The impact of the paradigm of complexity on the foundational frameworks of biology and cognitive science

Moreno, A., Barandiaran, X. & Ruiz-Mirazo, K.

Introduction

One of the major contributions of the sciences of complexity has been its capacity to reframe old questions and open new ones on key issues of science, philosophy of sciences and philosophy in general. Until recent time science has been developed according the Cartesian claim that an analytic and decompositional method was a necessary condition for human systematic understanding of complex objects of study (illustrated by the mechanistic approach to living beings). Years later Kant became aware that there was a profound difference between artifacts and organisms and first introduced the concept of self-organization in rational thought. What Kant introduced was the (now familiar) distinction between complicatelly ordered systems and complex organized systems (concluding that human understanding could not approach self-organized complex systems). However, a scientific understanding of complex systems did not arise until the second half of 20th century. Interdisciplinary research in this last half century made clear and tractable the fact that most of the forms of order and functioning of complex systems is the result of nonlinearly interacting parts, generating emergent properties, which became soon amenable to computer simulation and tractability. Both the new (more systemic) ways of thinking and the new methodological tools have developed a scientific understanding of how extremely complex systems can generate new simplified functional levels. In this chapter we will review the conceptual transformations that the sciences of complexity have made possible in biology and cognitive science.

Content of the chapter

I. Where and how have complex systems ideas played crucial roles in formulating the foundations of Biology and Cognitive Science?

1) The birth of Artificial Life as a discipline
2) Systemic approach to life and its origins
3) Self-organization as an additional evolutionary force in nature
4) Dynamic-systems approach to cognition

--- Main points/ideas used: ---

a) Non-decomposability. Non-linearity. Long range correlations
b) Noise. Fluctuations as a source of order
c) Robustness. Redundancy. Organizational homeostasis
d) Recursive/cyclic causal structure.
e) Emergence. Downward causation
f) Hierarchies and levels of organization.

II. What fundamental issues of conceptualization, principle or methodology have therefore been raised?

1) New paradigm for the naturalization of function (autonomy, agency, adaptivity,...) and information (as an organizational concept: decoupling)

--- Main authors (for the naturalization program): ---

a. Rules and constraints (Polanyi, Pattee, Kauffman)
b. Function and normativity (Bickhard, Christensen)
c. Meaning and information (Biosemiotics, Collier, San Sebastian group)

2) Organizational principles in biology

--- Main authors (for organizational principles): ---

a. Self-organization and Closure (Varela, Rosen, Kauffman)
b. Dynamic/hierarchical decoupling (Simon, Pattee, San Sebastian group)
c. Reconstruction/reinterpretation of evolution theory (Salthe, Bruce &Weber, Winsatt, Kauffman)

3) A new way to think the traditional separation between methodological, epistemological and ontological issues.

a. New holism: Systems Biology, AL; Connectionist AI, situated robotics (Fox Keller, Langton, Brooks, Webb). Computer simulations as a new experimental domain (Emmeche, Casti, Dennett, DiPaolo). Modeling (mainly computational) is itself a complex process, requiring functional reinterpretation

b. Cognitive phenomena emerge from (certain complex biological) systems: Nature gets epistemologized. Complex recursive naturalization (Hooker & Christensen)

c. The complex interplay between ontology and epistemology (due to naturalization of ontological concepts and the naturalization of epistemology and its relation of inclusion within the sciences of biology, cognition and sociology), between them and methodology (the epistemological role of computer models for theoretical problems) reorganizes the relationship between domains.

Dr. Alvaro Moreno
PhD (Philosophy of Science)
Associate professor, Department of Logic and Philosophy of Science
University of the Basque Country

Mr. Xavier Barandiaran
Department of Logic and Philosophy of Science
University of the Basque Country

Dr. Kepa Ruiz-Mirazo
PhD (Philosophy of Science)
Post-doctoral Fellow, Department of Logic and Philosophy of Science
University of the Basque Country