Evolutionary search and races in the adaptive immune system

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Biological evolution is a search process: microbes rapidly evolve to seek variants capable of surviving antibiotics; antibody-expressing B cells undergo accelerated Darwinian evolution to discover high-affinity mutants that bind and neutralize pathogens. Such rapid evolutionary search takes place in environments that are neither static nor completely unrelated in time, which poses a challenge to our understanding of the emergent properties of evolving systems. What might be useful spaces to describe adaptive "moves" in changing "landscapes"? How would correlation across environments impact the capacity of evolutionary novelty? Can environmental dynamics turn evolutionary constraints into opportunities of speedy paths? In this talk, I will present our recent attempts, using theoretical descriptions and numerical schemes, toward addressing these questions in the context of evolutionary races in the adaptive immune system, where immune repertoires evolve in a varying environment that is either programmed or adaptively changing. We find that epistatic interactions, generally regarded as constraining the set of adaptive paths, may play a beneficial role in evolving generalist solutions. Furthermore, new pathways toward generalists – the desirable outcome of vaccine strategies – may open as a result of meeting the demands for survival and adaptation that operate on different time scales.

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