

## **Designing and Steering Evolution and Evolvability in Hybrid Living Systems: selective context, evolutionary processes and the properties of ante-organisms**

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The biggest societal challenges of our times are concerned with designing and managing multiple interconnected complex adaptive systems. These include not just living systems or populations, but technical, informational, economic and, crucially, social systems and hybrids of all of these. All such systems are undergoing constant change and adaptation, but most often as non-standard evolutionary systems which may only partially meet the criteria required for natural selection to occur. That is, they do not tend to consist solely of a population of units of evolution. Steering, managing and interacting with the evolution of such systems hence presents challenges which require us to go back to the fundamentals of what constitutes an evolving system.

I propose that we can usefully consider the evolving systems that we wish to manage in a framework consisting of evolutionary context, process and properties. Context being the selective environment to which a system and its components are subject. Process: the type of selective process, whether evolutionary or learning, that a system and its components undergo. Properties: the criteria required for an “individual” to function as a unit of evolution, that is, individuality, variation, reproduction and heritability, and how they are met or approximated in the systems we wish to consider. Each of these may take different forms in the different sorts of systems which we wish to design and/or manage and each may be instantiated or manipulated in different ways in efforts to steer system evolution or evolvability. All must be taken into account in order to successfully manage evolution in hybrid or non-standard systems.

I will illustrate and compare the parts of this framework in the context of a wide range of different system types and different processes of management and adaptation from the socio-political to the microbial. In particular, industrial ecosystems and other designed human “ecosystems”, adaptive management of socio-economic-ecological systems, the design, appraisal and evaluation of policy in complex, nexus domains, attempts to impose group selection within human communities for the management of public goods, interaction with and management of useful microbial communities in, for example, anaerobic digestion and synthetic ecology approaches to steering single and multispecies microbial communities.

Using this framework as a basis I will then discuss the challenges and opportunities that we face in constructing and steering a range of evolvable and evolving systems. And crucially, how the technical challenges might be pragmatically addressed within the context of political processes and normative social domains.