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2024_71_Kew_EG: Evolution of adaptive traits in lichens: Mechanisms of chemical self-resistance and heat resistance.

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Lichens —obligate mutualisms comprising fungi, photosynthetic organisms and bacteria — are adapted to live in almost all terrestrial habitats. Some groups are particularly adapted to live in high UV and high temperature environments, and although they protect themselves from UV by producing various UV-protectant chemical compounds, some of these compounds are themselves cytotoxic. The mechanisms by which lichens survive high temperature stress and chemical inhibition are yet to be elucidated.

The order Teloschistales (Ascomycota) is a group of extremophile lichen-forming fungi that produce UV-absorbing anthraquinone pigments in high quantities. It is believed that the UV sun screening properties of anthraquinones have facilitated the colonization and adaptation of these lichens to exposed arid habitats. In a recent study, we used these photoprotective pigments in the Teloschistales as a case study to investigate how adaptive metabolic traits arise and diversify in lichen-forming fungi. Comparative genomics identified putative anthraquinone biosynthetic gene clusters (BGCs) in Teloschistales genomes and demonstrated that BGC diversification occurred via re-shuffling existing enzyme genes with novel accessory genes.

Curiously, in addition to being effective UV protectant sunscreens, certain anthraquinones are also cytotoxic antimicrobial compounds with effects on both fungi and bacteria. Self-resistance seems to be partly achieved though efflux pumps, but our own data shows there are also intriguing signs of point mutations in topoisomerase II, one of the known protein targets of anthraquinones. In addition to chemical self-resistance, lichens are also able to tolerate high environmental temperatures, a problem that will be exacerbated by climate change. Little is known about the mechanisms involved in extreme temperature resistance in lichens.

In this project, we aim at using a multi-omic approach to answer the following questions:

1) How do lichen-forming fungi produce anthraquinones without poisoning themselves and their microbial partners?

2) How do lichens adapt to environments with extreme temperatures?

Putative resistance mutations in target genes will be tested in yeast to see if anthraquinone self-resistance can be recapitulated in a model organism. Molecular modelling of anthraquinone-protein receptor interactions will then be used to provide detailed insights as to how resistance is achieved at a biochemical level, providing a picture of lichen secondary metabolite evolution in unprecedented detail. For heat tolerance, we will compare copy number and diversity of molecular chaperones between lichens from hot and cold environments. We will investigate chaperone binding partners using yeast two-hybrid protein interaction assays. Using comparative lipidomics of lichen symbionts from hot and cold environments, we will look for difference in plasma membrane composition that may affect membrane fluidity.