Molecular biophysics

Thursday, 3 p.m. (without a quarter) - 5 p.m. (two lecture hours with a break)

Auditorium IF PAN

This lecture course is thought as a concise introduction into the interdisciplinary field for newcomers as well as for those who study(ied) biophysics and need some clarification, ordering and extension of their knowledge. Discussions will be highly encouraged. Students may join the class at any point. The course is public and open to anyone interested.

The full course encompasses two semesters, *ca.* 30 hours each. Written exams in the form of open descriptive questions focused on understanding and interpretation of published results based on example articles from scientific literature are planned at the end of each semester.

The lecturers come from the Laboratory of Biological Physics: dr hab. Anna Niedźwiecka, prof. IF PAN (annan@ifpan.edu.pl) and dr Bożena Sikora (sikorab@ifpan.edu.pl)

Molecular biophysics I - topics

from 20.10.2023

Fundamentals, Principles, Phenomena, Processes

1. Physical bases of biological interactions: atoms, molecules, biomolecules; types of interactions; temperature ranges, energy scales, fundamental processes in the word of biomolecules; the role of water in biophysical processes;
2. Biomolecules and their structure, function, dynamics: nucleosides, nucleotides, nucleic acids, central dogma of molecular biology; amino-acids, peptides and proteins;
3. Sugars; fats, lipids, lipid bilayers, biological membranes. Biomolecular structural dynamics: globular, molten globule, pre-molten globule, intrinsically disordered, unstructured, fibrillary and membrane proteins. Additional topic by request: nucleosides, nucleotides and nucleic acids for therapeutic use;

Methods - Review of experimental methods and their applications

4. Complementarity and adequacy of biophysical methods. Typical energies and time-scales; resolution. Thermodynamics from the experimental point of view: microcalorimetry (DCS, ITC), van't Hoff equation from equilibrium studies;
5. UV/VIS Spectroscopy: absorption; Franck-Condon principle; circular dichroism; fluorescence: Jabłoński diagram; excitation and emission spectra, quenching, Förster resonant energy transfer (FRET). Additional topic by request: understanding the immune system - how it works; nanobodies.
6. When spectroscopy meets hydrodynamics: Fluorescence anisotropy (and time-resolved); Analytical ultracentrifugation with optical detection (absorption, fluorescence, interference) – sedimentation velocity and sedimentation equilibrium; Electrophoresis and 2D isoelectric focusing; Thermophoresis;
7. Optical microscopy. Confocal microscopy, fluorescent proteins, small molecules and quantum dots as probes, immunolabeling; 3D imaging, fluorescence-lifetime imaging microscopy (FLIM). Colocalization, FRET; Imaging-based diffusion studies by FRAP, FLIP, FLAP, PA/PC; superresolution microscopy;

8. Confocal microscopy *vs*. hydrodynamics – correlation-based diffusion studies by FCS, FCCS; diffusion by dynamic light scattering (DLS), Zimm equation, Debye plot, second virial coefficient *vs*. crystallization; static multi-angle light scattering (MALS);
9. Small-angle X-ray scattering (SAXS), Kratky plot. Wide-angle X-ray scattering and diffraction; Evanescent wave; total internal reflection fluorescence (TIRF) microscopy; Surface plasmon resonance (SPR); Infrared spectroscopy, FTIR, attenuated total reflection (ATR).

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10. Microwaves: electron paramagnetic/spin resonance (EPR/ESR) spectroscopy. Nuclear magnetic resonance (NMR) spectroscopy. Chemical shift, relaxation, Overhauser effect, multidimensional spectra. Structure determination of small molecules and macromolecules. MRI, fMRI in clinical practice; 12.01.2023
11. Examples from literature and individual consultations, 19.01.2023
12. **Exam 26.01.2023**

Intersession – no lecture on 02.02.2023

Please, note a minor change - the second semester will start on 09.02.2023 but 16.02.2023 will be free instead.

Molecular biophysics II - topics

from 09.02.2023

Methods - Review of experimental methods and their applications II

1. X-ray diffraction crystallography. Protein crystallization. In-house diffractometers, synchrotrons, XFELs. Structure determination of macromolecules; 09.02.23

Please, note – there will be no lecture 16.02.23. The lecture 09.02.23 is instead.

2. Electron microscopy: scanning EM, transmission EM. Negative staining and cryo-electron microscopy. 3D reconstruction of macromolecules. Cryo-electron tomography of cells; 23.02.23
3. Single-molecule methods *vs*. ensemble methods. Optical tweezers. Atomic force microscopy (AFM), force spectroscopy, imaging, real-time kinetics. smFRET, sm-FRET-FCS, PIFE; 02.03.23
4. Mass spectrometry, isotopic envelope, proteomics, hydrogen-deuterium exchange, cross-linking, protein conformational dynamics; 09.03.23
5. Microfluidics, biosensors (*e.g.* SERS) and other topics on demand. 16.03.23

Molecular machines – based on application of complementary methodological approaches

6. Membrane G protein-coupled receptors (GPCR) and signal transduction, conformational equilibria *vs*. drug design. The spliceosome and alternative splicing. The ribosome and translation; 23.03.23
7. Membrane-less organelles; liquid-liquid phase separation; other self-organizing structures; living cells and organisms. 30.03.23

Easter holidays 06.04.2023

Nanobiotechnology from 13.04.2023

8. Types of inorganic nanomaterials (the role of dimensionality), the impact of scale change (from macroscopic to nanoscopic) on the physicochemical properties of materials. Examples of nanomaterial production methods (eg "bottom up" and "top down"); 13.04.23
9. Fabrication and stabilization of core/shell structures. Types of nanomaterials produced from organic compounds (e.g. polymer nanoparticles, liposomes, dendrimers, fullerenes, carbon tubes). Aggregation of nanoparticles and methods of its prevention; 20.04.23
10. Experimental techniques allowing the study of nanoparticle structures with particular emphasis on imaging techniques. Experimental techniques to study the chemical composition of nanoparticles; 27.04.23

May long weekend: 04.05.2023

11. Application of nanomaterials in medical diagnostics (e.g. optical imaging methods, nanoparticles as magnetic contrast). Application of nanomaterials and nanoparticles in medical therapies (e.g. in gene therapy, in targeted drug delivery). The use of nanomaterials in "lab-on-a-chip". The dangers of using nanomaterials (especially in medicine); 11.05.23
12. Biofunctionalization - methods of attaching biologically active molecules to inorganic nanoparticles. Methods of transporting nanoparticles inside biological cells. 18.05.23
13. Individual consultations 25.05.2023.
14. **Exam 01.06.2023.**

There will be no lectures on Thursdays:

Christmas holidays: 29.12.2022, 05.01.2023

Inter-semester break: 02.02.2023 and 16.02.2023, but there will be a lecture 09.02.2023 instead of 16.02.2023

Easter holidays 06.04.2023

May long weekend: 04.05.2023

Further reading

Students will receive appropriate lecture notes and relevant references for further reading.

- Ludovico Cademartiri, Goeffrey A. Ozin, Nanochemia, Podstawowe koncepcje, PWN, 2011
- R.W. Kelsall, I.W. Hamley, M. Geoghegan, Nanotechnologie, PWN, 2008
- Krzysztof Kurzydłowski, Małgorzata Lewandowska, Nanomateriały inżynierskie konstrukcyjne i funkcjonalne, PWN, 2011
- Alberts B. *et al*., **Molecular biology of the cell**
- Stryer L. *et al*., **Biochemistry**

- Dill K. A., Blomberg S., **Molecular driving forces**
- Cantor Ch. R. and Schimmel P. R. **Biophysical Chemistry I, II, III**
- Serdyuk I. N., Zaccai N. R., Zaccai J, **Methods in molecular biophysics**