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Life and consciousness: self-organization through learning and memory

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Life at two levels

What is life? We all know what it is like to lead a life, and therefore the answer seems obvious. On a second thought, however, the question is rather vague, perhaps even rhetorical. A scientist would replace what with how: how do living things live? How are they different from non-living things? How does life go on rather than die out?

Human life continues at two levels: at the level of biology, the body is constituted in chemical compounds that sustain a stable organization. The biochemical processes of continual assembly (anabolism) and dissolution (catabolism) are called metabolism. At the level of psychology, the mind is constructed both by learning to encode life experiences into a sustainable organization of the self and by memory to decode the self during interaction with the environment, that is, perception and action.

1. How learning occurs

Learning is a process by which past experiences exert influence on the present action. All experiences induce changes in an intelligent system. Some of the changes will disappear when the experiences come to an end, whereas other changes will outlast the end. Learning involves the latter kind of changes.

Learning occurs in many organs in a living organism. The immune system, for instance, recognizes a new offender that have invaded into the body, and transforms itself in response to the invasion. It studies and learns the offender, be it a virus such as COVID-19 or an organ transplanted to replace a failing kidney or heart.

The brain is by far the most advanced system for learning. It records every experience it undergoes since its formation up until the present moment. It keeps traces of sensations, perceptions, thoughts, decisions, and actions that it have engaged. The traces are then assembled and organized into memory.

What makes learning possible in the brain is that the constituents and their connections in the neural system are plastic, i.e., malleable or changeable. This neuroplasticity is subserved by three broad types of neural mechanisms: 1) disinhibition of existing neural connections, 2) change in the efficiency of the connections, and 3) establishment of new connections.

These three types of changes share a common characteristic that they are tightly linked to the activity of the very connections that are changed. This characteristic is known as the Hebbian rule: the connection of neurons that fire together gets stronger.

It is important to recognize that learning always requires action, and yet the learning process itself is rarely the aim of the action. It is almost always a by-product of action. It just happens when one acts. Note that what we mean by action here is not just those involving movement of body parts, but rather broad, including actions of sensory apparatuses, cognitive systems, decision-making circuits, etc. Activity of all such networks in the brain will incur changes within and outside of themselves, resulting in learning.

Life is the totality of actions performed, but not just that, since the very actions performed entail changes in the system itself. Therefore, life is not simply something that a living system does, but rather a continuous process of re-making itself by the system.

2. How memory works

So far, we have examined the process whereby life is changed by its actions. Obviously, life also works in the opposite direction: life makes its actions. How does it do that?

Choice of an action in life is a complex interplay of what a living system is capable of and what the environment provides it with. The life of a living system is a continuous interaction with its environment, in terms of matter and information. The material interaction takes place in the metabolic processes whereby energy in the form of material is transferred across the boundary of a living organism. The energy then is utilized by the organism for action toward the environment and for maintaining itself.

In so doing, the boundary between the organism and the environment is maintained and the life renewed, despite the continuous transfer of matter across it and against the tremendous odds of death risked in the material exchange. The probability of death is always present and lurking, due to the universal second law of thermodynamics. Therefore, a living system must choose and execute actions wisely. This is where the need arises that the system interacts with the environment in terms of information.

Choice of actions in life involves information, not just material. Continuous renewal of an organism's life on earth depends as much on how it exchanges information with its environment as it moves chemical compounds in and out of its body. Such information exchange takes place at two levels of space-time scale. One at the evolutionary timescale and at the level of a species, and the other at the timescale less than the life span of an individual and at the spatial scale approximately of its brain.

Seemingly simple actions of an individual life-form may have been chosen by a complex series of selections during a long and convoluted history in evolution of the species. At each step of evolutionary selections, life experiences and ultimately death of the individuals exerts an influence. The choice between life and death by each individual is a cornerstone at every

juncture of selection for the species' survival. Each choice is then accumulated as information in each and every member of the species, and resurrected in each and every action the member carries out.

An action not only resurrects information accrued over the evolutionary history of a species, but also reactivates information stored, by learning, from experiences over the life so far of an individual member of the species. This reactivation may be implemented by at least three distinct brain systems, depending on the duration of information storage: 1) the system for perceptual memory, such as iconic memory, which may last up to a second, 2) that for short-term memory, including working memory, the duration of which can be up to several second without an interruption, and 3) the long-term memory systems, which can be further classified into explicit versus implicit, declarative versus procedural, semantic and episodic, and so on.

The role of memory in action is prominent in the choice as much as in the execution of an action. A motor program needs to be selected among competing alternatives more or less appropriate for a given situation. The outcome in the competition will be dictated by a total sum of information provided by intention, perception, and memory associated with the intention and triggered by the perception. The chosen motor program then will be executed by recruiting neural circuits to control body parts in accordance with the aimed movement. The execution is no less than an activation of the long-term procedural memory system.

3. Consciousness as an extension of life

What is the relationship between life and consciousness? There are various thoughts and discussions on what consciousness is. To answer this question, I would like posit the notion of consciousness in contrast to a few concepts. First, how is consciousness related to life? Some may take these two each at the opposite end: *zoe* versus *bios*, for instance. Life as *zoe*, that is, activities that are blindly biological, mostly unconscious, and without clear aims except its own survival. Consciousness in contrast enables us to make choices for some meaning and purpose, that is, to make a life as *bios* worth the effort. Second, others take consciousness as a part of

mind which is the opposite of matter. Implications of mind-matter dichotomy are many, but I would like to point out just one here, the opposition of freedom versus destiny, free will versus determinism (of divinity in the medieval times and of matter in modernity). These contrasting views on the relationship between life and consciousness are all good and have a certain truth to them, but I would rather think of them in a continuum. In that way, I believe we will advance our understanding of consciousness a little further.

In my fields of study, namely, neurology, neuroscience, and cognitive science, consciousness have no less than three meanings or usages. First, neurologists describe a patient as conscious, if he or she responds quickly and appropriately, as opposed to someone who is comatose, stuporous, or drowsy. Second, a conscious being is aware of the worlds surrounding it. Consciousness here means awareness. The content of the awareness varies from what is here and now to, let's say, scientific evidence on the Big Bang or economic data on inequality and injustice in the Korean society. Third, consciousness means reflections on these responses and awareness, including the thought on consciousness. Being aware of a thing is one thing, and being aware of the very awareness (of a thing) is quite another. In this sense, consciousness is a capacity of meta-cognition, i.e., consciousness on consciousness. Self-consciousness is a part of consciousness of this kind. Political consciousness of a social class recognizing its role in history is another example of this usage of the term.

Now, consciousness is a property of a living organism, and therefore consciousness may mean almost the same thing as life, if you take the first usage. On the other hand, if you take the second usage, it is exactly the opposite of material processes in life. A physicochemicobiological process will hardly be aware of the process itself or the environment that it interacts with. A stomach would not be aware of the flavorful beef steak it is digesting, lungs would not know that the air it inspires contains oxygen that it requires for the very act of inspiration, or a heart would never recognize that the very blood it squeezes comes back to it to supply energy. Noticing the third usage, I would consider the notion that life and consciousness are on a continuum. The continuity by which consciousness extends life is that both organizes itself, autonomously creating what is the self.

4. Putting together: the mind-matter hybrid organized through learning and memory

So far, we have reflected on how life works, how consciousness plays a role in life, and how they both continue existence by the cycles of learning and memory. Life creates itself, in itself and for itself. That is, life is a self-organization: life is both the subject and the object in the formation of an organic whole. Conscious thinking in the human organism takes a significant part in this self-organization, producing a self as an object. The self then initiates, as a subject, another round of self-organization.

In this view, consciousness may not be the exact name for the process. Subjectivity is perhaps better. Yet, I think intention is the best. In fact, in most cases where we engage consciousness, intention seems more appropriate. We say we make a conscious choice, when it is an intentional one. We commit a sin intentionally rather than consciously, and so on.

We have had much difficulty in understanding what consciousness is. One of the reasons, I think, is our mentalist tendency in approaching it. Consciousness is too often viewed as something mental, completely dissociable from material things. As alluded above, it is regarded as a business of the mind, while life as that of the matter. However, consciousness is part of life processes that involve both the mind and the matter. Life is constituted in and constructed by mental processes as well as material ones, and conscious thoughts and actions are no exceptions. Now, it is through learning and memory that the two types of life processes are inseparably linked. Learning lays mental experiences down into material traces in the brain by neuroplasticity, while these material traces, as memory, turn sensations into mental experiences of percepts, concepts, and eventually acts.