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Book Review: *Chaos: Making a New Science*

Chaos: Making a New Science. James Gleick, Viking, New York, 352 pp.

Imagine a Rip Van Winkle awakening after a sleep of 25 years and wandering into a modern dynamics conference. He would be startled not to find many landmarks, but instead he would encounter, with puzzlement, a new vivid terminology, such as: chaos; strange attractor; fractal dimension; devil's staircases; crisis; metamorphoses; Lorenz's butterfly; solitons; Smale's horseshoes; KAM tori; and renormalization groups. Newton's law and the Hamilton–Jacobi equations would perhaps not even be mentioned. If Newton were mentioned, it would most likely be for his method of finding zeros of polynomials and the ensuing fractal basin boundaries.

How did mechanics, 300 years after the publication of Newton's *Principia*, once again reach the forefront of science? The answer lies in the shift from linear to nonlinear dynamics, and the unifying force in this new interdisiplinary science is the phenomenon of chaos. This is the subject of Gleick's fascinating book. He traces, in a popular fashion, how disparate individuals and groups encountered the puzzle of chaos, struggled with the concept of stochasticity in dynamics and its implications, and finally succeeded in establishing the study of chaos as a scientific discipline. Unlike quantum mechanics, there is no single equation, such as Schrödinger's equation, on which to focus. One instead searches for universalities. Jim Yorke has suggested calling these galaxies instead of universes, because there are so many of them. Yorke, by the way, gave the field its name in his 1975 paper with Li, "Period Three Implies Chaos," in the *American Mathematical Monthly*.

Gleick has captured the spirit and manner in which scientists work and sometimes make great discoveries. We find Lorentz's numerical work on atmospherics leading to the butterfly attractor with its extreme sensitivity to initial conditions, May's investigation of period doubling in animal population dynamics, the birth of Ruelle and Takens' concept of a strange attractor, Feigenbaum's discovery of the startling universality in the period doubling route to chaos, Shaw's magnificent and mundane

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dripping faucet, and Mandelbrot's fractals providing the geometry in which chaotic trajectories reside.

Gleick does not ignore the experimentalists. He tells of Gollub and Swinney's verification of the Ruelle–Takens scenario for chaos in Couette flow, and Libchaber finding Feigenbaum's universal numbers in Rayleigh–Benard flow. He does miss Gorman's beautiful experiment on flow in a differentially heated annulus, which is governed by the Lorenz equations and verifies their predictions. Also, Linsay's early work on routes to chaos in a diode is absent.

The chapter entitled "Inner Rhythms" suggests that some of the most important applications of chaos may lie in the field of biology. Consider the heart. If it existed in a perfect mode-locked state, then essentially it would not be communicating with the rest of the body. Analyses of healthy EKGs show that the heart beat actually involves a $1/f$ noise component. This broadband noise apparently allows the heart flexibility to smoothly respond to numerous stimuli. EKGs of diseased hearts showed evidence of mode-locking and the loss of the $1/f$ noise spectrum. Thus, questions of transitions between mode-locked and chaotic states of an oscillator have relevance to health. Previously, Mandell has pioneered this paradigm down to the protein level. At the very least it appears that new techniques for analyzing chaotic signals, such as calculating dimension and entropy, may prove to provide techniques for medical diagnosis.

If any criticism can be found, it is perhaps that Gleick's history is dominated by the U.S. view. The European and especially the Russian school are, perhaps for reasons of budget and language, not fully represented. Also, the hot topic in nonlinear dynamics of the 1970s, solitons, is ignored. The interplay between such coherent structures and chaos is an important topic for the field of turbulence with its spatiotemporal complexity. The work on chaos so far has focused mainly on low-dimensional temporal complexity.

Gleick has succeeded in writing a truthful book about science and scientists, full of facts, concepts, and personal stories. The experts will probably discover something new about their colleagues, even if it is that their memories about the past no longer coincide. There are essentially no equations, so this is not the book from which to learn about the technical details of chaos, but it is the book from which to learn about the history of the making of this new science. It is a fun read.

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