The research carried out at the Laboratory of Biological Physics is interdisciplinary in nature and it has two tracks: experimental and theoretical. Its main scope may be defined as applying the methods and concepts of physics to problems that are relevant to life sciences, particularly at the molecular level of description. The interests in the Laboratory cover a wide range of specific subjects and they are as follows.

Experiment

Prof. Danek Elbaum: Biosensors. The main interest of the group is to design and invent two kinds of biologically relevant sensors: a) intracellular probes based on ZnO/MgO, up-converting materials: NaYF4:Yb, Er, ZnAl2O4:Yb,Er spinels and Gd2O3:Er,Yb,Zn nanostructures; b) extracellular probes, based on ZnO/ZnS core/shell nanofibers, obtained through electrospinning. The research, focused on infra red up-converting multifunctional NaYF4:Yb, Er and Gd2O3:Er,Yb,Zn nanoparticles, functionalized with organic and biological macromolecules, aims for biological and medical applications. The nanoststrures are synthesized by colloidal sol-gel, spray pyrolysis and hydrothermal precipitation techniques. We also synthesize nanoparticles with paramagnetic properties – they are mobile in external magnetic field and can be used as contrast agents in magnetic resonance imagining. Finally, we obtain nanostructures synthesized with photosensitizing properties – they are capable of generating reactive oxygen species, under the influence of infra red radiation, which allows for applications in targeted cancer therapy. The research interests includes intracellular transport of potential biological probes and biologically active molecules through cellular membranes and the analysis of their selective toxicity. We are inventing sensors which optical, electrical and magnetic properties could be directly applied in multifunctional medical theranostics.

Dr. Joanna Grzyb: Interactions of nanomaterials with proteins. One of the goals is to obtain useful and stable linkages of colloidal quantum dots with enzymatic proteins and other proteins that are involved in the redox reaction. Another goal is to design *de novo* proteins in order to obtain stable structures which are capable of performing specific tasks more efficiently. One example of such a task is electron transfer between subunits of larger complexes. This will lead to novel bio-nano devices that could be used in many kinds of assays in research and medical diagnostics. One of our successes is finding a way to make an enzymatically active conjugate of quantum dots CdSe/ZnS and oxoidoreductase. Another is design, expression and characterization of a next generation of proteins that bind hem and iron-sulphur clusters.

Dr. Anna Niedźwiecka: Biophysical bases of the post-transcriptional gene expression control. The research goal is to understand biophysical principles of fundamental biological processes involved in the control of eukaryotic gene expression at the post-transcriptional level. The subjects considered are biomolecular interactions responsible for superior functions in the regulation of the cell cycle and malignant transformation. One of the specific goals is to describe RNA-protein complexes formation in terms of thermodynamics. Protein-ligand and protein-protein interactions in solution, accompanying conformational changes and other thermodynamically coupled processes are studied by molecular spectroscopy techniques, single-molecule microscopy, and proton-deuteron exchange kinetics with mass spectrometry. The second main objective is single-molecule visualization of biological objects at the micro- and nanoscale, and real-time imaging of biological processes that are performed by protein complexes.

Dr. Remigiusz Worch: Molecular biophysics of influenza virus infection. Many details of influenza virus infection stages are still poorly characterized at the molecular level. We are currently involved in two projects. The first one relates to the membrane fusion occurring during the viral entry. It is mediated by the so-called fusion peptide, which is an N-terminal part of the hemagglutinin HA1 subunit. With a special interest in artificial membrane systems, we characterize fusion peptide partitioning, conformational changes and its fusion properties in different environmental conditions. The second project aims at the characterization of the influenza polymerase-catalyzed reactions on single molecule level in real time. We would like to characterize quantitatively the reaction kinetics and the influence of various factors, such as: presence of non-catalytic polymerase subunits, presence of the RNA 5' cap structure and environmental conditions mimicking the crowding environments present in cell nucleus. Our methods involve mainly fluorescence techniques (imaging, ensemble and single-molecule spectroscopy).

Theory

Prof. Marek Cieplak: Theoretical modeling of biomolecules and their dynamics. The specific subjects studied currently are: stretching of proteins and their complexes, protein folding, mechanical properties of virus capsids, interactions of proteins with solid surfaces, interpretation of large scale data such as obtained by the genetic micro-arrays, self-assembly of biofunctionalized nanoparticles, properties of cellulosome, action of the proteasome, proteins with knots and cysteine knots. The method used involve molecular dynamics in all-atom and coarse-grained models, exact enumerations in lattice models, and other methods of statistical physics.

Dr. Adolfo Poma: Multi-scale simulations and free energy calculations of proteinic complexes. The research is concerned with finding ways of spanning the multitude of time and length scales that characterize conformational changes in proteins and their complexes. Another objective is to account for quantum effects in functioning of biomolecules.

Dr. Bartosz Różycki: Coarse-grained models of protein assemblies. The first goal of research is to develop physics-based models and computational methods that will support biophysical and physicochemical experiments, and help explore the conformations, motions and mechanical stability of multidomain proteins, protein complexes and viral capsids. Our second goal is to use computational techniques to characterize and quantify the interactions of proteins with lipid membranes and solid surfaces.

Dr. Michał Wojciechowski: Simulations of proteins and their assemblies. The research is focused on proteins that are confined either through crowding environments of other diffusing molecules or through action of molecular complexes such as proteasomes. Another activity involves all-atom simulations of proteins providing control of eukaryotic gene expression at the post-transcriptional level.