▶ Constant (C) Domain
▶ Diversity (D) Gene
▶ Gene Type
▶ IMGT® Information System
▶ IMGT-ONTOLOGY
▶ IMGT-ONTOLOGY, IDENTIFICATION Axiom
▶ IMGT-ONTOLOGY, Leafconcept
▶ Immunogenetics
▶ Immunoinformatics
▶ Joining (J) Gene
▶ Variable (V) Gene

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Constant Domain

▶ Constant (C) Domain

Constant Gene

▶ Constant (C) Gene

Constant

▶ Constant (C) Gene

Constraint

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Synonyms

(Approx.) boundary condition; Control

Definition

Constraint refers to a reduction of the degrees of freedom of the elements of a system exerted by some collection of elements, or a limitation or bias on the variability or possibilities of change in the kind of such elements.

Although the term has several meanings in diverse scientific fields, the idea of a constraint is usually employed in relation to conceptualizations in terms of levels or ▶ hierarchies. Some general features of constraints such understood are the following: constraints do not interact with the elements they influence and their dynamics; they arise from dynamics at different levels of ▶ organization; constraint relations are always asymmetric, and may give rise to new phenomena.

In the tradition of the theories of emergent evolution of the early twentieth century and, even clearer, in the theory of levels of integration of the organicist tradition of the 1930s, higher levels are understood as arising from lower-level elements or processes, whose laws all obey, but concurrently exerting some specific influence on those very elements or processes (see Blitz 1992). Later on, in most approaches to hierarchy theory, the very concept of constraint is profusely used to account for the specificity of nontrivial inter-level relation, where lower level and upper level act upon each other but in different ways (see, e.g., Allen and Starr 1982; Salthe 1985). Even the introduction of some specific senses of constraint in evolutionary biology (as developmental constraints and historical constraints) is due to the attempt to accommodate different explanations, stemming from diverse factors or forces, and is a potential alternative, if not rival, to adaptive selection, in an unavoidably multilevel explanatory construction.

Characteristics

The development of more specific characterizations of constraint (or alike) are attempts to spell out the interaction among levels of organization by deriving them from epistemologically legitimate concepts grounded in the physical sciences or in their explanatory armory.

The difficult issue of interlevel relation is rendered more concrete by Polanyi's (1968) account of organisms (and machines) as dual control systems, which relies on an indistinct concept of boundary conditions. Polanyi deliberately employs the machine example to introduce his idea of boundary conditions "harnessing the laws of nature" that govern matter and the forces acting on it. In a machine, the harnessing is exerted with a goal, which makes easier to describe the dual control: the design of the machine, by which the machine does what it is intended for, and the laws of physics and chemistry, that the components of the machine and the machine itself must obey.

In the organism "its structure serves as a boundary condition harnessing the physical-chemical processes by which its organs perform their functions" (Polanyi 1968, 1308). The machine analogy goes on to compare morphogenesis, as the process that develops that structure, with the shaping of the machine. Yet, as Polanyi emphasizes, the analogy ends here: Although both are systems under dual control (unlike inanimate systems which may exhibit boundary conditions without being subject to dual control), organisms are not artificially designed. Therefore, the harnessing principle in organisms has to be autonomous (▶ Autonomy), task that Polanyi attributes to the informational account of heredity.

Is precisely this the challenge that Pattee (see, e.g., 1968, 1972) undertakes in his research on the origin of life and the nature of biological function and heredity, using the concept of constraint as an explanatory tool derived from Mechanics. He develops in several papers the concept and the relevant distinction between holonomic (▶ Constraint, Holonomic) (structural-like) and non-holonomic (▶ Constraint, Non-holonomic) (▶ functional-like) kinds. Pattee claims that, in order to explain hereditary storage, transmission, and the action of genetic instructions, we should understand them in terms of non-holonomic constraints acting in the context of a very specific kind of interlevel relation (semantic closure).

Following his description we may recall that, in physics, initial conditions and laws of movement provide, in principle, an exhaustive description of the possible behavior, future and past, of a mechanical system. No other conditions are needed. The choice of the coordinates of the system that specifies its space of configuration or space of states defines all the possible degrees of freedom in the system or all the possible trajectories of movement of its elements. These coordinates establish the variables of the movement equations of the system. In this context, constraints are those additional equations that are introduced as auxiliary conditions in order to define the specific mechanical system subject to calculation (see, e.g., Sommerfeld 1952). In other areas of Physics, constraints may be expressed in a more general form as boundary conditions. In Chemistry, constraints refer to the steady state of elementary particles (chemical bonds). When referred to dissipative systems, the concept acquires an even more specific sense as it becomes dynamical (an unstable macroscopic pattern that remains as long as there is energy contribution). Finally, its presence is patent in any form of biological regulation (starting from a membrane) and more controversial in its contribution to the understanding of evolutionary paths. In social and artificial systems, it is clearly manifested in the form of rules. In sum, constraints refer to certain conditions or rules additional to the laws of dynamics (that are taken as basic), that rule/govern the behavior of the elements and that arise from their aggregation.

Whereas natural laws are, in principle, inexorable and incorporeal, constraints are, by necessity, accidental or arbitrary, and require some distinct physical materialization (as molecules, membranes, or surfaces). Constraints are alternative descriptions of part of the system. Namely, constraints cannot be expressed in the same language than the microscopic description of matter. In fact, what a constraint does is to selectively ignore microscopic degrees of freedom in order to obtain a simplification in the prediction or explanation of movement. The concept of constraint means a selective loss of detail or a predetermined rule about what is going to be ignored.

Therefore, for Physics constraining forces are, unavoidably, linked to a new hierarchical level of description. When in Physics a constraint equation is added to the equations of movement, we are always dealing with two languages at the same time. The language of the equation of movement relates the detailed trajectory or the state of the system with dynamical time, whereas the language of the constraint does not deal at all with the same kind of system, but with another situation in which the dynamical detail has been purposely ignored. In other words, constriction forces are not detailed forces of the individual particles but forces of the collections of particles or, sometimes, forces of simple units averaged out in time. In any case, some form of statistical averaging process has substituted microscopic detail. In Physics, then, in order to describe a constraint, the detailed dynamical description has to be abandoned. A constraint requires, therefore, an alternative description.

Another relevant contribution to naturalize the concept of constraint in the biological domain has been provided by theoretical biologist Stuart Kauffman, who has recently proposed the idea of the "Work-Constraint cycle" (Kauffman 2000, 2003). The Work-Constraint cycle is supposed to capture what Kauffman takes as a central feature of all biological organisms, namely, the fact of acting "on their own behalf" (Kauffman 2003, 1089). Whereas this idea appears to be in accordance with common intuition, Kauffman's scientific challenge consists in giving a naturalized and consistent account of it. The concept of a Work-Constraint cycle plays precisely this role. The main idea is to link the idea of action to that of "work," the latter being defined, following Atkins, as "constrained release of energy into relatively few degrees of freedom" (Kauffman 2003, 1094). In this definition, the concepts of work and constraint are related: work is constrained release of energy. This connection gives a way to interpret the slogan acting "on their own behalf." A system acts on its own behalf if it is able to use its work to regenerate at least some of the constraints that make work possible. When this occurs, a Work-Constraint cycle is realized. In physical terms, it requires very specific conditions to occur. Actually, the cycle is inevitably a thermodynamic irreversible process, which dissipates energy and requires couplings between exergonic (spontaneous, energy releasing) reactions and endergonic (non-spontaneous, energy requiring) ones, such that exergonic processes are constrained in a specific way to produce work that may 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).

In evolutionary biology, the concept of constraint has mainly been introduced as a challenge by developmental approaches regarding the scope of selection and the extent to which ▶ adaptation remains the main explanatory factor (see ▶ Explanation, Developmental). Besides the specific issue of connecting developmental with evolutionary accounts, the concept of constraint plays an important role, for instance, in the criticisms to adaptationism, in the discussion regarding the relevance of stasis and other macroevolutionary patterns, or in the morphologically oriented proposals of structuralism or ▶ complexity theories (see Orzack and Sober 2001).

In an already classic paper that may be considered to be an attempt to build a "consensus" position on the subject, a developmental constraint is defined as "a bias on the production of variant phenotypes or a limitation on phenotypic variability caused by the structure, character, composition, or dynamics of the developmental system" (Maynard Smith et al. 1985, 266). The origin of this bias or limitation may be attributed to various sources (materiality, genetic dynamics, evolutionary pathways, complexity regime, etc.) but what is agreed upon is that they have an impact in evolution. A distinction is also drawn between universal constraints, deriving from general laws of physics or from invariant properties of some material or complex systems, and local constraints, confined to particular taxa.

Amundson (1994), while accepting that constraint "implies some sort of restriction on variety or on change," claims that the key rests on the answer to the question: "What is being constrained?" Thus, he identifies two possible answers depending on whether the explanandum is adaptation or form. We would therefore have to distinguish between understanding the effect of developmental principles on evolution as constraints on adaptation, that is, as restrictions imposed by embryology on the adaptive optimality of adult organisms on the potential of adaptation, or constraints on form, in the sense that in the morphospace there are morphologies that cannot be achieved by the process of development.

This distinction is orthogonal to the previous one between local and universal kinds of constraints since both of them may operate, irrespectively, on the prospects of reaching more optimal adaptations and on the scope of generation of organic form.

Sometimes, other kinds of constraints are mentioned in the context of contending evolutionary explanations, even if they are not generally accepted as specific constraints. For instance, historical constraints are often brought up to contrast with developmental ones though maintaining the same feature of imposing restriction on adaptation, but they are due to more "evolutionary" common factors such as contingency or accident creating some kind of bias. Ecological constraints can also be sometimes evoked.

Regarding these uses and besides those distinctions about how to understand the concept, there is another point worth mentioning, since it allows connecting the concept of developmental constraint with the more general idea defined in the beginning of this entry. According to Schwenk and Wagner (2003), this collective definition highlights the separation between constraint and selection by distinguishing the "generation of variation from the operation of selection on that variation" (p. 54). In this sense, the force of selection would assume the role of the general law upon which some rules are imposed and, here too, some potential degrees of freedom are reduced due to what Polanyi was calling boundary conditions and what Pattee called constraints in their more general approaches.

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Cross-References

▶ Adaptation
▶ Autonomy
▶ Complexity
▶ Constraint, Holonomic
▶ Constraint, Non-holonomic
▶ Explanation, Developmental
▶ Explanation, Evolutionary
▶ Explanation, Functional
▶ Functional
▶ Hierarchy
▶ Interlevel Causation
▶ Organization

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