PHYS 146B/230B: Biological Physics & Molecular Machine

https://canvas.eee.uci.edu/courses/54926

Instructor: Jin Yu, PhD https://www.physics.uci.edu/jin-yu
Email: jin.yu@uci.edu Office Hour: Mon/Wed/Fri 10:50-11:20 am
Lectures: M/W/F 10:00 AM - 10:50 aM (PSCB240) (Apr 3 Mon– June 9 Fri)

Course contents (weekly topics listed)

1. *What are the essential math/physics to the living systems?*
    - From population to individual, from tissues to cell and to molecular machinery
    - Deterministic equations, probability theory, and statistical physics basis

2. *What are the essentials structures and biochemistry in the cell?*
    - Water, membrane, cytoplasm, protein, DNA/RNA, and the central dogma
    - Structure-function, reaction coordinate, free energy landscape, chemical kinetics

3. Diffusion, fluctuation & dissipation (*Small systems employing randomness)*
    - Random walk, Brownian motion, Einstein relation, fluctuation & dissipation
    - Membrane permeability, transcription factor protein search, and gene editing

4. Life at low Reynolds number (*Micro-swimmers & regulation)*
    - Friction, viscosity in solution vs particle size & inertia
    - Bacteria swimming, chemotaxis (flagellar & motor)

5. Stochastic dynamics & simulation (*Quantitative approaches to effective dynamics*)
    - From kinetic Monte-Carlo to reaction-diffusion
    - From Langevin dynamics to Fokker-Planck equation
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6. Enzymes and molecular machines
    - Enzymatic cycle, mechanochemistry, non-equilibrium steady state operation
    - Essential molecular engines: rotatory ATP synthase, DNA packaging motor, replisome etc

7. Single-molecule manipulation & imaging
    - Monitoring & manipulation one at a time, FRET, optical/magnetic tweezer, tracking etc
    - Transcription under tension/torsion and noises regulation in genetic regulation

8. Molecular cooperativity
    - Ising-type model (cooperativity to phase transition) with neighbor-neighbor coupling
    - Allostery (action in distance) inside protein, along DNA, and multi-subunit cooperativity

9. Molecular modeling and simulations
    - Molecular simulations as computational microscope
    - Sampling, statistical data learning & multi-scale modeling

10. From classical to quantum systems
    - Enzymatic reaction and QM/MM calculation
    - Photosynthesis, vision, bird navigation etc.

Recommend textbook: Biological Physics (Biological Physics: Energy, Information, Life *Student Edition, 2020*) by Nelson

Additional reference books: Physical Biology of Cell by Rob Phillips; Biophysics: Search for Principles by William Bialek; Molecular Modeling and Simulation (An Interdisciplinary Guide, by Tamar Schlick); Computational Cell Biology (Interdisciplinary Mathematics, Edited by Christopher P. Fall); Stochastic Processes in Physics and Chemistry by NG VAM KAMPEN; Mathematical Biology by James Dickson Murray

Weekly arrangements:
Mon class: Lecture (assign/suggest study group* with HWs and literatures/implementations)
Wed class: Problem/technique session (HW due & discussion/presentation in groups)
Fri class: Literature/implementation session (Literature review/presentation in groups)

*Four study groups assigned randomly each week (3-4 persons each group)

Grading (up to 100 points):

- In-class peer review (Wed/Fri class);
- 4 points each HW with presentation (Wed);
- 4 points each literature/implementation assignment (Fri)
- Weekly assignments up to 72 points (10 weeks; 18 sessions planed);
- Presentation representing the group: 1 point each time (up to 18 points);
- Class participation (0.5 point for each class attendance per record, up to 15 points)
- Final report (2-3 page essay 5 points; 10-min presentation 5 points last class or online; technical reproducing 5 points; up to 15 points)