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Closure, causal

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2 Closure, Causal

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7 Definition

8 In biological systems, closure refers to a holistic fea-
9 ture such that their constitutive processes, operations,
10 and transformations (1) depend on each other for their
11 production and maintenance and (2) collectively con-
12 tribute to determine the conditions at which the whole
13 ► **organization** can exist.

14 According to several theoretical biologists, the con-
15 cept of closure captures one of the central features of
16 biological organization since it constitutes, as well as
17 evolution by natural selection, an emergent and dis-
18 tinctively biological causal regime. In spite of an
19 increasing agreement on its relevance to understand
20 biological systems, no agreement on a unique defini-
21 tion has been reached so far.

22 Characteristics

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

28 The contemporary application of closure to the bio-
29 logical domain comes from a philosophical and

theoretical tradition tracing back at least to Kant who 30
claimed, in the *Critique of Judgment*, that biological 31
systems should be understood as natural purposes 32
(*Naturzwecke*), i.e., systems in which the parts are recip- 33
rocally causes and effects of the others, such that the 34
whole can be conceived as organized by itself, self- 35
organized. The essence of living system is a form of 36
internal and circular causality between the whole and the 37
parts, distinct from both efficient causality of the phys- 38
ical world and the final causality of artifacts (Kant 1985). 39

One of the most influential contemporary charac- 40
terizations of closure in the biological domain has been 41
provided by Francisco Varela (1979). In his account, 42
he builds on an algebraic notion, according to which “a 43
domain K has closure if all operations defined in it 44
remain within the same domain. The operation of 45
a system has therefore closure, if the results of its 46
action remain within the system (Bourgine and Varela 47
1992, p. xii).” 48

Applied to biological systems, closure is realized as 49
what Varela labels *operational* (or *organizational*) 50
closure, which designates an organization of processes 51
such that “(1) the processes are related as a network, so 52
that they recursively depend on each other in the gen- 53
eration and realization of the processes themselves, 54
and (2) they constitute the system as a unity recogniz- 55
able in the space (domain) in which the processes 56
exist” (Varela 1979, p. 55). 57

It should be noted that Varela himself has proposed, 58
over time, slightly different definitions of operational 59
closure. In addition, more recent contributions have 60
introduced a theoretical distinction between organiza- 61
tional and operational closure. Whereas “organiza- 62
tional” closure indicates the abstract network of 63
relations that define the system as a unity, “operational” 64

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

67 In Varela's view, operational closure is closely
68 related to ► **autonomy**, the central feature of living
69 organization. More precisely, he enunciates the "Clo-
70 sure Thesis," according to which "every autonomous
71 system is operationally closed" (Varela 1979, p. 58). In
72 principle, the class of autonomous systems realizing
73 operational closure is larger than the class of biological
74 systems. As a consequence, operational closure is
75 taken as a necessary but not sufficient condition to
76 define biological organization. Biological systems, in
77 fact, constitute a subclass of autonomous systems,
78 which realize a specific form of operational closure,
79 which Varela labels, with Humberto Maturana,
80 ► **autopoiesis** (Varela 1979). The specificity of opera-
81 tional closure as autopoiesis is that, unlike other pos-
82 sible forms, it describes the system at the chemical and
83 molecular level, and supposes relations of material
84 production among its constituents.

85 A crucial distinction is usually made between orga-
86 nizational/operational and *material* closure, where the
87 latter indicates the absence or incapacity to interact.
88 While being organizationally closed, biological sys-
89 tems are structurally coupled with the environment,
90 with which they exchange matter, energy, and infor-
91 mation. The concept of biological closure implies then
92 a distinction between two causal levels, an open and
93 a closed one – an issue which have been more explic-
94 itly addressed by the account proposed by Robert
95 Rosen (Rosen 1991).

96 Rosen's account is based on a rehabilitation and
97 reinterpretation of the Aristotelian categories of causal-
98 ity and, in particular, on the distinction between efficient
99 and material cause. Let us consider an abstract mapping
100 f between the sets A and B , such that $f: A \Rightarrow B$.
101 Represented in a relational diagram, we have (Fig. 1):

102 When applied to model natural systems, Rosen
103 claims that the hollow-headed arrow represents mate-
104 rial causation, a flow from A to B , whereas the solid-
105 headed arrow represents efficient causation,
106 a ► **constraint** exerted by f on this flow.

107 Rosen's central thesis is that "a material system is
108 an organism [a living system] if, and only if, it is closed
109 to efficient causation" (Rosen 1991, p. 244), whereas
110 a natural system is closed to efficient causation if and
111 only if its relational diagram has a closed path that
112 contains all the solid-headed arrows. It is worth noting

113 that, unlike the varelian tradition, Rosen takes closure
114 as the *definition* of biological organization.

115 According to Rosen, the central feature of
116 a biological system consists in the fact that all compo-
117 nents having the status of efficient causes are materially
118 produced by and within the system itself. At the most
119 general level, closure is realized in biological systems
120 among three classes of efficient causes corresponding
121 to three broad classes of biological ► **functions** that
122 Rosen denotes as *metabolism* ($f: A \Rightarrow B$), *repair*
123 ($\Phi: B \Rightarrow f$), and *replication* ($B: f \Rightarrow \Phi$) (Fig. 2).

124 By providing a clear-cut theoretical and formal
125 distinction between material and efficient causation,
126 Rosen's characterization explicitly spells out that bio-
127 logical organization consists of two coexisting causal
128 regimes: closure to efficient causation, which grounds
129 its unity and distinctiveness, and openness to material
130 causation, which allows material, energetic, and infor-
131 mational interactions with the environment.

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

142 The Work-Constraint cycle represents an interpreta-
143 tion of organizational closure that links the idea of
144 "work" to that of "► **constraint**," the former being
145 defined, as "constrained release of energy into relatively
146 few degrees of freedom." A system realizes a Work-
147 Constraint cycle if it is able to use its work to regenerate
148 at least some of the constraints that make work possible.
149 The cycle is a thermodynamic irreversible process,
150 which dissipates energy and requires a coupling
151 between exergonic (spontaneous, which release energy)
152 and endergonic (non spontaneous, which require
153 energy) reactions, such that exergonic processes are
154 constrained in a specific way to produce a work,
155 which can be used to generate endergonic processes,
156 which in turn generate those constraints canalizing
157 exergonic processes. In Kauffman's terms: "Work
158 begets constraints beget work" (Kauffman 2000).

159 A complementary account of closure has been pro-
160 posed by Howard Pattee, who focused on its informa-
161 tional dimension (Pattee 1982). In his view, biological

162 organization consists of the integration of two
 163 intertwined dimensions, which cannot be understood
 164 separately. On the one side, the organization realizes
 165 a dynamic and autopoietic network of mechanisms and
 166 processes, which defines itself as a topological unit,
 167 structurally coupled with the environment. On the
 168 other side, it is shaped by the material unfolding of
 169 a set of symbolic instructions, stored and transmitted as
 170 genetic ► [information](#).

171 According to Pattee, the dynamic/mechanistic and
 172 informational dimensions realize a distinct form of
 173 closure between them, which he labels *semantic clo-*
 174 *sure*. By this notion, he refers to the fact that while
 175 symbolic information, to be such, must be interpreted
 176 by the dynamics and mechanisms that it constrains, the
 177 mechanisms in charge of the interpretation and the
 178 “material translation” require that very information
 179 for their own production. Semantic closure, as an
 180 interweaving between dynamics and information, con-
 181 stitutes then an additional dimension of organizational
 182 closure of biological systems, complementary to the
 183 operational/efficient one.

184 **Cross-References**

- 185 ► [Autonomy](#)
- 186 ► [Constraint](#)
- 187 ► [Emergence](#)

- [Explanation, Biological](#) 188
- [Explanation, Functional](#) 189
- [Function](#) 190
- [Holism](#) 191
- [Information, Biological](#) 192
- [Organization](#) 193

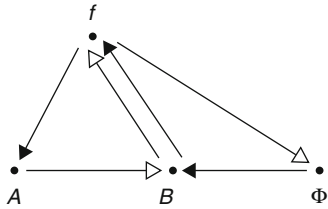
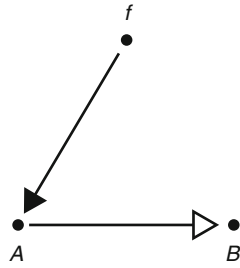
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Uncorrected Proof

Closure, Causal, Fig. 1



Closure, Causal, Fig. 2

Uncorrected Proof