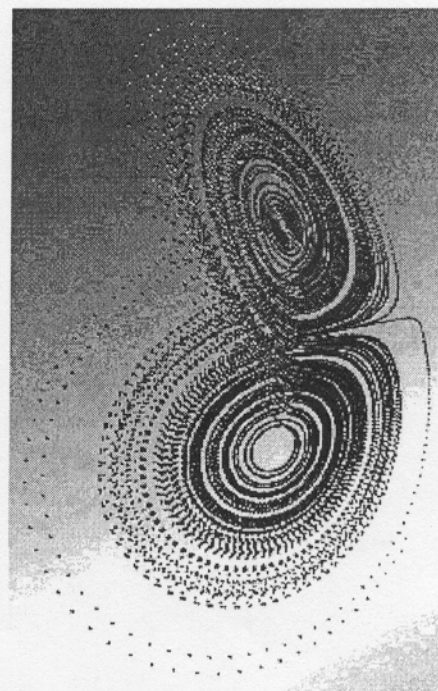


Complexity and the Universe I

SCI 318U (CRN 65417) & PH 366U (CRN 65418)

A comprehensive picture seems to be emerging, spanning time from the earliest beginning of the universe to the present, and covering size scales from quarks to galaxies.

In *Complexity and the Universe*, we survey this picture, including such topics as patterns in nature, the connectedness of the world, an understanding of adaptability and evolvability, fractals, chaos, order, classes of behavior, the workings of life, the units that act as building blocks for complexity, the close connection between complexity and computation, cognition, and group behavior. We also look at the how our understanding is influencing the arts and our lives through bionanotechnology.



Instructor: Dr. Jack Semura (503) 725-4229,

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Physics Department

4 credits, Tues -Thurs 2:00-4:00

Science Building 2, Room 469

Complexity and the Universe I

Version 1 Outline of Topics

This is an approximate schedule. Times and topics, including the quiz/exam dates will be modified as we progress. We will try to include most of these topics, but we may need to abbreviate this list during a short 10-week term.

- Week 1: 0. Introduction, Handouts, Names, About Complexity.
 1. Introduction: Comprehensive Picture Emerging
 2. Emergence in the Universe
- Week 2: 3. A World of Building Blocks and Forces
 4. Hierarchy and Emergence
- Week 3: 5. Fractals and Patterns in Nature
 Lab: fractal dimension
- Week 4 Quiz/Exam 1
 6. Simple Laws with Complex Behavior
- Week 5 7. Chaos, Order, and Classes of Behavior
 8. An Interconnected World
- Week 6 9. Life
 10. Artificial Life
- Week 7 11. Thresholds and Transitions
 12. Self-Organization, Adaptability, and Evolvability
- Week 8 13. Group Behavior
 Quiz/Exam 2
- Week 9 14. Cognition and Connectionism
 15. Computation and Complexity
- Week 10 Poster papers.
- Final Exam: Quiz/Exam 3

Additional topics we will try to include during the term: 16. Complexity in the Arts, 17. Bio and Nano Technology

Grading:

Grades will be based on:

- I. Participation: attendance, class projects, and presentations: 40%
- II. Exams/Quizzes (three) 30%
- III. End of Term Poster Paper 30%

Required Readings and Materials for this Class:

1. Read chapters 1 and 2 and selected sections to be assigned from Sole and Goodwin, *Signs of Life* (New York: Basic Books, 2000)
 2. Additional material will be presented in the form of
 - A. online assignments with links on the course website
 - B. handouts, lab experiments, outlines, focus questions, and terms to know
 - C. lectures
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Additional (Not-Required but Recommended) References:

General Book:

- Waldrop, M. Mitchell (1992), *Complexity: the Emerging Science at the Edge of Order and Chaos*, New York: Simon and Schuster (ISBN 0-671-87234-6).
- Ball, P. (1999). *The self-made tapestry: pattern formation in nature*. New York: Oxford University Press. Best book surveying pattern formation with scores of examples and pictures.

Complex Systems and Emergence in the universe:

- Kauffman, Stuart (1996). *At Home in the Universe*, Oxford University Press, New York and London, 1995 (ISBN 0-19-509599-5, hardcover), or in paperback (1996).

Chaos:

- Gleick, James (1987). *Chaos: making of a new science*, New York: Viking Penguin. (ISBN 0-670-81178-5).

Connectivity and patterns:

- Duncan J. Watts, *Small Worlds: The Dynamics of Networks between Order and Randomness*, Princeton University Press, Princeton, NJ, 1999. The modern classic of connectivity.

Computation

- Crevier, Daniel (1993). *AI: The tumultuous history of the search for artificial intelligence*. New York: Basic Books Division of HarperCollins.
- Davis, Martin. *Engines of Logic: Mathematicians and the Origins of the Computer*. New York: W. W. Norton, 2000. Good history of the development of traditional computation.

Astronomy:

- The Astronomers*. This PBS video series is the best video series on our understanding of the universe is usually available at the library and Blockbuster.

Other references:

- If you would like to follow certain threads further, try the following:
- Ruthen, R. (1993), Adapting to complexity, *Scientific American*. Jan. 1993: 130-140.
- Bak, P. and Chen, K. (1991), Self-Organized Criticality, *Scientific American* Jan. 1991: 46-53.
- Joseph Campbell, *The Power of Myth* video series with Bill Moyers. For an understanding of the mythic foundations that structure our quest for understanding—including the scientific quest. (Campbell further writes about the scientific search in Campbell, J. (1986). *The inner reaches of outer space*. New York: Harper and Row.)
- Levy, Steven, *Artificial Life*, Vintage Books (Random House), New York, 1992 (ISBN 0-679-74389-8). This book explores the subject of creating artificial life within computers.
- Swimme, Brian, and Berry, Thomas (1992). *The Universe Story: From the Primordial Flaring Forth to the Ecozoic Era—A Celebration of the Unfolding of the Cosmos*, Harper, San Francisco, 1992 (paperback).
- Science*, magazine published weekly by the American Association for the Advancement of Science (AAAS), is one of the most up to date and comprehensive general scientific source.

End of Term Poster Paper for Complexity and the Universe Part I

Paper:

Near the end of the term, turn in your poster paper (3 – 5 pages, 1500 + words). Also email this paper to me (semuraj@pdx.edu)

Poster session:

During the last week of the term we will have a class poster session for you to present your poster paper. The poster sessions are scheduled tentatively for the last two class days of the term. Half of the class members will display on each day and the other half will evaluate the displayed projects.

Project evaluation:

Evaluating the projects will be by both peer evaluation and instructor evaluation. Assessment is based on the following point system:

| Evaluation Criteria | Points |
|--|--------|
| Originality and creative ability | 30 |
| Does the work show independent thinking? | |
| Does the project show understanding? * | 25 |
| Is there a question you're trying to resolve? | |
| Is there a conclusion of some sort? | |
| Overall quality | 25 |
| or: If this is a group project, is the amount of work appropriate? | |
| Clarity of presentation | 20 |

What to try to avoid:

Try to avoid doing a project that basically reports on an article or work that doesn't involve your own thinking. Of course, it is OK to do your own *independent* scientific evaluation of other work *if* you apply your own questions, reasons, and conclusions.

Examples of projects and papers by previous class members:

Attractors in the family: Analyzing attractors and feedback loops in children and family dynamics
The world wide web as a self-organizing system.
Sunspot cycles since 1840 for possible chaotic attractors
Heart ekg data for attractors.
Analyzing the geometry paint splatter patterns
Tensegrity patterns of cells: Trying to understand how our bodies feed back into cellular structure
Analyzing the lock-in of economic patterns
Patterns in Wallace Stegner poems: chaos and cycles
Dimensionality of patterns in photographs of nature
Chaotic attractors and cycles in weather, stock market, tides, and economic cycles. (This was 130 pages.)
Testing the logarithmic spiral in the chambered nautilus: is it really a logarithmic spiral?
Self-organization in an insect community: ants, termites, and aphids
Studies of programmed simulation models.
Sports as a complex adaptive activity.
Herds as a self-organizing system.
The structure of stampedes.
The sound of incense.
The rhythmic patterns of John Cage.

Some Project Suggestions

Look at patterns around you. It's usually easiest to start with something small that interests you. Can you find another pattern that appears to be similar? Be imaginative. Here are several categories of projects.

Using the new tools and concepts:

Among the tools developed in the course are:
fractal and distribution analysis
attractors and attractor reconstruction

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attractors and attractor reconstruction

Is there a testable predictive rule? The rule should be operationally testable, even if you cannot test it yourself with the tools that you have right now. This rule can be expressed in several different ways. It can be an algorithm, a trend, an equation. But it can also be a word statement. Sometimes a conclusion is negative; it rules out a possible explanation. But there should be evidence for your conclusion. The alternate case is: Can you take previous testable predictive rules and apply these rules to a new example? This is often known as “proof of principle.”

What is the question that you’re trying to resolve? Is there a clear statement of your question? Does the question show quality? Is it thought out well?

What to try to avoid:

Try to avoid only reporting on the work of someone else without bringing in your own analysis. We should add the distinction that it is fine to do an independent scientific evaluation or analysis of your own of someone else’s work. Again, the question of thought, reasoning, and evidence apply.

SAMPLE PROJECT EVALUATION FORM

Title: _____

Project Author: _____

Evaluating the projects will be both peer evaluation and instructor evaluation. Assessment is based on the following:

| Criteria | Possible Points | Points |
|---|------------------------|---------------|
| Originality and creative ability Does the project show originality and creative ability? | 30 | |
| Does the project show understanding? * | | |
| Scientific thought | 25 | |
| Overall quality | 25 | |
| Clarity of presentation | 20 | |
| TOTAL | 100 | |