

STATISTICAL PHYSICS AND BIOPHYSICS

By A. Pelizzola

Subject fundamentals

Mandatory course for the Master in Physics of Complex Systems, 1st year, 2nd term. In this course the knowledge of statistical physics, started in Introduction to quantum mechanics, quantum statistics and field theory, is deepened, with a particular attention to its applications to the physics of biological systems. To this end, a few basic elements of fluid dynamics and molecular biology are also introduced.

Expected learning outcomes

The student must acquire a deep knowledge of statistical physics, of its methodologies and its relationships with information theory. The student must also acquire some basic elements of fluid dynamics and molecular biology and must learn to apply the techniques of statistical physics to some problems from the physics of biological systems, mainly in the field of biopolymers.

Prerequisites / Assumed knowledge

Basic elements of statistical physics, in particular the canonical ensemble.

Contents

Canonical and grand-canonical ensembles, non-interacting systems.

The Ising model: introduction and exact solutions in one dimension and on the fully connected graph.

Mean-field approximation.

Beyond mean-field approximation: Bethe-Peierls and belief propagation.

The two-dimensional Ising model: Peierls argument, low- and high-temperature expansions, free energy in zero field on a square lattice.

The two-dimensional XY model at low temperatures.

An introduction to the real-space renormalization group.

Introduction to molecular biology: the cell; small molecules; proteins and nucleic acids.

Stretching a single DNA molecule: experiments, the Freely Jointed Chain, the one-dimensional cooperative chain, the worm-like chain.

DNA melting: experiments, zipper model, Poland-Scheraga model.

The helix-coil transition. Polymer collapse: Flory's theory. Collapse of semiflexible polymers: lattice models and the tube model. The self-avoiding walk and the $O(n)$ model.

An introduction to protein folding and design. RNA folding and secondary structure. Protein and RNA mechanical unfolding.

Molecular motors.

Texts, readings, handouts and other learning resources

M. Plischke and B. Bergersen, *Equilibrium statistical physics*, World Scientific

R.K. Pathria and P.D. Beale, *Statistical mechanics*, Academic Press

L. Peliti, *Statistical mechanics in a nutshell*, Bollati Boringhieri

J.P. Sethna, *Entropy, order parameters and complexity*, Clarendon

K. Sneppen and G. Zocchi, *Physics in molecular biology*, Cambridge

P. Nelson, *Biological Physics*, Freeman

B. Alberts et al, *Molecular biology of the cell*, Garland
Lecture notes and slides will be provided

Assessment and grading criteria

The exam is based on two oral tests, one for Statistical Physics and one for Biophysics. Both tests typically involve questions on 2-3 topics, the first one being chosen by the student.