An Integrated Perspective  
on the Constitutive and Interactive Dimensions of Autonomy  

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Abstract  
Enaction’s claim of continuity between life and mind is a bold one. We investigate one aspect of this claim using a glider in the Game of Life as a toy model. Specifically, we study the relationship between theories of glider constitution and glider interaction, demonstrating how a glider’s constitution completely determines its interaction graph, but not the particular life that it enacts, which also requires knowledge of the dynamics of its environment.

Introduction  
Within enactive approaches that emphasize the autonomous character of biological individuals, a continuity between life and mind is often claimed, sometimes expressed in the slogan Life = Cognition (Stewart, 1992; Stewart, 1996; Thompson, 2007; Kirchhoff & Froese, 2017, Di Paolo, 2018). This claim is rooted in Maturana’s earliest work on the biology of cognition (Maturana & Varela, 1973/1980). But what exactly does this assertion mean? Are life and mind one and the same thing? Do the phenomena of cognition reduce to those of biology? Are these two sets of phenomena distinct but co-occurring? Does one entail the other? Or do they stand in some more complicated relationship?

In order to focus our investigation, let us follow the enactive literature by distinguishing between the constitutive and interactive domains of description of an autonomous system. A constitutive description, usually associated with metabolism, emphasizes how the interactions between an emergent individual’s underlying components and processes give rise to and maintain its integrity. In contrast, an interactive description, usually associated with behavior and cognition, emphasizes the way in which the individual as a whole engages with its environment. Roughly speaking, constitution is concerned with what an individual is, whereas interaction is concerned with what that individual does. Thus, our question becomes: What is the relationship between the constitutive and interactive dimensions of autonomy?

Confusion on this issue can be traced all the way back to Maturana. On the one hand, Maturana wrote that

“Living systems are cognitive systems, and living as a process is a process of cognition” (Maturana & Varela, 1973/1980:13),

implying that life and mind are inextricably intertwined. On the other hand, he also wrote

“Systems as composite entities have a dual existence, namely, they exist as singularities that operate as simple unities in the domain in which they arise as totalities, and at the same time, they exist as composite unities in the domain of the operation of their components. The relation between these two domains is not causal; these two domains do not intersect, nor do the phenomena which pertain to one occur in the other.” (Maturana, 2002:12).

implying that the constitutive and interactive domains are completely distinct.

Di Paolo has emphasized the difficulties associated with this sharp distinction, likening it to “a systemic analogue of mind-body dualism” (Di Paolo, 2009:17). If the two domains do not overlap, then how are the compensations to perturbations mediated by constitution and the relational characteristics of interaction coordinated? Clearly “grounding mind in life requires establishing the necessary links between phenomena in these two domains” (Di Paolo, 2009:18). While Di Paolo ultimately uses this critique to argue for major extensions to the biology of cognition framework, the goal of this paper is more modest: to simply elucidate the relationship between constitution and interaction.

In order to move beyond verbal debate, we must construct and evaluate actual theories. Toward that end, persistent spatiotemporal patterns such as gliders in the Game of Life cellular automaton have been proposed as toy models of emergent individuals (Beer, 2004). Since we now have theories of both constitution (Beer, 2015) and interaction (Beer, 2014; Beer, in press) for such individuals, this toy model provides a natural laboratory for investigating the relationship between the constitutive and interactive domains of description.

The paper is organized as follows. The next section introduces the toy model, reviews the current constitutive and interactive theories, and points out a limitation of the constitutive theory as it is currently formulated (namely, that it was devised under the assumption of an otherwise empty universe). The next three sections address this limitation by abstracting the notion of a process and using this abstraction to characterize the general glider organization. The following section then examines how this generalized glider organization relates to a glider’s interactive description. The paper ends with a discussion of broader lessons that can be drawn from this analysis.
A Toy Model

A toy model is a highly simplified theoretical construct that attempts to make explicit only what are thought to be the central features of a phenomenon of interest while temporarily discarding all other details as irrelevant. Toy models often play an essential role in the early stages of theory development. At their most successful, such as the Ising model of phase transitions in statistical physics, toy models can pave the way for a more general theory from which the toy model can eventually be rederived as a special limiting case. But at the very least, they can be used to rigorously explore conceptual issues, test formalizations of theoretical concepts, and identify and/or build the necessary mathematical and computational tools for working with such theories.

In this paper, we will utilize Conway’s Game of Life (GoL) as our toy model of emergent individuals (Beer, 2004). GoL is a 2D binary cellular automaton whose time evolution is governed by a single universal law that is local in both time and space. We will think of this law as specifying a kind of physics: the Conway physics. This law can be compactly written as

\[ U_{t+1} = \delta \Sigma U_t + \delta \Sigma U_t \otimes U_t, \]

where \( U_t \) denotes the 2D discrete binary field defining the state of the GoL universe at time \( t \), \( \Sigma \) is a spatial operator that gives the Moore neighborhood count field of a discrete binary field, \( \delta \) denotes a field-oriented Kronecker delta function, and \( \otimes \) denotes the Hadamard (element-wise) product of two fields.

From the Conway physics we can derive a simple spatiotemporal chemistry in which local arrangements of 0- and 1-components “react” to produce new arrangements. We will distinguish several kinds of processes. Production processes create a new 1-component, destruction processes destroy an existing 1-component, and 0-maintenance and 1-maintenance processes preserve a 0- or 1-component, respectively. In addition, we will call the process occurring in the quiescent vacuum state of GoL the null process. Since the components produced by one process can serve to enable other processes, dependency relations exist between processes. The organization of such dependency networks will be our principal concern in this paper.

During the time-evolution of a GoL universe from random initial conditions, one observes the appearance and persistence of a variety of bounded spatiotemporal patterns. Among the most well-known of these patterns are blocks, blinkers and gliders, but hundreds more have been identified and named. For concreteness, we will focus on the specific example of a glider.

In previous work, a constitutive theory of gliders was developed using a formal interpretation of the concept of autopoiesis (Beer, 2015). We first identified the processes underlying a glider. We then demonstrated how each constituent process produced products that in turn enabled other constituent processes in an organizationally-closed manner, satisfying the self-production condition of autopoiesis. Then we showed that a glider possesses a boundary of 0-components that is both produced by the network of processes and required by that network for its continued operation, satisfying the self-distinction condition. A schematic representation of the glider organization that results from this analysis is shown in Figure 1A. The same analysis can be applied to other emergent individuals in GoL and should be easily generalizable to other cellular automata.

A theory of glider interaction was also developed in previous work using formal interpretations of the concepts of domain of interaction and structural coupling (Beer, 2014). Gliders were exposed to all possible local environments. Those environments were then divided into subsets that preserved or destroyed the glider organization. The nondestructive environments were further subdivided into classes according to the relative change in glider configuration after the perturbation, resulting in six perturbation classes that were arbitrarily labeled by the colors BLACK, BLUE, BROWN, ORANGE, GRAY and GREEN. By interconnecting the various configurational changes that result from the different classes of perturbation, one obtains a glider interaction graph that summarizes the domain of interaction of a glider. One representation of this graph is shown in Figure 1B. Finally, by considering the mutual constraints between the glider interaction graph and the interaction graph of an environment to which it is structurally coupled, the set of all possible lives that a glider can enact in that environment can be derived (Beer, in press).

The theory of glider constitution sketched above has one important limitation. It is formulated for vacuum conditions only, that is, it assumes that the GoL universe in which the glider exists is otherwise empty. This was done for two reasons. First, an analysis of autopoiesis is generally seen as theoretically prior to an analysis of structural coupling in the literature, and vacuum conditions are the simplest in which to characterize the glider organization. Second, unlike dissipative structures in the physical world, gliders in GoL can persist indefinitely without a flow of matter and energy to sustain them. However, even gliders regularly occur in nonempty universes, and there is no reason why other persistent entities in GoL might not require nonempty environments to survive. Interestingly, addressing this limitation will also turn out to open a path to reconciling the constitutive and interaction dimensions of autonomy.

**Figure 1:** A visualization of constitutive and interaction theories of a glider. (A) The glider organization. Each node denotes an individual process colored according to its type (blue = production, red = destruction, black = 1-maintenance, and white = 0-maintenance) and each arc represents a dependency between processes. (B) The glider interaction graph. Each node represents a glider configuration and each arc represents a possible nondestructive glider transition colored according to its class (BLACK, BLUE, BROWN, ORANGE, GRAY and GREEN).
Partial Processes

In order to formulate a description of the glider organization that holds across all environments in which a glider can persist (not just empty ones), we need a way to describe processes which are only partially constrained. We proceed in three steps. First we review the definition of a process from previous work. Second, we define a generalized process (called the Conway process) which is grounded in the Conway physics and from which all specific processes ultimately derive. Third, we define a class of partially-constrained processes which lie between the completely general Conway process and the specific individual processes.

In our spatial chemistry, a process is defined as a specific $3 \times 3$ arrangement of 0- and 1-components whose outcome under the Conway physics is either the maintenance or transformation of the central component. The graphical notation that we use to denote processes is illustrated in Figure 2A. The color of the central square represents whether this is a production (blue), destruction (red), 1-maintenance (black) or 0-maintenance (white) process. The shade of the surrounding squares represents which neighboring cells must be ON (dark gray) or OFF (light gray) for that process to be triggered. An important feature of this notation is that it makes explicit the local spatial relations that must hold between individual components for each process to be triggered.

All individual processes can be understood as specializations of the single generalized Conway process that is directly determined by the Conway physics (Figure 2C). Here yellow denotes enabling cells whose states are unspecified and the split colors of the central cell indicate the unspecified process type. Each color is labeled by a constraint on the state $s$ of the central cell and the Moore neighborhood sum $\Sigma$ that must be satisfied for a process of that type to take place. For example, for $s = 0$ and $\Sigma = 3$, the Conway process partially specializes to a set of production processes such as the first one shown in Figure 2A.

Intermediate between the fully-specified processes of Figure 2A and the fully generalized Conway process of Figure 2C are partial processes (Figure 2B). Partial processes are defined by constraining a subset of the cells in the Conway process or, equivalently, by abstracting some of the cells in a specific process. We will be concerned here only with past-centered partial processes, in which the current states of the central cell and a subset of the enabling cells are known. When $s = 0$, the partial process can be either a 0-maintenance or a production process depending on the value of $\Sigma$ (left). When $s = 1$, the partial process can be either a 1-maintenance or a destruction process depending on $\Sigma$ (right). Since in both cases the colors of the central cell imply the value of $s$, we can drop the $s$ condition from the constraint specification.

The Vacuum Glider Organization

The procedure for extracting the organization of an emergent individual in GoL is straightforward (Beer, 2015). It is illustrated for the vacuum glider organization in Figure 3. In an empty universe, a glider undergoes a particular sequence of

Figure 2: Partial processes in GoL. (A) Examples of production (blue), destruction (red), 1-maintenance (black), and 0-maintenance (white) processes. (B) The partial processes resulting from the production process (left) and the destruction process (right) in part A when the values of the three neighborhood cells indicated in yellow are unspecified. Here $\Sigma$ denotes the sum of the values of the yellow cells and split central cells denote the two possible process types that can occur depending on the correspondingly colored conditions indicated. (C) The generalized Conway process, which can become any type of process depending on the unspecified value of the central cell and the sum $\Sigma$ of the unspecified yellow neighborhood cells.

Figure 3: Extracting process dependencies from the 4-cycle of glider configurations and the sets of processes that they enable in an otherwise empty GoL universe. The local arrangement outlined in blue in configuration (1) triggers the blue production process, which in turn produces the blue 1-component in configuration (2), which finally triggers the $3 \times 3$ set of processes outlined in blue. Brown arrows indicate the corresponding process dependencies.
transformations before returning to its original configuration displaced by one cell diagonally. Each of these configurations triggers a specific set of processes. Importantly, even though the location of the glider has changed after four steps (compare configuration (1) to configuration (5)), both the type and relative spatial layout of the set of processes triggered by the final configuration are identical to the one triggered by the initial configuration. Ultimately, this is what leads to the closure of the glider organization.

Now consider the local arrangement of components outlined in blue in configuration (1) on the left side of Figure 3. This arrangement triggers a blue production process in the upper left corner of the Figure which subsequently produces the blue 1-component in configuration (2). This new 1-component in turn plays a role in triggering nine new processes outlined in blue in the upper right corner of the Figure. By virtue of the role that this new 1-component plays in enabling those nine processes, they develop a dependency on the earlier production process, as indicated by the curved brown arrows. Note that these arrows indicate what exact role the product of a source process plays in the enabling conditions of the target process.

The same analysis applies to every process shown in Figure 3. The product of each process plays a role in enabling subsequent processes in a cycle of dependencies that ultimately closes back on itself. By identifying the totality of process dependencies underlying an emergent individual, we extract its circular organization. Note that this representation works not only for the glider configurations shown, but also for any translation, rotation or reflection of those configurations. Suppose, for example, that we rotate the glider configurations left by 90°. This in turn would rotate the processes they generate in the same way. Crucially, although the configurations and the processes are rotated, the products of each process play identical roles in the subsequent processes that they enable. In other words, the topology of the process dependency network is invariant with respect to translation, rotation and reflection of configurations.

Despite its advantages, this representation can become somewhat dense when all process dependencies are shown. For the purposes of visualization, we can simplify the presentation of this circular organization in two ways. First, we abstract over process identity by representing each process by a circle whose color indicates the process type. This also has the effect of obscuring the specific role that each process product plays in the processes it enables. Second, since all that really matters for the organization is the topology of the process dependency network, we can remove all spatial information. With these two simplifications we obtain precisely the vacuum glider organization graph shown earlier in Figure 1A. Further simplifications, such as collapsing all occurrences of the same process into one, can also be performed (Beer, 2015).

The Generalized Glider Organization

Unfortunately, our description of the vacuum glider organization is significantly limited in its scope. To see why, suppose that the bottom right-hand cell of the glider’s environment in configuration (1) of Figure 3 (marked with an \( \times \)) was ON rather than OFF. This means that the glider no longer exists in an empty universe and, strictly speaking, the vacuum glider organization no longer applies. More specifically, the additional ON cell changes the lower right-hand process of the glider into a different process than the vacuum glider organization specifies. However, since the type of this process remains the same (a 0-maintenance process), its product plays the same role in enabling the processes that depend upon it. Thus, we have an example of a perfectly valid glider instantiation that is not captured by the vacuum glider organization shown in Figures 1A and 3. Clearly, we need to generalize our description of this organization so that non-empty environments that have the same effect as empty environments on the transitions and dependencies of a vacuum glider are included.

The notion of a partial process introduced earlier turns out to be the crucial ingredient for this generalization. The basic idea is illustrated in Figure 4. All processes that depend upon the states of environmental cells (that is, all processes that lie along a glider’s boundary) become partial processes. This means both that the states of some of their enabling cells are unspecified (yellow) and that their process type is split. In this Figure, we focus on a 0-maintenance process from the vacuum glider organization which depends upon one environment cell. In order for this process to correctly enable the next set of processes necessary for the vacuum configuration change to take place (solid brown lines), certain conditions must be met. Specifically, the \( \Sigma \neq 1 \) condition ensures that this partial process becomes the required 0-maintenance process.

![Figure 4: The effect of an environment cell state on a partial boundary process of the vacuum glider organization. As long as \( \Sigma \neq 1 \) (i.e., environment cell is OFF), this partial process becomes a 0-maintenance process that correctly enables the next set of processes for the vacuum glider organization (solid arcs). However, when \( \Sigma = 1 \) (i.e., the environment cell is ON), this partial process becomes a production process instead, enabling processes not in the set of processes that normally follow, but in the set of processes after that (dashed arcs).](http://direct.mit.edu/isal/proceedings-pdf/isal2020/32/202/1908460/isal_a_00245.pdf)
The same idea applies to the bottom righthand process marked with an × in configuration (1) of Figure 3. As long as \( \Sigma \neq 3 \) for that process, it will properly enable the next processes in the cycle. Having the bottom righthand environment cell in ON state still satisfies that condition. Thus, by replacing boundary processes with conditional partial processes, we can extend our description of the vacuum glider organization to nonvacuum circumstances that still preserve it. Indeed, making the totality of these conditions explicit allows us to define the limits of a vacuum glider’s viability.

But our generalization is far from complete. What happens when conditions such as that shown in Figure 4 are not satisfied? In many cases, the glider will simply disintegrate. However, in other cases, the glider survives even though the subsequent processes enabled are different. One such example is shown in Figure 4 (dashed brown lines). As we have seen, the \( \Sigma \neq 1 \) condition on this partial process ensures that it becomes a 0-maintenance process that plays a role in enabling the next set of processes in the vacuum glider organization (top right). When \( \Sigma = 1 \), that partial process becomes a production process instead and thereby enables a very different set of processes (bottom right). Nevertheless, this new set of processes remains within the normal 4-cycle of the vacuum glider organization. In effect, the \( \Sigma = 1 \) condition contributes

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**Figure 5:** Another example of the effect of an environment cell state on a partial boundary process. When \( \Sigma = 0 \) for that partial process, its behavior is similar to that of the process shown in Figure 4, enabling processes in one of two different process sets within the same 4-cycle. However, when \( \Sigma \neq 0 \), this process enables processes supporting process sets forming a different 4-cycle.
to the ability of a glider to skip ahead one configuration in this organization. This possibility extends the vacuum glider organization in a fundamentally new way.

But still we are not done. Consider the partial process shown in Figure 5. When $\Sigma = 0$, its specialization as a production process is equally well able to enable either the set of processes at top right or the set of processes at bottom right. But what happens when $\Sigma \neq 0$? In this case the partial process becomes a 0-maintenance process whose products enable different sets of processes in a 4-cycle that is also different from the one we have been considering in Figures 3 and 4.

This turns out to be the general case. Every process in Figure 5 enables other processes that support one of the 16 glider configurations. Thus, when we consider non-vacuum conditions, the sets of processes triggered by different glider configurations are necessarily tied together into one large generalized glider organization whose boundary processes are conditioned on the particular external context in which they operate. If we fill in the dependencies for all processes in Figure 5 and simplify the resulting graph as described at the end of the previous section, then we obtain a schematic representation of the generalized glider organization analogous to the one shown for the vacuum glider organization in Figure 1A.

**From Constitution to Interaction**

The generalized glider organization shows us how the interdependencies between all of its component processes fit together to constitute a glider in all circumstances in which a glider can persist. Of special note is the way that moving from the vacuum glider organization to the generalized one has made clear the conditional nature of boundary processes on the external environment. But these are only local dependencies. What do they tell us about the interactions that a glider as a whole engages in with its environment? In short, how does this constitutive description relate to the interactive description shown in Figure 1B?

The answer to this question is already implicit in Figure 5, but needs a bit of unpacking to make explicit. We can begin by adding a few more dependency links (Figure 6). We can also color those links in a suggestive way, with different colors assigned to links according to which sets of processes they connect while taking the symmetry of the graph into account. If we now compare Figure 6 to Figure 1B, we can begin to see a correspondence between this generalized glider organization and the glider interaction graph. Now imagine replacing each set of processes in Figure 6 with the glider configuration that triggers them and bundling all process dependencies between any two configurations into a single transition edge of the same color. The correspondence is now complete.

What is the significance of this correspondence? It essentially demonstrates that the constitutive and interactive dimensions of a glider are two sides of the same coin. A glider’s domain of interaction is nothing more than the coordinated action of the totality of conditional and unconditional processes that make it up playing out in the particular context of the environment in which it finds itself. We can in fact derive the glider interaction graph from the generalized glider organization rather than exhaustively computing it as was originally done.

The final ingredient for such a derivation is a way to characterize how a set of local processes are globally coordinated so as to determine a unique transition of the glider as a whole. Recall from our earlier discussion of Figure 1A that a glider organization does not have any inherent spatial organization; the topology of the process dependency network is all that matters. So how does a process such as the one highlighted in Figure 5 “choose” between the different processes it could subsequently enable! The answer, of course, is that processes choose nothing. They simply produce the product specified by their type (conditioned on their local environment if they are partial processes occurring along the glider’s boundary). Rather, what determines the larger set of processes of which this process is a part is the constraints operating between processes.

Interprocess constraints have both spatial and temporal aspects. Spatially, adjacent processes have overlapping neighborhoods. If some cell in one process’s neighborhood takes on a particular value, then that cell must have the same value for any other process whose neighborhood shares that cell. This strongly constrains the way in which processes can be embedded in space. But temporal constraints are operating as well. The fact that a given process is taking place now constrains the types of processes that had to be taking place in this spatial region in the immediate past. Likewise, a current process constrains what processes can take place in this region in the immediate future. When all of these local constraints are jointly taken into account, they determine a network of global glider transitions conditioned on the environment of the glider as a whole. This network is precisely the glider interaction graph.

As an example of this correspondence in action, consider the problem of calculating a glider’s *umwelt*, that is, the way in which a glider parses local environmental configurations (e.g., BLACK, BLUE, etc.) into a world that is significant to it. Previously, these classes were derived by writing down a set of equations that must be satisfied for each observed glider transition to take place and then solving these equations for the environments that support these transitions. However, we can equally well derive these classes from the generalized glider organization and the interprocess constraints. Indeed, the two derivations turn out to be completely equivalent. When writing out the equations for a given glider transition, we are implicitly taking into account the underlying processes and constraints. Likewise, when working from the generalized glider organization, we are implicitly taking into account the way the glider’s environment enters into the process constraints via the conditions on partial boundary processes.

**Discussion**

In this paper, we have examined one aspect of life-mind continuity via an investigation of the relationship between the constitutive and interactive descriptions of a glider in the Game of Life. Using the notion of a partial process, we generalized a previous vacuum description of the glider organization. Not only does this generalization fully describe the vacuum glider organization for the first time, but it also demonstrates how conditional process dependencies interrelate the possible instantiations of that organization, forming a generalized glider organization that accounts for all of the different circumstances.
in which a glider can persist. This in turn determines the glider interaction graph that governs how a glider responds to every environmental perturbation it receives.

Of course, the particulars of a glider’s existence are of little general interest. The art in utilizing toy models lies in identifying the right broader insights that can be obtained from them. What general lessons can we extract from our analysis of the relationship between constitution and interaction in GoL?

The first, and most important, general lesson that can be drawn from our investigation is that, contra Maturana, the constitutive and interactive domains are deeply intertwined. Even the constitutive dimension of an emergent individual is fundamentally interactive, conditioned on the environmental context in which it occurs. When an individual encounters a given environment, it is in virtue of that individual’s constitution that it exhibits the interactive properties that it does. When such an individual distinguishes between some environmental situations and fails to distinguish between others, it is because the operation of its closed organization is sensitive to the former differences but insensitive to the latter. When that same individual responds in the way it does to a given situation, it is because this response is the inevitable consequence of the playing out of its constitutive processes in that situation. At least for simple enough systems, such

Figure 6: An elaboration of Figure 5 displaying the partial boundary processes of all process sets. Additional dependency links are also shown, colored according to the process sets they connect in such a way as to highlight the correspondence between this figure and Figure 1B. Conditions on the dependency links have been suppressed for clarity.
statements can be formalized to the point where it becomes possible to derive an individual’s interaction graph from its organization.

A second general point worth emphasizing is that such statements should not be taken to imply that an individual’s interactions are completely reducible to its constitution, which was presumably Maturana’s central concern. Relational facts between an individual and its environment will not in general predict that individual’s internal dynamics, and physiological facts will not in general predict that individual’s behavior (Di Paolo, 2018:83). For example, knowing how an individual’s responses to each possible situation are grounded in its constitution does not uniquely determine how an interaction will unfold over time. For that, we also need to know the interactive dynamics of its environment. Constitution at most determines only the interactive possibilities of an individual. Only when the interactive dynamics of both an individual and its environment are fully known, as well as the nature of their coupling, is the set of lives that that individual can enact in that environment fully determined (Beer, in press).

A third general issue to mention is the possibility of non-constitutive contributions to interaction. One’s stance on this issue turns on the breadth with which the notion of constitution is understood. If constitution is interpreted narrowly as mere metabolism, as is often the case, then clearly there can be other processes going on in an individual that aren’t directly tied to metabolism (Egbert et al, 2010). Perhaps the most discussed such example is the nervous system (Barandiaran & Moreno, 2006; Moreno & Mossio, 2015). On this view, the key fact about nervous systems is that they are largely decoupled from metabolism, allowing a relatively independent new domain of autonomy to take root. On the other hand, a nervous system can also be understood as just another component of a multicellular animal’s constitution. From this perspective, constitution refers not just narrowly to metabolism but more broadly to the entire set of physiological processes that maintain an individual as a functioning whole. This seems to be closer to Maturana’s original view when he argued that nervous systems are unnecessary for cognition, but when present they do vastly increase the structural possibilities available to an individual (Maturana & Varela, 1973/1980).

Let me end with a methodological observation. Debating conceptual issues such as life-mind continuity in the abstract is all well and good, but at some point one actually has to spell out what the processes are for a given system, what dependencies exist between those processes, how these dependencies are organized into a network, in what way that network’s operation is closed to form an emergent individual, how that individual interfaces with its environment, what the nature of that environment is, etc. Even fledgling theories of constitution and interaction in a simple toy model allow us to begin to tackle conceptual issues in a more rigorous way than is possible through verbal debate alone. Of course, the GoL toy model is lacking in many ways and other toy models should certainly be considered. In addition, the details of each concrete example will obviously differ. But it is much easier to abstract once we have understood in depth n special cases for some n > 0.

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