Self-organization and non-equilibrium systems

(2.5 ECTS, 2nd Semester)

Objectives:

This course provides an insight into complex systems. Using thermodynamics of far from equilibrium systems and information theory, the course provides the basic tools to model and describe a variety of complex systems.

Contents and Structure:

I. Non-equilibrium thermodynamics.
   1. Thermodynamics of irreversible processes.
   2. Entropy.
   3. Local equilibrium and stationary states.
   4. Fluctuations.
   5. Reaction-diffusion equations.
   6. Spatio-temporal oscillations.
   7. Self-organization in physical, chemical and biological systems.
   8. Prominent examples: Rayleigh-Bénard convection and Belousov-Zabotinsky chemical reaction.

II. Information theory.
   1. Mathematical theory of the discrete probability. Definition of information.
   2. Shannon and Boltzmann entropy.
   3. Fischer and Chaitin-Kolgomorov information.
   4. Entropy and Information.
   5. Adaptation and self-organization. Examples in linguistics and ecology.
   6. Graph theory and the emergence of fractals in nature.

III. Thermodynamics and Information.
   1. Complexity and morphogenesis.
   2. Natural selection.
   3. Adaptation and self-organization.
   4. Discussion: open questions in biological and other systems.

Teaching Organization:

The ratio between theoretical and practical lectures is 3 to 1.

Theoretical lectures: 30 hrs.
Practical lectures (CosmoCaixa): 12 hrs.
Research assignment: 24 hrs.

Evaluation:

The evaluation combines the assignments given to the students along the course with a final assignment that applies the concepts and instruments of the course to a particular research field.

References:

- Thomson, D'Arcy W., *On Growth and Form: A New Edition,* Cambridge University Press, 1942.
- Wagensberg J., J. Valls & J. Bermúdez *Biological Adaptation and the Mathematical Theory of Information,* Bulletin of Mathematical Biology, **50,** 445-464**,** 1988.
- Wagensberg, J. (1982) *Patterns in Nonequilibrium Organization*. En Selforganization and Dissipative Structures. The University of Texas Press 14 (239).
- Bell Graham. *Selection, the Mechanism of Evolution.*Chapman & Hall, 1997.
- Wagensberg J. & Valls, J. *The [Extended] Maximum Entropy Formalism and the Statistical Structure of Ecosystems,* Bulletin of Mathematical Biology, **49,** 531-538**,** 1987.
- Pastor Satorras, R y J. Wagensberg*, The maximum entropy principle and the nature of fractals,* Physica A 251 (291-302), 1998.
- H-O Peitgen, J. Hartmut & D. Saupe. *Chaos and Fractals, New Frontiers of Science,* Springer-Verlag, 1992.
- Dennet C.D. *Darwin dangerous idea,* Penguin Science, 1996.