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On Structure-Function Asymmetry

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Abstract

This is a short opinion article pointing out the importance of examining more precisely the intimate relationship between structure and function that arises for all complex systems. It is claimed that this relationship is highly asymmetrical, which has many unforeseen consequences. The presented claims are made based on intuition and inductive reasoning. Although some claims may be only partially valid, for instance, under yet to be specified conditions, they can inspire new research directions to investigate in future.

Keywords: Function; Complex systems; Asymmetry; Biological evolution

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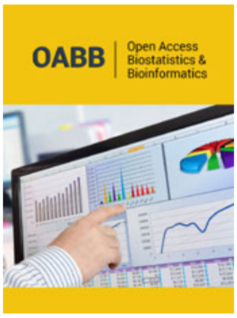

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Introduction

The complex systems of which biological systems are the most notable example have many distinctive properties [1]. These systems must be studied across many different spatio-temporal scales involving different chemical, electromagnetic, mechanical, quantum and other types of physical interactions in order to uncover their properties and inner workings. It is unclear whether the set of all properties describing complex systems is countably or uncountably infinite. Thus, we may never be able to generate a complete set of mathematical models fully defining complex systems, since any mathematical model can only capture some, but never all of the properties. It also means that these systems can never be completely controlled as unforeseen side effects always exist. Even though mathematical models of complex systems are only approximations, they are usually good enough in many practical scenarios. Mathematical models of complex systems are increasingly used, for example, to identify interventions that can most likely lead to desired outcomes. More importantly, mathematical models are also used to study how structures produce a function, and how function emerges from the structure.

Asymmetry of Maps between Structure and Function

One of the most defining characteristics of complex systems is that there is a strong linkage between their structure and function. For example, it is commonly accepted that proteins having a similar amino acid sequence are homologous, i.e., they have a similar 3D structure, and thus, also the same or similar function [2]. More importantly, the relationship between structure and function of complex systems is fundamentally highly asymmetrical. Mathematically, let S be a set of structural configurations (e.g., of a protein), and F denote a set of possible functions of these structures. Neither S nor F has to be complete for the sake of our argument. However, there must exists a non-empty map, u, from some elements in S to some elements in F, and another non-empty map, v, from some elements in F to some elements in S. We can formulate the following hypothesis about structure-function asymmetry. For any complex system, the map from structure to function, $u: S \rightarrow F$, is non-injective, whereas the map from function to structure, $v: F \rightarrow S$, is injective.

In particular, possibly a large number of different structural configurations can provide the same function, so the function can be predicted for a given structure. However, finding or designing the structure for a given function is a much harder problem. The structure design is often constrained by requiring that it can provide some level of efficiency, for example, with respect to material, energy or information consumption. This observation has a number of very fundamental consequences as discussed next [3].

Consequences of Structure-Function Asymmetry

We make the following three claims. First, complex physical systems are limited in how much their structure can change when they adapt to changes in the internal and external conditions. The structure of complex systems tends to be preserved, so any modification to their function is secondary and fundamentally constrained by the allowable change in their structure. The adaptation starts at higher levels with changes to the primary structure occurring at last. Preserving the structure over adaptation in function in biological systems is likely one of the basic laws of biological evolution to maintain structural continuity.

Second, social systems involve human beings, so they are a good example of complex systems. It implies that preserving a social hierarchy representing the structure of social systems is more important than functional adaptation of societies to new situations, which appears to be secondary. For instance, accepting new research finding that promises a paradigm shift would lead to a structural change in the existing research community. Therefore, such a disruptive research finding is going to face a lot of resistance before it is eventually accepted by the research community. This was the case for nearly all major scientific discoveries in the past.

Third, there is nowadays an enormous interest to mimic general intelligence as we understand it, i.e., as the intelligence arising in the context of the human brain [3]. Since human beings are entirely dependent on existence within social structures, the structure-function asymmetry discussed above for social systems inevitably applies to general intelligence of the human brain. Thus, our intelligence can be considered to be a function provided over the structure of the human brain and of our societies. It implies that our intelligence, for example, as our ability to solve difficult problems, is considerably limited by the existing social structures. In fact, we even conjecture that general intelligence is a very unlikely anomaly that has occurred during our biological evolution. It means that chasing after other forms or realizations of general intelligence may be an illusion, since it is a secondary function in our biological evolution. Moreover, new functions provided by the developed AI systems are secondary to the structure-preserving social systems. The AI will be limited by the allowable change in the human societies unless AI would be allowed to exist well outside our society.

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