

# The Emergence of Symbols and Representations

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## Abstract

The notion of internal representation in cognitive systems and its role in intelligent behavior has been undergoing serious reformulation in cognitive science, ranging from rejection [FREEMAN and SKARDA 1990] [Varela, Thompson, and Rosch 1991] [Van Gelder and Port 1995] to externalization or leakage into the environment [Clark 1996]. Ultimately, however, such reformulation must address the familiar computation (or symbolic, information processing) versus dynamics (or emergent, connectionist, self-organizing) debate. Typically, researchers deal with this debate by choosing the side of one of these paradigms and pursuing its own research questions without getting any nearer to one of the key problems of cognitive science: the matter-symbol problem. Likewise, in Biology and Artificial Life a similar debate exists between those who posit that the essential component of evolutionary systems is the gene, conceived as a representation of aspects of the phenotype, and those who posit that evolutionary systems are better understood as dynamical systems (e.g. [Goodwin 1994]). Similarly, researchers in either side of this debate fail to discuss the problem of the origin of genetic representations, regardless of their importance, from chemical dynamics – which is the problem of the origin of life.

In cognitive science, several researchers have tried to approach the explanatory shortcomings of either of the two extreme paradigms above alone, by re-working the concept of representation into an essentially dynamics view of embodied agents in an environment (e.g. [Clark 1996]). In particular, Michael Wheeler and Andy Clark [Wheeler and Clark 1999] have proposed the biologically motivated notion of *genic representation* to discuss the need to incorporate information processing elements in complementary models of cognitive behavior. Such models do justice to the recently accumulated tremendous evidence supporting the embodied, dynamic view of cognition while also explaining the symbolic dimension that clearly exists in biological organisms. From the complex systems perspective, Melanie Mitchell [Mitchell 1998] has espoused a similar approach, while further offering a set of experiments based on a class of Cellular Automata where we can observe the emergence of representations from a dynamical substrate. All of them are attempting to tackle the problems cognitive science right in the neglected middle: the origin and nature of representations. Indeed, we know that in biological systems a coded, symbolic form of replication (genetic reproduction) has emerged and evolved out of the dynamics of self-organization [Wills 2001; Bedian 2001]. It is at least plausible that other dynamic systems, such as embodied brains, have undergone a similar origin of symbols development, and make use of those symbols for their functioning.

Thus, a complementary view of cognitive science must deal with this problem of the origin of symbols from dynamics in an evolutionary setting. Pattee [Pattee 1982] suggests that cognitive science should tackle such an origin problem by dealing with much simpler matter-symbol systems than the matter-mind problem of the

brain:

“We need simpler embodiments of *natural* matter-symbol systems with both empirical power and conceptual generality. Why should we work only with the ultimate functional complexity of brains, or the ultimate artificiality of computers, or the ultimate meanings of philosophical discourse? As a first trial I suggest trying to adapt our fundamental concepts of cognitive science to the basic symbol-matter problems of biology, and even physics, where a few rungs have already been secured.” [Pattee 1982] page 327

Wheeler and Clark follow this suggestion with their genic representation idea. Mitchell proposes Cellular Automata as a simpler, yet artificial, matter-symbol system to study the origin of representations. Both of these approaches call for a more explicit study of the different kinds of representations that can exist in biological and emergent computation symbol systems. To build empirical knowledge from simpler symbol-matter systems, as Pattee suggests, we need to agree on a set of concepts that allow us to contrast several such systems with one another, and ultimately with the mind-brain system itself. In this talk, we explore what we expect natural representations (and their simulations) to be in embodied agents. From this, we evaluate Mitchell’s Cellular Automata systems, supplemented with some computational results of our own, as simulations of the process of emergence of natural matter-symbol systems.

It needs to be stressed that this exercise is not an attempt to generalize the concepts of representation or cognition. We are not interested in claiming that cells or emergent computation in cellular automata are systems with minds. Rather, we are interested in mapping out different types of representations that occur in simpler symbol-matter systems, that may eventually lead to a greater understanding of the origin of symbols in cognitive and biological systems.

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