EVOLUTIONARY COMPLEX SYSTEMS

I. B. Bálsamo
National Academy of Sciences of Buenos Aires, Argentina

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Contents

Summary

This article shows how evolution emerges from the complexity of a system. A self-contained description regards systems as wholes formed by elements, complexity as the multiplicity of relations among components, and evolution as the emergent property to explain the changes in structure and organization.

Historically, evolution has been regarded as a vital impulse of nature or a progressive tendency of culture and humanity. This linear understanding of evolution has progressively been replaced by cyclic models, by which the results of changes in the system affect the system itself. The terms associated are feedbacks and self-organization.

From the natural sciences to cultural and social sciences, the concept of evolution has been used as explanatory principle, mechanism, process, and emergent property, to explain the changes of organisms, organizations, and systems in their environment. As the concept of selection and variation, inherited from Darwinian evolutionary theory, evolution has been associated with the concept of adaptation. As a general concept of selection, variation, and re-stabilization, evolution explains the structural change, the genesis of forms, and the continuity of systems of any type. As systemic law of conservation and variation, evolution is a tool for research and development in science

and technology.

The theory and practice of sustainable development—by which each level of the hierarchy (physical, chemical, biological, social and cultural) is supported by the previous one—has, in theories of evolution of complex systems, a useful scientific and technological tool for designing, planning, monitoring, and evaluating different strategies and interventions.

Finally, with regard to the development of knowledge from the perspective of evolutionary complex systems, diversity has relevance for problem solving, as does compatibility between non-transcendent validation and the transcendent function of knowledge.

1. Conceptual Framework

Based on the general theory of evolution, evolutionary complex systems are usually distinguished as cases of catalytic systems. Evolutionary complex systems are considered not only as a theoretical approach but also as a model for such systems. The main concepts are explored below—systems, complexity, and evolution—and a self-contained description of evolutionary complex systems proposed.

1.1 Systems

There are many definitions of systems. They have in common the reference to wholes formed by connected and connecting parts. Since Aristotle, the basic and complex idea by which the whole is something over and above its parts, and not just the sum of them, has been at the core of system models and systemic thinking (see *Critical Systems Thinking*). This relationship is usually regarded as the defining feature of systems. The classic compactness of objects becomes a relational substance under the systemic light.

A system is a collection of parts or elements with changing interactions that form an integrated and consistent whole, isolatable from its surroundings. It may be a collection of states, where states are the elements of the system.

From a constructivist point of view the limits, boundaries, constraints, or restrictions of a system are delineated by the action of an observer. This perspective is compatible with a realist and determinist perspective by which systems specify their own limits, boundaries, and constraints in response to perturbations, interferences, and indeterminist relations. When certain relations of a system become invariant with respect to agents, systems are regarded as objects. The lack of a specific agent can be seen as the chance agent, or as an event that just happened.

By contrast to systems as objects, processes are sequences of stages. While certain constancy is typical of objects, ongoing change characterizes processes. Processes transform inputs into outputs. Although initial and final stages may be distinguished in processes, they may be referred to as infinite. When systems are regarded as processes, the objects under study become dynamic. When new properties emerge as the result of processes at system level, they are called emergent properties since they are not properties of the components or parts.

Methods for describing the dynamics of systems are employed to distinguish between structure and organization.

1.1.1 Structure

Structure is defined by the relations between or among the parts, elements, or components of a system. These relations become interactions when the constituent parts are agents that produce effects. The structure may also be regarded as multiple connections among connected and connecting parts.

Many definitions of systems are structurally based. They are basically formed by sets of internal and external relations of the system, and internal and external components of the system. This is the case with the system model by Mario Bunge, as presented in his 1996 book, *Finding Philosophy in Social Sciences*. This system model is comprised of three elements: composition, environment, and structure. Composition is the collection of the parts of system at a given time (for example, members of a community). Environment is the collection of things—not in the system—that are connected to parts of the system (for example, the physical surroundings of a community plus the human outsiders with whom members of the community have relationships). Structure is the collection of relations among members of the system plus the relations among these and those of the environment. The former is called the endostructure and the latter is the exostructure of the system (for example, the kinship relations inside the community, and the trade relations between the community and the outsiders, respectively). The part of the system whose components are linked directly to environmental items may be called the system boundary (for example, the representatives, salesmen, and public relations officers of a business firm constitute the latter's boundary).

These types of systemic definitions make it possible to pursue the differences in composition, environment, and/or structure of systems over time, and are complemented by more or less complex theories of change.

1.1.2 Organization

Other definitions of system distinguish between structure and organization. This is the case with the system definition which Humberto Maturana and Francisco Varela present in many of their works, especially in "*Autopoiesis, the Organization of Living Systems; its Characterization and a Model* (1974) and *The Tree of Knowledge* (1984). While structure is formed by the relations among components with their respective properties (for example, trade and kinship relations among the members of a community), organization is formed by those structures that give identity of class to the system (for example, density and quantity of people of an urban community, in contrast to a rural one).

When the system definition is based on the distinction between organization and structure, two domains are effectively differentiated—the logic-semantic level and the empirical-existing one, respectively. Organization evokes the Aristotelian *organon*, and becomes a conceptual tool with which to model systems. A system model that operates with the distinction between structure and organization may delineate the four scopes or domains that any complex unity contains:

(i) Domain of change of state or structural change: those differences that a system may undergo without loss of identity. Structural changes are differences in the components and/or in the relations among them, while changes of state are differences in the properties of the components.
(ii) Domain of destructive change: those differences in the organization of a system which produce loss of identity.
(iii) Domain of productive interactions: those actions between the system and the environment which produce changes of state or structural changes.
(iv) Domain of destructive interactions: those actions between the system and the environment which produce changes with loss of identity.

Thus, for example, interactions such as the ecological disaster of Chernobyl produce the destruction of an urban community, while interactions like the growth of services maintain the identity of an urban community.

Since organization may be given or in process, complexity requires a differentiated treatment.

1.2 Complexity

Relationship is a condition of complexity of systems. When at least two elements or parts are connected, it is defined as complex in a wise way. Complexity increases with the amount of connections among parts. When relations, components, and properties increase in a proportional manner, their growth is depicted by a linear graph, complexity is characterized as linear and leads to predictability.

The multiplicity of connections among connected and connecting components introduces difficulties and problems in the analysis of systems, and may result in the destruction of the studied object. In such conditions, an extreme sensitivity of analysis is recommended, that deconstructs the system through the mode of composition or the simulation by computer. There are cases of entwined connections among connected and connecting parts in which connections constitute the substance of the parts, in the sense that they do not exist without their connectiveness.

In a more strict sense, complexity is defined as the impossibility of knowing the whole by the part, and is characterized by a break in symmetry, by which no part or aspect of a complex entity can provide sufficient information to actually or statistically predict the properties of the others parts. This symmetry-breaking compounds the difficulty of modeling associated with complex systems, as described by Francis Heylighen in *The Growth of Structural and Functional Complexity during Evolution* in 1996, and evokes in complexity terms the Aristotelian definition of system, by which it is impossible to reconstruct the whole by the part.

According to Heylighen, complexification, or the process by which complexity increases, is defined as a combination of differentiation and integration in at least the spatial, temporal, and scale dimensions.

Complexity, in a strict sense, is referred to as the emergence of new properties—whole properties which are non-reducible to the properties of the parts or components. It generates new levels of organization, which constitute hierarchies or heterarchies when they are referred to other organizations in the environment of the system of reference. These differences in degrees of connectiveness, or levels of implications, increase the difficulty of measuring complexity.

From the perspective of the philosophy and theory of knowledge, complexity becomes the reason used to justify the absence of a complete knowledge of something, or a complete system modeling, from the realist's point of view. Because any system model implies a knowable complexity, completeness is regarded as the known complexity from the constructivist's point of view.

A constructivist, dynamic, and processual vision of systems, by which emergent properties are regarded as outputs that connect themselves with inputs, introduces the notion of feedbacks. These are effects, which feed back to causes. There are two types of feedbacks, negative and positive. A feedback is characterized as negative when it tends to stabilize the system and results in a certain order, while a positive feedback leads to instability, or chaotic configurations. Feedbacks result in nonlinearities and constraints on system behavior, leading to unpredictability. In a strict sense, nonlinearity characterizes systems whose behavior is not changing proportionally to the agents of change (for example, small perturbations can produce drastic and large changes in systems) (see *Chaos*).

In a general sense, feedback processes introduce more complexity into systems, and are associated with the functional differentiation of subsystems of control, self-regulation, self-organization, and teleonomy.

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Biographical Sketch

Iris B. Bálsamo is Licentiate in Psychology, Doctor in Sociology and fellow of the National Academy of Sciences of Buenos Aires, Argentina. She researched and taught at the Faculty of Philosophy and Humanity, National University of Córdoba, and Faculty and Museum of Natural Sciences, National University of La Plata, Argentina, and is author of several works mainly on explanation in Social Sciences with a special focus on Systems Science.