ISHPSSB 2015 Montreal

Organaized session

BOUNDARIES AND LEVELS OF BIOLOGICAL ORGANIZATION

This double session will discuss the notion of biological organization from a system-theoretical perspective. In particular it will focus on its intrinsic hierarchical dimension, and on the role organization plays in the understanding of the transition from pre-biotic to minimal living systems and of the evolution towards more complex forms of biological, cognitive and ecological systems. It will also address issues regarding individuality and autonomy at cellular and multicellular levels, from developmental and ecological perspectives as well as from genetic and evolutionary ones. Formation of boundaries at prebiotic scenarios and complex interactions at individual versus environment interfaces are also dealt with. The conceptual framework involves clarification of such general concepts as those of organization or level in terms of constraints, the characterization of regulation at its minimal instances or the assessment of diverse attempts to naturalize teleology. The double session is divided into two parts: a more general and conceptual one first, followed by another more specific and field centered.

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PART I

From levels of organization to the organization of levels

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We propose a theoretical and formal way to account for the various levels of organization that biological systems may realize. Our key assumption is that levels of organization are to be understood as specific networks of interdependences among the functional constituents. More precisely, we will rely on the notion of organizational closure, which refers to the mutual construction and stabilization of constituents playing the role of constraints within the system. A level of biological organization, we will argue, is a level of closure of constraints.

With this characterization in hand, we will first discuss those situations in which different levels of organization can be distinguished, and hierarchically articulated, by relying on sharp discontinuities. In particular, this is the case of cells within multicellular organisms. We will then focus on those more complex cases in which the description of a level of organization requires appealing to the notion of "tendency to closure", which aims to deal with the qualitative notion of level of organization by quantitative means. In particular, the tendency to closure involves a quantitative measure of functional interdependences at the relevant spatial scale at which constraints operate.

We conclude with a preliminary discussion of the spatiotemporal conditions (in particular: the dependence on large space scale and small time scale) that enable the coherence of organisms realizing high levels of organization (e.g. mammals).

Regulation in Biological Systems

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The appeal to the notion of regulation is widespread in biology. This property is usually ascribed to a variety of mechanisms and behaviours involved in living systems' responses to perturbations. Yet, the meaning of this notion is left somehow vague, very dissimilar types of phenomena are gathered under this label,

and its relationship with akin concepts, such as control, homeostasis, robustness, and feedback is hardly stated in clear terms
To contribute to a deeper understanding of this notion, we will propose an organisational account of regulation by focusing on the mechanisms underlying compensations for perturbations in minimal living systems. In the first place, we will analyse different forms of control in the cell, and how they contribute to the maintenance of a biological organization. In the second place we will analyse how basic biological organisation can recruit forms of control to viably compensate to internal or external perturbations. It does so in two main ways: through holistic responses as networks or by means of the action of specific subsystems dedicated to handle perturbations. On this basis we will distinguish between two different classes of responses, respectively: dynamical stability and regulation. we will describe the limits of stability as an adaptive response, and we will provide a definition and a minimal set of organizational requirement for regulation, by pointing out the differences with similar concepts such as feedback, robustness and homeostasis.
Finally, we will discuss the importance of the invention of regulation for the evolution in complexity in biological systems.

Teleology and biology, a scientific alternative to naturalization

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In this paper we address the problem of teleological language in biology. In particular, we explore a scientific alternative to what is generally known as the solution of naturalization that consist in deriving teleology from efficient causation. We first take into account some classical attempts of naturalization in order to show their weaknesses and problems. Above all we analyze three ways of naturalization: the naturalization of teleology by the process of evolution, the reduction of teleology to fundamental matter by the notion of genetic program and the naturalization of teleology by its role in a proper organized system. We point out the fact that, in these solutions, teleology is never completely derived from efficient causation. On the contrary, some teleological notion seems always added as a special theoretical condition, hided under other concepts. However these concepts are derived from a teleological logic. In order to overcome this problem, we suggest an alternative way that consist in legitimate this addition in a scientific sense as a constitutive condition. Starting from a brief analysis of the Kantian third critique, we explore the possibility of a constitutive place for teleology, in a peculiar different sense then a simple heuristic usage. We analyze some analogies with the conceptualization of causes in physics and we finally detail a naturalistic usage of teleology as a constitutive principle.

PART II

Developmental and ecological processes of multicellular organization

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Philosophy of biology is exploring different ways of being an individual organism. At the cellular level, free living single cells are viewed as autonomous individuals, whereas those in a multicellular organism appear to be just parts of it. The extent to which microbes and multicellular entities can be compared as organismal entities is challenged by the role of microbes in multicellular organisms.

According to models such as Buss's, individual cells give up their autonomy and independence, which is subdued by a larger organization for which cells lineages divide and differentiate following developmental processes and rules. Recent evidences of the role of the microbiota in multicellular organization suggest that processes beyond genealogical lineages, plausibly of an ecological character, play a constitutive role. Yet, how do multispecies cells populating the organism acquire their roles in the multicellular whole? How are relations among microbial components constrained by the multicellular organization? How do rules of development (division and differentiation) and ecological/economical rules governing the interactions (symbiosis, etc.) integrate? In sum, an important issue of multicellular individuality is how biological levels of cellular organization are conceived.

This paper considers that levels of multicellular organization can be explored both in terms of developmental and of ecological interactions among cells, with conflicting consequences about the individuality of multicellulars, as at least two levels of organization and interactions appear to coexist, one regulated by the upper level of organization and developmental rules and a second one regulated different evolutionary and ecological rules, and in which the boundaries of the individual organism will appear blurred.

In what concerns multicellular autonomy, this view is coherent with the perspective that autonomy is not a fact of the living condition but a norm being pursued under contingent conditions of life.

Extended inheritance and extended organizational boundaries

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In this presentation, I argue that the increasing data about non-genetic inheritance requires the construction of a renewed conceptual framework that should complement the inclusive approaches already discussed in the literature. More precisely, I hold that this framework should be epistemologically relevant for evolutionary biologists: in capturing the limits of extended inheritance and of extended biological systems transmitting traits to their offspring, it should open an alternative way to apprehend the impacts of extended inheritance on evolutionary thinking. I outline the first elements of an organizational account of extended inheritance, based on earlier works on biological organization (Mossio et al., 2009, 2010) and extended physiology (Turner, 2004). In such an account, the category of inherited factors is neither restricted to genes nor extended to ill-defined stable resources related to trans-generational patterns of variation. Instead, it includes multifarious elements whose specific role is to harness flows of matter and energy – and thereby to maintain extended metabolic and functional networks – across generations of clearly delimited extended organized systems. This both inclusive and restrictive framework is therefore tightly associated to the conceptualization of new levels of organization, appearing as various levels at which evolutionary causality can take place.

'Protocell autonomy': constructing boundaries to organise basic biological processes and interactions

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Autonomy does not mean independence. It refers, rather, to the capacity of a system to generate its own rules of operation as such a system, including the rules of interaction with its environment. This applies to biological systems, which are able to build their boundaries (selectively permeable lipid membranes) and other functional components (proteins, sugars, nucleic acids…) through the transformation of externally available material and energetic resources. They manage to do so by putting together and coordinating (both spatially and temporally) a complex network of reaction processes that take place in non-homogeneous, far-from-equilibrium thermodynamic conditions. Thus, biological systems, being necessarily open systems, constitute a dynamic organisation of processes that becomes clearly distinct from the inert environment that nurtures them and, at the same time, collects the products of their ongoing activity.

In this contribution, I will argue that autonomy, in its most basic and minimal sense, had to be developed quite early in the sequence of transitions that led from complex physical-chemical systems to the simplest biological ones. Apart from relevant experimental evidence provided in present days by several labs, a theoretical model will be introduced to show how this could be achieved: namely, through the coupling of autocatalytic chemical reaction networks with processes of lipid self-assembly forming the membrane of the system. This marks an important transition, in which 'vesicles' (closed lipid bilayers) transform into 'protocells', for they gain control on the production of their own boundaries, a crucial step for autonomous individuation and system-level coordination. In this context, autonomy will be claimed as a necessary *but not sufficient* theoretical construct to account for living phenomena, whose evolutionary-historical-collective dimensions also need to be taken specifically into account.

Ruiz-Mirazo, K. & Moreno, A. (2012): Autonomy in evolution: from minimal to complex life. *Synthese* 185 (1): 21-52.

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