SYDN 1: Physics of Self-Organization in DNA Nanostructures

DNA nanotechnology provides a wide range of tools for the fabrication of nanostructures by self-assembly, thus bridging the gap between fabrication strategies, which rely on top-down miniaturization of materials, and those, which create materials from the smallest entities by more traditional synthetic strategies. In addition, the ability of DNA nanostructures to reconfigure in response to external triggers makes these systems ideal candidates for studies of self-organization at the nanoscale. The field has witnessed tremendous progress during the past years, especially due to the development of the DNA origami technique and other synthetic techniques leading to well-ordered structures with dimensions up to several hundred nanometers. This symposium will give an overview of the methods for building nanostructures by self-assembly and of the principles of their interaction with the environment. It will thus provide insight in the possibilities for the construction of controlled nanosystems which new developments in DNA nanotechnology offer.

Thursday 09:30–12:15 H1

Invited Talk SYDN 1.1 Thu 9:30 H1

Functional DNA Nanostructures and Their Applications — •Itamar Willner — Institute of Chemistry, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

The base sequence of DNA encodes substantial structural and functional information into the polymer. The triggered reconfiguration of nucleic acids provides means to control the functions of DNA nanostructures and materials. This will be exemplified with four examples: 1. DNA machines triggered by auxiliary stimuli, such as a bipedal walker or interlocked circular DNA nanostructures (catenanes), will be introduced. The application of the machines to organize switchable and programmed Au nanoparticle assemblies will be presented. 2. DNA origami tiles provide versatile building blocks for the guided assembly of functional structures. This will be exemplified with the reconfiguration of origami dimer tiles and the use of the system for programmed catalysis. In addition, the triggered unlocking of holes in origami tile, and the use of the nano-holes as confined environments for programmed catalysis will be introduced. 3. DNA-based constitutional dynamic networks (CDNs) provide organized assemblies mimicking complex biological networks. The adaptive and emergent, signal-triggered, functions of CDNs will be introduced, and their application for the programmed transcription/translation of proteins will be addressed. 4. Reversible, signal-triggered DNA-based hydrogels, revealing switchable stiffness properties, are constructed. The stimuli-responsive hydrogels are applied as shape-memory matrices, self-healing materials, signal-controlled drug carriers and mechanical devices.

Invited Talk SYDN 1.2 Thu 10:00 H1

Gaining control of DNA-based nanodevices — •Francesco Ricci — Chemistry Department, University of Rome, Tor Vergata, Rome, Italy

Nature has invented a number of tricks and strategies by which the behaviour of proteins and other biomolecular machines can be finely controlled. These highly optimized and evolved mechanisms allow to control biological pathways with different chemical and environmental stimuli and are at the basis of the high specificity and selectivity of biomolecular machines.

Motivated by the above arguments we have characterized and recreated in-vitro several mechanisms to control the response of DNA-based nanodevices for diagnostic and drug-delivery applications. Using these mechanisms we can finely control the activity of DNA-based nanodevices with different chemical and environmental stimuli including pH, antibodies, enzymes, small molecules and electronic inputs.

I will present an overview of the most representative and recent examples developed in our lab in the above research directions and I will give a brief presentation of the new routes and possibilities that these results offer.

Invited Talk SYDN 1.3 Thu 10:30 H1

Self-assembly and optical properties of single molecule polymers on DNA origami — •Kurt Gothelf — iNANO, Aarhus University

We are using DNA as a programmable tool for directing the self-assembly of molecules and materials. The unique specificity of DNA interactions and our ability to synthesize artificial functionalized DNA sequences makes it the ideal material for controlling self-assembly and chemical reactions of components attached to DNA sequences. In particular we are using DNA origami, large self-assembled DNA structures as a template for positioning of materials such as organic molecules, polymers and biomolecules. In recent years we have developed methods for functionalizing conjugated polymers with multiple DNA strands in a graft type fashion. We have prepared long phenylene-vinylene and fluorene polymers and synthesized DNA strands extending from most of the repeat units of the polymers. The polymers self-assemble on tracks of complementary DNA strands extending from DNA origami structures and in this way the routing of the individual polymers can be controlled. By immobilizing fluorescent dyes along the polymer we have investigated the properties of the polymers as single molecule optical wires.

15 min. break

Invited Talk SYDN 1.4 Thu 11:15 H1

DNA origami nanostructures aid the super-resolution microscopy interrogation of proteins and allow single-molecule force measurements on biological systems — Leonhard Jakob[1], Kevin Kramm[1], Julia Molle[2], Tim Schröder[2], Philip Nickels[3], Alessandro Vannini[4], Tim Liedl[3], Philip Tinnefeld[2], and •Dina Grohmann[1] — [1]Department of Biochemistry, Genetics and Microbiology, Institute of Microbiology, Single-Molecule Biochemistry Lab, University of Regensburg, Universitätsstraße 31, 93053 Regensburg, Germany — [2]Department for Chemistry and Center for Nanoscience, Ludwig-Maximilians-Universität München, Butenandtstr. 11, 81377 München, Germany — [3]Faculty of Physics & Center for Nanoscience (CeNS), Ludwig-Maximilians-Universität (LMU), Geschwister-Scholl-Platz 1, 80539 München, Germany — [4]The Institute of Cancer Research, London SW7 3RP, UK

DNA nanotechnology is aiming to create complex functional structures on the nanometre scale with the aim, among others, to exploit these structures in biological research. While DNA-scaffolded nanostructures have been successfully developed over the last decade, the integration of functional biological molecules into DNA origami structures remains challenging. Here, we report on two projects that combine the DNA origami technique with single-molecule microscopy/spectroscopy to gain insights into the structure and function of protein assemblies.

(1) A long-standing question has been whether super-resolution (SR) microscopy can be employed for the structural interrogation of proteins in the sub-20 nm range. Here, we show that the marriage of DNA nanotechnology and single-molecule biochemistry allows the first steps towards the investigation of the structural organization of a protein using DNA PAINT SR microscopy.

(2) We exploit a self-assembled molecular force clamp built from DNA to perform force spectroscopy measurements on biological samples. Among others, we probed the force sensitivity of the DNA scissor Cas9 and quantified the influence of DNA strain on the assembly of the transcription initiation machinery.

Invited Talk SYDN 1.5 Thu 11:45 H1

Structural stability of DNA origami nanostructures under application-specific conditions — •Adrian Keller — Nanobiomaterials group, Technical and Macromolecular Chemistry, Paderborn University, Warburger Str. 100, 33098 Paderborn, Germany

With the introduction of the DNA origami technique, it became possible to synthesize almost arbitrarily shaped molecular nanostructures at nearly stoichiometric yields. The technique furthermore provides absolute addressability in the sub-nm range, rendering DNA origami nanostructures highly attractive substrates for the controlled arrange-

ment of functional entities such as proteins, dyes, nanoparticles, DNA topologies, and drugs. Consequently, DNA origami nanostructures have found applications in numerous areas of fundamental and applied research, ranging from drug delivery to structural biology to inorganic materials synthesis. Since many of those applications rely on structurally intact, well-defined DNA origami shapes, the issue of DNA origami stability under numerous application-relevant environmental conditions has received increasing interest in the past few years. This talk will summarize our recent and ongoing activities aimed at identifying factors and parameters that determine DNA origami stability, denaturation, and degradation under conditions relevant for applications in biophysics and biomedicine.