CoCo Seminar Series Spring 2018

The Role of Criticality of Gene Regulatory Networks on Emergent Properties of Biological Systems

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Wednesday April 18, 2018 8:30-9:30am
Engineering Building H-9 (Knoll-MacDonald Commons / Watson Commons)

Whereas the relationship between criticality of gene regulatory networks (GRNs) and dynamics of GRNs at a single cell level has been vigorously studied, the relationship between the criticality of GRNs and properties of multicellular organisms at a higher level has not been fully explored. Here we aim at revealing potential roles of the criticality of GRNs at a multicellular and a hierarchical level, using a random Boolean network as a GRN. We perform three studies. Firstly, we propose a GRN-based morphogenetic model, and delve into the role of the criticality of GRNs in morphogenesis at a multicellular level. Secondly, we include an evolutionary process in our morphogenetic model by introducing genetic perturbations (e.g., mutations) to GRNs, and examine whether the role of the criticality of GRNs can be maintained even in the presence of the evolutionary perturbations. Also, we look into what the resulting morphologies are like and what kind of biological implications they have from the epigenetic viewpoint in morphology. Lastly, we present multilayer GRNs consisting of an inter-layer and an intra-layer. A network in an inter-layer represents interactions between cells, and a network in an intra-layer means interactions between genes. All the nodes of an intercellular network have identical intracellular GRNs. We investigate how the criticality of GRNs affects the robustness and evolvability of the multilayer GRNs at a hierarchical level, depending on cellular topologies and the number of links of an intercellular network. From the three studies, we found that the criticality of GRNs facilitated the formation of nontrivial morphologies at a multicellular level, and generated robust and evolvable multilayer GRNs most frequently at a hierarchical level. Our findings indicate that the roles of the criticality of GRNs are hard to be discovered through the single-cell-level studies. It justifies the value of our research on the relationship between criticality of GRNs and properties of organisms in the context of multicellular settings.

Hyobin Kim is a Ph.D. candidate in Systems Science at Binghamton University. Her research interests include complex dynamical networks, artificial life, computational and systems biology, and other complex systems related topics.

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