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COMMENT

Consciousness and Learning from the Biosemiotic Perspective

Comment for the Target Article by Jablonka and Ginsburg

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Background

The target article by Jablonka and Ginsburg (2022) addresses the fundamental question of biology: "what consciousness means?" There is no consensus among biologists and philosophers on the distribution of cognition, learning, and consciousness among living species. Some biologists consider any encoded experience of organisms as learning, or knowledge and code-dependent regulatory processes as cognition or consciousness (Baluška & Reber, 2021; Bechtel & Bich, 2021; Shapiro, 2011); according to them, learning and cognition can be found even in bacteria. But the dominating view is that cognition is restricted to animals with a nervous system and that consciousness requires strong integration of sensory, motor, memory, and value-generating processes (Dehaene & Changeux, 2011). Dickinson and Balleine (1994, 2000) were among the first to link consciousness with learning and goal-directed behavior in animals. Recently, Ginsburg and Jablonka (2019) developed a concept of consciousness that combines evolutionary and functional criteria, and where advanced form of associated learning plays the key role. In this commentary I compare the theory of consciousness developed by Jablonka and Ginsburg in their Target Article with similar ideas in biosemiotics.

Cognitive Evolutionary Transitions

The theory of major evolutionary transitions emerged from many earlier attempts to depict the progressive evolution of organisms by biologists and philosophers including Lamarck, Spencer, Haeckel, Bergson, Teilhard de Chardin, and Vernadsky. Evolutionary transitions were conceptualized first by Turchin (1977) and then by Maynard-Smith and Szathmáry (1995). According to these concepts, organisms acquire qualitatively new levels of adaptability and freedom in macro-evolution.

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The emergence of cognition was counted as a 'metasystem transition' by Turchin (1977); he described it as thinking and modeling that allows control of associating (i.e., conditioning).[1] Maynard Smith and Szathmáry (1995) did not include cognition or consciousness into their list of major transitions in evolution. Systematic analysis of consciousness as one of major evolutionary transitions was done later by Ginsburg and Jablonka (2019) in their book *The Evolution of the Sensitive Soul*, where authors argue that the evolution of subjective experience in animals was driven by learning, and that the key feature of minimal consciousness is Unlimited Associative Learning (UAL). UAL is characterized as open-ended, representational, generative, and recursive form of associative learning,[2] where different features of a compound object are perceived as single gestalt-percepts (Jablonka & Ginsburg, 2022: Table 1). UAL is opposed to Limited Associative Learning (LAL), which includes classical and instrumental conditioning based on elemental stimuli and actions. The emergence of UAL is presented as a switch to a more advanced mode of being in living organisms, which happened mostly in three taxonomic lineages of animals: vertebrates, some arthropods, and some cephalopods. The emergence of consciousness qualifies as evolutionary transition because it is based on the new system of values and goals, perceptual integration, and second-order conditioning that together support open-ended associative learning (Ginsburg & Jablonka, 2019, 2021).

Ginsburg and Jablonka (2019) proposed that classical conditioning to new compound conditioned stimuli (CS) can be used as a test for UAL: a conscious animal should be able to reliably recognize compound CS after training sessions where the CS is presented together with unconditioned stimulus (US) that normally causes a specific behavioral response. The CS is assumed to be recognized if the animal associates the original CS (but not the modified CS with missing or rearranged components) with US and responds to the CS presented alone in exactly the same way as it responds to US. This type of conditioning is also known as 'non-elemental learning' (Guirfa, 2003). Jablonka and Ginsburg (2022) include several additional requirement for UAL such as second-order conditioning, context-dependency, and accounting for a possible time gap between stimuli. They also compiled a consensus list of other capacities associated with UAL, which include global accessibility to sensorial input and executive systems, flexible value attribution, intentionality, agency, goal-directed behavior, and the sense of self.

Ginsburg and Jablonka (2019) hypothesize that the emergence of UAL was one of the major factors that accelerated the evolution of animals in the Cambrian period. In particular, associative learning may have facilitated increased behavioral plasticity of animals that opened new opportunities for evolutionary change via phenotypic accommodation. Emergence of first conscious animals coincided with dramatic extinction of non-conscious species which could have been caused by increased competition and predator–prey relations. Many species evolved learning capacities as a counter-measure when confronted by conscious competitors and enemies.

[1] Turchin's (1977) 'cognition' is roughly equivalent to 'consciousness'.

[2] Associative learning is establishing a new cognitive interpretation (object/concept) of a sensorial stimulus based on individual experience (i.e., not programmed hereditarily or by other means).

Consciousness played an important role in qualitative evolutionary changes in the nervous system because it facilitated selection towards the development of sensory and motor integration, dedicated memory unit, feelings, emotions, goal-directedness, value control, and decision-making.

According to Ginsburg and Jablonka (2019, 2021), two additional evolutionary transitions followed the emergence of minimal consciousness, which resulted in the development of imagination and symbolic thinking. Imagination allows animals to develop virtual scenarios of their actions and compare the value of expected outcomes. It also supports dreaming and playing in animals. Emergence of organisms capable of imagination qualify as the major transition because it provides a new level of selection among virtual scenarios, requires a new type of information storage – episodic memory, integrates representations of past experience, and generates additional control pathways. Symbolic thinking is characterized by using abstract concepts ("true", "good"), rational goal selection, and language. It is fully-developed only in the human species, although some animals show elements of symbolic thinking. In humans, each word stimulates specific imagination in the recipient and this allows passing of complex meanings between individuals.

The target article by Jablonka and Ginsburg (2022: 10) draws our attention to some new aspects of the evolution of learning and consciousness. The first is "turbulent inwardness" which is based on spontaneous activity of *plasticity default networks* in living organisms; authors call it *vivaciousness*. This feature is present in all living beings but it is implemented differently in various parts of organisms and diverse species. In particular, vivaciousness is employed in exploration-stabilization processes that are necessary for all levels of learning: modulation of conditioning in LAL, dynamical consciousness in UAL, and emergent reflectiveness of the symbolic mode of being.

The second issue that caught my attention is the emotional aspect of consciousness, which is not totally new, as it has been described starting from Aristotle. But in the target article it is presented vividly as a *joy of exploration* that covers access to sensory stimuli, activity, and free will. For example, ponies that were confined to coal mines during their whole life experienced incredible joy after they were brought to the surface (Crane, 1894). Such built-in emotional reward is an important stimulus for learning; it may appear even stronger in some animals than functional rewards from problem-solving.

The third important issue is that consciousness plays an active role in evolution. This fact *breaks the monopoly of natural selection* as the leading factor of evolution. Thus, the target article contributes to the ideas of the Extended Evolutionary Synthesis (Noble, 2021; Pigliucci & Müller, 2010), according to which, neo-Darwinism theory needs a major revision. Jablonka and Ginsburg (2022: 24–25) wrote:

> Importantly, variations among perceived sensory and motor patterns and variations in the evaluations of such patterns determine the ways in which selection operates on interacting conspecifics as well as on individuals from other interacting species (Jablonka, 2021). Sexual selection is a case in point: the complex patterns on the peacock's tail could evolve only if peahens could discriminate among variant patterns and assign value to them; the song of the

male nightingale evolved because females discriminate among and prefer complex and varied songs, and the evolution of the visual and olfactory patterns of flowers could evolve because of the ability of insects and birds to discriminate among visual and olfactory patterns.

In short, selection that drives evolution is often done by organisms which make informed conscious choices in their living activities. Hence, goal-directedness of organisms is a part of the evolutionary process.

A Biosemiotic View on Evolutionary Transitions

Biology needs specific terms to acknowledge goal-directed functionality and regulation of molecular-level processes in all living systems. Some scholars (Baluška & Reber, 2021; Ginsburg & Jablonka, 2021; Shapiro, 2012) use anthropocentric terms (e.g., ‘cognition’, ‘consciousness’, and ‘learning’) for this purpose. But these terms are historically applied to representational cognition and learning in conscious animals and humans; thus, it is misleading to apply them to molecular-level plasticity in bacteria which involves entirely different mechanisms. To avoid over-reaching metaphors, it makes sense to characterize the functionality and regulation of all organisms by non-anthropocentric terms. The term ‘information’ would be suitable if it were not stripped of meaning and value within the information theory of Shannon (1948).[3] Thus, to describe meaningful communication and signaling in biology, it is reasonable to use the terminology of semiotics, which is another non-anthropocentric doctrine that is focused on meaning and interpretation of signs. In particular, biosemiotics studies signs and sign processes (semiosis) in living organisms and systems (Anderson et al., 1984). Following Sebeok (1976), it assumes that semiosis exists only in living systems (and in some life-dependent systems). An important notion in biosemiotics is *semiotic agenc*y, which is a “capacity for acting purposefully and using signs to make informed choices” (Sharov & Tønnessen, 2021: 153). Agency is a generalization of the notion of organism; besides organisms, agents include autonomous parts of organisms (subagents) and multi-organism units. Goal-directedness of agents can be acquired by evolution and learning or imprinted by parental agents (e.g., in subagents).

Several studies in biosemiotics attempted to delineate major transitions in evolution that caused qualitative changes in semiotic processes. Hoffmeyer and Stjernfelt (2016) described the following eleven steps: (1) molecular recognition, (2) eukaryotic cell, (3) multicellularity, (4) from irritability to phenotypic plasticity, (5) sense perception, (6) behavioral choice, (7) active information gathering, (8) collaboration, deception, (9) learning and social intelligence, (10) sentience, and (11) consciousness. In this hierarchy, consciousness is the last transition and it implies “iconic inner experience, works as a holistic marker focusing the enormous diversity of ongoing calculations upon a single path of action” (ibid: 24).

[3] The notion of ‘functional information’ is suitable because it includes goal-directedness and meaning.

To delineate major transitions in the evolution of life, I follow the Umwelt theory of Jakob von Uexküll (1982 [1940]), according to which animals develop species-specific models of their environment (Umwelten) which include links with living functions. An elementary component of Umwelt is a functional circle, where sensing, perception, and action are integrated into a self-sustained and adaptive feedback loop (von Uexküll, 1926, 1957). In semiotic terms, a percept is a sign that is interpreted as a cue for action via historically acquired habit. Habits emerge by adaptive evolution, development, and learning, and thus are generally beneficial for the agent.

The first evolutionary transition is the origin of life, which is the emergence of functional circles represented by simple catalytic agents capable of self-production and niche construction (Sharov & Tønnessen, 2021). These functional elements diversified via Darwinian-like evolution and were forced to cooperate if they shared resource units, such as oil droplets in water. These functional molecules eventually formed polymers capable of template-based pairing and self-replication, which marks the second major evolutionary transition. Subsequent evolution led to hierarchical integration of molecular functional circles into larger functional units, which formed new levels of functional circles. One of them was associated with the emergence of membrane-bound cells with primitive internal metabolism. Several additional transitions were required to reach the level of basic prokaryotic cell, such as the emergence of ribosomes and protein synthesis, DNA-based genome, regulation of cell division, production of cell wall and various appendages.

Although bacteria demonstrate very complex processes of information processing and signaling, such as chemotaxis, quorum sensing, habituation, sensitization, and immune response (Shapiro, 2011), their semiotic processes are fundamentally simpler than those in most eukaryotic organisms. Thus, two major levels of semiosis are distinguished: *protosemiosis*[4]—processing of signals without perception of objects—in prokaryotes, and *eusemiosis*—perception and categorization of objects—in most eukaryotes (Sharov & Vehkavaara, 2015). In protosemiosis, (i) individual signals are processed either directly or via simple logic gates, (ii) no reality is assumed outside the cell as a source of receptor excitation, and (iii) signals are processed in a threshold-based way. In contrast, eusemiosis, which is equivalent to *minimal mind*, includes (i) rich and diverse sensory input that is filtered via cascades of signaling networks, (ii) capacity to attribute sensory patterns to objects in the environment, and (iii) categorization of objects based on patterns of sensorial stimuli (Sharov, 2018). Using terms of von Uexküll, Umwelt appears in eusemiosis, whereas protosemiosis is represented by weakly linked functional circles that comprise a *signal-world* (Sharov & Tønnessen, 2021). Eusemiosis can be implemented without a nervous system as in protists, fungi, plants, and primitive animals (sponges). In unicellular eukaryotes, it is implemented by large organelles that integrate diverse signaling pathways, such as cell membrane, centrosomes, nucleolus, chromatin hubs, golgi, ribosomes, and nuclear stress bodies. In multicellular

[4] The term 'protosemiosis' was introduced by Prodi (1988) for molecular signaling processes, such as detection of specific molecules by protein receptors.

organisms without neurons, it includes chemical communication between cells, differentiation, and cell movements.

The origin of eukaryotic cell is included in the list of evolutionary transitions by Maynard Smith and Szathmáry (1995) and by Hoffmeyer and Stjernfelt (2016). But these authors were focused on the symbiogenesis and on the reduction of horizontal gene transfer in eukaryotes. As a result, they overlooked the difference between molecular signaling in cells (protosemiosis) and object perception and recognition by eukaryotic organisms (eusemiosis); in contrast, this difference was emphasized by Pantin (1956: 588) and Prodi (1988).

Neural implementation of eusemiosis, or *cognition*, is certainly a major evolutionary transition because neurons with appendages (axons and dendrites) radically increase the integration of parts of an organism into a united whole. Nervous system can be compared to an 'internet' that supports fast communication between all parts of the body and facilitates sensory-motor associations. Primitive cognition is based on innate classifiers of objects and events, which become associated with innate behavioral patterns (simple reflexes). But the nervous system provides enough plasticity to adjust innate neural networks of an animal to the actual environment and to make them functional. Thus, even primitive neural mechanisms are easily adjusted by habituation, sensitization, and Hebbian association. Such adjustment is done without conscious control, and thus I call it 'plasticity' rather than 'learning'. Many cases of conditioning also do not qualify as 'learning'. For example, the unusual release of gill retraction reflex in the mollusk *Applisia*, which is considered by Jablonka and Ginsburg as associative learning, does not involve memorizing of a new sensorial pattern. Instead, it is based solely on the plasticity of a unitary innate association, and is a far simpler process than real associative learning in mammals and birds.

The next evolutionary transition is the emergence of *consciousness*, which is a *learning-based cognition*.[5] I agree with Jablonka and Ginsburg that the hallmark of consciousness is integration of multiple stimuli generated by various sense organs, or stimuli arranged into spatial or temporal patterns (e.g., visual images or sound sequences). Consciousness also supports integration of elemental actions into new activity patterns and context-dependent modification of perception and action.

Early evolutionary stages of learning (e.g., imprinting) are likely based on a holistic gestalt-percepts with a static composition of features. But more advanced learning allows animals to assign weights to features of a perceptual image based on repeated experience and degree of reinforcement. Eventually, these weights can become context-dependent, which adds another layer of integration to the consciousness. Another criterion of advanced consciousness in animals is *reflectiveness*, when animals recognize themselves and other animals as conscious agents. Reflective consciousness is beneficial because it facilitates imagination and play behaviors,

[5] Habituation, sensitization, and natural selection do not quality as 'learning' because they are omnipresent in organisms and based on different types of memory. It is better to call them 'plasticity'. True learning involves memorizing a specific new pattern of signals (e.g., visual, acoustic, or chemical), new pattern of behavior, or context-dependent association.

accelerates learning and decision-making. The evolutionary transition from hominid primates to humans involved multiple dramatic changes in cognition, communication, and use of artifacts, but these changes are beyond the topic of this commentary.

Conclusion

Evolutionary transitions of signaling and cognitive capacities of organisms described by Jablonka and Ginsburg (2022) mostly match with the analysis of semiotic competence levels of organisms in biosemiotics. In particular, both approaches emphasize the connection of consciousness with learning of new patterns in perceived objects, behaviors, and associations between them. The differences include: the broader definition of learning and cognition and the absence of protosemiosis-eusemiosis transition in the approach of Jablonka and Ginsburg, and the absence of LAL in the biosemiotics approach. The merits of the theory of Jablonka and Ginsburg include formulation of vivaciousness as a proactive exploration activity of organisms, operational definition of UAL, compiling a set of consensus-features associated with UAL, making schemes of functional architecture of UAL, elaboration of the emotional status of organisms capable of UAL, and the analysis of advanced levels of consciousness associated with imagination and symbolic representation.

Declarations

Conflict of Interest The author declares no conflict of interests.

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