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Preface

Systems Biology

Nobel Symposium 146

Systems Biology has emerged as a research approach in recent years and attracted much attention. However, Systems Biology is not an entirely new field. Rather, the systems approach has evolved over at least 50 years through theoretical biology, molecular physiology, ecology, and more recently functional genomics and bioinformatics. Systems Biology aims to identify and understand the phenotypes that emerge through interaction in biology. Such interaction may concern molecules within a cell, different genes or cells, tissues and organs within an organism, or even organisms within an eco-system. Common to the systems approach is that studies do not focus on the properties of individual units (molecules, cells, organs, organisms) but rather on those of modules and networks. In other words, after decades of a reductionist focus in biology and medicine we are now shifting towards studying the properties of networks and how these control the behaviour of cells and organisms in health and disease. Systems Biology is inherently interdisciplinary, as it requires the integration of experimental biology with mathematical modelling. Furthermore, Systems Biology employs the rules of chemistry and physics, as well as engineering, to explain the properties of biological systems. It became apparent that novel types of data are needed, often quantitative and time-resolved in nature. Generating such data often requires collaboration between biologists, clinicians, physicists, and chemists. This type of integration is novel and it brings together different, traditionally separated, scientific disciplines. In fact, Systems Biology requires research and education to operate across the (hindering) boundaries of departments and faculties and thus the development of new constellations in which research and education can be performed.

At this point there are (at least) two major directions in Systems Biology which employ largely different experimental and computational approaches: (1) data-driven or top-down Systems Biology and (2) module-driven, data-requiring, bottom-up Systems Biology. Top-down approaches are a further development of Functional Genomics and Bioinformatics. The concept encompasses building of, sometimes genome- or organism-wide, networks of different types (e.g. protein interaction networks, genetic interaction networks, metabolite maps, phosphorylation networks, gene expression networks and integration of those in multi-scale modelling) and analysing their properties employing suitable mathematical models and simulations. This area is developing driven by the rapidly increasing ability of generating at high-throughput various types of “omics” data.

Bottom-up approaches have developed over decades under the terms Physiology and Theoretical Biology. This area experiences a major boost by the development of experimental approaches that make it possible to study selected processes in living cells at high temporal and spatial resolution. In combination with classical biochemical assays, high resolution in vivo data makes it possible to develop and test quantitative models of actual cellular processes. Commonly, these mathematical models encompass only a limited number of components of a defined cellular module but allow analysis of processes over time and space. Especially the developments of single-cell analysis tools that allow monitoring processes in real time as well as determining cell-to-cell variation and noise are drivers in this area. Many of these single-cell approaches are enabled by Green-Fluorescent Protein (GFP) technologies, whose development was awarded a Nobel Prize in Chemistry in 2008.

Eventually, top-down and bottom-up Systems Biology should integrate in order to enable studies of the dynamics of large, potentially whole cell or organism networks.

Over one week in June 2009 a Nobel Symposium on Systems Biology drew together leading scientists in the field of Systems Biology. The Symposium provided an overview of the present state-of-the-art in the field, covering both top-down and bottom-up approaches. It became clear that the field is in rapid development. Several recent success stories further stimulated visions for what the systems approach can potentially accomplish. But it also became apparent that the field will require time (and resources) to more deeply integrate different fields of the sciences in order to fulfil its promises. The present special issue of FEBS Letters features contributions of many of the speakers at the Symposium. It provides an impression of where this exciting approach stands at the moment and where it may be heading in the near future.

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