Thinking in Complexity: The Complex Dynamics of Matter, Mind, and Mankind, by Klaus Mainzer, 1994, Heidelberg: Springer-Verlag, 329 pp., subject and name indexes, 118 figures

A lecturer in philosophy and economics at the University of Augsburg, Klaus Mainzer has produced one of the most penetrating and thoughtful books using the framework of nonlinear complex dynamics to range across a variety of intellectual disciplines in an effort to develop a unified picture of the world as a whole in both its non-human and human parts. It may be his deep grounding in philosophy that allows him to do a better job than others attempting a similar feat, such as John Casti or Erich Jantsch. But his book, drawing significantly on the synergetics tradition of Hermann Haken, succeeds admirably in this effort.

The book has a sophisticated mathematical grounding, but is not heavily mathematical in the sense of consisting primarily of equations or theorems. Most of the math is presented verbally, graphically, or figuratively. Thus it is more accessible to a broader audience than many books published by Springer-Verlag or on complex nonlinear dynamics above the purely popular level. This is a book with considerable depth as well as breadth. Mainzer's stance can be seen most clearly by listing the names of those who appear on more than ten pages in the book: Aristotle, Boltzmann, Darwin, Descartes, Einstein, Galileo, Heraclitus, Kant, Leibniz, von Neumann, Newton, Plato, Adam Smith, and Turing. Mainzer is concerned with foundational intellectual issues from the entire history of philosophy and science, as well as current developments in a variety of fields and their interrelationships.

Chapter 1, "From Linear to Nonlinear Thinking," presents a summary and overview of the book as a whole. He makes an argument for the synergetics "slaving principle" on Ockham's Razor grounds, but declares more broadly that the complex systems approach challenges established concepts of epistemology and ethics. He also provides a table listing disciplines from quantum mechanics through artificial intelligence, characterized by the nature of their system, their elements, their dynamics, and their principal order parameter.

Chapter 2, "Complex Systems and the Evolution of Matter," presents a view of the evolution of the inorganic universe as well as a history of astronomy and physics from the Ancient Greeks to quantum mechanics and the grand unified field theories. He begins with the conflict between Parmenides' view of the universe as unchangeable being and Heraclitus' view of it as in a state of constant change and flux. From there he passes through the development of the laws of motion, to chaotic dynamics in quantum mechanics, and finally the emergence of order from subatomic particles to galaxies in a dissipative universe.

Chapter 3, "Complex Systems and the Evolution of Life," moves to organic evolution. Again, he starts from the Greeks, Thales of Miletus, with views of biology through Descartes and Leibniz to Darwin. Boltzmann's thermodynamics with Schrödinger's interpretation are then brought in, as is Prigogine's dissipative structures viewpoint. Eigen's hypercycle and Haken's version of morphogenesis are relied upon for the evolution of organisms, and Lotka-Volterra dynamics are examined for broader ecological population processes.

Chapter 4, "Complex Systems and the Evolution of Mind–Brain," is the most innovative and the longest chapter in the book, its real core where Mainzer attempts to grapple with what are to him the ultimate questions. He attempts to resolve the age-old mind–body problem using complex systems dynamics. This is a topic which has recently received renewed attention and controversy. I cannot say that Mainzer necessarily succeeds, but his effort is dazzling. Proceeding again from Plato's conception of the soul to La Mettrie's conception of humans as soulless machines through a dense thicket of philosophy, he proceeds to attack the issue dialectically with the

tools of neural networks, Hebbian learning, Hopfield systems, Köhlerian gestalts, detailed examinations of brain structures in various species, the problem of self-consciousness and the regress of thinking about thinking, to the musings of John Searle on intentionality and the "Chinese room" problem. He ultimately sees intentionality as present in the crocodile brain and berates humans for their vanity as failing to see where their own intentionality derives from.

This leads naturally to Chapter 5, "Complex Systems and the Evolution of Artificial Intelligence." For once he does not start with Greeks, but rather with Leibniz's *mathesis universalis* and Turing machines. This leads quickly through Gödel's Theorem and Church's Thesis to expert systems, LISP, and Schrödinger's Cat. Then he deals with Conway's cellular automata, neural networks again, and synergetic computers with the slaving principle driving pattern recognition. He closes on a borderline sci fi zone of cyberspace speculation a la William Gibson and "neurobionics," with speculations about whether or not programmed brains in vats could realize that they are programmed brains in vats.

Chapter 6 moves to the at once higher level, if perhaps less esoteric subject of "Complex Systems and the Evolution of Human Society." Here he starts with the Greeks again, Aristotle and Plato, to run through Hobbes, Quesnay, with a major emphasis on Adam Smith's view of the invisible hand as a self-organizing market economic system, on to Keynes, game theory, and nonlinear chaotic business cycles a la Goodwin, followed by Arthur's path dependence models of technological change. The chapter ends with a section on communication and migration drawing on the work of Peter Allen, Wolfgang Weidlich, and Glance and Huberman, with an invocation of the emergence of a global information system via the internet. Chapter 7, "Epilogue on Ethics: Complexity, Responsibility, and Freedom," draws heavily on Kant to declare the necessity of maintaining human freedom and responsibility in a nonlinear global electronic village.

Given the tour de force nature of this book, it is hard to single out anything that is particularly objectionable, much less outright incorrect. Much of it is well known to many people, and thus somewhat boilerplate in nature. But much is not, and the firm philosophical framework and perspective keeps a high tone throughout the discussion. If there is a problem at all it is more in the nature of what or whom is left out, rather than with what is included. But in a book of this scope yet with a reasonably tight structure, making such a criticism seems churlish. Nevertheless, let me note a couple of notable lacunae.

One is the complete absence of any mention of the work of either Benoit Mandelbrot or René Thom, and thus of neither fractal geometry of catastrophe theory. One can argue that they are not necessary for his story, that fractal geometry is an unnecessary encumbrance if one has moved on to neural nets and that catastrophe theory is a limited model of phase transition which has been superseded by synergetics. Nevertheless, in several chapters he presents models of hierarchies in the universe or in the mind–brain that could well be enhanced by the fractal perspective. Also, the kinds of discussions of the sudden emergence of pattern recognition and similar discontinuous phenomena have been modeled with catastrophe theory with considerable insight. Thom, in particular, has the kind of philosophical perspective that would seem to appeal to Mainzer.

Another odd lacuna is the general absence of reference to work of the Santa Fe Institute. Now one can argue that its efforts have been overhyped by the media, or whatever, but certainly this has been one of the leading, if not the leading, center of research in complexity theory in the world. Granted there is reference to Brian Arthur's work on path dependence and also Conway's cellular automata model, but there is none to John Holland's work on adaptive systems or to Stuart Kauffman's work on the emergence of order at the edge of chaos. All of this would seem to be right up Mainzer's alley, but somehow it simply is not there. It may be that this reflects

his preference for Haken's synergetics approach as a unifying principle, but he certainly discusses numerous other concepts of dynamics as well, and thus this nearly complete ignoring of the work at the Santa Fe Institute is somewhat mysterious.

Yet another is his ignoring of the Austrian school of economists, some of whom, notably Friedrich Hayek and Don Lavoie, have developed self-organizing models of the economy inspired by Smith's view and influenced by Prigogine, in much the manner presented by Mainzer. However, it must be admitted that many of their fellow economists generally ignore the Austrians as well. So, he cannot be taken to task as much in this matter as perhaps he can be for ignoring the Santa Fe Institute's work.

All in all, however, this is a very impressive and thought–provoking work, both for the reasonably educated "layperson" as well as the knowledgeable specialist in nonlinear complex dynamics or any of the disciplines covered in this stimulating and insightful book.

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