Graduate School Event

Thesis Defense: Biological functionality without biochemistry: designing nanomachines for target behavior

Andreas Ehrmann (Goodrich and Hannezo Groups)
Goodrich and Hannezo Groups

Host: Paul Schanda

Biology is overwhelmingly good at designing building blocks that are orchestrated in remarkable processes to enable the functioning of complex organisms. Is it possible to achieve similar complexity in nanotechnology? The field of self-assembly offers a promising route towards bio-inspired functionality. While significant progress has been made in the inverse design of complex structures, little is currently known about embedding these structures with dynamics and functional behavior at levels found in biology. Unlike biology, we do not have million years of evolution to result in optimal behavior. We aspire to discover fundamental design principles in simple physical systems by taking an optimization approach that builds up on methods developed by the Machine Learning community to achieve a desired function. Many future nanotechnologies will need to do more than hold a designed shape: they will need to move, switch states, and interact with other objects in controlled ways. Is it possible to replicate the precise, targeted energy delivery of ATP hydrolysis in synthetic systems, where we cannot rely on biochemical interactions, to power synthetic nanomachines? In this thesis, we develop a mechanical model for a controlled energy-delivery mechanism between bistable nanostructures, and discover key design features necessary to generate a pathway for efficient energy transduction. Inspired by the universality of ATP hydrolysis, this achievement could serve as a scheme for powering more and more complex tasks. We show how bistable nanostructures can be designed so that their conformational changes produce a prescribed behavior. By separating the energetic control of a nanoscale switch from the geometric placement of its binding sites, we identify which aspects of its energy landscape can be programmed under realistic constraints. The results provide design principles for turning synthetic nanostructures into functional, machine-like objects. By demonstrating how we can translate the scheme for energy delivery to three-state molecular machines walking along a track at a very basic level, we take a first step towards performing a task. We reveal a fundamental speed-efficiency tradeoff and important design considerations. This research contributes towards designing nanomachines that might eventually be able to contest with the levels of complexity and functionality found in biology.

Friday, September 4, 2026 10:00am - 11:00am

Central Bldg / O1 / Mondi 2a (I01.O1.008)

This invitation is valid as a ticket for the ISTA Shuttle from and to Heiligenstadt Station. Please find a schedule of the ISTA Shuttle on our webpage: https://ista.ac.at/en/campus/how-to-get-here/ The ISTA Shuttle bus is marked ISTA Shuttle (#142) and has the Institute Logo printed on the side.