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Defence announcement

Public Defence on 18th of June 2025

Building functional virus-(un)like nanostructures using DNA origami

Title of the doctoral thesis	Virus-mimetic structures through protein engineering and nucleic acid origami
Content of the doctoral thesis	Viruses are the most abundant and diverse biological entity across Earth's ecosystem. Despite causing (devastating) diseases, viruses are known for their outstanding material and assembly properties. In particular, the virus capsid proteins – the proteins that form a protective 'shell' around the genome of a virus – are utilized for constructing precisely structured protein assemblies. However, the resulting virus-based assemblies are typically limited to a specific size, shape, and topology, which are largely determined by the virus strain. Gaining control over the assembly process to reprogram the morphology, regardless of the virus strain, would be attractive for the development of new drug delivery systems and vaccines. In this work, so-called DNA origami – rigid, custom-made nanostructures entirely made from DNA – were explored for templating functional virus-mimetic structures. Specifically, the negative charge of the DNA origami, a property originating from the phosphate groups in the DNA backbone, was exploited to guide the assembly of positively charged (capsid) proteins into user-defined sizes and shapes. The assembly can be pictured like wrapping a present – the proteins assemble on top of differently shaped DNA origami, and different proteins are like different wrapping paper, thereby assigning certain properties to the protein-DNA origami assemblies, resulting in protection, targeting and enhanced uptake into cells. On top of serving as a platform for protein assembly, the DNA origami can be tweaked to perform application-relevant functions. Firstly, their high programmability and addressability were utilized to precisely place enzymes on the DNA origami surface, turning them into biocatalytic systems. At the same time, the assembled protein shell was used to control enzyme-substrate interactions. Secondly, the DNA origami was upgraded with messenger RNA (mRNA). Since mRNA is the reading template for cells to synthesize a protein – therapeutic mRNA was used for instance in COVID-19 vaccines – the resulting mRNA-DNA origami should be translated into a protein in cells. To this end, the design and fabrication of these origami and subsequent protein translation was investigated. The doctoral thesis demonstrates the applicability of origami to template highly ordered virus-mimetic structures and promotes the development of functional and responsive protein-DNA origami-based multipurpose systems.
Field of the doctoral thesis	Chemical Engineering
Doctoral candidate and contact information	M.Sc. (Eng.) Iris Seitz iris.seitz@aalto.fi
Public defence date and time	18th of June 2025 at 12 o'clock (in Finnish time)
Remote defence	https://aalto.zoom.us/j/69557213913
Place of public defence	Aalto University Lecture Hall U006, Ekonominaukio 1, Espoo
Opponent(s)	Associate Professor Nicholas Stephanopoulos, Arizona State University, USA
Custos	Professor Mauri Kostiainen, Aalto University School of Chemical Engineering
Link to electronic thesis	https://aaltodoc.aalto.fi/handle/123456789/51
Keywords	DNA origami, mRNA-DNA origami, virus capsid protein, electrostatic self-assembly, antigen targeting, stimuli-responsiveness, biocatalysis

Dissertation will be on public display at https://aaltodoc.aalto.fi/doc_public/eonly/riiputus/