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Circularities, Organizations, and Constraints in Biology and Systems Theory

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Upshot: The target article defends the fundamental role of circularity for systems sciences and the necessity to develop a conceptual and methodological approach to it. The concept of circularity, however, is multifarious, and two of the main challenges in this respect are to provide distinctions between different forms of circularities and explore in detail the roles they play in organizations. This commentary provides some suggestions in this direction with the aim to supplement the perspective presented in the target article with some insights from theoretical biology.

Introduction

1. Manfred Füllsack's target article defends the role of circularity in science. It begins by emphasizing how this concept has often raised uneasiness in mathematics and logic due to the unusual approach to causation it entails, incompatible with a mainstream view based on well-specified first causes from which to build chains of causal relationships. Similarly, circularity was excluded from the natural sciences by the theoretical and formal framework of classical physics, i.e., the "Newtonian paradigm," whose limits in this regard were pointed out and analyzed by Robert Rosen (1991) among others.

Such exclusion is the direct consequence of very specific restrictions imposed on scientific descriptions by some fundamental theoretical assumptions (Bich & Bocchi, 2012), i.e., that:

(a) all entities can be exhaustively characterized by their intrinsic properties without reference to anything else;

(b) that the environment (the boundary conditions) is fixed and cannot be influenced by the entities that interact in it; and

(c) that the rules that describe these interactions are extrinsic – that is, interactions do not change the properties of the interacting entities and vice versa.

2. These three dimensions of the scientific description – objects, boundary conditions, and rules of interaction – have been assumed to be independent and segregated in distinct descriptive categories. As soon as the result of this operation of theoretical

construction was no longer considered the product of just one of several possible strategies of description and was assumed as the ontological foundation of the natural world, the resulting picture was that of a passive nature incapable of transformation, studied through the tools of reductionist science. Thus, circular causal relationships did not find a place in the natural world constructed with the tools of modern science (see also Kant 1987).

3. Yet the experience of phenomena such as the self-producing and self-maintaining dimension of life, which resists and cannot be accounted for by physical causality and contradicts the three assumptions listed above, called for a reintroduction of circularity into science. The paradigmatic example is the cell. By building and maintaining its membrane, a cell defines the spatial scale of the system and the concentration of the components in the cytoplasm, thereby establishing a new internal environment with specific boundary conditions distinct from those of the external environment. Through this selective compartment produced from within, the cell is capable of exerting a control over the dynamics of its internal components, which are no longer completely determined by the external environment. The internal metabolism, enabled by such new local boundary conditions, is capable of producing new components that can behave in different ways, therefore changing the previous rules of interaction and, in turn, cospecifying and modifying the boundary conditions of the internal environment. Moreover, the system as a whole, operating as an agent, can change its external environment. Originating with Immanuel Kant (1987) and Claude Bernard (1865), this line of reasoning in biochemistry and biology produced between the 1960s and the 1980s some fundamental theoretical and epistemological tools to understand circularity (often in close relation to mathematical modeling), not only in organisms but in systems in general. In particular, I refer to the work of Jean Piaget (1967), Robert Rosen (1972), Howard Pattee (1973), Humberto Maturana and Francisco Varela (Varela at al., 1974), Tibor Ganti (1975), and Stuart Kauffman (1986). They all characterized living systems as inherently circular (see also Mossio & Bich 2014). This line of thought has posed major challenges to approaches to biology that are based on linear chains of causes, such as genetic determinism with genes as first causes. This pioneering work can fruitfully supplement the analysis developed in the target article by making it possible to ground distinctions and to identify the pertinent elements in understanding different types of circularity.

Different types of circularities

4. Füllsack points out that “circularity can be regarded as a macro phenomenon with a seemingly air-built stability” (§3). The idea is that systems exhibit more stable behaviors than their parts and are capable of manifesting emergent macroscopic properties. I agree with the author, but my concern is that the approach proposed in the target article might encounter some difficulties in developing the idea further. By emphasizing the importance of the holistic dimension of circularity, the target article does so at the expense of a more fine-grained analysis of the mechanisms underlying it and of a deeper understanding of how circular organizations work. If the goal is to understand circularity as not a mere metaphor, but to make it useful for both modeling

and theoretical work, one of the challenges is to move from a holistic approach toward an integrative one that is capable of accounting for the different ways components interact with each other to bring about circular organizations.

5. Circularity is multifarious, and there are several possible ways to distinguish between interactions of components that bring forth stable circular topologies of interactions and give rise to stable macroscopic regimes (Bich 2016). Some systems achieve circularity as a form of recursivity of operations in which the output of one subsystem is the input of the subsequent one, like in communication networks or in the operations of a computer (see also Füllsack's §35).

6. A qualitatively different type of circularity – which could be defined as "generative" – is holistically captured by the self-referential function $f(f) = f$ and, more analytically, by internally differentiated models such as Rosen's (M, R) systems, in which the focus is not only on operations and variables but also on the determination of operators by the system itself (Rosen 1972; Montévil & Mossio 2015). The generative approach, based on a mutual dependence between components rather than on the recursivity of operations, has been developed to account for the distinctive ability of biological systems to produce their own functional constituents from within (enzymes, compartments, genomes, etc.), and should also be put to use studying other types of systems. I wonder: Does the model proposed in the target article better describe the first or second type of circularity (Q1)? And what are the specificities of circularities in social networks with respect to other types of systems? (Q2)

7. There are also some other important issues. One of them is hierarchy: stable or self-stabilizing loops such as negative feedbacks can be actualized in qualitatively different ways, from "flat" networks of coupled subsystems interacting by means of inputs and outputs on a single level, to hierarchies of control that cut across different levels of organization (Bich et al. 2016). Another issue is time: the interactions that bring forth circular regimes are processes and therefore exist in time. The stability of an organization is relative to a temporal dimension as well. Accounts of circularity should not sacrifice this element but rather try to reconcile the relational – a-temporal – dimension with the processual one (see for example Montévil & Mossio, 2015).

The micro-macro relationship and the observer

I agree with Füllsack that a crucial aspect of circular organizations is their "bulkiness" (§34). As convincingly pointed out in the target article, systems with circular regimes are characterized by an overall coherence that gives rise to a distinction between micro and macro levels. One possible strategy for capturing the emergent nature of circularity in organizations without sacrificing the inherent details of its generative and temporal dimensions might be to focus on constraints as conditions of existence of processes (Mossio et al. 2013). A constraint is a structure or configuration that harnesses a process without being directly affected by it – by reducing its degrees of freedom and enabling specific novel, or otherwise improbable, behaviors. Examples are a pipe harnessing a flux of water in a specific direction or the action of a catalyst on a biochemical reaction, etc. A system brings forth an emergent circular regime, in a generative sense, when it is able to produce some of its constraints from within and therefore to specify part of the boundary conditions that enable and control its dynamics.

Such a regime implies a circular relationship between causes and effects through a mutual (generative) dependence between self-produced constraints acting on basic processes in a highly integrated context: the organization produces effects (e.g., the catalysis of metabolic reactions), which in turn contribute to maintaining the organization (e.g., metabolic reactions enable the production of enzymes and, thereby, the maintenance of the organization). In this context circularity can be addressed in detail by focusing on how each of these constraints depends on the action of the other constraints in the system for its existence, and in turn it contributes to specify the conditions of existence for the other constraints.

The double nature of constraints as (1) structures harnessing processes and (2) conditions of existence of the system they integrate into and upon which they depend for their existence provides several advantages in addressing the micro-macro relationship. In the first place, it makes it possible to analyze the constituents of circular organizations by focusing on structures acting as constraints. Furthermore, it provides a possible understanding of the bulkiness of strongly integrated macroscopic regimes in terms of mutually dependent constraints that exist and operate in virtue of being part of a specific organization. Finally, it makes it possible to make sense of the role of the observer who describes the system at the micro and macro scales through nonequivalent sets of filters: one level of description is represented by constraints as structures, i.e., material parts characterized through their intrinsic properties; the other by constraints as functional components of the system, characterized contextually in terms of their contribution to the organization that harbors them.

Conclusion

The target article addresses some issues that are fundamental to developing an understanding of circularity as a scientific tool rather than a metaphor: the micro-macro relationship, the emergence and the bulkiness of circular systems, and the role of the observer. Yet, this enterprise might be hindered if we stick to strictly holistic, rather than integrated, approaches to circular organizations. In order to prevent that situation, a bigger effort should be made to go into the details of the mechanisms underlying circular regimes by relying on contributions from various disciplines. Examples of this strategy can be found in system-oriented theoretical biology. It remains an open question, though, how and to what extent these insights can be applied to social systems.

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