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ORIGINAL PAPER

Life's organization between matter and form: Neo-Aristotelian approaches and biosemiotics

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Abstract In this paper, I discuss the neo-Aristotelian approaches, which usually reinterpret Aristotle's ideas on form and/or borrow the notion of formal cause without engaging with the broader implications of Aristotle's metaphysics. In opposition to these approaches, I claim that biosemiotics can propose an alternative view on life's form. Specifically, I examine the proposals to replace the formal cause with gene-centrism, functionalism, and structuralism. After critically addressing these approaches, I discuss the problems of reconciling Aristotelianism with the modern view of life's organization. I claim that the notion of the final cause proposes a cosmological hierarchy and that this is the main problem with applying the formal cause to biology. An alternative categorization of conceptualizing life's form involves (1) the processual identity, (2) relational property clusters, and (3) context-dependent transmission of representational units. The third category points to a semiotic basis of the form of life. In this context, I offer to readjust the focus of the problem of matter-form duality by pointing out that form is primarily an issue of the subject-object relation. Biosemiotics helps to understand the constructive role of symbolic representation in living systems, which is crucial to extend the analysis of the form from cognitive representations to external phenomena. Emergence of subjectivity and perspectivity of interactions are key elements to bridge the form and actual processes within a non-hylomorphic account. To demonstrate transitions from the physical influence of shapes to the organic recognition of forms, I address the biological studies on the synchronization of coincidental inputs and enzyme specificity.

Keywords Neo-Aristotelianism · Hylomorphism · Semiotics · Genetic determinism

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1 Introduction

Beyond the recent increase in the interest in Aristotelianism that focuses on issues such as dispositionality and hylomorphism (Austin, 2018), the ideas of Aristotle have often appealed to philosophers and scientists who aspire to challenge the theoretical borders of modern science. This paper discusses neo-Aristotelian approaches towards the question of life's form, and because these approaches seem inadequate for an extensive theoretical basis, it proposes biosemiotics as an alternative. A main issue that underlies neo-Aristotelianism is matter-form duality. I believe that this is a genuine problem which cannot be eliminated by a mechanistic approach. In this context, I admit the philosophical value of the Aristotelian view, as it promotes a non-reductionist attitude toward organisms by focusing on the relation between dynamic forms and biological functions. Yet, hylomorphism is likely to complicate the question of life's form because of its controversial metaphysical commitments such as teleology. I offer to remedy this issue by divorcing the philosophical enquiry on life's form from the historical burdens brought by hylomorphism. The approaches I discuss vary between solid neo-Aristotelian conceptualizations and the rather superficial contacts with Aristotelianism that simply utilize the ideas around matter-form duality. In general, the formal cause is employed as an element of a conceptual toolkit to spell out certain theoretical problems in biology. The main problem here is that borrowing the notion of formal cause will not be conclusive without engaging with major discrepancies between Aristotelianism (or any other candidate for challenging today's paradigms) and modern scientific views. As a result, ramifications immediately appear when the formal cause is applied as a patch for contemporary gaps in the theory. This issue is responded by either embracing deeper implications of Aristotelianism when challenging mainstream scientific ideas, which implies a strict neo-Aristotelianism, or borrowing the notion of formal cause without dealing with its core ideas. Besides, reviving hylomorphism usually involves revisions of the formal cause to various extents.

Prima facie, naturalism seems to presuppose that the form could be eliminated within mechanistic explanations. However, such an eliminative attitude would disguise fundamental issues such as matter-symbol complementarity (see Sect. 5.1.), which are originated in the interwoven characteristic of biological processes and formal elements. For instance, cell's functioning utilizes the symbolic nature of amino acid sequences, and this kind of symbolic behaviours enables living systems to simplify and regulate the informational inputs of their internal control (Pattee, 2012). Irrespective of the level of awareness concerning the Aristotelian root of the problem, it is hard to avoid similar implications of matter-form duality within the research on living systems. On this basis, I argue that forms have a mind-independent (external) ground, whereas we cannot explain their externality without considering the naturalistic meaning of the subject-object relation beyond human agency. I also claim that understanding life's form as well as the ability of living systems to perceive the form require a biosemiotic analysis that considers the evolutionary basis of subjectivity. Modern applications of hylomorphism stress certain dimensions of the question of form, whereas none of these accounts provides an extensive theoretical frame to integrate various aspects of this notion. Since the form primarily denotes a mental representation, a key issue is to describe how subjectivity is materialized; synchronically, as a relation between the evaluator and the evaluated, and diachronically, as an evolving phenomenon. Biosemiotics emphasizes various ways in which signs become associated with signified entities as a key issue of organic processes. Thereby, I contend, it provides an alternative theoretical basis to integrate representational and external dimensions of the form.

In Sect. 2, I begin with a brief review of Aristotle's ideas on matter-form duality in order to point out connections with broader implications of his philosophy. The notion of final cause entails a cosmological hierarchy, and because the formal cause is dependent on the final cause, it suggests a unified teleological understanding as opposed to a modern biological view that emphasizes diverse local factors. In Sect. 3, I critically examine the proposals to replace the formal cause with gene-centrism, functionalism, and structuralism. Gene-centrism suggests an upward determination of the form from molecular to higher levels, whereas morphogenesis and regulation of genetic networks suggest a downward determination of the form. Despite some parallel thoughts between the Aristotelian view on functions and modern functionalism, the former is not presented within an evolutionary perspective, whereas the latter is restricted to biological claims without making any metaphysical assumptions. Structuralist views based on Aristotelianism usually appeal to a notion of pure form and disregard the fact that structure is an abstraction. One of the structuralist interpretations of hylomorphism tries to overcome this problem by associating form with abstract principles of organization and matter with lower-level components. However, this kind of matter-form duality corresponds to a relative condition because lower-level components are also subject to relationality. In Sect. 4, I elaborate an alternative non-hylomorphic conception of the form. Three explanatory foci are essential for defining what form is: (1) processual identities based on self-maintaining dynamics, (2) relational property clusters that are abstracted by prioritizing certain coherent types, and (3) context-dependent transmission of representational units. The last of these foci is essential to recontextualizing the problem by starting from its (bio)semiotic basis. In Sect. 5, I argue that a naturalist interpretation of Peircean semiotics can help to illuminate the subjective basis of forms, which I claim to be emergent due to the internal evaluation of coincidental events. As a critical revision of Peirce's view that associates sign relations with quasi-minds, I claim that quasi-subjects and quasi-objects appeared with the evolution of organisms' internal control. The role of sign systems and internal evaluations suggests that there is an objective ground for the form in living systems based on relationality. Finally, I develop an analysis concerning the relational dynamics of living systems that give rise to an evaluative capacity based on a hypothetical condition of enzyme specificity. A general conclusion of this paper is that biosemiotics, which sheds light on the representational and relational dimensions of the form, provides a theoretical frame to analyse the emergent evolution of subjectivity. Matter-form duality is rooted in this relational and evolutionary ontology.

2 Aristotle on life's form and contemporary views: a problematic reconciliation

Prior to discussing specific neo-Aristotelian approaches towards life, in this section, I briefly review the Aristotelian understanding of form and its specific relation to living systems, and provide an overview of the general philosophical problems of neo-Aristotelianism. My focus is Aristotle's metaphysical ideas that relate to life's form—because I believe that they should not be overlooked—rather than his extensive studies on living systems. As it is well-known, modern physics was established as a critique of Aristotelian physics. Is it possible to revive Aristotelianism in biology by merely holding on to the assertion that biology is beyond Newtonian physics? Although a neo-Aristotelian account could be backed up by Aristotle's anti-reductionist attitude toward life, this would not suffice to solve two core issues, namely: the meaning of plural causal explanations in Aristotle's philosophy and the naturalization of teleology in modern scientific theory. Within the philosophical attempts to settle these issues in favour of Aristotelianism, the presumed association between Aristotelian notions and modern organizational viewpoint is in general too optimistic that the potential inconsistencies are usually ignored.

In Aristotle's philosophy, the form refers to the shape of an entity vis-à-vis the matter that is to be shaped. However, shape and the potential to be shaped are reciprocally defined, and therefore they are both context-dependent. In a well-known example given by Aristotle, the form of a bronze statue denotes what is made from the bronze: The formal cause is the statue form, and the material cause is the bronze. Matter is the non-determined, non-demarcated, and shapeless, characterized by potentiality, while form is determined—either by nature, by artificial production, or by chance—demarcated, and shaped, characterized by actuality (*De Anima,* 412a28; *Metaphysics,* VII and VIII 2 1043a25). This hylomorphic duality is presupposed due only to aspects that are analysed, because contrary to Plato's theory of forms, Aristotle considers form and matter as inseparable in actuality. We can speak of a specific form relating to different entities such as the spherical form of different bronze spheres, whereas this does not mean that there can be form as distinct from materiality (except the unmoved mover), for spherical form cannot exist without a particular sphere (*Metaphysics* VII).

The example of the shape of a statue could be misleading in some cases because Aristotle always considers the role of change when describing a case of matter-form duality. An analysis of diachronic identity underlies the question of dynamic form. Differentiation involves both persistence and alteration, which could be due to accidental change or generation (*Physics* I 7; II 8). As for living systems, the way that Aristotle defines form points to a dynamic condition. The form of organisms is understood not only due to their shapes, but also to their functions (*Physics* II 3). This is because the form of living things is preserved only based on a condition of functionality. For example, we can say that a bronze sphere is made of bronze, and therefore the matter of the sphere is bronze. However, we cannot simply say that a horse is made of flesh and bones without considering the lively organizational context. This is because a horse is not an arbitrary mixture of flesh and bones, and flesh and bones cannot continue to exist as they are without the organism's living organization. Similarly, the form of an eye is established due to the function of seeing. The eye of a statue or of a dead animal does not have the real form, and thus this type is only homonymously an eye (*De Anima* II 1, 412b10-25; *Metaphysics* VII 10, 1035b9-25). As an underlying thought of this point, form is explained due to what is substantial to the existence of something, and this is closely linked to the function of that entity. We describe an eye through the function of seeing. Therefore, the form of an eye is understood through the act of seeing.

The hylomorphic duality is contextualized within a view of potentiality. According to Aristotle, "matter is potentiality, while form is actuality" (*De Anima* 412a9). The soul, which involves basic metabolic activities, perception, and reasoning, is the form, an actuality of the natural body (412a22), but it also embodies efficient and final causes (415b8-27). On the other hand, the body, as the matter, provides an organic potentiality for life.[1] The formal cause is described based on the implications of the final cause, which is a main reason of exegetical complexities as a weakening aspect of neo-Aristotelian approaches. The role of final cause in this context is due to an intrinsic tendency of self-moving entities, leading to the actualization of form toward maturity, e.g. a seed has a potential to grow and become a tree (412b27). The form and the end are in accordance with each other (*Physics* 198a23-26), as the dynamism of the form is justified by internal purposiveness. The link between form and finality reveals a specific way of seeing the world that focuses on transformative and functional hierarchies. Matter denotes a condition of possibility—typically corresponding to lower-level components—vis-à-vis the form of organizational unity. Clay is the matter of a brick, and in this matter-form unity, brick is the form. On the other hand, brick is also the matter of the house, and the form of the house is described based on its function of sheltering for people.

The connection between form and ends creates a possibility to consider the formal cause in line with a modern understanding of functions and organization. In modern science, due to the influence by Descartes and Newton, causal relations are analysed primarily based on positional identification and prediction of an object's trajectory, whereas the causal pluralism of Aristotelian philosophy has attracted researchers who challenge the limitations of this paradigm. However, applying the notion of goal-directed forms, if taken as an Aristotelian idea in its origin, requires addressing further metaphysical implications of Aristotle's philosophy, since patching Aristotelian notions into modern scientific theories exposes a burden of deeper

[1] This potentialist view has appealed to modern biologists who aspired to challenge preformationism. In this regard, researchers such as Hans Driesch, who showed that embryo cells have a latent capacity to differentiate into different types of cells, and Hans Spemann, who claimed that a certain part of an embryo can have a formative initiative that acts on other cells (later called Spemann organizer), found intellectual support in Aristotle to justify their ideas. Driesch's idea on pluripotency has been confirmed due to the systems biology approach to developmental biology. In particular, stem cell studies demonstrated that embryonic or adult stem cells, which are initially in a pluripotent state, are capable of differentiating into specialized cells depending on external manipulations (Allen, 2008).

paradigmatic inconsistencies. As it is well-known, the discrepancy goes back to the beginnings of modern science, when paradigmatic objections to Aristotle were raised by scientists and philosophers such as Galileo, Bacon, and Descartes. Bacon complained that Aristotle confused logic with natural philosophy by suggesting the co-existence of different causal explanations. He stated that the explanatory pluralism corresponds to various ways to interpret phenomena, but not an ontological plurality of causes (*Novum Organum,* I, Aphorisms XIX and XCVI). As a response to this kind of criticisms, it is pointed out that Aristotle's "conception of a cause has both a metaphysical and an epistemological component" (Falcon, 2019). A cause was defined differently in Aristotle's era, and therefore enforcing the modern distinction between causation and explanation would be an anachronic effort (Hankinson, 1998). Another controversy on Aristotle's view on causation is due to its teleological nature. In this view, the question of why something has occurred relates to both living and non-living systems. Although it could be claimed that applying the notion of *telos* to non-living things creates the danger of psychologizing nature, it is emphasized that final cause is actually a concept beyond purposiveness, as it refers to the question of for the sake of which a thing has come to be (Vinci & Robert, 2005).

As these controversies demonstrate, a main exegetic question is whether the four causes are explanatorily reducible or they are irreducibly complementary. A closer look into Aristotle's philosophy reveals that the four causes are irreducible to explanatory differences, because they correspond not only to different ways of explaining the world but also to different ways that causes by themselves are involved in the phenomena being explained. The formal cause is described, beyond abstractions, and even beyond pure relationality, as a principle that reflects a transformative power, which is justifiable within a cosmological hierarchy of functionality. In this sense, Aristotle's view on causation implies a non-reductionist view which is inspired by his biological research, and in return, which is apt for understanding living processes (Leroi, 2014). Form and function, along with efficient causes, are considered in the context of a thing's coming into being. Aristotle describes goal-directed activities depending on functionally viable end-states, e.g. the reason why an animal has sharp teeth is explained through a repetitive action of cutting as the function of the teeth. We gain the empirical possibility to acknowledge goal-directedness because a viable end-state occurs repeatedly. This reveals a formal abstraction that depends on a typological situation of a certain process, which refers to a more extensive ontological area beyond a difference between epistemological perspectives. Thus, in terms of the formal-final causes vis-à-vis efficient causes at least, an explanatory reduction to the latter would be inconclusive. In fact, a proposal to reduce the pluralism of Aristotelian causality to mechanistic causes is reflective of an anachronic misinterpretation of this ancient philosophical approach that preceded mechanicism by more than two millennia, because causation-explanation dichotomy is laden with several presumptions of the latter.

Aside from the inconvenience of reducing teleology to mechanical causes, it is disputable that teleology is reducible in any way. In Aristotle's understanding, the formal cause is made fully intelligible due only to the final cause, since the dynamicity of the form is characterized by an approximation of entities—including organisms—toward their finalized condition. This consideration per se is enough to suggest that the final cause is presumed to be a sui generis causal factor.[2] In the modern context as well, the connection between form and finality resurfaces as a problem of naturalizing teleology, which does not necessarily mean a reduction of teleology. One of the modern interpretations in the context of naturalizing teleology involves associating the emergent aspect of biological organization with the formal and final causes. In far-from-equilibrium systems with attractors such as vortexes and Bénard cells, random collisions among the particles are self-organized into coherent patterns acting as a forming principle over the system. The attractor is an emergent condition that has a role of downward causality. Based on this, Juarrero (2002) claims that the role of attractors in these nonlinear systems is comparable to the final cause. Accordingly, downward causality is interpreted as a naturalistic version of final causation, because it has a characteristic of self-directing activity determining the form of the system it is involved. Juarrero (2014) also points out that living systems, although more complex than attractors, are formed by this type of downward causality, as organization at a higher-level determines the reconfiguration of components at a lower level. She claims that higher levels are characterized by combinatory novelty that constraints the distribution of lower-level parts, creating bifurcations in a space of equipossibility. Emergent patterns and organisms are both characterized by far-from-equilibrium conditions, which corresponds to complex systems that create their own boundary conditions. As they are non-equilibrium systems, their existence cannot be sufficiently explained by thermodynamic principles. In other words, the existence of these complex systems is thermodynamically improbable, and therefore kinetic control and the role of information have to be considered as preferable accounts. Associating the final cause or the formal cause with emergent patterns is a common idea that is not limited to Juarrero's account. Yet, Hulswit (2005) points out drawbacks here relating to both the notion of downward causation and the Aristotelian basis. He claims that the phenomenon associated with downward causality in fact does not correspond to a causal principle because global patterns emerging within systems, as they are already identical with the parts of these systems, cannot literally have a causal effect unlike efficient causes. Therefore, he concludes, downward causation is in fact "downward determination" (Hulswit, 2005, p. 282). On this basis, Hulswit criticizes the application of the formal cause by arguing that form is in fact a way of determination. Concerning the Aristotelian basis, too, he opposes applying the formal cause in isolation from the broader cosmological claims of Aristotelian philosophy. He points out that in current scientific view, causation is limited to efficient causes, which is explained due to universal laws. This implies a sharp contrast with the Aristotelian plurality of causal explanations. Thus, one cannot apply the Aristotelian solution without dealing with this inconsistency between these two worldviews (Hulswit, 2005).

[2] A detailed analysis against the reducibility of the final cause can be found in Cameron (2002). Cameron justifies the idea that the final cause is considered by Aristotle as a sui generis factor by comparing the Stagirite's conception of teleology with previous understandings.

Although I agree with Juarrero's point on the far-from-equilibrium conditions as a common basis of the forms of self-organizing systems and organisms, the questionable part in this claim is the reinterpretation of final cause. Hulswit's criticism, which primarily targets downward causation, is predicated on the modern distinction between causation and explanation, associating downward causation with the latter. I believe that a processual view of emergence based on part-whole dynamics—a causal claim indeed—is defendable, though I do not intend to discuss the implications of downward causation here. As for the neo-Aristotelian implications, however, it is hard to deny Hulswit's points. Considering the radical paradigmatic differences between Aristotelianism and self-organization, it appears that a conceptual link between final cause and downward causation is far from being obvious. Aside from its own explanatory value, downward causation cannot be a substitute for the final cause, which also renders relevant modern interpretations of teleology problematic. Self-organizing dynamics involve bottom-up factors that emerge in complex systems, and emergent patterns such as attractors are key to the self-maintenance of dynamic form of the relevant systems. We can find certain parallels between the modern notion of self-organization and Aristotle's anti-reductionist consideration of the form. As Matthen and Hankinson (1993) point out, indeed, "Aristotle's universe is a self-maintaining structure" (p. 425). Aristotle's causation is also anti-reductionist because the form of the whole determines the parts. On the other hand, causal effects of parts are ascribed to material causation, which is subordinated to the formal cause. Time is conceptualized through motion, and motion occurs due to *telos*. Temporality is involved as a part of the explanation due to final causation, hence the question of dynamic form is implied in final causation (Matthen & Hankinson, 1993). Van de Vijver (2013) highlights the dissimilarity between Aristotelian and modern notions of organization, which can be considered as supportive of Hulswit's relevant argument. She states that the formal cause is put forward as part of a general view based on the developmentalism of the one, whereas in contemporary organizational approaches such as Developmental Systems Theory, the basic notion is the "developmentalism of the many" (Van de Vijver, 2013, p. 248). According to Aristotle, form is determined within a cosmological hierarchy, while in today's organizational theories, self-organization points to local, contingent, and diversifying dynamics of organization. Therefore, the formal cause is not exactly consistent with the levels of organization in the contemporary approach.

Reconsidering the implications of the material cause is also necessary to understand the basic difference between the Aristotelian and contemporary viewpoints. In Aristotle's philosophy, the aspect that is material is assumed to be in contradistinction with the efficient, formal, and final causes. In this way, the causing element is put forward not only vis-à-vis the caused, but also the material. Causal separation of matter and movement is a basic metaphysical postulate of Aristotle that underlies many of the confused interpretative deviations in neo-Aristotelian accounts. Sure enough, this reflects a radically different understanding of what "matter" is.

Hylomorphism asserts that matter is restricted to a passive element, whereas the remaining aspects of causation that are associated with movement have non-material roots.[3] This idea is in contrast with the naturalistic perspective that does not attribute matter and change to distinct causal roots—notwithstanding various competing interpretations within the materialist/naturalist worldview. In Aristotelian cosmology, pure form, which is equivalent to pure thought, is the unmoved mover. This assumption is complemented with the observation that there are always degenerating elements of form in our world (sublunar region in Aristotelian cosmology). Therefore, for earthly beings, it takes effort to construct and maintain the form. Such a conceptualization of pure form implies an extrapolation of the cognitive dimension; in return, suggesting that a universal principle of reason is a cause of order in the world. This metaphysical commitment contradicts the main claim of this paper that cognitive basis of form is a product of prior evolutionary processes. Thus, contrary to hylomorphism, I maintain that there is no matter-form duality as a metaphysical principle that applies eternally, but rather forms reflect a specific way of causal relations that appeared with evolving complexity.

As a result of this review, a concluding remark can be made as follows. In Aristotle's philosophy, the ultimate role of the final cause in the formal cause suggests an extrapolation of agency at the cosmological scale in which end-states are correlated with the intrinsic mobility of entities. Granted, not all the neo-Aristotelian interpretations take all the metaphysical commitments of Aristotle seriously by adapting these commitments into a coherent worldview of our day, and neither this seems possible. Yet, the main point of my emphasis on this cosmological aspect is that a neo-Aristotelian view cannot escape from at least some of these mentioned consequences when it appeals to the formal cause. As a response to the ongoing philosophical debates on teleology, one could be embracing this notion, reconceptualizing to make it consistent with naturalism (e.g. teleonomy), or even refuting the main idea completely. In any case, an author's view on teleology would have unavoidable implications for her possible espousal of the formal cause. Modern theory reflects certain similarities with the presupposed metaphysical relation between formal and final causes insofar as self-regulating capacity and purposiveness emerge within complex systems. However, according to the evolutionary view, the relation between local and more inclusive levels of organization is not associated via an

[3] Henry (2019) points out that in some cases Aristotle seems to consider matter not as merely passive, but as the origin of movement. According to one of them, cold and hot are active, whereas dry and moist are passive. So, Aristotle applies the relation between those that acts and those that is acted upon even to the elementary forces which constitute the basis of compound matter. Other cases are parthenogenesis, in which only the female creates an embryo, and spontaneous generation, which is the belief that organisms can be formed out of the non-living. Aristotle thinks that in these examples, matter could begin motions without the involvement of seed, which is supposed to be the only carrier of form. Henry (2019) remarks that this poses a contradiction with another statement of Aristotle that matter *qua* matter is passive, and that this makes reaching an exegetic conclusion difficult. I think this detail (whether matter has a limited capacity of movement or not) would not make a difference in terms of Aristotle's opposition to materialism because in any case he contrasts matter and formative movements.

all-encompassing teleology. Today's conception of the unity of organization could rather be a network of ecosystemic islands, where all these ecosystems have their context-dependent transformations depending on the constraints that appear locally in developmental processes. In brief, the main problem is that Aristotle's philosophy presumes a cosmologically downward determination of the form that is in line with teleology, while the emergent patterns—including those in the biological organization—are dependent on assimilating local and contingent elements, which presume the interaction of bottom-up and top-down dynamics.

3 Neo-Aristotelian approaches

Despite the widespread efforts to associate the formal cause with modern theories on life's organization, no consensus exists on its interpretation in the context of other Aristotelian causes. For example, it is claimed that the formal cause implies a specific relationality condition of organisms, which makes them unaffected by efficient causes (Hofmeyr, 2018; Rosen, 1991), or a restricting condition on the possibility space (Auletta et al., 2008). According to some other interpretations, form is acquired through the construction of biological identity, and the efficient cause and the formal cause are unified in the material causation of organisms (López-Moratalla et al., 2011); the efficient and final causes can be subsumed under the formal cause (Thom, 1989); or an organism's individuality can be understood based on the link between the final cause and the formal cause (Emmeche et al., 2000; Salthe, 1993). Although most of these considerations agree on the role of multiple levels of organization, the contrary reductionist position of gene-centric explanation is also defended in the same context (Delbrück, 1971).

There are so many interpretations of the formal cause that it is not possible to discuss all of them here. Instead, below I focus on specific problems of the use of the notion of formal cause as they are embedded in main approaches in biology. The theoretical approaches I discuss involve genetic programmes, the functional explanation based on natural selection, and structuralist explanations based on developmental processes and part-whole relations. These attitudes provide different justifications for the relevance of formal cause insofar as their objects and theoretical problems in focus differ. Despite certain drawbacks, when these approaches are considered separately, I do not underestimate their value in terms of illuminating different considerations and aspects of life's form. My general objection is raised based on the inconsistency of these neo-Aristotelian theories in the face of the complexities of the problem. I think this inconsistency reflects the need of a general understanding of the form in biology.

3.1 Gene-centrism

The genetic programme is a metaphor introduced by Ernst Mayr and Jacques Monod in separate but parallel accounts to express the claim that genes include instructions for the construction of the phenotype (Peluffo, 2015). Mayr (1997) claimed that

Aristotle's thoughts on this issue can be made consistent with modern biology by replacing the form with the concept of the genetic programme (p. 154). In a similar vein, Max Delbrück, a physicist known for his contribution to research on the genetic structure of viruses, asserted that the role of genes corresponds to the Aristotelian notion of the unmoved mover (Delbrück, 1971). Mayr cannot be associated with a strict gene-centric attitude, considering his emphasis on the complementary role of historical explanations provided by evolutionary biologists. Although the metaphor of the genetic programme that Mayr introduced was used later to support a preformationist conception of the form, Mayr's theoretical association with Aristotle is quite different from Delbrück's reductionism because in fact Mayr is supportive of the Aristotelian plurality of causal factors. Instead of embracing basics of Aristotelian metaphysics, or revising Aristotle's general thoughts, Delbrück seems to have found an ancient supporter in Aristotle the biologist for his gene-centric view, and more specifically, for the notion that genes are characterized by mere informational contents. He specifically cites the sections of *Generation of Animals* which emphasizes that semen involves a non-material, pure formal element, or where Aristotle likens the formal element by semen to the role of a carpenter, and the material element by the female to a bed (Delbrück, 1971, pp. 53–54). Here, Delbrück identifies one of the main ideas in Aristotle's worldview as it is applied to biology, that is, the ubiquitous interactivity between the active forming principle, and the passive receiver of this effect, which is material. In Aristotle's approach to the reproduction of the biological form, Delbrück (1971) sees a rudimentary form of the idea that semen holds DNA, and thus, information, which shapes the matter when it is read out within the phenotype without being shaped by it (p. 54).[4]

The coding of a three-dimensional protein structure based on a specific amino acid sequence serves as a paradigm case for the gene-centric explanation of the form. Yet, the upward determination explains the form at higher levels only to a certain extent. Genetic coding involves complex regulatory processes that are holistically interconnected. One of the main examples is epigenetic networks, which were identified by Conrad Waddington. These are complex structures of feedback loops that canalize embryonic development. Since Waddington, it has also been understood that environmental effects can trigger epigenetic changes such as histone modifications that turn on or turn off certain genes. The discovery of regulatory factors proves that it is not only genes that take responsibility in coding processes. For example, spliceosome, which is an RNA–protein complex, consists of small molecules that are named snRNAs, and these molecules combine the beginning and the end of introns by independent recognition processes (Barbieri, 2008, p. 588). As a result, the process of alternative splicing dynamically determines the expression of genes (depending on organizational needs) by selectively removing introns.

[4] In this claim, Delbrück overlooks a more fundamental (and scientifically problematic, of course) aspect that Aristotle assumed that male's contribution to progeny is formal and female's contribution is material. The antagonism between the male and female contribution to inheritance points to further complexities of Aristotle's view on the formal cause (see Henry, 2006). Still, since this issue is not addressed by him, it seems that it is considered trivial.

The remaining part of exons are responsible for protein coding, and introns, which are non-coding sequences, can take part in other regulatory processes. Furthermore, expression of genes does not have a one-to-one but mostly a one-to-many or a many-to-one relationship between molecular and higher levels due to functional equivalency of higher-level components. A specific genetic sequence can be involved in the coding of many types of cellular membranes because the context of gene expression creates coding variations; vice versa, a specific functional type of cellular membrane can be coded by different genes (Moss, 2003). Gene expression is influenced by the interactions between genes, cytoplasm, and signalling networks across cellular membranes, and therefore, the form of an organism is not strictly dependent on genes.

Contrary to the presumption of upward determination of form from genetic programmes at the micro level to phenotypes at the macro level, the way that regulatory systems work suggests a downward determination of the form. In this context, it has been claimed that form of organisms primarily depends on morphogenetic factors, and genes have a function of stabilizing the form (Newman & Bhat, 2009; Newman & Linde-Medina, 2013; Riedl, 1978).[5] This is supported by experimental studies suggesting that in relatively simple organisms, morphogenetic development can occur independent of genes. The experiments on *Acetabularia,* which is a big single-celled organism living in subtropical waters, show that when this unicellular organism is split, not only the part of the cell with the nucleus, but also the part which does not include the nucleus—hence genes—is partially capable of regenerating itself (Goodwin, 1985). This capacity emerges due to a process of dynamical patterning, as a self-organizing response to the calcium gradient in water. Still, these morphogenetic dynamics are not sufficient for the regeneration in more complex multicellular organisms, and from this, it is concluded that physico-chemical dynamics of patterning cannot establish form without the stabilization of genes (Newman, 2012). To sum, contrary to the claims of the proponents of gene-centric preformationism, the form of organisms is determined by a complex interaction of bottom-up and top-down factors, including the regulatory function of genes and the morphogenetic patterns. Genes have a role in the making of the form of organisms due to providing organizational stability, but this role is contributory, so the form in biological processes cannot be explanatorily reduced to genes.

The question of the biological form has many aspects, and in this regard, it should be emphasized that the inheritance of form and self-maintaining nature of form are not completely overlapping problems. The former is a matter of persistence and variability, whereas the latter is due to the dynamic biological processes that enable the constant reconstruction of form through life cycles. Aristotle dealt with these as interrelated problems: Concerning the former question of how the form is inherited to the offspring, he often mentioned that a main issue is to understand why horses beget horses and humans beget humans. Concerning the latter question of

[5] The authors of the mentioned researches also put forward that genes have emerged subsequently to morphogenetic patterns, although this claim marks a controversial area relating to a bigger issue of the origin of life.

self-maintenance, Aristotle asserted that organisms realize their own form both as individuals and as to their species. Genes seem to answer the first question, but only to a certain extent because there are other forms of inheritance such as the inheritance of the maternal cytoplasmic material, microorganisms, epigenetic modifications, and cultural habits. Mayr (1997) proposed the notion of the genetic programme as an answer to the second question. However, the abovementioned remarks based on regulatory networks apply to this consideration as well. Reciprocal relations that include both genetic and non-genetic factors are effective in maintaining the organism's form, and as is suggested by the abovementioned morphogenetic studies, a better description instead of genetic programmes involves considering organisms as self-organized wholes. Beyond the essential but not exhaustive role of genes, accounting for how the form is inherited to the next generation due to genes does not suffice to answer the question of how the biological form is reconstructed, self-sustained, and dynamically preserved. Thus, even if we disregard other aspects of inheritance and assume that genomes explain how the form is inherited, a gene-centric explanation is not sufficient to reach a scientific understanding of the biological form.

3.2 Functionalism

Both functionalist and structuralist explanations in biology are associated with Aristotelianism in different ways. In this section, I discuss the functional basis of form prior to addressing Aristotelianism's connection with the structuralist programme. Rieppel (1990) appeals to Aristotelian causes in order to support an integrative view that involves both bottom-up and top-down dynamics of evolution. Bottom-up dynamics are investigated by the structuralist research programme, which focuses on developmental constraints in ontogeny, whereas top-down dynamics are analysed by functionalism, which addresses how traits are moulded by natural selection. Following Ernst Mayr's distinction between proximate and ultimate causes in biology, Rieppel (1990) claims that pluralism in the Aristotelian view of causality allows a complementary view of these research programmes. Accordingly, structuralism is associated with the material and efficient causes, which are proximate, realized in ontogeny, whereas functionalism is associated with the formal and final causes, which are ultimate causes, representing a teleological aspect of the form of organisms.

The constraining role of function in the constitution of the form indeed is an association analogous to the one between the formal cause and the final cause. A core question at this point is: how could these causal associations broaden our theoretical view of the modern theory of evolution? Aristotle's biology is compared to modern analyses of functional explanations, and this is for good reasons. According to Aristotle, functional explanations are key to understanding living systems beyond descriptions. This involves unravelling functions that underlie various forms and processes, e.g. asking why fishes have gills but not lungs, or why do they have fins but not legs (Leroi, 2014). Can we consider the link between form and function as a common aspect of Aristotelian and Darwinian accounts? I believe that this is a complicated issue that indicates both divergent and parallel explanatory bases of these theories. Appealing to functional explanation is a matter of the specificity of form, i.e. the explanandum of functional explanations in biology in this context is the underlying purpose of certain forms, such as the suitability of the shape of a dolphin's fin for swimming. In this regard, Aristotelian and Darwinian approaches appeal to functions in similar ways. For instance, Aristotle saw a causal link between sharp teeth and the function of tearing due to a causal regularity of using the teeth to tear, and hence, form is explained based on final causation (Aygün, 2017). The repetition of a specific function is key to explaining the structure, because the survival of the organism at stake is dependent on performing this regular activity. Thus, Aristotle emphasized that tearing by sharp teeth cannot be examined as an actualization of chance events. This parallelism is highlighted by Depew (2008) as well. According to Depew, Aristotle and Darwin appeal to consequence aetiology when explaining the properties of organisms, for they both consider traits as to their functional consequences.[6] Nevertheless, he also stresses a crucial difference: Aristotelian explanation does not involve the specific justification of modern functional explanation, which accounts for the evolutionary emergence of traits due to their historical functions typical in the survival of adaptive traits. Despite the effort to reconcile the Aristotelian notion of form with a modern notion of form-function association, in many aspects, Aristotelian metaphysics and the post-Darwinian understanding of biology are inconsistent. The Darwinian account emphasizes the role of differential variation and natural selection within populations, and this implies a permissible level of indeterminacy and diversity within the form of a species. On the contrary, Aristotle was eternalist, not an evolutionist about species, which was highlighted as to rendering Aristotelian philosophy irreconcilable with Darwin's theory (Depew, 2008; Hull, 1965).

The incongruity marks a basic difference concerning the form of living systems. Biological evolution enables the contribution of contingent factors; accidents such as mutations or other low-chance events that can be embodied in life's forms, while Aristotle thought that the role of accidental events is limited. Even though Aristotle tried to account for the inheritance of species' form as well as individual variations, changes would not lead to radical transformation of essences. On the other hand, Lennox (2017) asserts that certain interpretations in philosophy of biology—he mainly targets the one by David Hull—created the myth that Aristotle's attitude toward life's form was essentialist. Lennox concedes that Aristotle was not evolutionist, but he also emphasizes that Aristotle's works on biology analysed the form of organisms based on continuous variations within kinds, as Aristotle was focusing on similarities between species as well as the extent of dissimilarities within each category of trait. Darwin admired Aristotle's biology, and this general variational perspective of Aristotle was the underlying reason of Darwin's admiration. Hence,

[6] Here, consequence aetiology refers to an understanding of a functional explanation based on the consequences of a cause-effect relations. The notion is rooted in the arguments by Wright (1973), who introduced the idea that the constitution of a functional relationship can be a result of the consequence through the transformation of random factors into repetitive cases.

these two intellectual giants were closer than this myth suggests (Lennox, 2017). In a revisionist interpretation, Henry (2006) asserts that Aristotle's biology is open to the idea of evolution by natural selection. According to his argument, Aristotle's speculation on disruptions in the spermatic movements that effect inheritance suggests something similar to mutations. Henry (2006) claims that Aristotle's cosmological eternalism, which led him to think that the environment is unchanging, underlies his denial of evolution (p. 454). However, considering the metaphysical implications of Aristotle's substance ontology, I think it is not plausible that Aristotle expected adaptive superiority as a result of the disruption of form. Accordingly, Sowa (2016) disagrees that Aristotle employed any notion of a mutation. She disagrees with Henry by claiming that Aristotle actually referred to the merging of ancestral characteristics through spermatic movements (Sowa, 2016, p. 12). Aristotle did not assume any historical change for nature, and in *Generation of Animals,* he stated that species remain constant. Still, (as Lennox points out) considering that Aristotle acknowledged the continuity of adaptive variations, his attitude was also beyond strict essentialism. Aristotle's emphasis on the relation between adaptation and form makes out a limited case for functionalism. But from this, it cannot be concluded that natural selection is to be considered as the formal cause in biology.

Finally, appealing to the formal cause as a basis of functional explanations would suffer from an ambiguity due to conflating methodological motivations in biology and ontological questioning of form. Unlike Aristotelianism, the way that functionalism conceptualizes life's form does not necessarily engage with certain crucial philosophical issues such as materiality, substance, and potentiality. Instead, the efforts to connect Aristotelianism and functionalism tend to acknowledge the former's conclusions on these issues in a superficial manner. Both Aristotelian and modern functionalism try to explain the specificity of form, that is, the question of why *this form* as opposed to *that form* appears (e.g. why dolphins have evolved to have fins). However, the latter's ontological commitment is restricted to this way of questioning in the light of the explanatory basis of natural selection. Contrary to well-identified connections between biological explanations and their metaphysical bases in Aristotle's philosophy, this way of questioning does not involve a first-hand account about why we should consider certain explanatory elements in the context of form as opposed to other possible complementary notions.

3.3 Structuralism

Considering that Aristotle was a pioneering naturalist in the study of embryology, and that he considered organisms as the paradigm case of substances due to their capacity to realize their form, associating the formal cause with ontogeny and structuralist approaches seems quite convenient. Aristotle analysed form as an issue of transformation from a potential toward an actual state, and in this regard, it is emphasized that this ontogenetic basis is key to understanding structural constraints in cellular and developmental processes as an alternative to the problematic supposition of upward determination from molecular level to higher levels (Anzaldo, 2016). Vice versa, the application of Aristotelian ideas to ontogenetic processes has been a fulcrum of the arguments in favour of structuralism, in particular, those supporting the notion that organization constitutes a formal aspect of living systems. Below, I discuss the structuralist claims based on Aristotelianism, which relate developmental modules that are claimed to have individuality, regulative mechanisms that are characterized by an organism-level feedback circuitry, and organization at higher levels vis-à-vis lower-level components. I point out that these accounts provide support for structuralism by redefining the original notions of Aristotle. Moreover, neo-Aristotelian interpretations of structuralism usually tend to disregard certain consequences of the physicality of living systems by restricting form within an abstract consideration, and this creates other philosophical problems beyond the Aristotelian basis of these approaches.

Austin (2018) argues that developmental modules constitute a formal aspect of life, since their trajectories are multiply realizable. A developmental module is characterized by high internal connectivity and relatively low external connectivity with other parts of an organism. As a consequence of modularity, cellular differentiation leads to a specific morphological trait based on the coordination of intra-cellular and intercellular mechanisms and genetic regulatory networks, which are involved in this coordination as transcription factors. Based on the claim that developmental modules are traceable over generations, Austin (2018) concludes that they can be considered as biological individuals, constituting a level of selection (p. 317).[7] Moreover, he claims that morphological state-space of developmental modules is conceptually independent from the mereological makeup of the relevant modules (Austin, 2018, p. 333). In line with a hylomorphic scheme, he proposes that a multiply realized developmental trajectory reflects formality because it is characterized by the supra-individual possibility space of developmental constraints instead of a concrete developmental process. In his view, a typical trajectory as a representation of higher-level organizational robustness is an abstraction beyond the particularity of an actual organism. Austin asserts that this formal abstraction is not simply a heuristic operation because it points to an ontological basis concerning self-directing trajectories of the ontogenetic processes. Austin (2018) concedes that hylomorphism denies ontological distinctness of form and matter. Yet, he claims the conceptual independence of the formal analysis of developmental trajectories based on the emergent characteristic of their organization. We can establish the self-directing nature of developmental modules only by analysing the multiple realization of trajectories, and from here, Austin concludes that "the possible outstrips the actual" (Austin, 2018, p. 330).

[7] Attributing individuality to sub-systems of organisms is controversial because of the philosophically unsolved issues over the modularity of development. Modularity refers to the fact that certain processes of morphological traits are internally more connected, whereas this interconnectivity does not always correspond to compositionally distinct parts, but mostly to context-dependent cases of interactive processes (Mitchell, 2006). Moreover, genetic regulatory networks operate at the organism level, so it is not usually appropriate to distinguish a specific subset of genes in relation to a specific developmental module. Still, I will not address these problems because what I would like to focus on here is the implicit structuralism instead of the controversies over modularity.

It is true that this consideration of developmental constraints reflects a formal aspect of biological organization, but is it possible to assert that abstracted topology "outstrips" the actual condition? I believe that the answer depends on how we conceptualize a multiply realizable trajectory vis-à-vis an actual state of the relevant system. The way that Austin (2018) appeals to the formal cause leads to conflating an abstraction of the formal aspect with an ontological condition of organization. As a model of the morphological state-space, a Boolean network is an abstract description of a bio-attractor state, whereas the organization itself is always realized through an actual process. I think promoting the relevant possibility space as an alternative to the actual state reflects a misinterpretation of the structure. It is paradoxically assumed that the formal aspect of organization instead of this actual state is decisive, as if the possible and the actual in this case are mutually exclusive. Yet, even though a particular developmental process embodies a viability condition that is multiply realizable, the real process is not necessarily characterized by any ontological deficiency in terms of novelty factors or emergent properties. Therefore, we cannot claim that actuality is outstripped by possibility in the ontological sense. I would concede that the morphological state-space is in a way independent from the mereological makeup in case of reformulating this expression. As a revision, we could claim that topology of the state-space is non-reducible to any static consideration of the mereological makeup (Still, contrary to Austin's claim, not independent from it, because matter and form are inseparable.). In this way, the contrast will be presupposed between a processual convergence due to the multiply realizable trajectory and the static material composition of the developmental module.

A key question here is whether structuralism is merely an explanatory perspective or it is also related to certain ontological features. According to Austin (2018), the structure, which is the multiply realizable trajectory, is ontological. In fact, this seems to be the reason why Austin appeals to the formal cause, though above I pointed out some of the ambiguities in this account. Moreno and Suárez (2020) provide a slightly different justification for the ontology of structures, which could help to remedy these issues. They remark that structural explanations connect various actual systems based on certain patterns that are studied mathematically. In this sense, they argue, structural strategy offers an alternative to both deductive-nomological explanations, which appeal to the laws of nature, and mechanistic explanations, which aim to reveal causal pathways that underlie specific functions. The mathematical structure does not correspond to a specific mechanism, but rather to emergent organizational features of the system (Moreno & Suárez, 2020, p. 148). Thus, structural explanations focus on the relations between the network architecture of a complex system and its dynamics. Instead of causal mechanisms (which cannot be entirely mapped in most of the complex systems already), mathematical analysis of the structure helps to understand the global behaviour of the system. Living systems involve self-organizing processes that create organizational robustness by tolerating perturbations and that enable the system to shift between various causal regimes. Moreover, biological systems could internally constrain the behaviour of their components. On this basis, Moreno and Suárez (2020) claim that such network-based properties points to a special ontological condition that is correlated with structural explanations.

Robert Rosen's structuralist account has been highly influential in providing an abstract basis of the formal cause. Rosen (1991), as a mathematician who tried to formalize the structural basis of organisms, argues that the formal cause must be reconsidered in order to overcome the reductionist limitations of Newtonian science and its basis in efficient causation. Rosen claims that Newtonian dynamical analysis tries "to throw away the organization and keep the underlying matter". In contrast, his relational approach intends to "throw away the matter, and keep the underlying organization" (Rosen, 1991, p. 119). To achieve this, Rosen proposes developing a purely syntactical language, as a sublanguage of scientific models within natural language that includes both syntactic and semantic elements (DiFrisco, 2014, p. 510). His mathematical work in elementary category theory, which is an area used to map the transformations of sets, focused on abstract relational characteristics of living systems. In this regard, Rosen considers a transformative account of the formal cause, assigning materiality to the initial state and formality to the emergent structure. He claims that the organism is closed to the effects of efficient causes due to the relationality of its structure. Concerning the tension between the abstract and the actual, Rosen's attitude seems to represent a strong bias toward the former.

Rosen's approach has been criticized for being extremely structuralist, that is aimed to get rid of materiality by focusing on the abstract nature of self-replicating systems (Pattee, 2007). In his theory, the fact that we can abstract the principles of form has led to a misconception that form is inherently abstract. The misconception stems from the idea that relationality can be perfectly represented as pure form that can be examined without considering the actuality of living systems. Yet, as what we abstract is in fact an aspect of relationality that partially reflects various material realizations of living systems, this assumption seems unconvincing. Because an actual living system establishes real relations with its environment, an understanding of ontogeny requires considering not only abstract relationality, but also specific spatial and temporal settings of these real relations. As is done in evolutionary analysis, we can also interpret actuality in relation to the historical context of living systems. The historicity and actuality of biological processes are beyond the scope of a formalized analysis of temporality, and this is why analyses of living systems—unlike Rosen's formalism—should also take into account the empirical context of biology.

Another Aristotelian interpretation of structuralism focuses on the part-whole dynamics: De Haan (2017) assigns materiality to lower-level state components and formality to higher-level organization, claiming that hylomorphism approximates to the understanding of complexity by new mechanistic philosophy. This hylomorphic account is used to support structural realism (or structure realism),[8] which presupposes that the relational nature of entities can be analysed within an epistemic level beyond materiality. New mechanistic philosophy focuses on the

[8] Structural realism has in fact various applications that can be either limited to epistemic claims or inclusive of ontological implications. This interpretation of hylomorphism is limited mostly to epistemic claims, and therefore should be separated from the more ambitious versions criticized above. However, other philosophical problems appear in the Aristotelian analysis of part-whole dynamics (see below).

dynamic configurations of matter in complex systems against limiting the scientific explanation to the laws of nature. In this way, it supports explanatory pluralism and non-reductionism in biology and cognitive science. De Haan (2017) claims that hylomorphism promotes a similar organizational view. In this consideration, it is supposed that there is an antagonism between static, atomistic parts, as matter, and dynamic, relational nature of organization, as form.[9] A revision of hylomorphism in line with matter-organization duality suffers from an unresolved inconsistency between the atomistic conception of matter and Aristotelian metaphysics. According to Aristotle, matter denotes the passive element that provides a capacity for change, which also implies that, unlike Democritean atomism, there is no micro-level entities that are immune to qualitative change. Thus, forms of things, of organisms in particular, cannot be considered due to configurations of unchanging atomistic particles. However, as it is known modern scientific view is rather inclined to atomism, and relations are considered external in contradistinction with matter. In the same vein, biological organization is considered to be a product of higher-level organization whose matter consists of non-relational components at a lower level. Therefore, associating the Aristotelian form with organization (or *telos* with function) means a deep manipulation of an original idea that considers forms of living systems due to internal transformations as a result of active forces on passive elements.

Although Aristotelian metaphysics is quite compatible with the idea of levels of organization, the mechanistic approach based on matter-organization duality has its own conundrums that undermine its association with Aristotelianism. The models of living systems begin either with matter as constituting the basis for a bottom-up approach or with form as the basis for a top-down approach (DiFrisco, 2014). Still, regarding the philosophical understanding of form, restricting our focus to this context could easily lead to disguising a relative condition concerning the intrinsic relationality of these lower-level components. Matter cannot be dissociated from its organizational context because relationality determines the nature of things. When we go down to a lower level, what was previously described as "matter" is found to be organizational and contextual (Karaca, 2019). For example, biomolecules constitute a basic level for life's organization at higher levels, and in this sense, they can be considered the matter of living systems. However, biomolecules can also be subject to a relational analysis. As to their involvement in biomolecules, carbon atoms can be associated with a lower-level component basis in the context of a duality between carbon as matter vis-à-vis the relationality of the biomolecule. Matter versus organization duality in this context reflects only a relative condition, because associating carbon atoms with a condition of materiality implies that the analysis of organization stops at the atomic level without going into the sub-atomic level. As a result, since the physical properties of carbon also appear as a manifestation of organization, we would be acknowledging the

[9] As a detail, this interpretation seems to be admissible in terms of Aristotle's biology, since Aristotle also emphasized that organisms are heterogenous systems and that biological function depends on the configuration of parts. According to Aristotle, life's organizational hierarchy ascends from elements, to compounds, uniform organic parts, non-uniform parts (organs), and finally to the whole organism. Life's organization is established as a result of the functional assembly of these parts (Moya, 2000).

latter under the cover of certain physical properties: Carbon is capable of making four covalent bonds, includes six protons and six neutrons (considering the most common isotope), etc. These are the qualities of carbon that are prima facie fundamental and stable, but only from an external viewpoint that acknowledges them by the very nature of carbon. However, a consideration of the internal relationality of atoms leads us to look into the sub-atomic level. As the physical properties such as covalency and atomic mass are supervenient on the specific arrangements of the parts of atoms, the context of organization cannot be ruled out easily. A desire for explanatory reduction might lead a researcher to examine further the lower levels of organization by decomposing higher-level qualitative differences into identical lower-level components and the geometrical arrangement of these components. In the case of atoms, the number of protons underlies the qualitative differences between elements, different arrangements of up quarks and down quarks underlie the differentiation of neutrons and protons, and so on. Beyond the relative condition of lower-level matter versus higher-level organization duality, if we approach the question of matter from a universal perspective, as denoting what there is in the world, then we could acknowledge that matter always has an organizational context, which also gives the reason why complex entities with hierarchical levels—organisms in particular—are to be understood based on a relational ontology. In terms of the matter-organization duality, what is identified as matter is in fact nothing but a label that disguises where analysis no longer reveals the relational basis of things by decomposing the organization further into lower levels. This implies that not only the biological but also the physical is dependent on organization because it is relevant at a fundamental level of things beyond living systems. Thus far, this example is compatible with the Aristotelian conceptualization of matter in many aspects, although Aristotle prioritizes forms that alters the whole explanatory frame. On the other hand, mechanistic approach is not open to the idea that matter itself could be the process-relational occurrences, as it postulates a strict distinction between atomistic components and their configurations.

Aside from the issues that I targeted in my critique, we surely cannot say that the abovementioned efforts to make sense of life's form are in vain. In fact, they do tackle the formal nature of living systems in different ways: There are indeed certain determinative ties between genes and phenotypic traits, albeit this relates to controversies over the notion of information as an underlying theme of biological form. Functionalism focuses on the role of natural selection to illuminate the form-function relation, and structuralism is fundamental to acknowledge the role of developmental constraints and other organizational factors. Each of these neo-Aristotelian accounts offer partial explanations of form. However, their common problem is that they all claim that life's form is centred on a single determinant, ignoring the multifaceted nature of the issue. The advent of various interpretations led to a pluralism in the meaning of formal cause that is likely to confuse a modern reader who is mainly interested in current theoretical problems of biology rather than ancient philosophy. The pluralism in question points to diverse understandings and multiple ontological aspects of forms in biology. I believe that the notion of form could be demystified by a philosophical analysis that prioritizes the requirements of current biological research, which I offer in the following section.

4 Different conceptualizations of life's form

This section is a transition between the previous critical analysis of neo-Aristotelian approaches and the alternative way of conceptualizing life's form based on the subject-object relation. The philosophical problems that I dealt with in the context of hylomorphism originate in a lack of a comprehensive analytical scope that investigates form in all aspects. As an alternative, I offer a new categorization in an attempt to integrate various relational dynamics of the form in living systems. I propose that there are three different foci that include the underlying dynamics of forms, namely:

(1) Process-based formal identities, which refer to the self-organizing systems including organisms (Juarrero, 2014; Kant, 1790/2007; Schrödinger, 2012);
(2) Relational property clusters, which I adapt based on the notion of homeostatic property clusters (Boyd, 1991) in order to define a structuralist approach toward forms; and
(3) Context-dependent transmissions of forms, which primarily denote a semiotic way of producing and conveying specific mental representations of objects and relational clusters, but also an evaluative capacity of living systems in general.

The main target of this categorization is to provide a basis to integrate various underlying issues concerning the processual nature of things and the role of subjectivity. In this context, below I explain these three aspects of form, and then discuss the connections between them. (1) refers to a mind-independent, external aspect of form, while subjective and objective elements are intertwined in (2) and (3). (1) and (2) are associated with the ways that Aristotelian philosophy understood the form, whereas (3) is a common theme in cybernetics and biosemiotics.[10] Although all these aspects of form have been investigated in a neo-Aristotelian way or another, what I propose as novel is their classification as different conceptions of form. As I mentioned before, matter-form duality is a multifaceted issue, which is why I am not claiming that this categorization must be exhaustive.

(1) Process-based formal identity refers to a condition of formal stability based on constant material flow, which also makes the mentioned identity independent of a material identity. Typical examples of the process-based identity are self-organizing systems and organisms. Self-organizing systems sustain themselves by replacing their material and draining energy from the surroundings. Organisms have a higher degree of self-maintaining capacity. As they are autopoietic systems, organisms' matter is constantly replaced, whereas their form sustains. For example, in a unicellular organism, there is a reciprocal relation between the membrane and the internal chemical processes for the production of the membrane parts, and likewise, the ontogeny of multicellular organisms is characterized by constant change and relative stability of form. The form of organisms

[10] Even though Aristotle also dealt with the perception and transmission of forms, the intersubjective aspect that I describe here is not necessarily in line with Aristotelian claims.

is not strictly dependent on material identity, because organisms maintain their processual form by replacing their matter. As a main line of thought, this issue has been debated in the context of thermodynamics, which was explained by the negentropic activity of organisms against dissipative decay (Schrödinger, 2012). The form as a synchronic condition is dependent on an underlying diachronic condition, which is the processual basis of constant energy input and renewal of the parts. Replacement of material components through metabolic activities enables the constitution of dynamic form, which cannot be reduced to the static integrity of parts.

Aristotle also thought that organisms have a special status as substances because of their self-maintaining structure.[11] Considering the Aristotelian interpretations, what I describe in (1) approximates to intrinsic formal cause, which refers to the internal coherence of objects (see Footnote 12). Previously, I pointed out that Aristotle was focusing on the capacity of organisms to maintain their individual form as well as the form of the species by reproduction. I also claimed that the notion of self-maintaining forms is rather compatible with the modern notion of morphogenetic unity of organisms through development, which cannot be explained by the role of genes per se. The dynamic form, as a basis of self-maintaining capacity, can be understood due to self-organization of organisms and other dynamical systems that create their own boundary conditions. The common theme here is a holistic regulation that regenerates or directs the parts of the relevant system, which brings individuation. On the other hand, what I describe here is slightly different from the Aristotelian notion of form. This kind of form does not vindicate hylomorphic duality because formal identity that I describe here still pertains to processes that are characterized by material influx. In other words, self-maintaining systems are processual, and even though they gain independence from strict material identities, we cannot conclude from this that their form is to be contrasted to the passive involvement of matter. My definition here points to an objective aspect because a processual identity is realized without any direct involvement of mental representations, although mental representations (in a broad sense, any kinds of semantic units) are necessary to identify these identities.

(2) Relational property clusters refer to any type of formal integrity based on mutually sustaining properties of a group of individuals. This notion is a revision of homeostatic property clusters, whose definition is "determined by the members of a cluster of often co-occurring properties and by the (homeostatic) mechanisms that bring about their co-occurrence" (Boyd, 1991). As this phrase suggests, homeostatic property clusters are already relational. Still, I prefer the notion of a relational cluster because homeostatic clusters focus on biological species as natural kinds, whereas relational clusters that I propose here involve any kind of co-existent formality. In living systems, relational properties usu-

[11] In modern analyses, self-maintaining identity is associated with downward causality, and it is also claimed that downward causality provides a contemporary explanation for formal cause (Juarrero, 2014, see Sect. 2).

ally arise based on genealogy, developmental constraints, or functional coherence, which means that relationality in biology usually has an objective basis. Allometry is such an objective basis for the appearance of relational properties. It focuses on specific ratios between anatomical parts or other traits such as the ratio between the metabolic rate and the size of the organism. Allometric principles also imply morphological similarities between different species. For example, as the mass of an animal increases, the ratio of the thickness of bones to the bodyweight that is required to hold the animal becomes higher, so that the bone has to be proportionally thicker. This is a physical constraint which creates relational similarity at a supra-species level. On this basis, comparative anatomy can identify a Bauplan as a structural type. Baupläne as well as other kinds of relational clusters are formal, and their formality is correlated with specific causal factors: a common ancestor underlying a homologous structure, a selection pressure underlying an analogous structure, etc. What I suggest by relational clusters is quite similar to the way that structural realism conceptualizes formality in living systems. The underlying pattern of this kind of forms is mainly an objective element such as physical constraints, but this objective element is not directly embodied within a single individual. Instead, it refers to typical occurrences of formal qualities.

What I emphasize here is pure relationality instead of natural kinds. Clustering of properties is dependent on prioritizing certain qualities pertaining to a group of individuals, and thus, determination of formality needs to be partially subjective. Even if the aim is finding out relational necessities that are objective, it involves the prioritization of certain groups of properties. For example, quadrupedality in mammals is typical. The origin of quadrupedality can be ascribed to developmental constraints, evolutionary contingency, or selective advantages, all of which support this formal quality as a distinct phenomenon. The causal relation between the form of quadrupedality and these evolutionary factors is external, whereas focusing on the quality of having four legs among numerous possible combinations of traits involves a subjective preference. This means that subjectivity cannot be completely ruled out when identifying property clusters. After the focused qualities are associated with certain relational factors, form could be justified on objective grounds, enabling the abstraction of formality that could be applied to multiple species.[12]

[12] Deely (2001) states that the role of the subject that prioritizes certain formal qualities is described as extrinsic formal cause by Latin philosophers such as John Poinsot. "Extrinsic" formal cause refers to a kind of blueprint that guides production processes or the specifying awareness of the subject (Deely, 2001, pp. 29–30), as opposed to the intrinsic formal cause (which is primary in Aristotle's view) that refers to the self-maintaining identity (as mentioned above, what corresponds to my description in (1)). Aside from my critical points toward hylomorphism, (2) and (3) can be associated with extrinsic formal cause due to involvement of a specifying role of an external evaluation—which has an intersubjective nature (as Deely points out). Note that the formal cause is supposed to be extrinsic to the object that has the form, which is not to be confused with—and in fact, contrary to—what I suggest by an external ground. The latter refers to the non-cognitive, objective basis of form, which is in line with intrinsic formal cause.

(3) Context-dependent transmission of the form refers to the dynamics that influence how forms are transmitted, i.e. the ways that they are generated, received, and interpreted. Typically, forms are produced, processed, and conveyed by subjects with cognitive powers (primarily by humans, and considering the approaches such as zoosemiotics, arguably by other intelligent animals as well). Consider the form of a bronze sphere. Sphere is the shape, which is a core element of the form, whereas the abstractive exploration of the form is not limited to the immediate shape as it appears, i.e. geometry of the sphere implies a quantifiable explanation of the shape, and this requires the involvement of other theoretical tools such as the theorems of Euclidian geometry. Thus, transmission of forms corresponds to an extensive cognitive area where actual systems are abstracted away, reconceptualized, and modelled. Through cognitive operations, real systems are projected as representational elements, which then could be integrated within further abstract procedures. Identification of structural properties also helps to explore the possibilities of physical rearrangement of things, so that the relevant agent could gain a regulatory capacity by processing formal qualities. In this way, mental representations pave the way to behavioural changes of the agent that generates them.

These interpretative and behavioural changes are the nexus of the context-dependent transmission of the form. For instance, perception–action cycles are basic feedback systems where form is embodied within material processes. These cycles imply that identification of formality as a mental operation is transferable to behavioural outputs for the holders of form. On the other hand, since we have begun to speak of the interpretative and behavioural context of mental representations, forms are not to be considered exact representations anymore. They become now means of making decisions and constructing networks of meaning, which ultimately constitute the *Umwelt* of an organism. Let us suppose that an animal perceives the shape of an entity. What is transmitted here is a mnemonic entity, which is a simple mental representation. As soon as this form is transmitted behaviourally or internally (by interpreting)—or even whilst it is generated—it becomes open to various manipulations. Thereby, forms are immediately turned into signs through transmissions. Of course, this explanation involves a simplification of the shape-form-sign transitions. If we consider the complexity of high cognitive skills, it becomes obvious that forms are usually generated due to various factors of abstraction such as categorization, mental association, pattern recognition, etc. Therefore, a representation is influenced by the semiotic universe from its making, which also means that no representation is an isolated mirroring of an external entity.

Context-dependent transmission of forms is enabled by the existence of (1) and (2), and in return, these preceding aspects are amalgamated through cognitive transmissions. Self-maintaining processes and relational property clusters appear externally, that is, structural continuity that is identified as forms actualizes in the first place without the existence of an observer. On the other hand, associating structural continuity with the notion of form is also a matter of mental representations which allow to recognize the underlying individuation behind raw perceptual experience.

So far, I described the transmittance of forms as a mind-dependent phenomenon. In fact, (3) is not restricted to the cognitive domain. As I elucidate in Sect. 5, mechanisms for the internal evaluation of multiple inputs are to be considered the evolutionary basis of form-recognition. This implies a proto-subjectivity condition that is more fundamental than mental representations.

This categorization also explains how such different discourses that I examined in Sect. 3 originate in the notion of form. Gene-centrism, functionalism, and structuralism develop their arguments upon the same problem. Their common explanandum is the organism as a self-maintaining entity, which points to the processual identity (1). Their explanantia, however, vary between each other, and the basis of this variation is the prioritization of specific underlying factors (2). A simple shape, a complex pattern of self-maintenance, or systematic structural factors might underlie a form, but in any case, only when the source is interpreted, i.e. turned into a representational unit within a certain context, can we speak of the possibility of transmittance of forms (3). Therefore, form should be analysed on a relational basis, according to which not only the object as the origin of form, but also the background and the nature of receiver should be taken into account. This points to a semiotic grounding.

5 Biosemiotics as an alternative to hylomorphism

Due to the previously noted issues related to hylomorphism, we should seek new considerations of the form of living systems. In this context, below I will attempt to reinterpret matter-form duality by deconstructing the subject-object relation. Form is primarily an abstractive operation based on mental representations, and to obtain an objective basis beyond this, we first need to deconstruct its mind-dependent nature. This leads my analysis to the semiotic nature of the transmission of forms, which helps to demonstrate the underlying relational dynamics. However, the scope of semiotics should be extended to non-cognitive phenomena, which requires firstly abandoning Cartesian dualism of matter and mind. Peirce also rejects the Cartesian duality as well as any subjectivist position that it brings, instead calling his approach objective idealism. Accordingly, he describes the interpretant without necessarily a human interpreter. Peirce rules out subjectivity due to an extensive consideration of cognition, which is consistent with his panpsychist tendency. As a result, Peircean semiotics as it stands is not helpful with explaining the emergence of subjectivity. Extending semiotics beyond the scope of mind toward biosemiotics—and decentring the role of mind—entails a naturalistic revision of the original ideas. My assumption at this point is that there are degrees of subjectivity, which we can conceptualize in comparison with our own subjective relation with the world.[13] Furthermore, the

[13] Readers of Kant would notice that this argument is similar to Kant's account on the heuristic role of teleology in our conceptualization of biological phenomena (Kant, 1790/2007). Stjernfelt (1999) states that Kant's approach on this is insightful, considering the parallelism with current semiotic discourse. However, what I propose in fact involves an essential deviation from this Kantian position. I believe that ascribing forms to functional requirements, which is an Aristotelian stance at heart, is not a viable solution in the final analysis. For this reason, the role of subjectivity in the appearance of forms is not reducible to a naturalistic account of teleology.

emergence of form can be understood by examining selective interactions in biological processes. On this basis, I offer to replace hylomorphism with a relational conceptualization of the form.

5.1 An overview of biosemiotics

Biosemiotics, as an integrative discipline, explores the ways that the presumptions of semiotics are embodied in living systems. The systematic research tradition of biosemiotics began with Thomas Sebeok's and Thure von Uexküll's revivalist attempts on Jacob J. von Uexküll's works. Despite the significance of this main line of thought, I would like to focus on another key figure in semiotics, Charles S. Peirce, as his thoughts are more relevant to the main philosophical problems of this paper. Peirce's focus was not biology, but his theory of signs had a big influence on biosemiotics. Peirce proposed a triadic system for sign relations, which includes the object, the sign, and the interpretant. The sign represents the object, as the object determines the conditions of signification by constraining the sign. The interpretant is a further elaboration of the relation between the object and the sign, a varied determination on the way that representation occurs. As Deely (2014) states, the reason behind the interpretant as a third element is that the relation of signification is something different from both the object and the sign itself. For example, causal relations between the fire and the smoke that comes up from the fire, or clouds and the rain that drops from the clouds are dyadic in nature, but only due to the existence of this third element, the interpretant, smoke can be a signifier of fire and clouds can be a signifier of rain (Deely, 2014, p. 390). A triadic system can become the object of a further interpretation, and thereby triadic systems are linked to each other within a universal chain of signs (Collier, 2014).[14] In fact, the object, the sign, and the interpretant are established only due to these connections between triadic systems; the object is a result of preceding sign relations, whereas the interpretant leads to further ramifications of the meaning, and so on.

Peirce interprets Aristotle's matter-form duality from the perspective of his own theory. As he states, "so far as the 'Truth' is merely the object of a sign, it is merely the Aristotelian *Matter* of it" (Peirce, 1998, p. 304). He remarks that objects belong to the same universe and associates Aristotelian matter with this unity aspect. Signs denote objects and signify qualities, and via signs, we are able to extend the categories of objects and qualities. In this respect, what the sign signifies is the Aristotelian form.[15] According to Peirce, "any medium for the communication or extension of

[14] Atkin (2013) points out that if the chain of triads is not infinite, then it would be inconsistent to assert that the object and the interpretant are always linked to other triads. This is because in a finite chain, an initial object and a final interpretant will not be linked to other triads. On the other hand, Atkin also states that in his later works Peirce replaced the claim on the infinity of signs with an idealized end.

[15] An issue that should not be eschewed here is Aristotle's own view on signs. Aristotle acknowledged signs, although he believed that the logical use of signs is quite limited. According to him, there is only one condition that makes a sign demonstrative: the sign corresponds to a middle term, and the premise that is based on this sign is connected to a universal statement that justifies the conclusion, forming a valid syllogism. For example, "since this woman has milk in her breasts (middle term), she is pregnant" is a valid syllogism because "all women who have milk are pregnant" (Asmis, 1984, p. 214). Aristotle

a Form" is a sign (Peirce, 1998, p. 477). In fact, sign relations constitute a broader area than a context-dependent transmission of form that I described in (3),[16] and in return, the explanatory area of signs does not necessarily include some of the issues with the form (such as (1)). Peirce classifies signs in three respects: distinctions based on the object, the sign, and the interpretant, proposing that a mutual influence of these determines the final character of a sign. There are three sub-categories of the object depending on the ways that it is denoted. Firstly, an icon refers to the signification of a qualitative property of an object without requiring the actual existence of it, such as a painting.[17] Secondly, an index denotes the case in which there is an external causal relation between the object and the sign, such as the smoke as a sign of fire. Finally, a symbol, such as a word,[18] is a result of a conventional or lawful relation between the object and the sign based on habits. As a logical system,[19] Peirce's sign theory prioritizes the role of interpretative elaborations over objects, hence even variations based on the object actually consider the object-sign relation. This interpretative freedom implies that context-dependent transmission of the form paves the way to more complex relations. Once put into context, forms cannot be considered plainly as if they are the shadows of reality. Instead, forms turn into signs inasmuch as the interpretative context becomes prominent.

Deely (2014) emphasizes that the third term in a triadic sign relation is the interpretant, not the interpreter. He states that this is a crucial difference demonstrating Peirce's stance that sign relations do not have to be intellectual (Deely, 2014, p. 392). Still, cognitive domain is primary in Peircean metaphysics. Peirce was not precise on the nature of non-mental triadic relations, and he provided only one example, which is his statement that if a sunflower gains reproductive capacity by turning towards

Footnote 15 (continued)
remarks that the use of signs can be only rhetorical when signs are not accompanied by universal statements, pointing to the fallacies in these rhetorical uses. Asmis (1984) compares Aristotle's view in question to the ways that Epicurus and other Hellenistic philosophers use signs. In the Epicurean use, observations are considered as signs of the unobserved so that conjecturing the nonapparent becomes possible. Contrary to Aristotle's claim that signs are mainly rhetorical, various philosophers from three main Hellenistic schools (Epicureans, Stoics, and sceptics) explored the uses of signs in analogical and inductive ways of reasoning. Still, Asmis (1984) points out that Aristotle –despite his own denouncing—also appeals to this inductive aspect of signs. She gives examples from Aristotle's investigations on various topics, and concludes that Aristotle was a precursor of the Hellenistic considerations of signs. However, whether Aristotle approved the use of signs or not, his own understanding of forms does not essentially overlap with the affirmative way that Peirce linked signs with forms.

[16] For instance, not only things, but also relations between things can be included in the analysis of sign relations.

[17] Because I primarily address the question of the externality of forms, I cite Peirce's classification relating to the object. Peirce proposes further categorizations for signs, interpretants, and even sub-categories for these. For example, see Peirce (1998, pp. 273–274) for the sub-categories of an icon.

[18] The symbol here is not a word as it is written down on a paper, but as it exists in our minds and denotes a kind of thing (Peirce, 1998, pp. 9–10).

[19] In fact, Peirce's focusing on logic is consistent with his objective idealism, which prioritizes minds in the explanation of the nature of things, considering matter as the effete mind (Peirce, 1992, p. 293). Nonetheless, Peirce himself admitted that extending sign relations to physical phenomena is a difficult issue and left it unclarified. This led to controversies over pansemiosis and physiosemiosis (Deely, 2001; Salthe, 2005).

the sun, thereby generating a similar relationship between the sun and the flower in the next generation, then the sunflower is to be considered a Representamen (sign) of the sun (Peirce, 1998, p. 273). Sebeok (2001) extended the research scope of semiotics to other animals, proposing the notion of zoosemiotics (p. 41). Sebeok's semiotic approach is based on the notion of *Umwelt,* which denotes an organism's semiotic world that is constructed via the functional relationship between the organism and the environment. Other extensions of semiotics were also proposed, which involved internal biological processes (endosemiosis; von Uexküll et al., 1993), plants (phytosemiotics; Krampen, 1981), the origin of life (Salthe, 2005), molecules (Prodi, 1988), and even all physical phenomena (physiosemiosis: Deely, 2014).

The biosemiotic accounts given by Collier (2014), Salthe (2005, 2008) and Vehkavaara (2002) have taken issue with the idealist character of Peircean semiotics and attempted to propose naturalistic reinterpretations. In the remaining part of this paper, I will follow this exegetical approach. As Vehkavaara (2002) rightfully remarks, an obstacle for applying semiotics to life's form is that "[t]o be the basic concept of representation for biosemiotics, the Peircean concept of sign is still too anthropomorphic" (p. 12). To overcome this issue, I think the panpsychist tendency within the theory of Peirce should be neutralized by decentring his thought-based metaphysics.

5.2 Symbols and the emergence of subjectivity

In this final section, I explain how semiotics can be extended to include biological phenomena, where symbols have an essential organizational role. Such an extension is already made under the title of biosemiotics, and I follow the basic assumptions of this area. The unique aspect of my analysis is focusing on the question of form in search of an integrative explanation. Consider the construction of a form as a mental representation. Say, we see an entity, and conclude that its form is spherical. In order that we are able to speak of the spherical form of this entity (the communicative transmission of forms), perception, memory, and other cognitive factors must be involved—even if we declare that the entity is spherical while still observing it, memory would be involved because we need to recall the meaning of sphericity, etc. As soon as the notion of "spherical" in this case gains an intersubjective character, the form becomes a sign. If the spherical form is also considered as a symbol relating to a third element, the context is prioritized over the physical connection between the concrete entity and its form. Thus, forms pave the way to the generation of symbols. What is the role of subjectivity here? Although an individual identification of form is a subjective process, communicating forms—and thus, signs—requires an overlap with another subjective identification, and this points to an intersubjective phenomenon. Signs as specific forms, and symbols as specific signs are conceptualized depending on our cognitive subjectivity, where resides multiple networks of the units of our memory and a capacity to generate new symbolic connections. On the other hand, if it can be demonstrated that symbolization and form-recognition also appear within mind-independent biological processes, we can conclude that semiotics is also applicable to more fundamental processes of life. Our own subjective identification of symbolic elements within these biological processes would not suffice to justify extending the scope of semiotics, because what we need to explore is a pre-cognitive capacity that could establish symbols as biosemiotic elements. Below, I claim that such a capacity is evident, and that it appears as a proto-subjectivity condition. I support my claim respectively with Howard H. Pattee's theoretical analysis on the use of symbols, internal evaluation nodes that synchronize certain coincidental inputs, and a hypothetical case of the relational dynamics in enzyme specificity. Finally, I explain the implications of this general biosemiotic perspective that relates to the critique of hylomorphism.

As stated above, symbols denote a way of specifying signs. Stjernfelt (1999) remarks that signs are underdetermined as opposed to an overdetermining environment, and that this makes signs efficient but also fallible (p. 550). The evolution of life has adopted this efficiency. Peirce (1998) defines the symbol as a conventional relation between a sign and an object, which suggests that symbols can be used to develop codes and language systems. Human language is a highly complex system which exemplifies the cognitive use of symbols. Besides, there are other species that use various types of languages. For example, symbolic nature of dance communication in honeybees is so efficient and sophisticated that it has been referred to as a language (Crist, 2004). In this communication system, distance, direction, and type of resources are announced by using dance movements as symbols. The cognitive dimension of the honeybee dance involves controversies on issues such as intentionality, so the degree to which it can be presented as a case that supports my aim to expand the scope of semiotics is questionable. On the other hand, non-mental incidences of the use of symbols are based on the "coding" behaviour in life's processes, in which symbols are essential to constructing organizational levels and creating robustness. A symbol is "something that stands for something else by reason of a relation, but it is implicit in this concept that the relationship of symbol to referent is somewhat exceptional" (Pattee, 2012, p. 205). A symbol in a biological process is a decoupled element, which leads to an asymmetry between the controlling and the controlled. For example, hormonal signalling, as a centralized mechanism of communication, is decoupled from cellular processes. A few molecules would be sufficient to initiate signalling cascades, and therefore a small energy investment can sustain the function. For a small amount of hormone is sufficient to create the effect, hormones can be highly influential in a regulative system without being influenced by the functional parts to the same extent. In this way, hormones can act in accordance with the holistic needs of the organism. Organisms are characterized by the regulatory cohesion in which symbols enable the continuity of form against perturbations by using internal information within the system. This type of organizational closure is key for the functioning of living systems (Pattee, 2012).

Pattee's theoretical approach illuminates how the formal aspect at the molecular level is linked to biological evolution through symbols. Symbols help to increase controlling and survival abilities of organisms in specific environments (Pattee, 2012, p. 214). This is done via a biological way of measuring. Measuring activities depend on reducing the material degrees of freedom of systems to a few semantic references, which is equivalent to the basic role of symbolic information in constraining and controlling living systems. In an ordinary physical measuring, the distinction between symbol and matter is clear. Yet, this is not the case in organisms because of the difference between an external analysis and internal utilization of symbols. From an external viewpoint, we need to fully investigate the complexity of relevant systems to understand the function of symbols. For example, in order to externally determine and reinstate the symbolic role of a gene sequence in protein coding, in addition to the specific role of symbols, the computation of the whole complex mechanism across the hierarchy of organization is necessary. However, from an internal perspective, to perform the folding within a cell, all that is required is the reading of the base sequence. In other words, symbols enable organismic functions by simplifying the functional relationship between regulatory processes and their requirements.

Pattee (2009) proposes his view on the matter-symbol complementarity as part of a biosemiotic explanation of the evolutionary emergence of symbols (although Pattee is not a strict follower of biosemiotics himself). Matter denotes physical processes, whereas symbolic world is representational, timeless, and semantic. He points out that biosemiotics focuses on the relationality of matter and symbols, unlike the Cartesian approach which postulates that matter and mind are distinct (Pattee, 2009, p. 524). The epistemic cut between the knower and the known, which also implies a categorical distinction between measurements and laws of nature, underlies matter-symbol complementarity. The observer's measurements—as well as its initial state—are local and irreversible, while the dynamic laws are universal and reversible. The observation is made from the perspective of a different system that is distinct from the one being observed, and it freezes certain features of a system as a form or a record that is kept in a memory, hence this symbolic aspect is timeless (Pattee, 2009, p. 527). For instance, DNA has such a symbolic nature vis-à-vis evolutionary changes, as gene sequences are like memory records of evolution. Moreover, selective control of the rate of matter and energy flow within the living systems is exerted through the instructions of symbols. Protein synthesis is one of the processes that is regulated by systems that utilize symbols, as the rates of genetic expression and enzymatic activities are internally controlled due to the symbolic function of amino acid sequences (Pattee, 2012). Similarly, symbolic and dynamic factors are integrated through the connection between enzymatic RNA and the relevant enzyme. Enzymatic RNA takes part in both the translation process that builds an enzyme and keeping the symbolic record of the enzyme. In the former, it is folded in a three-dimensional configuration, becoming active, whereas in the latter, it is an unfolded passive sequence. On this basis, Pattee (2009) claims that enzymatic RNA bridges the rate-dependent material construction and the frozen symbolic (formal) aspect (pp. 534–545).

The symbolic nature of biological organization points to the ways in which timeless elements are involved in regulatory control. On the other hand, this leads to the question of the receiver of formal/symbolic elements. The answer lies in the utilization of forms in dynamic regulation, which points to the existence of internal evaluation processes within living systems. Endogenous mechanisms that create synchronicity underlie such an internal evaluation. A synchronic consideration involves the values of multiple factors in context, that is, instead of decomposing a relational system into consequent events, these values are considered simultaneously. Bruni and

Giorgi (2015) state that living systems involve variability in representational capacity. On this basis, they define the capacities of internal decision-making as proto-subjectivity. In the mechanistic approach, the observation of a causal interaction is made by presupposing that the observer can have no influence on the system. On the contrary, simultaneity of multiple evaluations leads to internal control in living systems (Bruni & Giorgi, 2015).[20] Organisms involve multiple internal elements that detect simultaneity and make choices between mutually exclusive possibilities of action. This in return brings about the possibility of error and incompatible inputs, but these downsides can be resolved by appealing to a broader context. This synchronicity condition corresponds to the biosemiotic system where a relation between two components gains a new "meaning" in coincidence with a third (at least). In this way, such a triadicity could constitute a bridge to more complex systems of synchronicity.

Internal nodes of determining coincidental inputs imply an organic evaluation mechanism, which is specific to an individual, and which does not necessarily have a cognitive context (although cognitive processes could be supervenient on these mechanisms). Proto-subjectivity exemplifies the emergence of interpretants, and thus, non-cognitive embodiment of forms. Peirce claimed that triadic relations require the existence of at least two quasi-minds (Peirce, 1998, p. 544). Rather than the quasi-mind, what appears at this biological level can be defined as the quasi-subject and the quasi-object. I describe the quasi-subject as a local capacity for a perspectival contextualization of externalized elements, and the quasi-object as the source of form that is to be put into context. Replacing the Peircean notion of the quasi-mind with the quasi-subject vs. quasi-object relation would support the biological explanation of proto-subjectivity, and help to make semiotics consistent with materialism. In the abovementioned case, internal evaluation nodes act as the quasi-subject, whereas the inputs that are synchronized become the quasi-objects of the internal decision-making.

But can we extend this semiotic analysis to include the physical basis of living systems? I believe that this is possible, but taking a last step to integrate the relevant dynamics in physical interactions will be necessary to conclude the naturalist reinterpretation of sign relations. Living systems are widely characterized by goal-directed activities. Such an extension, on the other hand, would help to reveal the underlying dynamics of the form that enable these goal-directed activities. Since our question is a natural explanation of semiotics that is consistent with a historical (evolutionary) explanation, we need to answer how the interpretant—hence other elements of semiotics—appeared in the first place, preceding an anthropomorphic subject as an interpreter. In other words, historically, semiotic "meaning" should have emerged without a high form of cognitive agency, and there should have been

[20] A synchronic consideration of various factors was also maintained by cybernetics, which similarly involves the notion of controlling systems internally. This type of cybernetic analysis states that the relation between A and B depends on the value of a third component of C (Ashby, 1962, pp. 255–256). The idea of internal control in cybernetics was inspired by organisms. See Arnellos et al. (2012) for another comprehensive account of the role of synchronicity in living systems, which is provided in relation with anticipatory systems and biosemiotics.

proto-semiosis preceding the semiotics in complex biological systems. Giorgio Prodi proposes an approach which could help to fill this gap; a relational ontology, in which complementarity in physical interactions is presumed as a ground for biosemiotics. He focuses on the determinative nature of the relations themselves, ascribing meaning of signs to the transformation of previous relations. On this basis, the main goal of Prodi's project is to explain semiosis as a consequence of biosemiosis, for he believes that otherwise the former will remain as an idealist theory (Cimatti, 2018, p. 56). Prodi (1988) points out that dualities of matter vs. form and structure vs. function can be misleading because reality is structured through interactions. Pointing to the relational basis of the form, he states that "[a] material complex cannot exist without a given volume and a given form. However, a form can only be identified by interaction with its matter and through the energy exchanges produced by this interaction" (Prodi, 1988, pp. 193–194).

In Prodi's viewpoint, perspective is involved even in a basic interaction between two molecules. He analyses the basic conditions of biosemiotics by focusing on a relation between two molecular units (Prodi, 1988). Cimatti (2018) explains Prodi's theoretical view with the following hypothetical case: *A* moves freely in its environment, and runs into the molecules of *B, C, D,* and *E.* Suppose that *A* is a protein that has a specific steric structure, which enables a key-lock complementarity with *B,* but not with *C, D,* or *E.* Upon encountering, *A* and *B* integrate each other merely depending on their respective structures. Only the relation between *A* and *B* leads to a certain biological continuity, e.g. an enzymatic reaction, and this means that *A* and *B* "choose" each other (Cimatti, 2018, p. 52–53). It should be noted that there is no purposefulness behind this selective interaction. Instead, *A* meets *B* as a consequence of the probabilistic outcome of their alternative presences. Whereas once they coincide, the *AB* assemblage becomes a new relational unit that enables new possibilities for biological organization—and semiotically, new categorizations and interpretations. These kinds of basic interactions are reciprocal, and therefore they do not involve any differentiation of the object and the subject. As Prodi (1988) remarks, in such an interaction, "B is a sign for A and vice versa" (p. 195), because it is the shape of *A* from *B*'s perspective as well as the shape of *B* from *A*'s that enable their integration. Moreover, "the sign is embodied in the event" (Prodi, 1988, p. 196), as the event in question could be semiotically incorporated within a larger assembly of organization. On this basis, Prodi analyses how more complex semiotic structures emerge (cognitively), enabling the representation of a referent even if the referent as a body is lacking.

According to key-lock model, the direct reason of complementarity is supposed to be the cavities and indentations within the active site which make the relevant enzyme physically fit to contact certain substrates. However, this model is outdated and recent biological research has shown that the underlying dynamics are usually more sophisticated. As an alternative, induced fit theory claims that the enzyme structure is flexible, and the active site is altered upon the first contact between the enzyme and the substrate in a way to stabilize the binding. Various additional mechanisms have been analysed as well, e.g. transition state stabilization presumes that numerous unfavourable interactions within the enzyme–substrate complex help to distort the shape of substrate in a way that the process of catalysis is facilitated

(Palmer & Bonner, 2011). In this sense, a more refined description of the enzyme function involves that complementarity is an acquired situation depending on the perspectival effects on shapes (between the active site and the binding substrate). Prima facie, this makes a ground to claim for a primitive evaluation of forms, as the components of integration are (or become) functionally sensitive to the shapes of each other. However, there is another crucial element that is required to prove the relevance of forms within such biological interactions. Before I pointed out that transmittance of forms only appears as an outcome of (proto) subjectivity. Without proto-subjectivity in biological processes, the event in this example is to be plainly considered a physical contact, and the form would be in the eye of the human observer, since there would be no objective ground to show the relevance of forms beyond shapes. In other words, if organic evaluations are ruled out, then it would be only the anticipating observer who sees the potential for forms in the complementarity of shapes, suggesting the teleological view of functions and forms.

Prodi's emphasis on the reciprocity of sign relations at a basic interactional level is key to identifying the beginnings of proto-subjective evaluation, but this requires a critical examination of the main idea. As mentioned above, Prodi states that *A* and *B* act as signs for each other. Claiming that signs are reciprocal in this way actually provides no ground as to the specificity of interrelation that could determine the sign objectively. I concede that there might be reciprocal processes such as this, occurring without any (quasi) subject-object relationship. However, for the appearance of forms, it is essential that reciprocal relations should be specified as directional causal interactions which allow the mechanisms of form-recognition. In the abovementioned example, reciprocal selection between *A* and *B* is quite coincidental,[21] since *A* freely explores its surroundings, and then matches up with *B*. Yet, there are other mechanisms at the molecular level that impose additional constraints to make either *A* or *B* "see" the other. Allosteric regulation of the enzyme functions, which denotes the role of dynamic factors upon the complementarity between molecules, exemplifies the emergence of "form-sensitivity" in this way. Let us reconsider the abovementioned situation on this basis. Suppose that *A* is an enzyme, whereas *B* and *C* are two different substrates. *A* normally catalyses the substrate *B,* but not *C* (due to complementarity). These kinds of functional specificities are typical to enzymes. In real systems, allosteric regulation is usually so complex that it appears in pathways with various dynamics such as feedback inhibition, but for the sake of analysis, let us simply hypothesize that *D* is an inhibitor for *A*-*B* reaction, and *E* is an activator for *A*-*C* reaction.[22] When only *D* steps in before any reaction, *A* will catalyse neither *B* nor *C,* whereas when only *E* steps in, *A* could catalyse both *B* and *C* (assuming that *B* and *C* are not competitive). When both *D* and *E* step in, *A* will not catalyse *B,*

[21] On the other hand, in Prodi's account, this does not have to be the case for more complex structures. Prodi claims that a federation of readers, which arises with more complex biological structures, enables distinguishing the sign from its referent. For Prodi, this is mind (Cimatti, 2018, pp. 55–57).

[22] Allosteric inhibitors disrupt the function of enzyme for a substrate either by competitively binding to the active site of the enzyme, or by altering the shape of the enzyme, whereas activators enable a catalysis by altering the enzyme's shape.

but it will catalyse *C*. As a result, *A*'s shape could be altered in three different ways. So, there will be four reaction possibilities (including the default *A*–*B* reaction).

Inhibitors and activators could interfere depending on the needs of organisms, e.g. an inhibitor checks an excessive amount of a product. When the relevant inhibitor or activator dissociates, the enzyme returns to its initial functioning. In this way, internal perspectives of shape recognition could be dynamically regulated by altering the conditions of complementarity. Alternatively, consider that the abovementioned combinations are provided without the regulation of the closure of organization, but these five components freely move around by giving rise to interactions by chance. In this case, determination of the perspective of interrelations is not incorporated within goal-directed processes, but rather as probabilistic outcomes of alternative sequences of encounters. In this scenario, possibilities of altering the enzyme shape remain intact, and complementarity between the molecules is still dynamically regulated, albeit on a random basis. This means that the probabilistic relations between these five components involve internal transformation dynamics that shifts the reading of the reciprocal shapes. Besides, [*A* and (*D* and/or *E*)] gains a proto-subjective evaluative capacity through these relations. This is because enzyme-inhibitor/activator interactions alter the dynamics of form-reception, whereas no similar alteration is presupposed as a result of the remaining combinations (Interrelations between non-enzymes and the *A*–*C* interaction have no effect in terms of changing the reaction possibilities, and a preceding *A*–*B* reaction would not make a difference for *A*–*C* anyway.). This creates directionality in causal relations. In this way, even if the molecules contact probabilistically, a subset of interrelations (enzyme-regulatory molecules) will determine the perspective of complementarity, hence the ways in which forms are recognized.

My analysis so far has focused on different dimensions of semiotics, namely, mind (which involves subjectivity at first hand), proto-subjectivity in biological processes, and perspectivity in the physical basis of living systems. Although I started my examination from the synchronic condition of mind (synchronic due to involving form as a timeless representation), as for the diachronic condition (evolution), matter is antecedent. To completely illuminate the underlying physical phenomena, engaging crucial philosophical problems such as potentiality would be necessary, however these are beyond the remit of this work. Still, I would like to mention a philosophical approach due to its relevance to the main problem of this paper, an approach which could also shed some light on the role of potentiality. This is Gilbert Simondon's theory and his critique of hylomorphism. Karatay et al. (2016) make a critical comparison between Peircean semiotics and Simondon's theory of individuation. The authors point out the drawbacks of objective idealism of Peirce—although without making it explicit that idealism is the origin of these issues—and claim that these downsides can be remedied by appealing to Simondon's theory. Peirce believes that matter is effete mind, and that gaining of habits by repetition is the basis of the laws of nature. As for hylomorphism, he incorporates into his theory the Aristotelian notion that matter is passive and potential. Karatay et al. (2016) criticize Peirce's prioritizing of the mind. They claim that matter-form duality is an underlying theme of Peirce's approach, pointing out that habitual evolution of the universe is contradictory to this kind of material cause (Karatay et al., 2016, p. 429). On the other hand, in contrast with Peirce, Simondon refuses hylomorphism, arguing that it inappropriately presupposes a principle of individuality that exists before the process of individuation. Instead of such a preceding principle, an unstructured preindividual state (metastable domain) precedes individuation, e.g. a potential state for crystallization waiting for a germ of structure to initiate the process. Physical mode of individuation loses its potential to change once the individual emerges, whereas in vital mode of individuation, the individual interacts with preindividual states to discover new domains of metastability. Karatay et al. (2016) remark that, unlike some dualities, Simondon refers to an ontic state of operative relations. According to their interpretation of Simondon, mind is not the origin, whereas the evolution of individuals that are characterized by spatiotemporal locality is a central theme. On this basis, they propose to revise Peirce's view on mind-matter relation with a statement that "structure of individuated being is effete preindividual potential in the process of individuation" (Karatay et al. 2016, p. 427). Simondon's theory considers not only processual aspect of identities that I emphasized before (1), but the nature of process-relational identities. Thus, reconciling this approach with biosemiotics supports both my general critique of hylomorphism and the relational ontology that I promoted above as a naturalistic alternative. Of course, this brief summary of Simondon's philosophical theory provides a research perspective instead of direct empirical evidence, pointing to the openness (a system's being undetermined and engaging with its own indeterminacy) of individuation processes of organisms. I believe that this view is a candidate to pose an alternative to the cosmological teleology of organization that I criticized earlier.

The synchronic condition of form that I emphasized before reflects a timeless conceptualization of the surroundings, which is an aspect that overlaps with the nature of symbols in biological processes. On the other hand, the form also has a diachronic condition, which denotes the evolutionary basis of accumulating continuities that are embodied within present interrelations. Pre-cognitive and cognitive dimensions of subjectivity have emerged out of the potential of relationality, ascending from perspectival interrelations to proto-subjectivity in organic processes, and finally to complex networks of transmitting forms including mental representations. What is the lesson from here for hylomorphism? Aristotle's hylomorphism is dependent on substances in which matter as unformed potentiality, the dynamics of processual identity, and the formative influence that is ultimately reflective of *telos* are embodied. Contrarily, a modern way of explanatory reduction of matter-form duality could be suggested on the basis of a physicalist understanding. After all, the physicality of events points to a general description which precedes the emergent nature of subject-object relationship due to which relations, qualities, entities, and their forms become individually identifiable. As I argued throughout this paper, hylomorphism versus explanatory reductionism is a false dilemma. As a third option to hylomorphism and its modern dissidents, biosemiotics proposes a relational understanding of forms, in which forms are complexified further through sign relations. Considering the biological basis of subject-object differentiation that I explained above, we need to acknowledge that a new dimension of physicality consists in the specific relations that give rise to forms. As the ontological roots of forms which go down to the perspectival nature of physical interactions show, if a comprehensive analysis of life's organization is the case in point, then explaining away forms is not an option. Empirically as well, there is no way to escape the necessity that reality is described through the emergent differentiation of forms.

6 Conclusion

In this paper, I aimed to point out some deadlocks of the revivalist attitudes toward the formal cause. I also developed an alternative account by investigating the intertwined characteristic of the externality condition and the representational basis of form. In general, my criticism of neo-Aristotelianism pointed at the cosmological hierarchy and teleology at the roots of the formal cause. The assumptions based on the formal cause will have to deal with the metaphysical burden of the broad consequences of Aristotle's philosophy that accompany this notion, whereas these metaphysical implications usually are not investigated within the accounts that integrate Aristotelianism and modern biology. Moreover, I exposed that many of the contemporary interpretations of the formal cause have superficial and/or manipulative aspects. I addressed the efforts to reconcile hylomorphism with gene-centrism, functionalism, and structuralism. These approaches problematize form in different ways, and as a consequence, provide partial accounts that are not adequate on their own to cover the philosophical basis of the issue. Gene-centric explanation reduces the determination of form to the "coding" at molecular level, underestimating the role of other factors. As a revision of this view, considering genes due to their role in stabilizing the form of organisms appears as a defendable position. Reconciling the formal cause with the role of natural selection is admissible only as to explanatory pluralism concerning the form of organisms. Still, it seriously deviates from the original idea because moulding effect of selection appeals to a phylogenetic consideration of the formal cause, instead of intrinsic directionality that is implicit in the origins of Aristotelian philosophy. Structural realism, which proposes abstract organizational properties as a replacement of the formal cause, is characterized by a revisionist interpretation of the main claims of hylomorphism. In this account, organization is distinguished from lower-level components, although components and organization are to be considered identical from a process-relational viewpoint.

Despite certain problems deriving from both ancient origins and modern interpretations, Aristotle's view on forms is based on a systematic view. In Aristotle's metaphysics, that forms are acquired and maintained through shaping matter is a central theme, and this is an ontological description which is quite suitable for understanding living systems. Sure enough, hylomorphism also presumes a link between representational and external bases of forms. So, why cannot we offer a new neo-Aristotelian approach based on semiotics, then? Since Peircean theory of signs has been influenced by Aristotle in certain ways (Belucci, 2016; also see Sect. 5.1.), this effort would not be utterly ungrounded. Nonetheless, a major problem here is that the way that Aristotle conceptualizes forms is highly influenced by his cosmology, in which pure form is associated with a godlike activity of thinking. As I explained in relevant sections, this speculative assumption underlies the distinction between matter and formative movements, which would pose a serious obstacle against naturalistic understanding of biosemiotics and life's form.

In addition to the incoherencies due to being too revisionist toward the original ideas of hylomorphism, the neo-Aristotelian approaches that I discussed involve limited understandings of the form because they disregard the organic basis of the subject-object relationship. These criticized approaches consider form merely in relation with its external features such as individuality or relational properties. However, the concept of form could be referring to external properties as well as to mental representations depending on the context, whereas the underlying reason of this equivocality is rarely questioned. The answer lies in the specificity of external elements that are internalized from certain perspectives of transmission (including the potential for subjectivity). Semiotics provides an explanatory basis for an integrative analysis of this specificity. In my analysis, this meant reorienting the focus of matter-form duality based on an empirical investigation beginning with the question of form as we construct it. A naturalistic interpretation of (bio)semiotics suggests that transmission of forms could occur based on a duality of the quasi-object and the quasi-subject, which helps bridging the physical level of perspectivity and the form as a mental representation. As evidenced by the internal nodes that synchronize coincidental inputs and specific alterations of complementarity, living systems involve pre-cognitive forms of subjectivity. On this basis, further arguments on the emergent evolution of mental subjectivity could be developed. My interpretation of biosemiotics hypothesised on the evolution of proto-subjectivity, whereas the hypothesis at hand could be better supported by more detailed analyses describing other relevant biological processes and evolutionary pathways. Future studies adopting a similar theoretical position toward this issue could help to fill this gap.

Emergent subjectivity also offers a solution to the dilemma of whether form-matter duality is a matter of explanation or causation. Form and matter refer to differentiating ways of seeing the world. However, in the meantime, they refer to differentiating ways that potential interrelations and individuations actualize. When we say that "this has a spherical form" or "this is made of bronze", we not only denote aspects of external reality per se, but also specific ways that we build relations with external phenomena. From our subjective perspective, the ways that these relations are built seem privileged, but semiotics also suggests that our subjective stance is a part of universal relationality. Differentiation of form and matter within our subjective understanding is rooted in the emergence of recognizing specific shapes. Thus, merely stating that everything is material is prone to a dull conceptualization which would be indifferent toward the ontology of subjectivity. As cognitive agents, we perceive and act through a semiotic interface, and only with this respect we need to acknowledge the epistemological primacy of forms. Beyond that, contrary to Aristotle, form is not to be metaphysically prioritized over matter, and contrary to Peirce, signs are not to be generalized in a mind-centred way. Historically, matter precedes forms because subjectivity emerged by evolution.

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