Statistical physics of living systems

The advent of high-throughput techniques is transforming biology into a fully quantitative and theory-rich science. For example, recent advancements in genetic sequencing has opened new avenues to study cellular processes at short time scales at the level of individual organisms, and on longer evolutionary time scales at the level of species and populations. Statistical physics is the right language to describe complex biological systems with many degrees of freedom, and is being used to uncover principles of molecular motions, protein folding, evolution of populations, or to interpret biological data. The main focus of this course is to explore recent work in biology in conjunction with topics in statistical physics and information theory. By highlighting examples from a broad range of biological phenomena, the course will cover topics on information theory and optimality, probabilistic inference, non-equilibrium processes in biology, and evolutionary dynamics. Inspired by these topics, students will work in groups on small projects and will present their work at the end of the quarter.

The course is co-listed as Phys 428 and Phys 578. The class assignments and the final project will be assessed differently for the graduate and the undergraduate level students.

Pre-requisite: Phys 328 (or equivalents).

Tentative course syllabus:

Week 1 **Efficient representation: Introduction to information theory**

Week 2 **Does biology care about bits?**

Week 3 **Optimizing information flow in biological systems I**

Week 4 **Optimizing information flow in biological systems II**

Week 5 **Statistical inference: physics meets large biological data I**

Week 6 **Statistical inference: physics meets large biological data II**

Week 7 **Sensitivity and speed in biology: non-equilibrium processes in biology**

Week 8 **Stochastic molecular evolution**

Week 9 **Non-equilibrium molecular evolution**

Week 10 **Student presentation**

Recommended reading:

Biophysics: Searching for Principles (William Bialek); Princeton University Press, 2012

Information theory, inference, and learning algorithms (David McKay); Cambridge University Press, 2003.