THE ORIGIN OF MIND

Alexei A. Sharov

Introduction

Many system scientists were fascinated by the vision of major transitions in the evolution of life (Turchin 1977; Maynard Smith, Szathmáry 1995). Kull (2009) attempted to describe major threshold zones in the evolution of living organisms using the classification of signs developed by Peirce. He distinguished between "vegetative" semiosis that is based on iconic signs, animal semiosis that is based on indexes, and cultural semiosis that is based on symbols. I agree with Kull on the importance of distinguishing levels of semiosis, however, I use different criteria for delineating them. In particular, I distinguish between *protosemiosis*, where signs directly encode and control functions of agents, and *eusemiosis*, where signs correspond to ideal objects (Sharov 2012). In this paper I focus on the transition from protosemiosis to eusemiosis, which is associated with the emergence of mind – a tool for classification and modeling of objects. The hallmark of mind is holistic perception of objects not reducible to individual features or signals. Protosemiotic agents use signs to directly control their actions, whereas eusemiotic agents use mind to associate signs with ideal objects. Ideal objects were initially designed for specific functions of agents, but later in evolution they became independent from functions and interconnected via arbitrarily established links.

Emergence of mind from elementary signaling processes

Although mind operates via molecular signaling processes it cannot be reduced to these processes. Following Prodi, I call these underlying processes as “protosemiosis” (Prodi 1988). Protosemiosis can be viewed as a “know-how” without “know-what”. Protosigns (i.e., signs used in protosemiotics) do not correspond to objects, which may seem confusing because our brains are trained to think in terms of objects. Although we associate a triplet of nucleotides with aminoacid, a cell does not have a holistic internal representation of aminoacids. Instead, a triplet of nucleotides in the mRNA is associated with an action of tRNA and ribosome, which together append an aminoacid to the growing protein chain. Protosemiosis roughly corresponds to “vegetative” semiosis, defined by Kull as communication based on icons (Kull 2009). However, the use of Peirce’s term “icon” in this context seems confusing. Icons “serve to represent their objects only in so far as they resemble them in themselves” (EP 2: 460–461). But similarity is derived from classification, which means that agents need a mind to interpret icons. Because protosemiotic agents do not have mind, they are unable to assess similarity and cannot use icons.

Mind represents a higher level of information processing compared to protosemiosis. It allows agents to classify and recognize objects and situations (e.g., food items, partners, and enemies), as well as predict object properties and events using models. Classifications and models represent the “knowledge” of an agent about itself and its environment (Uexküll 1982). This higher level of semiosis I proposed to call “eusemiosis” (Sharov 2012). Information processing in eusemiosis is no longer traceable to a sequence of signal exchange between components. Instead, it goes through multiple semi-redundant pathways, whose involvement may change from one instance to another but invariantly converge to the same result. Thus, attractor domains are more important for understanding the dynamics of mind than individual signaling pathways. Stable attractors that help to classify complex sensations into discrete meaningful categories I call “ideal objects”. Mind also needs a learning capacity to improve existing ideal objects and to create new ones. Requirement of learning does not imply that mind-carrying agents learn without stop. Mind may persist and function successfully in a non-learning state for a long time, but it cannot improve without learning.

All necessary components of mind can emerge at the protosemiotic level. Redundant signaling pathways ensure the reliability of the network, generate novel combinatorial signals, and increase the adaptability of agents. Stable attractors are necessary for all living organisms to maintain vital functions at optimal rates. Simple autocatalytic networks can support dynamic memory because they persist in two alternative stable states “on” or “off”. Moreover, such networks can support primitive learning (e.g., sensitization and habituation) as well as associative learning (Ginsburg, Jablonka 2009). Because all components of mind can emerge within protosemiotic agents, the emergence of mind seems inevitable.

Epigenetic regulation may have supported the emergence of mind

Epigenetic mechanisms include various changes in cells that are long-lasting but do not involve alterations of the DNA sequence. They are important for the origin of mind because: (1) they support practically unlimited number of attractors, and (2) these attractors represent rewritable memory that can be utilized for learning. As a toy model of cellular learning, consider a gene that can be activated via multiple regulatory modules in its promoter. Initially the chromatin is open at all regulatory modules, and DNA is accessible to transcription factors. Eventually, a successful action of a cell (e.g., capture of food) may become a “memory triggering event”, which forces the chromatin to condense at all regulatory modules except for the one that was functional at the time of the event. Then, as the cell encounters a similar pattern of signaling next time, a single regulatory module would be activated – the one that mediated a successful action previously.

Learning and anticipation can be found in organisms without nervous system (Krampen 1981; Armus et al. 2006; Ginsburg, Jablonka 2009). Thus, it is reasonable to assume that mind appeared in evolution before the emergence of a nervous system and was supported by epigenetic processes within individual cells. Then a multicellular brain should be viewed as a community of cellular "brains", whose functions are augmented via cell interactions. Each neuron needs to "know" its synapses because otherwise signals would be mixed up. In addition, neurons have to distinguish temporal patterns of signals (Baslow 2011). Thus, individual neurons require minimal mind to classify and model complex inputs.

Organisms learned to classify objects starting from their body

Because agent's body is most intimately linked with a large number of functions, we can hypothesize that body was the first object to be classified by mind. The purpose of classifying body states is to assign priorities to various functions, such as search for food, defense from enemies, and reproduction.

The usefulness of classifying and modeling objects depends on the ability of agents to track objects in time. For example, a predator that is chasing an object which was previously identified as a prey, does not need to repeat identification over and over again. Similarly, modeling appears beneficial only if the agent keeps track of the predicted object. The advantage of body as the first classified and modeled object is that it is always accessible, and thus, agents do not need additional skills for object tracking.

Modeling functions of mind

Modeling is the second major function of mind after classification of objects. Elements of modeling are present in any classification, because ideal objects are already models. However such models belong to the primary modeling system, where ideal objects are not connected, and therefore, not used for prediction or anticipation. Some of them are pure sensations, and others are integral sensation-actions. Advanced models that establish arbitrary relationships between ideal objects belong to the secondary modeling system (Sebeok 1987). The secondary modeling system allows agents to develop flexible relationships between signs and functions. It may have originated with the emergence of powerful sense organs that provided animals with more information than it was needed for immediate functions. Using a combination of a large number of traits, animals are able to recognize individual objects, associate them with each other, and make mental maps of the living space. Animals use dynamic models that link states of the same object in time and association models that predict the presence of one object from the observation of another kind of object. Association models are the main subject of Peirce's semiotics, where the perceived object is a sign vehicle that brings into attention the interpretant, or associated ideal object. Peirce, however, viewed sign relationship as a component of the world rather than model developed by agents. This philosophy (i.e., objective idealism), however, may lead to dogmatism as models become over-trusted. Because not all models generate reproducible results, they need to be tested.

Testing and communicating models

Model testing is one of the most important activities in science, and it has direct implications for epistemology (Turchin 1977; Rosen 1991; Popper 1999; Cariani 2011). Animals also test models, but they do not set experiments for the sake of testing hypotheses as humans do. Instead, they evaluate the success rate of their behavior strategies and make preferences for more successful behaviors. Model testing is a procedure that determines if predictions generated by the model match the changes in the real world. Formally it can be represented by three major components:

(1) model is a function F from input ideal objects to output ideal objects, (2) measurement is a function M that associates each real object O with ideal object $M(O)$ in mind, and (3) object tracking is a function that associates initial object O with the final object $G(O)$. Equation $M(G(O)) = F(M(O))$ represents successful model testing because the measurement of the final object matches the output of the model, where the measurement of the initial object was used as input. This equation is similar to the commuting diagrams proposed previously to explain principles of model testing (Rosen 1991; Cariani 2011), but function G was interpreted as an objective natural dynamics of the world. In contrast, I associate function G with agent's ability to track and/or manipulate objects. An example of non-trivial object tracking is the association of the "morning star" with "evening star" (i.e., planet Venus) on the basis of the model of planetary movement. This example illustrates that all components of the model relation are interdependent epistemic tools.

Most models used by animals are not communicated to other individuals. Thus, each animal has to develop its own models based on trials and errors. However, social interactions may help to develop models in young animals. For example, animals may copy the behavior of their parents and eventually acquire their models. However, efficient communication of models is possible only by language, which corresponds to the cultural level of semiosis, following the terminology of Kull (2009). In language, signs do not only correspond to ideal objects, they also replicate the structure of relationships between ideal objects in the model. Thus, the language itself becomes a modeling environment and represents the tertiary modeling system (Sebeok, Danesi 2000). Because the meanings of signs in language are fixed by convention within the communication system, a message with two interconnected signs is interpreted as a link between corresponding ideal objects within the model.

References

Armus, Harvard L.; Montgomery, Amber R.; Gurney, Rebecca L. 2006. Discrimination learning and extinction in paramecia (*P. caudatum*). *Psychological Reports* 98(3): 705–711.

Baslow, Morris H. 2011. Biosemiosis and the cellular basis of mind. How the oxidation of glucose by individual neurons in brain results in meaningful communications and in the emergence of "mind". *Biosemiotics* 4(1): 39–53.

Cariani, Peter 2011. The semiotics of cybernetic percept-action systems. *International Journal of Signs and Semiotic Systems* 1(1): 1–17.

EP = Peirce, Charles S. 1998[1893–1913].

Ginsburg, Simona; Jablonka, Eva 2009. Epigenetic learning in non-neural organisms. *Journal of Biosciences* 34(4): 633–646.

Krampen, Martin 1981. Phytosemiotics. *Semiotica* 36(3/4): 187–209.

Kull, Kalevi 2009. Vegetative, animal, and cultural semiosis: The semiotic threshold zones. *Cognitive Semiotics* 4: 8–27.

Maynard Smith, John; Szathmáry, Eörs 1995. *The Major Transitions in Evolution*. Oxford, New York: W. H. Freeman Spektrum.

Peirce, Charles Sanders 1998[1893–1913]. *The Essential Peirce: Selected Philosophical Writings*. II vols. [Peirce Edition Project, ed.] Bloomington, Indianapolis: Indiana University Press. [In-text references are to EP, followed by volume and page numbers].

Popper, Karl 1999. *All Life is Problem Solving.* London: Routledge.

Prodi, Giorgio 1988. Material bases of signification. *Semiotica* 69(3/4): 191–241.

Rosen, Robert 1991. *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life.* New York: Columbia University Press.

Sebeok, Thomas A. 1987. Language: How primary a modeling system? In: Deely, John (ed.), *Semiotics 1987.* Lanham: University Press of America, 15–27.

Sebeok, Thomas A.; Danesi, Marcel 2000. *The Forms of Meaning. Modeling Systems Theory and Semiotic Analysis.* Berlin, New York: Mouton de Gruyter.

Sharov, Alexei 2012 (in press). Evolution of natural agents: Preservation, development, and emergence of functional information. In: Kull, Kalevi; Hoffmeyer, Jesper; Sharov, Alexei (eds.), *Approaches to Semiosis of Evolution*. Berlin: Springer.

Turchin, Valentin F. 1977. *The Phenomenon of Science. A Cybernetic Approach to Human Evolution*. New York: Columbia University Press.

Uexküll, Jakob von 1982. The theory of meaning. *Semiotica* 42(1): 25–82.