Abstract: Microorganisms control electron flow between different redox biomolecules to regulate biological processes such as respiration, biosynthesis, and gene expression. Modulating these electron flows would allow researchers to monitor and control these intracellular processes in real-time. Exogeneous redox active molecules and nanostructures have been introduced into cells to modulate these processes, however, these approaches cannot target a specific redox pool, leading to toxicity or limited biological control. To overcome this challenge, our laboratory has pioneered a synthetic biology approach in which we introduce the Mtr extracellular electron transfer pathway from *Shewanella oneidensis* into non-native microorganisms. This genetic module provides a molecularly-defined path for electrons into and out of a specific redox pool. Using the Mtr pathway as a conduit for electrons out of the cell, we can electronically regulate lactate metabolism or convert sensing events into electronic signals. Additionally, we demonstrate that the Mtr pathway can also actuate specific biological processes by delivering electrons into *E. coli*. Our work shows that Mtr pathway can deliver cathodic electrons specifically to the reductases and that this electron flux can be used in a controllable fashion to drive biosynthesis or trigger transcriptional changes. More broadly, our work introduces a modular genetic tool to reduce a specific intracellular redox pool, to use electricity directly as a feedstock for biosynthesis, and to control metabolic rate and gene expression.