Band Science," tells how, long before the Santa Fe Institute began, several young veterans of the chaos wars, including Doyne Farmer and Norman Packard, started a research lab in an old adobe tavern down the hill from nearby Los Alamos. Following their intuition that life is a process that can be skimmed from its carboniferous substrate and programmed into a computer, the three scientists studied mathematical kaleidoscopes called cellular automata. A cellular automaton consists of a grid of cells that changes colors according to a few simple rules. Displayed on a computer screen at lightning speed, cellular automata can generate astonishingly complex patterns, some capable of navigating around their checkerboard universe and even cloning themselves. In explaining how this works, Levy gives a nice historical sketch of John Horton Conway, who in the days before cheap, abundant computer power, invented one of the more well-known cellular automata, The Game of Life, by manipulating tokens on a vast expanse of graph paper.

The next book on the shelves was Waldrop's *Complexity*. Though he focuses more broadly on complex systems—economies as well as organisms—and specifically on the Santa Fe Institute itself, we learn a lot about A-life along the way. Readers of the journal *Science* know that Waldrop is very good at translating the grayest abstractions into pictures we can hold comfortably in our heads. His book includes the best descriptions I have read of what can be very difficult work: Kauffman's attempts to tease out hidden orders that would show evolution to be less of a free-for-all than traditional Darwinists suppose, for example, or Langton's invention of the so-called lambda parameter, which may provide a rough measure of where a cellular automaton lies on a continuum between order and chaos. The other books say that there is something called the lambda param-

eter; Waldrop tells readers precisely what it is.

But Waldrop's apparent efforts to emulate Tracy Kidder's book, *Soul of a New Machine* (1981), are less successful. In Kidder's book, the drama comes from the reader's wondering whether the hero-engineers will succeed or fail in developing a new computer, and we know we will find out before we turn the final page. We will not know for years whether the Santa Fe Institute will come to be seen as the catalyst of a new science or as a noble footnote to history. Consequently, it is hard to develop an interest in all the institutional minutiae and blow-by-blow descriptions of political battles that Waldrop presents. The people-to-science ratio is much higher than in *Chaos*. Gleick used the scientists as vehicles to explain some pretty abstract mathematics; one learns very little about their personal lives and feels none the poorer for it. The scientists in *Complexity* are spun into full-blown characters. Much of this is very well done, but (as I heard the wife of one of the scientist-characters say) by the time you have read the third or fourth life story of an unappreciated genius who found a home at the intellectual mecca in Santa Fe, it is an effort to keep from skimming.

Both Levy's and Waldrop's books set a fast (sometimes frenetic) pace with the volume of the prose set at full blast. In some ways, then, it is refreshing to find that the third complexity book, by Roger Lewin, is more low-key, focusing on relaxed encounters with remarkable people. I liked how Lewin, whose long career as a science writer (he was also an editor at *New Scientist* and *Science*) gives him perspective and authority, and he ranges farther afield than Waldrop does. In addition to the conversations in Santa Fe, we listen in on discussions with the likes of Daniel Dennett and Patricia Churchland, two philosophers who speculate on the most complex of complex systems, human consciousness, and with those, like Stephen Jay Gould, who view the work at Santa Fe with a more jaundiced eye. Lewin's book is shaped not by the happenstances of the Santa Fe Institute but by the author's own curiosity. The scientific explanations are not as crisp or detailed as Waldrop's; nor is the writing as well-honed. But science writing too often comes off like cheerleading, and Lewin makes up for some of the book's shortcomings with his more detached, critical tone.

Yet I felt that even Lewin could have been more skeptical. Like the other two authors, he treats the idea of a phase transition between order and chaos as though it were done science. One would not know from these books that a backlash against the idea is already developing. The term *edge of chaos* has become so nearly a cliché that whenever it is uttered at the Santa Fe Institute, one can count on hearing groans from the loyal opposition. In their recent work, even some of the institute's more enthusiastic supporters raise serious questions about ideas that all three books take as gospel.

We will have to wait to see how all of this comes out. Meanwhile, now that the journalists have had their say, it will soon be the scientists' turn. Kauffman, Langton, and Gell-Mann all have contracts to write books about complexity. And they are aiming their words not at their students or colleagues but at the book-buying public.

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