Comment on Bourgine and Stewart's "Autopoiesis and Cognition"

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I wish to make a brief comment on "Autopoiesis and Cognition" by Paul Bourgine and John Stewart, specifically their statement that "[t]his reaction [formation of B] only occurs inside the volume enclosed by the membrane" [1, p. 321].

Although a bounding membrane is crucial for defining and delimiting an autopoietic system, the presence of such a boundary per se should not be essential to the individual processes that maintain the system. In particular, a process cannot distinguish a complete bounding membrane that fully encloses the system from a (possibly short) segment of membrane material. Processes operate with only local information about the chemical components in their immediate environment. Thus, if a process uses the surface of a bounding membrane material as a catalyst, the process must proceed in the same way whether or not that surface is actually part of the bounding membrane. Consider the three cases illustrated in Figure 1. In Case 1 the process reactants (A) are inside a complete boundary membrane (C). In Case 2, the reactants are inside just a segment of boundary material. In Case 3, the reactants are outside two nearby complete boundaries. Yet, in all cases the local environment that controls the reaction between the A's (indicated by underlining) is exactly the same, and thus the process cannot distinguish between them.

However, it is possible for a process within an autopoietic system to have *indirect* knowledge of being inside or outside the bounding membrane. For example, suppose one of the processes generates a product (P) to which the bounding membrane is (partially or totally) impermeable. Inside the bounding membrane, the concentration of P will rise (unless P is depleted by other processes). Outside the bounding membrane, any P produced can diffuse into a potentially infinite sink, so that P does not have a chance to become very concentrated. Thus, the concentration of P will be palpably different inside and outside the membrane, and that difference will alter the rate of any reaction for which P is either a reactant or a catalyst.

In making the above analysis, C is assumed to have no internal structure that influences its physical or chemical behavior; C is isotropic and rotationally symmetric. Thus, the catalytic properties of a chain of C elements would be unaltered if the chain were rotated 180°. Under these conditions, a potential reactant near a bounding membrane cannot know if it is near the inside or the outside of the space enclosed by the boundary (since, as illustrated above, that requires nonlocal knowledge of the membrane's topology).

However, it is possible to model a bounding element that does have internal structure, such as a hydrophobic and a hydrophilic end. With a polarized C, catalysis might be different depending upon

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                                           CCCCCCCCCCC
                                           C         C
CCCCCCCCCCC          CCCCCCCCC             CCCCCCCCCCC
C  A A    C            A A                    A A
C CCCCCCC C          CCCCCCCCC             CCCCCCCCCCC
C C     C C                                C         C
CCC     CCC                                CCCCCCCCCCC

   Case 1              Case 2                 Case 3
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Figure 1. Three membrane cases described in the text, where C's represent the membrane, and A's represent the reactants.

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the orientation of a reactant with respect to C. Assuming that in the membrane of an autopoietic cell the individual C elements tend to align with the same orientation, and that the membrane always forms with the catalytically active ends on the inside, a reaction catalyzed only on the inside becomes plausible. But then the model should track the (hidden) orientation of C, since that becomes an essential feature. This is especially important in modeling segments of C elements that have not yet formed cell boundaries.

Reference

1. Bourgine, P., & Stewart, J. (2004). Autopoiesis and cognition. *Artificial Life*, *10*(3), 327–345.

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