Biophysics, Engineering, and Interaction Design with Multi-Cell Assemblies

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Abstract:

I will share my vision that microbiological systems should be as programmable, interactive, accessible, constructible, and useful as our personal electronic devices. Multi-cellularity enables organisms and symbiotic systems to achieve complex tasks through division of labor among cells. Such systems transcend current electronics and robotics in many ways, e.g., they synthesize chemicals, generate active physical forms, and self-replicate. Harnessing these features promises significant impact for health (tissue engineering), chemistry (pathway modularization), ecology (bioremediation), manufacturing (bioelectronics), biodesign (art), and more. But our capacity to program multi-cell assemblies to cooperatively perform complex tasks is currently too crude to achieve such transformative applications.

I will describe my lab's synergistic bottom-up / top-down approach to multi-cell research:

(1) We utilize synthetic biology and biophysics approaches to facilitate the engineering and understanding of multi-cell assemblies. I will demonstrate an orthogonal library of genetically encoded heterophilic cell-cell adhesion pairs that enables the self-assembly and patterning of bacterial aggregates at the 5 μm scale [1], furthermore the optogenetic control of homophilic cell-cell adhesion that enables the programming of biofilm patterns onto surfaces at the 25 μm scale ('Biofilm Lithography') [2].

(2) We pioneered 'Interactive Biotechnology' that enables humans to directly interact with living multi-cell assemblies in real-time. I will provide the rational for this interactivity, demonstrate multiple applications using phototactic Euglena cells (e.g., tangible museum exhibits [3], biology cloud experimentation labs [4], biotic video games [5]), and show how this technology aided the discovery of a new microswimmer behavioral state and its biophysical analysis [6].

[1] Glass, Cell '18; [2] Jin, PNAS '18; [3] Lee, CHI ACM '15; [4] Hossain, Nature Biotech '16; [5] Cira, PLoS Biology '15; [6] Tsang, Nature Physics '18.

Short Bio:

Ingmar H. Riedel-Kruse is an Assistant Professor of Bioengineering and Biophysics at Stanford University. His research seeks to make it easier to engineer and program multicellular biological systems, circuits and devices in order to foster the human condition. He runs an interdisciplinary lab integrating diverse areas like synthetic biology, biophysics, human-computer interaction design, embedded cyber-physical systems, modeling, education, and games. He received his Diploma in theoretical solid-state physics at the Technical University Dresden, did his PhD in experimental biophysics at the Max Planck Institute of Molecular Cell Biology and Genetics, followed by a postdoc at the California Institute of Technology.

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