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.