Seismic Uncertainties

Fundamentals of Earthquake Prediction. CINNA LOMNITZ. Wiley, New York, 1994. xiv, 326 pp., illus. $89.95 or £66.

More than a century after Charles Darwin rode out the great Chilean earthquake of 1835, Cinna Lomnitz had a similar experience with the greatest earthquake of this century: "We could clearly see the trees leaning back and forth, tilting into and away from each other with a period of perhaps two seconds." Lomnitz observed these unusual rolling ground motions at his vantage point 200 kilometers from the epicenter of the 1960 Chilean earthquake, which had a moment magnitude of 9.5. Conventional seismic models fail to quantitatively explain the style of shaking involved, and on the basis of this and many subsequent observations of unusual ground motion and liquefaction, notably for the 1985 Mexican earthquake, Lomnitz advocates a far greater role for low-rigidity gravity waves in causing earthquake damage than does the conventional wisdom. This is one of several iconoclastic perspectives advocated in this wide-roaming book, which synthesizes many personal observations and ideas from the author's long career in earthquake seismology. Like Darwin, Lomnitz is a keen observer, and his remarkable experience base with large earthquakes around the world provides many interesting perspectives.

Any book purporting to elucidate the "fundamentals of earthquake prediction" is bound to elicit a broad diversity of response, given that some influential earthquake experts would assert that earthquakes are fundamentally not predictable. Indeed, as proves true of most books of earthquake prediction, there is only a token effort in this one to provide a first-principles theory

"Example of overturned building due to foundation failure in the 1985 Mexico earthquake. Here the piles were pulled out together with the intervening soil." [From *Fundamentals of Earthquake Prediction*]

"A jinami or 'frozen' gravity wave photographed on soft ground after the 1987 Chiba, Japan earthquake." [From *Fundamentals of Earthquake Prediction*; photo courtesy of H. Nirei]

for earthquake prediction. Lomnitz dabbles with "thermodynamics of earthquake precursors" and provides some useful insight into the probabilistic nature of nonlinear instabilities, but, as is the case with most earthquake-prediction enthusiasts, he relies largely on an intuitive faith that the earthquake process must involve precursory phenomena that can provide a basis for prediction. This perspective is unveiled in the context of enjoyable recountings of the earthquake prediction successes and failures of China, the United States, and Japan. The influence of cultural mindset on the posing of both scientific and pseudoscientific approaches to earthquake prediction is explored by a lengthy consideration of Chinese epistemology, medicine, and military science. Though he gives a somewhat critical assessment of many reported earthquake precursors (as well as of the institutions that have been set up to evaluate earthquake predictions), Lomnitz's optimism comes across in statements like "Precursory changes in flow were likely, but none were reported," with regard to groundwater perturbations associated with the 1952 Kern County, California, earthquake.

Lomnitz grapples with the very definition of earthquake predictability, an elusive concept for complex nonlinear dynamic systems. Unfortunately, he slips into loose usage of the term that conflicts with the general research community's definition involving specificity of time, location, and size of the event to occur. He equally categorizes under "prediction" efforts involving long-term seismicity patterns, short-term precursors, and insurance company probabilistic approaches. Lomnitz's definition involves almost any enhanced understanding of the earthquake occurrence and effects, ranging from statistical forecasting to hazard mitigation. This opens the door rather wide, and the author exploits that flexibility to delve into issues such as the gravity-wave hypothesis, which is relevant to shaking damage rather than event prediction.

The non-specialist will enjoy the diverse glimpses into the behind-the-scenes activities in this most controversial endeavor of the earthquake research community, including some rather soiled linen of the past few decades. But I expect that all readers will likely come away wondering whether there are in fact any "fundamentals" in this business. Unfortunately, the tremendous recent advances in our understanding of earthquake phenomena stemming from analysis of seismograms are totally unrepresented in this work. Those are deemed to be the "fundamentals" by many earthquake specialists. Though I would take issue with the author's assertion that "Today earthquake prediction is the best reason for becoming a seismologist," it nonetheless seems clear that there is tremendous merit in research to establish how predictable earthquake phenomena actually are, and under what circumstances. We do not know the answer to this question, and Lomnitz's book offers many arguments why we should strive toward an answer, even recognizing the chaotic behavior of nonlinear dynamic systems. Our state of ignorance is such that we may have to suffer sloppy empirical approaches to earthquake prediction for some time to come, but, as Lomnitz would argue, disaster preparation and improved earthquake engineering approaches are likely to be the best investments, and these can proceed apace. The greater societal issue is the extent to which operational earthquake prediction systems should be sustained when there is no cogent set of fundamentals underlying them. This book certainly provokes thought on this important issue, but it does not provide the answer.

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Virtually A-Life

The Garden in the Machine. The Emerging Science of Artificial Life. CLAUS EMMECHE. Princeton University Press, Princeton, NJ, 1994. xiv, 199 pp., illus. $24.95 or £18.95. Translated from the Danish edition (1991) by Steven Sampson.

The brief history of artificial life (or a-life) consists of two threads. One originates with the self-reproducing automata designed by John von Neumann. This mathematical approach was enlivened with a variety of computer models addressing evolutionary, ecological, and morphological aspects and led to what is nowadays officially perceived as a-life—a field defined, for all practical purposes, by a conference organized by Chris Langton in 1987. It is a measure of Langton's success that the rapid subsequent development has essentially followed the same themes. A spate of popular science books, more conferences, and a new journal have done much to keep the subject in the limelight. A-life's other thread runs mostly out of sight but has potentially an even larger effect upon public awareness: this is the sorry tale of computer viruses.

Claus Emmeche's book gives good, if sometimes a bit short, descriptions of a-life's favorite pets, such as John Conway's game of Life, Langton's self-reproducing loops, John Holland's genetic algorithms, Stuart Kauffman's Boolean networks, Craig Reynolds's flocks of "boids," and Kristian Lindgren's chronicles of the Prisoner's Dilemma. All these have been well described in other recent books, but it ought to be stressed that the original, Danish, version of *The Garden in the Machine* appeared some three years ago.

So far, a-life is a branch of experimental mathematics dominated by computer scientists. Only a handful of true-life biologists have ventured onto this new playground (Tom Ray, for instance, with his Tierra world, or Richard Dawkins with his biomorphs). A silent majority either remains blissfully unaware of the discipline or just waits for it to fade away, convinced that artificial life will soon meet natural death. Such an attitude of "business as usual" is unfortunate: if—as may well be possible—a-life has nothing much to contribute to biological theory, this ought to give rise to some lively scientific polemics.

Emmeche, who is a theoretical biologist himself, stakes out the claims for such a debate in a fairly nonpartisan way. His own perspective is closer to semiotics—the science of signs and meaning—than to computer science. This allows him to survey the field in a very broad philosophical context but leads him possibly to overemphasize the formal aspects of a-life's creatures. To be sure, they are not slimy little things based on a carbon cycle but computer programs. Some are, however, able to reside in a fairly real way in a computer's memory, at least in principle. That they are actually relegated to the memory of a simulated computer because of fears that they might spread ought not to be held against them. All too real experience with electronic worms make such a "computational containment" most advisable.

In a spirit of friendly skepticism, *The Garden in the Machine* describes artificial life as a postmodern activity "which leads toward what one may call a deconstruction of biological science." Such deconstruction—a current buzzword in discussions of art and literature—combines, as we are told, internally opposing tendencies in novel ways; this is today's equivalent of creating chimeras, artificial beings obtained by juxtaposing disparate parts of different animals, a pursuit that may constitute the oldest tradition of a-life.

The investigation of virtual realities is a respectable endeavor in mathematics, and it seems indisputable that research on artificial life has led, especially through its "bottom-up" approach, to the emergence of a wide range of fascinating and still largely unsolved problems relating to dynamical systems, information processing, and complexity theory. The question remains whether a-life will also enrich biology. Emmeche's discussion of this issue is even-handed and thoughtful, and his cautious conclusion—namely, that it is too early to decide—is doubtless correct. But he refers—to my taste—slightly too much to philosophers and not enough to biologists. We can learn more from J. B. S. Haldane and John Maynard Smith, skilled explorers of alternate realities in biological thought-experiments, than from the ponderings of Aristotle and Maturana. Actually, most a-lifers are philosophical enough and quite adept at discussing definitions of life. But such well-worn debates tell more about us than about life. Biologists will need more substantial fare if they are to take a-life seriously. One sometimes fears that this will be provided not by any refined biological argument but by the brain-child of some ill-advised hacker flouting computational containment.

This being said, Emmeche's book is a serious, sensible introduction to an exciting new field. It is not every day that one can see science fiction clash with natural philosophy in such a civilized fashion.

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Vignettes: Shifts in Biology

Biologists have often employed a range of metaphors to describe the real nature of organisms, and the metaphors have typically been borrowed from the technology that happened to be most fashionable at the moment. An ant, for example, can be viewed as a mechanical piece of clockwork, with precise, finely tuned parts, each with its distinct function. From a subsequent perspective, the ant can be viewed as a piece of energy technology: a thermodynamic design that—in analogy to a steam engine—consumes chemically bound energy by combustion and performs work while developing heat. Today we might view the ant as a little computer with associated sensory and motor organs: it processes a mass of information about the external world and reacts by feeding back various responses.

—*Claus Emmeche*, in *The Garden in the Machine: The Emerging Science of Artificial Life* (Princeton University Press)

Much of the history of biology can be expressed metaphorically as a dynamic tension between unit and aggregate, between reduction and holism. An equilibrium in this tension is neither possible nor desirable. As large patterns emerge, ambitious hard-science reductionists set out to dissolve them with nonconforming new data. Conversely, whenever empirical researchers discover enough new nonconforming phenomena to create chaos, synthesizers move in to restore order. In tandem the two kinds of endeavors nudge the discipline forward.

—*Edward O. Wilson*, in *The Biological Century: Friday Evening Talks at the Marine Biological Laboratory* (Robert B. Barlow, Jr., John E. Dowling, and Gerald Weissmann, Eds.; Marine Biological Laboratory and Harvard University Press)

Books Received

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Advances in Genetic Programming. Kenneth E. Kinnear, Jr., Ed. MIT Press, Cambridge, MA, 1994. xiv, 519 pp., illus. $45. Complex Adaptive Systems. From a workshop, summer 1993.

The Adventure Playground of Mechanisms and Novel Reactions. Rolf Huisgen. American Chemical Society, Washington, DC, 1994. xxiv, 279 pp., illus. $24.95. Profiles, Pathways, and Dreams.

Air Pollution and Climate Change. The Biological