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

https://canvas.eee.uci.edu/courses/63492

Instructor: Jin Yu, PhD https://www.physics.uci.edu/jin-yu
Email: jin.yu@uci.edu Office Hour: Mon/Wed/Fri 10:50-11:30 am
Lectures: M/W/F 10:00 AM - 10:50 aM (PSCB 240) (Apr 1 Mon– June 7 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)
Wed class: Problem/Technique Session (HW due & discussion/presentation in groups)
Fri class: Literature Session (Literature review/presentation in groups)

*Four study groups assigned randomly each week (2-3 persons each group)

Grading (up to 100 points):

- In-class peer review (Wed/Fri class);
- 4 points each HW with discussion/presentation (Wed);
- 4 points each Literature presentation 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 last class or online 5 points; technical reproducing 5 points; up to 15 points)