(A)Symmetries in biological systems and the underlying gene-regulatory principles

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Résumé

Symmetrical events are recurrent key principles at the foundation of living systems, involved in as diverse phenomena as the propagation of genetic information, the formation of dimeric structures or the duplication of genes, cells and body structures. During evolution successful principles were duplicated and acquired modified structures to enlarge the functional repertoire. Symmetrical events are essential for life - they support as diverse phenomena as the propagation of hereditary information from parent to their progeny, the organization of the body plan, the development of an organism or the binding of certain transcription factors to specific DNA sequences to regulate the expression of genetic information.
It is, however, asymmetry that accounts for the development of different species and the endowment of higher organisms with diversified and functionally specified body compartments/organs. At least four intrinsically non-symmetrical features cause the deviation from symmetrical founding principles, the temporal execution of the inherited genetic program, gradients that specify positional information1, mutual interactions with the environment and stochastic errors in the complex regulatory circuitries of living systems. Thus, symmetrical events are founding principles of living systems but deviation from symmetry created multicellular organisms that are temporally developing and evolving, autonomously regulated, environment-dependent and responsive, metastable systems with the capacity of indefinite propagation.

The development and maintenance of organisms generated by the interplay of symmetry and asymmetry requires continuous supply of energy to counteract the threat of disorganization (gain of entropy) and provide building blocks; organisms correspond thus to asymmetrically operating open systems with sophisticated autonomously operating systems control. The systems control, acting strictly hierarchical and directional, relies on species-specific genetic information. In the nucleus of a cell a super-structure ("chromatin") provides the information to establish regulatory networks2 that specify development and functionality. All these phenomena are inherently asymmetric – albeit derived from symmetric origins - at the level of the individual. Lack of energy support, supplies and/or improper regulatory control can generate disease or lead to death.
In the presentation examples of (a)symmetries in living systems - ranging from evolution and embryogenesis to gene regulation and complex regulatory networks, will be discussed.

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