Article

Adaptive Behavior

Adaptive Behavior
1–8

DOI: 10.1177/1059712319879747
journals.sagepub.com/home/adb
SAGE

Living beings as autopoietic bodies

Mario Villalobos[1,2]

Abstract

In the target article, it was claimed that the enactive extended interpretation of the autopoietic theory (AT) of living beings is incorrect, and an embodied reformulation of AT (EAT) was put forward to remedy and prevent such an interpretation. In this general reply, I want to clarify the motivation, reach, philosophical commitments, and theoretical status of EAT. I do this, mainly, by explicating the notions of body and autopoiesis, and by reconstructing EAT, not as a conceptual definition of life but as a theoretical identity statement of living beings as a natural kind.

Keywords

Embodied autopoietic theory, extended enactivism, autopoiesis, body

Handling Editor: Tom Froese, Okinawa Institute of Science and Technology, Japan

I want to thank the authors for taking the time to address some of the main points raised in the target article. Their thoughtful commentaries and challenging observations are more than welcome, as they expand and enrich the discussion that Razeto-Barry and I wanted to open around the autopoietic theory (AT) of living beings, and particularly, around the embodied version we offered there (embodied autopoietic theory (EAT), to use Meincke's designation).

I want to start my reply by refreshing the main points we wanted to make in the target article. We argued the following:

1. The extended enactive approach, in its current form, is incorrect as an exegetical development of AT.
2. AT, as is found in the letter of its original formulation, though not in the spirit, allows for an extended enactive interpretation of living beings.
3. An embodied formulation of AT is (a) needed to prevent the extended enactive conception of living beings and (b) correct as an exegetical development of AT.

The reactions to our argument go from different degrees of support (Harvey, 2019; Vecchi, 2019) to different degrees of skepticism about the scientific utility of the (too folk-minded, merely verbal) discussion itself (Beer, 2019; McGregor, 2019). In between, some think that EAT is basically correct but somehow redundant (Agmon, 2019; Maturana, 2019), whereas others argue that the job EAT aims to do is already done, in a much better way, by enactivism itself (Corris & Chemero, 2019). The most common reaction manifested in different ways, I would say, is the worry about EAT's theoretical consistency, scientific utility, and philosophical commitments. I take the main critical observations to be the next ones:

- EAT reduces living beings to their physical aspect, not giving enough attention to their (more fundamental) processual nature (Ayala, 2019; Virgo, 2019).
- EAT commits to a substance ontology, whereas the proper way to think of life should be through a process ontology (Meincke, 2019; Miller & Nave, 2019; Virgo, 2019).
- A functional approach to living beings, embracing full (spatial and material) multiple realizability should be preferred over an embodied one (McGregor, 2019; Peeters, 2019).

[1]Escuela de Psicología y Filosofía, Universidad de Tarapaca, Arica, Chile
[2]Instituto de Filosofía y Ciencias de la Complejidad, Santiago, Chile

Corresponding author:
Mario Villalobos, Escuela de Psicología y Filosofía, Universidad de Tarapaca, Arica, Arica y Parinacota 1010069, Chile.
Email: mario.kirmayr@gmail.com

- EAT does not consider the relational and context-dependent nature of living beings (Di Paolo, 2019; Stapleton, 2019).
- EAT does not provide a neat definition of living beings, and is so open to borderline cases and ambiguities (Clavel, 2019; Di Paolo, 2019; McGregor, 2019; Miller & Nave, 2019; Stapleton, 2019).
- EAT is incomplete since it lacks the thermodynamic specification of living beings as dissipative adaptive systems (Barrett, 2019).

These critical observations, in one way or another, hold that the idea of the autopoietic body fails to provide a neat, complete, and scientifically useful definition of living beings. In this reply, I will try to answer to this general concern by clarifying the motivation, reach, ontological commitments, and theoretical status of EAT. Except in some particular cases, I will not rehash the specific comments, questions, counterexamples, and objections raised by every author. Every author, however, should be able to find the answers (or the attempted answers) to their particular questions in the general reply.

1. EAT's motivation and ontological commitments

EAT's motivation is to improve AT by making explicit what is present in the spirit, but not in the letter, of AT's original formulation, namely, the idea that living beings are autopoietic bodies.[1] Agmon (2019), explicitly, and Maturana (2019), implicitly, think that this move is redundant because, according to them, the qualification of a molecular autopoietic system already does the job of restricting the notion of autopoiesis to discrete bodies. Peeters (2019) and McGregor (2019), however, consider that there is not even enough motivation to embrace EAT in the first place. According to the two, the notion of an autopoietic system, precisely because it is neutral regarding the spatial location of the living being's components, should be preferred over the notion of an autopoietic body.

I disagree with both views. First, qualifying an autopoietic system as molecular is not enough to secure that such a system is a body. And second, we need to restrict the notion of an autopoietic system to the notion of an autopoietic body if we want to target the extension of the concept of a "living being" correctly. To show this, let us analyze one representative example: the autocatalytic network. Autocatalytic networks, as it was argued in the target article, are molecular autopoietic systems because they consist in networks of chemical reactions that produce their molecular components and define their topology as such networks. However, they do not keep the proximity of their components and are not, therefore, bodies. To show that EAT is redundant, Agmon, Maturana, or someone else would need to demonstrate that autocatalytic networks do not qualify as molecular autopoietic systems according to the letter of AT's original formulation. AT's original formulation talks of the autopoietic network as one that specifies the topological domain of its realization as a network (Maturana & Varela, 1980, pp. 78–79), a property that does not entail, contra Agmon (2019), the more specific property of resisting the spatial diffusion of the network's components (as the very example of the autocatalytic network shows). What is the problem with not entailing this more specific property? Let us illustrate the point with the stances of Peeters (2019) and McGregor (2019).

For Peeters and McGregor, it is the very notion of a body that is problematic or unnecessary to think of living beings, so we should not worry that it is not entailed in the notion of a molecular autopoietic system. The point, however, is that if autocatalytic networks qualify, according to the letter of AT's original formulation, as molecular autopoietic systems, and if being a molecular autopoietic system suffices to be a living being, then Peeters and McGregor should be prepared to recognize and treat autocatalytic networks as living beings. Are they? I do not think so, which is sensical since most of the biologists would not be so prepared either. To rule out autocatalytic networks as living beings, as I think they correctly are in biology, we need to make explicit mention of the self-containing (resistant to diffusion) nature of living beings.

That is why Maturana (2019) needs to add the qualifier "discrete" several times when referring to living beings as molecular autopoietic systems, or to add the property of the "continuous generation of a molecular border." The need to add these qualifications seems to reveal that none of them is directly derivable from the more general property of specifying a topological domain of realization (Maturana & Varela, 1980, pp. 78–79). When talking of living beings, Maturana wants to talk, ultimately, of discrete molecular autopoietic systems that generate a molecular border. These qualifications suggest that despite Maturana's claims to the contrary, there would be instances of non-discrete molecular autopoietic systems from which living beings should be explicitly differentiated.

EAT's emphasis on the bodily aspect of living beings is not meant to overlook the processual (autopoietic) nature of living beings. The notion of autopoietic body, if correctly read, takes the processual and bodily aspects of living beings to be equally important. EAT does not establish the primacy of a substance ontology over a process ontology, nor the primacy of a process ontology over a substance ontology. EAT's formula is neither "living being = body" nor "living being = autopoietic network" (cf. Virgo, 2019). According to EAT, living beings are those bodies that are autopoietic and those autopoietic systems that are structured as

bodies. It is the combination of these two aspects, that is, body and autopoiesis, as mutually enabling conditions (not as merely co-occurrent conditions) which EAT holds as distinctive of living beings.

2. Body

In the formula of autopoietic bodies, many authors find the notion of body in need of clarification. I think this attitude is justified, since some passages in the target article trying to illustrate or make visible the notion of body were misleading. When we speak of a body, we speak, essentially, of a system that offers resistance to the diffusion (spatial dispersion) of its components, keeping them proximal enough to remain as an identifiable object. Many times, this condition is observable through manipulations (e.g. appreciable resistance to disaggregation and portability) but not always. For many others, it is observable due to the presence of distinguishable boundaries, but again, not always. Bodies, it should be clear, are not restricted to solids with neat and easily determinable boundaries. There are fluid bodies in the form of liquids, colloids, and plasms, and many of them do not offer neat boundaries for our observation or manipulation. The molecules of a volume of liquid water do not seem to offer, at the scale of our manipulations, resistance to separation. However, those molecules are organized through cohesive forces that, though weak for our scale, prevent the diffusion of the molecules in space. Thus, we can speak (as geography and hydrology do) of a "body of liquid water." A star is an astronomic fluid body (made of plasma) for which it may be complicated to pin down precise borders or limits. Where exactly does a star finish, and where does the rest of the universe begin? The difficulty in answering this question, however, does not prevent us from recognizing, for instance, the sun as an astronomic body. The important point about a body is whether some structural properties of the system prove to be necessary, under the conditions being observed, to prevent the leakage of its components in a way that is sufficient to conserve its integrity as a system.

The structural properties of the system that prove to be necessary to resist the diffusion of the system's components may be any as long as they effectively play such a role. For instance, in some bodies, the spatial dispersion of the components may be prevented mainly through a boundary structure (a wall, a lamina, a permeable or semi-permeable tissue, or membrane). In some others, it may be prevented mainly by the interactions of the system's components, without a dedicated containing structure (e.g. through cohesive or adhesive forces). In others, it may be prevented mainly thanks to gravitational forces (e.g. stars).

Importantly, when I say that a body is a system in which the components are kept in proximity due to certain properties of the system, I do not mean that it is the system alone, in absolute terms, disregarding any background condition that is responsible for keeping the proximity of its components. It is understood that every system has a surrounding and exists as such, partly thanks to the specific conditions provided by said surrounding. Every entity (be it a body, a process, or a phenomenon) exists and takes place as such only to the extent that some background or contextual conditions are obtained. Change those conditions enough, and the entity will cease to exist. Bodies, trivially, exist as such while some background conditions are given and cease to exist when those conditions change enough.

To be clear, when I talk of a body, I do not mean a system that offers sufficient conditions under any possible background or context to resist the diffusion of its components. The idea, rather, is that under the conditions being observed (whatever they may be), some structural properties of the system prove to be necessary to prevent the diffusion of the system's components.

The resistance to the diffusion of the system's components also varies according to the specific nature of the system. Given the same background conditions, some systems offer strong resistance to dissipation, while others offer a more relaxed one.

A bacterium, for example, which I take to be an autopoietic body, keeps the proximity of its components, thanks to the colloidal consistency of its cytoplasm (cohesive intermolecular forces) and to the containment action of its cell membrane.[2] How strong is the resistance of its cytoplasm and cell membrane to disaggregation? It is insignificant, I would say, to our scale of forces, but that is not the important point. The point is that, through its colloidal consistency and its membrane, the bacterium prevents the indiscriminate leakage of its components which, absent those structural properties and under the background conditions being observed, would diffuse and separate disintegrating the structure of the bacterium as such. That is, certain properties of the bacterium prove to be necessary (though not sufficient), under the background conditions being observed, to prevent the diffusion of the components. This prevention, of course, is not (and cannot be, for the sake of the bacterium) absolute. The thermodynamic condition at which the bacterium keeps alive (i.e. metabolizing) is one in which many molecules must diffuse and go out. The bacterium "needs," so to informally speak, a certain degree of diffusion of some of its components, otherwise it dies. The bacterium prevents the leakage of its components just in the way that is sufficient to conserve its integrity as a system.

Bodies, it should also be clear, are not immutable entities. They can vary numerically and qualitatively. Several bodies can adhere or fuse to form a single body, and one body can split to form several bodies. These phenomena can happen due to external forces (compression forces, fracture forces) or their own dynamics

(as in the cases of slime molds and cell mitosis, respectively). Bodies can change their material composition and their configuration, varying their shape and size, shrinking, expanding, or extending by different means (due to external forces or manipulations, or due to own dynamics). Bodies can get extended trivially.

3. Autopoiesis

Consider now the notion of autopoiesis and focus on the concept of poiesis. Poiesis is a concept that refers specifically to production processes, understood as processes that transform components; building them, modifying them, or destroying them. In the context of biology, these production processes refer to the chemical reactions through which molecules are built, modified, or destroyed. Two important implications follow from this.

First, for a system to count as a poietic system in the first place (allopoietic or autopoietic), it must execute productive processes as a system. If a system does not execute any production process, then that system, by implication, cannot be autopoietic (neither an autopoietic body). This is, for example, the key difference between living beings and most dissipative systems. From a thermodynamic point of view, living beings are dissipative systems, just like hurricanes and Bénard cells. Moreover, hurricanes and Bénard cells can be considered dissipative (fluid) bodies, like living beings. Even more, hurricanes seem to exhibit dissipative adaptation (McGregor & Virgo, 2011), and Bénard cells likely too (Kondepudi, 2012), like living beings. Barrett (2019), perhaps overinterpreting these similarities, claims that "many, if not all, dissipative systems, including many non-living systems, are autopoietic bodies." This is simply incorrect. Not every dissipative system is an autopoietic body. The key difference between autopoietic bodies and most dissipative systems is that only the former ones are constituted as networks of chemical reactions, that is, as poietic systems.[3] Dissipative systems such as hurricanes and Bénard cells are constituted by complex patterns of flows of matter, not by chemical reactions (see also Maturana, 2019).

Second, the notion of poiesis denotes a specific subset of the total set of physiological processes that take place in a living being. Not all physiological processes in a living being involve (or take place as) chemical reactions. In a cell, for example, many vital processes are not poietic in nature, such as protein transportation and osmosis. In animals, some substages of respiration, circulation, and many homeostatic processes are not poietic either.

Only a subset of the total set of physiological processes in a living being corresponds to poietic processes. And, out of this subset of poietic processes, only a subset is constitutive of the organism's autopoietic network. Many of the poietic processes that take place in a living being are constitutive of the latter's allopoietic network instead of its autopoietic one. That is, they are constitutive of a network that produces elements that do not remain as parts of the living being (neither as reactants nor as structural components). For a cell, for example, excretions and secretions are allopoietic processes.

Keeping this in mind is important when we face cases of physiological extension. Living beings' physiological systems can get extended, naturally or artificially. Turner (2000), in his excellent monography, provides a series of fascinating examples of naturally extended physiological systems. Peeters (2019) and Miller and Nave (2019) provide some plausible examples of artificially extended physiological systems. Most of these physiological extensions, as is expected per what I mentioned before, are not poietic because they do not extend the living being's productive network. For instance, extended control systems implemented through remote technology are extended physiological systems, but not autopoietic ones. To take Miller and Nave's example, an insulin-regulation biotechnological system that uses a wireless connection with remote technological platforms (e.g. smartphones) is an extended homeostatic system, but not an autopoietic one, because what gets extended outside the body is a control function, not a circuit of chemical reactions.

The same is the case with Peeters' imagined (but still plausible) case of a brain kept alive in a physiological vat (a surrogate physiological-metabolic body), wirelessly connected to a remote sensorimotor body. If the brain and the sensorimotor body are communicated and coordinated, why should not we consider them, just because they are distant, as a single living being? "Why," asks Peeters, "if they work as a unity as if they were physically together?"

> On Villalobos and Razeto-Barry's account, a densely coupled brain-body system—with the brain residing outside of the sensorimotor body—would not constitute a living being as it exhibits no "proximity of its components" (p. 6). It seems to me false to say that the brain-body system is not alive, when it would act, communicate, and, presumably, experience like us. This case, however, poses no problem for a theory of living beings as autopoietic systems (Peeters, 2019).

In response to Peeters, I would say that there is a lax sense in which EAT may admit that this brain–body system is alive, that is, the sense in which the components of the systems are alive. For instance, when we say that the crew of a lost ship is alive, what we mean is that every (human) living being of that crew is alive, not that we take the crew to be a single living being (e.g. a sort of super animal or superperson). In this sense, EAT would not deny that the brain–body system

is alive. What EAT denies is that such a system is an autopoietic body, that is, a living being. Why? The attentive reader, I believe, will guess the answer. The brain is metabolically integrated into the physiological vat, not to the sensorimotor body. It is the proximity with the vat which allows the brain to integrate an autopoietic system, and so it is this system (brain in the vat) which counts as an autopoietic body. (The brainless remote sensorimotor body, which is presumably alive, counts as another autopoietic body.) The brain and the sensorimotor body do not count as a living being because they are not metabolically (i.e. autopoietically) integrated. However, as Di Paolo (2019) remarks, there are many different levels of individuality and identity. If the brain is (wirelessly) communicated to the sensorimotor body in such a way that their dynamics are coordinated, then they form a sensorimotor system (composed of two distinct autopoietic bodies), no matter how distant they happen to be.[4]

4. The reach of EAT

The notion of the autopoietic body aims to capture what is distinctive of living beings, not to exhaust their characterization as natural systems. There are many important (but not distinctive) features of living beings that are not expressed in the formula of the autopoietic body. Living beings are much more than autopoietic bodies because not all their processes are poietic, and because not all their structures have the effect of keeping the spatial proximity of their components (some illustrations about this point soon). However, although not everything in a living being is an autopoietic body, being an autopoietic body, I argue, is what distinguishes a living being from any other natural system.

Let us take Barrett's observation to illustrate this point. Barrett argues that EAT is incomplete because it lacks the thermodynamic specification of living beings as dissipative systems. The EAT's formula should read, according to him, "[e]very living being is a dissipative autopoietic body" (Barrett, 2019, Emphasis added). Why does EAT not include this thermodynamic specification in its formula? EAT does not include this specification because it is not clear what (if any) theoretical job it would do. EAT's motivation is to provide a formula that gives the distinctive property (or properties) of all and only living beings. Such a formula, to be useful, must have the power to exclude cases that do not fall into the category. The formula of an autopoietic body has such a power because there are bodies that are not autopoietic (e.g. crystals, chairs, hurricanes), autopoietic systems that are not bodies (e.g. autocatalytic networks, candle flames), and because none of them qualify as a living being. The qualifier "dissipative" would be theoretically useful if it had excluding power, that is, if there were cases of non-dissipative autopoietic bodies. This, however, looks quite physically implausible (at least to me). I do not know of any natural system that exists as a self-contained network of chemical reactions and that has no dissipation of energy. I am quite open to being corrected on this point, but until Barrett comes with an instance of a non-dissipative autopoietic body, adding the qualifier "dissipative" to the EAT's formula will not seem to bring any theoretical contribution. But even if we had at hand cases of non-dissipative autopoietic bodies, we would still need a theoretical justification to rule them out as living beings. Imagine finding systems that are autopoietic bodies and that do not dissipate energy. Should we discard them as living beings? Again, I am open to being enlightened on this point, but until someone comes up with such a theoretical justification, adding the qualifier "dissipative" to the EAT's formula does not seem to make any critical contribution.

Since the notion of autopoietic bodies does not exhaust the characterization of living beings, it is not strange that the concrete materiality and physiology of living beings do not coincide with their being autopoietic bodies. The components (processes and parts) of the autopoietic body are only a subset of the components of the living being as a concrete totality. The autopoietic body is, so to speak, the ontological core of a living being, that is, its distinctive structure as a biological entity (more about this in the next section). This point is essential when asking what forms (or not) a part of a living being, and under what criterion are we going to say that a living being gets extended.

Elements or structures such as hairs, hooves, horns, and others are parts of living beings as concrete material entities, but not of them as autopoietic bodies. These structures are produced by the living being and may play non-trivial physiological roles, but do not have the effect of keeping the proximity of the cells, tissues, and organs through which the living being's autopoiesis takes place. They are parts of the living being's physical body, and when they grow, what gets extended is the living being's physical body, not the living being as an autopoietic body.

In some cases, there are bodily physiological extensions through the appropriation of external structures. For instance, take Di Paolo's (2019) example; think of the insect that manages to breathe underwater by attaching air bubbles to its abdomen. I would say that this is a case of an extended physiological body, but not of an autopoietic one. On one hand, the bubbles do not form a part of the structures that keep the proximity of the cells and tissues through which the insect's autopoiesis takes place. (Remove the air bubbles, and the insect will die due to hypoxia, but its cells and tissues will not disperse in space.) On the other hand, the physiological process allowed by the air bubbles (transportation of oxygen molecules from one place to another) is not poietic. The air bubble, though vital, is not a part of

the insect's autopoietic body, and it is not, therefore, an extension of it.

Now, as it was recognized in the target article with the case of the extraorganismic digestion, there are cases of extended physiological processes that are autopoietic. In those cases, what gets extended, as it was argued, is the living being's autopoietic network, not the living being as an autopoietic body.

In other words, bodily extensions without autopoiesis and extensions of autopoiesis without a body are not extensions of the living being as an autopoietic body. An extension of a living being as an autopoietic body is one in which both the autopoiesis and the body get extended conserving their mutually enabling relationship. This is what happens, for example, in the development of cytoplasmatic projections (e.g. axon formation in neurons) and embryogenesis processes (e.g. limb formation).

Finally, as it was argued in the target article, mere co-occurrence of autopoiesis and body is not enough to talk about an autopoietic body and, therefore, about a living being. GAIA, for instance, is a case in which we can distinguish autopoietic networks (as ecological trophic cycles) in a planetary body, but not a case of an autopoietic body. Why? The reason is that what keeps the proximity of the components of the productive networks, that is, the gravitational force of the planet, exists independently of those productive networks. Put another way, the planet's gravitational force was already there before the existence of the productive networks of GAIA and will surely remain after GAIA's eventual disappearance. The case is analog, if you will, to the autocatalytic network contained in a test tube. The autocatalytic network and the test tube do not form an autopoietic body because the latter exists independently of the former. In an autopoietic body, the autopoietic processes prove to be necessary to the existence of the body, and the body proves to be necessary to the existence of the autopoietic processes.

5. EAT's theoretical status

In the target article, EAT was presented, basically, as offering a definition of life in terms of necessary and sufficient conditions. That, I think, was incorrect and misleading.[5] EAT's formula "living being = autopoietic body" does not offer a convincing (neat, unambiguous, conclusive) definition of life because it is not a definition at all. It is, as I will try to show, a theoretical identity statement of living beings as a natural kind. Let us see this through an analogy provided by Cleland and Chyba (2002).

When modern chemistry tells us that water is H_2O, it is not giving us a definition of water but a theoretical identity statement of what water essentially is. The formula "water = H_2O" is a scientific abstraction. In daily life, we rarely find water in its pure chemical constitution. The formula H_2O does not tell us anything about the different phases in which we find water (liquid, solid, gaseous), nor anything about its sensible properties. What the chemical formula tells us is that the deep and universal structure of all instances of what we identify as water, no matter the disparity of its many different manifestations, corresponds, ultimately, to the molecule H_2O.

This theoretical identity statement does not aim to characterize the concrete manifestations of water exhaustively, nor to provide a measure to tell whether a particular volume of liquid is or not water. Let us try to answer, for instance, the following questions. "Is the water of rivers or seas really water?" Yes, it is. "Does that mean it is composed only by H_2O molecules?" No, it does not. "Should we stop then qualifying those liquid volumes as water? Exactly what percentage of chemical impurity can we admit in a given liquid volume to qualify it as water?" It is apparent that the scientific formula "water = H_2O" is not designed to answer this kind of definitional worries. Neither it is posed to provide empirical or operational criteria to tell exactly when, at which moment and under which specific background conditions, something is or becomes water. Since "H_2O" is not a definition of water, it is not posed to solve the typical problems of ambiguity and borderline cases that arise with classical (ideal) definitions. Think, for instance, of the following questions. "Exactly at which point in the interaction between two atoms of hydrogen and one of oxygen does water constitute?""Exactly at which spatiotemporal point of their electrons' dynamics are we going to say that these atoms have formed the corresponding chemical bonds of the molecule of water?" Given the quantum nature of the atomic interactions, in general, it seems quite out of the point to formulate this kind of question. A guide or recipe to answer these kinds of questions is not what we expect from the theoretical statement "water is H_2O," and the lack of such a guide is not, I think, a basis to object to it as a scientific statement. "H_2O" is not a definition of water, but it is, according to current chemical science, the most scientifically informative answer to the question "What is water?" (Cleland & Chyba, 2002).

Similarly, EAT's formula is not offered as a definition of life, but as a theoretical identity statement of living beings as a natural kind. The notion of the autopoietic body is an abstraction of the concrete realization of living beings and is one that, I argue, offers the distinctive structural core of all and only living beings. In that sense, I think EAT's formula should be viewed and evaluated as a candidate to be, for now, the most scientifically informative answer to the question "What is a living being?"

Is EAT's formula conclusive? It is not, of course. Being a scientific theoretical statement, it cannot be

(science's statements are always provisional). Does EAT's formula provide us with precise empirical and operational criteria to tell when, at which point exactly (of cohesion, of resistance to spatial dissipation), something that is not a living being becomes a living being? No, but since EAT's formula is not meant to be a definition, we should not expect from it a recipe to answer that kind of question. Borderline cases, fuzzy boundaries, and the ambiguities that arise from them (which worry Clavel, 2019; Di Paolo, 2019; McGregor, 2019; Miller & Nave, 2019; Stapleton, 2019) are problems for definitions, not for theoretical identity scientific statements.

There are many other meaningful, challenging, and exciting points in the commentaries on the target article that I have not been able to comment on here. I hope to address some of them in future work. I want to believe, though, that this general response has served to clarify the most important points presented in the target article, and that it will motivate the readers to enrich and move forward the discussion around the AT of living beings.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Mario Villalobos https://orcid.org/0000-0003-0567-2888

Notes

1. This is EAT's purpose, at least in my mind. It might be the case that, in the end, EAT proves to be not an improvement of AT in the sense of a simple reformulation but, as Meincke thinks, a major revision of the theory. I am not especially worried about this potential result. If EAT proves to be a useful and correct reformulation of AT, as I think it is, and if it is so at the cost of operating a major surgery on AT, so be it.
2. Expressions such as "The bacterium (...) keeps the proximity ..." and similar throughout the text are not meant to depict living beings as "agents" that "do" things in a teleological sense, as if they were not deterministic physical systems. Those expressions are used in a lax way just for the sake of brevity and simplicity.
3. There are, of course, dissipative systems that consist of chemical reactions, such as autocatalytic networks and candle flames. Nonetheless, as it was analyzed in the target article, they fail to be bodies, and therefore, are not living beings.
4. Peeters says that the example should not represent a problem for a theory of living beings as autopoietic systems, but that is not true. The case imagined by Peeters would not qualify as a living being even for a systemic version of autopoiesis, for the brain and the distant sensorimotor body are not coupled in a poietic way; they do not form a network of autopoietic processes. The brain is metabolically maintained by the physiological vat, not by the sensorimotor body. The coupling is functional, not poietic. Therefore, the brain–body system is not an autopoietic body and is not even an autopoietic system. What Peeters rather seems to put forward with his imagined example is a case for a full-blown functionalist non-autopoietic theory of living beings.
5. Maturana has insisted on the point that the concept of autopoiesis does not offer a definition of life but an abstraction of what we see when we observe cell metabolism (Maturana, 2011, 2019). I think he is right, but for reasons that he has not considered yet and that are crucial, in my opinion, in clarifying the present discussion.

References

Agmon, E. (2019). Deriving the bodily grounding of living beings with molecular autopoiesis. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319830645

Ayala, D. (2019). Cohesiveness is not an adequate theory of general individuation and it does not account for living individuals. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319833912

Barrett, N. F. (2019). Dissipative systems and living bodies. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319841306

Beer, R. D. (2019). Lost in words. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319867907

Clavel, M. J. (2019). Two challenges to the embodied version of the autopoietic theory. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319839641

Cleland, C., & Chyba, C. (2002). Defining "life."*Origins of Life and Evolution of the Biosphere*, *32*, 387–393.

Corris, A., & Chemero, A. (2019). The broad scope of enactivism. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319843268

Di Paolo, E. A. (2019). Why do we build the wall?*Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319834884

Harvey, I. (2019). Habeas corpus: The ins and outs of autopoiesis. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319836401

Kondepudi, D. (2012). Self-organization, entropy production, and physical intelligence. *Ecological Psychology*, *24*, 33–45.

McGregor, S. (2019). Why living bodies could be dead weight. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319838211

McGregor, S., & Virgo, N. (2011). Life and its close relatives. In G. Kampis, I. Karsai, & E. Szathmáry (Eds.), *Lecture Notes in Computer Science: Advances in artificial life: Darwin meets von Neumann—ECAL 2009* (Vol. *5778*, pp. 230–237). Berlin, Germany; Springer.

Maturana, H. (2011). Ultrastability ... autopoiesis? Reflective response to Tom Froese and John Stewart. *Cybernetics & Human Knowing*, *18*, 143–152.

Maturana, H. (2019). Reflections in relation to the article of Villalobos and Razeto. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319841740

Maturana, H., & Varela, F. (1980). Autopoiesis and cognition: *The realization of the living*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Meincke, A. S. (2019). Systems or bodies? On how (not) to embody autopoiesis. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319841301

Miller, M., & Nave, K. (2019). Slimes and cyborgs: Stretching the boundaries of life. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319843267

Peeters, A. (2019). Steering away from multiple realization. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319839056

Stapleton, M. (2019). Putting autopoietic bodies under pressure. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319840277

Turner, J. S. (2000). *The extended organism: The physiology of animal-built structures*. Cambridge, MA: Harvard University Press.

Vecchi, D. (2019). Entrenchment implies that physiological and developmental processes are not organism-bound but still organism-centric. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319838801

Virgo, N. (2019). The necessity of extended autopoiesis. *Adaptive Behavior*. Advance online publication. doi:10.1177/1059712319841557

About the Author

Mario Villalobos is an associate professor of Philosophy at the University of Tarapaca, Arica, Chile, and an associate researcher at the Institute of Philosophy and Complexity Sciences, Santiago, Chile. His area of research is the philosophy of mind and cognitive science, focusing mainly on the autopoietic theory of life and cognition.