Systems biology and the limits of philosophical accounts of mechanistic explanation

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Abstract

Mechanistic explanation has been developed as a philosophical alternative to traditional models of explanation as derivation from laws and equations, with Carl Craver having criticized several mathematical models as merely describing but not explaining. In contrast, I discuss systems biology as an area where explanation in terms of mechanisms and explanation by mathematical models is integrated. Against the vision of mechanistic explanation in terms of structural organization and qualitative interactions only, the paper lays out three cases from systems biology, focusing on questions about qualitative phenomena (rather than the explanation of quantitative details) where equations are still indispensable ingredients of the explanation. The development of mammalian teeth is modeled by nonlinear differential equations, so that the outcome to be explained is sensitive to quantitative parameters. The modeling of apoptosis illustrates the general phenomenon of bistability, i.e., a system being in either of two qualitatively different states (alive state and apoptosis state of a cell), to be quantitatively explained by a threshold behavior. The development of vertebrate segments is based on the presence of regular oscillations of gene activities inside individuals cells, and its synchronization between cells, which are qualitative explananda necessitating a mathematical model. Apart from the relevance of equations in mechanistic explanations, systems biology shows that a broader philosophical conception of mechanisms is needed, which takes into account quantitative changes and functional-dynamical aspects, transient entities and the generation of novel entities, complex interaction networks with feedback loops, and system-wide functional properties such as distributed functionality and robustness.

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sciencesconf.org:ishpssb2013:14861