L&PS – Logic and Philosophy of Science
Vol. IX, No. 1, 2011, pp. 381-388

On the Role of Constraints in the Emergence of Biological Organization

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ABSTRACT. In this paper we provide some theoretical guidelines for the characterization of the specificity of biological systems in terms of organization and constraints. In the first place we advocate the view according to which a sound account of biological organization requires an appeal to emergent causation, and we propose a theoretical justification of emergence against existing criticisms by considering it as a causal power stemming from the relational properties of material configurations. Then, by interpreting constraints as a specific form of this emergent causal power, we propose a distinction between the roles played by constraints in physical and biological systems. As a result we provide a possible definition of biological organization as a closed network of co-dependent and internally produced constraints.

Published by L&PS – Logic and Philosophy of Science
http://www2.units.it/ ~episteme — ISSN: 1826-1043

1. Introduction

Facing the question "*What is Life?*" (Schrödinger, 1944) - that is, dealing with the problem of the specificity of biological systems – requires also to take into consideration the possible relations that hold between the biological and the physico-chemical domains: whether or not adequate explanations in biology require appealing to a specific causal regime, emergent from and irreducible to the physico-chemical one.

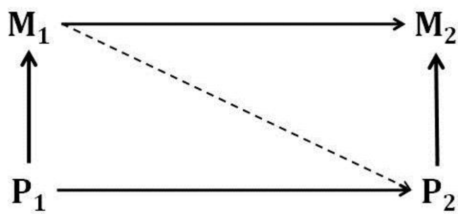
A tradition of thought that dates back to Kant's notion of *natural purposes* (Kant, 1790) and Bernard's concept of *constancy of internal milieu* (Bernard, 1965) has attempted to provide an answer to this issue through an analysis in terms of organization. During the last forty years the idea that the constitutive organization of biological systems does realize a distinctive causal regime has been put forward by a number of pioneering theoretical elaborations known under the wide denomination of "biological autonomy" (Piaget, 1967; Rosen, 1972, 1991; Maturana and Varela, 1980; Ganti, 1975; Kauffman, 2000; Ruiz-Mirazo and Moreno, 2004).

Despite the differences among the various formulations, the common idea that characterizes this theoretical perspective is that the distinctive feature of biological systems consists in that they realize a self-specified and self-maintaining organization: a network of processes of production and transformation of components that realize the same network that produces them, such that the system can be said to be globally able to self-maintain, despite the continuous changes at the level of its structural constituents and the perturbations triggered by the environment. The common focus of the analysis, besides the properties of individual physico-chemical constituents, is the global unitary mechanism of conservation of organization.

The idea of global self-maintenance seems to require more than just one order of causes, and its self-referential character posits the question whether or not it realizes a form of inter-level causation. Yet, the relations between organization, self-maintenance and inter-level causation are controversial and still under scrutiny, and no clear argument in favor of the emergent or reductionist position has been formulated so far. In this paper we will propose and defend a position of the first kind, focused on the irreducibility and specificity of the biological domain.

2. A defence of Emergence

One of the main challenges to emergence, that any emergentist framework needs to deal with, is constituted by Kim's *Overdetermination* or *Exclusion Argument* (Kim, 1998). Briefly, Kim's position claims that any account of emergence necessarily needs three elements, namely *supervenience*, *functional irreducibility* and *downward causation*. His argument against emergence then proceeds as follows. If an emergent property M_1 emerges from its basal conditions P_1, and M_1 is said to have some causal effect at the emergent level on another property M_2 then, due to the relation of supervenience, M_1 must also have a causal effect on P_2, the basal conditions of M_2 (downward causation). But P_2 is already sufficiently caused at the basal level by P_1, as shown in the following scheme.



The result is an over-determined system in which both M_1 and P_1 are nomologically sufficient for P_2. As a consequence - given that P_1 necessary and sufficient for M_1, due to the supervenience relation – Kim's *Exclusion Argument* states that M_1 is dispensable as an effective cause in the system and, therefore, the emergent level is epiphenomenal.

This argument implies a causal drain that makes biological explanation extremely problematic. Concepts like "integration", "control", "regulation" etc., in fact, would have no intrinsic causal power. They would constitute, at best, heuristic tools. The same can be said of a theoretical characterization of the living with respect to physico-chemical systems, the former being just epiphenomenal and reducible to the properties of its basic constituents.

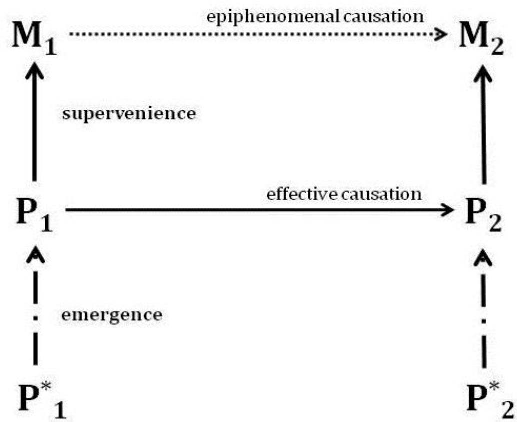
In order to deal with Kim's criticism, our argument in defense of emergence proceeds by considering three different kinds of properties - namely *global*, *configurational* and *basic* (*intrinsic*) ones – by separating supervenience and emergence, and by placing them on two different levels.

Firstly we reinterpret supervenience as a relation holding between global properties of a whole (M as a supervenient property) and properties P of *configurations* of components. It is necessary to specify here that the latter are different from properties of mere collections of constituents taken separately.

As such, they are possessed by components as components of a system, and they appear only when the configuration is effectively realized.

According to this idea, supervenience consists in a relation of *constitution* rather than a causal one. It is a way of renaming a collection of configurational properties. This implies that supervenient properties are reducible to properties of configurations of components, since the very notion of component itself already includes relational properties. At this step, therefore, Kim's Exclusion Argument still applies.

The subsequent step of our argument consists in redefining emergence as a relation that holds between the properties (P) of a configuration and those (P^*) of its emergent base. While supervenient properties have no distinctive causal powers with respect to the configurational ones, the configuration itself does possess irreducible properties to which we can ascribe causal powers without falling under Kim's argument. The reason is that new relations, as such, are not functionally reducible to the collections of constituents taken separately. More generally a configuration is irreducible – and, thus, emergent – to whatever other entity that does not actually possess the same set of properties. This also implies that the emergent configuration does not supervene on its basis.



Following this definition, three main kinds of emergent base can be distinguished for a same configuration. A configuration, in fact, is emergent on: (1) the properties of whatever proper *subset* of its constituents P^*_{sset}; (2) the properties P^*_{sstr} of its *substrate* – that is, the collection of its constituents taken separately, the potential ingredients of the system as if they were not components; (3) the properties P^*_{surr} of its *surroundings* – that is, the elements that do not constitute the configuration itself.

This is a basic and broad account of emergence that, nevertheless, has the following advantages. The first is that it can justify irreducibility without necessary denying the thesis of the inclusivity of levels, which states that higher levels are build upon lower ones and do not violate lower level laws. Secondly, it does not necessarily imply inter-level causation and, as a consequence, it is not subject to the conceptual problems related to it. In the third place it justifies from the theoretical point of view the appeal to different domains of descriptions, like the biological one, characterized by observables and relations which are not present in whatever emergent basis.

3. Constraints in Physics and Biology

The term "constraint" usually refers to a relation which takes place between a system and its surroundings. It is an element introduced as an alternative description that provides the missing specification in those cases in which the behavior of the system under study is underspecified (e.g. the boundary conditions). A typical example is constituted by the sliding of an object along an inclined plane. The latter, as the boundary condition of the system, allows the description of the movement of the object by reducing its degrees of freedom.

According to the framework introduced in the previous section, constraints are causal effects produced by emerging properties of configurations. They are, in fact, emergent from P^*_{sset}, P^*_{sstr} and, especially, from their surroundings P^*_{surr} – that is, the object they exert the constraining action on. To the extent that they can be defined as emergent, they imply the reference to at least two orders of causes, concerning respectively the basal properties and the emergent ones. As such they can be considered as second order causes that act in addition to other causes on which they emerge, without necessarily involving inter-level causation.

The appeal to the role of constraints in order to build a satisfactory description of a system is ubiquitous in natural sciences. Nonetheless constraints are often used to explain the specificity of the emergent causal regime of biological systems (Pattee, 1972). Therefore, besides the theoretical justification of their emergent causal power we need a specification of the role they play in living systems.

As exemplified by the simple case of the inclined plane, in physical processes the constraining relation is usually *asymmetrical* and *extrinsic*. It is assumed as a prerequisite to the description of the object of study, and it consists in a set of external boundary conditions which are not affected by the dynamics of the system they act on.

In living systems, in turn, the relation between dynamics and constraints is more complex and, in some sense, unique: considering just the relation between the system and its surroundings is not sufficient. In realizing their self-production and self-maintenance, in fact, organisms separate their internal environment from the external one and self-specify the former through the realization of internally generated constraints that act on their own dynamics. In doing so, they produce and maintain a subset of their own boundary conditions.

In the context of the internal dynamics of living systems, therefore, the constraining regime has the following distinctive properties:

1. Unlike physical constraints, biological ones are affected by the same dynamics they act on.
2. Internal constraints do not merely influence the behavior of elements of the system –e.g. decreasing their degrees of freedom. They play also a generative role. By contributing to the specification of the internal environment of the organism as boundary conditions that allow the processes of production of components to take place, they enable the existence of other structures in the same system.
3. Each structure which exerts this kind of constraining action, being produced by the system, depends on another constraining structure inside the system for the specification of its conditions of existence.

4. Conclusive remarks: biological organization

What is realized in living systems is a cycle of actions on the conditions of existence of structures and processes. In other words organisms are *organized* as closed emergent configurations of constraints. The living organization assumes the form of a mutual dependence between internally produced constraints such that: for each constraint C_i, (at least some of) the boundary conditions required for its maintenance are determined by the immediate action of another constraint C_j, whose maintenance depend in turn on C_i as an immediate constraint (Mossio and Moreno, 2010). This emerging causal regime realizes a form of *organizational closure* that we consider specific of living systems.

This idea of organization has deep implications; one in particular concerns the characterization of components. In the basic account of emergence we provided in the second section, the (relational) properties of a component as such depend on its being involved in a configuration instead of a collection of elements, but its existence does not depend on it. In the organizationally closed configurations, instead, the various components acting as generative constraints exist as far as they are involved in the configuration itself.

As a consequence, organizational closure impose some limitations in the possible operations of theoretical fractionation of the system, thus conferring to the biological explanation an even higher degree of distinctiveness with respect to the physical and chemical ones than that justified on the basis of emergence alone.

AKNOWLEDGMENTS

The work was funded by Università degli studi di Bergamo, Italy (research fellowship to LB); and Ministerio de Ciencia y Innovación, Spain ('Juan de la Cierva' program to LB; ' Ramon y Cayal' program to MM).

REFERENCES

BERNARD, C. (1865). *Introduction á l'étude de la médecine experiméntale*. Paris: Baillière.

GANTI, T. (1975). Organization of chemical reactions into dividing and metabolizing units: the chemotons, *BioSystems*, 7, 189-195.

KANT, I. (1790). *Kritik der Urteilskraft*.

KAUFFMAN, S. (2000). *Investigations*. New York: Oxford University Press.

KIM, J. (1998). *Mind in a physical world*. Cambridge, MA: MIT Press.

MATURANA, M. AND VARELA, F. (1980). *Autopoiesis and cognition. The realization of the living*. Boston: Reidel.

MOSSIO, M. AND MORENO, A. (2010). Organizational closure in biological organisms. *History and Philosophy of the Life Sciences*, 32(2-2), 269-288.

PATTEE, H. H. (1972). Laws and Constraints, Symbols and Languages. In C.H.Waddington (ed.) *Towards a Theoretical Biology 4, Essays*, Edinburgh: Edinburgh University Press, 248-258. .

PIAGET, J. (1967). *Biologie et connaissance*. Paris: Gallimard.

ROSEN, R. (1972). Some relational cell models: the metabolism-repair systems. In R. Rosen (ed.), *Foundations of Mathematical Biology*, Academic Press, New York, vol. II, 217-253.

RUIZ-MIRAZO, K. AND MORENO, A. (2004). Basic Autonomy as a Fundamental Step in the Synthesis of Life. *Artificial Life*, 10, 235-259.
SCHRÖDINGER, E. (1944). *What is Life?* Cambridge: Cambridge University Press.