INDIAN INSTITUTE OF TECHNOLOGY KANPUR
Department of Physics

PHY 309/ SE 303: **Introductory Biophysics**
Instructor: Prof. Debashish Chowdhury
Pre-requisite: Basic Thermodynamics/Thermal Physics

Course objective:

Living matter is no different from non-living matter. What makes living systems different from non-living ones are some ``processes'' that occur only in living systems. These dynamic processes are governed by the same laws of physics (and chemistry) that were discovered in non-living systems. The movements of biological systems are caused by real physical forces (and not by any `vital force'), the laws of thermodynamics impose constraints on which processes are possible, and laws of kinetics impose constraints on the rates of those processes. Therefore, understanding of life as a process cannot be complete without insight into the physics of these processes. This course is an elementary introduction to the physical principles underlying the key dynamic processes in living systems.

Course Contents:

(1) **Mechano-biology of binding and bonding in living systems**: Introduction to conservative, dissipative and random forces; molecular binding/unbinding events, probing non-covalent ligand-receptor interactions with molecular force spectroscopy- slip bond versus catch bond.

(2) **Statistical thermodynamics for living systems**: Concepts of conformation and structure of a macromolecule of life; free energy change and generalized chemical force; concepts of thermodynamic equilibrium and non-equilibrium steady-state; coupled processes and engines of Life.

(3) **Kinetics of mechano-chemical processes in living cells**: Stepping of a motor protein; single molecule enzymology, fluctuating enzymatic reactions in a living cell- Michaelis-Menten form for the average rate; substrate specificity of an enzyme- induced fit versus conformational selection, kinetic proofreading for specificity amplification and role of energy dissipation;

(4) **Cellular and intracellular movements** : Diffusion- transport in bacterial cells; transport by motor proteins in eukaryotic cells; cooperativity of motors in vesicular transport; bi-directional movements of organelles by competing motors; motor-driven export/import of polymers of life across internal membranes; movements of chromosomes during mitosis.

(5) **Polymers of life and template-directed polymerization**: stretching and entropic spring; bending elasticity and persistence length; transcription and translation as examples of template-directed polymerization, competing demands of speed and fidelity; stall, backtracking and slippage of polymerization machinery; programmed errors and recoding.

(6) **Entropy, information, self-organization and emergence of life**:
Shannon entropy and information; evolution of genetic information encoding and information processing mechanisms; essential signatures of life and its definition- debates and controversies; plausible pathways for emergence of life- roles of energy and information.

Text Books and References:

1. "Physical Biology of the Cell", by R. Phillips et al. (Taylor & Francis, 2009)
2. "Biological Physics: Energy, Information, Life", by P. Nelson (Freeman, 2014).
3. "Mechanics of the Cell", by D. Boal (Cambridge Univ. Press, 2012).
4. "Biophysics: searching for principles", by W. Bialek (Princeton Univ. Press, 2012)