

## Unpredictability

**The Broken Dice and Other Mathematical Tales of Chance.** IVAR EKELAND. University of Chicago Press, Chicago, 1993. vi, 183 pp., illus. \$19.95 or £15.95. Translated from the French edition (1991) by Carol Volk.

Ivar Ekeland gained a large and enthusiastic following with *Mathematics and the Unexpected*, a brilliant and charming exposition of fundamental new discoveries in the theory of dynamical systems. *The Broken Dice* continues the same theme, and in the same elegant, seemingly effortless style, but focuses more closely on the implications of those discoveries for the rest of human culture. What are chance and probability? How has our thinking about them been changed by the discovery of chaos? What are all of these concepts good for?

According to tradition, says Ekeland, King Olaf Haraldsson of Norway played dice with the King of Gautland (Sweden) for the island of Hising. The Swedish king threw a double six and said there was no point in continuing. King Olaf pointed out that two sixes might turn up again. Then he threw the dice. One was a six; the other split in two, showing a six and a one. And so King Olaf took possession of the island. Many accuse Olaf of rigging the dice, but whatever the truth it's a wonderful story, and it makes an important point about the workings of chance: there is more than one kind of unpredictability.

So what is randomness? Paradoxically, the "random number generator" in your personal computer is nothing of the kind—it applies a perfectly deterministic rule, but an unpredictable one, unless you know the secret. If this most common source of random numbers is not random at all, is there such a thing as chance? The discussion leads to foundational problems in quantum mechanics and Einstein's espousal of "hidden variables" that determine when allegedly random events, such as the decay of a radioactive atom, will occur. In short, perhaps quantum theory has a hidden secret, just like that of the computer's random number generator. But does it? Nobody knows.

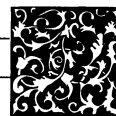
Chance leads to fate, here represented by deterministic processes in which every step is specified uniquely and precisely. And determinism leads to chaos, where again a hidden rule generates apparently random results—indeed in some cases demonstrably random results, according to any definition of randomness you care to propose. The secret this time is in the choice of initial condition, which "encodes" the desired random sequence, and of a dynamic rule

that can "decode" it, digit by digit. This is astonishingly easy to do, once you know what to look for. But it totally alters our view of what constitutes randomness.

That chaos is not truly random can be seen by considering the possibility of prediction. A truly random sequence is totally unpredictable: no amount of knowledge of the past affects the possibilities for the future. Chaos, in contrast, is predictable in the short term—an issue that is tackled in a chapter entitled "Anticipation," which begins with a legend about King Olaf's boat, *The Long Serpent*. (In a way it's a pity the book wasn't published by Viking.) What prevents lots of short-term predictions of a chaotic system from being strung together is sensitive dependence upon initial conditions—the celebrated butterfly effect—which is the subject of the next chapter of the book.

From there, the story moves toward more practical themes, risk and statistics. We find that even statisticians cannot demonstrate the occurrence of chance. They can only assume that it is present and exploit the resulting structure. As physics looks more deeply into the nature of space, time, and matter, it finds more and more that is contingent, indeterminate. But, argues Ekeland, if instead we build nature up by bringing things together, rather than dissecting them into ever tinier pieces, we find not chance but—

Ah, but, I mustn't give the game away, any more than I should if I were reviewing a detective novel. And this is just as gripping a tale. In any case, you need to read the whole story, not just the ending, be-



## Vignettes: Pictorial Trends

Some intellectuals . . . worried about the spread of illustrated books, increasingly common around the turn of the century. The ease of reproducing photographs in books meant that the author had less control; they feared that the illustrator would sway the reader more than the author, that illustrations forced people to form certain images in their mind. One letter to the editor . . . complained that illustrations . . . subverted books from an intellectual exercise into a commodity whose main purpose was to look pretty.

—Steven Lubar, in *InfoCulture: The Smithsonian Book of Information Age Inventions* (Houghton Mifflin)

At a time when the nonreading television generation is having an impact on the newspaper circulation in this country, and when, ironically, classes leading to visual skills are among the first cut by school districts feeling a financial pinch, the moment seems perfect once again for communicating knowledge with images on the hypermedia "page." Pixels are the movable type of the future.

—Barbara Maria Stafford, in *Artful Science: Enlightenment Entertainment and the Eclipse of Visual Education* (MIT Press)

cause the ending won't make sense out of context. Beg, borrow, or, preferably, buy a copy and do so. I guarantee you won't be disappointed.

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## Reprints of Books Previously Reviewed

**Darwin.** Adrian Desmond and James Moore. Norton, New York, 1994. Paper, \$17.95. *Reviewed* 257, 419 (1992).

**Global Warming and Biological Diversity.** Robert L. Peters and Thomas E. Lovejoy, Eds. Yale University Press, New Haven, CT, 1994. Paper, \$17. *Reviewed* 258, 1505 (1992).

**The Smithsonian and the American Indian.** Making a Moral Anthropology in Victorian America. Curtis M. Hinsley. Smithsonian Institution Press, Washington, DC, 1994. Paper, \$17.95. *Augmented reprint of Savages and Scientists. Reviewed* 213, 1489 (1981).

**The Uses of Life.** A History of Biotechnology. Robert Bud. Cambridge University Press, New York, 1994. Paper, \$19.95. *Reviewed* 262, 121 (1993).

## Books Received

**AIDS, HIV and Mental Health.** Michael B. King. Cambridge University Press, New York, 1994. x, 197 pp. \$39.95; paper, \$29.95. Psychiatry and Medicine.

**Allegory Old and New.** In Literature, the Fine Arts, Music and Theater, and Its Continuity in Culture. Marlies Kronegger and Anna-Teresa Tymieniecka, Eds. Kluwer, Norwell, MA, 1994. x, 326 pp., illus. \$110 or £74.50 or Dfl. 195. *Analecta Husserliana*, vol. 42. From congresses, Cambridge, MA and Luxembourg, April 1992 and June 1992.

**American Health Care.** Rebirth or Suicide? Benjamin F. Fuller. Thomas, Springfield, IL, 1994. x, 102 pp. \$29.75.

**Angler Survey Methods and Their Applications in Fisheries Management.** Kenneth H. Pollock, Cynthia M. Jones, and Tommy L. Brown. American Fisheries Society, Bethesda, MD, 1994 (distributor, AFS Publication Fulfillment, Evans City, PA). xviii, 371 pp., illus. \$88; to AFS members, \$53. American Fisheries Society Special Publication 25.

**Antarctic Meteorology and Climatology.** Studies Based on Automatic Weather Stations. David H. Bromwich and Charles R. Stearns, Eds. American Geophysical Union, Washington, DC, 1994. xiv, 207 pp., illus., + diskette. \$70; to AGU members, \$49. Antarctic Research Series, vol. 61.

**The Bio-Physics of Marine Larval Dispersal.** P. W. Sammarco and M. L. Heron, Eds. American Geophysical Union, Washington, DC, 1994. xiv, 352 pp., illus. \$42; to AGU members, \$29.40. Coastal and Estuarine Studies, 45. From a conference, Thredbo, New South Wales, Feb. 1990.

**Biochemical and Molecular Aspects of Selected Cancers.** Vol. 2. Thomas G. Pretlow II and Theresa P. Pretlow, Eds. Academic Press, San Diego, CA, 1994. xii, 542 pp., illus. \$120.

**Biodegradation and Bioremediation.** Martin Alexander. Academic Press, San Diego, CA, 1994. xii, 302 pp., illus. \$49.95.

**Biological Mass Spectrometry Present and Future.** T. Matsuo *et al.*, Eds. Wiley, New York, 1994. xxii, 666 pp., illus. \$180. From a conference, Kyoto, Japan, Sept. 1992.

**The Biology of Heat Shock Proteins and Molecular Chaperones.** Richard I. Morimoto, Alfred Tissières, and Costa Georgopoulos, Eds. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 1994. viii, 610 pp., illus. \$97. Cold Spring Harbor Monograph Series, 26.

**Catalyst Characterization.** Physical Techniques for Solid Materials. Boris Imelik and Jacques C. Vedrine, Eds. Plenum, New York, 1994. xxiii, 702 pp., illus. \$125. Fundamental and Applied Catalysis.

**Cellular and Molecular Immunology.** Abul K. Abbas, Andrew H. Lichtman, and Jordan S. Pober. 2nd ed. Saunders, Philadelphia, 1994. xiv, 457 pp., illus. Paper, \$27.95.

**Cellular Automata and Complexity.** Collected Papers. Stephen Wolfram. Addison-Wesley, Reading, MA, 1994. viii, 596 pp., illus. \$45.25; paper, \$24.75.

**The Concise Oxford Dictionary of Ecology.** Michael Allaby, Ed. Oxford University Press, New York, 1994. viii, 415 pp. Paper, \$12.95.

**Concrete Structures in Earthquake Regions.** Design and Analysis. Edmund Booth, Ed. Longman Scientific and Technical, Harlow, Essex, U.K., and Wiley, New York, 1994. xiv, 368 pp., illus. \$185. Concrete Design and Construction Series.

**Doing More Good Than Harm.** The Evaluation of Health Care Interventions. Kenneth S. Warren and Frederick Mosteller, Eds. New York Academy of Sciences, New York, 1993. xii, 341 pp., illus. Paper, \$90. Annals of the New York Academy of Sciences, vol. 703. From a conference, New York, March 1993.

**Ecology and Management of Invasive Riverside Plants.** Louise C. de Waal *et al.*, Eds. Wiley, New York, 1994. x, 217 pp., illus. \$95. Landscape Ecology Series.

**Extracellular Matrix Assembly and Structure.** Peter D. Yurchenco, David E. Birk, and Robert P. Mecham, Eds. Academic Press, San Diego, CA, 1994. xii, 468 pp., illus. \$120. Biology of Extracellular Matrix Series.

**Flight in America.** From the Wrights to the Astronauts. Roger E. Bilstein. 2nd ed. Johns Hopkins University Press, Baltimore, MD, 1994. xii, 386 pp., illus. \$50; paper, \$16.95.

**Fractal Modelling.** Growth and Form in Biology. Jaap A. Kaandorp. Springer-Verlag, New York, 1994. xiv, 208 pp., illus. \$39.95.

**Freshwater Fishes of the Carolinas, Virginia, Maryland, and Delaware.** Fred C. Rohde *et al.* James F. Parnell, photographer. University of North Carolina Press, Chapel Hill, 1994. x, 222 pp., illus., + plates. \$24.95.

**Hilbert Space Operators in Quantum Physics.** Jiří Blank, Pavel Exner, and Miloslav Haviřík. AIP

Press, Woodbury, NY, 1994. xiv, 593 pp. \$75. AIP Series in Computational and Applied Mathematical Physics.

**A History of the Division of Psychoanalysis of the American Psychological Association.** Robert C. Lane and Murray Meisels, Eds. Erlbaum, Hillsdale, NJ, 1994. xxii, 372 pp. Paper, \$49.95.

**HLA and Disease.** Robert Lechler, Ed. Academic Press, San Diego, CA, 1994. xiv, 186 pp., illus. \$40.

**Homage to Pythagoras.** Rediscovering Sacred Science. Christopher Bamford, Ed. Lindisfarne, Hudson, NY, 1994. 298 pp., illus. Paper, \$18.95.

**Home Is Where the Wind Blows.** Chapters from a Cosmologist's Life. Fred Hoyle. University Science, Mill Valley, CA, 1994. xiv, 443 pp., illus., + plates, \$32.50.

**How to Digitize Video.** Nels Johnson with Fred Gault and Mark Florence. Wiley, New York, 1994. xvi, 464 pp., illus., + CD-ROM. Paper, \$39.95.

**Human Gene Mapping 1993.** A Compendium. A. Jamie Cuticchia and Peter L. Pearson, Eds. Johns Hopkins University Press, Baltimore, MD, 1994. vi, 1047 pp., illus. Paper, \$95. From a meeting, Tsukuba Science City, Japan, Nov. 1993.

**The Human Nature of Birds.** A Scientific Discovery with Startling Implications. Theodore Xenophon Barber. Penguin, New York, 1994. xiv, 226 pp., + plates. Paper, \$10.95. Reprint, 1993 ed.

**Information Theory in Analytical Chemistry.** Karel Eckschlagner and Klaus Danzer. Wiley, New York, 1994. xviii, 275 pp., illus. \$64.95. Chemical Analysis, vol. 128.

**Instruction for Information Access in Sci-Tech Libraries.** Cynthia Steinke, Ed. Haworth, Binghamton, NY, 1994. xiv, 137 pp. \$34.95. Also published as *Science and Technology Libraries*, vol. 14, no. 2 (1993).

**Integrative Paths to the Past.** Paleoanthropological Advances in Honor of F. Clark Howell. Robert S. Corruccini and Russell L. Ciochon, Eds. Prentice Hall, Englewood Cliffs, NJ, 1994. xx, 716 pp., illus. \$60. Advances in Human Evolution Series.

**Interpreting the Hierarchy of Nature.** From Systematic Patterns to Evolutionary Process Theories. Lance Grande and Olivier Rieppel, Eds. Academic Press, San Diego, CA, 1994. x, 298 pp., illus. \$59.95.

**Introduction to In Vitro Cytotoxicology.** Mechanisms and Methods. Frank A. Barile. CRC Press, Boca Raton, FL, 1994. xvi, 222 pp., illus. \$69.95.

**An Introduction to Quantum Field Theory.** George Sterman. Cambridge University Press, New York, 1993. xviii, 572 pp., illus. \$100; paper, \$39.95.

**Introduction to Space Flight.** Francis J. Hale. Prentice Hall, Englewood Cliffs, NJ, 1994. xvi, 366 pp., illus. \$59.

**Iterative Solution Methods.** Owe Axelsson. Cambridge University Press, New York, 1994. xiv, 654 pp. \$59.95.

**Lyme Borreliosis.** John S. Axford and David H. E. Rees, Eds. Plenum, New York, 1994. xii, 332 pp., illus. \$95. NATO Advanced Science Institutes Series A, vol. 260. From a symposium, London, May 1993.

**Maple V by Example.** Martha L. Abell and James Braselton. AP Professional (Academic), Cambridge, MA, 1994. xii, 500 pp., illus. Paper, \$39.95.

**Mechanics and Control.** Ramesh S. Guttalu, Ed. Plenum, New York, 1994. x, 356 pp., illus. \$95. From a workshop, Los Angeles, Jan. 1992.

**Mindscapes.** The Epistemology of Magoroh Maruyama. Michael T. Caley and Daiyo Sawada, Eds. Gordon and Breach, Philadelphia, 1994 (distributor, International Publishers Distributor, Langhorne, PA). xxiv, 206 pp., illus. \$39 or £25.

**Modeling the AIDS Epidemic.** Planning, Policy, and Prediction. Edward H. Kaplan and Margaret L. Brandeau, Eds. Raven, New York, 1994. xxxii, 624 pp., illus. \$99.

**Molecular, Cellular, and Developmental Biology of Erythropoietin and Erythropoiesis.** Ivan N. Rich and Terence R. J. Lapping, Eds. New York Academy of Sciences, New York, 1994. xiv, 376 pp., illus. Paper, \$100. Annals of the New York Academy of Sciences, vol. 718. From a workshop, Irsee, Germany, April 1993.

**Molecular Magnetism.** Olivier Kahn. VCH, New York, 1993. xvi, 380 pp., illus. \$95.

**Moon Shot.** The Inside Story of America's Race to

the Moon. Alan Shepard and Deke Slayton with Jay Barbree and Howard Benedict. Turner, Atlanta, GA, 1994. 383 pp., + plates. \$21.95.

**Multiple Drug Resistance in Cancer.** Cellular, Molecular and Clinical Approaches. M. Clynes, Ed. Kluwer, Norwell, MA, 1994. viii, 393 pp., illus. \$137 or £94 or Dfl. 240. Reprinted from *Cytotechnology*, vol. 12 (1993).

**Nonlinear Dynamics and Chaos.** With Applications to Physics, Biology, Chemistry, and Engineering. Steven H. Strogatz. Addison-Wesley, Reading, MA, 1994. xii, 498 pp., illus. \$55.95. Studies in Nonlinearity.

**Nutrition and AIDS.** Ronald R. Watson, Ed. CRC Press, Boca Raton, FL, 1994. xii, 257 pp., illus. \$99.95. CRC Series in Modern Nutrition.

**Oceanography and Acoustics.** Prediction and Propagation Models. Allan R. Robinson and Ding Lee. AIP Press, Woodbury, NY, 1994. xviii, 257 pp., illus., + plates. \$65. AIP Series in Modern Acoustics and Signal Processing.

**Operation Crossroads.** The Atomic Tests at Bikini Atoll. Jonathan M. Weisgall. Naval Institute Press, Annapolis, MD, 1994. xx, 415 pp., + plates. \$31.95.

**Passages From the Life of a Philosopher.** Charles Babbage. Martin Campbell-Kelly, Ed. IEEE Press, Piscataway, NJ, and Rutgers University Press, New Brunswick, NJ, 1994. Various pagings, illus. Paper, \$18.95. Augmented reprint, 1864 ed.

**Philosophical Perspectives on Psychiatric Diagnostic Classification.** John Z. Sadler, Osborne P. Wiggins, and Michael A. Schwartz, Eds. Johns Hopkins University Press, Baltimore, MD, 1994. xvi, 399 pp. \$69.50; paper, \$24.95. Johns Hopkins Series in Psychiatry and Neuroscience.

**Phyllotaxis.** A Systemic Study in Plant Morphogenesis. Roger V. Jean. Cambridge University Press, New York, 1994. xiv, 386 pp., illus. \$74.95.

**Quantitative Methods in Soil Mineralogy.** R. J. Luxmoore and Jon M. Bartels, Eds. Soil Science Society of America, Madison, WI, 1994. xxii, 462 pp., illus. Paper, \$39; to SSA members, \$32. From a symposium, San Antonio, TX, Oct. 1990.

**Remarkable Agaves and Cacti.** Park S. Nobel. Oxford University Press, New York, 1994. x, 166 pp., illus. \$39.95; paper, \$19.95.

**Rules, Games, and Common-Pool Resources.** Elinor Ostrom, Roy Gardner, and James Walker, with Arun Agrawal *et al.* University of Michigan Press, Ann Arbor, 1994. xvi, 369 pp., illus. \$55; paper, \$18.95.

**Science in the Bedroom.** A History of Sex Research. Vern L. Bullough. Basic Books, New York, 1994. viii, 376 pp. \$25.

**Techniques and Concepts of High-Energy Physics VII.** Thomas Ferbel, Ed. Plenum, New York, 1994. x, 266 pp., illus. \$85. NATO Advanced Science Institutes Series B, vol. 322. From an institute, St. Croix, Virgin Islands, July 1992.

**Tesla.** Tad Wise. Turner, Atlanta, GA, 1994. 381 pp., illus. \$21.95. A novel.

**Thyroid Hormone Regulation of Gene Expression.** Graham R. Williams. Landes, Georgetown, TX, 1994 (distributor, CRC Press, Boca Raton, FL). viii, 143 pp., illus. \$89.95. Molecular Biology Intelligence Unit.

**Two-Dimensional DNA Typing.** A Parallel Approach to Genome Analysis. André G. Uitterlinden and Jan Vijg. Horwood (Prentice Hall), Englewood Cliffs, NJ, 1994. xii, 197 pp., illus. \$55. Ellis Horwood Series in Molecular Biology.

**Two-Dimensional Homotopy and Combinatorial Group Theory.** Cynthia Hog-Angeloni, Wolfgang Metzler, and Allan J. Sieradski, Eds. Cambridge University Press, New York, 1994. xii, 412 pp., illus. Paper, \$39.95. London Mathematical Society Lecture Note Series, 197.

**Vivre à Deux.** Processus d'Emprise et de Dégagement dans la Famille Monoparentale. Claudine Samalin-Amboise. Mardaga, Liege, Belgium, 1994. 224 pp. Paper, F 155 or BF 953. Psychologie et Sciences Humaines, no. 203.

**Wild Love.** Nan Richardson and Catherine Chermayeff. Chronicle, San Francisco, 1994. 80 pp., illus. \$14.95. Umbra Editions Book.

**The Wisdom of the Spotted Owl.** Policy Lessons for a New Century. Steven Lewis Yaffee. Island Press, Washington, DC, 1994. xxviii, 430 pp. \$45; paper, \$26.95.