IAS-IHPST WORKSHOP
BOUNDARIES AND LEVELS OF BIOLOGICAL ORGANIZATION

Abstracts

Hierarchical thinking in organicist and systems biology

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There are, at least, three wide conceptual elements that characterize, quite obviously, the philosophical significance of, at least, the "developmentally oriented" strand of early twentieth century organicism: centrality of the organism, systemic perspective, and hierarchical thinking in terms of levels of organization.
The hypothesis I want to explore in this work would hold that one of the aspects that deserves scrutiny, from an epistemological point of view, as a signal of the persistence of early 20th century organicist views in later decades is, precisely, **hierarchical thinking**.
I hold that it happens that both its presence and oblivion are coincident with a more general attitude (positive or negative) towards organicist like views in the life sciences. Even in some cases, this hierarchical view may be the only apparent trace of a more encompassing view.
As a specific and practical illustration I will offer the long trajectory of experimental and theoretical research of Paul A. Weiss. The concepts of 'system' or 'levels of organization' were key elements in the theories of organicists such as Bertalanffy, Needham and others. Among them, the work of Weiss in particular embodies rather nicely the continuity of hierarchical thinking in biology from the 20s to the 70s and the analysis of his scientific and intellectual career corroborates these claims.
As a complementary claim, I maintain that the absence of a genuine hierarchical approach in some current proposals as, for instance, within the emerging area of Systems Biology might indicate a different source and ambition of these proposals

Levels, orders and boundaries: a look into the architecture of biological organization

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Protocellular autonomy: getting organized through the construction of open boundaries

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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. The idea will be illustrated both for protocells made with various types of lipidic molecules, some of which are internally synthesized, and for more complex cases in which lipids are combined with oligopeptides, bringing about higher levels of robustness and a richer space of dynamic and functionally integrated behaviours.

Accordingly, lipid boundaries will not be portrayed as barriers, as molecular structures that serve for separation or disconnection with the surrounding milieu but, rather, as linkers of processes: i.e., as the organic interfaces in which diverse mechanisms to control energy-matter flows are anchored, making actually possible the continuous constructive dynamics of biological systems. The complementary relationship between boundaries and internal network of reactions will be, therefore, highlighted, following the steps of the autopoietic theory, but giving a more physically grounded and updated interpretation of the idea. Furthermore, 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.

Toward an organizational account of extended heredity

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Extended heredity is a major field of interest in scientific literature: whereas the multiplication of data regarding non-genetic inheritance encourages scientists to push for the adoption of inclusive models, non-genetic processes are said to be powerful evolutionary agents. In this presentation, I argue that pluralistic accounts of heredity, by inducing a principled extension of biological legacies and diversification of inherited factors, might however lead to the overlooked trap of hereditary holism, and turn extended heredity into a fruitless concept. Consequently, I assert that the increasing amount of data about non-genetic inheritance first and foremost requires the construction of an *integrative* theoretical framework that should be both inclusive and delimiting. I outline the first elements of a conceptual reform based on the theory of biological organization developed by Mossio and colleagues (2009, 2010). In permitting the individuation of reoccurring extended biological systems, such a perspective offers a relevant characterization of extended patterns of similarities and opens the way to a renewed definition of inherited factors – to be distinguished from other stable resources. Those reassessments have important implications for evolutionary thinking. They notably lead to the conceptualization of a new level of selection based on the holobiont model (Rosenberg /et al./, 2008) and thereby open an alternative way to conceive rapid evolutionary changes downplayed by the Modern Synthesis.

Teleology as a methodological principle

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Teleology as a form of causality seems to provide a deep comprehension of some specific dynamics of the living. Indeed, teleology stresses the role of the parts not only as included in a system, but as acting *for* the maintenance of a condition of this system. From this logic derive many relevant concepts to apprehend living systems : functions, norms, circularity, self-maintenance etc... Nevertheless, this causal form raises a metaphysical problem because it seems to introduce some project in nature. This is in contrast with the naturalistic vocation of life sciences. That is why, the main project, in the contemporary debate on teleology, is to restore efficient causation. A philosophical tradition, taking inspiration from Kant, tends to see in organization the good theoretical frame to take in account teleology. This project, yet very far from its original inspirations, generally takes the way of reducing teleology to a concatenate series of efficient causation inside a special form of circularity. Now, we argue, even would this not be impossible, the conditions to realize this project imply regrettable consequences. The losses in terms of conceptual richness provided by teleology are very important. These models always requires to be very abstracts, minimal and outside time. Here we claim, this project ascribes too importance to a rigid model of efficient causation coming from a deductive-nomological model of explanation. If we look at the physic of the XX century, the priority of this rigid form of causation is no longer arguable. Indeed, we claim that efficient causation is one of the causal possible principle in science, but not the only one. By showing the role of causation as a principle in general, and therefore also of causation in physics, we ascribe the status of a specific principle to teleology. In contrast to the Kantian prohibition, here we claim a constitutive and objective teleological principle is possible for biology, as well as it is for efficient causation in physic.

Failed intentions, or why adaptive behavior is not sufficient for cognition

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First, I will analyse the "Cognition = Behaviour" and show how it is insufficient to account for cognition as a specific phenomenon different to any dynamical systems (call it "agent") coupled to another one (call it "environment"). Then I will introduce the idea, defended by many, that the biological grounding of sensorimotor interactions can solve the problems posited by a purely behaviouristic account of cognition. Next, I will try to show that the existing formulations of the necessity and sufficiency of biology for cognition have not been formulated with precision and that additional requirements need to be added. Thus, I will expand the "Cognition = Adaptive Behaviour" into "Cognition = Adaptive Behaviour + X + Y + Z" where X, Y and Z represent those additional requirements that bring adaptive agency closer to intentional agency. I will try to argue that, despite the adding up of new conditions, the approach remains essentially problematic. To account for these problems I shall rely on a benchmark test: the skyline of our own subjective experience of intentionality-in-action (or intentional agency). Finally I will end up proposing some in-principle reasons for this failure and how we can still safe part of the basic intuition by moving the baby to a different bathwater: from biological autonomy to sensorimotor autonomy, from the self-maintenance of metabolic organization to the self-maintenance of the behavioural organization.

On the origin of autonomy: from chemical to biological organisation

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In the natural non-biotic world chemical systems are essentially driven by more or less complex external boundary conditions. Tough occasionally some processes occur in FFE conditions, ultimately processes are under TD control. Instead, in the biological world, organisms are chemical systems whose processes are essentially driven by a big number of highly complex mutually dependent constraints that are internally created and maintained. These processes occur permanently in FFE conditions. How this big change, from chemistry to biology, has been made possible? Here I will discuss which are the fundamental logical steps from the world of (mere) chemistry to that of biology. I will consider the following 3 steps: 1) chemical self-maintaining auto-catalytic cycles, 2) functional networks; and 3) self-regulated functional networks. Autocatalytic cycles are minimal forms of FFE chemical organizations. These systems are not only driven by external BC: a component – a catalyst– drives kinetically the network, and keeps them in FFE conditions. The cycle therefore is not only maintained by the external BC, but (though in a minimal sense) also by the catalyst, and the catalyst is maintained by its own action (minimal organizational closure). How this minimal organization can lead to a more complex type of chemical organization escaping from TD control? Stable organizations in FFE conditions would emerge when a set of constraints come together, in a sort of mutually reinforcing effect, which lies at the core of a new, more robust SM dynamics. This way, the action of constraints (i.e. a catalyst, a membrane) is to harness the underlying chemical interactions so that another constraint is produced, and so on until the process closes itself recursively. These diverse constraints should mutually enable their continuous regeneration. This is crucial for the emergence of a diversified functional domain: by internally synthesizing its own constraints the system becomes much more plastic; i.e., capable to perform a diversified modulation of its own SM dynamics. And it is in this organizational context where different constraints can make *distinguishable contributions* to the global SM of the system. However, the creation of new functional diversity cannot be, in principle, unlimited, because variations can affect the output of a specific constitutive constraint, which in turn may affect the structure and activity of other constraints, and so on. Due to the closure between constraints, the organization may progressively "drift" and, most likely, become disrupted after a short time. The solution is the invention of (self)regulation, namely, a set of endogenously synthesized second-order constraints operating on other, (primary or constitutive) constraints already present in the system, putting it together. These constraints must be *dynamically decoupled* from the subsystem or the process network that they regulate. Once regulation is in place, we have a chemical organization that is capable to manage the flow of matter and energy through it so that it can, at the same time, modify and control: (i) internal self-constructive processes and (ii) processes of exchange with the environment. This is what is an autonomous system and what, at the same time, essentially characterizes a living organism.

Gaïa: what was it *about*?

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The Gaïa hypothesis proposed in the early 1970's by James Lovelock suggested that life may regulate its planetary environment. Evolutionary biologists early pointed out the lack of explanatory mechanism supporting the hypothesis. Philosophy of biology, along with evolutionary biology, have then depicted the Gaia hypothesis as a misleading and dangerous metaphor comparing the Earth with an organism, not worthy of any sort of philosophical or scientific consideration.

I shall first point out that this narrative is at best incomplete: it at least fails to acknowledge that the reaction towards the Gaïa hypothesis in other scientific communities (namely, the Earth sciences), has been different from the ones in biological communities. I will then argue that the focus on the *explanans* (the lack of mechanism accounting for planetary homeostasis), pertinent as it was, left entirely untouched a discussion about a topic which should have been deemed prior, namely the *explanandum* of the hypothesis.

Indeed, ever since the beginning, the very *question* the Gaïa hypothesis aimed at raising was far from clear: what does "planetary homestasis" was supposed to mean? What does it mean to say that "Earth" is an "organism"? The focus of the talk will therefore be on these two questions: the hypothesis and the individual Gaïa is meant to refer to. Regarding the first, I will argue that in the literature on Gaïa and in the modelling litterature on Daisyworld, homeostasis, or stability, has been used to refer to very different sorts of phenomena. As for the second question, I will first point out that the individual referred by the term "Gaïa" is not "the Earth", but an entity which, if it exists (a point which will be discussed), would be a global ecosystem. I will then argue, *contra* current usages in the literature that the causal agents within this potential individual *cannot* be "organisms", or typical "living beings".