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COMMENTARY

The Issue of "Closure" in Jagers op Akkerhuis's Operator Theory

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Abstract Attempts to define life should focus on the transition from molecules to cells and the "closure" aspects of this event. Rather than classifying existing objects into living and non-living entities I believe the challenge is to understand how the transition from non-life to life can take place, that is, the how the closure in Jagers op Akkerhuis's hierarchical classification of operators, comes about.

Keywords Closure · Complexity · Natural philosophy · Operator · Origin of life · Systems biology

In the Special Issue on The Evolution and Development of the Universe, Jagers op Akkerhuis (2010a) proposes a definition of life based on his earlier theory of operators. A great variety of objects fall into the category of operator, and by introducing this term Jagers op Akkerhuis was able to draw a parallel between elementary particles, molecules, cells and multicellular organisms. The common denominator of these operators is their autonomous activity and maintenance of a specific structure. Consequently, operators were classified in a logical and hierarchical system which emphasizes the commonalities across what is normally called non-life (atoms, molecules) and life (cells, organisms). One very attractive aspect of the classification is that it joins the objects traditionally studied by physicists, chemists and biologists into one overarching system. Obviously, the hierarchy crosses the traditional border between life and non-life, so it should be possible to develop a definition of life from the operator theory. This is what Jagers op Akkerhuis attempt to do in the present paper. However, I believe he misses the point.

Rob Hengeveld (2010) did also comment on Jagers op Akkerhuis (2010a) paper. See Jagers op Akkerhuis (2010b) for replies.

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In the operator hierarchy, successive levels of complexity are separated by "closure events", e.g. when going from from hadrons to atoms, from molecules to cells and from multicellular eukaryotes to memic organisms. One of these closure events actually defines the origin of life: the transition from molecules to cells. Death, as defined by Jagers op Akkerhuis, is the loss of this closure, a fall-back from cells to molecules. There is another important transition, the origin of self consciousness, a closure event that accompanies the highest level of complexity in the classification of operators. Life with this level of complexity (maybe call it "hyper-life"?) is included in Jagers op Akkerhuis's definition of life.

Another interesting aspect of the operator system is that it is strictly hierarchical, that is, every operator can be classified on a more or less linear scale and the big leaps forward are punctuated by closures on that scale. This aspect of the system is reminiscent of the "Great Chain of Being", or *scala naturae*, which was the dominating view of life for many centuries. In evolutionary biology, it is now recognized that pathways can split and run in parallel, maybe even achieving similar closures independently from each other. I am not sure how this aspect fits into the operator classification of Jagers op Akkerhuis.

To define life in terms of the operator theory I believe the focus should be on the transition from molecules to cells and the closure aspects of this event. In other words, the closure of operating systems defines life better than the classification of operators. However, Jagers op Akkerhuis seems to add another seemingly hopeless definition of life to the nearly 100 already existing. Classifying what is life and what is not is, I believe, a rather trivial exercise. Everybody knows that a flame is not life, and it only becomes a problem when you spend too many words on it. Rather than classifying things into living and non-living entities I believe the challenge is to understand how the transition from non-life to life can take place, that is the how the closure in Jagers op Akkerhuis's hierarchical classification of operators, comes about.

The issue of closure is intimately linked to that of emergence. Both concept recognize that the characteristic properties of a living system cannot be reduced to its component parts only, but also depend on the way in which the components are organized in a network. The properties that arise from interactions between components are said to be "emergent". Emergent properties are not shared by the components, they "appear" when many components start interacting in a sufficiently complex way.

The concept of emergence plays an important role in genomics, the science that studies the structure and function of a genome (Van Straalen and Roelofs 2006). After about a decade of genome sequencing, scientists started to realize that the genome sequence itself does not define the organism. The human genome turned out to contain no more than 24,000 genes, much less than the earlier assumed 124,000. This raised the question how it could be possible that such a complicated organism as a human being could be built with so few genes. Obviously the pattern of gene and protein interaction defines human nature much more than the genes and proteins themselves. A new branch of biology was defined, systems biology, which was specifically geared towards the analysis of interacting networks, using mathematical models (Ideker et al. 2000).

Schrödinger (1944), in discussing the question "What is life?" foresaw a new principle, not alien to physics, but based on physical laws, or a new type of physical laws, prevailing inside the organism. These are the kind of laws that systems biology is after. The operator classification of Jagers op Akkerhuis is an important step because it emphasizes the continuity between physical systems and biological systems. However, the challenge of defining life is not in classification but in understanding the closure phenomenon by which life emerged from non-life.

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