

Abstract (150 words):

Eco-evolutionary feedback loops represent a fundamental challenge: species evolve in response to environments they simultaneously modify. We propose that adaptive systems operate through generation-validation cycles: organisms generate phenotypic variants (incomplete fitness specification), environments validate variants through selection (partial fitness resolution), and validation modifies environmental conditions, creating new generation problems. This framework unifies niche construction, coevolution, and evolutionary transitions under a single mathematical structure. We derive testable predictions regarding relationships between environmental modification rates and evolutionary rates, conservation patterns in multi-level validation hierarchies, and re-emergence of latent phenotypes following validation removal. Our approach provides formal grounding for Baldwin effects, genetic assimilation, and ecosystem engineering, while offering novel insights into evolvability and macroevolutionary transitions. This framework is generalizable beyond ecology, with potential applications in other adaptive systems.

Keywords: eco-evolutionary dynamics, niche construction, generation-validation cycles, adaptive feedback, evolutionary transitions, formal theory