The chemical biology of sulfur is complex. The molecular mechanisms by which sulfur contributes to redox homeostasis, signal transduction, metabolism and natural product biosynthesis are often challenging to elucidate, because sulfur can adopt many redox states, allow hypervalency, attack as nucleophile or as electrophile and engage in radical chemistry. In our laboratory we examine O$_2$-dependent enzyme reactions that make or break carbon-sulfur bonds. We focus on two enzymes classes that catalyze completely different reaction, but share a common protein fold. One enzyme is the non-heme iron sulfoxide synthase EgtB that catalyzes O$_2$-dependent C-S bond formation between $\gamma$-glutamyl cysteine and N-$\alpha$-trimethyl histidine as the central step in ergothioneine biosynthesis. The second enzyme is the formylglycine generating enzyme (FGE) that catalyzes O$_2$-dependent conversion of specific cysteine residues on client proteins to formylglycine. In this presentation I will discuss the catalytic mechanism of these two unlike enzymes based on kinetic and structural observations.