

Working Course Outline

Evolutionary Systems

Each subject we examine this semester in Evolutionary Systems is an enormous subject all its own. Each subject has entire books, or college courses devoted to it. In some areas you can even get a degree studying it. And, for most of these subjects a higher degree is required to understand it at a technical and professional level. Plus, these higher degrees are spread across the disciplines: math, economics, biology, etc.

We cannot give you more than an outline understanding of this broad and complex subject. But we are satisfied with that. You should think about the course as a series of flashbulb images taken in darkness. For a fraction of a second you see things clearly, and for a time afterward there is an after image that sticks with you. And if it intrigues you enough we hope it will entice you to go back at leisure, in the light, and examine it more.

What we plan to do is develop for you a series of concepts and strategies within chaos/complexity theory to explore evolutionary systems. And we have designed it so that the series of flashbulb images will, by the end, give you a good understanding of what complex evolutionary systems are. The course has three interrelated goals.

First, to develop in you the knowledge and experience to recognize any self-organizing, complex system for what it is when you see it, even if it is now "frozen in time."

Second, to develop in you the knowledge and experience so you can observe any complex system - physical, chemical, biological, social, economic, etc. - and not only deduce the general rules by which it is operating but also be able to describe the modes and patterns of its behavior.

Third, to enable you to put your finger on the pulse of those systems, and deduce from their behavior their "r" value ("r" = rate of growth, or how hard the system is being pushed) at any point in time, and describe their resulting attractor state, potential for change, and the possible direction and predictability of that change.

Chaos Theory/Complexity Theory

1. **LECTURE: There Are Things about the Universe We Just Don't Understand**
 - < The Second Law and Disorder
 - < Top-Down vs. Bottom-Up

Experiment 1: Life3000 (Option One)

Discussion: Cellular Automata

Reading Assignment: Non-Equilibrium Thermodynamics . . .

- < *A Glossary of Terms and Concepts . . .*
 - < *The X-next Equation*
2. **LECTURE: The Problem of Problems**
 - < Prigogine and Non-Equilibrium thermodynamics
 - < Bronowski and stratified stabilities
 3. **LECTURE: Models in Science**
 4. **LECTURE: Chaos Theory**
 - < The Computational Viewpoint

Experiment 2: X-next Equation/Period Doubling Route to Chaos

Discussion: X-next

Experiment 3: Bifurcation Diagrams and Sensitive Dependence

Discussion: Bifurcation

Homework: Complexity Theory and Artificial Life

5. **LECTURE/DEMONSTRATION: Complexity Theory and Self-evolved Criticality**
 - < Properties of Complex Systems
 - < Per Bak and the Sandpile analogy

Self Organization in Physical Systems

6. **LECTURE: Attractors and Adaptive Landscapes**
 - < Embedding Time Series diagrams in phase space
7. **LECTURE: Chaos in Physical Systems**
 - < Flicker noise in a pendulum

Experiment 4: Galaxy: The Three Body Problem

Discussion: Galaxy

Attractors, Fractals, and the Quality of Information

Experiment 5: Attractors

Discussion: Attractors

8. **LECTURE: Fractal Geometry**
 - < Self Similarity and Scaling Relationships
 - < Dimension: Fractal, Topological, Embedding
 - < Power Law Distributions and $1/f$ noise
 - < Statistics and Fractals

Experiment 6 - Fractals

- Mandelbrot Set
- Icons as strange attractors
- Return to bifurcation diagram parabola attractor
- Use Poincare section analogy for attractor

Discussion: Fractal Geometry

Experiment 7 - Calculating Fractal Dimensions

- Box Counting

9. **LECTURE: The Quality of Information**
- < Observation and Prediction in Science
 - < Discussion: How Much Information is enough?

Experiment 8: The Quality of Information

- Frangos' topographic model
- Simicon and the amount of information
- X_{next} and how much do you need to know to know when and if the system will attenuate?

Discussion: The Quality of Information

Self Organization in Chemical Systems

10. **LECTURE: Classical and Thermodynamic Physics: The Search for a Rational Universe**
- < Order Without Selection?
 - < Kauffman Quote P 17 - failure to predict does not mean failure to understand or explain
11. **LECTURE: Oscillating Chemical Reactions**
12. **LECTURE: Fractionating Igneous Systems**
- < Fractionating vs Elaborating Evolutionary Attractors

Artificial Life Systems: Cellular Automata

Homework: Cellular Automata

- Reading: *Cellular Automata: How they are Created and Work*
- Exercises in *Cellular Automata: Problems 1-2*

Discussion: Cellular Automata Homework

13. **LECTURE: Artificial Life**
- < Local Rules/Global Behavior
 - < Autopoietic Networks

Discussion: Is Artificial Life, Life?

Experiment 9 - The Game of Life (Using Life3000) (Option Two)

Discussion: The Game of Life Using the Life3000 Program

14. **LECTURE: Information Flow in Cellular Automata**

Experiment 10 - Information Flow in The Game of Life

Discussion: Information Flow in The Game of Life

- Self Organization in the Cellular Automata
- Avalanche behavior in the game of life

Homework Assignment: Laboratory Experiment on Boids

Experiment 11 - Boids

- <http://www.geocities.com/SiliconValley/Bay/5922/>
- <http://www.red3d.com/cwr/boids/>

Discussion: Boids

- Are Boids and Cellular Automata operating by the same principles?

Experiment 12 - Wordevol

Discussion: WordEvol

- But is natural selection enough? (Draw on Kauffman discussion)

Experiment 13 - Simulated Evolution

- "Simulated Evolution" and evolution of feeding paths. Coded behavior with no flexibility.

15. LECTURE: Artificial Life and Intelligence

- < The John Muir Trail
- < Ichnology
- < Intelligence and Learning: Top-Down vs Bottom-Up
- < Looking for Information

Artificial Life and Intelligence: Neural Networks

16. LECTURE: Neural Networks

- < Robotics
- < The structure of Neural Networks
- < Neural Networks vs coded behavior

Experiment 14 - Neural Networks

- Need to find/develop.

Artificial Life: Genetic Algorithms

Reading Assignment - Genetic Algorithms

17. LECTURE: Complex Adaptive Agents and Genetic Algorithms: Modeling Evolution and Life Processes

- < Adaptive Landscapes
- < Selective Agents

- < Complex Adaptive Agents

Experiment 15 - Gene and Manna Mouse

Discussion - Gene and Manna Mouse

Experiment 16 - Microants and Primordial Life

Discussion - Microants

Self Organization and the Origin of Life

- 18. **LECTURE: Autocatalytic Networks and Self Organization**
 - < Against thermodynamics how has the molecular diversity on Earth increased? (Kauffman, p 113).
 - < Self Reproducing chemical systems - order for free.
 - < Against thermodynamics how has the molecular diversity of earth increased?
 - < Supracritical explosions (Kauffman, p 114)
 - < Order for free
 - < Hypercycles
 - < Quazispecies
 - < If molecular diversity increases what constrains the chaotic diversity?
- 19. **LECTURE: Autopoietic Networks**
- 20. **LECTURE: The Origin of Life**
 - < Build on Kauffman's Chapter 3, quote p 47, 80.

Applications to Biological Evolution

- 21. **LECTURE: Biological Evolution as a Dissipative Structure**
- 22. **LECTURE: The Red Queen Hypothesis, and Scaling Fitness Landscapes**
 - < Ramps and Antiramps
- 23. **LECTURE: Extinction, Is it a Power Law?**
 - < Power Law Extinction in Cellular Automata.
 - < Kauffman, p 87-89, clusters of order poised on the edge of chaos in Boolean networks.
 - < Power Law Extinction in Genetic Algorithms.
 - < Power Law Extinction in the fossil record.
- 24. **LECTURE: Is evolution exogenous or endogenous?**
 - < What properties must they possess?
 - < How must they behave?
 - < Examples:
 1. History of Life
 2. The Cambrian Explosion
 3. Kuhn's scientific revolutions

Swarm Behavior: Ants, Butterflies and Economics

25. **LECTURE: What happens when Complex Adaptive Agents can influence each others' behavior?**
- < The ant model
 - < Exogenous vs Endogenous Behavior
 - < Applications to:
 - C Ants, termites, etc.
 - C City organization
 - C Economic systems

Game Theory, the Prisoner's Dilemma and The Evolution of Cooperation

Reading: Game Theory and the Prisoner's Dilemma

27. **LECTURE: the Evolution of Cooperation**

Discussion - Prisoner's Dilemma - Pre-Experiment Discussion

Experiment 17 - Prisoner's Dilemma and Sugarscape
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Discussion - Prisoner's Dilemma - Pre-Experiment Discussion:

1. The Effectiveness of Freedom
2. Kauffman quote p 28

The Gaia Theory

28. **LECTURE: The Gaia Theory**
- < Is the Earth as a whole a SOC system?
 - < Double Feedback loops

Experiment 18 - Daisyworld Models
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