Biological Autonomy and Systemic Integration

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Abstract In this article I will outline the basic theoretical assumptions of two examples of the confederative and the integrative views of the living - respectively Ganti’s Chemoton theory and Maturana and Varela’s autopoietic theory - by showing that they are both consistent perspectives, but they differ in the accounts they make of the role of organization in biological systems. In doing so I will also put into evidence how the choice between these two theoretical frameworks is strictly connected to the problem of structure and function in living organisms and entails different strategies of investigation.

Keywords biological autonomy, organization, autopoiesis, Chemoton theory
1. Introduction

The approaches to the study of the origins of life - and to the characterization of the minimal living system as well - based on the hypotheses of unity or confederacy have different implications from the theoretical, epistemological and heuristic points of views. From a theoretical standpoint the fact of considering how strictly subsystems are integrated in a living organism can be useful in order to understand more in depth what makes an organism a system of a certain class. Also, it allows us to deal with the problem of how being part of that system constrains or influences the behavior of the individual components, that is: to face the problem of downward causation in biological systems. An answer to this question has therefore important consequences as it can open the way to a shift of point of view in the investigation of the living from the properties of specific molecular components - from which to reconstruct life - to the properties of the system they realize, that is, to the conditions the constituents must satisfy in order to be part of it.

From the epistemological point of view, facing this dichotomy means to consider which level of description is, at least in principle, more pertinent in order to catch the specificity of the system under study: that concerning its basic constituents or an higher one. Heuristically speaking this distinction furthermore implies different modalities of fractionation of systems and of identification of relevant components, as I will show in the following.

2. Two possible “middle way” solutions

I think that a preliminary step in order to answer this question should consist in avoiding the radical dichotomy between two extreme positions on this issue: the mechanistic decomposition of the organism due to a strong version of modularity (Simon 1973), and the holistic view of living systems as not analyzable wholes: the first because it cannot catch the difference between a living system and a machine, the second one because it does not allow any fractionation of the system and, thus, any description of its internal dynamics.

This step brings us to a “middle-way” approach to the problem. It is focused on the role of organization, that is, on the way components are related in order to realize the organism. It aims at providing a description of the autonomy which characterizes biological systems in terms of their generative dynamics, which can be defined through the properties of self-production, self-maintenance and self-distinction from the environment.

In order to follow this pathway of investigation it is necessary to assume a meta-level of description focused on this global internal generative dynamics. From the analysis of the different possible “meta-structures” (Minati, 2008) – material or functional – that we can identify at this level two distinct sub-poles of the dichotomy emerge. Both derive from coherent frameworks and they differ in the point of view and in the emphasis given to confederative or unitary aspects. As a consequence they somewhat diverge in the character of their implications.
The first pole consists on a thesis on the partial decomposability of living systems into coupled but semi-independent subsystems. An example of it is provided by Tibor Ganti’s Chemoton theory (Ganti 2003). The second one is based on a more strict interdependency of sub-processes which can only be characterized in the light of the higher level system they integrate. This line of thought has been brought forth by the tradition of studies on biological autonomy (Maturana and Varela 1980; Rosen 1991).

The approach focused on the semi-independence of subsystems, exemplified by Chemoton theory, consists in an attempt to answer to the issue of the basic characterization of the living through the identification of a list of the components which are necessary for the realization of the generative dynamics defined before. Ganti indentifies three coupled subsystems:

a) a chemical motor (an autocatalytic metabolic subsystem)
b) a chemical information systems (the control subsystem)
c) a chemical boundary subsystem (the membrane subsystem)

According to this framework the basic living system is characterized by a topological closure, due to the production of a membrane, and by a specification of components instructively induced by a control subsystem. Its generative dynamics is characterized by the coupling between its subsystems according to a model of co-evolution between interrelated semi-independent entities. These are identified according to their intrinsic properties following a bottom-up observational direction. The organization of the system can be therefore defined as “structural”, because the relational properties of the constituents can be derived from their structural intrinsic ones.

Autopoietic theory is an example of the second approach, characterized by the thesis of interdependency of sub-processes. It is based on a systemic assumption: the characterization of the living is primary focused on the global organization rather than on the properties of the material constituents or subsystems (Maturana and Varela 1980). It consists in a reinterpretation of the cybernetic notion of circular self-stabilization which is not to be applied to single regulatory processes or subsystems, then coupled together, but to the whole living system (Bich and Damiano 2008). What is proposed here is a second order cybernetic loop of realization and conservation of the unitary organization of the organism (Bich 2008; Cornish-Bowden and Cárdenas 2008).

According to this model the living system is characterized by both a topological and functional closure, such that the interdependency of subsystems derives from the higher order organization which defines the identity of the whole system. In this case the relevant components are not the material ones, specified by an instructive subsystem, but functional sub-processes, which can be identified according to their relational properties and with respect to the system they integrate.

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1 The autopoietic organization can be defined as a net of processes of production, transformation and destruction of components, that: (1) through their interactions and transformations recursively realize and regenerate the same network that produces them; and (2) constitute the system as a concrete unity in the space in which they exist, by establishing its boundary and thus specifying the topological domain of its realization (Maturana and Varela 1980).
By comparing the two “middle-way” approaches we can see how in the first model, more focused on the properties of components, the meta-level of description is primarily structural, or at least the relational aspects can be reduced to the structural ones. In the second one, whose point of view is mainly focused on the global invariance, the structural and relational aspects are instead irreducible and complementary. According to these remarks, I sustain the thesis that it is the presence or not of the higher order integrative circularity – the autopoietic organization - what marks the difference between the two perspectives. In fact it provides the theoretical explanation of the looseness or tightness which the coupling between subsystems can assume.

From the epistemological point of view the opposition between unity and confederacy entails a further opposition between two distinct observational operations: the “structural” and the “functional” identification of subsystems (Bich 2009). In the former – “confederative” - approach, the subsystems are partially independent and can be identified logically and phenomenologically ex ante with respect to the realization of the living system they belong to (bottom-up approach): they are the material parts of the systems, characterized through their intrinsic properties. In the latter they can be characterized and identified only ex-post and with respect to the unity they integrate. Their condition of existence, in fact, is the presence of the biological system they realize through their interaction (top down approach): they are characterized through their relational properties. In this second approach the identification of the relevant components is more problematic, as this operation requires a multilevel complex strategy which needs to take into consideration both structural and relational aspects in order to provide a description of the generative dynamics of the basic living system.

3. Conclusive remarks: two ways of investigating the origins of life

The frameworks outlined here besides providing distinct models of the basic living systems, entail also two different strategies of facing the problem of the origins of life.

In the perspective based on the hypothesis of the semi-independence of subsystems the main strategy consists in identifying the pertinent basic components and in considering the process of their reciprocal stabilization inside a topological boundary. From both the theoretical and historical points of view, in fact, the emphasis is put on the role of assemblative and coupling aspects in the constitution of the living. Instead, in the autopoietic framework, characterized by a stronger interdependency of sub-processes, this strategy is only the first part of a more complex procedure which moves on different descriptive levels in order to combine the bottom up and the top down approaches. According to this approach the further operations would consist in a relational analysis of the functional components of the global organization and in an attempt to trace back the historical dynamics of the divergence between structural and relational aspects in early evolution.
In a wider perspective, in fact, these two strategies involve not just different models of the living but also different views of natural history. In the first case the implicit idea is that of a continuous process of complexification through the combination of some initial constituents and the stabilization of their interactions. In the second approach the implicit model of natural evolution is closer to Whitehead’s idea of process (Whitehead 1929) and it consists in a discontinuous creative process: a succession of emergences in which at any new step we assist to new reorganizations which give rise to new relational unities (Bocchi and Ceruti 1993; Bich 2008; Kauffman 2008).

References