One-Week Intensive Course:

COMPLEX PHYSICAL, BIOLOGICAL & SOCIAL SYSTEMS

A coherent program of study of complex systems concepts and methods.
A one semester course in a one week format.

Dates: January 9-13, 2006
Location: MIT, Cambridge, MA
Presented by: New England Complex Systems Institute

Description:

Introduction to essential concepts of complex systems and related mathematical methods and simulation strategies with application to physical, biological and social systems. The course will particularly focus on the use of multiscale representations as a unifying approach to complex systems concepts, methods and applications.

Concepts to be discussed include: emergence, complexity, networks, self-organization, pattern formation, evolution, adaptation, fractals, chaos, cooperation, competition, attractors, interdependence, scaling, dynamic response, information and function.

Methods to be discussed include: statistical methods, cellular automata, agent-based modeling, pattern recognition, system representation and informatics.

Demonstration of the application of complex systems methods will be made through studies of:

- Social systems: education system, health care system, military system
- Psychosocial systems: patterns of social behavior, mind, creativity, awareness
- Biological systems: evolution, physiology, immune system, brain, cellular systems, genetic networks
- Physical systems: meteorology

Course Organization:

Lecturer:	Prof. Yaneer Bar-Yam, NECSI
Lecture Content:	Syllabus indicated below
Discussion:	Throughout
Projects:	Evening work on group projects
	---computer modeling, analysis or literature review
	---Friday group project reports
Evaluation:	Students who receive credit for the course will be given a test on Friday to evaluate their progress. The test is optional for others.
Text:	*Dynamics of Complex Systems*

Prerequisites:

No formal prerequisites. The course will present material using a basic conceptual perspective and will introduce simulation and analytical tools in an intuitive way, allowing those who have quantitative backgrounds to make use of these tools in the context of a Complex Systems approach, and enabling those who do not have a quantitative background to begin using or collaborating with others who use these methods of research. Group projects, which are part of the course, will be tailored to individual backgrounds allowing either simulation, analysis or literature review, but individual participants will be encouraged to use methods that they have not used previously.

Syllabus (approximate):

Note: Each topic below reflects a 1/2 hour to 1 hour module.

DAY 1

1) Introduction: Examples, Questions and Methods. Emergence, Interdependence, and Networks.
2) Interactions and Pattern Formation: Spatial Patterns. Examples: developmental biology, collective behavior in social systems.
3) Patterns in Brain and Mind: neural networks, associative and feed forward networks, substructure in networks, attributes and creativity.
4) Fractal Patterns
5) Earth Topography Non-Fractal
6) Methodology of Spatial Patterns: Constructing models of collective behaviors: cellular automata, Agent-based models: predator-prey models, traffic jams. Frustration and complex landscapes, dynamics and optimization on complex landscapes, categories of network models.
7) Application of Complex Landscapes: development in the third world.

DAY 2

1) Describing Complex Systems: space of possibilities and complexity, multiscale representations, the complexity profile.
2) Application of Multiscale Analysis I: History of human civilization.
3) Application of Multiscale Analysis II: Social systems: medical system, education system, military conflict.
4) Application of Multiscale Analysis III: Global terrorism, complex warfare, home security.
5) Application of Multiscale Analysis IV: The history of art.
6) Methodology of Multiscale Analysis: constructing fine and large scale models, scaling, scale invariant models, blocking, clustering, dimensional reduction, relevant variables.
7) Connections: complexity and emergence, interdependence, and patterns.
8) Patterns and Meaning: The relationship of external and internal patterns. Example: art.

DAY 3

1) Dynamic Patterns and Chaos: characteristics of dynamic patterns, chaotic systems, modeling dynamical systems. Examples: feedback, evolutionary competition.
2) Methods: modeling dynamical systems: iterative maps, differential equations.
3) Randomness and Noise: ensembles and averaging, random walks, Markov chains, fractal time series, information theory.
4) Slow dynamics in small and large scale systems. Separation of time scales: treating fast, slow and dynamic degrees of freedom.
5) Minority Game.

DAY 4

1) Evolution: Darwinian evolution, neoDarwinian theory and the breakdown of the gene centered view.
2) Spatial Models of Evolution: biodiversity, ecology of natural habitats and preserves.
3) Competition and cooperation in evolution: altruism and selfishness, teams and individuals. Example: sports.
4) Application of Evolution: engineering and management.
5) Connections: evolution and emergence, interdependence, patterns, complexity.
6) Methodology of Evolution: optimization on complex landscapes, genetic algorithms, simulated annealing, Artificial Life, game theory, spatial evolution, multiscale approaches.
7) Network Topologies: small world networks, scale free networks, dynamics of and on networks.

DAY 5

1) Project Reports
2) Summary and Review
3) Test