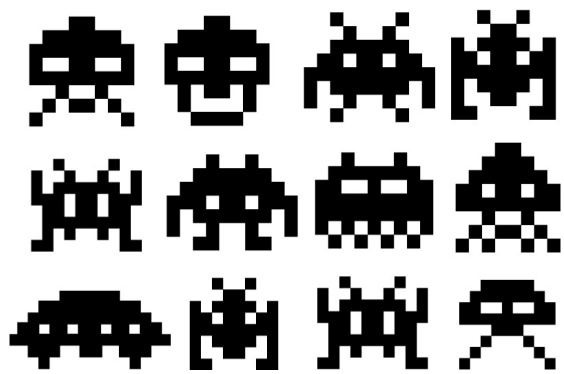
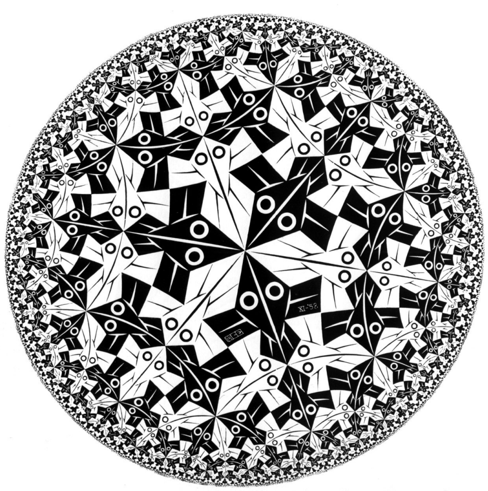
PHYS-60410 PATTERNS OF LIFE COURSE SYLLABUS



Statistical mechanics concerns with the collective behavior of a population of interacting objects. How should a physicist approach a system when its constituents are self-replicating? This course focuses on the general laws underlying the spatiotemporal patterns emerging in biological populations (of molecules or cells or organisms). The first part of the course focuses primarily on **population genetics and evolutionary biology**, while the second part will focus on **reaction diffusion equations and pattern formation**. Students will be expected to solve quantitative problems and will be guided towards developing research projects in theoretical and computational biology. Students are expected to be mathematically inclined and have some familiarity with differential equations and linear algebra.



Grading: Open ended homework problems: %30, Term Project: %25, In class presentations: 15, Peer review for project / presentation: 10%, Two take home exams: %20, Bonus points for non-academic communication (writing a Wikipedia article, giving a public talk etc.): %2.

Homework: Homeworks are the most important part of the class. In addition to standard bite size problems there will be difficult and often open ended problems designed to acclimate students to scientific thinking. Students are strongly encouraged to work on homeworks themselves before consulting their colleagues.

Keywords for Term Projects: Evolutionary Game theory, Population Dynamics, Turing patterns, Endosymbiosis theory, Viruses and transposable elements, Coevolution, Epigenetics, red queen / green beard / medea genes / intragenomic conflicts, artificial life, cellular automatons, genetic algorithms, memetics, chemical oscillations, micelles, evolution of / physics of biological aging, somatic evolution / cancer, reaction diffusion systems and chemical oscillations. Other topics of interest are welcome.

Office Hours: Right after class in 384G, or by appointment.

Lectures / Notes: Lectures are designed to fill the gaps in the book, to focus on unclear bits, and to motivate students to pursue knowledge independently. Taking notes is highly encouraged since lectures will synthesize material from multiple sources.

Cheating and Plagiarism: Students are allowed and encouraged to collaborate in their term projects and homework problems. Students are allowed to take a look at each other's work as a whole, or to discuss with colleagues, but not copy. Input from other sources (e.g. students, books or online resources) must be credited with numbered references. Using online resources is encouraged, as long as students understand what they are doing.

Auditing Policy: Auditing is allowed if the students enroll as "for audit". The term paper is optional for auditing students, however they cannot co-author / collaborate on the term paper with students taking the course for credit.

All material written by the students should be rigorous, and must be structured as indicated below:

Introduction (a) Provide full context. Where does your argument / calculation stand in the field of physics, biology and science? Why should the reader care about what you are writing about? (b) Survey different arguments and hypothesis in the field (c) Present own position / hypothesis and summarize the content of the paper. (d) Instill interest and excitement to readers both inside and outside the field.

Results and Discussion (a) State assumptions (b) State approximations and regimes of applicability (c) State implications. (d) Connect to data whenever possible, connect to technological or engineering applications whenever possible.

Conclusion (a) Indicate the strengths and weaknesses of your argument (b) Indicate how the argument / position/ hypothesis is similar or different to past work (c) Indicate possible future directions, and relevance to other fields (d) Which assumptions does the central results sensitively depend on? Which assumptions could be relaxed? Can the model be generalized to cover more ground? Can the model be applied to other domains for which it was not intended?

Required Books:

J. Murray, Mathematical Biology (Volumes I and II).

Other Useful References:

Mathematical Population Genetics, Ewens
Evolutionary Games and Population Dynamics, Hofbauer
Evolution and the Theory of Games, Maynard-Smith
An Introduction to Systems Biology, Alon

Lecture Topics (Subject to Change):

1. Theory of Evolution. Models of reproduction, Variation and selection. Continuous and discrete, stochastic and deterministic. Infinite and finite population models.

2. Neutral Evolution. Genetic Drift and Effective Population Size. Quasi-Species. Hardy-Weinberg Principle. Wright-Fisher Model, Moran Model. Branching processes. Methods of Phylogeny Reconstruction.

3. Interactions between Populations. Prey-Predator Dynamics. Territory formation. Migration. Transposons. Symbiosis, Evolution of infectious

diseases. Evolutionary Game Theory. Kinship. Hamilton's Rule.

4. Molecular Evolution. Reaction Diffusion Systems: Fisher-Kolmogoroff equation. Multi-species waves. Belousov-Zhabotinskii Reaction Kinematic Waves. Turing Mechanism.

5. Research Presentations

6. Pattern formation. Reaction Diffusion Equations and Turing patterns. Mammalian Coat Patterns, Butterfly Wing Patterns, Pigmentation in Alligators and Snakes. Development of Fingerprints. Fractals in Biology.

7. Biochemical Networks. Network motifs. Gene circuits.

8. Research Presentations

9. Active Brownian Particles. Bacterial Patterns and Chemotaxis. Run-Tumble model. Swarm ring patterns. Branching patterns.