Solvay Colloquium

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Optimal decoding of cell identities in multicellular systems

In a developing embryo, individual cells need to “know” where they are to do the right thing. How much do they know, however, and where is this knowledge written down? Here, we show that these questions can be made mathematically precise, using the framework of information theory and applying it to biological signaling networks. The same framework has been successfully applied to neural processing and under the name of “efficient coding” has been able to explain various non-trivial properties quantitatively from first principles. As such it has been able to make predictions “ab initio”, directly from data, rather than from fits to specific mathematical models. Here we’re building a similarly predictive theory for gene regulatory networks in the specific context of cell specification in the developing embryo. In this system, information about position is encoded by the the molecular concentration of several types of effector molecules, and a cell’s position ultimately encodes its identity. Can the cellular process of decoding position and thus cell identity from a set of concentrations be made explicit? We present an approach that tightly integrates experiments and theory, and which allows us to generate a quantitative and simple predictive theory of how cells decode positional information in the patterning gene network of the early fly embryo. We construct a decoder from wild-type gene expression patterns and show that it correctly predicts, with no free parameters and 1% accuracy, the patterns of pair-rule expression in mutant backgrounds as well as their temporal changes. Information about precise cell identities is thus available at the earliest stages of development, and we argue that the way in which this information is distributed reflects an optimization principle, maximizing the information available from a limited number of molecules. Our results suggest that evolutionary pressures may have been strong enough to drive mechanisms that extract as much positional information as possible given the physical constraints.

Tuesday 12 June 2018 at 4.00 P.M.

COFFEE AND TEA WILL BE SERVED AT 3.45 P.M. IN FRONT OF THE SOLVAY ROOM

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