Management 118A

Instructor: Bill McKelvey **Fall 2005**

Day: Mon. & Wed. Time: 9:30–11:50 Room D310, Cornell Hall in the Anderson Complex

Foundations of "NEW" Social Science: Applications of Complexity Science and Agent-based Models

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This course uses complexity science to bridge between old and new conceptions of social science. Newtonian science, neoclassical economics, and existing social sciences, in general, *all* build on the assumptions:

1. That all the basic "agents" comprising phenomena (atomic particles, atoms, molecules, organisms, people, groups, firms, etc.) are "*homogeneous*" and that the behavior of one is "*independent*" of the behavior of the others; and
2. Go forward in time under *equilibrium conditions* (interspersed with occasional, short-term disequilibrium periods).

None of these assumptions hold for most of human behavior in social settings. So, what to do to do good science?

"New" Economics, *"New" Management*, *"New" Social Science*, *Complexity Science*, and *Agent-based Models* posit that order-creation is the dominant condition of social systems and that order-creation is the outcome of interactions among autonomous heterogeneous agents. In *New Science*, equilibrium conditions are not things to be assumed but rather to be marveled at and studied if, when, and where they occur. *New Science* (mostly complexity science) simply accepts agents as stochastically idiosyncratic and then asks how and why macro structures emerge.

Complexity science focuses on "order-creation" rather than the "order-translation" process underlying the 1st Law of Thermodynamics (energy conservation), and replaces the 19th century mathematics of neoclassical economics, management, and social science with agent-based computational models (ABMs). Since order-creation is a more characteristic aspect of social phenomena than order-translation, it follows that *New Science* ABMs map onto social phenomena better than math models styled after classical physics and now dominating neoclassical economics. After all, *People <u>are</u> the Brownian motion!* The key question becomes, *How to research social systems as complex adaptive systems, in which agents and emergent structures coevolve in the context of pressures from ever changing environmental contexts?*

New Science is often called "*rule-based science*" or "*bottom-up science*." The idea is to explain the emergence of macro social phenomena—such as networks, groups, organizations, and larger structures—by taking extant theories and translating them into the "*rules*" that autonomous heterogeneous agents have to be following in order for such structures to emerge. Furthermore, agents (people) adaptively learn and coevolve with other learning agents and higher-level social structures—both upward *and* downward causality involved. Some of the research questions are:

1. What are the active agent rules?
2. Why do agents follow some rules and not others?
3. How and when do agents' rules change?
4. What kinds of emergent social phenomena arise from interacting and learning agents?
5. What role do contextual energy differentials (adaptive tension) play in motivating agent behaviors?
6. How to "manage" agents and get them to produce more economically viable teams, new product developments, entrepreneurial ventures, and generally, more effective socioeconomic and/or organizational (complex adaptive) systems?

Complexity scientists use agent-based models—often termed "adaptive learning models" to

1. Meet the model-centered epistemology of modern philosophy of science;
2. Model social phenomena without the warping homogeneity, independence, and equilibrium assumptions inherent in math models; and
3. Run computational experiments over time to more fully understand the interactions of nonlinearly related variables (rather than simply linearizing them) related to self-organizing phenomena.

Modern computers allow the use of increasingly sophisticated agent-based adaptive-learning models such as cellular automata, genetic algorithms, and neural networks. These offer methods of studying how macro structures emerge from the interactions of stochastically idiosyncratic, learning, agents. They are the methods of choice of many complexity scientists. Since people *<u>are</u> the Brownian motion* in social systems, it is surely ironic that the use of these models in the social sciences considerably lags their use in the physical and life sciences. A couple of years ago there were over 200 more cites per journal in natural science than in sociology. This course introduces you to the logic of agent-based theorizing, the different kinds of model platforms, and gets you started in the process of developing the agent "simple rules" that allow one to translate from old to new ways of modeling social phenomena.

- ✓ **<u>Open to All, BUT, Designed like an "Honors" Undergrad Course</u>**
- ✓ **Grades are based on a *Term Paper:***
- ✓ **For each week, key readings identified by the ➡. Where there are two ➡➡s, the first book is my first choice, but you may prefer the second one. Reading either one is ok with me.**
  Other readings listed each week offer a more focused set of <u>optional</u> additional readings for the student particularly interested in that week's topic.
- ✓ **The syllabus provides a broad overarching framework within which each student may develop a more idiosyncratic learning experience particularly suited to his/her preferred social science.**
- ✓ **Additional, more general, reading lists are available.**

<u>A CHALLENGE</u>

If you would like to read ONE—very challenging book—instead of several, you are welcome to buy and read:
Thinking in Complexity **(Klaus Mainzer, 1994/2004).**
This is my favorite book. BUT, you probably should have a background in physics or biology or computer science before taking up this challenge!! Or a lot of nerve!

1. BASIC COMPLEXITY SCIENCE

Topics:

Natural Science Origins
Kinds of Complexity
The Region of Emergence
External Energy Impositions, Thermodynamics, and Emergent Dissipative Structures
European School

Readings:

➡***Emergence: The Connected Lives of Ants, Brains, Cities, & Software*** **(Steven Johnson, 2001).**
The End of Certainty: Time, Chaos, and the New Laws of Nature (Ilya Prigogine (with I. Stengers 1997).
Self-Organization in Biological Systems. (Scott Camazine, et al., 2001).
Cosmic Evolution: The Rise of Complexity in Nature (Eric Chaisson, 2001)
Signs of Life: How Complexity Pervades Biology. (Ricard Solé and Brian Goodwin, 2000
Dynamic Patterns: Self-Organization of Brain and Behavior (Scott Kelso, 1995).
How Nature Works: The Science of Self-Organized Criticality (Per Bak, 1996).
How the Leopard Changed its Spots: The Evolution of Complexity. (Brian Goodwin, 1994).
Complexification (John Casti 1994).
Complexity: Metaphors, Models, and Reality (G. A. Cowan et al., eds., 1994).
Development and Evolution: Complexity and Change in Biology (Stanley Salthe, 1993).
Chaos and Order: The Co
mplex Structure of Living Things (Fritz Cramer, 1993).
Origins of Order (Stewart Kauffman, 1993).
Chaos and Complexity (Brian Kaye, 1993).
Exploring Complexity: An Introduction (Grégoire Nicolis and Ilya Prigogine, 1989).
Self-Organizing Systems: The Emergence of Order (Eugene Yates, 1987).
Order Out of Chaos (Ilya Prigogine and Isabelle Stengers, 1984).
Synergetics (Hermann Haken, 1977, 1983).
McKelvey, B. "Book Prospectus"

McKelvey, B. (2004). "Toward a 0th Law of Thermodynamics: Order-Creation Complexity Dynamics from Physics & Biology to Bioeconomics." ***Journal of Bioeconomics*****, 6: 31–68.**

2. ORDER-CREATION SCIENCE APPLIED to SOCIAL PHENOMENA

Topics:

Order-Creation at Different Levels of Analysis: Matter—Life—Brain—Artificial Intelligence—Social Systems
From Chaos to Complexity Theory: From Equations to Agents
Intrasystem Order-creation Dynamics: "Butterfly" Effects, Positive Feedback, Emergence
Independence vs. Interdependence
American School

Readings:

Complexity: Life at the Edge of Chaos (Roger Lewin, 1992/1999).
Thinking in Complexity (Klaus Mainzer, 1994/2004).
The Tipping Point. (Malcolm Gladwell, 2000).
From Biology to Sociopolitics: Conceptual Continuity in Complex Systems. (Heinz Herrmann, 1998).
Self-Organization of Complex Structures: From Individual to Collective Dynamics (Frank Schweitzer, ed., 1997).
Chaos Theory in the Social Sciences: Foundations & Applications (L. D. Kiel & E. Elliott, eds., 1997).
Chaos, Complexity, and Sociology (Raymond Eve, Sara Horsfall and Mary Lee, eds., Sage, 1997).
Chaos and Society (Alain Albert, ed., 1995).
At Home in the Universe (Stewart Kauffman, 1995).
Chaos and Society. (Alain Albert, ed., 1995).
Managing Chaos and Complexity in Government. (Douglas Kiel, 1994).
Out of Control (Kevin Kelly, 1994).
Interdisciplinary Approaches to Nonlinear Complex Systems (Hermann Haken and A. Mikhailov, eds., 1993).
Complexity (Mitchell Waldrop, 1993).
Autopoiesis and Cognition (R. Maturana and F. H. Verela, 1980).

McKelvey, B. (2004). "Toward a Complexity Science of Entrepreneurship."
Journal of Business Venturing**, 19: 313–341**

3. DYNAMICS OF COEVOLVING ECONOMIC ADAPTIVE SYSTEMS

Topics:
Orthodox and Evolutionary Economics: A Critique
Economies as Complex Adaptive Systems
Economists' Assumptions—Assuming Away What Is Interesting So the Math Works!!
Pareto Distributions, Power Laws, and Scale-free Theory

Readings:
➡***The Self-Organizing Economy*** **(Paul Krugman, 1996).**
Hollywood Economics: How Extreme Uncertainty Shapes the Film Industry**. (Arthur De Vany, 2004).**
Butterfly Economics **(Paul Ormerod, 1998).**
Agent-Based Computer Simulation of Dichotomous Economic Growth (Roger McCain, 2000).
Commerce, Complexity, and Evolution (William Barnett et al., eds. 2000).
Computable Economics (Kumaraswamy Velupillai, 2000).
The Complexity Vision and the Teaching of Economics, (David Colander, ed. 2000).
Evolution and Self-Organization in Economics (F. Schweitzer & G. Silverberg, eds. 1998)**????**
The Complexity of Cooperation: Agent-based Models of Competition and Collaboration (Robert Axelrod, 1997).
The Economy as an Evolving Complex System II (B. Arthur, S. Durlauf, D. Lane, eds., 1997). (**ADL**)
Computational Economic Systems: Models, Methods & Econometrics (Manfred Gilli, ed., 1996).
The Death of Economics (Paul Ormerod, 1994).
Chaotic Economic Dynamics. (Richard Goodwin, 1990)
Economic Complexity. (William Barnett, John Geweke, & Karl Schell, eds. 1989
The Economy as an Evolving Complex System I (P. Anderson, K. Arrow and D. Pines, 1988).
Andriani, P., and B. McKelvey (2005). "Beyond Gaussian Averages: Extending Organization Science to Extreme Events and Power Laws." Working paper, Durham Business School, U. Durham, Durham, UK.

4. ORGANIZATION, STRATEGY AND MANAGING COMPLEXITY DYNAMICS

Topics:
Kauffman's "Complexity Catastrophe"
Organization and Strategy Analysis
Details of the *NK* Model and *NK* Applications
Managing Complexity, Positive Feedback, and Coevolutionary Dynamics

Readings:
➡***Surfing the Edge of Chaos*** **(Richard Pascale, Mark Millemann and Linda Gioja, 2000).**
➡***The Complexity Advantage*** **(Susanne Kelly and Mary Allison, 1998).**
Competing on the Edge (Shona Brown and Kathleen Eisenhardt, 1998).
[***Dynamics of Organizations*** (Alessandro Lomi and Erik Larsen, 2001)].
Managing Complexity (Robin Wood, 2000)
Managing Emergent Phenomena: Nonlinear Dynamics in Work Organizations (Stephen Guastello, 2000).
Learning and Innovation in Organizations and Economies (Bart Nooteboom, 2000).
The Edge of Organization: Chaos and Complexity of Formal Social Systems. (Russ Marion, 1999).
Systemic Choices: Nonlinear Dynamics and Practical Management (Gregory A. Daneke, 1999).
Chaos, Catastrophe, and Human Affairs (Stephen Guastello, 1995).
Networks In and Around Organizations (Steven Andrews and David Knoke, eds., 1999).
The Unshackled Organization (Jeff Goldstein, 1994).
Mackey, A., B. McKelvey and P. K. Kiousis (2005). "Failing Firms During the 1990s Boom: Complexity Dynamics vs. Competing Explanations. Working paper, Ohio State University.

5. BOTTOM-UP SCIENCE—THINKING LIKE AN AGENT

Topics:
Order-Creation continued
Agent-Based, Bottom-Up Science
Growing an Artificial Economy
Growing Cities
Modeling Stock Markets

Readings:

➡***Growing Artificial Societies*** **(Joshua Epstein & Robert Axtell, 1996)**
➡***The Self-Organizing Economy*** **(Paul Krugman, 1996)**
LeBaron, B. (2001). "Evolution and Time Horizons in an agent-based Stock Market," Brandeis University. (details the model)
LeBaron, B. (2001). "Financial Market Efficiency in a Coevolutionary Environment."
LeBaron, B. (2001). "Volatility Magnification and Persistence in an Agent-Based Financial Market."
LeBaron, B. (2001). "A Builder's Guide to Agent Based Financial Markets."
LeBaron, B. (2000). Financial market efficiency in a coevolutionary environment. *Proceedings of the Workshop on Simulations of Social Agents.* Argonne National Laboratory
LeBaron, B. (2000). "Empirical Regularities from Interacting Long and Short Memory Investors in an Agent-Based Stock Market," *IEEE Transactions on Evolutionary Computation.*

6. SIMULATION AND SCIENCE:

Topics:
Overall View of Agent-Based Computational Modeling
Kauffman's *NK* Model
Cellular Automata
Detailing the *NK* Model

Readings:

⎩***Would-Be Worlds: How Simulation is Changing the Frontiers of Science*** **(John Casti, 1997).**
Connectionist Models of Social Reasoning and Social Behavior (Stephen Read and Lynn Miller, eds. 1998).
Computational Modeling of Behavior in Organizations (Daniel Ilgen and Charles Hulin, eds., 2000).
Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence (Gerhard Weiss, ed. 1999).
Simulating Organizations (Michael Prietula, Kathleen Carley, & Les Gasser, 1998).
Distributed Artificial Intelligence Meets Machine Learning: Learning in Multi-Agent Envs. (Gerhard Weiss, ed. 1996).
Computational Organization Theory (Kathleen M. Carley and M. Prietula, eds., 1994).
Artificial Intelligence in Organization and Management Theory (M. Masuch & M. Warglien, eds., 1992).
⎩**Yuan, Y. and B. McKelvey (2001). "Situativity of Learning Within Groups: An *NK* Modeling Study." Working paper, Annenberg School, USC, Los Angeles.**

7. JOHN HOLLAND AND OTHER "HOW TO DO IT" TEXTBOOKS

Topics:
Model Platforms
Genetic Algorithms
Neural Networks
Pattern Finding vs. Experiments
Detailing a GA

Readings:

➡***Hidden Order*** **(John Holland 1996). (More genetic algorithm oriented)**
➡***Emergence: From Chaos to Order*** **(John Holland, 1998). (More neural net oriented)**
Computational Finance (Yaser S. Abu-Mostafa, Blake LeBaron, et al. 2000).
Multi-Agent Systems (Jacques Ferber, 1999).
Simulation for the Social Scientist (Nigel Gilbert and Klaus Troitzsch, 1999).
Computational Techniques for Modelling Learning in Economics (Thomas Brenner, ed., 1999).
Macy, M.W. and Skvoretz, J. (1998). "The Evolution of Trust and Cooperation between Strangers: A Computational Model." *American Sociological Review*, 63: 683-660.

8. MODEL-CENTERED SOCIAL SCIENCE

Topics:
Role of Models in Science
Models as Mediators
Model-centered Science
Math vs. Agent-based Models
Agent models as "models" and "experiments"

Readings:
[*Models as Mediators* (MM) (Mary Morgan and Margaret Morrison, eds., 2000)—Source, but don't read]

➡**Morrison, M. & M. Morgan (2000). "Models as Mediating Instruments" in MM, 10–37.**

➡**Morrison, M. (2000). "Models as Autonomous Agents," in M. S. Morgan and MM, 38–65.**

McKelvey, B. (2005). "Complexity Science as Order-Creation Science: New Theory; New Method." ***Emergence: Complexity and Organisation,***

McKelvey, B. (2002). "Model-Centered Organization Science Epistemology," in J. A. C. Baum (ed.) *Companion to Organizations*, 752–780.

Henrickson, L, & B. McKelvey (2002). "Foundations of "New" Social Science: Institutional Legitimacy: Philosophy, Complexity Science, Postmodernism, and Agent-based Modeling," *Proceedings…Nat. Acad. of Sci.* 99, 7288–7297.

Read, D. W. (1990). "The Utility of Mathematical Constructs in Building Archaeological Theory," in A. Voorrips (ed.), *Mathematics and Information Science in Archaeology: A Flexible Framework*. Bonn: Holos, 29–60.
available at: http://repositories.cdlib.org/hcs/DWR1990/

9. EPISTEMOLOGY and PHENOMENA OF ORDER-CREATION SCIENCE

Topics:
Science vs. Postmodernism
Relation between Postmodernism and Complexity Science Ontologies
Force-based vs. Rule-based Science
Aristotelian Causality

Readings:

➡***Complexity and Postmodernism* (Paul Cilliers 1998).**

McKelvey, B. (2003). "Postmodernism vs. Truth in Management Theory." In E. Locke (ed.), ***Post Modernism and Management: Pro's, Cons and the Alternative. Research in the Sociology of Organizations,*** **21: 113–168. Amsterdam, NL: Elsevier Science, 2003, 113–168.**

Dynamics in Action: Intentional Behavior as a Complex System (Alicia Juarrero, 1999).

Evolutionary Systems: Biological and Epistemological Perspectives on Selection and Self-Organization (Gertrudis Van de Vijver, Stanley N. Salthe, Manuala Delpos, eds., 1998).

Evolution, Order and Complexity (Elias Khalil and Kenneth Boulding, eds., 1996).

The Philosophy of Artificial Life (Margaret Boden, 1996).

Thomas, C., R. Kaminska-Labbé, & B. McKelvey (2003). "Unraveling Entangled Organizational Dynamics: Coevolutionary Causalities Underlying 21st Century Management." Working paper, UCLA,

10. PHILOSOPHICAL FOUNDATIONS of 'NEW' BOTTOM-UP SOCIAL SCIENCE

Topics:
Recent Trends in Philosophy of Science
Legitimacy of Social Science
Centrality of Formalized Models
Evolutionary Scientific Realism
Campbellian Realism

Readings:

➡***Mapping Reality* (Jane Azevedo: 1997).**

➡***Economics & Reality* (Tony Lawson, 1997).**

McKelvey, B. (2003). "From Fields to Science." In R. Westwood & S. Clegg (eds.), *Point/Counterpoint: Central Debates in Organization Theory*. Oxford, UK: Blackwell, 2003, 47–73.

McKelvey, B. (1999). "Toward a Campbellian Realist Organization Science," in J. A. C. Baum & B. McKelvey (eds.), ***Variations in Organization Science: In Honor of Donald T. Campbell",*** **383–411.**

McKelvey, B. (1997)."Quasi-natural Organization Science," *Organization Science*, 8, 1997, 351–381.

Relevant Web Sites

Leigh Tesfatsion, Iowa State http://www.econ.iastate.edu//tesfatsi/
http://www.econ.iastate.edu/classes/econ308x/tesfatsion/

Kathleen Carley, CMU http://www.hss.cmu.edu/departments/sds/faculty/carley/39-350-2F750_2000_b_comporg.pdf
http://www.casos.ece.cmu.edu/home_frame.html

Art De Vany, UC Irvine: http://aris.ss.uci.edu/econ/personnel/devany/devany.html

Robert Axlerod, Michigan http://www-personal.umich.edu/~axe/complexity_syllabus.htm

Scott Page et al. http://www.pscs.umich.edu/lab/documentation/ICPSR-00/icpsr-Nonlinear-00.txt

Douglas R. White, UC Irvine http://eclectic.ss.uci.edu/~drwhite/Anthro179a/syllabus.htm

James Hughes, Chicago http://www.changesurfer.com/Acad/SocEco.html

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Repast: http://repast.sourceforge.net/
(Java-based multi-agent platform)

Cougaar http://cougaar.org/
(Java-based multi-agent platform)

AgentBuilder: (commercial) http://www.agentbuilder.com/

DIET http://diet-agents.sourceforge.net/DesignPhilosophy.html
(Java-based multi-agent platform)

Journal of Artificial Societies & Social Simulation http://jasss.soc.surrey.ac.uk/JASSS.html