Self-Organization of Complex Systems
Chaos, Fractals, Self-Organization and Emergence

John Boccio, Emeritus Professor of Physics
Swarthmore College

Syllabus **Fall 2016**

First Thoughts

Chaos

- Big Picture
- Difference Equations
- Approach to Chaos
- Dynamic systems and chaos
- Logistic map
- Time series and Phase space
- Attractors, fixed points, basins and limit points/cycles
- Period Doubling
- Return maps
- Lyapunov exponents
- Bifurcation diagrams
- Sensitivity to initial conditions
- Onset of chaos
- A real physical system - The damped-driven oscillator
    - Phase Space
    - Poincare plots
    - Strange attractors
    - Self-similarity
- Basins and attractors

Fractals

- Big Picture
- Fractal dimension
- Cantor Set
- Devil's Staircase
- IFS Fractal Generation
- L-System Fractal Generation
- Fractal dimension Program
- Complex maps - Mandelbrot set
- Roots of Three
- Fractal Examples in Nature
- First thoughts about complexity

Self-Organized Criticality, Complexity and Emergence

- First Thoughts
  - Emergence versus Reductionism
  - Complexity and Physics
  - Big Picture
- Complexity and Criticality
- Self-Organized Criticality
- Story Telling(Narrative) versus Science
- What Can a Theory of Complexity Explain?
- Catastrophes Follow a Simple Pattern
- Connection with Fractals
- Equilibrium versus Complexity
- Chaos is not Complexity
- The Discovery of Self-Organized Criticality
- Simple Models and Spherical Cows
- Computer modeling and simulation
  - Sand Piles and Rice Piles
  - Experiments with real systems
  - Flocking
- The crust of the earth
  - Landscapes and Earthquakes
- Life, Evolution and Punctuated Equilibrium
  - The Game of Life
  - Interacting Dancing Fitness Landscapes
  - Can We Model Darwin?
  - Dante Chialvo's Evolutionary Game
  - Mass Extinctions
    - Did an asteroid kill the dinosaurs?
  - Self-Organized Criticality and Gaia
  - Replaying the Tape of Evolution
- Some Possible Theories
- Complexity and Information
- Forest Fires and SOC
  - Percolation
  - Critical Points
  - Summarizing SOC
- The Brain
- Economics
- Traffic Jams