

How Low Can You Go? BioEnactivism, Cognitive Biology and *Umwelt* Ontology

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ABSTRACT

The viability of enactivist philosophy in providing descriptions of biological phenomena (bioenactivism) across the phylogenetic spectrum relies in large part on the scalability of its central concepts, i.e. whether they remain operative at varying levels of biological complexity. In this paper, I will examine the possibility of scaling two deeply intertwined concepts: cognition and surrounding world (*Umwelt*). Contra some indications from Varela and others, I will argue that the concept of embodied cognition can be scaled down below the level of the organism. I will draw upon the “cognitive biology” espoused by Kováč (2000, 2006) and Monod’s (1971) studies of protein behaviour to make this case. The downscaling of embodied cognition below the level of the organism has ramifications for how we understand the concept of surrounding world (*Umwelt*). Reconfiguring the relation between these two central bioactive concepts has further consequences for what ontological commitments bioactive thinking leads to, and what paths of investigation it points us toward.

1. Introduction

The viability of enactivist philosophy in providing descriptions of biological phenomena (bioenactivism) across the phylogenetic spectrum relies in large part on the scalability of its central concepts, i.e. whether they remain operative at varying levels of biological complexity and scale. Maturana and Varela’s insistence on the continuity between minimal (single-celled organisms) and

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human cognition (Maturana and Varela 1980); the “Strong Mind Life Continuity Thesis” that we find in Thompson (2007) and elsewhere (Thompson and Stapleton 2009); Di Paolo’s attempt at a non “species-specific” and non “biochauvanist” account of cognition (Di Paolo 2009); and De Jesus’s formulation of a biosemiotic variant of bioenactivism (De Jesus 2016) are all instances of this attempt to scale the concept of cognition across the phylogenetic spectrum and in some cases beyond the boundaries of the living to artificial systems.

In this paper, I will examine the possibility of scaling two intertwined concepts: cognition and surrounding world (*Umwelt*).¹ Drawing upon the “Cognitive Biology” developed by Kováč (2000, 2006) and Monod’s (1971) studies of protein behaviour, and contra some indications from Varela and others, I argue that the concept of embodied cognition can be scaled down below the level of the single-celled organism and that downscaling embodied cognition below the level of the organism has ramifications for how we understand the concept of *Umwelt*. Reconfiguring the relation between these – cognition and *Umwelt* – and other central bioactive concepts like autopoiesis and autonomy has further consequences for what ontological commitments bioactive thinking leads to.

My argument thus agrees with Bitbol and Luisi’s findings (2004) that cognition is a condition of the living, but disagrees that autopoietic systems are a pre-condition for cognition. I do not wish to argue that a system can be classified as living but not autopoietic, rather that cognition can be scaled below that level of autopoiesis; and subsequently the same holds for the concept of *Umwelt*.

Here, I agree with Ripps (2005) that: “the presence of such a boundary per se,” a condition for autopoiesis, “should not be essential to the individual processes that maintain the system.” Subsequently, cognitive processes can occur at sub-autopoietic levels. Such processes ground or are foundational for the boundaries, and consequently the identity of autonomous cognitive systems. My argument also runs counter to the idea that autonomy (and not autopoiesis) is the “crucial bridge to cognition” (Thompson and Stapleton 2009, p. 24). I do not doubt that there are “autonomous” systems that are not autopoietic, but rather that autonomy is a condition for cognition. Subsequently, I also question

¹ The term *Umwelt* is sometimes rendered into English as “environment” (e.g. Thompson and Stapleton 2009). I opt for “surrounding world”. A surrounding world is always a horizon of cognition and action, i.e. a place of “salience, meaning and value” (Thompson and Stapleton 2009, p. 25).

that the most basic form of living, cognitive system is the single-celled organism (Thompson and Stapleton 2009, p. 25).

In the following sections, I first briefly examine the idea of scaling in reference to concepts like cognition and *Umwelt*. Second, I examine some of the central foci of bioenactivist thinking, with particular attention to the original concept of autopoiesis, Di Paolo's (2009) emphasis on its virtual dimension and De Jesus's "biosemiotic enactivism" (2016). The combination of biosemiotics and the virtuality of cognition are important contributions to enactivist thinking and points toward significant consequences for how we think the relation between cognition and *Umwelt* at an ontological level. Third, I turn to Kováč's "cognitive biology" and Monod's analyses of protein bonding to argue for the further downscaling of embodied cognition and *Umwelt* below the level of the single-celled organism. Finally, I will sketch what I think the consequences of this further downscaling are for the project of developing enactivist ontology.

My contention is that it brings us toward an ontology of nested and overlapping *Umwelten* that are not necessarily proper to the level of the whole organism, autopoietic, or autonomous system. This calls for an account of the individuation and regulation of *Umwelten* that also maintains a place for the concept of the virtual.

2. Scaling Concepts

2.1 Scaling up and down

Scalability, in this context, entails that concepts are operative across different levels of systemic complexity in a fashion that is functionally and structurally akin, i.e. that roughly the same kind of thing is happening in roughly the same kind of way. This is a particular challenge for bioenactivism because many of its operative concepts seem to be drawn, at least initially, from philosophy of mind and human phenomenology and then scaled down to less complex systems. In this sense, enactivism opens itself up to charges of anthropocentrism. The affinity of much bioenactive thought to Hans Jonas's phenomenology of life further reinforces the legitimacy of these charges (see Wolfe 2015 and De Jesus 2016 on this point).

The concept of autopoiesis, as developed by Varela and Maturana – a concept which forms the basis and inspiration for bioenactivism as a sub field – is however not subject to downscaling, but is scaled up. Autopoiesis (self-constructing, or self-making) was developed as a descriptive concept from the

observation of minimal forms of life and then scaled up across the phylogenetic scale to account for greater levels of complexity. The concept of autopoiesis as a descriptive condition of minimal life is also used outside of the enactivist literature alongside related scaled down concepts like embodied cognition, embodied knowledge, surrounding world and communication (see, e.g. Mann 2012, Kováč 2006). Use of these concepts in discussions of minimal conditions of cellularity (Mann 2012, 2013) supports the hypothesis that they are scalable so long as the usage implies a structural and functional similarity.

2.2 Scaling worlds

An important distinction, introduced by Jakob von Uexküll, between *Umwelt* (surrounding world) and *Welt* (world) (von Uexküll 1926, 2010) illustrates how the concept of *Umwelt* is also scalable. An *Umwelt* “is a milieu of behaviour proper to certain organisms” [...] “the ensemble of excitations which have the value, and signification of signals.” (This is George Canguilhem’s definition of von Uexküll’s terminology (Canguilhem 2008, p.111).) The *Umwelten* of living-organisms can be contrasted to the *Welt* qua “universe of science.” *Welt* is a derivation and formalization of our *Umwelt*: our understanding of capacities at vastly varying scales remains derived from the species-specific human *Umwelt* that constrains our analyses, including our capacity to scale concepts. In this way, von Uexküll insists that his theoretical biology remains “Kantian” insofar as it remains within the constraints of human cognition, or the human *Umwelt*.

But there is no reason to simply presume that we project the structure of these interactions, and the concurrent appearance of teleonomy or teleology and normativity, onto other systems or *Umwelten*.² It is also possible that we observe cognition, norms, values, and similar structures of behaviour in other systems because their surrounding worlds share a similar structure to our own; this is indeed what von Uexküll seemed to think. This was also his reason for insisting on an ethological method of observing animals in their natural habitats as experimental conditions distorted their species-specific *Umwelten*, imposing the conditions and constraints of our own onto the experimental conditions.

² By teleonomic I mean genuinely goal-directed processes or behaviours whose goal directedness is the outcome of an evolutionary process (see Mayr 1974). Nb, teleonomic does *not* imply here an “as if” structure wherein the goal directedness is extrinsic to the process and ascribed by an external observer. Thanks to Paolo de Jesus for suggesting this clarification.

Up to this point, I have spoken of bioenactive scaling on a spectrum from single-celled organism to human beings. However, I want to bring into question the fundamental level or scale at which we can speak of embodied cognition, embodied knowledge, and *Umwelt*. Specifically, I want to call into question the privileging of the whole-organism or whole-system as the fundamental level of *Umwelt* analysis. The analytical privilege afforded to the whole organism or system level is, I think, a common feature across versions of bioenactivist philosophy. Di Paolo (2009) to an extent addresses this whole-organism bias in his attempt to arrive at a “non-species specific, non-bio-chauvinist definition of cognition.” He nonetheless seems to propose holding onto the intuition that cognition implies a self-constituted systemic identity to which cognitive norms refer (15).

Reasons not to adopt the whole organism or whole system as the fundamental level of cognition can be found in Kováč’s biochemistry inspired “cognitive biology.” Kováč proposes the biomolecular as the fundamental level of cognition and draws upon Monod’s (1971) account of the allosteric regulation of protein-ligand bonding to make this argument. Monod’s account of embodied cognition at the biomolecular level and his deployment of this phenomenon against holistic or organism-centric level of analysis raises significant issues for some of the core bioenactivist arguments.

3. Bioenactivism

3.1 Borders and *Umwelten*

Bioenactivist approaches to cognition are varied but share an emphasis on cognition as a reciprocal *enactment* of both a cognizer and a surrounding world, and not as a representation of a pre-given world by a pre-given mind. This has invited accusations of “idealism” (Pascal and O’Regan 2008) insofar as the surrounding world in question is proper to the level of the corresponding co-emergent system, e.g. organism or population. The more serious versions of this criticism focus on the fact, already noted, that autopoietic enactivism gives undue privilege to the single autonomous living system; and subsequently conceives cognition and world-formation in a fashion that is overly dyadic and confined to the membrane boundary (Wheeler 2010); despite the claims to a “relational” account of cognition (De Jesus 2016; Wheeler 2011). The charge of idealism is vague as idealism is an oft caricatured and contested term.

Nonetheless a reappraisal and revision of the notion of autopoiesis in its relation to cognition, enactivism, and autonomy should help to clarify to what extent this may be a legitimate critique. Ultimately, I think that the *Umwelt* centred approach that I develop here is not susceptible to the charge.

The term enactivism itself stems from the work of Maturana and Varela (1998) and also Varela's later work (1989; 2000; see also Luisi 2003). As Luisi points out, the term "co-emergence" might have been preferable. This is because enactivism understands the activity of cognizing and hence engaging with the world as a "dynamic embodied interaction" (De Jesus 2016) between a cognizing system and its surrounding world (*Umwelt*); the boundaries between which may be fuzzy and characterised by interchange, though ultimately discernible. What is central is that the self-organisation of the organism's internal-milieu and the reciprocal interaction with the surrounding world are co-constitutive of both the organism and the *Umwelt*.

This in no way rules out that the *Umwelt* which co-emerges with the organism/system contains meaning structures that pre-exist the organism/system. A surrounding world is both emergent on various levels with its proper system, and inherits pre-existing meaning-structures that are actualised precisely in the border-creating activity that occurs between material embodied knowledge(s) and the emerging surrounding world. In other words, the material components of a systems can bear embodied knowledge about an *Umwelt* that does not yet exist on the basis of inherited and evolved knowledge from other *Umwelten*; i.e. surrounding worlds proper to other systems – depending on the various forms of transmission of inherited information, e.g. vertical or horizontal gene transmission.

The process of ordering or individuation that enacts the internal milieu of the organism – its self-organisation – and concurrently also enacts an *Umwelt for* that organism/system is also what we can call an ecological development: the organism/system and its *Umwelt* now form a component or dimension of an over-arching ecology of interdependent and interacting *Umwelten*. These are ecologies of meaningful surrounding worlds, the latter emerging at varying levels of individuation (e.g. protein, cell, organism, population, species). We can think of something along the lines of enactive niche-construction, where a cognizing system does not just alter the material conditions of its and other systems' physical environment, but also the sense-structures into which other borders are formed or emerge (in a sense parallel to Darwin's insight that the most important aspect of an organism's evolutionary niche were other

organisms). The dynamics of the overarching *Umwelten*-ecology can still only be analysed from within the perspective of an individual *Umwelt*. The co-constitution, individuation, or enactment of cognizing systems and corresponding *Umwelten*, and the impact of these individuations upon an overarching *Umwelten*-ecology is central if we wish to eventually speak of enactive ontology in the manner that I propose. This account is not necessarily out of step with Maturana and Varela's understanding of a "cognitive domain" as being a "region of the environment that has co-evolved" (Bitbol and Luisi 2003, p. 101) with the organisationally closed system to which it corresponds, and in which the system persists and develops through various perturbations.

This brief account, focussing on the relation between cognition and *Umwelt* generation, already incorporates a critique against Varela and Maturana's early autopoietic theory, i.e. that it was overly functionalist and structural at the expense of sense-making (Di Paolo 2005). The use of the term *Umwelt* indicates that the surrounding worlds in question are meaningful worlds of cues, affordances, and tintings that function as sign-relationships in the system/organism's modulation of its own comportment.³ It is nonetheless helpful to further review the basic dimensions of the initial concept of autopoiesis before moving to discuss its semiotic and virtual aspects.

An autopoietic system entails the establishment of a membrane which creates a border between the external and newly established internal milieu. The membrane is maintained by the dynamics of the internal milieu. Maintaining the border consequently establishes an identity for the cell or other form of autopoietic system. Both the membrane and the internal milieu must however be maintained and re-produced using materials and energy from the external milieu: metabolites. The role of the external milieu in providing the material and energetic means for maintaining the internal one, and the reciprocal function of the internal milieu in supporting the maintenance of the membrane, makes an autopoietic system organisationally closed but materially-thermodynamically open, which entails that the border/membrane is porous (allowing the system to resist entropy). Operational closure also implies that the internal milieu is

³ This point is nicely illustrated with the example of bacteria swimming up a sugar gradient. The sugar molecules have a significance to these organisms; but the significance is not intrinsic to the sugar molecule, rather it belongs to the *Umwelt* that is generated by the relation between system and surroundings and which has a history outlasting the system itself, which the system inherits. This example is used in multiple places in the literature, see, e.g. Thompson and Stapleton (2009, p. 24-25).

maintained by a network of processes that are all intertwined (at least at the minimal level). An autopoietic system can thus be described as an emergent property of said network. The argument that I want to make as we proceed is that cognition is occurring at the level of these processes below the level of the autopoietic systems as a whole. Another way to phrase this would be to ask if the self-production and maintenance of the system and its membrane are necessary for cognition and *Umwelt* enaction? I think not. This contention runs counter to autopoietic theory that focuses on the importance of the membrane; but I also want to argue that cognition and *Umwelt* do not require autonomy as a precondition, which runs counter to bioactive theory which shifts the emphasis from autopoiesis to autonomy and insists on the self-generation of systemic identity. First, it is necessary to explain in greater depth what cognition means in this context.

3.2 Cognition as Breaking with Chemical Necessity

Very coarsely, at the minimal cellular level, metabolic relations between the autopoietic system and its environment are deemed “cognitive” insofar as they are not chemically necessary but rather involve recognition and reaction as a result of a selective process (Di Paolo and De Jesus add the virtual and semiotic dimensions onto this coarse model). The system recognises aspects of its environment as having value or not for the perdurance of the system or for other forms of normative behaviour, e.g. fulfilling teleonomic function. These relations can be characterised biochemically, but this is distinct from being chemically necessary. The chemically necessary dynamics of the environment do not fully determine the dynamics of the internal milieu or the behaviour of the system (Luisi 2003). In autopoietic theory, the non-necessity of relations is attributed to the function of the membrane which insulates the system from its chemical environment. Living is thus the process of maintaining this boundary and the internal milieu that both relies upon and creates and maintains, materially and formally, the boundary.

The break from chemical necessity also gives the autopoietic system temporal or even historical dimensions. Cognitive interactions both within the cell and with the *Umwelt* proceed according to patterns that have been evolutionary selected for. These patterns also allow the system to anticipate changes or interactions in and with the environment (these anticipations can be faulty leading to the breakdown of the system or maladaptive behaviour). In this

way autopoietic and other autonomous systems acquire evolutionarily selected “habits” of interaction which help ensure the maintenance of certain patterns that sustain some degree of independence from environmental circumstances. These habits can be considered a form of embodied knowledge and can be transmitted across generations (e.g. vertical gene transfer) or throughout populations (e.g. horizontal gene transfer) through the mechanisms of materially embodied knowledge. It is in this sense that operative meaning-structures or significative relations can pre-exist any one particular *Umwelt* to which they belong.

The cognitive capacity of any system relies on its evolved embodied habits or knowledge; but these habits have a teleonomic or teleological orientation toward the system’s own persistence and can thus be said to operate along a value gradient that is particular to the system’s *Umwelt*. Merleau-Ponty summarises perfectly this dynamic: “it is the organism itself [...] which chooses the stimuli in the physical world to which it will be sensitive. The environment [read: *Umwelt*] emerges from the world through the actualisation or the being of the organism” (Merleau-Ponty 1967; also cited in Luisi 2003).

Several critical points can be made here. As Luisi points out, Maturana and Varela are not consistent on whether life should be equated with cognition, or whether the conditions of autopoiesis are a pre-condition for cognition (Luisi 2003, p. 54). These being: the system has a semipermeable boundary; the boundary is produced by the system; and the system encompasses reactions that regenerate the components of the system. Maturana and Varela also argue at points for equivalence between the three terms: cognition-autopoiesis-life. It is problematic either way as it is arguable that the second two conditions rely on molecular cognition which occurs at a lower level than the system itself – this is debatable within some experimental proto-cell systems that are deemed autopoietic without being cognitive (Bitbol and Luisi 2004) or living. This is linked to a related problem that seems to run throughout the bioenactivist literature, including Di Paolo’s anti-biochauvanism, namely that cognition occurs at the boundary of whole (organism-like) systems; and a critique more specific to Varela that single-celled organisms are the lowest level of cognition (Luisi 2003, p. 54, citing Varela and Maturana 1998, Maturana and Varela 1980). Most bioenactivists now seem to agree that adaptive autonomy and not autopoiesis is the condition for cognition, while nonetheless maintaining that biologically based non-autopoietic autonomous systems rely on basic

autopoietic cellular constituents. Cognition in the living remains subsequently founded on the cellular level of autopoiesis.

Another objection is that the all or nothing nature of autopoiesis – a system is either autopoietic or not, and if not, non-living – fails to capture the gradations of norms that characterise life (Di Paolo 2005); these would include health and illness, vigour and fatigue and so on (Di Paolo 2009, p. 14).

Adaptive autonomy (e.g. Di Paolo 2005, 2009, Thompson and Stapleton 2009; Froese and Di Paolo 2011), as an alternative to the all or nothing nature of autopoiesis, can be defined as a system's capacity to regulate its states in relation to its external milieu in a fashion that is teleonomically or teleologically oriented according to the various value gradients present in its *Umwelt*. And, in doing so, generate its own identity. That is, cognitive systems engage in anticipatory behaviour. There is no problem in saying that the cognitive workspace of adaptivity is evolutionarily determined in the fashion that I described above in relation to inherited meaning structures.

Di Paolo's adaptive autonomy based critique of autopoiesis is particularly relevant to the direction of my argument here insofar as he insists on a virtual dimension to cognitive capacity, which he equates with sense-making properly speaking. Di Paolo (2009) argues against the equivalence of living and cognitive systems, while making the claim that a living system is one that is capable of cognitive engagements. This simply makes the scope of the cognitive potentially broader than the scope of the living, while keeping it within the constraints of adaptive autonomy. Moreover, cognition properly speaking for Di Paolo involves future-oriented regulation of behaviour. It is the future-orientedness that implicates a virtual dimension. The virtuality comes from the selective behaviour between "otherwise equally viable paths of encounter with the environment" (Di Paolo 2009, p. 14). Once this virtual dimension is integrated into the definition of cognition, Di Paolo argues, in reference to Weber and Varela (2002) and Thompson (2007), we can begin to speak of behaviour and sense-making. A system that makes sense must be able to: "recognize in those states [of its surrounding world], and only in them, the virtual tendencies that relate it as a whole to the potential loss of its own viability and, in addition, it must be able to act appropriately on those tendencies" (Di Paolo 2009, p. 15). Incorporation of the virtual dimensions of the *Umwelt* into behaviour is precisely "adaptivity" and subsequently "agency." We can speak of agency here because there is a teleonomic and hence normative orientation of behaviour.

3.3 Biosemiotic Enactivism

De Jesus (2015; 2016) seeks a further revision of autopoietic enactivism by introducing a de-Kanted Uexküllian phenomenology (2016, p. 142). Two things should be noted here. First, De Jesus introduces von Uexküllian phenomenology as an alternative to the affinity between enactivism and Hans Jonas's work, which does not properly insulate itself from the charge of anthropocentrism. De Jesus seems to agree with Wolfe (2015) that Jonas analyses human subjective experience and then downscales in an effort that is more concerned with situating his phenomenology of human subjectivity within a post-Cartesian and Darwinian perspective than in being concerned properly for the nature of biological life per se (see De Jesus 2016, p. 134). Second, De Jesus attempts to de-Kant what he refers to von Uexküll's "overly subjectivist" construal of the *Umwelt*. This means rejecting the idea that the "Umwelt is an inner subjective appearance of exclusively subjective phenomena" in favour of a relational approach wherein the Umwelt is a "relational domain constituted through interactive sign processes, which are irreducibly triadic" (De Jesus 2016, p. 142). De Jesus also seeks to emphasize the commonality of animal worlds over and against von Uexküll's perceived focus on the disparity of *Umwelten*. In fact, von Uexküll seems to go both ways, arguing for the specificity of individual *Umwelten* and using species specific *Umwelten* as a kind of shorthand or scientific generalisation (see Tønnessen's introduction in Brentari 2015).

On this second point, it is important to make two comments. It is not possible to fully de-Kant von Uexküll's *Umwelt* theory without losing precisely the essence of the concept of *Umwelt*, its specificity. This is why von Uexküll continuously insisted that human scientific activity was carried out from within a human *Umwelt*, which is its widest scope is the world of science, and called his approach a kind of Kantian biology. To try to objectify the *Umwelt* is to turn it into the World qua world of science, and miss precisely the specificity of what the concept does. This is why we need to think *Umwelt* theory in terms of levels of nested and intertwined *Umwelten*. Such a theory allows us to maintain the idea of *Umwelten* proper to individual organisms or systems, and even to processes within systems, while at the same time acknowledging species and

population level *Umwelten* and the intertwining at higher levels; different species-level *Umwelten* may share sign-relations.

When we characterize *Umwelten*, including our own, we are doing a kind of modelling. Like all modelling, *Umwelt* modelling can proceed in finer and coarser grained fashion. The *Umwelt* of an individual organism is modelled in a finer-grained fashion than that of a species-level analysis, where certain generalities emerge in favour of idiosyncrasies.

What De Jesus also, rightly, objects to is a perceived internalism of von Uexküll's position. We thus move from *Umwelten* being constituted by "inner subjective appearances" to exterior semiotic relations not requiring a recourse to some variant of mental or affective representations.

Moreover, in drawing upon von Uexküll's *Umwelt* theory De Jesus aims to show that we needn't start from organisms functioning as "subjective agents" in their own right driven by a fundamental *experienced* desire to continue existence, but rather living systems negotiating their unique (or species-specific) *Umwelten* through the mediation of signs; wherein a difference in the perceptual environment is recognized as indicating and eliciting something else, i.e. normative if not chemically necessary action. The central point of von Uexküll's and hence De Jesus's analysis of organismic worlds is that perceivable differences in the surrounding world *matter* for the organism. A difference in the environment is perceived and transformed into a *sign* through what von Uexküll calls function cycles, which are specifically *not*, or *more than*, sensorimotor loops. A sign is understood here simply as something that stands for something else. Perceptual stimuli are differently interpreted by organisms depending on context.

Species, population, and individual specific function cycles are the result of an organism's evolutionary history, its morphological development, the challenges that it encounters in the environment, and its continuously changing relations to its environment. This is why we need a multi-layered and coarse vs. fine-grained approach to *Umwelt* analysis.

De Jesus's take home point is that a "system can be said to be cognitive if it uses signs." He argues that his biosemiotic proposal, which starts from an Uexküllian analysis of animal behaviour "offers a reversal of the [Jonasian] phenomenological argument" used to ground other versions of bioenactivism. De Jesus's account of human cognition is a scaling up of minimal biosemiotic relations to the level of human symbolic communication: humans use signs in a more complex manner, namely by the use of symbolic signs (language) where

the relation between signifier and signified is arbitrary and conventional. De Jesus maintains that bio-semiosis is intrinsically normative insofar as, for most living systems, a failure in the capacity to read the signs which present themselves in the *Umwelt* usually leads to the mal-adaptation of the living system to the environment.

The semiotic approach to the *Umwelt* also allows for the retention of the virtual dimension of cognition emphasised by Di Paolo. The scope or expanse of the virtual dimension of cognition is down to sign usage. The more complex and open (arbitrary) semiotic relations are, the broader the virtual dimension. Simple cognitive systems like the proteins we will discuss in the next section, inherit the virtual envelop of their behaviour and do not further develop it. Humans possess the semiotic capacity to arbitrarily assign semiotic relations between sign and signifier—human language. De Jesus cites Hoffmeyer in referring to “semiotic freedom” as “capacity for responding to a variety of signs through the formation of (locally) meaningful interpretants” (Hoffmeyer 2012, p, 122, cited in De Jesus 2016, p.140). What I referred to as the virtual envelop of cognition can be understood in a similar manner. The more semiotically flexible the cognitive relations, the greater room for exploring potential avenues of action. In other words, flexible sign relations expand the virtual envelop of cognition.

In this section, I have tried to establish three premises. First bioenactivist theories that start from the concepts of autopoiesis (critically or not) and cognition also imply the concept of *Umwelt* qua meaningful surrounding world. Second, the concept of *Umwelt*, if it is to be used productively, must, like the concept of cognition, be scalable. We need to talk about *Umwelten* at different levels that are nested and intertwined in various ways. We can think about *Umwelt* analysis not only on different levels, but also in terms of coarse and fine grained, depending on the level. Third, we can deepen the concept of cognition by recognizing the developments made by Di Paolo and De Jesus; namely that cognition requires a virtual dimension and semiotic relations; and that the virtual envelop of cognition is expanded alongside greater flexibility of semiotic relations. In the next section I ask if these premises apply when we attempt to scale further down to the biomolecular level. My contention, on the basis of Kováč’s “cognitive biology” and Monod’s analyses of proteins is that they do.

4. Cognitive Biology and the Regulation of Proteins

4.1 Goodwin and Cognitive Process

The term “cognitive biology” was coined by Goodwin (1978) to refer to his approach to biological process and organisation. What is at stake in Goodwin’s proposal is whether the rules explaining biological pattern formation are grounded in “natural law” or embodied knowledge derived from an evolutionary process. He opts for the latter. The argument is straightforward: these rules entail knowledge that is embedded in the evolved material structure of biological systems; systems which make use of knowledge are cognitive systems. Biological systems are thus cognitive in their formation and development. In this model, all biological systems have some knowledge about the world (coded and stored in DNA and other structures) and utilise that knowledge in order to survive and reproduce. Knowledge is defined here as “a useful description about some aspect of the world” (Goodwin 1976). Meaning emerges upon gene-expression and the “testing of hypotheses” about the environment in the interaction between the system and its environment. Meaning, in other words, emerges in the motile relations between the biological system and its environment (this point is agreed upon by enactivists). Goodwin uses this account to make a threefold distinction between information, knowledge, and meaning. Knowledge differs not only from meaning in the manner specified, but also from information insofar as knowledge also includes “instructions for action,” which in the relevant contexts are generative of meaning. This relation between knowledge and meaning allows for populations of cognitive systems to stabilise their behaviour and persist in potentially hostile circumstances through the adaptation of their behavioural responses. Advantageous responses are retained through natural selection, and adaptation of behaviour in line with a pre-defined goal gives the systems in question both a creative and teleonomic orientation and seemingly also indicates the virtual dimension, if we understand virtuality in this sense to mean “forming hypotheses” about future states of the *Umwelt* on the basis of embodied semiotic knowledge (meaningful sign relations) and also whatever degree of semiotic freedom or flexibility a system has. These hypotheses are then tested along adaptive, normative gradients.⁴ The virtual

⁴ The ontological upshot for Goodwin is that the cognitive process described is precisely that, process and nothing but. It cannot be reduced to a level of explanation that somehow abstracts from the process.

capacity of a system, is also materially embedded, inherited, and selected for or against depending on its efficacy in facilitating normative behaviour.

4.2 Kováč: How Low Can Cognition Go?

Following from Goodwin (and Monod), Kováč poses a version of the question that framed this paper: “at what level would the concept of cognition—with its inventory of consciousness, cogitation, feeling, perception, sensing and living—lose meaning and correspond only to lifeless interactions?” (Kováč 2000, 2006). By lifeless, he means interactions that are nomic or chemically necessary in character rather than cognitive.

Kováč’s variant of cognitive biology proposes the biomolecular level as the fundamental level of cognition and suggests a descriptive science of cognitive interactions containing nested levels from the molecular sensor upwards. Like Goodwin, he maintains that cognition is embodied in evolved material structures and these structures are chemical. Cognition is therefore the property of non-nomic chemical systems. An important characteristic of such systems is that they are not scalar (not to be confused with scalable as I’ve been using the term), i.e. they cannot be characterised in purely magnitudinal terms, but are by definition vectorial; they have a specified direction or orientation of development. The vectorial dimension of cognitive chemical systems is attributed to the composition and structure of proteins (Kováč 2006, p. 564). Proteins are evolutionarily selected to perform “goal-directed teleonomic functions” (Monod 1971); their corresponding capacity to take on diverse conformations over time in response to their sensing of the *Umwelt* combined with their teleonomic character is what gives them their vectoriality.⁵

Kováč describes the shape shifting of certain proteins as exploratory behaviour, insofar as it is a kind of testing the environment for appropriate ligands to bond with (ligands are substances that form complex biomolecules by binding with proteins in order to serve a teleonomic function). Because proteins alter their material conformation as a response to sign relations in the *Umwelt*, and because the alteration is not chemically necessary but evolutionarily selected, Kováč argues that they possess sentience: “the capacity to exhibit a variety of potential internal states, which respond to the immediate state of the

⁵ I am not unjustly superimposing the term *Umwelt* onto Kováč. He writes: Because of its intrinsic teleonomy, a protein gives meaning and significance to its environment—that is, to its ligand” (Kováč 2006, p. 564).

environment” (Kováč 2006, p. 564). By interacting in this fashion with its *environment*, the protein’s embodied evolutionary history and knowledge give significance to its surroundings transforming it into an *Umwelt*, wherein some recognized or perceived differences make a difference to the behaviour of the protein, hence functioning as signs, while others don’t. What makes a difference and what does not is modulated by an evolutionary history and is embedded in the material and spatial composition (how it is folded) that makes up the protein and modulates its dynamics. This process, by which a protein changes shape in accordance with its embodied knowledge and in order to bond with a ligand that it senses in its environment fulfils for Kováč the conditions of cognition. Cognition thus consists of recognition of meaningful differences in the environment turned *Umwelt* by the process of recognition itself and the historically mediated behavioural response to those differences.

4.3 Allosteric Enzymes and The Principle of Gratuity

Kováč’s analysis is based in part on Monod’s descriptions of the behaviour of allosteric enzymes (1971, pp. 65-78). While the cognitive function of “ordinary” enzymes is limited to the recognition of a specific substrate at the exclusion of all else, allosteric enzymes also selectively recognize and bind with several other substrates. This activity regulates the behaviour of the protein by inhibiting or increasing the rate of the protein’s metabolic activity in relation to the substrate. Most allosteric regulation is under the control of several effectors that work cooperatively or antagonistically (facilitating or inhibiting) to regulate metabolic processes.

What is central to Monod’s analysis is that the effector substrate molecules that regulate the allosteric enzyme play no role in the subsequent metabolic activity. They serve only a regulatory role. The regulatory interactions are made possible by shifts in the shape of the protein which allow for the recognition of different ligands; the capacity of the allosteric enzyme to recognize a diversity of ligands on the basis of their shapes depends on its modulation of its own shape. Monod emphasizes that (1) the regulatory activity and the (strictly speaking) metabolic activity are not chemically connected, there is no interaction between regulatory ligands and ligands to be metabolised; (2) the protein’s responses to variation in the concentration of regulatory ligands are non-linear; and (3) there is no chemical dependence between the teleonomic function of the protein and the regulatory signals controlling it (the principle of gratuity). Allosteric

reactions thus proceed from the protein's discriminatory or cognitive powers alone. The gratuity of these regulatory processes makes them semiotic: there is independence between the function and the signals controlling it. The protein reads signs in its *Umwelt*, but it also goes looking for them. These cognitive powers depend on the protein's capacity to assume various states, wherein recognition of different regulatory ligands occurs. Kováč calls this modulation of shape "exploratory behaviour" (Kováč 2006, p. 564).

We can draw from this several important points. Allosteric proteins clearly engage in cognitive behaviour that is teleonomic or teleological and hence normative. This cognition occurs independently at a systems-level below that of the cell, autopoietic system, or adaptive autonomous system (the protein does not generate its own identity as it is dependent upon transcription and translation processes for its identity). Yet, the allosteric protein has or is an instance of evolved "embodied knowledge" insofar as its scope for modulating its own shape has been evolutionarily selected for, but is also not chemically necessary. This makes the protein's behaviour temporal or historical. The scope for shape-change that Kováč calls exploratory behaviour can also be considered a virtual dimension of the protein's behaviour (the scope is real without needing to be actualised): the allosteric protein has a virtual design and cognitive work space. The virtual envelop of allosteric protein cognition is evolutionarily individuated by a process of selection for increased systemic coherence and efficacy. But, due to the gratuitous nature of the regulatory reaction it is also fundamentally open: everything is (or was once) possible (Monod 1971, p. 78). The fundamental openness relates to the regulation of the virtual envelop of cognition which is historically and not chemically necessarily constrained.

This structure of embodied cognition that Kováč and Monod identify on the molecular level seems to apply at all levels of cognition. Even at higher levels of biological complexity, cognition for the most part entails the exploration of "pre-programmed" alternatives, a pre-determined virtual space. There is a cognitive work space that expands or gains extra dimensions with the use of more complex forms of signification or semiotics: "in general all living entities are semantically closed [...] only humans, thanks to artefaction and the evolution of culture may be an exception, but much less so than one might assume" (Kováč 2006, p. 565). Cognition, as carried out by allosteric proteins, seems a scalable concept, up to the level of complex human behaviour.

Cognition within a meaningful *Umwelt* entails processes by which meaning is individuated into specific *Umwelten* that present specific cognitive

possibilities to their inhabitants at all levels, including proteins. Subsequently, “life as information” or “life as computation” metaphors are misplaced. Life as cognition is a continuous process of limiting information flow by way of selection and rendering in terms of embodied knowledge and meaningful *Umwelt* relations; it is the individuation of *Umwelten*. For this reason Kováč writes that the “triggering of pre-determined responses and indeed selecting among them, seems to me a more appropriate description than information processing” (Kováč 2006, p.565).

This account of cognition remains reductive in the sense that all cognition and behaviour at the organismic or biosystems level can be explained as “emergences” from the base cognitive level of biochemical or biomolecular cognition which is open to *Umwelt* analysis. And indeed, Monod uses the behaviour of allosteric proteins as an argument that autonomy at higher levels, i.e. the enactivist level of autonomous adaptive systems are dependent upon the cognitive activity occurring at the protein level.

5. Toward an Enactivist Ontology of Regulation

5.1 Consequences of Downscaling Cognition for Enactivism

The downscaling of cognitive biosemiotic relations below the level of the cell or autonomous system has consequences for the enactivist approach to biology. It brings into question a number of the central tenants of enactivist thought, while also reinforcing the value of the enactivist approach. The bioenactivist approach has typically assumed that it “reaches from the single cell organism” to higher levels of complexity (Thompson 2007, Froese and Di Paolo 2011, p.2). Di Paolo’s anti- biochauvanism eschews the reference to cells, but holds onto the idea of adaptive autonomous systems as the agents of cognition. But the downscaling of cognition shows that autonomy is not a criteria for the “non-mysterious emergence of non-reducible domains of activity” (Froese and Di Paolo 2011, p.3), at least not cognitive activity which includes the virtual dimension. The protein does not generate its own identity, but it nonetheless displays genuinely goal-directed, normative, semiotic, and cognitive (including the virtual envelop) behaviour in the fashion demanded by enactivist theory. Adaptive autonomy can no longer be considered the minimal form or level of sense-making (Froese and Di Paolo 2011, p.5). Neither the cell nor the autonomous system is the lower limit of the co-emergence of embodied

knowledge, meaning, cognition and *Umwelt*. Allosteric proteins qualify as having a “perspective of significance” which is “not intrinsic to the perturbation themselves,” or in somewhat clearer terms, not “chemically necessary.” The horizon of significance proper to the protein *Umwelt* has a history that extends beyond the particular protein.

5.2 *Umwelt* ontology: individuation and regulation

With the downscaling of cognition and *Umwelt* we arrive at a picture of intertwined and nested *Umwelten*. The *Umwelt* of the protein forms a dimension of the *Umwelt* of the cell, of which it is a material and meaningful constituent. These *Umwelten* are themselves components of and subject to regulative systems and dynamics of enormous scale and scalability: individuation and regulation of the sense-dimensions of a protein *Umwelt*, are but one regulatory aspect of a larger scale cellular process and so on. They are also processes of individuation of embodied knowledge. The processes by which embodied knowledge and *Umwelten* are individuated can only be separated by abstraction as they are aspects of the same individuation. Individuations within a particular *Umwelt*, that of an allosteric protein for example, insofar as they alter the behaviour of the cognitive system in relation to its surroundings, also function as individuations within the broader ecology of *Umwelten* at various levels.

What ontological commitments or avenues of investigation does this lead us toward? An enactive ontology must be one that has individuation and regulation of meaning-relations across all scales, not autonomy, as its central foci. We might turn to the enactivist *avant la lettre* Merleau-Ponty for some guidance. Merleau-Ponty’s last attempts at developing an ontology are indeed intimately linked to this idea. He also tried to approach this new ontology (at least in part) via von Uexküll’s concept of *Umwelt*. The intersection of the concept of *Umwelt*, and the concepts of individuation and regulation is what I think Merleau-Ponty is aiming to explore when he refers (one of only two times) in a working note to Gilbert Simondon. He writes: “The notion of regulation should be broadened [...] The concept of regulation should not be treated “objectively”, as indicating a process in the third person, as in the habit of science – Nor believe that regulation is each time the {operation} of the same Nature” (Merleau-Ponty 1959, p. 42).

The idea expressed within this passage is that regulation should be treated as an ontological concept (what Merleau-Ponty always had in mind when he used

terms like *broaden* or *generalise*); but also that it should remain within the constraints of an *Umwelt* analysis. That is, regulation should be studied as perceived in terms of meaningful relations as well as from a scientific, third person, cybernetic perspective, which we must be mindful to remember appears only within our *Umwelt*. He aims here at a phenomenological ontology of regulation. The study of animal *Umwelten* and of human perception as belonging to the nature that it perceives (a position that Merleau-Ponty adopted later in his life in contrast to his analyses of perception from the 1940s), were understood as ways into this endeavour.

This also points to a point of conflict with Simondon:

Simondon's point of view is trans-perceptive [...] Nevertheless, one no longer knows what one is talking about if one places oneself in the meta-perceptual [...] For my part, [...] the nexus [*foyer*] remains the perceptive field, insofar as it contains everything: nature and history. Simply, instead of saying: to be perceived and perception, I should rather say: brute or wild being and "foundation" (*Stiftung*). (Merleau-Ponty 1959, p. 42)

This is the issue that I first raised in relation the idea of enactivism as *Umwelt* analysis. We remain constrained by individuations and regulatory processes proper to our own *Umwelt* or perceptive field. This brings us back to the problem of the virtual. The individuation and regulation of *Umwelt* relations within an *Umwelt* ecology are a question of the regulation and constraining of the virtual conceived as some kind of raw potentiality ("transindividuality in Simondon's terms). This is, I think, another way of rendering what Monod meant when he said that everything is possible (Monod 1971, p. 78) but what has actually developed now constrains that envelop of initial virtuality, such that we speak of necessary relations that are not chemically necessary. They are necessary due to a history of individuation and regulation.

Merleau-Ponty, cognizant of his own *Umwelt* situatedness maintains that any access to this virtuality, what he calls brute or wild being, must be through perception. Foundation or "*Stiftung*" is the term Merleau-Ponty takes up (from Husserl) to indicate processes of individuation and regulation of the virtual in relation to the actual. This relation between virtuality and regulatory constraint, parsed through meaningful *Umwelt* relations must, in my view sit at the heart of an enactive ontology.

The insistence on an approach that remains within the realm of perceptive being should not be misunderstood. The studies of art, biology, and politics that Merleau-Ponty engaged in as part of this ontological project are precisely attempts to perceptually access the relation between virtuality and individuation-regulation. Had he lived another two years, he likely would have seen Monod's, Changeaux's and Jacob's studies (to which Monod refers in *Chance and Necessity*, e.g. Monod, Changeaux, Jacob 1963) as contributions to this new ontology. In his 1959 course on "Philosophy and Non-Philosophy" he told his students: "We are in contact with this type of [wild] being through our science and our private and public lives. But it does not have official existence: our 'philosophical' thought remains spiritualist, materialist, rationalist or irrationalist, idealist or realist [...]" (Merleau-Ponty 1996, p. 37). Enactivism, in its relation to neurology, biochemistry and other fields, perhaps technology, can be a continuation of this ontological project.

REFERENCES

- Brentari, Carlo. (2015) *Jakob von Uexküll: The Discovery of the Umwelt Between Biosemiotics and Theoretical Biology*. Dordrecht: Springer.
- Bitbol, M and Luisi, P.L. (2004) Autopoiesis with or without cognition: defining life at its edge. *Journal of the Royal Society Interface* 1, 99-107.
- Canguilhem, G. (2008) *Knowledge of Life*. New York, NY: Fordham.
- De Jaegher, H. and Di Paolo E. (2007) Participatory Sense-Making. *Phenomenology and the Cognitive Sciences* 6, pp. 485-507.
- De Jesus, P. (2016) From Enactive Phenomenology to Biosemiotic Enactivism. *Adaptive Behaviour* Vol. 24(2), 130-146.
- Di Paolo, E. (2005) Autopoiesis, adaptivity, teleology, agency. *Phenomenology and the Cognitive Sciences* 4(4), 429-452.
- Di Paolo, E. (2009) Extended Life. *Topoi* 28, 2-21.
- Froese, T. and Di Paolo, E. (2011) From Cell to Society: The Enactive Approach. *Pragmatics and Cognition* 1, pp. 1-36.
- Goodwin, B.C. (1976) *Analytical Physiology of Cells and Developing Organisms*. London: Academic Press.

- Goodwin B.C. (1978) A Cognitive View of Biological Process. *Journal of Social and Biological Structure*, 117–125.
- Hoffmeyer, J. (2012) The natural history of intentionality. A biosemiotic approach. In: T. Schilhab, T., F. Stjernfelt, F. and Deacon, T. (ed.), *The Symbolic Species Evolved*. (Biosemiotics 6), pp. 97–116. Dordrecht: Springer.
- Hutto, D.D. and Myin. (2013) *Radicalizing Enactivism: basic minds without content*. Cambridge, MA: MIT Press.
- Kováč, L. (2000) Fundamental Principles of Cognitive Biology. *Evolution and Cognition* 6, 51-69.
- Kováč, L. (2006) Life, chemistry and cognition. *EMBO Rep.* 7, 562–566.
- Luisi, P.L. (2003) Autopoiesis: a review and reappraisal. *Naturwissenschaften* 90, 49-59.
- Mann, S. (2012) Systems of Creation: the emergence of life from non-living matter. *Accounts of Chemical Research* 45(12), 2131-2141
- Mann, S. (2013) The Origins of Life: Old problems, new chemistries. *Angew. Chem. Int. Ed.* 52, 155–162.
- Maturana, H and Varela, F. (1980) *Autopoiesis and Cognition: the realisation of the living*. Boston, MA: Reidel.
- Mayr, E. (1974) Teleological and Teleonomic: A New Analysis. In: Cohen, R. Wartofsky, M (ed.) *Methodological and Historical Essays in the Natural and Social Sciences*, Boston Studies in the Philosophy of Science V. XIV, pp. 91-117.
- Merleau-Ponty, M. (1967) *The Structure of Behaviour*. A. Fisher (trans.) Boston: Beacon Books.
- Merleau-Ponty, M. (1996) *Notes des Cours au Collège de France 1958-1959 et 1960-1961*, Edited by C. Lefort and S. Ménasé, Paris: Gallimard.
- Merleau-Ponty, M. (2004) Notes de travail inédites. Cours 1959. *Chiasmi International* 7, 39–42.
- Monod, J. (1971) *Chance and Necessity. An Essay on the Natural Philosophy of Modern Biology*. Wainhouse, W. (trans.) London: Collins.
- Monod, J, Changeux, J.-P. and Jakob, F. (1963) Allosteric Proteins and Cellular Control Systems. *Journal of Molecular Biology* 6(1), 306-29.

- Pascal, F. and J.K. O'regan. (2008) Commentary on Mossio and Taraborelli: Is the Enactive Approach Really Sensorimotor?. *Consciousness and Cognition* 17(4), 1341-1342.
- Thompson, E. (2007) *Mind in Life*. Cambridge, MA: Havard University Press.
- Thompson, E. and Stapleton, M. (2009) Making Sense of Sense-Making: Reflections on Enactive and Extended Mind Theories. *Topoi* 28, 23-30
- Varela, F. (1989) Reflections on the circulation of concepts between a biology of cognition and systemic family therapy. *Family Process* 28, 15-24
- Varela F, Maturana H. (1998) *The Tree of Knowledge* (rev edn) Shambala: Boston
- Villalobos M. (2013) Autopoiesis, Life, Mind and Cognition: Bases for a Proper Naturalistic Continuity. *Biosemiotics* 6, 379-391
- Weber, A., Varela, F. J. 2002. Life after Kant: Natural purposes and the autopoietic foundations of biological individuality. *Phenomenology and the Cognitive Sciences* 1(2), 97-125.
- Von Uexküll, J. (1926) *Theoretical Biology*. Mackinnon, D (trans.) London: Harcourt Brace and Company
- Von Uexküll, J. (2010) *A Foray into the Worlds of Animals and Humans: With a Theory of Meaning*. von Uexküll, M and Joseph D. O'Neil, J. (trans.) Minneapolis: University of Minnesota Press.
- Wheeler, M. (2011) Mind in Life or Life in Mind? Making Sense of Deep Continuity. *Journal of Consciousness Studies* 18(5-6), 148-168
- Wheeler, M. (2010) Minds, Things and Materiality. In: Malafouris L, Renfrew C (ed.) *The Cognitive Life of Things: Recasting the Boundaries of the Mind*. Cambridge: McDonald Institute for Archaeological Research Publications, pp. 29-37
- Wolfe, C. (2015) Was Canguilhem a Biochauvanist? In: Meacham, D. (ed.) *Medicine and Society. New Perspectives in Continental Philosophy*. Dordrecht: Springer, pp. 197-212.