Review Note on Synthetic Biology

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Description

The debate over reductionism and antireductionism in biology is very old. Even the systems approach in biology is more than five decades old. However, mainstream biology, particularly experimental biology, has broadly sidestepped those debates and ideas. Post-genome data explosion and development of high-throughput techniques led to resurfacing of those ideas and debates as a new incarnation called systems biology. Though experimental biologists have co-opted systems biology and hailed it as a paradigm shift, it is practiced in different shades and understood with divergent meanings. Biology has certain questions linked with organization of multiple components and processes. Often such questions involve multilevel systems. Here in this essay we argue that systems theory provides required framework and abstractions to explore those questions. We argue that systems biology should follow the logical and mathematical approach of systems theory and transmogrification of systems biology to mere collection of higher dimensional data must be avoided. Therefore, the questions that we ask and the priority of those questions should also change. Systems biology should focus on system-level properties and investigate complexity without shying away from it.

Synthetic Biology

Synthetic biology research is often described in terms of programming cells through the introduction of synthetic genes. Genetic material is seemingly attributed with a high level of causal responsibility. We discuss genetic causation in synthetic biology and distinguish three gene concepts differing in their assumptions of genetic control. We argue that synthetic biology generally employs a difference-making approach to establishing genetic causes, and that this approach does not commit to a specific notion of genetic program or genetic control. Still, we suggest that a strong program concept of genetic material can be used as a successful heuristic in certain areas of synthetic biology. Its application requires control of causal context, and may stand in need of a modular decomposition of the target system. We relate different modularity concepts to the discussion of genetic causation and point to possible advantages of and important limitations to seeking modularity in synthetic biology systems.

The principal existing real-world application of synthetic biology is biofuels. Several ‘next generation biofuel’ companies Synthetic Genomics, Amyris and joule unlimited technologies claim to be using synthetic biology to make biofuels. The irony of this is that highly advanced science and engineering serves the very mundane and familiar realm of transport. Despite their rather prosaic nature, biofuels could offer an interesting way to highlight the novelty of synthetic biology from several angles at once. Drawing on the French philosopher of technology and biology gilbert simondon, we can understand biofuels as technical objects whose genesis involves processes of concretization that negotiate between heterogeneous geographical, biological, technical, scientific and commercial realities. Simondon’s notion of technicity, the degree of concretization of a technical object, usefully conceptualizes this relationality. Viewed in terms of technicity, we might understand better how technical entities, elements, and ensembles are coming into being in the name of synthetic biology. The broader argument here is that when we seek to identify the newness of disciplines, their newness might be less epistemic and more logistic.

The natural world consists of hierarchical levels of complexity that range from subatomic particles and molecules to ecosystems and beyond. This implies that, in order to explain the features and behavior of a whole system, a theory might be required that would operate at the corresponding hierarchical level, where self-organization processes take place. In the past, biological research has focused on questions that could be answered by a reductionist program of genetics. The organism (and its development) was considered an epiphenomenon of its genes.

Morphogenetic Field

However, a profound rethinking of the biological paradigm is now underway and it is likely that such a process will lead to a conceptual revolution emerging from the ashes of reductionism. This revolution implies the search for general principles on which a cogent theory of biology might rely. Because much of the logic of living systems is located at higher levels, it is imperative to focus on them. Indeed, both evolution and physiology work on these levels. Thus, by no means systems biology could be considered a 'simple' 'gradual' extension of Molecular Biology.

Synthetic biology is often understood in terms of the pursuit for well-characterized biological parts to create synthetic wholes. Accordingly, it has typically been conceived of as an engineering dominated and application oriented field. We argue that the relationship of synthetic biology to engineering is far more nuanced than that and involves a sophisticated epistemic dimension, as shown by the recent practice of synthetic modeling.

Synthetic models are engineered genetic networks that are implanted in a natural cell environment. Their construction is typically combined with experiments on model organisms as well as mathematical modeling and simulation. What is especially interesting about this combinational modeling practice is that, apart from greater integration between these different epistemic activities, it has also led to the questioning of some central assumptions and notions on which synthetic biology is based. As a result synthetic biology is in the process of becoming more "biology inspired".