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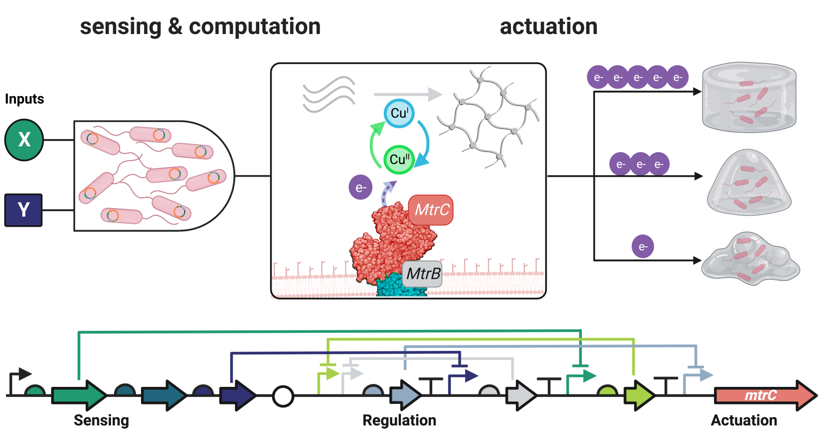
Expanding Cellular Metabolism through Extracellular Electron Transfer

Prof. Keith Keitz

Department of Chemical Engineering, UT Austin



Qualities exhibited by living systems, including self-regulation, self-healing, morphology control, and environmental responsiveness, are highly attractive from a material design perspective. However, biological materials including biofilms and tissues are generally less robust and more difficult to engineer than synthetic materials. Bridging these seemingly disparate properties could enhance the vast functional space of engineered materials with living characteristics. Paradoxically, such designs require methods to program genetic and transcriptional responses to control non-biological material properties. Addressing this challenge, our lab employs techniques from microbiology, synthetic biology, and metabolic engineering to control extracellular electron transfer (EET), a form of microbial respiration in which extracellular metals and metal oxides are used as terminal electron acceptors. Using the model electroactive bacterium Shewanella oneidensis, we demonstrate that EET can be coopted to establish metabolic and genetic control over a variety of redox-driven catalytic reactions. Specifically, we show that S. oneidensis can activate controlled radical polymerizations to form well-defined synthetic homopolymers, block copolymers, and crosslink hydrogels. We also show that EET can control alternative synthetic reactions, including Cu-catalyzed azide-alkyne cycloaddition. Finally, we establish that these reactions can be placed under transcriptional control using genetic circuits that regulate the expression of EET-relevant electron transfer proteins. Ultimately, our efforts demonstrate how the chemical reaction space available to bacteria can be expanded using EET and how this novel form of bacterial respiration can endow synthetic materials with the properties of living systems.