Enzyme Mimicry: New Active Detergents

The annual worldwide sale of detergents exceeds AUD $60 billion. Detergents are multi-component formulations, although the only components that actively degrade stains are *enzymes*. The enzyme market exceeds AUD $7 billion and is rising at 6.1% pa. However, enzymes are expensive, they have a limited operating window, and they have low stability. This project targeted the development of new surfactants for soap formulations that **mimic enzymes**, hydrolytically cleaving chemical bonds – **actively degrading stains**. The goal was to create efficient detergents that have enhanced stability and importantly, will work at low temperatures. Thus significantly reducing global energy demands from laundry and enabling products to be exported into developing countries, where hot water is not available.

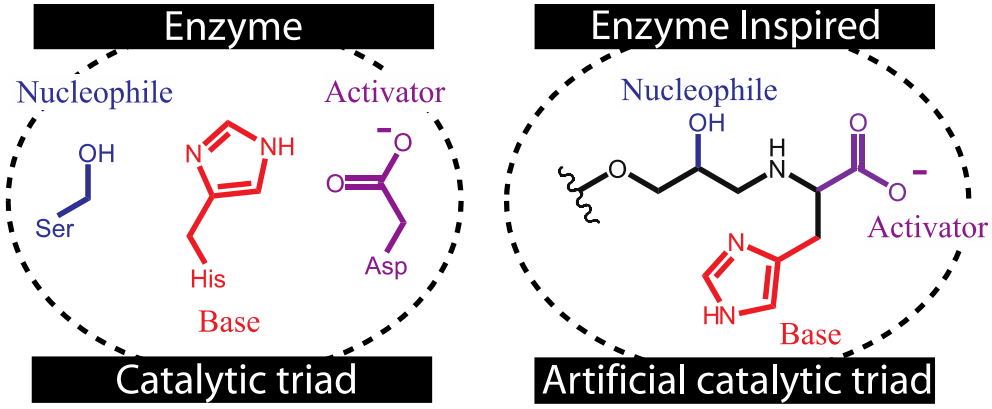

***Figure 1*: A synthetic mimic of the catalytic triad.** Incorporating the functional groups at the core of the serine proteases on a single, tri-functional molecule- the artificial catalytic triad (ACT). This versatile and scalable approach holds promised for the design of new, robust enzyme alternatives.

In collaboration with the researchers at the University of California, Santa Barbara and our industry partner Unilever, the outcomes of the project have been three-fold:

1. Development of a synthetic enzyme mimic based on the structure of a common biological and industrial enzyme family, the serine proteases.

Despite the complex structure of natural enzymes, they employ a relatively small functional unit to mediate their important reactions, known as the active site. The active site of the serine proteases is composed of just three key amino acids, termed 'the catalytic triad'. We have been successful in preparing an enzyme-mimicking catalyst by incorporating the active groups of the catalytic triad on a single tri-functional molecule – a novel and extremely versatile approach (**Figure 1**). We have further developed this approach by optimising the spatial arrangement of the three groups on the catalyst and establishing a synthetic procedure to make this new material quickly, cheaply and on a multi-gram scale. These findings have been published in the May 2017 edition of the general chemistry journal *Chem* (DOI: 10.1016/j.chempr.2017.04.004).

2. Optimised an enzyme-micking catalyst by incorporation of surfactant functionality, and attachment to resins.

Leveraging the polymer self-assembly expertise of Prof. Craig Hawker and his team at UCSB, our new catalyst materials have been further optimised for a laundry detergent application. John Stocker Postgraduate Scholar Mitchell Nothling undertook an extended research visit in Prof.

Hawker's laboratory in 2015 and was successful in designing and preparing a library of enzyme-mimicking surfactants. These new materials display impressive catalytic properties under the conditions of a typical laundry wash, with some systems challenging the performance of native enzymes at room temperature (**Figure 2**). These enzyme-mimicking surfactants form the basis of three international patents (two published, one pending) and a peer-reviewed manuscript and have been supplied to Unilever research for further commercial investigation.

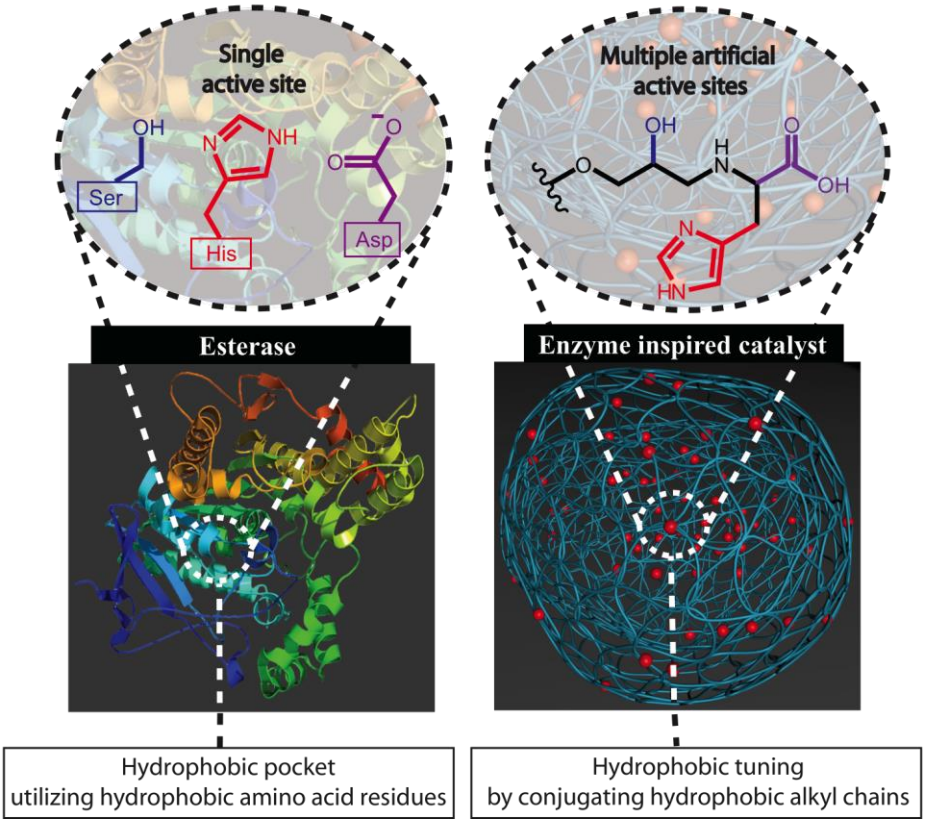

Figure 2. **Multiple catalytic sites and additional chemical functionaility afforded by ACT functionalised resins.** Comparison of the native catalytic active site – *the catalytic triad* – of the serine proteases and the artificial enzyme mimic loaded into a polystyrene resin.

3. Established a rigorous evaluation procedure for catalytic performance, and made progress toward understanding the mechanism behind the enzyme-like function of the new materials.

The key goal of this study was the development of a material that could perform hydrolytic catalysis like the serine proteases. As such, significant effort was given to a benchmarking procedure by which we could measure the performance of the new catalytic materials as they were prepared and compare this directly with the performance of native enzymes. In short, model substrates were selected for degradation in our assay procedure that could be traced using UV-Vis spectrophotometry, a common technique employed by enzyme kineticists. A deeper understanding of this procedure was provided through computational modelling performed in collaboration with Prof. Michelle Coote at the Australian National University. Importantly, the concerted action of our functional materials follows a process very similar to that performed by native enzymes, an exciting result with long-term implications for the future design of enzyme mimics.