# Linking Temporal Parts in Processual Biological Ontology

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**Abstract.** There are two conflicting foundational approaches to biological reality. Substantialism says that objects are more fundamental than processes, whereas processualism argues for the converse: processes are more basic than objects. It is of practical significance to harmonize a substantialist framework for biological data with a processual one. This short paper aims to propose that temporal parts of biological objects in processual ontology be linked in a dispositionally causal way.

**Keywords.** biological ontology, process ontology, temporal part, causation, disposition



## 1. Introduction

Biological ontologies need to provide a *general* description of biological reality that holds independently of ever-changing biological knowledge and practice in order to promote the integration of biological data that are dispersed in different information systems, including databases. It is thus not only theoretically challenging but also practically rewarding to scrutinize foundational perspectives from which to represent a wide array of biological phenomena.

This paper concentrates on the relationship between objects and processes *vis-à-vis* the biological domain. Classical examples of biological objects include molecules, cells, organs, and organisms; and those of biological processes cell division, heart pumping, and an organism's progressive development. On the one hand, substantialism claims that objects are more fundamental than processes: processes are, in some sense, activities of objects (whether animate or not). On the other hand, processualism counters that processes are more basic than objects: objects are, in some sense, abstractions of processes. As we will see below, some biological ontologies adopt substantialism but others processualism; and it would be notoriously difficult to unify those foundationally contrasting biological ontologies. In this regard, the substantialist/processualist debate is relevant to effective data management in the context of life sciences.

In this short paper we explore a *practical* strategy for harmonizing the substantialist and processual views of biology, thereby contributing to the long-term enhancement of the interoperability of different biological ontologies. The rest of the paper is structured as follows. Section 2 delineates substantialism and processualism with an emphasis on their connection with the issue of persistence and their usage in biological ontologies. While recognizing the importance of persistence for our objective, Section 3 argues that

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temporal parts of biological objects in processual ontology should be connected in a dispositionally causal manner. Section 4 concludes the paper with a brief discussion on future possible directions of research.

## 2. Substantialism and Processualism (in Biology)

Philosophy of biology traditionally centers on the substantialist's worldview according to which processes always involve the doings of objects and they merely reflect the change in the properties of objects over time. To take one example, the process of mitosis cell division can be seen as a sequence of the activities (e.g., DNA replication) of cells. There is however an increasing interest in the processual approach in the contemporary discipline [1]. Dupré and Nicholson [2] offer several biological motivations for processualism. Given the relevance of metabolism for organisms' living conditions, for instance, an organism may be well characterized as fluid processes of matter and energy that exhibit dynamic time-relative stabilities (see also [3]); most biological objects (paradigmatically organisms) can be regarded as a series of morphological and behavioral changes during their life cycles; and organisms are fundamentally relational entities in the sense that they exist only in virtue of their complex and reciprocal interactions with the environment, including other organisms.

The substantialism/processualism opposition is intimately connected to the topic of persistence. An object persists if and only if it exists at one time, and also exists at another distinct time: e.g., a frog persists if it existed as an embryo and exists as a tadpole. Note that an object is something that *persists*, whereas a process is something that *happens* or *occurs*. Philosophy of persistence pivots around the debate between endurantism and perdurantism [4, pp. 202-204].[2] Perdurantism is the thesis that objects persist by 'perduring', i.e., by having (proper) temporal parts. On the perdurantist account, a frog has its 'embryo temporal parts' and its 'tadpole temporal parts', just as the frog has the head as its spatial part. Endurantism consists in rejecting perdurantism and insisting that an object persists by 'enduring', which is typically construed as saying that an object is 'wholly present' at every time at which it exists. Notwithstanding controversy as to what this phrase is supposed to mean (see e.g., [5,6]), we can interpret endurantism as the doctrine that objects do *not* have (proper) temporal parts at every time at they exist.[3] Not surprisingly, perdurantism (resp. endurantism) is well concordant with processualism (resp. substantialism), even if they are not necessarily paired. Granted that processes are in nature temporally extended and they have temporal parts, perdurantism would recognize the primacy of processes over objects by treating objects as process-like; and

[2] We avoid using the terms 'three-dimensionalism' and 'four-dimensionalism' that tend to be highly polysemous both in formal ontology and in philosophy, although they are sometimes regarded as synonymous with endurantism and perdurantism, respectively.

[3] Strictly speaking, we should be wary of the understanding of persistence based on temporal parts. Although temporal parts are traditionally taken to be the crux of the subject of persistence (see e.g., [4, pp. 202-204]), there is nowadays a growing consensus among philosophers of persistence that the endurantist and perdurantist accounts of persistence should be primarily characterized in light of spatiotemporal location (namely, how objects are located in spacetime) and it serves at best as an auxiliary assumption whether objects have or lack (proper) temporal parts [7-9]. We are justified in regarding persistence as the matter of temporal parts, however, insofar as the discussion is concerned on the relationship between the substantialist/processualist dispute and persistence (especially in philosophy of biology) [1].

contrariwise, endurantism would prioritize objects over processes because it respects the ontological autonomy of objects: objects 'survive' various changes over time.

To exemplify the substantialist/processualist debate in biological knowledge representation, let us compare two biological ontologies: the Cell Ontology (CL) [10] and GFO-Bio [11]. The CL is built to cover the domain of canonical, natural biological types in compliance with the Open Biomedical Ontologies (OBO) Foundry [12]: a collaborative project to coordinate ontologies to support biomedical data integration that tends to adopt as a standard upper ontology Basic Formal Ontology (BFO) [13].[4] On the other hand, GFO-Bio aims to be a core ontology [15] for biology (i.e., an ontology that formally describes and defines the basic categories within the biological domain) that is constructed in accordance with an upper ontology General Formal Ontology (GFO) [16].

On our view, the CL and GFO-Bio are committed to substantialism and processualism because so are BFO and GFO, respectively. Let us illustrate this point with cells, which we intuitively understand as objects. The CL classifies cells as a subtype of the BFO category of material entity: "An independent continuant that has some portion of matter as part, is spatially extended in three dimensions, and that continues to exist through some interval of time, however short" [13, p. 180], where an independent continuant is: "A continuant entity that is the bearer of qualities and a participant in processes. Independent continuants are such that *their identity can be maintained over time* through gain and loss of parts, as well as through changes in qualities." [ibid., our italicization added]. The CL characterization of cells is attuned to the substantialist's perspective because they are thought to 'endure' over time.

In GFO-Bio, by contrast, cells fall into the GFO category of presential: "an individual which is entirely present *at a time-point*. (…) presentials are individuals that may exist in the presence, where we assume that the presence has no temporal extension, hence, happens at a timepoint" [16, p. 309, our italicization added]. As for the object-process integration, GFO says in principle that, for every material object *Obj*, there exists a GFO: process *Proc(Obj)* such that the presentials exhibited by *Obj* equal the GFO: process boundaries of *Proc(Obj)* (see [17, 18] for formal details). Consequently: "In comparison to other top-level ontologies, GFO is the only ontology, used in practical applications, for which the processes [in the GFO sense of the term] are the most fundamental category of spatio-temporal individuals, whereas objects and their snapshots (presentials) depend on processes." [18, p. 350]. In this respect, GFO and GFO-Bio accept the processual and perdurantist picture of reality in which cells are conceived in a primarily processual way.

## 3. Harmonizing Practically Substantialism and Processualism in Biology

### *3.1. Three Strategies: 'Dictatorial', 'Monarchical' and 'Republican'*

There is presently a growing trend towards collaborative development of modularized biomedical ontologies; and the usage of explicit upper-level categories and relations is recommended for semantically adequate ontologies that serve as a stable framework for

[4] Borgo and Hitzler [14, p. 3] spell out upper ontologies (aka foundational ontologies) as follows: "(…) while a top-level ontology is a classification system that deals with general domain-independent categories only, a foundational ontology is a top-level (formal) ontology that has been built and motivated by the upfront and explicit choice of its core principles."

more context-dependent biomedical knowledge representation [19]. This will inevitably mean in the long run that we should find some way of reconciling substantialist (e.g., the CL) and processual (e.g., GFO-Bio) biological ontologies. We may describe three major solutions to this problem by employing political metaphors. First, the *dictatorial strategy* requires (virtually) all the developers of biological ontologies to embrace substantialism (resp. processualism) and to revise in the substantialist (resp. processual) manner, or even to abandon altogether, all the existing processual (resp. substantialist) biological ontologies. This is obviously a simplistic and unrealistic approach.

Second, the *monarchical strategy* advocates an alternative foundational perspective to substantialism and processualism as a new conceptual framework for integrating both kinds of biological ontologies; and one candidate worldview might be that objects and processes are equally fundamental (Cf. [20]). This stance would be also problematic, however. For one thing, it is highly questionable whether two sharply opposed kinds of entities can be of the same fundamentality, although the notion of fundamentality is outside the scope of our current investigation (see e.g., [21]).[5] For another, even if it is the case that objects are as fundamental as processes, it is rather unclear whether and how this claim contributes to the practical unification of biological ontologies: e.g., what is a third, non-circular definition of cells that is neither substantialist nor processual?

Third, the *republican strategy* (on which we will expound below) aims to let ontology users maintain their worldviews by ensuring the practical interoperability between substantialist and processual biological ontologies. To explore this line of inquiry, we focus upon persistence because both sides agree on the fact that (if not *how*) objects persist. On the processual/perdurantist account of reality, persisting objects have temporal parts, whereas the substantialist/endurantist says that they do not. To move from the latter to the former, we only have to introduce the concept of temporal part, which can be intuitively understood as a temporal analogue of a spatial part.[6] To proceed conversely, however, we need to theorize on a means of combining together temporal parts of a given perduring object (e.g., 'embryo temporal parts' and 'tadpole temporal parts' of a frog) back into a single enduring object (e.g., the 'wholly present' frog) . It is only when this task is accomplished that we will take the initial step towards the workable harmonization between substantialism and processualism in biological ontology.

### *3.2. Dispositionally Causal Links between Temporal Parts in Processual Biology*

The topic of how a perduring object is composed by its temporal parts can be seen as an instance of the more general, so-called 'special composition question' [24]: under what circumstances some objects come to compose a further object. Two of the most common answers are (mereological) nihilism and universalism. Nihilism says that nothing ever composes; and the standard nihilist believes that all that exists are simples (namely, something that has no proper part): e.g., subatomic particles [24,25]. Universalism endorses, on the contrary, unrestricted composition: composition always occurs [4,23]. For any plurality of objects which the reader names, as universalism goes, there is an object that compose them. Nihilism and universalism have been criticized for yielding undesirably the excessive depletion and proliferation of composite objects, respectively. Another, more moderate position is restrictivism, which argues for restricted

[5] See Toyoshima [22] for a formal-ontological approach to fundamentality.

[6] There is considerable disagreement on how to define explicitly what temporal parts are meant to be, though. See Sider [23, Chapter 3] for their definition currently most widely used in the literature.

composition: composition occurs only in some specific conditions (which are sometimes called 'unity conditions' in the literature) [26]. The restrictivist is motivated to save the intuition, for instance, that a particular configuration of cells composes a frog, while a collection of cells of all the readers of this paper does not compose anything.

We will hereafter consider unity conditions in which composition is restricted in the context of processual biological ontology. First of all, nihilism is off the table since perdurantism (which we are now examining) stipulates the composition of persisting objects. In fact, we can remain neutral about whether universalism or restrictivism should be adopted in our discussion. For the restrictivist, (composite) objects exist when they meet unity conditions; and the universalist can also invoke unity conditions to distinguish what we usually conceive as (composite) objects (e.g., cells and organisms), which satisfy those condition, from counterintuitively existing objects (e.g., a sum of cells of all the readers of this paper), which fail to meet them. Briefly, restrictivism and universalism take unity conditions to be an ontological and epistemic criterion for specifying so-called 'ordinary (material) objects', respectively. We may be willing to hold restrictivism, though, partly because we are working on processual biological *ontology*, partly because universalism would add complications (i.e., an ontological commitment to 'monstrous objects') to be preferably circumvented in our investigation.

We suggest that unity criteria for restricted composition be causal in biological processualism and perdurantism. For one thing, Williams [27] convincingly argues by thought experiment (into which we do not delve for simplicity) that, their popularity notwithstanding, spatiotemporal continuity [28] sortal continuity [29] are at best necessary conditions for perdurance; and that only the right kind of causal connection is sufficient to link between temporal parts of perduring objects.[7] For another, DiFrisco [31] develops a causal account of the identity and individuation of (biological) processes. Although DiFrisco explores processes rather than perduring objects, we can interpret his sophisticated approach as a piece of evidence to support a causal standard for perdurance, since we contended in Section 2 that perdurantism can be reasonably coupled with processualism by offering a process-like view of objects.

We further propose that a causal condition for perdurance be elucidated by a dispositional theory of causation in processual biological ontology. A disposition is a property that is linked to a realization, namely to a specific possible behavior of an object that is the bearer of the disposition. To be realized in a process, a disposition needs to be triggered by some other process. Paradigmatic examples include fragility (the disposition to break when pressed with a certain force) and solubility (the disposition to dissolve when put in a certain solvent). Characteristically, dispositions may exist even if they are not realized or even triggered. A glass is fragile even if it never breaks or even if it never undergoes any shock, for instance. At the nub of the dispositional understanding of causation is that causation occurs when some disposition is realized [32]. For example, the dispositional account attributes the process of the breaking of a glass to the realization of the fragility disposition of the glass.

For a general reason for dispositionally causal unity conditions for perdurance, Williams [27] justifies the combination of perdurantism with a dispositional view of causation on the grounds that the kind of causal links between temporal parts of a

[7] Sortals are, broadly speaking, are a kind of linguistic terms (or of concepts) that take numerical modifiers, that is, can be associated with numerical adjectives. For instance, the word 'cat' is a sortal because it is a linguistic term that takes numerical modifiers, as is observed by the fact that we can say 'two cats'. See Grandy [30] for controversy as to the exact philosophical definition of sortals.

perduring object must come from *within* the object itself, so that each temporal part is the cause of the next; and dispositional causation can come up to this task because dispositions are intrinsic properties with their own causal potency. For a more domain-specific reason, dispositions serve as such a useful conceptual tool for the analysis of the explanatory practice in the biological sciences [33] that a dispositional theory of causation captures well the dynamicity, continuity, and context-sensitivity of biological phenomena [34]. It has been also argued in [35,36] that a dispositional analysis of causation helps to contribute to evidence-based medical practice [37] more than its counterfactual analysis such as [38] (but see [39] for criticism).[8] Moreover, it is important to remark that the BFO upper ontology (on which the CL is based) explicitly has the category of disposition [13, pp. 101-102], which would facilitate along our line of argument the 'translation' of perduring objects in processual ontologies (including GFO and GFO-Bio) into enduring objects in the BFO and CL substantialist ontological framework.

## 4. Discussion and Concluding Remarks

In summary, we highlighted the vexed problem of the integration of substantialist and processual biological ontologies and endorsed the 'republican strategy' to ensure the interoperability between them while respecting each ontology user's worldview. To advance this solution, we considered a way of 'converting' temporal parts of a certain perduring object in processualism into a single enduring object in substantialism, thereby suggesting that temporal parts of perduring objects be glued together in a dispositionally causal fashion in the domain of processual biological ontology. It is well worth noting that the issue of the practical harmonization between substantialism and processualism comes across the board in general ontology research.

In the future we will investigate a rigorous conceptualization and formalization of the idea of 'dispositional perdurance' as well as its practical application examples (e.g., cells) because logical specification is an important desideratum for well-designed biomedical ontologies [19,40]. This will require that we tackle some thorny issues regarding ontology of dispositions because the kind of dispositions (say p-dispositions) that enable perdurance differ considerably from canonical dispositions such as fragility and solubility. While presupposing that each temporal part of a perduring object is the realization of a p-disposition of its immediate predecessor, Williams [27] submits that (i) p-dispositions have realizations (i.e., the existence of further temporal parts) that are type-identical with the p-dispositions that produce them; (ii) p-dispositions can be realized with no need for stimulation; and (iii) the realizations of p-dispositions can be instantaneous (granted that temporal parts can be so [23]). Although we have some formal-ontological works (e.g., [41,42]) on dispositions available that have been widely used in biomedical ontologies (see e.g., [43]), it is not straightforward to apply them to the formalization of p-dispositions because the features (i) and (ii) go beyond the scope of the previous formal-ontological modeling of dispositions. For our further step towards the practical harmonization between substantialist and processual biological ontologies, therefore, a radical reconsideration of dispositions (e.g., their identity [42]) may be warranted. Finally, it is an interesting line of research to explore more nuanced,

[8] See Toyoshima [22] for a general formal-ontological study of causation, dispositions, counterfactuals, and the interrelationships among them.

perspectivist and/or pragmatic avenues for the substantialist/processualist orchestration in connection with general ontology alignment and translation [44,45].

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