Overview of topics covered in the course

Biophysics of Macromolecules, SS2014
Prof. Rädler/Prof. Lipfert

Fundamentals/Introduction:

What is life?

The "family tree of life" – phylogeny and ribosomal RNA

The central dogma of molecular biology

The DNA double helix

DNA replication by DNA-polymerases

DNA transcription by RNA-polymerases

Translation: ribosomes in action

Physical interactions in a biological world: Electrostatics, van der Waals, and beyond

The physical nature and biology roles of hydrogen bonds

ATP, the "energy currency" of life

Proteins:

Natural (and unnatural) amino acids

The peptide backbone and Ramachandran plots

Protein secondary structure and circular dichroism (CD) spectroscopy

Alpha-helices and the helix-coil transition

Afinsen's hypothesis and protein structure

Levinthal's paradox and protein folding

Free energy and protein (un-)folding

Hofmeister's series and the role of the solvent for biological interactions

Chaperones: helping proteins fold

Molecular dynamics simulations

Physics-based prediction of protein structure

Knowledge-based prediction of protein structure

Protein structure design

Protein-ligand interactions:

Protein-ligand interactions and drug design
Basics of binding equilibria: affinity, free energy, and rates
Binding cooperativity and allostery
Modeling cooperative binding 1: Hill model
Modeling cooperative binding 2: Monod-Wyman-Changeux model
Modeling cooperative binding 3: Koshland-Némethy-Filmer model
Enzyme catalyzed reactions
Michaelis-Menten kinetics

RNA:

Traditional roles of RNA in the central dogma
RNA beyond the central dogma 1: Ribozymes
RNA beyond the central dogma 2: RNA-interference
RNA beyond the central dogma 3: Riboswitches
RNA beyond the central dogma 4: The RNA world hypothesis
Roles of ions in RNA folding
Salt dependence of nucleic-acid protein interactions
Poisson-Boltzmann theory

Polymer physics

Freely-jointed chain (FJC) & Worm-like chain (WLC)
Excluded volume interactions à la Flory
Small-angle X-ray scattering and the Guinier approximation
Enthalpic stretching à la Odijk and DNA overstretching transition(s)

Single-molecule experiments:

The Atomic Force Microscope (AFM)
AFM tapping mode imaging
Unfolding proteins by AFM
Optical tweezers
Optical Force Clamp
Studying molecular motors using optical tweezers
Magnetic tweezers basics

DNA torque and twist in magnetic tweezers

Powerspectra and the calibration of single-molecule instruments

Dynamic force spectroscopy 1: Bell's model for the off-rate

Bell-Evans theory for the load dependence of rupture forces

From molecules to cells:

The constituents of the cytoskeleton: Actin, microtubules, and intermediary filaments

Polymerization of linear polymers: Einstein polymers

Polymerization of multi-stranded polymers

Force generation through polymerization of filaments

Actin treadmilling

Dynamic instability of microtubules

Brownian ratchets

Linear motors: Myosin and kinesin

Force generation in muscle & the mechano-chemical cycle of myosin

Life at low Reynolds number

Transport by diffusion vs. motility

Bacterial motility: Swimming *E.coli* and the bacterial flagellar motor

Bacterial chemotaxis: Runs and tumbles

DNA, nucleosomes, chromatin, and the structure of the genome

Molecular crowding