



Darwinian functional biology (*Biología funcional darwiniana*)

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ABSTRACT: One of the most important things that the Darwinian revolution affected is the previous teleological thinking. In particular, the attribution of functions to various entities of the natural world with explanatory pretensions. In this change, his theory of natural selection played an important role. We all agree on that, but the diversity and heterogeneity of the answers that try to explain what Darwin did exactly with functional biology are overwhelming. In this paper I will try to show how Darwin modified previous functional biology. Pre-Darwinian naturalists did not hesitate to attribute functions in which, for example, the traits of one species were in the service of other species. I will try to show that this has consequences on the discussion regarding the nature of functional language, since the main approaches, the systemic and the etiological, do not adequately account for these changes and therefore do not account for the way functional biology regulates the kind of legitimate functions. I will outline a possible new solution to this problem: appropriate functional attributions in Darwinian functional biology could be regulated by a theory or a set of laws that provide the criteria for determining its fundamental concepts.

KEYWORDS: teleological thinking; Darwinian revolution; function; etiological account; systemic analysis.

RESUMEN: Una de las cosas más importantes a las que la revolución darwiniana afectó es el pensamiento teleológico previo. En particular, la atribución de funciones a diversas entidades del mundo natural con pretensiones explicativas. En este cambio, su teoría de la selección natural desempeñó un papel importante. Todos estamos de acuerdo en ello, pero la diversidad y heterogeneidad de las respuestas que tratan de explicar lo que Darwin hizo exactamente con la biología funcional son abrumadoras. En este artículo intentaré mostrar cómo Darwin modificó la biología funcional anterior. Los naturalistas predarwinianos no dudaban en atribuir funciones en las que, por ejemplo, los rasgos de una especie estaban al servicio de otras especies. Intentaré mostrar que esto tiene consecuencias en la discusión sobre la naturaleza del lenguaje funcional, pues los principales enfoques, el sistémico y el etiológico, no dan cuenta adecuadamente de estos cambios y, por tanto, no dan cuenta de la forma en que la biología funcional regula el tipo de funciones legítimas. Esbozaré una posible nueva solución a este problema: las atribuciones funcionales apropiadas en la biología funcional darwiniana podrían estar reguladas por una teoría o un conjunto de leyes que proporcionen los criterios para determinar sus conceptos fundamentales.

PALABRAS CLAVE: pensamiento teleológico; revolución darwiniana; función; enfoque teleológico; análisis sistémico.

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I ain't never done nothin' to nobody,
 I ain't never got nothin' from nobody, no time!
 And until I get somethin' from somebody, sometime,
 I don't intend to do nothin' for nobody, no time!

From the song *Nobody*
 by Bert Williams and Alex Rogers

1. Introduction

There is a broad consensus about the fact that Charles Darwin changed the way scientists and non-scientists perceive reality in the present. Biology (or natural history), of course, changed drastically. Not only were factual theories replaced, but also aims and methods. The role of contingent historical explanations in the current constitution of things; the change from typological thought to population thought, or more generally, the rejection of essentialism; the notion of species and the very meaning of taxonomy; the abandonment of the chain of being or the ordering of beings according to their perfection; the rejection of the idea of evolution directed towards an end or of progress in general, are all usually cited as part of this change. In the previous list we omitted one of the most surprising things that Darwin modified: Darwin did something with what is sometimes called previous “teleological thinking”. The expression “teleological thinking” is quite ambiguous. For example, it can be understood as the presence of a target in evolution. This is incompatible with Darwinism. The aspect that interests me here is a different one. Specifically, I’m interested in the attribution of functions to various entities of the natural world with explanatory pretensions. We will refer to the area of biology that allows for functional attributions with the expression “functional biology”.¹ Darwin changes functional biology. In this change, his theory of natural selection played an important role. We all agree on that, but the diversity and heterogeneity of the answers that try to explain what Darwin did exactly with functional biology are overwhelming. I will discuss this in section 2. This divergence in meta-theoretical analysis regarding the nature of the change introduced by Darwin in functional biology is substantially related to the diversity of responses from the philosophy of biology (practiced by scientists or philosophers) about the nature of functional language. Of course, agreement on meta-theoretical issues is difficult to achieve. Yet sometimes, some consensus is achieved in certain areas, and discussion progresses to a better understanding of the object. The different approaches to functions, in turn, suffer from such a (meta)incommensurability that is difficult to imagine a meeting point between them.

This work has, then, this double objective: A better understanding of Darwin’s change in functional biology is a major and primary objective. The second objective, however, is that

¹ This use of “functional biology” does not completely coincide with Ernst Mayr’s distinction between functional and evolutionary biology (Mayr, 1961). Moreover, it is important to note that the use of functional language in biology is not restricted to what I mean here by “functional biology”. For example, functional language is also used in ecology (see for example Bellwood, Streit, Brandl, & Tebbett, 2019; Nunes-Neto, Moreno, & El-Hani, 2014). It is not clear that functional language in ecology should be explicated in the same way as functional biology. I will not address this issue here, although it is interesting.

this work on Darwinian thought should have consequences to the discussion regarding functional language and functional explanation in the current philosophy of biology. Therefore, the work will have a historical part, and a second part that attempts to draw consequences from this analysis on the philosophical discussion of functional biology. But in both cases the approach is less historiographical than philosophical. I am not so much interested in what Darwin thought about the matter, but rather in how best to think about what Darwin did.

Regarding the historical part, based on previous work (Ginnobili, 2014), I intend to show the sense in which Darwin modified the previous functional biology. It is often argued that the theory of natural selection provides a superior alternative to previous theories (intelligent design² and laws of use and disuse plus inheritance of acquired characters) to account for how the traits of organisms adapt to the environment (how they acquire functions or increase the effectiveness with which certain functions are performed in the environment in which they live). We will develop and limit this idea. In a strict sense, Darwin changes the notion of adaptation by changing functional biology. Pre-Darwinian functional biology is not compatible with natural selection. For in it, the traits of organisms, and the organisms themselves, can act for the exclusive benefit of other species. The Darwinian world, in which the rule is the struggle for existence, lacks the harmony existing in the Pre-Darwinian naturalists' world, where trees feed animals with their fruits, oxygenate the air with their leaves and beautify the world with their flowers. I will discuss this in section 3.

In section 4, of a more metatheoretical nature, I will discuss the best way to understand this change. I will show that the most important approaches that seek to account for functional language and functional explanation fail to adequately account for the Darwinian revolution in functional biology. I will only focus on the ability of such approaches to reconstruct or explicate the scientific practices of functional attribution—in the Carnapian sense of “explicate” (Carnap, 1950b)—though this is not necessarily the only objective of such approaches. In turn, in section 5, I will defend that it is more appropriate to analyze this change by appealing to the idea that there is a functional theory that was substantially modified by Darwin. If my approach is correct, there are interesting consequences to the way of thinking about functional biology today: functional language does not seem eliminable, and the best way to approach functional biology is not through the notion of *explanation* but the notion of *theory*. Just as it can be argued that what all classical explanations of accelerations in classical physics have in common is an appeal to the laws of classical mechanics (and not some kind of explanatory structure), what functional explanations would have in common would be the appeal to biological functional theory. The laws of this theory would never have been explicit, even though they were ubiquitously used in the practice of biologists.³ This point will become clearer later when I address this issue at greater

² I will use the expression “intelligent design” to refer to the explanation of the functional traits of organisms that appeals to a designer who has certain conscious goals. In particular, for the natural theologians of the 19th century, on whom I will focus specifically, the designer is God. I am not referring with this expression to the current political movement.

³ Of course, in the face of the long discussion about whether laws exist in biology, to say that a specific area in which no laws of its own are usually recognized, like functional biology, may seem audacious. I will assume that in biology there are laws in the minimal and not so controversial Kuhnian or structuralist sense (Díez & Lorenzano, 2013, 2015; Ginnobili, 2016). I will present this conception in more detail in section 5.

length, but to sketch the main idea: functional attribution is regulated by a specific theory, with its own theoretical concepts, and that theory is not reducible either to evolutionary biology or to mere descriptions of how the organism works. In section 6 I will present my conclusions.

In this paper, I will assume that Darwinian functional biology has not undergone substantial modifications since it was outlined by Darwin. This is an important assumption since I intend to draw consequences about current functional biology from Darwin's functional biology. It is possible to show that functional attributions are still similar to Darwinian ones with a more detailed study, but it exceeds the limits of this work. Nevertheless, I think that this is not a controversial assumption and it can be conceded by the reader.

Because I am Darwinian, I believe that the history of an object is more than relevant to understanding the current configuration of the object. In this same sense, to understand the way we think about the present, we not only have to focus on present practices, but also must appeal to how the current conceptual frameworks were forged by those on whose shoulders we stand. We hope that this unquestionably useful way of addressing problems will yield results in this case.

2. *What did Darwin do?*

Given the centrality that the notion of *final cause* and *teleology* has in the history of philosophy, it is impossible to even review its history in one article. It is generally accepted that the notion of final cause, central in the scholastic-Aristotelian worldview, was eliminated from the world of physics in the Newtonian revolution. It is also generally agreed that teleology and the final cause continued to be important, and central to the debate in natural history. It can also be argued that Darwin resolved the issue for natural history by proposing a theory that explained the (apparent according to some, literal according to others) design of living organisms. The impact this had on the rest of science and philosophy, in general, is more disputed. Darwinian philosophers do not hesitate to argue that the impact was enormous.

It is usually (and traditionally) held that the Darwinian revolution would be a continuation of the Newtonian one precisely because it undermines the teleological worldview. The magic would be carried out by natural selection, which would provide the connection between the physical world without purpose and the world of life.

The philosophical relevance of Darwin's ideas (although astonishingly Darwin is not the subject of traditional philosophy courses in many cases) was (and still is) that by offering a natural explanation of how traits of organisms can acquire functions or improve the effectiveness with which previous functions are performed, he provided the solution to the problem of teleology and finality (Ariew, 2007; Wouters, 2005). Natural selection resembled processes proposed before Darwin, where certain random, non-directed, or blind processes could lead to apparent designs (as the explanation proposed by Empedocles), but unlike those, it respected the uniformist methodological criteria established by Charles Lyell. The phenomena on which natural selection was based (variation, inheritance, exponential growth, reproductive success) could be studied scientifically in the present. This is why the natural selection was important to Darwin, and it is not controversial to say that it still is one of the main roles of natural selection, at least in biology, in the present.

These statements are not controversial among Darwin’s scholars. What is controversial is the specific way in which the solution can be approached. The disagreement is strong (at least on the surface). According to some, Darwin eliminated the teleology of natural history; according to others, Darwin gave it new foundations. This disagreement goes back to Darwin’s contemporaries (Beatty, 1990; Lennox, 1993; Lennox & Kampourakis, 2013). In the philosophy of biology nowadays, the discussion about teleology becomes somewhat brutal (at least by the standards of journal articles) in the discussion between Michael T. Ghiselin and James G. Lennox (Ghiselin, 1994; Lennox, 1993, 1994). Lennox aims to show that Darwin did not eliminate the teleology of biology but proposed a new teleology. This new teleology did not fit in with the way teleology was thought of in the 19th century (as dependent on vitalism or intelligent design), but it would fit in with the way biologists and philosophers currently think of teleology (behind the disagreements)—Of course, Ghiselin’s virulent response somewhat contradicted this last statement.

Against Ghiselin’s idea that Darwin’s use of finalist language is metaphorical or ironic (Ghiselin, 1969, Chapter 6), Lennox argues that the appeal to expressions like “design” and “final cause” is literal. This is thorny terrain. Darwin’s texts (like all revolutionary texts) attempt to express new ideas with previously available language, provided by previous paradigms with which the new ideas are incompatible and incommensurable. More relevant than what Darwin says, is what he does. And this is Lennox’s attitude to the issue. To show the teleological nature of Darwinian explanations, he reviews Darwin’s work on the dimorphic condition in the genus *Primula* (Darwin, 1861), a work which, Darwin says in his autobiography, gave him great satisfaction as a scientist (Darwin, 1958, p. 128).

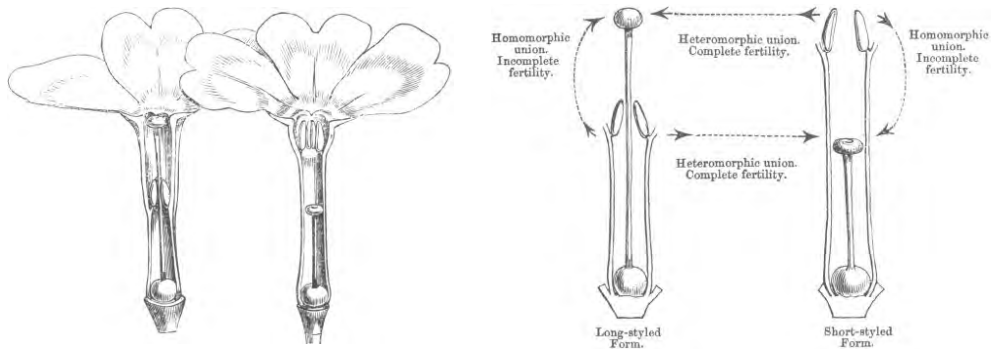


Figure 1

Figures from the paper of Darwin about *Primula*

Lennox reconstructs the explanation to show its teleological character as follows:

1. V (Dimorphism) is present in P (*Primula*).
2. V has the effect E (avoid self-fertilization).
3. E is advantageous to P (because the offspring of interbreeding is more vigorous).
4. Therefore, V in P would be selectively favored.
5. Therefore, V is present in P because of E .

Although Darwin is not very explicit in the work cited regarding 4 and 5, this is not an inadequate attribution of Lennox considering the Darwinian corpus in general.

Why is this explanation teleological? The key lies in the last two points of the explanatory scheme. It is often stated that an explanation of a trait is *teleological* if the end of the trait explains that the trait is there. This is explicitly advocated by Larry Wright (1973, 1976) and is a central component of many (though not all) philosophical approaches to functions. Lennox cites Wright as what he has in mind when he wants to defend the new form of Darwinian teleology (Lennox & Kampourakis, 2013, p. 421). If the reconstruction is adequate, the end of the division into forms in *Primula*, promoting cross-fertilization, would be the reason why the trait was fixed in the population. Lennox strengthens his point by extending it to Darwin's treatment of the subject in his book on orchids (Darwin, 1877b), but the central argument is this.

The central point of Ghiselin's reaction to Lennox's work has to do with the perniciousness of using the notion of "teleology" with the influence that teleological thinking has on scientific practice, and that its analysis adds nothing new or original except to use the term "teleology" (Ghiselin, 1994, p. 490). In contrast, others like Dennett still defend the idea that the language of design should be understood as literal (Dennett, 2017, p. 37). The discussion about whether teleological language is literal or metaphorical, whether natural selection designs, or whether it is an apparent design produces some perplexity. There can hardly be any doubt that both Ghiselin and Dennett understand perfectly what natural selection is about, and how can explain how the functions of the traits of organisms are acquired. What exactly is the disagreement about?

I intend to set the discussion on firmer ground. To try to raise questions that, unlike metaphysical or purely terminological questions, are likely to be answered by the analysis of Darwinian explanatory practices. In this sense, I will follow Lennox's strategy. I will try to show however that in the discussion of the texts about flowers and their importance, some questions are usually left aside, and such questions allow to strengthen and deepen Lennox's point.

I will stop referring to the notion of "teleology" and move on to the field of discussion regarding functional biology and how the practices (and not only the foundations) of functional biology were modified by Darwin. Later, I will come back to the question of teleology.

3. *The Darwinian revolution of functional biology*

To understand what Darwin did with teleology I will concentrate on the question of how Darwin modified functional biology. This question is both explicative and analytical, and its more manageable meta-theoretical character may allow the discussion to progress. Specifically, it may be able to progress in areas where both historiographical discussion (around what Darwin believed) and metaphysical discussion (around the relationship between purposes and ends and naturalism or physicalism) are stuck.

I will introduce my point based on the discussion that exists concerning the *explanandum* of the theory of natural selection (that is, that which the theory seeks to explain). It is generally accepted, and moreover, it is what Darwin himself affirms time and again that what natural selection allows us to explain are the adaptations of organisms to the environ-

ment (features of organisms “adjusted” to the environment in which the organism lives). The theory that Darwin usually chooses as a competitor is the intelligent design proposed by natural theologians. Darwin and William Paley (to mention Darwin’s favorite natural theologian) refer to such features with the same term “adaptations” and also characterize them in the same way: complex entities with coadapted parts that exhibit purposes or ends (Darwin, 1859, pp. 3, 60; Paley, 1809, pp. 1-3) –this is the same way in which features that allow design to be inferred from the very origins of philosophy are historically characterized.

There is a discussion in the specialized literature as to whether there has been a change in the perfection of the adaptations (Blanco, 2008; Ospovat, 1981). However, I would like to focus on another point. Perfect or imperfect, the adaptations as they were conceived by natural theologians suffered a radical change in the Darwinian revolution. The question revolves around the new Darwinian way of conceiving the “economy of nature” and how such a change can be seen as fundamental to the establishment of today’s ecology (Caponi, 2020b; Stauffer, 1960; Vorzimmer, 1965).

The classic source regarding the economy of nature is found in Linnaeus’ work (Linné, 1972). Camille Limoges presents the idea as follows:

In this conception nature is a unique structured and hierarchical whole: the whole universe obeys the same economy, the same disposition of divine wisdom; everything depends on everything, the phenomena necessarily involve each other. (Limoges, 1972, p. 9)

This conception not only applies to living organisms, but also to the mineral kingdom and it is in this framework that the purposes that govern them are understood (Limoges, 1972, p. 10). Linnaeus’ notion strongly influenced Darwin’s (what we would today characterize as) ecological reflections (Stauffer, 1960). But the concept of nature’s economy underwent a radical change in Darwin’s thinking. For the balance is not determined from outside (by the plan of creation) but is the product of negotiation between different types of organisms in the struggle for existence (Limoges, 1970, p. 151, 1972, p. 11; Mayr, 1982, pp. 482-485). This implies, of course, a fragile equilibrium.

Both Caponi and Limoges point out that this feature of functional biology is not restricted to natural theology but is common among pre-Darwinian naturalists. I will focus on the functional biology of natural theologians (mainly in William Paley’s works) because numerous examples of functional attribution can be found in their works and also because it is with them that Darwin is discussing functional attributions.

This notion of the economy of nature can be found as a framework in the texts of natural theologians (Limoges, 1970, p. 61). It is in this economy that the adaptations of organisms acquire meaning and are explained. The change produced by Darwin will imply a radical change in the way of conceiving (not only explaining) the adaptations themselves. Gustavo Caponi refers to this as a gestalt change and characterizes the idea that Darwin explained with natural selection the same kind of adaptations that natural theologians explained by appealing to an intelligent designer, as “the myth of pre-Darwinian adaptationism” (Caponi, 2011, Chapter 1).

To understand and develop what this change consists of, it is interesting to analyze how natural theologians ascribed functions. They attribute functions to traits of organisms by appealing to the goal of maintaining the natural economy, e.g. Paley attributes to fruits

the function of feeding animals (Paley, 1809, p. 351). Similarly, he attributes to plants the function of purifying the air (Paley, 1809, p. 372). Natural theologians also consider that beauty can be a goal. The function of flowers is to beautify creation, sometimes as a goal in itself (Paley, 1809, pp. 199-200), sometimes concerning human aesthetic pleasure (Paley, 1809, p. 202). In the same sense, the plumage of birds or the color of the iris of the eye also has aesthetic functions (Paley, 1809, pp. 198-199). Many times, they attribute functions anthropocentrically. Kirby thinks that the function of wool in sheep is to provide us with raw materials for our comfort (Kirby, 1836, pp. 34-35). Finally, we can find function attributions that are applied neither to organisms nor parts of them. For instance, for Paley, it is not the sleep of animals that adapts to night, but it is night itself which has the function of allowing for the sleep of animals (Paley, 1809, p. 295).

I will call these functional attributions “*pre-Darwinian*” where the benefit does not fall on the organism itself, nor on relatives, nor on the group to which the organism belongs, but on the general system or on organisms of other species.

Not everything is strange in the functional biology of natural theology. For example, physiological adaptations were not changed by Darwin (see e.g. Roget, 1834). Additionally, Paley, in some cases, resorts to ecological (Darwinian) adaptations of the sort attributed by Darwin, for example, when he claims that the lights of fireflies have the function of attracting mating partners (Paley, 1809, p. 336), and the structures that allow seeds to glide have the function of enabling the plant to disperse its seeds (Paley, 1809, p. 355).

Natural selection was put forward by Darwin mainly to account for the acquisition of adaptations, that is, the way a population of organisms fixes traits that manage to perform their function efficiently. But since natural selection only selects traits that improve the reproductive success of the organism bearing that trait (or, in any case, the group the organism belongs to, if, as Darwin did, one accepts group selection), the fixation of traits that benefit individuals of other species at the expense of the organism’s reproductive success, or the economy of nature system in general, could not be explained. And it is within this framework established by Limoges and Caponi that we must understand the meaning of the following Darwin’s claim:

If it could be proved that any part of the structure of any one species had been formed for the exclusive good of another species, it would annihilate my theory, for such could not have been produced through natural selection. (Darwin, 1859, p. 201)

Therefore, much of the functional biology of the natural theologians, with whom Darwin argued, was incompatible with the theory of natural selection. What Darwin did was to change functional biology (consciously, as the above quote indicates) by removing the re-Darwinian functional attributions from it. Then, not only does it explain in a new way (appealing to natural selection) the acquisition of adaptations, but it modifies the way of conceiving the adaptations themselves since many of the adaptations that the pre-Darwinian naturalists detected in nature were not compatible with natural selection.

At times, Darwin had to reformulate cases of pre-Darwinian functional attributions to show that the analyzed trait contributes to other functions already known. Fruits, for example, would no longer serve the purpose of feeding animals, but that of dispersing the seeds (Darwin, 1909, p. 92). Adaptations that had the goal of embellishing the world, like the irises of eyes or the colorful plumage of males in birds, now have the function of attract-

ing reproductive partners (Darwin, 1859, p. 88, 1871, vol II, 72), and they are to be subsequently subsumed under sexual selection.

In the case of flowers Darwin proposes a function that had not been identified before. What is the function of flowers, if their purpose cannot be to beautify creation? Darwin, who had learned from breeders that endogamic reproduction produced increasingly weaker varieties, devoted a great extent of his time and writings to show that many of the features of flowers have the function of facilitating crossed fertilization (Darwin, 1861, 1876, 1877b, 1877a).

This role of the writings on flowers is not taken into account by Lennox, and as we will see, it is relevant both to understanding how Darwin affected the notion of final cause and, as we will see later, the role of teleology in Darwin and in biology today.⁴

The kind of objectives that traits can pursue in the functional biology of natural theology (see figure 2) is reconfigured by Darwin explicitly in his different texts, according to the kind of functions that natural selection can produce, and I do not think it is controversial to say that such reconfiguration is maintained until the present (see figure 3). In this Darwinian world of negotiation and competition, altruistic features are a puzzle to be solved. A clear example of the enigmatic character of altruism is Darwin's own approach to the puzzle that implies that there is a caste that does not reproduce in the case of some social insects (Darwin, 1859, pp. 236-237). How could working bees have their peculiar adaptations if they do not reproduce? Or what explanation is there for the bearing of traits, such as the sting in bees that causes the death of the bee after stinging (Darwin, 1859, p. 202). Darwin appealed to group selection to answer the origin of such adaptations. It is a sign that we live in this Darwinian world that we are still discussing the proper way to solve such puzzles.

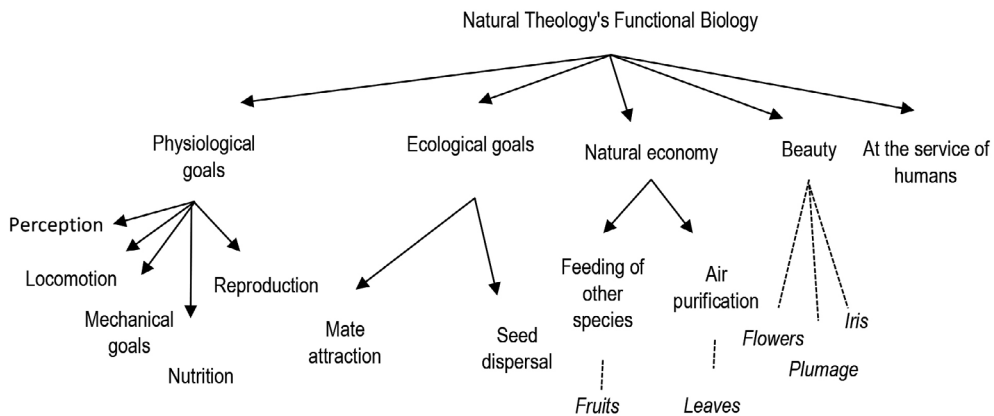


Figure 2

Types of goals that traits have according to natural theology—
Dotted lines connect goals with specific traits

⁴ Even though within the framework of the discussion regarding the Aristotelian ideas Lennox discusses the possibility that in Aristotle features of organisms can benefit other species (Lennox, 2001). Gottlieb and Sober discuss this point (Gottlieb & Sober, 2017).

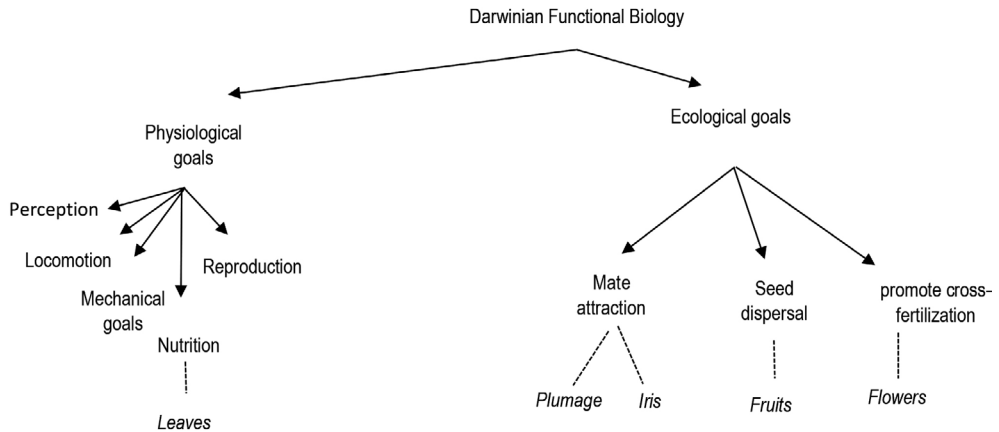


Figure 3

Darwin's review of previous functional biology, with the elimination of the pre-Darwinian goals, the relocation of some cases that fell under these, and the addition of the new goal that allows for the accounting of the flowers. Of course, these goals are not conscious, as they are in the case of natural theology

4. *The inadequacy of the main approaches to account for the change in functional biology*

In the previous section I presented Darwin's modification of previous functional biology in a metatheoretically descriptive way—in the sense that I did not appeal to any of the metatheoretical frameworks available among those who attempt to understand functional biology.

That section concluded that Darwin modified the previous functional biology, in which functions were ascribed by appealing to goals related to the maintenance of the natural economy, the beauty of creation or for the benefit of humans, appealing only to those objectives compatible with natural selection, that is, with those that could affect the reproductive success of the organism or of the group to which the organism belongs.

Now, how can we characterize what I have just said, in a metatheoretical appropriate way? The discussion in functional biology has reached a level of complexity and a proliferation of approaches that makes it difficult to deal with all of them in one paper, much less in one section of a paper. So, I will refer only schematically to two approaches, or types of approaches. The intention is not to be completely fair to the complexity of such approaches, but to draw metatheoretical consequences from what is said in the previous section. First, I will discuss how functional biology is thought of from systemic analysis. Second, I will discuss how it is thought of from those approaches that defended that functional attribution is equivalent to some kind of affirmation of the trait's evolutionary history.

The systemic analysis was originally proposed by Robert Cummins (Cummins, 1975, 1983)—he called it “functional analysis”. The proposal was later developed and modified by the (new) mechanist philosophers (Craver, 2001, 2007; Machamer, Darden, & Craver, 2000).

The functional analysis aims to explain how a system S has a certain capacity Ψ . Such capabilities are understood as dispositions exhibited by systems behaving in a certain way

under certain specific circumstances (1983: 18). What it intends to explain is how the system possesses such a capability or disposition Ψ , or why manifestations of the disposition are caused by such specific circumstances. The functional analysis offers this explanation by appealing to certain sub-abilities of the parts or sub-systems of the system, whose programmed manifestation results in or is equivalent to Ψ (1975: 759).

From Cummins' point of view, the capacities that would be functions are those analyzing sub-capacities ϕ that appear in an adequate functional analysis, where the adequacy of the functional analysis is relative to the extent to which it satisfies a series of specific requirements (Cummins, 1983: 30). Mechanistic philosophers have later discussed and strengthened such requirements, but those details are not relevant to my discussion.

Let's start with the strengths of the approach, which make it interesting to think about the change in the functional biology in question. First of all, Darwin's functional research can be adequately reconstructed from the systemic analysis. Concerning flowers, for example, he starts with a specific activity, the facilitation of cross-fertilization, and asks how the parts of the flower interact to make that activity happen. In orchids, for example, each part of the flower plays a role in making cross-fertilization occur. And that role is the function of those parts (Olmos, Roffé, & Ginnobili, 2020).

A recurrent objection to the systems approach shows that, although the analysis can account for some of the Darwinian practices and also for the functional biology of our time (Olmos & Ginnobili, 2016; Olmos *et al.*, 2020), it cannot adequately account for the change in functional biology that we are dealing with here since it cannot account for the distinction between functions and mere side effects (Wouters, 2005). Thus, for example, one could say that the function of a certain tumor is to put pressure on a certain cerebral artery (and thus explain the organism's ability to die from cancer) (Neander, 1991a, p. 181). This problem arises from the fact that according to the approach the choice of the capacity Ψ to which the analysis is applied, and for which one hopes to find a mechanism and attribute the respective systemic functions is arbitrary. It depends on our specific interests. Certainly, it would be possible to conduct a flower analysis by choosing non-Darwinian activities (such as beautifying the world, feeding animals, or benefiting humans). And it would be possible to carry out a systemic analysis based on such capacities, where the color of the flower will not have the role of attracting insects, but of satisfying our aesthetic taste. Or one can even argue, like Paley, that the function of the night is to allow sleep, that is, to attribute functions to non-living things (Millikan, 1989b, p. 294). The promiscuity of the approach makes it insufficient to explain the effort made by Darwin to review the functions of the traits of the organisms, since it lacks the normative capacity to regulate which functional attributions are adequate. Then, It would be reasonable to think that to account for the Darwinian revolution in functional biology any approach about functions needs to have this normative capacity.

Given that the changes that Darwin began to make in functional biology derived from constraints from his evolutionary theories, approaches that consider functional attribution to be essentially related to evolutionary reflection may be better able to accomplish the required task. Again, the presentation I'll make will be schematic. Wright's writings on functions are often pointed out as the origin of the etiological approach (Wright, 1973, 1976)—even though you can find it in George Williams earlier (Williams, 1966). The general idea of the approach is to assert that functional attribution to a trait is equivalent to

a claim about the history of the trait (in some cases, as in Wright himself, the position is weaker and the history of the trait is equivalent to a necessary condition of functional attribution, but for the purposes of this paper it is not necessary to take these differences into account). Etiological theories have proliferated in philosophical literature since Wright's original proposal (Garson, 2017; Godfrey-Smith, 1994; Millikan, 1984, 1989b; Neander, 1991c, 1991a). The general idea of the approach (or family of approaches) is that the expression "the function of X is to make Y " allows to explain how x is here (Wright, 1973, p. 156), that is, its etiology. If one asks why humans have hearts, the answer would be: because the function of hearts is to pump blood. In the case of natural functions, the mechanism by which the effects become explanatory of the presence of their causes is provided by the theory of natural selection (Wright, 1973, p. 159). In the case of artifacts (such as a watch), the etiological history could appeal to the history of their manufacture and the conscious goals pursued by the designer (the watchmaker).

Let us begin by reviewing the strengths of the approach in accounting for Darwin's change in functional biology. First, as I said, it takes into account the fact that there was not only a change in the explanation of a phenomenon (adaptation) but a reconceptualization of the phenomenon. The disagreement between Paley and Darwin is not only about how to explain the function of the fruits, but what that function is and how the functional attributions themselves are performed. In fact, some have criticized that the etiological approach cannot adequately account for the history of biology since if functional attribution is equivalent to a selective history, functional biology could not have existed before Darwin (Neander, 1991b, pp. 168-169). From what we have seen, we can argue that Neander's answer is to some extent, and at first sight, adequate (Neander, 1991b, pp. 175-176). Pre-Darwinian functional biology is not the same as Darwinian functional biology. Under the etiological perspective, Paley's statement "fruit serves to feed animals" (where fruit plants are artifacts) would be equivalent to "God put fruit on plants so that they could feed animals", while Darwin's statement "fruit serves to disperse seeds", not only implies a different functional attribution but is equivalent to an etiological story of a different kind "the ancestors of plants had more attractive fruits for animals; so, they were able to better disperse their seeds improving their reproductive success".

However, the etiological approach fails to adequately explicate the functional attribution practices carried out by Darwin. According to his definition of the concept of function, functional attribution presupposes knowledge of the evolutionary history, and the type of evidence on which functional attribution to a trait should be based should coincide with the evidence that should be appealed to determine the selectionist history of the trait. It is quite clear that in his long discussion of the function of flowers, Darwin never used evolutionary evidence. He carries out detailed systemic analyses of how fertilization works in flowers, he carries out experiments determining sufficient and necessary conditions for fertilization to take place, he shows that the objective that according to him flowers have, to facilitate cross-fertilization, is fulfilled throughout the vegetable kingdom by the most diverse stratagems. But he never appealed to evolutionary evidence of any kind. Of course, there's a rhetorical reason why he didn't. His evolutionary theories were not yet accepted at that time. The idea of "flanking the enemy" is just about changing functional biology from within, with no mention of natural selection.

However, I will present four arguments against the idea that not appealing to evolutionary evidence is only a matter of rhetoric.

First, Darwin himself states: “Although an organ may not have been originally formed for some special purpose, if it now serves for this end we are justified in saying that it is specially contrived for it.” (Darwin, 1877b, p. 283).

But as I said before, sometimes it is not so important what the authors think they are doing, but what they are actually doing. However, this is not merely a statement by Darwin, but has to do with a fundamental point that has been called an anomaly of the etiological approach (and which even its proponents treat as a puzzle to be solved). The traits constantly change functions. The etiological approach fails in traits that have just acquired a new function. But the functions of the parts of an orchid are all new! This point is central to Darwin’s book of orchids and has been one of the interpretations of what their role is in the long argument throughout his work. Well, the orchids would show how natural selection works with what it has at hand, since the parts of the flowers were co-opted for different functions than usual (Gould, 1980, Chapter 1). This is the second reason why functional biology is not reduced strictly to evolutionary biology. It must be possible to attribute functions independently of evolutionary theory to be able to speak adequately of changes in function throughout evolution. The third argument, the strongest and simplest, is the observation that functional biology is in fact independent of evolutionary biology, in Darwinian practices (which may have been affected by their particular circumstances) and in current biology (Amundson & Lauder, 1994; Caponi, 2013, 2020a; Kitcher, 1993; Wouters, 1999). Functional attribution is often much simpler than determining evolutionary histories (Amundson & Lauder, 1994), which gave Darwin a simpler ground for discussion.

Finally, I said earlier that at first glance one might think that the change in the notion of adaptation (i.e., in functional biology) could constitute an argument in favor of the etiological approach. However, I believe that this perspective exaggerates the difference between Darwin and natural theologians. For, as we saw in the previous section, there is a large portion of functional biology that Darwin leaves untouched. Physiological functions, and certain ecological functions, while explained differently (no longer by intelligent design but by natural selection) do not seem to be conceptualized in divergent ways. If the etiological approach were correct, the expression “light from light bugs has the function of attracting females” said by Darwin and by Paley would express completely different propositions. “God put a light on the light bugs so they can attract sex partners” for Paley, “the light was acquired in the light bugs by natural selection” for Darwin. This doesn’t seem plausible. It would imply that the incommensurability between Darwin and Paley would be complete, and it fails to make clear that functional biology was a (partially) common ground on which discussion was possible.⁵

⁵ I do not want to get into the details of the discussion of the approaches I am dealing with, because that would extend too much the work, but as an anonymous reviewer pointed out, there is a point that may be interesting to note and it may be clarifying. The advocates of the etiological approach are familiar with biology and know that functional attribution is made in many cases based on criteria that are not evolutionary. That is why they distinguish between minimal, immediate or putative functional attributions and proper, mediate or actual functional attributions (Millikan, 1989a; Neander, 2017). It is obvious that at the level of proper functions, which have to do with the explanation of the acquisition of the functional trait, there is a substantial change between Darwin and natural theologians. What I want to point out, and I believe that the etiological approach does not address, is the differ-

These criticisms are not new, and advocates of the etiological approach have tried to respond to them. What interests me here is to point out how these anomalies of the approach are related to the specific point of the work. From the etiological approach it is not possible to account adequately for the change produced by Darwin in functional biology.

5. *Change in functional biology as theory change*

In the previous section I discussed only two approaches that try to understand the way functional language works in biology. I tried to show that neither can adequately account for the change introduced by Darwin in functional biology. I am interested to note that both approaches have an eliminationist attitude towards the language of functional biology. Under the systems approach, functional biology is reduced to a description of how complex systems behave. Functional language emerges only to indicate roles that arise once one arbitrarily chooses something that the complex system does. In the etiological approach, functional language can be replaced by evolutionary language (in which there would be no functional language).⁶

As I was saying, Darwin does indeed perform systemic analyses of organisms. However, such analyses are guided by the prior determination of what are the genuine goals that organisms follow: feeding, reproduction, avoiding predators, favoring cross-fertilization, improving the performance of the group to which one belongs, etc., but not favoring the natural economy, benefiting humans, beautifying the world, etc. These types of objectives are indeed constrained by those functions that natural selection can explain, however, in both cases, the proposal of new objectives (as in the case of favoring endogamy) and in functional attributions based on already established objectives, the functional attributions are justified in Darwin (and as we saw many believe that this also occurs in current biology) independently of natural selection.

ence that exists at the level of putative functional attributions. This is the important aspect of the Darwinian revolution in functional biology, in which I want to focus on. Darwin modified the acceptable (non-evolutionary) criteria for how putative functions are ascribed. This is what I claim that requires a special explanation, to which neither the systemic nor the etiological approach provide an answer, and therefore constitutes an anomaly for those approaches, or, at least, an unexplained puzzle.

⁶ Some approaches do not have such eliminative pretensions. For example, the approach of Arno Wouters (Wouters, 2007), which considers that functional or “design” explanations give an account of why the structure and activity of a certain part of the organism are as they are, showing why it is more advantageous than a certain hypothetical alternative, given certain constraints (physical, metabolic, etc.), where the advantage refers to the organism’s ability to stay alive (i.e., maintain itself, grow, develop and produce offspring). Other approaches could be interpreted as non-eliminative (or at least, it can be argued that they are not constitutively eliminative). For example, the approach of contribution to an objective, as it is thought by some of its defenders (Boorse, 2002)-Nagel, who originally proposed the approach, was indeed eliminative, because he considered that every functional statement was equivalent to a non-functional one (Nagel, 1961, p. 403). Something similar could be said about the organizational approach (Mossio, Saborido, & Moreno, 2009). In both cases, the promiscuity of the systemic approach is dealt with by appealing to non-evolutionary criteria, which could be peculiar to functional biology. Although it would be pertinent to the objectives of this article, it would take a lot of space to discuss such approaches and contrast them with the one I propose.

What I have tried to show is that any approach that claims to account for practice in Darwinian functional biology needs to explain how legitimate goals in functional attribution are regulated. This is often overlooked and is excluded from the issues that any approach about functions must address (see for example the list of intuitions about function in Wouters, 2005, pp. 133-134). This is the most relevant point I have tried to make in this paper, and what I think the appeal to the history of the Darwinian revolution in functional biology helps to make explicit.

In this direction, Caponi considers that systemic analyses allow the detection of biological functions when the capacity of the system considered complies with the realization of the life cycle of the organism in question: development, survival, giving rise to progeny, etc. (Caponi, 2013, 2020a). But, one can ask again, of course, why improving the natural economy, or “being beautiful” is not part of the life cycle of organisms. Or, in the same sense, how does biology regulate those goals that are part of the life cycle of the organism?

I think the simplest answer to the question is to appeal to the way that this happens in general in scientific theories. For example, how is it determined within the framework of classical particle mechanics what forces can be appealed to for explaining the movements of particles? The answer may vary according to the metatheoretical framework accepted. Elliott Sober would answer that the forces that can be legitimately appealed to are determined by a set of source laws that allows calculating the values for the different forces (Sober, 1984, Chapter 50). The structuralists would say—in a view similar to that outlined by Thomas Kuhn (Kuhn, 1970)—that what regulates the type of forces that can be appealed to are the different special laws in a theory-net—formed by a fundamental law (the second principle) and a set of special laws that arise by the specification of abstract concepts of the law plus some added constrictions (Balzer, Moulines, & Sneed, 1987). Intuitively and pre-technically, the answer is, what regulates which forces can be used is a theory, the theory of classical mechanics. Of course, the typical work is to find new applications for existing laws, but sometimes a small “revolution” takes place in normal science when a new force is discovered—that is, when a new source law/special law is discovered.

Functional biology could be thought of in the same way, as being governed by a theory (implicit, unlike classical mechanics) regulating functional attributions (Ginnobili, 2011, 2018). Darwin’s texts about flowers would precisely propose a new objective (a new source law / special law). And what Darwin would have done with functional biology is to revise a theory, leaving aside those functions that we call “pre-Darwinian”, explaining what was explained with these under other available source laws/special laws or proposing new ones.

I have offered a reconstruction of the theory implicit in functional biology appealing to metatheoretical structuralism elsewhere (Ginnobili, 2011, 2018). Here my aim is more modest: to present an outline of the main components of the biological functional theory. As a metatheoretical approach I will be following some ideas of Kuhn, Sneed and metatheoretical structuralism in an informal and enunciative way (following the presentation style of Díez & Lorenzano, 2013, 2015; Ginnobili, 2014, 2016). More specifically, I want to highlight/emphasize some general characteristics of theories:

- Scientific theories are composed of a general statement (which we can call “fundamental law”) and its specializations (special laws).
- In the fundamental law, all the concepts of the theory are related. It has little empirical content and is abstract. It is what all applications of the theory have in common.

- Special laws are not deduced from the fundamental law, because they have more empirical content. They have more specific versions of their concepts and do not necessarily have the same form because they include additional restrictions. Each of the special laws applies only to a subset of the intended applications of the theory.
- Scientific theories typically (but not always) include new concepts to account for their intended applications. The systems that form the global *explanandum* of the theory are conceptually enriched to explain their behavior.

I will present the biological functional theory (following Ginnobili, 2011, 2014, 2018) from the Darwinian explanation of certain floral structures of orchids. Darwin begins by offering a description of the floral structure and its behavior, where the following concepts can be found: Organisms of a certain type (Orchid of a certain species or variety, for example, *Orchis pyramidalis*) possessing certain traits (pollinia with a viscous extremity) that in different environmental conditions have different effects (when rubbed with a pencil they remain attached to it detaching from the orchid, when an insect touches them with its proboscis they remain attached to it fertilizing flowers on which the insect lands, etc.) (see figure 4).

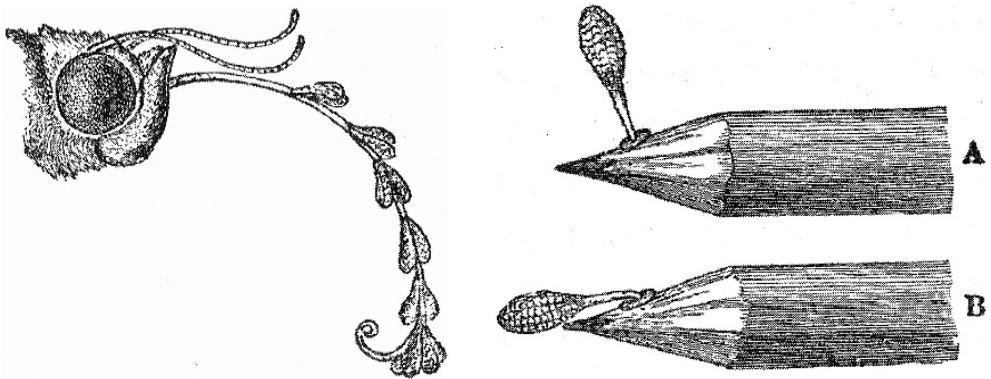


Figure 4

Illustrations from Darwin's Orchid book on different effects of the pollinium. Head of *Acontia luctuosa* with seven pairs of pollinia attached to its proboscis on the right (Darwin, 1877a, p. 31). Pollen mass attached to a pencil on the right (Darwin, 1877a, p. 12)

Darwin accounts for the behavior of the structure in question by relying on the fact that one of the effects of the trait fulfills some purpose of the organism. In this case, the effect of the pollinium adhering to the proboscis of certain insects in the peculiar way it does favors cross-fertilization, while preventing self-fertilization (Darwin, 1877b, pp. 13-14). The theory then rewrites the intended application by conceptually enriching it with the notion that “the effect of a trait satisfies a certain objective with a certain effectiveness” and that “the organism pursues (of course, not consciously) that goal” or “the goal is part of the organism's life cycle”. This allows me to present a specific application of biological functional theory:

The objective of promoting cross-fertilization is included in the life cycle of orchids and the behavior of polonium to stick to the proboscis of certain insects allows it to satisfy this objective with some effectiveness in certain environments.

Abstracting from this specific case, we can also present a special law of the theory, the one referring to the objective of promoting cross-fertilization:

The objective of promoting cross-fertilization is part of the life cycle of certain organisms and some effects of their traits allow them to fulfill this objective with some effectiveness in the environment they live in.

This law, of course, applies throughout the animal and plant kingdom to account for many of their structures and behaviors. Many other special laws establish which specific objectives may be part of the life cycle of organisms (evading predators, facilitating hunting, obtaining reproductive mates, feeding, breathing, dispersing seeds, etc.). This list is not definitive, it can be extended (as Darwin did with the case of favoring cross-fertilization) by finding new applications of the theory, but it regulates the type of objectives that can be appealed to (leaving aside the Paleyan objectives such as improving the natural economy, feeding other species, beautifying creation, etc.). The fundamental law, which would be what all special laws have in common, could be presented as the following:

For every organism, if an objective is part of its life cycle, then some of the effects of its traits, in the environmental conditions in which it lives, will satisfy such an objective with some effectiveness.

The direction of the conditional reflects that proposing a new objective —as Darwin did with cross-fertilization— implies an abductive leap that cannot be made only from the examination of a specific structure of a specific type of organism, but, instead, by showing that the floral structures of an enormous number of vegetable species fulfill this objective through the most varied stratagems.

Since the special laws, according to my presentation, arise from the specification of the general concept of objective, Figure 2 presented above would be a schematic presentation of Darwin's biological functional theory and Figure 1 a presentation of the biological functional theory of natural theology.⁷

Elsewhere (Ginnobili, 2011, 2018) I have shown how this approach solves many of the problems that an approach about functions is intended to solve. Here I will only point out the three that are of particular interest to us:

- It allows us to understand the change in functional biology in a clearer way. Darwin would have modified a previous functional theory, eliminating many special laws incompatible with natural selection, and proposing at least one new one (in which the reproductive goal of favoring cross-fertilization is presented).
- It has the normative force that we expect from an approach that regulates which are adequate functional attributions, in the same sense that classical mechanics regulates what types of forces can be appealed to. However, this regulation is revisable

⁷ It could be interesting to establish relations between my theory-based approach and other approaches to functions, such as those mentioned in note 6. It may be possible to present such non-eliminativist approaches to functional language as theories, and in that sense they could be analogous to the one I propose at least in some aspects. Unfortunately making such a comparison exceeds the limits of this paper.

since it allows us to discover or eliminate previous special laws without abandoning the theory. This arises from empirical research.

- It achieves this normativity without reducing functional biology to evolutionary biology. This explains how Darwin introduced modifications to functional biology and how current biologists make functional attributions without appealing to evolutionary biology.
- All the above is achieved without appealing to any peculiarities. The practices of functional attribution are regulated by theories, as it is the case with other explanatory practices in the same or other disciplines.

This approach has an interesting consequence. Methodologically, it has always been thought that the key to understand functional biology lies in analyzing the functional explanation. This has been the case since Hempel faced the task many decades ago (Hempel, 1965), and it continues to be the preferred way in which the issue is discussed. If functional biology is governed by theories, which provide criteria for determining functional concepts, then the strategy should be different. We do not have to think about what the structure of the functional explanation is, but what the structure of the functional theory is. This implies explicating the concepts of functional biological theory and finding how they are related. Only then we will be able to discuss the structure of the functional explanation.

Another interesting consequence of considering that functional language appeals to the conceptual framework of functional theory is that the search for a definition (in the strict sense) of functional notions seems misguided. Something that logical empiricists already knew is that theoretical concepts are usually not defined since they have blurred boundaries (Hempel, 1958). Classical mechanics is applicable and its concepts can be operationalized in the absence of strict definitions of its fundamental concepts. In this sense, explicating functional notions does not imply defining them. Instead, it implies reconstructing the laws that allow their application. This has consequences for their elimination. It is not to be expected that there are definitions in terms of necessary and sufficient conditions (because there are usually none for theoretical terms), and in fact, it does not seem that there are necessary and sufficient conditions for functional attribution. Andrea Olmos has carried out an exhaustive analysis of functional attribution in the framework of behavioral sciences, showing precisely the heterogeneity of the evidence used to carry out functional attribution and showing that none of them is treated as either sufficient or necessary for functional attribution (Olmos, 2018). Moreover, it is interesting to point out that it is not usual for theories to strictly define the type of entities to which they apply. The domain of application of a theory has fuzzy boundaries and it is not fixed, since scientists are always trying to extend it. In this sense, the attempt of various philosophical approaches to functions to strictly define the kind of objects that can have biological functions may also be inadequate. Of course, it does not imply that it is impossible to provide those kinds of definitions, but that the attempt to find them might be excessive, since it would demand more accuracy from functional language than from other theoretical concepts in the same and other disciplines.

The idea that functional biology is governed by a functional theory leaves open the metaphysical question of whether functional concepts have a reference in the world, in the external sense of the question (Carnap, 1950a). This is a question that one can ask of any scientific law or scientific laws in general. Regardless of my attitude towards these external issues, which is Carnapian, this approach is compatible with realistic interpretations and

with those that consider teleological speech essential but only as a methodological device (Ratcliffe, 2000).

The presentation I make leaves open a lot of specific problems about which it would be necessary to pronounce in a more detailed reconstruction. My objectives here have to do with proposing a new strategy for approaching the nature of functional language helping to understand the teleological character of Darwinian thought and the change introduced by Darwin in functional biology. This allows the Lennox point to be held more clearly. Darwin did not eliminate previous functional theories, nor did he reduce them to more general theories. But he did modify them substantially. The strategy suggests, but does not prove, that that functional language appeals to concepts of its own, undefined and non-eliminable.

6. Conclusion

I have tried to show the influence of the Darwinian revolution was more profound than is usually recognized. For, not only does it have to do with evolutionary biology, but it influences all functional biology. Also, I have tried to draw consequences from this change in the discussion regarding functional language and functional biology.

The idea, which we present in section 2 of this paper, that Darwin eliminated the final causes and teleology of natural history/biology, has as a correlate with the suspicion that the language of design, objectives, purposes used in biological practice is a didactic metaphorical resource —according to some suitable, according to some dangerous— that could be eliminated without losses —more than perhaps pragmatic (Ruse, 2000)— from biology. This attitude of suspicion for functional language appears in the philosophy of biology under eliminationist approaches. Sentences with functional language would be replaceable without loss by statements in which there is no functional language. So, one way to discuss whether functional biology is teleological or not is to discuss whether functional language is eliminable or not.

The etiological approach has been characterized as teleological. The idea is that by signaling the end of a trait you are explaining why the trait remains in the population. The end would explain the presence (or rather, the maintenance) of the trait (Wouters, 2005, p. 129). However, the etiological approach is eliminationist of functional language, given that functional biology is reduced to evolutionary biology, and given that the statement of a functional attribution is equivalent to that which describes an adaptive history in which there is supposedly no functional language.⁸ So, one can argue that it is not teleological enough to account for Darwinian functional biology.

This allows us to deepen Lennox's assertion that Darwin was a teleologist, to extend it to the stronger assertion that there is a sense in which the current biologist is a teleologist, and to do so not on debatable metaphysical grounds, but on the scientific practice itself

⁸ This is also the case in Wright's weaker approach, where adaptive history is only one of the requirements upon which attribution works, as it is possible to replace functional attribution with an equivalent where there is no functional language. In this sense, Lennox's appeal to Wright's approach to support the sense in which according to him biology is teleological would not be adequate. Otherwise, as noted by Short, his approach cannot differ much from Ghiselin's, and the discussion seems only terminological (Short, 2002).

(like Lennox wanted). Of course, it is not the intentional teleology of natural theologians, where goals are derived from conscious goals of the creator, nor is it an immanent teleology of vitalism (Wouters, 2005, p. 129). It is the teleology that natural selection produces in living beings. We must thank Darwin for explaining its origin and nature.

You may prefer not to call this functional, non-eliminable language, which was drastically changed and grounded in new foundations by Darwin, “teleological”. For the word is terribly vague and can be confusing given its usual uses (as Ghiselin argued). Perhaps you prefer the expression “teleonomy”, like Mayr (1988, pp. 44-48), or Ghiselin himself (1994). That’s fine, as long as you understand what Darwin did with functional biology and the role of functional language in today’s biology.

It is interesting to ask why in presentations and discussions about the Darwinian revolution there is often no mention of Darwin’s change in functional biology, even though Darwin dedicated much of his work to that.

It is not strange that this change has gone unnoticed given the predominant distrust with functional language from biology and philosophy of biology. This attitude has led to the rules that govern functional attribution being part of the tacit knowledge never made explicit by the biologist, but which is constantly used. This, in turn, has led to a gap in biology between what is said (and believed to be done) and what is done. This false consciousness is dangerous for scientific activity and an obstruction to the teaching and communication of science.

Faced with this situation, we must learn from the meticulous and detailed work of Darwin (who changed our world by discussing details of plant reproduction) and not aim to cut out complex knots but rather to untie them. I hope that this work has shown, in addition to the pronounced way in which Darwin’s vision permeates the present one, an interesting strategy with which the knot of teleology can begin to be untied.

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