University of Chicago
POLITICAL SCIENCE 473:
COMPLEXITY

Winter 2002
Monday 1:30-4:30
Pick 407

Prof. John F. Padgett
Office Hours Fri 9-10:30
Pick 512

This course presents an overview for social scientists of recent theories and models of self-organization and emergence. These theories, associated with the Santa Fe Institute, have been developed for the most part in the physical and biological sciences. The course will explore, largely through discussion, the relevance of these theories for the social sciences.

The University of Chicago has participated in this intellectual movement through the development of the agent-based simulation platform Repast, which is oriented toward social science applications and is available for free: http://repast.sourceforge.net

The course requirements are weekly 4-5 page book reports. You may pick any book or bunched set of articles to write about, one from each section (except first and eleventh). Include one conjectured social application in your discussion. Book reports are due by 9am the day of class, and should be distributed electronically to everyone in the course.

Week 1: **Popular Overviews**

Frijof Capra, The Web of Life (1996)

M. Mitchell Waldrop, Complexity: The Emerging Science at the Edge of Order and Chaos (1992)

PART I: FOUNDATIONS

Week 2: **Introduction to Self-Organization**

Thomas Schelling, Micromotives and Macrobehavior (1978)

Mitchell Resnick, Turtles, Termites, and Traffic Jams (1994)
http://www.media.mit.edu/starlogo

Scott Camazine et al., Self-Organization in Biological Systems (2001)
http://beelab.cas.psu.edu

Joshua Epstein and Robert Axtell, Growing Artificial Societies (1996)
http://www.brook.edu/sugarscape/

Lars-Erik Cederman, Emergent Actors in World Politics: How States and Nations Develop and Dissolve (1997)

Gregoire Nicolis and Ilya Prigogine, Exploring Complexity (1989)

Week 3: **Introduction to Evolution** (and to debates therein)

Ernst Mayr, What Evolution Is (2001)

Richard E. Mellon, Darwinian Dynamics: Evolutionary Transitions in Fitness and Individuality (1999)

Herbert Simon, "The Architecture of Complexity," in The Sciences of the Artificial (1996 [1968])
Gunter Wagner and Lee Altenberg, "Complex Adaptations and the Evolution of Evolvability," Evolution 50: 967-76 (1996)
Jonathan Bendor and Dilip Mookherjee, "Institutional Structure and the Logic of Collective Action," American Political Science Review 81: 129-154 (1987)

John Holland, Adaptation in Natural and Artificial Systems (1975)

John N. Thompson, The Coevolutionary Process (1994)

Brian Goodwin, How the Leopard changed its Spots (1994)

Rudolf A. Raff, The Shape of Life: Genes, Development, and the Evolution of Animal Form (1996)

Niles Eldredge, The Pattern of Evolution (1999)

Week 4: **Evolutionary Game Theory**

John Maynard Smith, Evolution and the Theory of Games (1982)

Robert Axelrod and William D. Hamilton, "The Evolution of Cooperation," Science 211:1390-96 (1981)
Robert Axelrod, The Evolution of Cooperation (1984)

H. Peyton Young, Individual Strategy and Social Structure: An Evolutionary Theory of Institutions (1998)

Kristian Lindgren, "Evolutionary Phenomena in Simple Dynamics," in Christopher G. Langton et al. (eds.), Artificial Life II (1992)
Martin Nowak and Robert May, "Evolutionary Games and Spatial Chaos," Nature 359:

826-29 (1992)
Michael D. Cohen, Rick Riolo and Robert Axelrod, "The Role of Social Structure in the Maintenance of Cooperative Regimes," Rationality and Society 13:5-32 (2001)
Rick L. Riolo, Michael D. Cohen and Robert Axelrod, "Evolution of Cooperation without Reciprocity," Science 414: 441-43 (2001)

Jonathon Bendor and Piotr Swistak, "The Evolution of Norms," American Journal of Sociology 106: 1493-1545 (2001)

PART II: BIOLOGICAL NETWORKS AND LIFE

Week 5: **Ecological Communities**

Robert May, Stability and Complexity in Model Ecosystems (1973)

John Tyler Bonner, The Evolution of Complexity (1988)

Stuart Pimm, The Balance of Nature? (1991)

K.S. McCann, "The Diversity-Stability Debate," Nature 405: 228-33 (2000)
Ricard V. Sole, David Alonso, and Alan McKane, "Scaling in a Network Model of a Multispecies Ecosystem," Physica A 286: 337-44 (2000)
Ricard V. Sole, David Alonso, and Alan McKane, "Self-Organized Instability in Complex Ecosystems," Santa Fe Institute Working Papers # 01-11-065 (2001)

Brian A. Maurer, Untangling Ecological Complexity: The Macroscopic Perspective (99)

Week 6: **Hypercycles and the Origin of Life**

Erwin Schrodinger, What is Life? (1944)

Manfred Eigen and Peter Schuster, The Hypercycle: A Principle of Natural Self-Organization (1979)

Josef Hofbauer and Karl Sigmund, The Theory of Evolution and Dynamical Systems (1988)

John F. Padgett, "The Emergence of Simple Ecologies of Skill: A Hypercycle Approach to Economic Organization," in W. Brian Arthur et al., The Economy as an Evolving Complex System II (1997)
Sanjay Jain and Sandeep Krishna, "Autocatalytic Sets and the Growth of Complexity in an Evolutionary Model," Physical Review Letters 81: 5684-87 (1998)
Sanjay Jain and Sandeep Krishna, "Large Extinctions in an Evolutionary Model: The Role of Innovation and Keystone Species," Santa Fe Institute Working Papers

01-12-076 (2001)

Walter Fontana and Leo Buss, "The Arrival of the Fittest: Toward a Theory of Biological Organization," Bulletin of Mathematical Biology 56: 1-64 (1994)

Week 7: **Phenotypes and Macroevolution**

A.M. Turing, "The Chemical Basis of Morphogenesis," Philosophical Transactions of the Royal Society B 237: 37-72 (1952)

Stuart A. Neumann, "Generic physical mechanisms of tissue morphogenesis: A common basis for development and evolution," Journal of Evolutionary Biology 7: 467-88 (1994)

I. Salazar-Ciudad, S.A. Newman, and R.V. Sole, "Phenotypic and dynamical transitions in model genetic networks, I and II," Evolution and Development 3: 84-103 (2001)

Stuart Kauffman, The Origins of Order: Self-Organization and Selection in Evolution (1993)

Leo Buss, The Evolution of Individuality (1987)

John Maynard Smith and Eors Szathmary, The Major Transitions in Evolution (1995)

David Jablonski, Douglas Erwin, and Jere Lipps (eds.), Evolutionary Paleobiology (1996)

Douglas H. Erwin, "The Origin of Bodyplans," American Zoologist 39: 617-29 (1999)

Steven Jay Gould, Wonderful Life: The Burgess Shale and the Nature of History (1989)

Simon Conway Morris, The Crucible of Creation: The Burgess Shale and the Rise of Animals (1998)

Lauren W. Ancel and Walter Fontana, "Plasticity, Evolvability, and Modularity in RNA," Journal of Experimental Zoology 288: 242-83 (2000)

John F. Padgett, "Organizational Genesis, Identity, and Control: The Transformation of Banking in Renaissance Florence," in James Rauch and Alessandra Cassella (eds.), Networks and Markets (2001) [do not write book report on this]

PART III: PHYSICAL NETWORKS AND THE MIND

Week 8: **Statistical Mechanics and Self-Organized Criticality**

Barry M. McCoy and Tai Tsun Wu, The Two-Dimensional Ising Model (1973)

J. M. Yeomans, Statistical Mechanics of Phase Transitions (1992)

Daniel Stein (ed.), Spin Glasses and Biology (1992)

Lawrence E. Blume and Steven N. Durlauf, "The Interactions-Based Approach to Socioeconomic Behavior," in Steven N. Durlauf and H. Peyton Young (eds.), Social Dynamics (2001)

Steven N. Durlauf, "Statistical Mechanics Approaches to Socioeconomic Behavior," in W. Brian Arthur et al. (eds.), The Economy as an Evolving Complex System II (1997)

Lawrence E. Blume, "The Statistical Mechanics of Strategic Interaction," Games and Economic Behavior 5:387-424 (1993)

P. Bak, C. Tang, and K. Wiesenfeld, "Self-organized criticality: An explanation for 1/f noise," Physical Review Letters 59: 381-84 (1987)

Per Bak, How Nature Works: The Science of Self-Organized Criticality (1996)

Henrik Jeldtoft Jensen, Self-Organized Criticality: Emergent Complex Behavior in Physical and Biological Systems (1998)

K. Nagel and S. Rasmussen, "Traffic at the Edge of Chaos," in R.A. Brooks and P. Maes (eds.), Artificial Life IV (1994)

T. Ohira and R. Sawatari, "Phase transition in a computer network traffic model," Physical Review E 58: 193-95 (1998)

Ricard Sole and Sergi Valverde, "Phase Transitions in a Model of Internet Traffic," Santa Fe Institute Working Papers # 00-03-020 (2000)

Bernardo A. Huberman and Rajan M. Lukose, "Social Dilemmas and Internet Congestion," Science 277: 535-37 (1997)

Bernardo Huberman (ed.), The Ecology of Computation (1989) [optional background]

Week 9: **Neural Nets**

William Bechtel and Adele Abrahamsen, Connectionism and the Mind: Parallel Processing, Dynamics, and Evolution in Networks (2002 [1991])

Andy Clark, Associative Engines: Connectionism, Concepts, and Representational Change (1993)

Patricia S. Churchland and Terrence J. Sejnowski, The Computational Brain (1992)

Robert N. McCauley (eds.), The Churchlands and their Critics (1996)

A. Engel and C. Van den Broeck, Statistical Mechanics of Learning (2001)

Week 10: **Artifacts, Translation, and Language**

Edwin Hutchins, Cognition in the Wild (1995)

Antonio Damasio, Descartes' Error: Emotion, Reason and the Human Brain (1994)

Andy Clark, Being There: Putting Brain, Body, and World Back Together Again (1997)

George Lakoff, Women, Fire, and Other Dangerous Things: What Categories Reveal about the Mind (1987)

Gilles Fauconnier, Mappings in Thought and Language (1997)

Week 11. **Consciousness and Quantum Mechanics**
(an extra session led by Alex Wendt)

Danah Zohar and Ian Marshall, The Quantum Society: Mind, Physics, and a New Social Vision

Stuart Hameroff, "Quantum Coherence in Microtubules: A Neural Basis for Emergent Consciousness?" Journal of Consciousness Studies 1: 91-118 (1994)
David Chalmers, "Facing up to the Problem of Consciousness," Journal of Consciousness Studies 2: 200-19 (1995)
David Hodgson, "Nonlocality, Local Indeterminism, and Consciousness," Ratio 9: 1-22 (1996)
Michael Esfeld, "Quantum Holism and the Philosophy of Mind," Journal of Consciousness Studies 6: 23-38 (1999)
Bruce Rosenblum and Fred Kuttner, "Consciousness and Quantum Mechanics: The Connection and Analogies," The Journal of Mind and Behavior 20: 229-56 (1999)
David Sloan Wilson and Elliott Sober, "Reviving the Superorganism," Journal of Theoretical Biology 136: 337-356 (1989)