The Role of Constraints in Origins-of-Life Research

Contemporary research into the origins of life is a highly interdisciplinary endeavour seeking to account for how our biomolecules formed from simple precursors and self-assembled for the first time on the early Earth, more than 3.5 billion years ago. Even though the research target is historical, unlike other historical sciences, origins-of-life research is largely experimental – famously starting with the Miller-Urey experiment in 1953. This is due to a challenging epistemic situation: direct evidence for chemical processes on the early Earth is extremely scarce, and prebiotic conditions are uncertain. However, experimental research also needs to start somewhere, even if the target is a long-completed historical process. As Winsberg (2009) remarks: "In both cases of simulation and experiment, you need to know something to learn something." This seems to pose a special problem for sciences of the origin, including origins-of-life research. How do scientists gain traction in this kind of epistemic situation?

In this talk, I argue for the importance of constraint-based research strategies as a way of dealing with the above issue in origins-of-life research and historical sciences more generally. Constraints limit and therefore reduce the number of factors or values we need to take into account when investigating a specific scientific target – they tell us something about a target and guide further investigation by excluding things. A detailed account of the role of constraint-based reasoning and explanation in the life sciences has been given by Green and Jones (2016). They focus on the role of formal constraints in systems biology, but their account allows for other kinds of constraints as well and I am going to use a generalised version of constraint-based reasoning to apply to specific cases from origins-of-life research.

I focus on two examples from origins-of-life research to illustrate the importance of constraints. Both fall under the subfield of prebiotic chemistry. Prebiotic chemists study the formation of biomolecules under prebiotic condition drawing on methods from synthetic organic chemistry. The first example shows the importance of combining constraints from different disciplines to ensure that prebiotic chemistry experiments employ reaction conditions that are 'prebiotically plausible'. The second example consists of a sequence of experiments that synthesize potentially prebiotic nucleic acids in the structural neighbourhood of RNA. I argue that while in the first example, the researchers apply constraint-based search and reasoning, the second case goes beyond that: the emphasis is on experimentally determining usable constraints in the first place.

Finally, I compare the role of constraints and constraint-based reasoning in origins-of-life research to existing accounts of reasoning in historical sciences, particularly those focusing on consilience (Forber & Griffith 2011, Wylie 2011) and coherence (Currie 2017). I take my points to be largely compatible with these accounts.