The Modular Architecture of Cellular Decision Making

Raúl Guantes[1], and Juan F. Poyatos[2]

***Short Abstract* — It is generally believed that positive feedback loops are at the core of cellular decision making. However, considering the number of differentiation scenarios found in cells, little is known about how this diversity is reflected on their associated control structures. Here, we consider this issue by first exploring much of the known molecular circuitry already available. We identify minimal architectures characterized by the auto-activation of their molecular constituents. These topologies regulate two canonical types of differentiation processes, progression towards a new state or decision between two alternative ones, enable these switches with distinct information-processing features, and ultimately represent fundamental design principles of cellular decision making.**

***Keywords* — Cellular differentiation, molecular switches, signal processing.**

I. Purpose

THE confluence of molecular studies with theoretical ideas obtained with the use of Dynamical Systems Theory [1] demonstrated the role of positive feedback loops at the core of many of the known regulatory networks involved in cellular differentiation and decision-making. However, it is clear that not all these networks regulate the very same type of processes. How are these differences then reflected on the architecture of the underlying control loops?

II. Results

We have identified various minimal topologies associated to several decision-making scenarios found in cells, e.g., [2-7]. We introduced simple mathematical models to analyze the dynamical behavior of these architectures. This allowed us to consider three different decision-making transitions, or switch types: *progre*-switch, *deci*-switch and *hybri*-switch [8].

These switches denote three fundamental dynamical behaviors (bifurcations of the dynamical systems) which correlate with two main classes of binary decisions. In a first class, differentiation can be viewed as a progression from an initial to a final state. In a second type, differentiation can be interpreted as a decision in which a primordial cell commits to become two alternative cell types. Any cellular differentiation can be generally reduced to these two classes.

Contrary to what one could a priori expect we find that a single topology can exhibit all possible switches (dynamical behaviors). What factors determine then when a given topology is chosen for a particular switch type? In addition, why is a given switch type used, once a particular topology is fixed? We focused on robustness and signal-processing properties to provide a plausible answer to these questions. In my talk, I will be discussing specifically some ideas related to asymmetric/symmetric signaling, flexible discrimination and noisy information-processing

III. Conclusion

We present three types of switching behavior associated to several feedback loops architectures which are used in various cellular differentiation contexts. We argue that signal processing could be a major determinant to select a particular structure and switch type in any given scenario. These ideas provide an unifying framework to understand cellular decision-making and highlight the rich information-processing role that positive loops could exhibit in living cells.

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[1]Instituto Nicolás Cabrera, Facultad de Ciencias C-XVI, Universidad Autónoma de Madrid, Madrid, Spain. E-mail: raul.guantes@uam.es

[2]Evolutionary Systems Biology Initiative, Spanish National Cancer Centre (CNIO). E-mail: jpoyatos@cnio.es

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