

## A functional account of minimal cellular life

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Life seems to be one of the most fundamental categories in nature. But how exactly do material objects that are living differ from those that are not? Is there any a fundamental difference? And if so, is it a dichotomy or a matter of degree?

One answer to these questions abstracts away from chemical details and instead concentrates on living system's functional properties. In fact, the protocell research community more or less agrees that minimal cellular life forms are defined by chemically integrating three functionalities (Rasmussen et al., 2008, *Protocells*, p. 71). First, the system maintains an identity over time by localizing all its components, concentrating reagents and protecting key chemical reactions from molecular parasites and poisons. Second, it utilizes free energy from its environment to digest environmental resources in order to maintain and repair itself, to grow, and ultimately to reproduce. Third, these processes are under the control of inheritable information that can be modified during reproduction. The three functionalities mutually enable and support each other. They are collectively autonomous in the sense that they are created and sustained by the operation of the whole functional triad itself, rather than by any external governing agency.

Why should we believe that minimal cellular life is a chemically integrated functional triad of container (C), metabolism (M), and genetic program (P)? The rough consensus in the protocell community lends CMP view some weight, but not enough to convince skeptics. Other functionalities often associated with life-like reproduction, autonomous behavior, and sensitivity to the environment can be explained by the functional triad, which lends it further support. Going even further, the CMP view can be explained as a consequence of a more fundamental view according to which the essence of life is open-ended evolution. Elsewhere I have defended this view on the grounds that it best explains life's familiar hallmarks (Bedau, 1996, *The Philosophy of Artificial Life*, p. 332, Oxford UP) and puzzles (Bedau, 1998, *Art. Life*, 4, p. 125).

One puzzle about life concerns whether the distinction between life and non-life is dichotomous or continuous. The functional triad view implies that there is an array of thousands of different possible kinds of functional organizations, and they all more or less match the paradigm organization used to define life. Instances of some other functional organizations would be pretty clearly alive, and instances of others would be pretty clearly not alive, and a gray zone of further possible functional organizations separates those two clear cases.

One could divide the gray zone with any number of bright lines purporting to separate those systems that are "really alive" from those that are not, but I recommend not doing this. Instead, I think there is no deeper fact of the matter about the life/nonlife distinction other than the graded array of functional organizations. Attempting to find a more precise "definition" of life would be to invent a categorical distinction that does not exist in nature.