

James P. Crutchfield

Curriculum Vitae

Date of Birth: 30 June 1955

Place of Birth: San Francisco, California

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Education

Ph. D., Physics, University of California, Santa Cruz, 1983.

B. A. Physics and B. A. Mathematics, University of California, Santa Cruz, 1979.

Employment and Affiliations

Director, Complexity Sciences Center, University of California, Davis, since July 2007.

Professor, Physics Department, University of California, Davis, since July 2004.

External Faculty, Santa Fe Institute, Santa Fe, New Mexico, July 2004–June 2007.

Research Professor, Santa Fe Institute, Santa Fe, New Mexico, September 1997–June 2004.

Co-Founder, Scientific Director, and Vice President, Art & Science Laboratory, Santa Fe, New Mexico, since January 2000.

Adjunct Associate Professor, Physics Department, University of New Mexico, Albuquerque, New Mexico, February 1995–June 2004.

Research Physicist, Physics Department, University of California, Berkeley, October 1986–August 1997.

External Associate Professor, Santa Fe Institute, Santa Fe, New Mexico, 1990–August 1997.

Visiting Research Professor, Beckman Institute, University of Illinois, Champaign-Urbana, September–December 1991.

IBM Post-Doctoral Fellow, Physics Department, University of California, Berkeley, October 1985–September 1986.

Miller Institute Post-Doctoral Fellow, Physics Department, University of California, Berkeley, September 1983–September 1985.

Visiting Staff Member, Center for Nonlinear Studies, Los Alamos National Laboratory, Los Alamos, New Mexico, June 1982–1997.

Honors, Awards, and Service

Director, *Complexity Sciences Center*, University of California at Davis.

Director, *Network Dynamics Program*, Santa Fe Institute.

Director, *Computation, Dynamics, and Inference Program*, Santa Fe Institute.

Member, *Committee on Information Technology and Creativity*, Computer Science and Technology Board, National Research Council.

Scientific Director, Vice President, and Cofounder, *Art and Science Laboratory*.

Member, Advisory Board, *Dactyl Foundation for the Arts and Humanities*.

Bernard Osher Foundation Fellow, San Francisco Exploratorium.

Distinguished Visiting Research Professor, Beckman Institute, University of Illinois, Urbana-Champaign.

Post-Doctoral Fellowships: IBM Thomas J. Watson, Miller Institute for Basic Research in Science.

Ph.D. in Physics, *summa cum laude*.

University of California Regents Graduate Fellowships.

Baccalaureates: Highest Honors in Physics, Honors in Mathematics, and College Honors.

Resident Scholar, Rockefeller Foundation *Bellagio Conference Center*, Bellagio, Italy.

Referee for journals in physics, computer science, engineering, mathematical biology, nonlinear mathematics, dynamical systems, statistical mechanics, complex systems, and other areas.

Current Funding

Co-Principal Investigator, *CI-TEAM Implementation Project: Enabling interactive visual exploration and remote collaboration for the geosciences and physical sciences*, NSF Office of Cyber-Infrastructure (\$930K) 1 April 2008 - 31 March 2011. (L. Kellogg, P.I., J. P. Crutchfield, M. Billen, D. Sumner, and B. Hamann).

Principal Investigator, *Structure and Complexity in Complex Interactive Networks*, Intel Corporation (\$750K) November 1999 - December 2008 (J. P. Crutchfield).

Principal Scientist, *Support for SFI Core Research*, NSF (\$3M) 1 October 2008 - 31 September 2012 (G. West, P.I, and other Principal Scientists, incl. J. P. Crutchfield).

Pending Requests

Co-Principal Investigator, *UC-CNLS Collaborative Research and Training (CRT) Program in Applied Statistical Physics of Biological Systems and Information Science*, Office of the President, UC (\$3.5M) 1 January 2009 - 31 December 2012. (R. Ecke, B. Olshausen, J. P. Crutchfield, H. Levine,).

Principal Investigator, *Organization, Inference, and Optimization of Complex Network Systems*, Office of the President, UC (\$1.7M) 1 January 2009 - 31 December 2012. (J. P. Crutchfield, L. Bettencourt, R. M. D'Souza, A. Hagberg).

Co-Principal Investigator, *Information-Theoretic Approaches to Model Inference and Optimization in the Dynamics and Structure of Complex Systems*, Office of Basic Science, DOE (\$1.4M) 1 January 2009 - 31 December 2012. (L. Bettencourt, P.I., J. P. Crutchfield, A. Hagberg).

Past Support

Principal Scientist, *Support for SFI Core Research*, NSF (\$3M) 1 October 2002 - 31 September 2007 (T. Kepler, P.I, and other Principal Scientists, incl. J. P. Crutchfield).

Principal Investigator, *The Dynamics of Learning and the Emergence of Distributed Adaptation*, Defense Advanced Research Projects Agency (\$1.85M) 1 June 2000 - 31 December 2005 (J. P. Crutchfield).

Principal Scientist, *A Founding Program in the Study of Robustness*, David and Lucille Packard Foundation (\$995K) 1 January 2001 - 31 December 2004 (J. P. Crutchfield, W. Fontana, S. Forrest, E. Jen, S. A. Levin).

Co-Investigator, *Evolutionary Dynamics*, W. M. Keck Foundation (\$1.5M) 1 January 1999 - 31 December 2003 (E. Jen, J. P. Crutchfield, M. Feldman, W. Fontana, P. Schuster, and J. Padgett).

Co-Principal Investigator, *The Theater of Pattern Formation*, Ford Foundation (\$40K) 1 September 2002 - 31 August 2003 (J. P. Crutchfield, D. Dunn, D. Falliers).

Co-Principal Investigator, *The Theater of Pattern Formation*, Rockefeller Foundation (\$40K) 1 January 2002 - 31 December 2002 (J. P. Crutchfield, D. Dunn, D. Falliers).

Co-Principal Investigator, *The Art and Science Laboratory*, Rockefeller Foundation (\$100K) 1 July 2001 - 30 June 2002 (J. P. Crutchfield, D. Dunn, S. Vasulka, and W. Vasulka).

Co-Principal Investigator, *The Art and Science Laboratory*, Daniel Langlois Foundation (\$33K) 1 July 2001 - 30 June 2002 (J. P. Crutchfield, D. Dunn, S. Vasulka, and W. Vasulka).

Co-Principal Investigator, *The Art and Science Laboratory*, Rockefeller Foundation (\$100K) 1 July 2000 - 30 June 2001 (J. P. Crutchfield, D. Dunn, S. Vasulka, and W. Vasulka).

Co-Principal Investigator, *The Art and Science Laboratory*, Daniel Langlois Foundation (\$30K) 1 July 2000 - 20 June 2001 (J. P. Crutchfield, D. Dunn, S. Vasulka, and W. Vasulka).

Principal Investigator, *Novel Computation—Beyond the Digital Hegemony*, NSF/Air Force Office of Scientific Research (\$100K) April 1999 - March 2001 (J. P. Crutchfield).

Co-Principal Investigator, *Pilot Program for NSF Physics Graduate Students Fellowships at SFI*, National Science Foundation (\$322K) 1 September 1999 - 31 August 2001 (E. Jen, D. Campbell, J. P. Crutchfield, and S. Forrest).

Principal Investigator, *Collective Intelligence and Learning in Distributed Dynamical Systems*, Sandia National Laboratory AU-4978 (\$100K) October 1997 - September 1998 (E. Jen and J. P. Crutchfield).

Co-Principal Investigator, *A New Computational Infrastructure at the Santa Fe Institute*, National Science Foundation CISE-97-24666 (\$202K) October 1997 - September 2000 (E. Jen, J. P. Crutchfield, S. Durlauf, C. Langton, and M. Mitchell).

Principal Investigator, *Evolving Cellular Automata to Perform Computations*, National Science Foundation IRI-9705830 (\$300K) October 1997 - September 2000 (J. P. Crutchfield and M. Mitchell).

Scientific Director (1997-98), *Foundations of Complex Systems*, Defense Advanced Research Projects Agency (\$4M) 1 June 1995 - 31 September 1999 (E. Goldberg and E. Jen, P.I.s; J. P. Crutchfield and R. Palmer, Scientific Directors).

Principal Investigator, *Intrinsic Computation in Neurodynamical Systems*, Office of Naval Research N00014-95-1-0524 (\$146K) 1 April 1995 - 28 February 1997 (J. P. Crutchfield).

Principal Investigator, *Evolving Cellular Automata to Perform Computations*, Department of Energy DE-FG03-94ER25231 (\$150K) October 1994 - September 1996 (J. P. Crutchfield and M. Mitchell).

Principal Investigator, *Evolving Cellular Automata to Perform Computations*, National Science Foundation IRI-9320200 (\$225K) October 1994 - September 1997 (J. P. Crutchfield and M. Mitchell).

Principal Investigator, *Computation Theoretic Analysis of Astrophysical Time Series*, NASA (\$12K) 15 December 1993 - 15 December 1995 (J. P. Crutchfield).

Co-Principal Investigator, *Algorithms to Analyze Random and Chaotic Time Series*, NASA (\$50K) 1 October 1993 - 30 September 1995 (J. P. Crutchfield, D. L. Donoho, and J. Scargle).

Principal Investigator, *Discovering Coherent Structures in Nonlinear Spatial Systems*, Office of Naval Research N00014-92-J-4024 (\$90K) April 1992 - June 1994. (J. P. Crutchfield).

Project Scientist, *Hierarchical Learning of Complex Systems*, Air Force Office of Scientific Research Contract 91-0293 (\$640K) April 1991 - August 1995 (J. P. Crutchfield and D. A. Glaser).

Project Scientist, *Algorithms to Analyze Random and Chaotic Time Series*, NASA-AMES University Consortium Interchange (\$46K) 1 March 1990 - 30 September 1991 (J. P. Crutchfield, D. L. Donoho, and J. Scargle).

Project Scientist, *Statistical Mechanics of Learning Complex Dynamics*, Office of Naval Research Contract N00014-90-J-1774 (\$25K) March 1990 - December 1990 (J.P. Crutchfield and C. D. Jeffries).

Project Scientist, *Spatio-Temporal Complexity in Condensed Matter Systems*, Office of Naval Research Contract N00014-86-K-0154 (\$500K) October 1986 - February 1990 (J. P. Crutchfield and C. D. Jeffries).

Principal Investigator, *Computational Complexity and Dynamical Systems*, 1989 Summer Workshop at the Aspen Center for Physics, supported by the Office of Naval Research (\$7K) (J. P. Crutchfield, J. L. Tennyson, and R. Fishbane).

Principal Investigator, *Modeling and Prediction of Complex Dynamical Systems*, 1988 Summer Workshop at the Aspen Center for Physics, supported by the Office of Naval Research (\$7K) (J. P. Crutchfield and L. M. Simmons).

Professional Affiliations

American Physical Society, New York Academy of Sciences, American Association for the Advancement of Science.

Editorial Boards: **Chaos and Bifurcations**; **Chaos: An Interdisciplinary Journal of Nonlinear Science**; **Complexity**; and others.

Meetings Organized

Understanding Complex Systems: The Future of Interactive Visualization, Santa Fe Institute, 15-19 September 2008 (J. P. Crutchfield, M. Mitchell, and S. Larsen).

The Science of Complex Systems, Weekly Seminar Series, Center for Computational Science & Engineering, University of California, Davis, 1 January 2006 to present (J. P. Crutchfield, K. Wiesner, and R. D'Souza).

Business Network Meeting on Truly Complex Systems, UCD & Santa Fe Institute, Cisco Corporate Headquarters, San Jose, California, 22-23 March 2004 (J. P. Crutchfield and A. Stagg).

DARPA TASK Principal Investigator Meeting, Santa Fe Institute, Santa Fe, New Mexico, 9 – 11 October 2002 (J. P. Crutchfield, T. Frazier).

Collective Cognition—Mathematical Foundations of Distributed Intelligence, Santa Fe Institute, Santa Fe, New Mexico, 21-24 January 2002 (J. P. Crutchfield, C. Shalizi, K. Tumer, and D. Wolpert).

DARPA TASK Principal Investigator Meeting, Santa Fe Institute, Santa Fe, New Mexico, 17-19 April 2001 (J. P. Crutchfield, S. Forrest).

Business Network Meeting on Network Dynamics, Santa Fe Institute, Santa Fe, New Mexico, 22-23 March 2001 (J. P. Crutchfield and S. Dulle).

Structure and Dynamics in Complex Interactive Networks, Santa Fe Institute, Santa Fe, New Mexico, 10-12 August 2000 (J. P. Crutchfield and D. Watts).

Towards a Comprehensive Dynamics of Evolution: Exploring the Interplay of Selection, Neutrality, Accident, and Function, Santa Fe Institute, Santa Fe, New Mexico, 5-9 October 1998 (J. P. Crutchfield and P. K. Schuster).

Measures of Complexity Session, International Conference on Complex Systems, Nashua, New Hampshire, 21-26 September 1997.

Computational Issues in Learning Models of Dynamical Systems, AAAI Spring Symposium, Stanford University, Stanford, California, 25-27 March 1996.

Computation in Dynamical Systems, Computation, Dynamics, and Inference Program Workshop, Santa Fe Institute, Santa Fe, New Mexico, 14-23 July 1996.

Computational Complexity and Dynamical Systems, Aspen Center for Physics, Aspen, Colorado, June 1989.

Prediction and Modeling of Complex Systems, Aspen Center for Physics, Aspen, Colorado, June 1988.

Selected Invited Talks

Artificial Science and the Dynamics of Signals: Computers and Chaos: A Practical Symposium on the Applications of Chaos Theory to Computer Design, Clearpoint Research Foundation, Stowe, Vermont, 5-7 February 1989.

Computation at the Onset of Chaos: Workshop on Entropy, Complexity, and Physics of Information, Santa Fe Institute, Santa Fe, New Mexico, 29 May-2 June 1989; NATO Advanced Study Institute on **Information Dynamics**, Kaufbeuren, Germany, 21 June 1990; NATO Advanced Study Institute on **Chaos and Patterns**, Lago Como, Italy, 5 July 1990; Workshop on **Complexity and Evolution**, Institute for Scientific Interchange, Torino, Italy, 11 July 1990; IEEE Japan First Annual Meeting on **Applications of Nonlinear Dynamics in Electrical Circuits**, Kube, Japan, 25 July 1990; Colloquium, Physics Department, University

- of Tokyo, Komaba, Japan, 27 July 1990; Colloquium, Physics Department, Waseda University, Tokyo, Japan, 30 July 1990.
- Inferring Statistical Complexity*: International Workshop on **Quantitative Measures of Dynamical Complexity in Nonlinear Systems**, Bryn Mawr College, Bryn Mawr, Pennsylvania, 21-25 June 1989; International Computer Science Institute, Berkeley, California, 14 July 1989; IBM Thomas J. Watson Research Center, Yorktown Heights, New York, 20 July 1989; IV International Workshop on **Nonlinear and Turbulent Processes in Physics**, Kiev, USSR, 9-22 October 1989; Second Woodward Conference on **Nonlinear Structures in Physical Systems**, San Jose State University, California, 17 November 1989; Colloquium, Center for Nonlinear Studies, Los Alamos National Laboratory, Los Alamos, New Mexico, 13 February 1990; NATO Advanced Study Institute on **Complexity and Evolution**, Les Houches, France, 13 March 1990; Colloquium, Computer Science Department, Ohio State University, Columbus, Ohio, 12 April 1990; Condensed Matter Department, Bell Communications Research, Red Bank, New Jersey, 16 April 1990; International Conference on **Fuzzy Logic and Neural Networks**, Iizuka, Japan, 23 July 1990; Yukawa Institute for Fundamental Physics, Kyoto, Japan, 31 July 1990; Second Soviet-American Conference on **Chaos**, August 1990.
- Complexity: Order contra Chaos*: Symposium on **Order and Chaos**, Steirischer Herbst, Graz, Austria, 14-19 October 1989.
- Inferring Forms of Randomness*: Lecture course, International Conference on **Fuzzy Logic and Neural Networks**, Kyushu Institute of Technology, Iizuka, Japan, 20 July 1990.
- Nonlinear Engineering*: **International Satellite Video Conference**, Kyushu Institute of Technology (Iizuka, Japan), NASA Space Flight Center (Houston, Texas) 22 July 1990.
- Hierarchical Modeling*: Santa Fe Institute Workshop on **Nonlinear Modeling and Forecasting**, Santa Fe, New Mexico, 20-24 September 1990.
- Computation in Chaos*: Colloquium, Physics Department, San Jose State University, San Jose, California, 15 November 1990; Electronic Materials Group, XEROX Palo Alto Research Center, 7 December 1990; IBM Almaden Research Center, 11 December 1990; Lecture course, sponsored by the Fuzzy Logic Systems Institute, 20-21 September 1991, Fukuoka, Japan, and 24-25 September 1991, Tokyo, Japan; Colloquium, Center for Complex Systems Research, Beckman Institute, University of Illinois, Champaign-Urbana, 11 October 1991; Institute for Scientific Computing Research, Lawrence Livermore National Laboratory, Livermore, California, 2 July 1992; Colloquium, Interval Research, Inc., Palo Alto, California, 8 June 1993.
- The Attractor-Basin Portrait of a Cellular Automaton*: Colloquium, Santa Fe Institute, Santa Fe, New Mexico, 1 March 1991.
- Discovering Coherent Structures in Nonlinear Spatial Systems*: at the Applied Physics Laboratory Symposium on **Nonlinear Dynamics of Ocean Waves**, Johns Hopkins University, Maryland, 30-31 May 1991.
- Computational Mechanics: Toward a physics of complexity*: lecture course, Beckman Institute, University of Illinois, Urbana-Champaign, November-December 1991.
- Dynamics and Model Inference and The Semantics of Mechanical Systems*: Conference on **Dynamic Representations in Cognition**, Indiana University, Bloomington, Indiana, 15 and 16 November 1991.
- Computation in Chaos: toward a physics of complexity*: **Dynamics Days**, Texas, Austin, Texas, 8-11 January 1992.
- The Calculi of Emergence: Complexity as the Interplay of Order and Chaos*: Santa Fe Institute **Integrative Themes** Workshop, Santa Fe, New Mexico, 8-15 July 1992.
- Thermodynamics of Inference*: NATO Advanced Studies Institute **From Statistical Physics to Statistical Inference and Back**, Cargese, France, 31 August - 12 September 1992.
- Innovation, Induction, and Complexity*: Santa Fe Institute Workshop on **Computation, dynamical systems, and learning**, Santa Fe, New Mexico, 16-20 November 1992.

Critical Computation and Hierarchical Learning: Colloquium, Institute for Theoretical Physics and Synergetics, University of Stuttgart, Germany, 26 March 1993; Nonlinear Dynamics Seminar, Tokyo Institute of Technology, Tokyo, Japan, 12 April 1993.

Observing Complexity and the Complexity of Observation: Max Planck Institute sponsored workshop on **Endo-Exo Problems in Physics**, Ringberg Castle, Bavaria, Germany, 29 March - 2 April 1993.

The Calculi of Emergence: Complexity as the Induction of Order and Chaos: 36th Oji International Seminar on **Complex Systems—from Complex Dynamical Systems to the Sciences of Artificial Reality**, Fujitsu Forum, Numazu City, Japan, 5-9 April 1993.

Turbulent Pattern Bases for Spatial Systems: APS meeting **Computational Physics 1993**, Albuquerque, New Mexico, 3 June 1993.

Fluctuation Spectroscopy: Workshop on **Fluctuations and Order: the new synthesis**, Los Alamos, New Mexico, 9 September 1993.

Critical Computation, Phase Transitions, and Hierarchical Learning: The Seventh Toyota Conference **Towards the Harnessing of Chaos**, Mikkabi, Japan, 1 November 1993.

Towards a Statistical Dynamics of Genetic Algorithms: Workshop on **Theoretical Foundations of Genetic Algorithms**, Santa Fe Institute, New Mexico, 11-13 January 1994.

The Evolution of Emergent Computation: **International Conference on Dynamical Systems and Chaos**, Tokyo Metropolitan University, Tokyo, Japan, 23-27 May 1994.

Computational Mechanics: Towards a Physics of Complexity: Two lectures presented to the Extended Workshop on **Dynamics and Complexity**, Technical University, Lisbon, Portugal, 14 and 16 September 1994; invited review presented to the Workshop on **Theory and Applications of Nonlinear Time Series Analysis**, Potsdam, 20-30 September 1995; Symposium on **Computational Issues in Learning Dynamical Systems**, AAI Spring Meeting, Stanford University, 26 March 1996; Santa Fe Institute Summer School on Complex Systems, 12 June 1996; Computational Neurobiology Laboratory, Colloquium, Salk Institute, La Jolla, California, 20 July 1996; University of Michigan-Santa Fe Institute Seminar, University of Michigan, 17 October 1996.

How do Nonlinear, Time-Dependent Processes Compute? Neurosciences Institute 11th Summer Atelier on Theoretical Neurobiology, La Jolla, California, 23 September 1994.

Observing Complexity and the Complexity of Observation: Joint Physics and Philosophy Colloquium, Reed College, Portland, Oregon, 9 November 1994.

The Evolution of Emergent Computation: Seminar, Mathematics Department, Reed College, Portland, Oregon, 10 November 1994; CIRES Colloquium, University of Colorado, Boulder, Colorado, 13 April 1995; SIAM Conference on Nonlinear Dynamics, Snowbird, Utah, 12-14 May 1995; International Conference on **Self-Organization of Complex Structures**, Berlin, 24-28 September 1995.

How Does Nature Compute? Joint Colloquium, Keck Center for Integrative Neurobiology and Sloan Center for Theoretical Neurobiology, University of California, San Francisco. 15 December 1995.

Forms of Randomness—Embodiments of Computation: Workshop on **Dynamics, Computation, and Cognition**, Santa Fe Institute, Santa Fe, New Mexico, 12-14 May 1996.

What is a Pattern? Discovering the Hidden Order in Chaos: Bernard Osher Fellowship public lecture, San Francisco Exploratorium, 3 July 1996.

Pattern, Structure, and Function: What Do Computation Theory and Nonlinear Physics Have to Say? Altenberg Workshops in Theoretical Biology—**The Emergence and Evolution of Organization**, Konrad Lorenz Institute for Evolution and Cognition Research, Altenberg, Austria, 28 September 1996.

Embodiments of Computation: Joint Santa Fe Institute/University of Michigan Meeting on Adaptive Agents, Ann Arbor, Michigan, 17 October 1996.

Computational Mechanics—Steps to a Theory of Complex Systems: Spring Science Symposium, Santa Fe Institute, Santa Fe, New Mexico, 7 March 1997.

Pattern, Meaning, and Emergence: Center for Social Sciences, Columbia University, New York, 2 April 1997.

Turbulent Landscapes: International Workshop on **Art and Complexity**, Abisko, Sweden, 17-21 May 1998.

The Evolutionary Unfolding of Complexity: Artificial Life VI, Workshop on **The Right Stuff: Appropriate Mathematics for Evolutionary and Developmental Biology**, University of California, Los Angeles, 26 June 1998; Astrobiology Colloquium, NASA-Ames Research Center, Moffet Field, California, 31 August 1998; DIMACS Workshop on **Evolution as Computation**, Princeton University, New Jersey, January 1999; Colloquium, Physics Department, University of California, Davis, 15 March 1999; Colloquium, Physics Department, University of Wisconsin, Madison, 16 April 1999; Colloquium, Intel Research Laboratories, Portland, Oregon, 21 May 1999; Complex Systems Summer School, Santa Fe Institute, 22 June 1999; Computational Economics Summer School, St. John's College, 24 June 1999; Biology Department, University of Utrecht, Utrecht, The Netherlands, 27 September 1999; Program in Theoretical Biology, Institute for Advanced Study, Princeton, New Jersey, 8 October 1999; Colloquium, Computer Science Department, University of Western Ontario, London, Ontario, Canada, 24 March 2000.

Cellular Automata Pattern Dynamics: Constructive Cellular Automata, Santa Fe Institute, 14-17 November 1998.

Complexity: Invited Talk, Workshop on *Institutions, Complexity, and Difficulty*, Santa Fe Institute, 5 March 1999; Complex Systems Summer School, Santa Fe Institute, 8 June 1999; Computational Economics Summer School, Santa Fe Institute, 24 June 1999; Computational Economics Summer School, Santa Fe Institute, 22 June 2000.

A Concise History of Chaos and Complexity: panelist for *Chaos in Literature, History, and Science*, Dactyl Foundation, New York, New York, 6 April 2000.

Intrinsic Computation: AFOSR Contractors and Grantees Meeting, Stanford University, Stanford, California, 28 June 2000; Seminar, Sociology Department, Columbia University, New York, New York, 13 September 2000.

Objets d'Bits: Thinking about Emergent Structures in Cellular Automata: Center for the Study of Complex Systems, University of Michigan, Ann Arbor, 27 October 2000; Center for Studies in Biology and Physics, Rockefeller University, New York, 7 November 2000; Mathematics Department, California State University, Northridge, Los Angeles, 20 November 2000.

Dynamics of Learning and the Emergence of Distributed Adaptation: DARPA TASK Program Kickoff Meeting, Charleston, South Carolina, 3-5 October 2000.

Pattern Discovery: Hewlett-Packard Research Laboratories, Palo Alto, California, 8 March 2001.

Network Dynamics: SFI Business Network Meeting, Santa Fe, New Mexico, 22 March 2001; Workshop on **The Internet as a Complex Adaptive System**, Santa Fe Institute, Santa Fe, New Mexico, 29 March 2001.

Synchronizing to the Environment: DARPA TASK PI Meeting, Santa Fe, New Mexico, 17-19 April 2001.

New Algorithms for Adaptive Learning: DARPA TASK CAHDE REF Meeting, Media Lab, MIT, 27-28 August 2001.

Causality and Pattern Discovery: Max Planck Institute workshop on **Determinism**, Ringberg Castle, Bavaria, Germany, 4-8 June 2001; **DisIntegrative Themes** meeting, Santa Fe Institute, 23-27 July 2001.

Pattern Discovery in Art and Science: Art and Science Laboratory's **Evenings with Techne and Eros 2001**, Georgia O'Keeffe Museum, Santa Fe, New Mexico, 27 July 2001; Rockefeller Foundation Bellagio Conference Center, Bellagio, Italy, 26 October 2001.

Inferring Causal Architecture, DARPA TASK Principal Investigator Meeting, Washington, D.C., 9-10 January 2002.

Collective Cognition, Workshop on Collective Cognition: Mathematical Foundations of Distributed Intelligence, SFI, 21 January 2002.

Intrinsic Computation, AAAS Meeting, Special Session on Novel Computation, Boston, 14 February 2002.

Intrinsic Computation, Colloquium, Computer Science Department, Dartmouth College, Hanover, New Hampshire, 18 February 2002.

Causal Synchrony in Dynamic Networks, SFI Workshop on Failure and Contagion, Columbia University, New York, 24 May 2002.

Causal Synchrony, International Workshop on Evolutionary Innovation, Czech Academy of Sciences, Prague, 28 May 2002.

Computational Mechanics, Lecture Course, SFI Complex Systems Summer School, St. John's College, 11-12 June 2002.

Causal Synchrony in Multiagent Systems, DARPA TASK Principal Investigator Meeting, Chicago, 19-20 June 2002.

Computational Mechanics, Lecture Course, International Complex Systems Summer School, Collegium Budapest, 16-19 July 2002.

Pattern from Process, SITE SantaFe, Santa Fe, New Mexico, 24 August 2002. (J. P. Crutchfield and J. F. Simon).

Information Theory and Computational Mechanics for Multiagent Systems, DARPA TASK Principal Investigator Meeting, SFI, Santa Fe, 9 October 2002. (J. P. Crutchfield and D. P. Feldman).

Game-Theoretic Dynamical Systems Models for Multiagent Systems, DARPA TASK Principal Investigator Meeting, SFI, Santa Fe, 10 October 2002.

The Theater of Pattern Formation, Art Technology Center, University of New Mexico, Albuquerque, 1 November 2002. (J. P. Crutchfield and D. Dunn).

Patterns and Pattern Discovery, The Philosophical Club, SFI, 8-9 November 2002.

The Theater of Pattern Formation, Advanced High Performance Computing Center, University of New Mexico, Albuquerque, 13-14 January 2003. (J. P. Crutchfield and D. Dunn).

Multiple Agents Servicing Multiple Tasks, DARPA TASK Principal Investigator Meeting, 19-20 February 2003, Miami.

Patterns and Pattern Discovery, Lecture Course, Centro di Ricerca Matematica Ennio de Giorgi, Scuola Normale Superiore, University of Pisa, Pisa, Italy, 24-27 February 2003.

Is Anything Ever New? University Lecture Series on Emergence, University of Michigan, Ann Arbor, 3 April 2003.

Terrorizing Complex Systems, SFI Business Network Topical Meeting on Modeling Terrorism as a Complex Adaptive System, 10 April 2003.

The Theater of Pattern Formation, Center for Contemporary Arts, Santa Fe, New Mexico, 15 April 2003. (J. P. Crutchfield and D. Dunn).

Pattern from Process, Zero-One Spring Lecture Series, Microsoft Corporate Headquarters 2003. Mountain View, 20 May 2003.

Dynamics of Multiagent Systems, BISON Consortium Meeting, Telenor, Oslo, Norway, 3 June 2003.

An Introduction to Computational Mechanics, SFI Complex System Summer School, St. Johns College, Santa Fe, New Mexico, 11-13 June 2003.

Automated Pattern Discovery, Invited Plenary Lecture, SIAM Meeting on Industrial Applications of Complex Systems, Toronto, 13-15 October 2003.

Dynamical Embodiments of Computation in Cognition, Ron Brachman (IPTO Director) et al visit, Santa Fe Institute, Santa Fe, New Mexico, 22-23 October 2003.

Complex Systems Theory? Invited Lecture, SFI Faculty Retreat, Bishop's Lodge, Santa Fe, New Mexico, 24-25 October 2003.

Intrinsic Computation, Physics Department Colloquium, University of California, Davis, 12 November 2003.

Automated Pattern Discovery, Engineering Department Seminar, University of California, Davis, 13 November 2003.

Form and Function: From pattern to semantics and on to function, Collegium Budapest-SFI

Workshop on Form and Function, Budapest, Hungary, 16-19 November 2003.

The Making of 'The Theater of Pattern Formation, Graduate Center, City University of New York, New York, 1 December 2003.

The Theater of Pattern Formation, Graduate Center, City University of New York, New York, 1 December 2003.

Dynamics of Learning in Distributed Robotics, TASK PI Meeting, Washington DC, 4-5 December 2003.

Intrinsic Computation and Pattern Discovery, Colloquium, Physics Department, University of New Mexico, Albuquerque, 12 January 2004.

Intrinsic Computation and Nanotechnology, Invited lecture, Conference on Nanotechnology, Biotechnology, Information Technology, and Cognitive Science, New York, 26 February 2004.

Theory Theory, Invited lecture, Seminar on Computation in Natural Systems, Center for Nonlinear Studies, Los Alamos National Laboratory, 29 March 2004.

Practical Computational Mechanics, Dynamics of Learning Group, Seminar, Santa Fe Institute, 6 April 2004.

Pattern Discovery and Automated Theory Building, Physics-Astronomy Colloquium, Northwestern University, Chicago, Illinois, 9 April 2004.

Complex Systems Theory? Science Board Spring Meeting, Santa Fe Institute, 7 May 2004.

MultiAgent Dynamical Systems: Completion of the Theoretical Framework and Simulator, TASK PI Meeting, Washington, DC, 5 August 2004.

RoMADS—Robotic MultiAgent Development System and MultiAgent Dynamical Systems, TASK Demonstration, Washington, DC, 4 August 2004.

Pattern and Pattern Discovery—A Review of Computation Mechanics, Redwood Neurosciences Institute, Menlo Park, California, 2 September 2004.

Cellular Automata Computational Mechanics—Patterns and Discovery, Keynote speech, ACRI 2004, Amsterdam, Netherlands, 26 October 2004.

The Evolution of Structural Complexity, Center for Living Technology and Statistics Department, Universite de Ca Forsca, Venice, Italy, 2 November 2004.

Chaos and Complexity, Graduate Seminar, Venice International Program of the University of Virginia, Venice, Italy, 4 November 2004.

Objects that make Objects: The Population Dynamics of Structural Complexity, Research Focus Group in Mathematical Biology, Department of Mathematics, University of California, Davis, 15 February 2005.

Pattern Discovery for Spatial Processes, Sun Microsystems Laboratory 2005 Open House, Computer Museum, Palo Alto, California, 27 April 2005.

Multiagent Dynamical Systems, Seminar Series in Complex Systems, Environmental Sciences Department, UC Davis, 2 June 2005.

Multiagent Dynamical Systems, Sun Microsystems Research Laboratories, Mountain View, California, 17 August 2005.

Objects that make Objects: The Population Dynamics of Structural Complexity, Invited lecture, Workshop on the Evolution of Complexity, Mathematical Biosciences Institute, Ohio State University, Columbus, Ohio, 29 October 2005.

Multiagent Dynamical Systems, J. P. Crutchfield, Evolution and Economics Seminar, University of California, Davis, 25 October 2005.

Frontiers in Complex Systems, Keynote speech for Hackers 2005, Santa Cruz, California, 13 November 2005.

Objects that make Objects: The Population Dynamics of Structural Complexity, Workshop on the Evolution of Biological Complexity, Ohio State University, Columbus, Ohio, 17 November 2005; Mathematical Biology Seminar, UC Davis, 15 February 2005; Workshop on the Evolution of Gene Regulatory Logic, Santa Fe Institute, Santa Fe, New Mexico, 7 January 2006; The Science of Complex Systems, Seminar, Center for Computational Science & Engineering, UC Davis, 11 January 2006; Evolution of Complexity Workshop, ALife X

Conference, University of Indiana, Bloomington, 3 June 2006 First Annual Residency Month, Instituto de Sistemas Complejos de Valparaiso, Valparaiso, Chile, 21 December 2006 ; Workshop on the Evolution of Complexity, Tenth International Conference on Artificial Life, University of Indiana, Bloomington 3 June 2006; Mathematical Biology Seminar Mathematics Department, University of California, Davis, 12 March 2007; Bristol Centre for Complexity Sciences, University of Bristol, Bristol UK, 13 November 2007; Biology on the Edge Seminar, Keck Graduate Institute, Claremont, California, 29 November 2007.

Structure, Meaning, & Function: A Dynamical Systems Perspective, International School on Semiotic Dynamics, Language, and Complexity, Ettore Majorana Foundation & Centre for Scientific Culture, Erice, Italy, 14 December 2005; Colloquium, Cognitive Science Program, Indiana University, Bloomington, Indiana, 30 October 2006.

Theater of Pattern Formation, Center for Explorations in Art, Information, and Technology Festival, California Institute of the Arts, Roy and Edna Disney Center for Arts and Technology, 28 January 2006 (with D. Dunn).

Multiagent Dynamical Systems and Representations, Study Group on Adaptive Representations, Department of Computer Science and Artificial Intelligence, MIT, 12 July 2006.

Introduction to Computational Mechanics, Lecture Course, Santa Fe Institute Complex Systems Summer School, Chinese Academy of Sciences, Beijing, 19-21 July 2006.

Pattern & Process, Size Matters: Perception at the Edge of Space Critical Studies & Humanities Lecture Series, Cranbrook Academy of Art, Bloomfield Hills, Michigan, 1 November 2006.

Reconstruction Deconstruction: A Brief History of Building Models of Nonlinear Dynamical Systems, Computer Science Department, University of Hawaii, 5 February 2007, Honolulu, Hawaii; Neural Information Processing 2006 Workshop on Revealing Hidden Elements of Dynamical Systems, 8 December 2006, Whistler, British Columbia.

Beyond Big Iron: Artificial Science, Strategic Issues in eScience & CyberInfrastructure, California Institute of Technology, Pasadena, California, 14 June 2007.

Insects, Trees, & Climate, Mutamorphosis, Prague, Czech Republic, 9 November 2007.

Risk: Closing the Feedback Loop between Knowledge & Action, SFI Forum on Financial Risk, University Club of New York, One West 54th Street, New York, NY 10019, 15 November 2007.

Structure or Noise? Dynamics Days 2008, Knoxville, Tennessee, 5 January 2008.

Insects, Trees, & Climate: Case Studies in Parallel Perception, Berkeley Big Bang, Berkeley Art Museum/Pacific Film Archive, University of California, Berkeley, California, 3 June 2008.

Spontaneous Tinkering: Structural Hierarchies and the Emergence of Natural Selection, SFI Workshop on Selection Tinkering and Emergence in Complex Networks, Google Research, Mountain View, California, 24 June 2008.

Computation in Chaos, 25 Years of Nonlinear Dynamics, Amelia Island, Florida, 21 July 2008.

Papers

1. *Prediction and Stability in Classical Mechanics*, Senior Thesis in Physics and Mathematics, University of California, Santa Cruz, June 1979; submitted to APS First Annual Apker Undergraduate Thesis Competition.
2. *Chaotic States of Anharmonic Systems in Periodic Fields*, Phys. Rev. Lett. **43** (1979) 1743-1747. (B. A. Huberman and J. P. Crutchfield).
3. *Power Spectral Analysis of a Dynamical System*, Phys. Lett. **76A** (1980) 1-4 (J.P. Crutchfield, J. D. Farmer, N. H. Packard, R. S. Shaw, G. Jones, R. Donnelly).
4. *Fluctuations and the Onset of Chaos*, Phys. Lett. **77A** (1980) 407-410 (J.P. Crutchfield and B. A. Huberman).
5. *Geometry from a Time Series*, Phys. Rev. Lett. **45** (1980) 712-716 (N. H. Packard, J.P. Crutchfield, J. D. Farmer, and R. S. Shaw).
6. *Noise Phenomena in Josephson Junctions*, App. Phys. Lett. **37(8)** (1980) 750-753 (J. P. Crutchfield, B. A. Huberman, and N. H. Packard).

7. *Power Spectra and Mixing Properties of Strange Attractors*, Annals of the New York Academy of Sciences **357** (1980) 453-472 (J. P. Crutchfield, J. D. Farmer, H. Froehling, N. H. Packard, and R. S. Shaw).
8. *On Determining the Dimension of Chaotic Flows*, Physica **3D** (1981) 605-617 (H. Froehling, J. P. Crutchfield, J. D. Farmer, N. H. Packard, and R.S. Shaw).
9. *Fluctuations and Simple Chaotic Dynamics*, Physics Reports **92** (1982) 45-82 (J. P. Crutchfield, J. D. Farmer and B. A. Huberman).
10. *Scaling for External Noise at the Onset of Chaos*, Phys. Rev. Lett. **46** (1981) 933-935 (J. P. Crutchfield, M. Nauenberg, and J. Rudnick).
11. *Unexplained Helium Film Effect with Dielectric Resonators*, Phys. Lett. **80A** (1980) 87-90 (R. Shaw, J. P. Crutchfield, F. Bridges, and B. Rosenblum).
12. *Symbolic Dynamics of One-Dimensional Maps: Entropies, Finite Precision, and Noise*, Intl. J. Theo. Phys. **21** (1982) 433-466 (J. P. Crutchfield and N. H. Packard).
13. *Computing the Topological Entropy of Maps*, Commun. Math. Phys. **88** (1983) 257-262 (P. Collet, J. P. Crutchfield, and J.-P. Eckmann).
14. *Noise Scaling of Symbolic Dynamics Entropies*, in **Evolution of Order and Chaos**, ed. H. Haken, Springer-Verlag, Berlin (1982) 215-227 (J. P. Crutchfield and N. H. Packard).
15. *Symbolic Dynamics of Noisy Chaos*, in Physica **9D** (1983) 201-223 (J. P. Crutchfield and N. H. Packard).
16. **Noisy Chaos**, Ph.D. Dissertation, University of California, Santa Cruz, August 1983; University Microfilms International, 300 N. Zeeb Road, Ann Arbor, Michigan 48106 (1983).
17. *Low-Dimensional Chaos in a Hydrodynamic System*, Phys. Rev. Lett. **51** (1983) 1442-1446 (A. Brandstater, J. Swift, H. L. Swinney, A. Wolf, J. D. Farmer, E. Jen, and J. P. Crutchfield).
18. *Space-Time Dynamics in Video Feedback*, Physica **10D** (1984) 229-245.
19. *Experimental Mathematics: The Role of Computation in Nonlinear Science*, Comm. ACM **28** (1985) 374-384 (D. Campbell, J. P. Crutchfield, J. D. Farmer, and E. Jen).
20. *Chaos*, Scientific American **255** (December 1986) 46-57 (J. P. Crutchfield, J. D. Farmer, N. H. Packard, and R. S. Shaw).
21. *Chaos, Computer Graphics, and Natural Phenomena*, accepted for publication in **Transactions on Graphics**, December 1987.
22. *Equations of Motion from a Data Series*, Complex Systems **1** (1987) 417-452 (J. P. Crutchfield and B. McNamara).
23. *Phenomenology of Spatio-Temporal Chaos*, in **Directions in Chaos**, Hao Bailin, editor, World Scientific Publishers, Singapore (1987) 272-353 (J. P. Crutchfield and K. Kaneko).
24. *Are Attractors Relevant to Fluid Turbulence?* Phys. Rev. Lett. **60** (1988) 2715-2718 (J. P. Crutchfield and K. Kaneko).
25. *Subbasins, Portals, and Mazes: Transients in High Dimensions*, J. Nucl. Phys. B **5A** (1988) 287-292.
26. *Spatio-Temporal Complexity in Nonlinear Image Processing*, IEEE Trans. on Circ. Sys. **35** (1988) 770-780.
27. *Inferring Statistical Complexity*, Phys. Rev. Lett. **63** (1989) 105-108 (J. P. Crutchfield and K. Young).
28. **Quantifying Spatial Chaos**, Research and Development (November 1989) 12-17.
29. *Computation at the Onset of Chaos*, in **Entropy, Complexity, and Physics of Information**, W. Zurek, ed., Addison-Wesley, Redwood City, California, (1989) 223-269.
30. *Inferring the Dynamic, Quantifying Physical Complexity*, in **Measures of Complexity and Chaos**, A. M. Albano, N. B. Abraham, P. E. Rapp, and A. Passamante, eds., Plenum Press, New York (1989) 327-338.
31. *Information and Its Metric*, in **Nonlinear Structures in Physical Systems—Pattern Formation, Chaos, and Waves**, L. Lam and H. C. Morris, editors, Springer-Verlag, Berlin (1990) 119-130. Proceedings of the Second Woodward Conference, San Jose State University, San Jose, California, 17-18 November 1989.

32. *Chaos and Complexity*, in the **Handbook of Metaphysics and Ontology**, Philosophia Verlag, München (1990) 139-144.
33. *Complexity: Order contra Chaos*, in Proceedings of the **International Conference on Fuzzy Logic and Neural Networks**, S. Yasui and T. Yamakawa, editors, Iizuka, Japan (July 1990) World Scientific Publishers, Singapore (1990) 605-612.
34. *Reconstructing Language Hierarchies*, in **Information Dynamics**, H. A. Atmanspracher and H. Scheingraber, editors, Plenum Press, New York (1990) 45-60.
35. *Knowledge and Meaning ... Chaos and Complexity*, in **Modeling Complex Systems**, L. Lam and H. C. Morris, editors, Springer-Verlag, Berlin (1992) 66-101.
36. *Semantics and Thermodynamics*, in **Nonlinear Modeling and Forecasting**, SFI Studies in the Sciences of Complexity, Proc. Vol. XII, M. Casdagli and S. Eubank, editors, Addison-Wesley, Reading, Massachusetts (1992) 317-360.
37. *Discovering Coherent Structures in Nonlinear Spatial Systems*, in **Nonlinear Dynamics of Ocean Waves**, A. Brandt, S. Ramberg, and M. Shlesinger, editors, World Scientific, Singapore (1992) 190-216.
38. *The Attractor-Basin Portrait of a Cellular Automaton*, *J. Statistical Physics* **66** (1992) 1415-1462 (J. E. Hanson and J. P. Crutchfield).
39. *Unreconstructible at Any Radius*, *Physics Letters A* **171** (1992) 52-60.
40. *Attractor Vicinity Decay for a Cellular Automaton*, *CHAOS* **3:2** (1993) 215-224. (J. P. Crutchfield and J. E. Hanson).
41. *Turbulent Pattern Bases for Cellular Automata*, *Physica D* **69** (1993) 279-301. (J. P. Crutchfield and J. E. Hanson).
42. *The Quasi-Periodic Oscillations and Very Low Frequency Noise of Scorpius X-1 as Transient Chaos: A Dripping Handrail?* *Astrophys. J. Lett.* **411** (1993) L91-L94. (J. D. Scargle, D. L. Donoho, J. P. Crutchfield, T. Steiman-Cameron, J. Imamura, and K. Young).
43. *Revisiting the Edge of Chaos: Evolving Cellular Automata to Perform Computational Tasks*, *Complex System* **7** (1993) 89-130. (M. Mitchell, P. Hraber, and J. P. Crutchfield).
44. *Fluctuation Spectroscopy*, *Chaos, Solitons, and Fractals* **4** (1993) 5-39 (K Young and J. P. Crutchfield).
45. *Dynamics, Computation, and the "Edge of Chaos": A Re-examination*, in **Complexity: Metaphors, Models, and Reality**, G. Cowan, D. Pines, and D. Melzner, editors, SFI Series in the Sciences of Complexity, volume XIX, Addison-Wesley, Reading, MA (1994) 497-513. (M. Mitchell, J. P. Crutchfield, and P. Hraber).
46. *Observing Complexity and The Complexity of Observation* in **Inside versus Outside**, H. Atmanspacher, editor, Springer-Verlag, Berlin (1994) 234-272.
47. *Critical Computation, Phase Transitions, and, Hierarchical Learning* in **Towards the Harnessing of Chaos**, Proceedings of the 7th Toyota Conference, M. Yamaguti, editor, Elsevier Science, Amsterdam (1994) 29-46.
48. *Evolving Cellular Automata to Perform Computations: Mechanisms and Impediments*, *Physica D* (1994) 361-391. (M. Mitchell, J. P. Crutchfield, and P. Hraber).
49. *The Calculi of Emergence: Computation, Dynamics, and Induction*. *Physica D* **75** (1994) 11-54.
50. *Is Anything Ever New? Considering Emergence* in **Complexity: Metaphors, Models, and Reality**, G. Cowan, D. Pines, and D. Melzner, editors, SFI Series in the Sciences of Complexity **XIX**, Addison-Wesley, Redwood City (1994) 479-497.
51. *Dripping Handrails and the Quasi-Periodic Oscillations in the AM Herculis Objects*, *Astrophys. J.* **435** (1994) 775-783. (T. Steiman-Cameron, K. Young, J. D. Scargle, J. P. Crutchfield, J. Imamura, M. T. Wolff, and K. S. Wood).
52. *A Genetic Algorithm Discovers Particle Computation in Cellular Automata*, Proceedings of the Conference on **Parallel Problem Solving in Nature—PPSN III**, Y. Davidor, H.-P. Schwefel, and R. Männer, editors, Lecture Notes in Computer Science, Springer-Verlag, Berlin (1994) 344-353. (Refereed). (R. Das, M. Mitchell, and J. P. Crutchfield).

53. *Evolving Globally Synchronized Cellular Automata*, Proceedings of the Sixth International Conference on Genetic Algorithms, L. J. Eshelman, editor, Morgan Kaufman Publishers, San Mateo, California (1995) 336-343. (Refereed). (R. Das, J. P. Crutchfield, M. Mitchell, and J. E. Hanson.)
54. *The Evolution of Emergent Computation*, Proc. Natl. Acad. Sci. **92**:23 (1995) 10742-10746. (J. P. Crutchfield and M. Mitchell.)
55. *Computational Mechanics of Cellular Automata: An Example*, Physica D **103** (1997) 169-189. (J. E. Hanson and J. P. Crutchfield).
56. *Evolving Cellular Automata to Perform Computations*, in **Handbook of Evolutionary Computation**, Bäck, T., Fogel, D., and Michalewicz, Z., editors, Oxford University Press, Oxford (1996) G1.6.1-9. (M. Mitchell, J. P. Crutchfield, and R. Das).
57. *Evolving Cellular Automata to Perform Computations: A review of recent work*, in **Proceedings of the First International Conference on Evolutionary Computation and Its Applications (EvCA '96)**, Moscow, Russia, Russian Academy of Sciences (1996) 42-55. (M. Mitchell, J. P. Crutchfield, and R. Das).
58. *Turbulent Landscapes—A Dialogue*, Complexity **2**:2 (1996) 3-7. (J. P. Crutchfield and N. Kahn).
59. *Embedded-Particle Computation in Evolved Cellular Automata*, T. Toffoli, M. Biafore, and J. Leao, editors, in the Proceedings of the **Fourth Workshop on Physics and Computation: PhysComp96**, New England Complex Systems Institute, Boston, Massachusetts (1996) 153-158. (W. Hordijk, J. P. Crutchfield, and M. Mitchell).
60. *Statistical Complexity of Simple One-Dimensional Spin Systems*, Physical Review E **52** (1997) 1239R-1243R. (J. P. Crutchfield and D. P. Feldman).
61. *Finite Populations Induce Metastability in Evolutionary Search*, Physics Letters A **229**:3 (1997) 144-150. (E. van Nimwegen, J. P. Crutchfield, and M. Mitchell).
62. *Statistical Dynamics of the Royal Road Genetic Algorithms*, Theoretical Computer Science, Special Issue on Evolutionary Computation **229** (1999) 41-102. (E. van Nimwegen, J. P. Crutchfield, and M. Mitchell).
63. *Quantum Automata and Quantum Grammars*, Theoretical Computer Science **237**:1-2 (2000) 275-306. (C. Moore and J. P. Crutchfield).
64. *Measures of Statistical Complexity: Why?* Physics Letters A **258** (4-5) (1998) 244-252. (D. P. Feldman and J. P. Crutchfield).
65. *Dynamical Embodiments of Computation in Cognitive Processes*, Behavioral and Brain Sciences **21**:5 (1998) 635-637.
66. *Mechanisms of Emergent Computation in Cellular Automata*, Proceedings of the Conference on Parallel **Problem Solving in Nature—PPSN V**, A. E. Eben, T. Bäck, M. Schoenaur, and H.-P. Schwefel, editors, Lecture Notes in Computer Science, Springer-Verlag, Berlin (1998) 613-622 (Refereed) (W. Hordijk, J. P. Crutchfield, M. Mitchell).
67. *Discovering Noncritical Organization: Statistical Mechanical, Information Theoretic, and Computational Views of Patterns in Simple One-Dimensional Spin Systems*, J. Stat. Phys. (1998) submitted. (D. P. Feldman and J. P. Crutchfield). SFI Working Paper 98-04-026.
68. *Optimizing Epochal Evolutionary Search: Population-Size Independent Theory*, Computer Methods in Applied Mechanics and Engineering **186**:2-4 (2000) 171-194. Special issue on Evolutionary and Genetic Algorithms in Computational Mechanics and Engineering, D. Goldberg, editor. (E. van Nimwegen and J. P. Crutchfield).
69. *Thermodynamic Depth of Causal States: Objective Complexity via Minimal Representations*, Physical Review E **59** (1999) 275-283. (J. P. Crutchfield and C. R. Shalizi).
70. *The Evolutionary Design of Collective Computation in Cellular Automata* in **Evolutionary Dynamics—Exploring the Interplay of Selection, Neutrality, Accident, and Function**, J. P. Crutchfield and P. Schuster, editors, Santa Fe Institute Series in the Science of Complexity, Oxford University Press, New York (2001) 361-411. (J. P. Crutchfield, M. Mitchell, and R. Das).

71. *Optimizing Epochal Evolutionary Search: Population-Size Dependent Theory*, Machine Learning (2001) 77-114. (E. van Nimwegen and J. P. Crutchfield).
72. *Evolving Two-Dimensional CA to Perform Density Classification: A Report on Work in Progress*, Parallel Computing **27** (2001) 571-585. Also in **Cellular Automata: Research Towards Industry**, S. Bandini, R. Serra, and F. Suggi Liverani, Springer-Verlag, ISBN 1-85233-048-1 (1998) 3-14. (F. Jimenez-Morales, J. P. Crutchfield, and M. Mitchell).
73. *The Evolutionary Unfolding of Complexity*, in **Evolution as Computation: DIMACS Workshop, Princeton, 1999**, L. F. Landweber and E. Winfree, editors, Lecture Notes in Computer Science, Springer Verlag, New York (2001). (J. P. Crutchfield and E. van Nimwegen).
74. *Neutral Evolution of Mutational Robustness*, Proc. Natl. Acad. Sci. USA **99** (1999) 9716-9720. (E. van Nimwegen, J. P. Crutchfield, and M. A. Huynen).
75. *Comment on "Simple Measure for Complexity"*, Physical Review E **62** (2000) 2996-2997. (J. P. Crutchfield, D. P. Feldman, and C. R. Shalizi).
76. *Computational Mechanics: Pattern and Prediction, Structure and Simplicity*, Journal of Statistical Physics **104** (2001) 817-879. (C. R. Shalizi and J. P. Crutchfield).
77. *Resource Sharing and Coevolution in Evolving Cellular Automata*, IEEE Trans. Evolutionary Computation **4:4** (2000) 1-6. (J. Werfel, M. Mitchell, and J. P. Crutchfield).
78. *Metastable Evolutionary Dynamics: Crossing Fitness Barriers or Escaping via Neutral Paths?* Bulletin of Mathematical Biology **62** (2000) 799-848. (E. van Nimwegen and J. P. Crutchfield).
79. *An Upper Bound on the Products of Particle Interactions in Cellular Automata*, Physica D **154:3-4** (2001) 240-258.
80. *Information Bottlenecks, Causal States, and Statistical Relevance Bases: How to Represent Relevant Information in Memoryless Transduction*, Advances in Complex Systems **5:1** (2002) 1-5. (C. R. Shalizi and J. P. Crutchfield).
81. *A Processing Automaton for Intensive Data*, Proceedings of the Virtual Observatory of the Future, ASP Conference Series, R. J. Brunner, S. G. Djorgovski, and A. Szalay, editors, (2000) to appear. (J. D. Scargle, A. Connors, J. P. Crutchfield, C. Glymour, R. Hewitt, and T. Loredó).
82. *Synchronizing to the Environment: Information Theoretic Constraints on Agent Learning*, Advanced in Complex Systems **4:2** (2001) 251-264. (J. P. Crutchfield and David P. Feldman).
83. *When Evolution is Revolution—Origins of Innovation*, in **Evolutionary Dynamics—Exploring the Interplay of Selection, Neutrality, Accident, and Function**, J. P. Crutchfield and P. Schuster, editors, Santa Fe Institute Series in the Science of Complexity, Oxford University Press, New York (2001) 103-135.
84. *Dynamics of Evolutionary Processes*, in **Evolutionary Dynamics—Exploring the Interplay of Selection, Neutrality, Accident, and Function**, J. P. Crutchfield and P. Schuster, editors, Santa Fe Institute Series in the Science of Complexity, Oxford University Press, New York (2001) xiii-xxxiv. (J. P. Crutchfield and P. Schuster).
85. *Evolving One-Dimensional Cellular Automata to Perform a Nontrivial Collective Behavior Task: One case study*, Computational Science-ICCS 2002, Part I, Proceedings 2329 (2002) 793-802. (F. Jimenez-Morales and M. Mitchell and J. P. Crutchfield).
86. *What Lies Between Order and Chaos?* In **Art and Complexity**, J. Casti, editor, Oxford University Press (2002).
87. *Discovering Planar Disorder in Close-Packed Structures from X-Ray Diffraction: Beyond the Fault Model*, Phys. Rev. B **66:17** (2002) 156-159. (D. P. Varn, G. S. Canright, and J. P. Crutchfield).
88. *Coupled Replicator Equations for the Dynamics of Learning in Multiagent Systems*, Physical Review E **67:1** (2003) 40-43. (Y. Sato and J. P. Crutchfield).
89. *Pattern Discovery in Time Series, Part I: Theory, Algorithm, Analysis, and Convergence*, Journal of Machine Learning Research (2003) submitted, Santa Fe Institute Working Paper 02-10-060; arXiv.org/abs/cs.LG/0210025. (C. R. Shalizi, K. L. Shalizi, and J. P. Crutchfield).
90. *Regularities Unseen, Randomness Observed: Levels of Entropy Convergence*, CHAOS **13:1** (2003) 25-54. (J. P. Crutchfield and David P. Feldman).

91. *Synchronizing to Periodicity: The Transient Information and Synchronization Time of Periodic Sequences*, *Advances in Complex Systems* **7**:3-4 (2004) 329-355. (D. P. Feldman and J. P. Crutchfield).
92. *A Direct Method for Inferring Planar Disorder and Structure from X-ray Diffraction Studies*, *Acta Crystallographica Section A* (2007) submitted. (D. P. Varn, G. S. Canright, and J. P. Crutchfield).
93. *Inferring Pattern and Disorder in Close-Packed Structures via ϵ -Machine Reconstruction Theory: Examples from Simulated Diffraction Spectra*, *Acta Crystallographica Section A* (2007) submitted. (D. P. Varn, G. S. Canright, and J. P. Crutchfield).
94. *Inferring Pattern and Disorder in Close-Packed Structures via ϵ -Machine Reconstruction Theory: Structure and Intrinsic Computation in Zinc Sulphide*, *Acta Crystallographica Section B* **63**:2 (2006) 169-182. (D. P. Varn, G. S. Canright, and J. P. Crutchfield).
95. *Structural Information in Two-Dimensional Patterns: Entropy Convergence and Excess Entropy*. *Physical Review E* **65**:5 (2003) 051103. (D. P. Feldman and J. P. Crutchfield).
96. *From Finite to Infinite Range Order via Annealing: The Causal Architecture of Deformation Faulting in Annealed Close-Packed Crystals*, *Physical Letters A* **234**:4 (2004) 299-307. (D. P. Varn and J. P. Crutchfield).
97. *Reductions of Hidden Information Sources*, *Journal of Statistical Physics* **210**:3-4 (2005) 659-684. (N. Ay and J. P. Crutchfield).
98. *Persistent Chaos in High Dimensions*, *Physical Review E* **74**:5 (2006) 057201. (D. Albers, C. S. Sprott, and J. P. Crutchfield).
99. *Stability and Diversity in Collective Adaptation*, *Physica D* **210**:1-2 (2005) 21-57. (Y. Sato, E. Akiyama, and J. P. Crutchfield).
100. *Objects that Make Objects: The Population Dynamics of Structural Complexity*, *Journal of the Royal Society Interface* **3** (2006) 345-349. (J. P. Crutchfield and O. Görnerup).
101. *Automated Pattern Detection—An Algorithm for Constructing Optimally Synchronizing Multi-Regular Language Filters*, *Theoretical Computer Science* **359**:1-3 (2006) 306-328. (C. S. McTague and J. P. Crutchfield).
102. *Hierarchical Self-Organization in the Finitary Process Soup*, *Artificial Life Journal* **14**:3 (2008) 245-254. (J. P. Crutchfield and O. Görnerup).
103. *Language Diversity in Measured Quantum Processes*, *International Journal of Unconventional Computation* **4**:1 (2008) 99-112. In **From Utopian to Genuine Unconventional Computers**, A. Adamatsky and C. Teuscher, editors, Luniver Press, Beckington, United Kingdom (2006). (K. Wiesner and J. P. Crutchfield).
104. *Computation in Finitary Stochastic and Quantum Processes*, *Physica D* **237**:9 (2008) 1173-1195. [pdf] arXiv:0608206 [quant-ph]. Digital Object Identifier (DOI).. (K. Wiesner and J. P. Crutchfield).
105. *Entomogenic Climate Change*, Leonardo (2008) in press. [pdf] 08053851 [q-bio.PE].
106. *Insects, Trees, and Climate: The Bioacoustic Ecology of Deforestation and Entomogenic Climate Change* (David Dunn and J. P. Crutchfield) (2006) [pdf] [html] arXiv:0612.019 [q-bio.PE]. (David Dunn and J. P. Crutchfield).
107. *The Organization of Intrinsic Computation: Complexity-Entropy Diagrams and the Diversity of Natural Information Processing*, (David P. Feldman, Carl S. McTague, and J. P. Crutchfield) *CHAOS* (2008) submitted [pdf] arXiv:0806.4789 [nlin.CD].
108. *Optimal Instruments and Models for Noisy Chaos*, *CHAOS* **17** (2007) 043127 (C. C. Streliaoff and J. P. Crutchfield) [pdf] arXiv:0611054 [cs.LG].
109. *Optimal Causal Inference*, *J. Machine Learning Research* (2007) submitted. (S. Still and J. P. Crutchfield) [pdf] arXiv:0708.1580 [cs.IT].
110. *Structure or Noise?* *Physics Letters A* (2008) submitted. [pdf] arXiv:0708.0654 [physics-gen-ph]. (S. Still and J. P. Crutchfield).
111. *Primordial Evolution in the Finitary Process Soup*, *Electronic Journal of Theoretical Physics* (2007) submitted. [pdf] arXiv:0704.3771 [q-bio.PE]. (O. Görnerup and J. P. Crutchfield).

- 112., *Inferring Markov Chains: Bayesian Estimation, Model Comparison, Entropy Rate, and Out-of-class Modelin*", Physical Review E 76:1 (2007) 011106. [[pdf](#)] [math.ST/0703715](#). (C. C. Streliaoff, J. P. Crutchfield, and A. Hubler).
113. *How Random Is a Coin Toss? Bayesian Inference and the Symbolic Dynamics of Deterministic Chaos*, Conference on Neural Information Processing, Workshop on Dynamical Systems, Stochastic Processes and Bayesian Inference (2006) [Online Proceedings](#). [[pdf](#)] [cs.LG/0611054](#). (C. C. Streliaoff and J. P. Crutchfield).
114. *Computation in Sofic Quantum Dynamical Systems*, Lecture Notes in Computer Science (2007) submitted. [[pdf](#)] [arXiv:0704.3075 \[quant-ph\]](#). (K. Wiesner and J. P. Crutchfield).
115. *Intrinsic Quantum Computation*, Physics Letters A **374**:4 (2008) 375-380. [[pdf](#)] [arXiv:0611202 \[quant-ph\]](#). (J. P. Crutchfield and K. Wiesner).
116. *Infinite Correlation in Measured Quantum Processes*, Quantum Information Processing Workshop (2007) submitted. [[pdf](#)] [quant-ph/0611143](#). (K. Wiesner and J. P. Crutchfield).

Books

1. **Evolutionary Dynamics—Exploring the Interplay of Selection, Neutrality, Accident, and Function**, Oxford University Press, New York (2002) (J. P. Crutchfield and P. K. Schuster).
2. **Beyond Productivity: Information Technology, Innovation, and Creativity**, A Report of the National Research Council Computer Science and Technology Board's *Committee on Information Technology and Creativity*, National Academies Press (2003). (W. Mitchell, A. Inouye, and M. Blumenthal, editors; J. P. Crutchfield, ITC Committee Member).
3. **Pattern Discovery in Spacetime—Exploring the Interplay of Structure and Disorder in Cellular Automata**, publisher under negotiation (2008) in preparation (J. P. Crutchfield).

Film and Video

1. **A Friendly Introduction to Strange Attractors**, 16mm, black and white, 10 min. (1979) (J. P. Crutchfield, J. D. Farmer, H. Froehling, N. H. Packard, and R. S. Shaw). Premiered at the New York Academy of Sciences *Conference on Nonlinear Dynamics*, New York, (December 1979).
2. **Mixing Properties of Strange Attractors**, 16mm, black and white, 10 min. (1979) (J. P. Crutchfield, J. D. Farmer, N. H. Packard, and R. S. Shaw). Premiered at the New York Academy of Sciences *Conference on Nonlinear Dynamics*, New York, (December 1979).
3. **Chaotic Attractors of Driven Oscillators**, 16mm, black and white, 10 minutes (1981). Premiered *Dynamics Day La Jolla*, La Jolla, California, (January 1982). Distributed by Aerial Press, P.O. Box 1360, Santa Cruz, California 95060.
4. **Space-Time Dynamics in Video Feedback**, Video, 15 minutes (1984). Premiered *Dynamics Day La Jolla*, La Jolla, California, (January 1985). Distributed by Aerial Press, P.O. Box 1360, Santa Cruz, California 95060.
5. **Chaotica I**, Aerial Press, Santa Cruz (1987). Video, 30 minutes. Distributed by Aerial Press, P.O. Box 1360, Santa Cruz, California 95060.
6. Video feedback special effects for **Pulse**, Columbia Pictures, Hollywood, California (Spring 1987).
7. Computer graphic animation for **Chaos**, Danish Broadcasting Service, Copenhagen, Denmark (Spring 1988).
8. Computer graphics animation for **Chaos**, *InCA*, TV4, London, United Kingdom, (Fall 1988).
9. Computer graphics animation for **Chaos**, *NOVA*, WGBH/PBS, Cambridge, Massachusetts (January 1989).

Post-Doctoral Researchers

Current and former advisees.

1. David Albers (Physics, University of Wisconsin, Madison).
2. Lisa Borland (Physics, University of California, Berkeley, 1986-1988).
3. James Hanson (Santa Fe Institute, 1992-1994).
4. Rajarshi Das (Santa Fe Institute & Los Alamos National Lab, NSF Post-Doctoral Fellow, 1995-1996).
5. Erik van Nimwegen (Santa Fe Institute, 2000-2001).
6. Cosma Shalizi (Santa Fe Institute, 2001-2002).
7. Yuzuru Sato (Santa Fe Institute, 2003-2004).
8. Karoline Wiesner (Santa Fe Institute, UC Davis, 2004-).

Ph.D. Students

Current and former advisees.

1. Benny Brown (Ph.D. in Physics, University of California, Davis, 2009 expected).
2. Rajarshi Das (Ph.D. in Computer Science, 1997, Colorado State University; NSF Post-Doctoral Fellow).
3. Chris Ellison (Ph.D. in Physics, University of California, Davis, 2009 expected).
4. David Feldman (Ph.D. in Physics, University of California, Davis, 1998).
5. James E. Hanson (Ph.D. in Physics, University of California, Berkeley, 1994).
6. Wim Hordijk (Ph.D. in Computer Science, University of New Mexico, 1999).
7. Peter Hrabec (Ph.D. in Biology, University of New Mexico, 1998).
8. Kristin Lui (M.S. in Applied Mathematics, University of California, Davis, 2008 expected).
9. John Mahoney (Ph.D. in Physics, University of California, Davis, 2009).
10. Spencer Mathews (Ph.D. in Computer Science, University of California, Davis, 2009 expected).
11. Bruce McNamara (Ph.D. in Physics, University of California, Santa Cruz, 1993).
12. Erik van Nimwegen (Ph.D. in Physics *cum laude*, University of Utrecht, 1999).
13. Cosma R. Shalizi (Ph.D. in Physics, University of Wisconsin, Madison, 2001).
14. Chris Strelief (Ph.D. in Physics, University of Illinois, Urbana-Champaign, 2007 expected).
15. Daniel R. Upper (Ph.D. in Mathematics, University of California, Berkeley, 1996; NSF Graduate Fellow).
16. Dowman P. Varn (Ph.D. in Physics, University of Tennessee, Knoxville, 2001).
17. Sean Whalen (Ph.D. in Computer Science, University of California, Davis, 2008 expected).
18. Karl Young (Ph.D. in Physics, University of California, Santa Cruz, 1995; NRC Post-Doctoral Fellow).
19. Victoria Alexander (Ph.D. in Literature, Graduate Center, City University of New York, 2002).

SFI-NSF Physics Graduate and Other Graduate Programs.

1. Robert Haslinger (Physics, University of Wisconsin, Madison).
2. Eric Lee (Physics, Columbia).
3. Dowman P. Varn (Physics, University of Tennessee, Knoxville).
4. Karoline Wiesner (SFI Steinmetz Fellow; Physics, University of Uppsala, Sweden).

Masters Students

Former advisees.

1. Olof Gornerup (Masters in Computer Science, Chalmers Institute of Technology, Sweden; June 2003).

Undergraduate Students

Students advised under NSF Research Experience For Undergraduates summer programs.

1. Matt Austern, SFI Summer 1995 (Physics, Princeton University).
2. Elizabeth Ayer, SFI Summer 1995 (Computer Science, Duke University).
3. Beverly Steinhoff, SFI Summer 1997 (Mathematics, Boston University).
4. Alex Wo, SFI Summer 1997 (Physics, Harvard University).
5. Justin Werfel, SFI Summer 1998 (Physics, Princeton University).
6. Chris Douglas, SFI Summer 1998 (Physics, MIT).
7. Jason Wyman, SFI Summer 1998 (Physics, Middlebury College).
8. Kristina Klinkner, SFI Summer 2000 (Computer Science, University of San Francisco).
9. Patrick Yannul, SFI Summer 2000 (Computer Science, Drexel University).
10. Carl McTague, SFI Summer 2001 (Mathematics, Music, University of Cincinnati).
11. Alison Binkowski, SFI Summer 2001 (Computer Science, Wesleyan).
12. Jacob Usinowicz, SFI Summer 2002 (Physics, College of the Atlantic).
13. Sara Friedman, SFI Summer 2002 (Applied Mathematics, University of California, Berkeley).
14. Erik Talvitie, SFI Summer 2003 (Computer Science, Oberlin).
15. John Albers, SFI Summer 2003 (Aeronautics, University of Wisconsin, Madison).
16. Selah Frost Lynch, SFI Summer 2003 (Physics, LeHigh University, Bethlehem, Pennsylvania).
17. Steve Piantadosi, SFI Summer 2004 (Computer Science, University of North Carolina).
18. David Berwick, SFI Summer 2004 (Mathematics, Oberlin College, Ohio).
19. Rebecca Morrison, UCD Summer 2007 (Physics, Scripps College, Claremont, California).
20. Jake Ellowitz, UCD Summer 2008 (Physics, Clark University, Worcester, Massachusetts.)

Other interns.

1. David Solina, UC Berkeley 1991 (Physics, UC Berkeley).
2. Sue Whitfield, UC Berkeley 1993 (Mathematics, UC Berkeley).
3. Peter Hraber, SFI 1992-1993 (St. John's College).
4. Adam Messinger, SFI 1994 (Physics, Reed College).
5. Alex Lancaster, SFI 2000 (Physics, UC Berkeley).
6. Gina LaCerva, SFI 2002, 2003 (Santa Fe Preparatory High School).
7. Veronica Hart, SFI 2003 (Santa Fe Preparatory High School).

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