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Integrating Peptides and DNA for Tailored Material Design

In nature, sequence-specific biopolymers, such as peptides and nucleic acids, are essential to various biological systems and processes. These biopolymers are utilized in materials science to achieve precise property control. Typically, variations in amino acid sequences focus on functional regulation while nucleotides are used for structural control. This raises the question: How can we integrate peptide-based functionality with the spatial precision of DNA nanotechnology for innovative material design? Here, I will present examples illustrating the incredible properties of peptide self-assembly from my PhD, and the remarkable nanoarchitecture design achieved through DNA nanotechnology from my Postdoc. These two key elements establish a vision of utilizing and synergizing peptide functionality with structural control achieved by DNA nanotechnology.

Specifically, I will show how subtle changes in the molecular environment influence the morphology and behavior of peptide assemblies such as diphenylalanine crystals and enable control over their growth and disassembly processes, revealing insights into peptide-based material manipulation (*Nat. Commun.*, 2016). Another example is that of the amorphous assemblies of tri-tyrosine peptides, where we linked the molecular arrangement to unique mechanical and optical properties of glass-like peptide structures (*Nature*, 2024).

Next, I will introduce the principles of DNA nanotechnology for advanced structural control. By designing DNA nano-frames capable of self-assembling into organized lattices, we created micron-scale 3D materials. We discovered that a minor modification in DNA linker length induces a crystalline phase transition, from simple cubic to face-centered cubic structures, altering lattice geometry. In addition, we established a method using acoustic waves to achieve scalable and morphologically controllable DNA assemblies at the millimetric scale (*Nat. Commun.*, 2024). This approach highlights how DNA nanotechnology provides unparalleled spatial control, decoupling structural architecture from functional elements such as peptides and nanoparticles. Together, these projects illustrate how peptides and DNA nanotechnology can be potentially integrated to engineer novel materials and enhance our capacity to design materials with tailored properties across scales.