

BIOPHYSICS

Course for ICTP QLS Diploma 2019-2020 (50h)

Edgar Roldan

Table of Contents

1 Review: Cell Biology without numbers

- Cells (eukaryotes and prokaryotes) and organelles
- Biomolecules: water, sugars, fatty acids, aminoacids, nucleic acids
- Central dogma, and cell division
- Energetics and disorder (thermodynamics): first law, second law of thermodynamics, energy-conversion processes in life; free energy
- Enzymatic reactions: Arrhenius law, free energy, catalysts, reaction coupling

2 Appetizer: Cell Biology with numbers

- Cell census: water, ions, proteins, mRNA, ribosomes
- Size: cells, organelles, biomolecules, and filaments
- Energies and forces: ATP hydrolysis, membrane potential, cell motility
- Times and rates: diffusion, chemical reactions, ion channels, rotary motors

3 Interlude: Stochastic processes

- Stochastic processes: definitions; random walk
- Stationary processes
- Markov processes in discrete and continuous time: continuous Markov (Ornstein-Uhlenbeck) and discrete (Markov chains).
- Non-Markovian persistent random walk
- The Master equation
- Gillespie's algorithm
- Stochastic differential equations
- Stochastic calculus (Ito and Stratonovich) and Langevin equations
- Fokker-Planck (Smoluchowski) equation

4 Main course: Stochastic physics in Cell Biology

- Ion channels
- Biopolymers: generic properties and key models
- Molecular motors: active transport and transcription
- Sensory systems I: chemoreception
- Sensory systems II: hearing
- Cell division and microtubule dynamics
- Cellular traffic and endocytosis

5 Bonus: Stochastic thermodynamics

- Stochastic energetics
- Stochastic entropy and second law at mesoscopic scales
- Fluctuation theorems
- Thermodynamic uncertainty relation and efficiency of molecular motors
- Extreme-value statistics of molecular motors