Building Better Biofilms: Chemical Interactions and Structure-Function Relationships in Bacterial Communities

Microbial communities are ubiquitous – found in natural and anthropogenic environments – and regulate processes spanning vast scales and ecological niches from the human microbiome to biogeochemical cycles. Surface-associated bacterial communities, called biofilms, are smart materials: they are self-organizing, self-renewing, respond to environmental stimuli, and perform complex functions. Therefore, biofilms represent an ideal system in which to study structure-function relationships in bacterial communities. Chemical gradients, such as of oxygen, nutrients, and signaling molecules, determine critical processes within biofilms. Biofilm morphology, species segregation and organization affect these gradients and thus community function. In this talk, I will describe our efforts to parse and manipulate the interactions governing community development in multispecies bacterial biofilms of Escherichia coli and Pseudomonas aeruginosa. These species have an antagonistic relationship in coculture, and we have identified some of the chemical and biophysical driving forces of these interactions, including a new biofilm dispersal signaling pathway. Furthermore, using microfabricated growth substrates, we are able to modulated the competitive signaling interactions within these coculture biofilms. Structured substrates alter biofilm morphology and deterministically switch a biological signaling pathway between E. coli and P. aeruginosa via manipulation of metabolite exchange rates. In this way, physical cues are transduced to chemical stimuli which control biofilm outcomes and community properties, including antibiotic susceptibility and probiotic resistance to pathogens. With these and other studies of biophysical mechanisms of bacterial signal transduction, we are developing design principles for engineering the structure and properties of multi-species bacterial biofilms.

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