Closure, causal

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Definition

In biological systems, closure refers to a holistic feature such that their constitutive processes, operations, and transformations (1) depend on each other for their production and maintenance and (2) collectively contribute to determine the conditions at which the whole ► organization can exist.

According to several theoretical biologists, the concept of closure captures one of the central features of biological organization since it constitutes, as well as evolution by natural selection, an emergent and distinctively biological causal regime. In spite of an increasing agreement on its relevance to understand biological systems, no agreement on a unique definition has been reached so far.

Characteristics

The concept of closure plays a relevant role in ► biological explanation since it is taken as a naturalized grounding for many distinctive biological dimensions, as purposefulness, normativity, and functionality (Chandler and Van De Vijver 2000).

The contemporary application of closure to the biological domain comes from a philosophical and theoretical tradition tracing back at least to Kant who claimed, in the *Critique of Judgment*, that biological systems should be understood as natural purposes (*Naturzwecke*), i.e., systems in which the parts are reciprocally causes and effects of the others, such that the whole can be conceived as organized by itself, self-organized. The essence of living system is a form of internal and circular causality between the whole and the parts, distinct from both efficient causality of the physical world and the final causality of artifacts (Kant 1985).

One of the most influential contemporary characterizations of closure in the biological domain has been provided by Francisco Varela (1979). In his account, he builds on an algebraic notion, according to which “a domain K has closure if all operations defined in it remain within the same domain. The operation of a system has therefore closure, if the results of its action remain within the system (Bourgine and Varela 1992, p. xii).”

Applied to biological systems, closure is realized as what Varela labels *operational* (or *organizational*) *closure*, which designates an organization of processes such that “(1) the processes are related as a network, so that they recursively depend on each other in the generation and realization of the processes themselves, and (2) they constitute the system as a unity recognizable in the space (domain) in which the processes exist” (Varela 1979, p. 55).

It should be noted that Varela himself has proposed, over time, slightly different definitions of operational closure. In addition, more recent contributions have introduced a theoretical distinction between organizational and operational closure. Whereas “organizational” closure indicates the abstract network of relations that define the system as a unity, “operational”

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closure refers to the recurrent dynamics and processes of such a system (Thompson 2007).

In Varela's view, operational closure is closely related to ▶ autonomy, the central feature of living organization. More precisely, he enunciates the "Closure Thesis," according to which "every autonomous system is operationally closed" (Varela 1979, p. 58). In principle, the class of autonomous systems realizing operational closure is larger than the class of biological systems. As a consequence, operational closure is taken as a necessary but not sufficient condition to define biological organization. Biological systems, in fact, constitute a subclass of autonomous systems, which realize a specific form of operational closure, which Varela labels, with Humberto Maturana, ▶ autopoiesis (Varela 1979). The specificity of operational closure as autopoiesis is that, unlike other possible forms, it describes the system at the chemical and molecular level, and supposes relations of material production among its constituents.

A crucial distinction is usually made between organizational/operational and *material* closure, where the latter indicates the absence or incapacity to interact. While being organizationally closed, biological systems are structurally coupled with the environment, with which they exchange matter, energy, and information. The concept of biological closure implies then a distinction between two causal levels, an open and a closed one – an issue which have been more explicitly addressed by the account proposed by Robert Rosen (Rosen 1991).

Rosen's account is based on a rehabilitation and reinterpretation of the Aristotelian categories of causality and, in particular, on the distinction between efficient and material cause. Let us consider an abstract mapping f between the sets A and B, such that f: $A => > B$. Represented in a relational diagram, we have (Fig. 1):

When applied to model natural systems, Rosen claims that the hollow-headed arrow represents material causation, a flow from A to B, whereas the solid-headed arrow represents efficient causation, a ▶ constraint exerted by f on this flow.

Rosen's central thesis is that "a material system is an organism [a living system] if, and only if, it is closed to efficient causation" (Rosen 1991, p. 244), whereas a natural system is closed to efficient causation if and only if its relational diagram has a closed path that contains all the solid-headed arrows. It is worth noting that, unlike the varelian tradition, Rosen takes closure as the *definition* of biological organization.

According to Rosen, the central feature of a biological system consists in the fact that all components having the status of efficient causes are materially produced by and within the system itself. At the most general level, closure is realized in biological systems among three classes of efficient causes corresponding to three broad classes of biological ▶ functions that Rosen denotes as *metabolism* (f: A=>> B), *repair* (Φ: B=>> f), and *replication* (B: f=>>Φ) (Fig. 2).

By providing a clear-cut theoretical and formal distinction between material and efficient causation, Rosen's characterization explicitly spells out that biological organization consists of two coexisting causal regimes: closure to efficient causation, which grounds its unity and distinctiveness, and openness to material causation, which allows material, energetic, and informational interactions with the environment.

More recently, the scientific work on biological closure has been developed in various directions (Chandler and Van De Vijver 2000). In particular, a thriving research line has specifically focused on the critical nature of systems realizing closure, which must maintain a continuous flow of energy and matter with the environment in conditions far from thermodynamic equilibrium. To capture this dimension of closure, Stuart Kauffman has proposed the notion of Work-Constraint cycle (Kauffman 2000).

The Work-Constraint cycle represents an interpretation of organizational closure that links the idea of "work" to that of "▶ constraint," the former being defined, as "constrained release of energy into relatively few degrees of freedom." A system realizes a Work-Constraint cycle if it is able to use its work to regenerate at least some of the constraints that make work possible. The cycle is a thermodynamic irreversible process, which dissipates energy and requires a coupling between exergonic (spontaneous, which release energy) and endergonic (non spontaneous, which require energy) reactions, such that exergonic processes are constrained in a specific way to produce a work, which can be used to generate endergonic processes, which in turn generate those constraints canalizing exergonic processes. In Kauffman's terms: "Work begets constraints beget work" (Kauffman 2000).

A complementary account of closure has been proposed by Howard Pattee, who focused on its informational dimension (Pattee 1982). In his view, biological organization consists of the integration of two intertwined dimensions, which cannot be understood separately. On the one side, the organization realizes a dynamic and autopoietic network of mechanisms and processes, which defines itself as a topological unit, structurally coupled with the environment. On the other side, it is shaped by the material unfolding of a set of symbolic instructions, stored and transmitted as genetic ► information.

According to Pattee, the dynamic/mechanistic and informational dimensions realize a distinct form of closure between them, which he labels *semantic closure*. By this notion, he refers to the fact that while symbolic information, to be such, must be interpreted by the dynamics and mechanisms that it constrains, the mechanisms in charge of the interpretation and the "material translation" require that very information for their own production. Semantic closure, as an interweaving between dynamics and information, constitutes then an additional dimension of organizational closure of biological systems, complementary to the operational/efficient one.

Cross-References

- ► Autonomy
- ► Constraint
- ► Emergence
- ► Explanation, Biological
- ► Explanation, Functional
- ► Function
- ► Holism
- ► Information, Biological
- ► Organization

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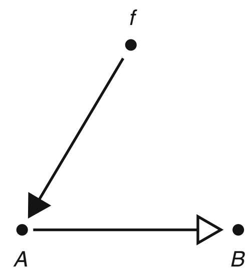
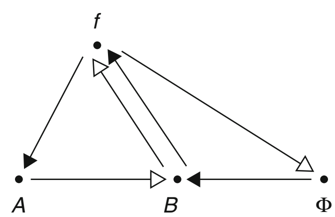
Closure, Causal, Fig. 1





Closure, Causal, Fig. 2