

# Code Biology and Enactivism: Bringing Adaptors to Basic Minds

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**Abstract.** The paper presents a preliminary attempt at exploring the potentially fruitful intersection between Code Biology and enactivist research. As an umbrella label, ‘Enactivism’ designates different strands of research in the radical, anti-representationalist cognitive sciences. The paper begins by motivating the need for nuancing basic claims central to Autopoietic Enactivism and makes the argument that Code Biological insights and notions can be used to deflate the supposedly strong autonomy of individual sense-makers. Then, it goes on to show that Code Biology has the potential for informing Sensorimotor Enactivism by revealing some of the complex codifying mechanisms involved in not just visual perception but virtually any kind of sense-making across the evolutionary board. The paper builds on these insights to substantiate Radical Enactivism’s information-as-covariance and, beyond this, the mechanisms which enable ‘basic mentality’. Finally, a critical developmental perspective is considered.

**Keywords:** Cognition, Basic Minds, Adaptors, Ecological codes, Life-mind continuity.

## 1 Introduction

According to Barbieri, Code Biology can be understood in two senses. In its specific sense, Code Biology is the study of organic codes across the scales of evolution and in relation to the biological functioning of living beings whether these belong to Archaea, Bacteria or Eukarya. [1] As such, Code Biology in the specific sense can be traced back to the middle of the last century with the discovery of the genetic code [2] and the subsequent discovery of the epigenetic code [3], the histone code [4] etc. In its more general sense, Code Biology is the “study of all codes of life, from the generic code to the codes of culture” [1] and it was introduced by Barbieri [5]. In its general sense, Code biology comprises “a deeply interdisciplinary field and necessarily requires the contribution of different scholars: biologists, neuroscientists, ecologists, linguists, philosophers, mathematicians and computer scientists” [1] (p. 4). Whether it is understood in the specific or general sense, Code Biology explores codified relations not just by means of experimental work in accordance with standard scientific methods but also theoretically [6] (p. 2). It comprises an alternative to the chemical paradigm in biology and, hence, the assumption that the genetic code is characterized by fixed translations from sequences of codons into proteins meaning that a codon is bound to translate into particular amino acids [7] (p. 14). Conversely, a Code Biology framework takes stock

of the fact that the genetic code is governed by arbitrary rules that are not inscribed with physical or chemical necessity thus recognizing that the same sequence of codons might translate into different proteins [6] (p. 2). In terms of definition, a code is a “mapping between the objects of two independent worlds that is implemented by the objects of a third world called adaptors” (Barbieri [8] – quoted in [6] (p. 6)). This very broad construal of the ontology of a code entails that Code Biology can be viewed as a general framework for not just encompassing codes pertaining to the biological realm but also as extending into the neural and the cultural domain (cf. [9]).

The current paper presents a first, preliminary attempt at discovering the possible synergies between Code Biology in the general sense (**Section 1.1**) and Enactivism. Enactivism is another general position which seeks to investigate the link between life and mind (broadly understood) and, hence, everything between the single cell and human cultural practices. Although having a strong basis in theoretical biology, Enactivism is predominantly a strand of research that has evolved in the context of the so-called radical cognitive sciences. Anti-representationalist models describe cognition as simpler processes compared to proponents of representationalism, who consider mental content as playing an enabling, intermediate role between, on the one hand, an agent’s cognitive and behavioral states, and, on the other, the environment. Also, anti-representationalist research investigates the embodied and embedded aspects of cognition (including affordance use), thus taking extrinsic factors into account, which are typically not considered by traditional cognitivist approaches, given their neurocentric focus. The ‘Enactive approach’ was born with the publication of *The Embodied Mind* in 1991. Here, Varela and colleagues make the programmatic claim that “cognition is not the representation of a pre-given world by a pre-given mind but is rather the enactment of a world and a mind on the basis of a history of the variety of actions that a being in the world performs” [10] (p. 9). The view challenges orthodox cognitive science and so-called ‘cognitivist models’ which, amongst other things, treat the mind as a digital computer involving planning based on symbol processing [11]. Thus, as Barandiaran [12] argues, enactivists challenge the idea that cognition unfolds as the intermediate step between sensed input and behavioral output as they assume a dynamic perspective on how the mind unfolds (cf. p. 410). As Hutto and Myin phrase it, enactivists thus hold “that the embedded and embodied activity of living beings provides the right model for understanding minds” and, hence, that “[t]o understand mentality, however complex and sophisticated it may be, it is necessary to appreciate how living beings dynamically interact with their environments” [13] (p. 4). Yet, as a position, enactivism is becoming increasingly heterogeneous with about a handful of different approaches that all commit to basic enactivist principles concerning the need for overcoming the computer-metaphor when explaining cognition. Consequently, I limit the inclusion to three of the most prominent branches namely Autopoietic Enactivism (**Section 2**), Sensorimotor Enactivism (**Section 3**) and, finally, Radical Enactivism (**Section 4**). The purpose in so doing is not only to stress compatibility but also to explore what a Code Biology-informed take on enaction potentially has to offer. The paper concludes with some critical remarks concerning the current state of Code Biology and its possible prospects in an enactivist context (**Section 5**)

## 1.1 Code Biology (in the general sense)

In the general sense, Code Biology stipulates a ‘three worlds’ view. As Barbieri writes, Code Biology, in the specific sense, is dedicated to exploring phenomena unfolding strictly in the organic world (World 1), where no appeal to ‘interpretation’ is needed to make sense of them. In other words, the processes unfolding in this particular realm can be exclusively understood in terms of ‘organic semiosis’ and the organic mechanisms that enable them [1]. However, animal and human semiosis (Worlds 2 and 3) are assumed to be different in the sense that they not only involve organic processes but also neural ones. Thus, Barbieri claims that an appeal to organic mechanisms cannot stand alone. It must also include, at the very least, so-called ‘interpretive’ ones. In the case of humans, there is an additional component that is characteristic of its functioning, namely, a reliance on symbols. Whereas other types of signs (i.e., icons and indexes) presuppose a sort of natural connection between a sign and its object in terms of either structural similarity or a physical link, symbols differ [7] (p. 186). Symbols are manmade and relative to the specific conventions and rules pertaining to certain socio-cultural practices. As such, symbols are signs characterized by an arbitrary relation between the sign itself and its object or referent. For instance, a word is a symbol because there is no natural connection between a word (‘cat’) and its object/referent (‘a furry four-legged animal that purrs’). The relation between the two is necessitated merely by social conventions.

Yet, when it comes to interpretative mechanisms, it is clear that Barbieri assumes that cognition (understood as ‘interpretation’) is bound to be representational. For instance, at one point, he claims that semiosis in animals occurs as they ‘receive signals from the environment, transform them into mental images, and perform mental operations’ [7] (p. 143). Elsewhere, Barbieri puts it equally bluntly by arguing that “the mind can only act on representations of the world, and that is why it must use signs which have both internal and external meanings...” (p. 165). However, Barbieri operates with a very broad definition of code from the outset, which makes no ontological claims about the so-called ‘worlds’ it supposedly connects. Thus, in the context of this paper, it becomes prudent to ask whether Code Biology, in its general sense, can be developed through an interplay with Enactivism to acknowledge anti-representationalist aspects of cognition.

## 2 Autopoietic Enactivism

The ‘Enactive approach’ as formulated by Varela and colleagues has effectively evolved into what is now commonly referred to as Autopoietic Enactivism (cf. [14] – for some examples, see [15][16][17][18]). Inspired by Maturana and Varela’s [19] notion of autopoiesis, Autopoietic Enactivists take the autonomous agency of the individual cognizer as the basis for the evolution of multi-agent systems and all the way up to human culture and language [20] (p. 4). Indeed, as in the case of an autopoietic system, the autonomous agent is ‘operationally closed’. This means that the agent is essentially self-constituting with regards to its own identity whereby it enables the agent to differentiate itself over against the environment [20]. The autonomy of agents – which in the

minimal sense pertains to the individual cell – comprises the basis for other core enactivist concepts including adaptivity, agency, mentality, sociality and culture [20] (p. 4). In this connection, mentality refers to cognition that is irreducible to metabolic states but also relies on so-called “other-related concerns” such as social norms. Autopoietic Enactivism stresses so-called strong life-mind continuity meaning that “Mind is life-like, and life is mind-like” [15] (p. 385). Living agents are per definition cognizers – or, in autopoietic enactivist parlance: sense-making agents:

“Sense-making is tantamount to cognition, in the minimal sense of viable sensorimotor conduct. Such conduct is oriented toward and subject to signification and valence. Signification and valence do not pre-exist “out there,” but are enacted or constituted by the living being. Living entails sense-making, which equals cognition” [15] (p. 387).

Effectively, it is agents and their distinctive selves which give rise to their worlds. Sense-making is a radical notion which places emphasis on the constitutive relations brought forward by agents as they engage with their surroundings. Thus, on this view, cognition is inseparable from perception and action; or enacted perception (ibid.). So, although Froese and Di Paolo stress that emergent properties that arise on the basis of the sense-making of autonomous agents also have the potential to affect their own constitutive background [20] (p. 4), the core of cognitive phenomena (also in the sense of whatever precedes basic sense-making) are de facto traceable to autonomous agents and, hence, the minimal case of the autopoietic cell. On this view, meaning or ‘significance’ is not represented, rather it is dynamically enacted as an organism responds to its environment [11]. In this connection, it is worth noting how Code Biology seems to be able to inform Autopoietic Enactivism on two related fronts:

First, there is the basic insight that life precedes the autopoietic cell. Following Barbieri, Code Biology recognizes that the genetic codes in cells are traceable to a common ancestor (in the form of a ribonucleoprotein system). In other words, such codes exist prior to the evolution of cells where spontaneous proteins and genes prevailed [6] (p. 6). Yet, these lacked specificity in that ancestral systems did not reproduce in the autopoietic sense (and were not individuals) but, instead, gave rise to qualitatively different systems [21] (p. 297). As Barbieri puts it: “Autopoiesis, in other words, did not exist before the first cells, so it was not the mechanism that gave origin to them.” [6] (p. 7). Thus, rather than assuming that autopoiesis is intrinsic to life, it makes sense to embrace the view that what Barbieri calls *codepoiesis* precedes autopoiesis and, hence, that there is more to life than the operational closure of living entities. Indeed, the common ancestral system had the sole capacity of generating new codes. This situation changed with the origin of the genetic code which, on the one hand, fixed the rules so that “no other modification in the coding rules was accepted” while, on the other hand, kept a capacity for exploring new codes (ibid.). Bacteria lived for billions of years without becoming multicellular, functioning as individuals, or using vertical reproduction. Since they did rely on DNA, autopoiesis can be seen as having evolved from codepoiesis as a simplex way of limiting adaptivity. As Barbieri [21] summarizes, codepoiesis thus entails the dual processes of code generation and code conservation (p. 298). The view also allows for the fact that not all cells following the evolution of the genetic

code are autopoietic in the strict sense of the term (cf. *ibid.*). Luisi [22] points out that the same can be said about viruses for the simple reason that a virus neither produces its own protein coat nor its nucleic acids (p. 51). In other words, it is not autopoietic or self-reproducing.

Second, the Autopoietic Enactivist emphasis on the strong autonomy of individual sense-makers is far from unproblematic. In what follows, I summarize an enduring criticism [23][24][25][26]. The issue with strong autonomy is exemplified by De Jaegher and Di Paolo [27] who explain the progression from individual sense-making to participatory sense-making by means of a tacit shift in their explanatory locus: whereas individual sense-making is explained as being determined by intrinsic teleology and, hence, agent-internal values, participatory sense-making entails that the strong autonomy of agents is superseded by ‘the interaction’ in which the agents participate. Indeed, De Jaegher and Di Paolo recognize this when arguing that “not only must the process itself enjoy a temporary form of autonomy, but the autonomy of the individuals as interactors must also not be broken (even though the interaction may enhance or diminish the scope of individual autonomy)” [27] (p. 492).

Critically, this brings about an explanatory issue. For by presupposing that the interaction can take up autonomy in its own right, De Jaegher and Di Paolo tacitly acknowledge that there are circumstances where interactional outcomes do set aside (or: transcend) the strong autonomy of individual agents as the agents take on agent-external norms for guiding their behavior. But it remains unclear to what extent this is at all possible without at the same time violating the strong autonomy of agents that participate in the interaction and, hence, the principle of intrinsic teleology. As an explanatory principle, strong autonomy leaves no room for weak autonomy thus rendering it unclear how agents can operationalize agent-external values and norms (so-called ‘culturally prevalent behavioral norms’ – [27] p. 495) without violating Autopoietic Enactivism’s core claim that agents, per default, are strongly autonomous. Autonomy can be traced to the very core of the notion of ‘enact’ in the sense of ‘acting from within’ [21]. Another way of conceiving this problem is to see it as being related to how autonomy and heteronomy are both influential in an agent’s sense-making activities. Relatedly, some scholars such as Kirchhoff [28; 29] have criticized autopoietic theory for the fact that it offers internalist explanations, arguing that adaptivity – a crucial aspect of life-mind continuity – cannot be adequately explained unless one instead adopts an externalist explanation like the one linked to the so-called ‘Free Energy Principle’ [28] (p. 2363). Yet, as Allen and Friston [30] show, proponents of the Free Energy Principle assume that cognition relies on a degree of internalism and more specifically, prediction which ties with autopoiesis which, on their view, is not entirely internalist (as presented Kirchhoff) but nevertheless entails a degree of ‘extended’ autopoiesis which involves aspects of the world as well as those internal to the agent. For as they claim, the “causal machinery of the brain and its representations are enslaved within the brain-body-environment loop of autopoiesis” (p. 2477).

Although recognizing that fully developed cells indisputably come with autopoietic traits, Code Biology is not tied to a commitment to strong autonomy. Thus, it has shown to have no problems in recognizing the fact that cognition can be both shaped by extrinsic and intrinsic factors. For instance, as to the ontology of code, it is worth noting

that it is indeed not anchored in individual agents or organisms. Rather, it is ontologically unspecific in the sense that it is open to interpretation of what counts as ‘independent worlds’ and, further, what characterizes their differences as such. Such lack of specificity might not be a bad thing since it provides ample room for the development of Code Biology in the general sense. For instance, Andersen and Prinz have stressed how prosthetic device-usage showcases the fact that human agents are weakly autonomous and, hence, the fact that the heteronomy of social norms and values play a constitutive role to the successful integration of a prosthesis [26]. Specifically, they argue that the experience of being ‘whole’ which is a prerequisite for optimal performance in any skillful activity is secured only if the prosthetics wearer accommodates their sensorimotor contingencies to the embodied actions recognized by a community. In this connection, heteronomy is indispensable because “the agent would have to adapt to existing norms and rules regarding how particular movements should be executed. This is a prerequisite in order for the prosthesis to become fully integrated into the patient’s life. Thus, pointing, stirring, clapping, cheering, punching etc. are all actions that are defined by social practices or ‘culture’ in the sense that they are arbitrarily determined by certain social conventions” [26] (p. 16) On this view, qualitatively different codified relations enable the embodied agency of amputees to re-enter into social communities by, above all, accustoming themselves with their prosthesis to the extent that they are able to experientially transcend its presence. Such transcending allows the prosthesis to function in a smooth way in the sense that it becomes functionally equivalent to the body part it has replaced.

### 3 Sensorimotor Enactivism

As introduced by O’Regan and Noë, Sensorimotor Enactivism challenges neurocentrism and the idea that cortical maps can be the sole source for explaining visual perception [31] (p. 393) in the sense that visual experience arises as visual stimuli basically trigger brain-internal mechanism. Rather, proponents of this enactivist branch appeal to the laws of so-called sensorimotor contingencies or, as formulated by Ward and colleagues, ‘patterns of dependence obtaining between perception and exploratory activity’ [11] (p. 371). These contingencies comprise ‘various motor actions’ and can thus be used for distinguishing vision from other perceptual modalities [31] (p. 941). Indeed, the key differences between different senses can be traced to the structures of their related actions in the sense that, for example, eye-movements and blinks have an effect on visual perception but not on olfactory or auditory perception (cf. *ibid.*). Thus, perception is ultimately based in active, environment-exploration through law-governed contingencies which are relative to one or more of the five senses. In terms of codified activity, Sensorimotor Enactivism hereby brings an important insight to the fore by showing that visual experience is irreducible to neural codes and, thus, how the brain may or may not represent objects [31] (p. 942). Rather, they show that much pertains to the constitution of perceived objects and, more specifically, the contingencies by means of which they are perceived. The claim gives rise to the somewhat provocative thesis, at least in the context of neural-centric culture, that the neural codes used for

representing objects are in fact dependent on the motor actions relative to a given sense (cf. *ibid.*). Thus, on the view of Sensorimotor Enactivism, a sensory modality is “a mode of exploration mediated by distinctive sensorimotor contingencies” [31] (p. 943). Such an ensuring and differentiation of the basic perceptual qualities is insufficient for bringing about perceptual experience. It is also necessary to address the ‘awareness’ intrinsic to such experiences – and awareness which O’Regan and Noë trace to ‘the knowledge’ inherent in the sensorimotor contingencies [31] (p. 944). ‘Knowledge’ thus allows for the skillful execution of a perceptual modality and remains intrinsic to our experience of perceiving a something as a something. O’Regan and Noë explain:

“The experience of red, for example, arises when we know (though this is not propositional, but rather, practical knowledge) that, for example, if we move our eyes over a red region, there will occur changes typical of what happens when our non-homogeneously sampling retinas move over things whose color is red.” [31] (p. 963)

Yet, as Noë reveals elsewhere, an appeal to such knowledge is also used by proponents of Sensorimotor Enactivism to stress the continuity between basic perception and more sophisticated or ‘intellectual’ modes of cognition (e.g., propositional attitudes, planning etc.) [32] (p. 1). Such intellectual attitudes are traditionally deemed to be ‘representation-hungry’ [33] in the sense of being reliant on mental stand-ins (or: representations). As such, they are normally taken to be the hallmark of human intelligent cognition. In this connection, Noë recognizes that concrete concepts condition human basic perception. Yet, the downside of this move is that such conceptual knowledge conflates with sensorimotor contingencies thus making it difficult to distinguish the two but also to distinguish non-conceptual knowledge from its conceptual counterpart thus leading to an explanatory conundrum. This conundrum emerges from Noë’s paraphrasing of Heidegger’s point that “the things we encounter are always already familiar” in the sense that it is the basis for such familiarity to arise in the first place. Yet, we find no explanation of how such familiarity arises in the first place given that sensorimotor enactivists place decisive emphasis on prevalent sensorimotor contingencies and, hence, extant knowledge as the enabler of perception [32] (p. 3).

Although Sensorimotor Enactivism has been successful in exploring especially visual perception, it faces a well-known issue namely that it has a narrow focus on human perception in relation to the perceiving human agent and, hence, “largely ignores or downplays the other theoretical principles associated with Enactivism, such as the co-production of organism and environment, emphases on biodynamics and a commitment to life/mind continuity” [11] (p. 371). This resonates with Degenaar and O’Regan’s point that Sensorimotor Enactivism restricts its focus to perceptual consciousness [34]. It is especially in this regard that a Code Biology framework has the capacity for informing Sensorimotor Enactivism by revealing some of the complex codifying mechanisms involved in not just visual perception but virtually any kind of sense-making across the evolutionary board.

For instance, Cowley [35] argues in favor of extending the basic principles of the Organic Code-model proposed by Barbieri [7] to include the human domain and, more

specifically, the activity of human individuals. In a nutshell, the Organic Code-model describes the basic process wherein protein synthesis unfolds and, hence, how transfer-RNAs (with anchoring RNA) function as adaptors as they relate DNA to ribosomal RNAs through codified relations. Cowley's basic claim for an extension of the model is that the human body - and herewith what sensorimotor enactivists deem 'sensorimotor contingencies' - also functions in adaptor-like ways [35] (p. 1). Cowley formulates it thus:

“as adaptor-like, humans become code intermediaries who attune to perceived translations at an interface (in Tetris) or in deriving signals from script (in Morse). However, they also develop as apparatuses that can exert whole-body control (based on 'knowing' the rules or 'how to play' the game). Since these powers link skills with expertise, they are cognitive. Even sending signals without understanding (as in operating in Morse) relies on acting in ways that (inadvertently) prevent and reduce errors. All being well, the system's lee-way enables a person to self-fabricate adaptor-like ways of effective acting.” [35] (p. 3)

Cowley contrasts his take on codes with the 'received view of codes' which is prevalent in, for instance, traditional linguistics ('fixed code telementationism' cf. [36]) and representationalism in the cognitive sciences and philosophy of mind and that treats functionality as fundamentally rule-governed and, hence, sense-making processes as passively triggered by means of external stimuli thus eliciting basic linear 'Sense (input) → Plan (compute) → Action (output)'-models. As Barandiaran argues, such models are the negative target of enactivist research [12] (p. 410). Thus, the received view places emphasis on how adaptors use codes irreducible to the rules of the codes themselves thus granting flexibility and unpredictability in code-based processes. On Barbieri's view, however, adaptors bring forth the 'coding rules' [7] (p. 43). They comprise the rules that “establish a mapping between two independent worlds” and, hence, reveal “the presence of a code” [7] (p. 35). Codemakers, on the other hand, ensure the making of the code itself as a kind of artifact-making [7] (p. 12) and, hence, are the agents of coding processes [7] (p. 26):

“Signs, meanings and conventions, however, do not come into existence of their own. There is always an 'agent' that produces them, and that agent can be referred to as a codemaker because it is always the making of a code that gives origin to semiosis” [7] (p. 30)

In a crucial addition, Cowley shows how human embodied agents can function both as adaptors and codemakers meaning that adaptors are not subdued or strictly conditioned by codemakers as suggested by Barbieri [35].

Although the relation between the two has yet to be systematically clarified in the realms beyond organic codes, it is evident from Cowley's work that, at least in terms of human meaning-making activities, the wide-view of cognition entails that adaptors



and codemakers are basically juxtaposed. On the one hand, the agent functions as an adaptor in processes defined by external rules (e.g., social rules and conventions). On the other hand, the agent skillfully enacts their understanding of such rules in relation to what they ascribe status to as 'a sign' thus effectively bringing about not just semiosis but the effectuation of the code (as it comes to be realized in the semiotic nexus of, on the one hand, a received or learned code (e.g., mastering of social conventions or 'adding meaning to information' cf. [8] (p. 95)) and, on the other, the enactment of a relation which builds on the former but is irreducible to it in the sense that it brings about unique experience or meaning thus doing more than simply adding meaning to information. With Cowley's contribution emphasis falls on how agents bring about novelties based on codified processes thus exhibiting creative and adaptive 'self-fabrication' [35] (p. 2).

But Code Biology-based insights can also be used to show the wideness of cognition (to paraphrase Wilson [37]) thus testifying to how it extends beyond the situated individual agent (Cowley's focus) by including populations. Indeed, we must keep in mind that codes also function as 'community rules' [8] (p. 95). For instance, in evoking appeal to soundscapes, understood as 'a vocal milieu', Farina shows how 'semiotic mechanisms' play a decisive role the sense-making of soniferous species [34]. Emphasis is placed on the fact that the capacities for producing and receiving meaningful sounds are ultimately tied to an animal's genome in the sense that 'each individual [belonging to different species] has the capacity to extract information from a series of acoustic cues' [38] (p. 150). Yet, Farina also recognizes the vital role played by complex adaptive processes and, specifically, the role of 'cultural transmission' within species communities [38] (p. 148) as well as more general soundscape traits. Farina shows that sensorimotor engagements are irreducible to individuals in that it spreads across populations and the communities they have formed (at the so-called 'acoustic community level') [38] (p. 149). So, although species are said to perceive their environment by means of 'function-specific cognitive templates' [38] (p. 151) based on their needs, it is far from all perceptual processes that are driven by internal mechanisms. While some emphasis is placed on biological codes and autopoietic processes in individual organisms, Farina also stresses the need for considering other ecological codes. In fact, ecological codes including ecoacoustic ones are vital for ensuring organism-environment feedback loops: "[T]he biological codes initiate a process of intra- and interspecific communication, and the ecological codes extend such communication mechanisms to the environment, creating a flow of continuous semiotic feedback between organisms and their habitats" [38] (p. 150).

The presence of such loops is the basic requirement for affecting the genome and, hence, in allowing for population-level patterns to emerge over time or as Farina formulates it: "complex codes operate within specific evolutionary forces that shape the genome and require time to spread and establish across populations" (ibid.). Ecoacoustic events are irreducible what unfolds on the ecoacoustic community level as they are also relative to the overall soundscape which includes ecological contingencies and human behavior. Crucially, and in parallel to the sensorimotor enactivist focus on the conceptual meanings involved in human perception, the theory of soundscapes showcases how the categorical aspects of conceptual perception are non-conceptually

implied in ecoacoustic codes [38] (p. 150) and genetically conditioned in population dynamics.

## 4 Radical Enactivism

Radical Enactivism or, REC, comprises a radicalized alternative to both Sensorimotor Enactivism and Autopoietic Enactivism. Hutto criticizes how sensorimotor enactivists tend to fall into a cognitivist trap when making claims concerning the brain's role in perception by stressing its capacity to 'judge', 'assume' and 'conclude' [39] (p. 392). Thus, as Hutto states, it very much looks as if perception is taken to involve propositional attitudes and, hence, mental content. So, although O'Regan and Noë are committed to a non-cognitivist take on cognition, it is nevertheless the case that they tend to conflate practical, non-represented knowledge with its propositional, represented counterpart (cf. *ibid.*). With regards to Autopoietic Enactivism, REC pushes a similar negative claim although explicitly recognizing that proponents of this particular strand differ from those sympathetic to the sensorimotor branch in that they seek to "make a complete break with cognitivism and representationalism" [13] (p. 33). REC's criticism of Autopoietic Enactivism predominantly relates to the use of metaphors such as 'production' or 'consumption' when proponents of the latter attempt to explain how meaning in sense-making processes is relationally constituted in the coupling of agents and their environment [13] (p. 35). Effectively, this reflects that there is not a decisive move away from cognitivist parlance. Moreover, Hutto and Myin (2013) target the fact that supporters of Autopoietic Enactivism use the same general notions (e.g., 'cognition', 'understanding', 'interpretation') across the board and thus exhibit a "quite liberal understanding of the nature of cognition" (*ibid.*). In this connection, they argue, it is important to bear in mind that:

"The simplest life forms are capable of an intentionally directed responding of a kind that when suitably augmented provides a necessary platform for cognition, interpretation, understanding, sense-making, and emoting; however, their activities do not, in and of themselves, qualify as these forms of mentality." [13] (p. 36)

In effect, on a REC-view, the use of notion such as 'understanding', 'sense-making', 'interpretation' fails to bring clarity to basic modes of cognition because they denote phenomena which are generally not characteristic of basic mentality. As a means for securing REC's radicality, Hutto and Myin express a commitment to the so-called Radical Embodiment Thesis introduced by Chemero [40]. In so doing, they push the view that cognitive behavior which is normally explained by means of computationalist and representationalist models can also simply be explored by means of 'dynamical' explanations (i.e., explanations coming from dynamical systems theory) [13] (p. 2). For as Varela and colleagues [10] also stressed, far from all cognition involves content [13] (p. 5). As a means for countering the shortcoming of Autopoietic Enactivism, REC evokes a distinction between basic forms of cognition and more sophisticated kinds pertaining to humans and which involve 'judging', 'understanding' etc. The difference

between the two is ultimately traceable to the fact that they involve two qualitatively different kinds of information: Information-as-covariance and information-as-content [13] (p. 67). With this distinction in place, it becomes possible for REC to acknowledge that more sophisticated, content-involving kinds of cognition differ in kind from their basic counterparts precisely because they involve mental content whereas basic modes involve organic responses which neither “create, carry or consume meanings” [13] (p. 34). Thus, so-called ‘basic minds’ exploit covariance relations while scaffolded cognition pertaining to certain human-specific phenomena such as ‘propositional attitudes’, ‘language’ and ‘careful planning’ involve mental content [13] (p. xviii, 40, 65).

Basic minds “are fundamentally, constitutively already world-involving” [13] (p. 137) meaning that they are not internal to the cognizer’s brain but instead constituted through “concrete patterns of environmental situated organismic activity, nothing more or less” [13] (p. 11). As such, these minds do not exploit ‘messages’ nor rely on information that is communicated through encoding and decoding sequences [41] (p. 31). Basic minds are exemplified by certain developments in behavioral robotics including, most prominently, the so-called Creatures developed by Rodney Brooks at MIT in the 1980s [13] (p. 41). Brooks pioneered first-generation behavior-based robots by showing that it is possible to design AI-intelligent systems which do not need a description or plan of their environments in order to engage with it nor do they need a centralized representation system. Following Brooks, the intelligence of these creatures was precisely non-representationalist in the sense that they worked on the basis of complex interrelations:

“Just as there is no central representation there is not even a central system. Each activity producing layer connects perception to action directly. It is only the observer of the Creature who imputes a central representation or central control. The Creature itself has none; it is a collection of competing behaviors. Out of the local chaos of their interactions there emerges, in the eye of an observer, a coherent pattern of behavior.” [42] (pp. 148-149)

With regards to covariant information, however, REC is still in need of clarifying the nature of such informational relations. For instance, with their formalized definition, Hutto and Myin effectively exemplify information-as-covariance in relation to a non-cognitive phenomenon: the rings of a tree’s trunk which covary with the tree’s age. In this context, covariance is defined as follows: “s’s being F ‘carries information about’ t’s being H Iff the occurrence of these states of affairs covary lawfully, or reliably enough” [13] (p. 66). But with regards to cognitive systems in the context of REC, there is no specific delineation of where and under what conditions such states of affairs exist. For instance, are both kinds of states of affairs extrinsic to the cognizer or might one or perhaps even both of them be internal (i.e., neural or organic) (for examples of such, see [43] (p. 67); [44] (p. 653)). Indeed, we do find evidence that Hutto and Myin allow the latter to be case such as in the following quote:

“The number of a tree’s rings can covary with the age of the tree; however, this doesn’t entail that the first state of affairs says or conveys anything true about the second, or

vice versa. The same goes for states that happen to be inside agents and which reliably correspond with external states of affairs— these too, in and of themselves, don't "say" or "mean" anything just in virtue of instantiating covariance relations." [13] (p. 67).

Relatedly, as Hutto and Myin clarify, an appeal to covariance makes it possible to clarify the "correspondences to which the brain is sensitive" [41] (p. 238).

In this connection, the question is obviously whether we can consider basic cognition as involving a myriad of covariance relations in complex organisms? Here, a Code Biology framework can bring significant insights to the fore.

In their paper on signal-transduction codes, Marijuán and colleagues explore basic cellular communication in relation to *E. coli* K-12 [45]— which, interestingly, has also been a paradigm case for Autopoietic Enactivism [46]. Signal transduction is the process whereby the cell's membrane receptors transform "signals from the environment (first messengers) into internal signals (second messengers)" thus exhibiting how the cell adjusts or responds to changes in its environment [6] (p. 4). Initially, Marijuán and colleagues stress that in prokaryotic signaling processes, the molecular apparatuses involved can be either simple or complex. In the simple cases, we find the so-called one component systems which involve a "direct fusion of an input domain with an output domain, both put together in a single protein molecule" [45] (p. 30). Such simple systems entail that a signal molecule is immediately recognized by a cellular receptor which binds the external signal molecules [47] (p. 13). The cellular receptor acts as an adaptor: it mediates in ways that enable the messenger to function while allowing the cell to show sensitivity towards aspects of its environment (i.e., sensed external stimuli). Considered in REC-terms, we may say that such adaptors ensure the reliability in covariance processes in the sense of enabling particular signaling pathways whereby the cell can exhibit sensitivity towards the environment (in the specific form of sensed external stimuli) through the subsequent triggering of one or more functionally adequate intracellular responses. More specifically, given their sensitivity to the presence of vitamins, antioxidants etc. such basic component systems are vital to the cell's survival [45] (p. 30). In living organisms, covariance depends on multi-component systems that perform as adaptors. While these systems involve greater cell-internal complexity, they entail the mediacy which is the hallmark of the adaptor by ensuring the workings of intermediate mechanisms such as receptors (e.g., histidine kinases) and response regulators prior to the triggering of intracellular responses. Here, on the overall or general level of the cell it is a matter of which environmental stimuli effect (or covary with) the transcription of genes in the cell or as Barbieri puts it:

"The membrane receptors that implement signal transduction, furthermore, are molecular adaptors that create links between first and second messengers just as the transfer-RNAs create links between codons and amino acids." [6] (p. 4)

On the specific level, however, we see that different covariance relations function in conjunction in the sense that there is 1) the covariance between the external stimuli and the response sensor's (i.e., histidine kinase) transferring of a phosphoryl group and, following this, 2) a response regulator which in its activation of a transcription factor

ensures covariance between the transferred phosphoryl group and the subsequent gene transcription [45] (p. 30). Yet, considering the fact that *E. coli* K-12 cells themselves are vastly complex in the sense of involving a myriad of more than one hundred of such simple and complex component systems [48], it becomes difficult, if not impossible, to delimit the singleness of the ‘basic mind’ on the basis of the covariant relations which constitute it. In fact, as Hofmeyr points out, given the interactional complexity (or, following Brooks, chaos) of *E. coli* K-12 cells, “the question of what the actual codes are becomes very difficult to answer” [47] (p. 13). Yet, what Code Biology here has to offer is a window into the complex mechanisms that enable adaptors to contribute to cellular responses which allow the cell to function as (or like) a ‘basic mind.’

## **5 Towards a synergistic future?**

One advantage for Code Biology is that it basically resonates with the enactivist assumption that agents bring forth aspects of their own environments. Given the fundamental arbitrariness of codes and, hence, the fact that life is different from pure chemical necessities and the spontaneity of non-living processes, code-making (and, hence, life as such) is seen as a constructive process: as artifact-making [9] (p. 6). In this connection, it is worth mentioning that a residue of what Cowley [35] terms the ‘received view’ nevertheless remains in Code Biology. For when it comes to information, there is a clear tendency to assume that codes involve the transfer of informational content which, effectively, is taken to be synonymous with Shannon-style information [13]. This links with the fact that Code Biology in the general sense has emerged out of semantic biology [8] and, thus, the view that information transfer can be considered as content-vehicle relations which unfold through linear exchanges (or transfers) in input-output systems. Whereas this could be emphasized as a decisive weakness in Code Biology that might bring it at odds with REC’s take on basic mentality as being free of informational content, one could also see it as a positive aspect. If one decides to venture this route, two factors should be kept in mind: First, that the definition of a code is wide and not tied to a specific ontology which is underlined by the vagueness or generality pertaining to the so-called independent worlds which a given code is assumed to connect. Second, that in recent work, Paredes and colleagues have stressed the relevance of Bateson-style information to Code Biology and, hence, the fact that information can basically be described as ‘a difference which makes a difference’ [48]. The importance of this move can hardly be overstated in that it not only opens up for a radically different take on informational relations which does not presuppose Claude E. Shannon’s dualist ontology but also that it gives evidence of the fact that a Code Biology-framework can be compatible with different (or even: potentially contrasting) notions of information. In an enactivist context, and especially considered in relation to REC, we find that Code Biology might be the framework needed for not just overcoming REC’s covariance-content distinction but also for unpacking the nature of qualitatively different informational relations more generally (cf. the example of the different levels of covariance in signal-transduction). Yet, one could argue that an appeal to ‘information’ is problematic in the context of Autopoietic Enactivism considering that

Maturana and Varela explicitly contrast autopoiesis to notions such as ‘coding’, ‘message’, and ‘information’ [19] (p. 90). Yet, as remarked elsewhere [49], Maturana and Varela are here criticizing information as it was conceived by Shannon. Effectively, their criticism merely pertains to non-relationalist notions of information thus leaving it open for alternative conceptions of information to align with principles of autopoiesis.

While the generality of the ontology of codes - understood as the ‘mapping between the objects of two independent worlds that is implemented by the objects of a third world called adaptors’ - has shown to be quite useful due to its interpretative flexibility which opens up a space for interdisciplinary work, we also find that its very flexibility might become Code Biology’s Achilles’ heel. The reason for this is that it opens up for distinguishing between, on the one hand, recurrent codes and, on the other, relations which can be described as codified but which nevertheless might be so special, arbitrary or rare that they have no general constitutive relevance to biofunctions, neurofunctions or culture-related phenomena. This means that Code Biology has both an explanatory and a descriptive potential. Yet, for the sake of making it appealing in an enactivist context, it is the explanatory potential of Code Biology that would have to be developed further. In this connection, the co-development with enactivist positions can be potentially useful since the latter offer notions for systematically expanding code biological insights in relation to cognitive phenomena (e.g., ‘teleology’, ‘basic minds’, ‘sense making’, ‘scaffolded cognition’, ‘sensorimotor contingencies’). Enactivist terminology can function as a theoretical anchoring point for developing Code Biology’s theoretical framework which, so far, includes general notions such as ‘codemakers’, ‘worlds’, ‘adaptors’, ‘meaning’ etc. which could benefit from being made more specific in the general realm (i.e., beyond organic coding) including in the context of human-specific phenomena.

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