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RESEARCH

The Biosynthesis of Proteins for Nano Engines as a Normative Process

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Abstract

In this article two questions are discussed with regard to semiosis in protein biosynthesis for nano engines. (1) What kind of semiosis is involved in the construction of these proteins? and (2) How can we explain the semiotic process observed? With regard to the first issue we draw attention to comparisons between semiosis in protein biosynthesis and human natural language. The notion of *normativity* appears to be of great importance for both. A comparison also demonstrates differences. Nevertheless, because of the normative symbolic information processing in it, we suggest to employ the term *symbolic reference* (employed in linguistics as a distinguishing feature of human language) to indicate the semiotic processes in protein biosynthesis. With regard to explaining semiosis in protein synthesis we compare different approaches. We conclude that a *Kantian approach* should be preferred. In such an approach strengths of the mechanistic and organicist approaches can be combined, and the observed symbolic information processing acknowledged.

Keywords Normativity · Symbolic reference · Kantian approach · Protein synthesis · Nano engines

Introduction

It has been argued that some fundamental steps of intracellular self-organization has been realized through semiosis (Beekman & Jochemsen, 2023). Disequilibrium conversion is realized through employing information from coding DNA specifying proteins which are part of nano engines. Hence, some kind of information process is at the core of living entities. However, the argument in the aforementioned paper leaves two important questions unanswered, namely: (1) What kind of semiosis is

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involved in the construction of these proteins, and (2) how can we explain the semiotic process observed? With regard to the first issue we draw attention to comparisons of semiosis in protein synthesis and human language (Semiosis in the Biosynthesis of Proteins section). In particular the notion of *normativity* is discussed. With regard to the second issue we compare different approaches (How to Explain the Observed Semiosis in Protein Synthesis? section).

Semiosis in the Biosynthesis of Proteins

Our analysis of the phenomenon of semiosis in protein synthesis in living cells will begin, after some introductory remarks, with a discussion of the concept of *symbolic reference* as shaped by Deacon. In the next section (What is the Character of the Semiosis in the Biosynthesis of Proteins? section) we discuss the question what kind of semiosis is involved in the biosynthesis of proteins. We mainly limit ourselves to the first part of this synthesis, namely the synthesis of polypeptides. This will ends up in discussing biological normativity (Biological Normativity section) and some conclusions (Conclusion section) regarding the first research question of this paper.

Semiosis, Especially with a View on Human Language

Peirce defines a *representamen* (actually called a *sign*) as something that stands for something else (its *object*) in such a way that it ends up producing a third relational entity (an *interpretant*), which is the effect a sign produces on an interpreting system (an *interpreter*). Peirce divides signs by three trichotomies. According to the trichotomy that is most employed in biosemiotics, a sign ("representamen")—because of its form of reference—may be termed an *icon*, an *index*, or a *symbol*. Peirce (1867) presents this division in his well-known paper *On a new list of categories* and dwells on the concept of symbol in *New elements* (Peirce, 1904). Peirce (1904, p. 313) argues that "every sufficiently complete symbol governs things"—"and that symbols alone do this"—because the symbol is a law.

Pierce "focused on representation as process, not as a static relationship, and recognized these sign types as hierarchical levels of representation, not as opposed categorical alternatives," Terrence Deacon remarks (1997, p. 467) in his ground-breaking monograph *The symbolic species: The co-evolution of language and the brain*. Deacon draws on Peirce's just mentioned categories of referential associations (icon, index and symbol). As Deacon (2018, p. 67) notices, "iconic and indexical forms of communication are ubiquitous in the animal world as well as in human communication." *Symbolic* reference, however, is a distinguishing feature of *human* communication, especially of human *language* (i.e., verbal communication) (Deacon, 1997). Deacon hypothesizes that "although forms of iconic and indexical communication were present in many species (…) only humans built on these to communicate symbolically" (Stjernfelt, Schilhab, & Deacon, 2012, p. 2). Linguistic symbolic reference is not a simple mapping relation (Deacon, 2018). A linguistic convention is much more than an arbitrary mapping—i.e., a code—between a *signifier* (i.e., a sound image) and a *signified* (i.e., a concept). Isolated linguistic terms have to be embedded in *a combinatorial construction*—i.e., in a grammatical relationship in order to obtain *symbolic reference* (Deacon, 2018). In other words "language appears with syntax" (Kull, 2003, p. 15). The notion of *normativity* is pivotal to the methodology of linguistics. In human language and linguistics correctness and rationality are important types of norms (Mäkilähde et al., 2019). Humans acquire the *interpretation* of linguistic symbolic reference by learning. Unmistakably the relation between language, cognition, and brain is complex (cf. Deacon, 1997). We realize that Stjernfelt (2007) questions aspects of Deacon's analysis (see e.g. Stjernfelt et al., 2012; Bennett, 2021). Yet, in this article we maintain the term *symbolic reference*, as it is substantively filled by Deacon. We do not accept Deacon's *formal* thesis that symbolic reference is *a distinguishing feature of human communication*, which would rule out to find it elsewhere.

What is the Character of the Semiosis in the Biosynthesis of Proteins?

It will be enlightening here first pay attention to two early (i.e., in the 1970s) attempts to compare human language and molecular genetics before attempting to answer the above question.

1. The indissoluble dialectic unity of code (langue) and message (parole) is an axiom of Saussurian linguistics. Accordingly, the structural linguist Jakobson (1970) compares the subunits of the genetic code (nucleotides) directly with phonemes in human natural language, and codons (triplets) with words. The dictionary of the genetic code encompasses 64 distinct words, whereof 61 carry an individual meaning (i.e., an amino acid), while three are used merely to signal the end of a genetic message. Jakobson titles the translation of the nucleic message into the peptide language the basic phenomenon of molecular genetics and concludes to much similarity in structure with human natural language. We will now pay attention to a contrasting view.
2. The linguist Shanon (1978), employing concepts of Chomsky's theory of generative grammar (Chomsky, 1965), compares the genetic code and human language. He concludes that they are fundamentally different. Similarity between the two systems—e.g., both demonstrate arbitrary combination of 'sign' and 'signified'—are misleading. We will mention the main arguments he raises for this view. In linguistics the distinction *competence* (grammar; i.e., a kind of *tacit knowledge*) and *performance* (production and comprehension of actual sentences) is important. This distinction is not at issue in genetics. Further, "in general, genetic processing is algorithmic, but linguistic processing is heuristic" (p. 407). In contrast to natural languages, the genetic code does not need a genetic syntax, thanks to its isomorphism between form and meaning, its linearity, and its mechanistic manifestation. Finally, the genetic code is context-free.

Against the background of these arguments we will now discuss the question: What kind of sign process is involved in the cellular construction of proteins? It is not iconic reference, for the codons do not represent the amino acids by similarity or analogy. Neither is it indexical reference, for the action of the codons does not depend upon association by contiguity. Employing Barbieri (2015b), we may describe—RNA transcripts of—codons and amino acids, as two independent worlds, which are connected by transfer-RNAs functioning as adaptors. The mapping between codon and amino acid is by a nearly universal, context independent (i.e., fixed) code, named the genetic code. The signs involved are called *symbols*, indicating that they are associated with an object by an entirely arbitrary link (Barbieri, 2015b; cf. Pattee, 1972; Keller, 2009; Emmeche, 2011), not by similarity or a physical link. But how does cellular protein synthesis relate to *symbolic reference*, which is much more than a simple mapping relation (Semiosis, Especially with a View on Human Language section)? Arbitrary relations alone do not make a semiotic code (Lacková et al., 2017). The biosynthesis is not realised by mental or psychic interpretation, but by a natural, non-psychic receptive system. In the processing of coding DNA, which has fixed semantics, we do not observe the "semantic openness characteristic of information exchange in human communication" as discussed by Emmeche and Hoffmeyer (1991). Linguistic symbols are conventional signs that are additionally conventionally mediated in the way they represent (Deacon, 2012). It seems that semiosis in protein biosynthesis does not meet the criteria for *symbolic reference*. But we should not jump to conclusions. The semiosis in protein synthesis is a triadic relation between a DNA coding region (a sequence, i.e., a linear pattern, of *signs*), a living cell (a *receptive system*), and a polypeptide (an *object*). Let us compare this with symbolic reference in linguistics.

The information in DNA is mediated by the cell, not by convention, but by a system, the receptive system, which makes this mediation physically necessary. However, this system should not be underestimated! The living cell can only be a receptive system due to the cellular organization, including the translation system of the ribosomes. This receptive system can be perceived as a form of "tacit knowledge," a term not coincidentally employed both in biosemiotics (Hoffmeyer & Emmeche, 1991) and in linguistics (Chomsky, 1965). Regarding morphogenesis Hoffmeyer and Emmeche write (p. 137) that "the 'tacit knowledge' of the cellular apparatus is not itself a part of the DNA-redescription. This, in fact, parallels the problem of using technical knowledge for the construction of actual machinery." Analogically it may be said that the *tacit knowledge* of the cell as receptive system is necessary for the functioning of coding DNA in polypeptide synthesis. If we compare protein synthesis and human natural language, there is a remarkable similarity. Küppers (1990, p. 13)—a biophysicist and philosopher—points out that "a nucleic acid molecule does not necessarily carry genetic information: as in a language, this depends upon the sequence of its monomers." We should interpret this relational. The pattern of nucleotides only carries protein-coding information in the context of a receptive system capable to employ the information. In protein synthesis *indexical reference* is employed (the genetic code), to 'read' the more than indexical 'technical' information in coding DNA. These observations justify to also speak about *symbolic reference* in protein synthesis, although our use of this term does not correspond exactly with Deacon's (1997, p. 41) definition of symbolic reference as "the way words refer to things."

Differences are the restricted syntax of the genetic code and the algorithmic processing of the coding sequences (cf. Shanon, 1978). On a deeper level, however, accordance with Deacon's view exists, as he indicates that "symbolic reference depends upon indexical reference" (Deacon, 1997, p. 74), being much more than a simple mapping relation (Deacon, 2018). It is true that the genetic code as such is a quite simple mapping relation (as Jakobson and Shanon both acknowledge). Merely the intricate issue of coding DNA referring to complex parts of functional objects, justifies the term symbolic reference. The observation that in living cells DNA sequences give rise to very specific contextually functional proteins—admittedly, after some modifications—is an utmost amazing phenomenon in protein synthesis. It is the *tacit knowledge* of the cell, which makes this possible (which Jakobson and Shanon both disregard). This is a decisive argument to call the cell not only a receptive system, but also an *interpretive system*. This system is non-mental and non-psychological (cf. Lacková & Faltýnek, 2021). It should be noted that the proteins of this system in their turn are encoded in the DNA and their own synthesis requires a form of an interpretive system. A main difference between symbolic reference in protein biosynthesis and human natural language appears in the lack of a learning process in protein biosynthesis (cf. Deacon, 1997).

Semantic openness, which is not observed in the processing of coding DNA, might be found in regulative DNA, epigenetics, post-translational modifications, protein folding, gene transfer, and some processes of mutation and selection. Semiotic and linguistic approaches should be practiced to clarify this. In her discussion of the concept of *participative opposition* in the context of the relation between genotype and phenotype, Lacková (2018, 2020) observes that there are quite a few processes between them that justifies to consider their relation as participative opposition. We agree. Furthermore, we consider all the above mentioned processes between genotype and phenotype as part of the interpretive system of the cell.

In some sense semiosis in protein biosynthesis has characteristics not found in human language. Human conscious and unconscious linguistic processes generate concepts (or ideas), whereas in protein synthesis corporeal products are formed according to normative precepts. This brings us to an important similarity of linguistics and molecular genetics, namely the centrality of the concepts *correctness* and *rationality*. Specific far from equilibrium states in cells (see How to Explain the Observed Semiosis in Protein Synthesis? section), indispensable for biological life, depend on macromolecular complexes (protein or protein-RNA complexes) to form the right nano engines (Beekman & Jochemsen, 2023; cf. Branscomb et al., 2017). The two mentioned concepts require not only the genetic code, but also proper information in the DNA coding regions. This means that "eusemiosis", i.e., "the advanced kind of semiosis" (Sharov & Vehkavaara, 2015, p. 123) must have been part of living cells from the origin of life (pace Sharov & Vehkavaara, 2015). Qua correctness and rationality this information is comparable to conventional signs of distinguished quality. Normative concepts as correctness and rationality, which are pivotal in language and linguistics, appear central in biology too. We will discuss normativity in biology in the next section.

Biological Normativity

In introducing the concept of natural purpose, Immanuel Kant (1724–1804) called attention to the particularity of living entities. For discussing Kant's concept of natural purpose we draw on the work of Steigerwald (2006). Next to the concepts of *nature* (Kant, 1781) and *purpose* (Kant, 1788), Kant characterized the concept of *natural purpose* (Kant, 1790). The purposiveness Kant attributes to organisms is (primarily) *internal* purposiveness: organisms *are* natural *ends* in themselves. As Steigerwald (p. 712) summarizes, the concept of natural purpose "is necessary for the *identification* of organisms as [1] organized and [2] self-organizing, and as subject to [3] unique norms and [4] causal relations between parts and whole" (numbers and accentuation added). We elaborate on these points. [Ad 1:] Kant deemed the question of the ultimate relationship between nature and purposiveness "as ultimately irresolvable for human cognition" (p. 713). [Ad 2:] Nevertheless, the organism is "cognized as a natural product" (p. 717). [Ad 3:] The purposeful regularity manifested by organisms conforms to "normative laws[1], standards or constraints," Steigerwald indicates (Steigerwald, 2006, p. 726; cf. Ginsborg, 2001). [Ad 4:] "Each part exists not only as a result of and for the sake of all the rest and the whole, but also reciprocally produces the other parts and the whole, so that the organism is thus *'both cause and effect of itself'* " (2006, p. 717). We agree that these four notions articulate peculiar characteristics of animate entities.

But this raises the question, what does it mean that *the purposeful regularity manifested by organisms conforms to normative laws, standards or constraints*? Living entities with their typical features are both products of nature and contingent with regard to causal-mechanical laws. Ginsborg, while studying the issue of the normativity of nature in reflection on Kant's (1790) *Critique of Judgement* (see e.g. Ginsborg, 2015), points out (Ginsborg, 2014) that the function of a trait or entity is what it *should*, or *ought* to 'do'. It should serve the life of the entity concerned. Ginsborg (2006) argues how, according to Kant, *normative regularity* may be ascribed to organisms. We call this *biological regularity*. The normative concepts correctness and rationality appear of central importance in the biological regularity observed in protein synthesis—which is 'steered' by symbolic information processing. Of course, these expositions do not resolve current discussion on functionality (see e.g. Ratti & Germain, 2022), but they offer important insight in the relation between mechanical causality and biology: animate entities possess chemically atypical features. Features which have to be studied from both physical and semiotic perspective.

Conclusion

Semiosis in cellular protein synthesis has many features in common with human language. Biological regularity in protein biosynthesis appears dependent on *normative symbolic information processing*. This justifies to call it *symbolic reference*. In

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[1] Kant does not call such "practical rules" *(praktische Regeln)* "laws" *(Gesetze)*, but "only precepts" *(nur Vorschriften)* (Kant, 1790, p. 172).

living entities this information is embodied in coding DNA embedded in a receptive system. The internal purposeful employing of this information by living cells justifies to call this system *interpretive*. *Biological symbolic reference* in coding DNA lacks the semantic openness of human communication. Unlike human language—which is producing (mental) concepts—coding DNA is an integral part of a semiotic system leading to the production of specific material (physical) entities.

How to Explain the Observed Semiosis in Protein Synthesis?

Self-Organization Through Semiosis

Self-organization as a result of physical-chemical interactions between (macro-) molecules has been noticed both in inanimate nature, e.g. whirlpools and vortices, and in animate nature, e.g. membrane systems formation. However, self-organisation through semiosis differs from such a "dynamic self-organization arising out of statistical interactions" (Moss 2003, p. 60). Such self-organisation through semiosis depends on symbolic information in coding DNA. The question we have to answer in this section (How to Explain the Observed Semiosis in Protein Synthesis? section) concerns a scientific understanding of the origination of this information.

A pivotal preliminary question is, whether living cells could exist without specific far from equilibrium states. We concur with Branscomb et al. (2017, p. 43) when they are arguing that "living systems are inherently maintained in highly specific, dynamic, very far from equilibrium states; without which they would have neither structure nor coherent activity." They call this "the defining thermodynamic distinction between inanimate and animate organizations of matter." We will discuss two approaches of the issue of the rise of semiosis in polypeptide synthesis, namely a mechanistic (Mechanistic Approach section) and an organicist one (Organicist Approach section). Subsequently, we will discuss a Kantian approach (Kantian Approach section) and draw a conclusion (Conclusion section).

Mechanistic Approach

Within the common mechanistic approach in biology the view reigns that molecular semiosis has come into existence by the rise of a coding process. Information in living cells must have arisen by evolution of macromolecules. In this view, the origination of the genetic code is the *explanandum*. Some important theories in this context are the *stereochemical theory* and the *coevolution theory*. The stereochemical theory (Gamow, 1954) states that the physical-chemical properties of amino acids were crucial in organizing the genetic code, whereas the coevolution theory (Wong, 1975) states that the biosynthetic relationships between amino acids determined the origination of the genetic code. Both theories, however, do not explain the arbitrariness in the connection between a codon and an amino acid. Recently a new scenario for code evolution has been suggested (Koonin, 2017) involving a *renewed stereochemical model* enabling arbitrariness in the relation between codons and amino acids—viz. as a 'frozen accident' (cf. Crick, 1968). A putative primordial stereochemical code should have evolved by expansion. Thereafter the standard code would have originated as a frozen accident. We are interested in empirical evidence to support this hypothesis.

The way in which arbitrariness in the mapping between codon and amino acid originated, was explicitly discussed by Barbieri (2015a). After a phase with merely "statistical"—i.e. stochastic—proteins, biological specificity (the ability of producing specific proteins) came into existence by ambiguity reduction, a mechanism that had a 'biological logic.' He named this the *ribosome-oriented model*. This model describes a mechanism that accounts for a steady reduction of ambiguity in the evolution of the genetic code. This process ended with the origin of biological specificity, the very hallmark of life as we know it. The rules of the genetic code are *biologically generated constraints*. In an extended version of this model—the *ambiguity-reduction theory* (Barbieri, 2019) —Barbieri presents ambiguity reduction as a general mechanism in the evolution of biological codes.

Barbieri views semiosis as coming into existence by molecular mechanisms in a prebiotic evolutionary process. He views life as artefact making by copying and coding (Barbieri, 2015b). The first major transition in the evolution of life was the origination of bond-makers and copy-makers, he poses. Afterward the genesis of the genetic code, the signal transduction codes, and several other codes, represent major steps in macroevolution. Barbieri defines *information* and *meaning* in empirical scientific terms (Barbieri, 2016). He defines *organic information* as the specific sequence produced by a copying process, and *organic meaning* as an entity which is related to another entity by a code. Organic meaning is present whenever the information of a sequence is translated by a process of decoding. According to Barbieri (2015a), the rules of the genetic code are *biologically generated*. However, his definitions of *information* and *meaning* fall short with regard to biological normativity. They give attention to correctness, but ignore the norm of rationality in the sense of functionality for the cell. Therefore we rename them *relative information* and *relative meaning*. It misses a relation to functionality (cf. Biological Normativity section). The key question is even more difficult than the issue addressed in Barbieri's—otherwise very clever—explanations. How can DNA become a carrier of biological meaningful information? Meaningful in the sense it delivers (eventually after some post-translational modification) a functional protein to a living cell. DNA contains *functional* information precisely in the context of the *system* of the *living cell*, i.e., its spatial and temporal organization (cf. Weiss, 1969). We have to face the question how DNA sequences with functional information did originate simultaneously with the origination of the first receptive system in a cell that demonstrated key characteristics of a living cell (e.g. metabolism to maintain a far from equilibrium state). This question concerns a complex relation between functional information and a receptive system established by a hierarchical organization comprising the whole cell (cf. Pattee, 1973). To start biological regularity physically embodied biological information with relevant functional meaning is needed.

The submarine alkaline hydrothermal vent (AHV) theory is an interesting hypothetic theory for the emergence of life. Branscomb et al. (2017) suppose that the AHV hypothesis can provide a solution to the issue of the origination of life sustaining disequilibria in cell-like structures. They suppose that some minerals can function as the specific disequilibria converting engines that are needed for proto life. A confirmation of this hypothesis would weaken our conclusion (in What is the Character of the Semiosis in the Biosynthesis of Proteins? section) regarding the necessity of nano engines *ab initio*. However, in our opinion their article—which underlines necessary specificity and dynamics of disequilibria in living cells and protocells—in fact supports a view as expressed in our article. In our view, in light of the present scientific evidence it is inconceivable that the rules of the genetic code were *biologically generated*. Biological entities presuppose a genetic code.

Koonin (2011) has argued that an overwhelming importance should be attributed to chance in the interplay between chance and non-random processes (i.e., necessity) in the emergence of life on earth, from a mechanistic point of view. Even for the evolution of a hypothetical primordial RNA world, ribozymes consisting of a few hundreds of nucleotides are rather complex molecules and according to Koonin their evolvement in a prebiotic setting could be nontrivial. Such considerations led him to welcome the many worlds in one (MWO) model of Garriga and Vilenkin (2001) that changes the very definitions of *possible, likely, and random*, with respect to any historical scenario (Koonin, 2011). In this context it must also be kept in mind that *biological* regularity is observed only in systems with interdependent parts, containing nano engines, among other things. This relativizes the possible role of Barbieri's ribosome-oriented model, which regards *specific* proteins, but not *functional* proteins.

These various considerations point to the methodical limits of a mechanistic explanation of the origin of functional proteins as a prerequisite for living cells.

Organicist Approach

An organicist semiotic approach reasons from the normative nature of semiosis in living cells. Kull et al. (2008, p. 43) remark that "*Sebeok's Thesis*" denominating the concept that *life and semiosis are coextensive* is "one of the basic positions held in contemporary biosemiotics." At the same time, Sebeok (2001) underscores that there can be no semiosis without interpretability. However, the state of the art in biological research is that semiosis in protein synthesis is realised by a physically embodied receptive system, not by psychic events. We agree that—reasoning from a semiotic point of view—this receptive system realizes a form of 'interpretation' of the information in coding DNA.

Deacon (2021, p. 541) aptly argues that "replicator models" do not suffice, and that an interpreting system is needed. But how did living cells originate? According to Deacon (2021, p. 540), "the origin of life problem brings together three seemingly incommensurate properties": 1. The spontaneously production of an extremely simple molecule system. 2. Its persistence far from thermodynamic equilibrium. 3. Its selective interaction with the immediate environment in ways that support the persistence of these processes. However, realizing that Deacon's second property must concern specific and adapted disequilibria from the beginning, we understand that the molecular system involved in semiosis cannot be simple nor spontaneously produced.

From an organicist semiotic point of view, also the "concept of pansemiosis" has been put forward (Hoffmeyer, 2008, p. 603), as well as the view that *physiosemiosis* does "in the physical universe effect a scaffolding preparatory for the advent of life" (Deely, 2014, p. 395). However, the issue of the origination of the information involved and required in cellular protein synthesis—and, connected to this, the issue of the origin of biological regularity in general—seems beyond the limits of natural science. We agree with Lacková and Faltýnek (2021) that the lower semiotic threshold should be established at protein biosynthesis.

Organicists commonly employ mechanical explanations of living entities, but regard mechanisms not as ontological conceptions. According to Nicholson (2010, p. 165), a causal mechanism "heuristically abstracts away the complexity of a living system." He designates causal mechanisms in biology as *epistemic conceptions*. This means, he conceives of causal mechanisms in biological explanations as epistemic rather than ontological conceptions, i.e., they enable a certain kind of knowledge of biological entities, but cannot claim to adequately represent the biological reality. In our view, it is particularly important to realize that mechanistic explanations in biology presuppose living entities and do not explain their ultimate origination. Only alterations of one or more already existing living entities, or parts of entities, are explained.

Kantian Approach

Kant (1790, p. 387) expresses an antinomy that—according to him—arises in explaining living entities scientifically: "The first maxim of the power of judgment is the thesis: All generation of material things and their forms must be judged as possible in accordance with merely mechanical laws. The second maxim is the antithesis: Some products of material nature cannot be judged as possible according to merely mechanical laws (judging them requires an entirely different law of causality, namely that of final causes)." In Kant's view, scientific explanation entails mechanical explanation. At the same time, Kant considers living entities mechanically ultimately inexplainable. Regarding antinomies, Kant (1790, p. 340)[2] writes: "The resolution of an antinomy amounts merely to the possibility that two apparently conflicting propositions do not in fact contradict each other, but can be compatible with each other, even though the explanation of the possibility of their concept exceeds our faculty of cognition."

Kant's philosophy of Transcendental Idealism has been discussed since the appearance of the first edition of his *Critique of Pure Reason* (Kant, 1781). For example, Stjernfelt (2007) observes "a constant tension in von Uexküll's naturalized Kantianism" (p. 230), although "Peirce's pragmatizing Kant enables him to escape the threatening subjectivism (p. 95). Favouring a Kantian approach in biological

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[2] English translations of quotations of Kant's works are from Kant et al. (2002).

explanation does not *necessarily* mean endorsing Kant's Transcendental Idealism. Kant's account of natural ends in the *Critique of Judgement* actuated a prolific *teleomechanist* program in nineteenth century Germany in which scholars holding different world views were involved (Lenoir, 1982; cf. Beekman & Jochemsen, 2022).

Kant tries to demarcate natural philosophy (i.e., the precursor of modern natural science) from metaphysical belief. In *Critique of Judgement* he heuristically distinguishes normative, final causality in living beings. However, he denies explanatory value to these concepts. Teleological concepts only belong to the description of living entities, scientific—i.e. according to Kant, physical—explanations should just employ concepts of efficient causality. Kant formulates "provisionally that a thing exists as a natural end *if it is cause and effect of itself*" (Kant, 1790, p. 370f). In other words, "an organized product of nature is that in which everything is an end and reciprocally a means as well" (1790, p. 376). In the *Opus postumum* Kant explains that he considers such definition to be "a mere idea, which is not assured of reality *a priori* (i.e., that such a thing could exist)" (quoted via Guyer in Kant et al., 2002, p. 389). Organisms are "mechanically" [i.e., scientifically] (1790, p. 429) inexplicable: the first origination of organic complexity [i.e., adaptation] does not allow proper scientific explanation. Kant regarded biology as part of the physics of his time, however, not a proper part since biology is missing *a priori* principles (Van den Berg, 2014). Because our "discursive [i.e., argumentative, not intuitive] understanding" (1790, p. 407), we conceive of organisms as irreducible wholes (cf. Denton et al., 2013). We cannot comprehend the ultimate efficient cause of living entities, nor the first origin of the normative regularity—which we call biological—they manifest, without ascribing finality to nature.

Conclusion

Regarding the explanation of the origination of biological normativity mechanistic and organicist approaches part ways. Different metaphysical assumptions appear in the models they present. In the former the origin of the order organisms expose is attributed to chance and necessity (cf. Monod, 1970), whereas in the latter it is attributed to teleological processes in inanimate nature.

A Kantian approach in biology is careful and modest. In a Kantian approach strengths of mechanistic and organicist approach are combined. After Kant's (1790) plea to demarcate natural science (i.e., empirical science) from origin of life views, many observations have been made which underline the specificity and complexity of living cells, compared with inanimate nature. One of the most fundamental is the observation that self-organization in living cells is entangled with genetic mechanisms and hence with employing symbolic information. In the twentieth century, molecular biology has "molecularized" the concept of natural end (cf. Roth, 2014) by making plausible the semiotic background of functional proteins.

Discussing the origin of the genetic code, Yockey (2005, p. 173) concludes that "the process of the origin of life is *possible* but *unknowable*." However, the origin of the first living cells involves an even larger complex of questions than only the origin of the genetic code. It also comprises, among others, the origin of the information for manufacturing nano engines to generate and maintain necessary disequilibria, and the tacit knowledge embodied in the corresponding receptive system embodied in the cell. Living entities display causal/mechanical lawfulness, as does inanimate nature. At the same time, living entities display semiotic processes. *Symbolic reference* in protein biosynthesis is a qualitative new phenomenon with respect to inanimate nature. Therefore, biology is not a part of physics but a distinct scientific discipline employing at least physical-chemical methods and semiotics. Causal mechanisms are explanatory regarding the operation of semiotic processes in polypeptide synthesis. However, they are not explanatory regarding the origination of the first living cell(s), encompassing the semiotic processes involved. Granting that those mechanisms would explain them, would entail assigning finality to physical processes. To avoid this pitfall, Kant understood living entities as natural ends and irreducible wholes. The observed semiosis in protein biosynthesis can best be understood in a Kantian approach.

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