Emergence in exact natural science

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Abstract

The context of an operational description is given by the distinction between what we consider as relevant and what as irrelevant for a particular experiment or observation. A rigorous description of a context in terms of a mathematically formulated context-independent fundamental theory is possible by the restriction of the domain of the basic theory and the introduction of a new coarser topology. Such a new topology is never given by first principles, but depends in a crucial way on the abstractions made by the cognitive apparatus or the pattern recognition devices used by the experimentalist. A consistent mathematical formulation of a higher-level theory requires the closure of the restriction of the basic theory in the new contextual topology. The validity domain of the so constructed higher-level theory intersects nontrivially with the validity domain of the basic theory: neither domain is contained in the other. Therefore, higher-level theories cannot be totally ordered and theory reduction is not transitive. The emergence of qualitatively new properties is a necessary consequence of such a formulation of theory reduction (which does not correspond to the traditional one). Emergent properties are not manifest on the level of the basic theory, but they can be derived rigorously by imposing new, contextually selected topologies upon context-independent first principles. Most intertheoretical relations are mathematically describable as singular asymptotic expansions which do not converge in the topology of the primary theory, or by choosing one of the infinitely many possible, physically inequivalent representations of the primary theory (Gelfand – Naimark – Segal-construction of algebraic quantum mechanics). As examples we discuss the emergence of shadows, inductors, capacitors and resistors from Maxwell ' s electrodynamics, the emergence of order parameters in statistical mechanics, the emergence of mass as a classical observable in Galilei-relativistic theories, the emergence of the shape of molecules in quantum mechanics, the emergence of temperature and other classical observables in algebraic quantum mechanics.

Keywords:	Intertheoretical relations. Higher-level theories. Singular asymptotic expansions. Gelfand – Naimark – Segal-construction. Emergence of novelty.
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