Unexpected Connections: From Quantum Entanglement to Developmental Symbiosis

The purpose of this paper is to offer transversal reflections on two current major fields of biology and physics, namely Ecological Developmental Biology (EDB) and Quantum Mechanics (QM). Critical to these fields are, respectively, the ubiquitous phenomena of symbiosis and entanglement. Heterogeneous as they may seem, I shall attempt to highlight the common pattern underlying these two domains, and show how the unexpected connections that both EDB and QM reveal in nature could form part of a broader ontological framework that places these very connections at its centre. To this end, I shall proceed in two stages:

In the first one, I shall briefly outline the nature and significance of the aforementioned phenomena in relation to each other, focusing on the way they essentially portray nature as non-separable, revealing necessary connections between individual entities previously thought as distinct and independent. As is known, entanglement phenomena can indeed generally be described as phenomena where the states of physical entities cannot be fully specified without reference to each other and to the whole complex in which they enter. In such cases, it is not possible to assign an absolute value to one parameter, independently of the assignation we make to another related one. Similarly, at a biological level, what the all-pervading phenomenon of symbiosis is revealing is that an individual organism with its specific genome is incomplete, insofar as it has always been co-developing with other organisms whose metabolism is deeply intermingled with that of their host, which in turn depends on this relationship for its construction and identity. This interdependent arising implies that a change in one symbiont brings about a corresponding change in the other ones so that their respective phenotypes and developmental pathways cannot be "factored" into separate, non-relative functions.

Across disciplinary boundaries, a common relational pattern seems thus to emerge, challenging our views about individuality. Relations, long thought to be purely external to the things themselves, turn out to be constitutive of their very being and nature, transforming the classical conception of an individual – a *discrete* entity endowed with *intrinsic* properties – into one in which relatedness becomes an essential and defining feature of all particular things. Instead of a reductionist approach that considers self-contained units as constituting the fundamental basis on which everything else supervenes, the lessons learned from QM and EDB point toward the necessity of another approach that regards relations – to use Donna Haraway's own words – as "the smallest possible pattern for analysis".

In a second stage, I shall thus propose to sketch an integrative ontological framework deploying such a relational, holistic approach. To this end, I shall draw on two major strands of contemporary philosophical interpretations that have been developed in the context of QM: the so-called "Ontic Structural Realism" (M. Esfeld) and "Quantum Holism" (J. Ismael and J. Schaffer). While their arguments differ in some important aspects, both theories hold that the relational structure of reality has to be seen as fundamental and consequently reject the idea of individuals ontologically independent and that of intrinsic natures. Although accounting for biological facts was beyond their initial target, I shall argue that these theories could be expanded in scope to encompass and account for EDB as well, an extension across domains which would in turn enhance their empirical foundation and deepen their unifying explanatory power. In line with these theories are indeed the core metaphysical claims I shall put forward as attempts at interpreting entanglement and symbiosis phenomena at an ontological level,

namely, (1) that individual entities are not radically distinct, but interdependent parts of a more fundamental whole – as implied for instance in the Holobiont paradigm; (2) that the properties of individuals can be fully expressed in relational terms; and ultimately, (3) that their individuating feature is to be found in (and only in) their relational properties.