

Are Your Cells Conscious?

Review of *The First Minds: Caterpillars, 'Karyotes, and Consciousness* by Arthur S. Reber.

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The origin and nature of sentience, the ability to subjectively experience, is one of the big questions of biology and psychology, a topic that has challenged and tormented scholars since its inception. In the last decade, several evolutionary approaches to the topic have been developing, and Arthur Reber, in his book *The First Minds: Caterpillars, 'Karyotes, and Consciousness* explores one intriguing evolutionary approach. He proposes that sentience is a primitive of life, and has emerged as the first living entities appeared on our planet. Cells, single cells like bacteria, and the cells from which our bodies are composed are, he suggests, sentient, or conscious. He puts forward two related claims:

“(i) The origins of mind and consciousness will be found in the simplest, single-celled organisms,

and,

(ii) Consciousness, subjectivity, phenomenal experience or, if you prefer, sentience, is an inherent feature of living organic form(s).” (Reber 2018, p. ix)

Reber develops this thesis in two stages. In the first part of the book (chapter 1-3) he exposes the problems of current approaches to consciousness. He critically discusses the claims that consciousness may be realized in robots, and scrutinizes the views of several philosophers, including John Searle, Dan Dennett, and David Chalmers. He then tries to explain why his own full thesis on the origin of consciousness has not been suggested before, although certain scientists came close to it, and reviews some of the current theories of consciousness and some of the philosophical problems related to them. In the second part of the book (chapters 4 and 5), which is the focus of our review, Reber develops his bold claim that the simplest, single-celled organisms, such as bacteria and amoebae, have minds and free wills. Among other actions and activities, they feel, decide, think, and know. He calls his theory of the origin of sentient minds

The Cellular Basis of Consciousness (CBC), describing the many intricacies in the structure and behavior of unicellular organisms and providing some tantalizing examples of their sensory feats, distinctions, metabolic activities, environmental reactions and motility. These examples of adaptive plasticity are equated with awareness, sentience and consciousness. In his own words: "When some event is sensed it *is* felt. It *is* experienced. It is encoded as a subjective phenomenal state — even when the organism doing the sensing is unicellular" (page 119, Reber's emphases). In the last chapter of the book, Reber discusses the possibility that plants are non-conscious, and explores some secondary benefits of the CBC stance that may allow us to avoid certain philosophical puzzles and "epistemic dead ends". Reber's thesis has an intuitive appeal, he touches upon important open questions and his engaging style makes the book accessible to a wide audience. Furthermore, his disarming airs and sense of humor make him very likable. But he did not convince us.

In what follows we attempt to present the core of Reber's thesis and its relation to and departure from a view of minimal *cognition* developed by Francisco Varela and Humberto Maturana (e.g. Maturana and Varela 1980) and their followers, and, from a different perspective, also by Dennis Bray (2009), and Pamela Lyon (2015). We then discuss Reber's argument about the possible non-sentience of plants (and presumably other sessile organisms) and suggest that it is a red herring from his own point view. Even if this red herring is avoided, we maintain that his argument, equating adaptive plasticity with sentience does not solve the philosophical problems he identifies, although his ideas do highlight important and as yet unresolved biological questions.

Life and mind

As Maturana and Varela famously argued, "living systems are cognitive systems and living as a process is a process of cognition" (Maturana and Varela 1980, p. 13). They defined cognition very broadly, as the ability of an autopoietic system (a system that is self-maintaining and self-regenerating and that has a distinct topological, partially environmentally-autonomous, identity) to regulate its relationship with the environment. The relation is such that an autopoietic system like a cell persists in spite of the endless changes in both its external and internal milieu. In other words, adaptive plasticity is a necessary attribute of an autopoietic system, a primitive of

sustainable life. The idea of adaptive plasticity as a primitive of life is not new: it was central to the biological view of Jean Baptist Lamarck (1809), the biological philosophy of Hans Jonas (1966), and the biological perspective offered by Mary Jane West Eberhard (2003), to name just a few.

Our growing knowledge of the ways in which adaptive plasticity is implemented in single cells is central to Reber's view of the cell as a sentient being. Like Bray, Lyon and their historical predecessors, Reber focuses on the sophistication and adaptive plasticity of single cells, of bacteria and protists: their multiple sensors, complex signals transduction pathways, memory mechanisms, collective interactions such as quorum sensing, and, in some cases, their motility and their ability to learn through habituation and sensitization (although ontogenetic learning and evolutionary learning in lineages and colonies is confused; e.g., Mitchell et al. 2009). Central to Reber's view of the cell as displaying not only cognition but also sentience, is its ability to evaluate incoming signs and outcomes of its own activity: these signs have valence that depends on how they affect the departure or closeness of the organism to a homeostatic state. This ability to attribute positive or negative valence is for Reber evidence of a primitive but effective form of sentience.

Reber stresses, following Bray, that these various capacities are based on computations occurring in cellular networks that involve polymers such as proteins, nucleic acids, and complex polysaccharides as well as many small molecules that together form a soup-like, slurry medium with a lot of never-ending movement, the result of thermal diffusion and other stochastic processes. Bray calls "The sum of all the information rich molecular processes inside a living cell", *wetware* (Bray 2009 p.6). Both in terms of material (slurry soup) and in terms of the identity of the computing units with the structural units, which are the very same entities, the living cell is very different from a silicon-based robot. The kind of adaptive plasticity displayed by a living cell enables it to maintain itself and to regenerate itself. It is the basis of life as we know it.

We agree with Reber that no current artificially constructed robot approaches the feats of a living cell, and we too have argued for the view of cells and multicellular non-neural organisms as

cognitive entities able to ontogenetically learn through epigenetic mechanisms (Ginsburg and Jablonka 2009, 2019). We also believe that the incredible plasticity afforded by “wetware” may be very difficult to simulate in non-carbon-based materials, and that it is possible that sentience will turn out to require carbon-based materials. We do not, however, accept Reber’s assumption that single cells’ adaptive plasticity, including the ability of valence-attribution is synonymous to sentience. We know that there are several types of stress response systems in both prokaryotes and eukaryotes, for example, to extremes of temperatures, to toxins, to starvation, to DNA damage, to infection. We do not see why the structure and activity of these valence systems, which signal departures from homeostasis and trigger responses that often lead to the relief from stress, require sentience. One can, of course, *assume* that the effects of stress responses entail something like feelings, but this is then an axiom, not an argument.

One might argue that there is biochemical continuity between the stress responses of single cells and the neuro-hormonal stress responses of animals to whom we attribute sentience such as ourselves. Since mental stress, like every other systemic activity in a multicellular body, is mediated by cellular activities, Reber suggests that single cells too *feel* stress and do not just respond to stress. There is, indeed, amazing conservation at the molecular level between all living organisms. This conservation tells us the molecular tinkering is abundant and inevitable given evolutionary history but this has no bearing on the question of sentience. Similarly, the fact that mental stress is based on cellular activities is not an argument for cellular sentience. After all, the simplest living entity is made up of molecules but this does not make molecules alive.

Why plants may not be sentient: a red herring

The adaptive plasticity of plants is legendary. Plants can change their growth trajectories and hence their relation to their environment, adaptively alter their morphologies and physiologies at several scales, communicate with conspecifics and with other species, display (epigenetic) memory and simple forms of learning, and adaptively respond to multiple types of biotic and abiotic stresses (for many specific examples of adaptive plasticity in plants see Chamovitz 2012).

Reber, however, is agonistic about plants’ sentience because they do not move in the way animals move. He speculates that a sessile life style and a rigid cell wall may have led to the loss

of sentience, because motility, in the sense of locomotion is central to his view of sentience. Although, as we indicated above and argue in more detail in the next section, we do not accept Reber's CBC theory and we do not believe that plants are sentient, we are puzzled why, from his own point of view, he denies sentience to plants. His view raises five major problems:

- If sentience is a primitive of life, then was the ability to move also a feature of the first forms of living beings? As far as we know, unlike the case of adaptive plasticity, there is *no* theory of the origin of life that suggests that the ability to control locomotion was a feature of the first protocells.
- There is plenty of evidence for the evolution of motility mechanisms. For example, in bacteria the flagellum seems to have evolved from the secretory Type III system (Pallen and Matzke 2006), and in Archaea from Type II transport system. Active, controlled locomotion is therefore not a requisite for life, although its benefits, once in place, are obvious and explain the parallel evolution of locomotor mechanisms in the three great domains of life (Khan and Scholey 2018).
- Reber's argument that sentience was lost when a cell-wall and a sessile life style evolved is puzzling. If sentience is a primitive of life, why was its loss not lethal? How is the adaptive plasticity of non-sentient plants that can nevertheless handle shifting conditions in amazingly sophisticated ways, compatible with Reber's view that adaptive plasticity in carbon-based systems is equated with sentience? Are the genes for locomotion the genes for sentience, so once we fully identify these genes using for example the CRISPR gene-editing technique (p. 189), this will unravel the genetic basis of sentience? We regard such a conclusion as absurd, because like life, sentience is a system property. Just as there are no genes for life there can be no genes and codes for sentience, and just as it makes no sense to talk about the metabolic cost of life, there is no sense of discussing the metabolic cost of sentience. Identifying genes and codes for sentience and discussing its metabolic cost is, as we see it, a category mistake.
- Self-directed motility in plants is accomplished (mainly) through differential growth, but it is definitely in place.
- What about other sessile organism and non-motile cells within a multicellular organism? Does Reber believe that most fungi and sponges lost their sentience too? And what about cells in a multicellular body that have become non-motile after embryogenesis?

Although, like many others, we believe that self-directed locomotor mobility was a necessary (though not a sufficient) condition for the evolution of consciousness in neural organisms (Ginsburg and Jablonka 2019, chapter 6) we do not see how it can be both a necessary and a sufficient condition for single cell consciousness.

We therefore do not see why are the plastic, adaptive, sentient-like behaviors that are exhibited by plants are merely “genetically encoded” (as Reber puts it, see p. 212) without entailing sentience or subjective experience, while those of motile bacteria cells must be interpreted as sentient. We think that a claim that *all* cells are sentient would be much more consistent with Reber’s view of sentience as a primitive of life and avoid the theoretical dead ends to which an identification of sentience with locomotion leads.

If the intellectual blind alley about plants and other sessile organisms with cell-walls is avoided, how can we evaluate Reber’s arguments? If his view of sentience as a primitive of life suggests solutions to long-standing philosophical dilemmas and opens up new research directions, we would be ready to suspend judgment and doubt our own neuro-based position. Although we do not think that the CBC theory provides such solutions, Reber’s view does lead to more focused questions about the kind of computations in which cells engage. In other words, we see his book as a contribution to the discussion of minimal *cognition* rather than minimal *sentience*.

The CBC theory: losses and gains

We start by looking at the problems (losses) of the CBC theory, and will end with the gains it offers. Many of the problems with the theory involve the relation between neural-based and cell-based sentience, which is intimately related to the problem of emergence. Reber claims:

“From the CBC approach, the individual cells of our bodies are assumed to have levels of sentience rather like bacteria do. Suppose that something happens to cause tissue damage to the muscle cells in your leg. The cells in the area have among them some that have evolved nociception — a cell-level, aversive subjective sense that something is amiss. However, because they are all parts of a large collective (you), their genetic make-up directs them to communicate their experience to other cells, in particular the local afferent neurons, in coordinated ways so as to signal their experience of being in pain.” (p. 195).

It seems that Reber suggests that brain-based sentience is made up of the coordinated sum of the tiny bits of sentience of the individual cells. But we know that dogs and humans in deep coma have billions of busy living cells that do not add up to anything at the mental level. So clearly, something must be lost without the communication with the brain, and this something is covered by the phrase “coordinated ways”. But if the loss of collective coordination leads to such dramatic effects, then the outcome of the sum of the coordinated cellular bits of sentience must have some non-additive, novel, properties. Such properties are usually called emergent, something that Reber is at pains to avoid. The problem of emergence is therefore not removed but rather transferred to the emergence of brain-based sentience from cell sentience bits, and the mental brain-based emergence is not explicated – the suggestion that consciousness is transferred between levels even within the brain (pp. 195-196) is a *restatement* rather than an explanation. Similarly, Reber’s claim that “Human consciousness is special but it isn't a distinct type. It's merely another token along a continuum of forms of phenomenal experience” (p. 53) seems to obscure rather than clarify the nature of human consciousness. What is special about it? Is it non-symbolic consciousness writ large, or is the special aspect of human consciousness an emergent property?

The emergence problem is related to Reber’s notion of evolutionary continuity. While material, phenotypic continuity is a fact of biology, as the evidence of molecular evolution suggests, continuity is not the same as lack of emergence. Living organization is a product of chemical evolution, and in this sense is continuous with it, but there is no reasonable doubt that a system of chemical reactions that are not organized in a very special autopoietic manner, is not alive, while (certain) autopoietic adaptively plastic, carbon-based systems are recognized as alive. There are some gray areas between the merely chemical and the living organization where the attribution of life depends on the theory of life the researcher holds, but these gray areas do not go all the way to the simplest chemical reactions: some minimal attributes of complex and interdependent chemical reactions underlying, for example, re-production, metabolism and a degree of closure, have to be in place. Similarly, when discussing the major transitions in evolution that led to major changes in complexity and new types of individuality, Maynard Smith and Szathmáry (1995) point to the novel and emergent nature of these transitions which are, of course, based on molecular and phenotypic continuity. There are points along the

spectrum of change where there would be overwhelming consensus that a multicellular entity is more than an assembly of cells and represents a new kind of individual and other points at the opposite pole where there would consensus about it being merely an assembly. Adopting only a close-up perspective, seeing always the trees rather than the forest, obscures important emergent phenomena. An analysis of levels of individuality requires shifts in perspective between level of organization, and arguments about the emergence of a new levels of individuality have to be justified, something that is theoretically and philosophically analyzed by Moreno and Mossio's (2015) excellent treatise on biological autonomy.

Another set of problems with the CBC theory is related to the notion of a single cell's self. Self is a notoriously difficult concept describing a dynamic ongoing process rather than a state, which makes more than metaphorical sense within a brain-based framework, as shown by cognitive biologists like Bjorn Merker (2007) and philosophers like Thomas Metzinger (2003). What the self of a single cell is, remains, however, unclear. Finally, the testability of the CBC theory has eluded us. It seems to us that unless there is some distinction between living and subjectively experiencing ("sentienting") no testable predictions are possible.

The CBC theory also has some interesting gains. First, Reber's focus on valence is important, and the relationship between cellular stress responses and mental stress is a fascinating and as yet under-studied topic of research, as is the related research of the mechanisms of positively valenced behaviors (e.g., sexual partner seeking). Second, the study of reafference mechanisms (mechanisms that allow a system to distinguish between self-generated and world-generated stimuli) in single cells is an important question that may shed light on types of biological computations that form the basis of agency. Third, the relation between epigenetic cell memory, neural memory and neural-mental memory is likely to be an important area of learning research (Ginsburg and Jablonka 2019). Fourth, the focus on extensive exploratory mechanisms that are the hallmark of living carbon-based life is a major topic related to the affordances and constraints of the material cause of life and mind that needs a lot more theoretical study than it currently receives. Such studies may be important for roboticists who try to build ever-more sophisticated robots: they may show whether and/or how wetware affordances can be circumvented in hardware-software based beings.

In conclusion, Reber's book is an interesting, concise and accessible contribution to the development of a theory of minimal cognition, but not, in its current form, to a theory of sentience.

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