New Directions in the Philosophy of Biology: A New Taxonomy Of Functions

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I. Introduction

Many things in the philosophy of science have changed in the last decades. A clear example of this is the debate on the concept of biological function.. The supposed teleological and normative character of so-called functional explanations is at the heart of one of the most profitable and valuable discussions that currently exist.[2] What is more, the development of this discussion allows us to understand many of the changes and controversies that have marked the direction that the philosophy of biology has taken at the beginning of the 21st century.

In this paper, I review the different theories on functional explanation that can be found in the current debate in philosophy of biology. I take it that the current state of the philosophical discussion is dominated by two major classical perspectives that address functional explanations and consider functions as a kind of disposition. The first of these major views, the "causal-role" or "systemic" approach, describes functions as causal effects of a biological trait in the frame of a system or organism. The second approach, the "evolutionary" one, considers that functions can be identified with the biological effects that are the "causes of existence" of biological traits by appealing to the evolutionary role of these effects. Although these two views have a relatively long history, in the last years a number of new theories have emerged within these perspectives. In the taxonomy of functions I present here, I introduce these new theoretical formulations of the causal role, as well as explain the evolutionary approaches and compare and critically analyze their strategies and explanatory focus.

I will begin by presenting a critical review of these two ways of interpreting the notion of function in light of the current theoretical proposals. I will then analyze an attempt to overcome this dichotomy: the recent Organizational Approach. I claim that this last approach constitutes the major novelty in the philosophical discussion on functions. According to organizational theories, a function is a disposition of a particular current biological trait that has explanatory relevance,

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[2]See, for instance, the following collections: Allen *et al*. 1998, Buller 1999, Ariew *et al*. 2002, Krohs & Kroes 2010.

in organizational terms, with regard to the presence of the function-bearing trait. The organizational account claims that a functional effect can be understood as a condition of existence of that very trait (without appealing to evolutionary history) to the extent that it is a necessary condition for the process of biological self-maintenance of the organism (see also Schlosser 1998 and McLaughlin 2001). In the present article, I maintain that the Organizational Approach implies an integration of the etiological explanatory strategy and the causal-role framework by considering that a function is both a cause for the existence and a current disposition of a biological trait token.

II. Functions, teleology and normativity

"Function" is a key notion in the biomedical sciences. In a general sense, every function is a disposition of a biological trait. In fact, it is quite usual to interpret functions in terms of dispositions, or related notions such as “powers”, “abilities” or “potencies”. Therefore, the functions of a trait would be determined by the potential causal effects of such trait under some given circumstances. According to many authors (see Popper [1959], Shoemaker [1980], Bird [2007]) dispositions can be understood as nomic or causal roles, and this is precisely the way in which the different theories interpret the notion of function[3]. A functional trait is a trait that has a disposition to produce a specific effect that has relevance with respect to a goal (the achievement of a systemic capacity, the increment of the system's fitness, the preservation of the biological self-maintenance...). Therefore, all theories understand that functions are a kind of *dispositional* and *causal* effect.

However, there seems to be a general consensus that not every disposition is a function. Many authors defend that what characterizes functions is that these have a *normative* and *teleological* dimension.

Functions are teleological at least in one sense but they can also be so in another one. First of all, functional attributions imply a teleology because they seem to refer to certain "raisons d'être", "purposes" or "intentions" related to the entities to whom one attributes these functions. An effect of a feature is a function only in relation to an (internal or external)

[3]According to the classical definition based on the Simple Conditional Analysis, an item is disposed to do something in given circumstances if and only if this item would do that very same thing in the cases that these circumstances are present. So, for instance and following the canonical example proposed by Carnap: *“x is soluble iff, when x is put into water, it dissolves”.* In this paper I claim that functions are dispositions in this sense. A trait T has a biological function F if and only if T has the disposition to perform F, or in other words, F is a function of T iff, given the “appropriate circumstances”, T effectively performs F. Of course, a theory of functions should clarify what are the “appropriate circumstances” because, in the absence of a developed theory, a biological trait has a potentially undetermined list of potential effects or dispositions that can be interpreted as functions.

purpose to which this effect contributes.

Second, certain types of functional explanations are also teleological in a stronger sense, since they try to explain the existence of a feature through some effects or consequences of its own activity, i.e., its function(s). To affirm – by quoting what is probably the most recurring example in this debate – that “the heart's function is to pump blood” is, ultimately, equivalent to saying that this effect of the heart, the pumping of blood, is relevant in order to explain the existence, structure and morphology of hearts (Buller 1999: 1-7).

Therefore, it is possible to hold that there are two ways of talking about teleology. First, there is a teleology related to all those statements that refer to certain "ends", "goals" or "intentions", as in the case of functional explanations. And, second, there is a special kind of functional explanation according to which a system's trait having a certain function implies that there is an effect of that trait that explains the existence of the very trait in that system. These explanations are teleological because they offer an explanation (*logos*) about the existence of a specific feature precisely through the functional purpose (*teIos*) that we attribute to it. In Walsh's terms: “Teleology is a mode of explanation in which the presence, occurrence, or nature of some phenomenon is explained by appeal to the goal or end to which it contributes” (Walsh 2008: 103). It is this strong sense of teleology that defines many theories on functions, such as the etiological approach since its beginning (Wright 1973), and it is this interpretation of teleology that has been strongly criticized by many theorists from the so-called "non-teleological" perspectives (for example, Cummins 2002, Davies 2001).

In addition to possessing this teleological character, the concept of function is inherently normative to the extent to which it refers to some effect that is supposed to take place (Price 1995, 2001: 12-15, Hardcastle 2002: 144). When a function is attributed, a certain rule is postulated at the same time, a rule which is applicable to the behavior of what we consider as functional. As McLaughlin (2001, 2009) has pointed out, functions show a particular type of relation between certain means and goals in a system, which go beyond the standard concept of causality and have a normative flavor: in order for some systemic goals to happen, some effects need to occur, effects to which we refer as functions. The attribution of functions consequently implies the postulation of a specific type of effect for the functional traits. This type-token relation is what allows us to evaluate a system's activity in normative terms. For example, saying that the heart’s function is pumping blood is equivalent to affirming that tokens of the type "heart" *should* pump blood. In case of not doing so, the heart would not be working properly, i.e, according to a norm ascribed to tokens of the type "heart".

Clearly, the normative dimension of functions requires an appropriate theoretical justification of the criteria under which the functional relations are identified as such and distinguished from all the other causal relations in the activity of a system. Functions are understood as the norms that must be satisfied and it must be explained why this is so in order to defend that these causal relations must be accomplished whereas others (the non functional or "accidental" effects) simply occur.

Both aspects, teleology and normativity, overcome the traditional scheme of the causal classic explanations and therefore they mean a real challenge for a naturalistic perspective in science and philosophy (Achinstein 1977; Buller 1999; Mossio *et al.* 2010). In the current debate many different theories have faced this challenge from very different perspectives. In the following, I will review the main current theoretical analyses of the concept of function in Biology, which are mainly classified under the perspectives of causal role and evolutionary approaches. After that, I will introduce the organizational view and explain its approach to these teleological and normative dimensions.

III. Functions as causal roles

One of the classic strategies consists in interpreting functional dispositions as causal roles of a specific trait with respect to a capacity or activity of the global system. A disposition is a function if and only if it has a causal effect that contributes to the achievement of a higher-level activity or goal. The discrepancies here are related to the different ways of grounding the systemic notion of "goal".

The most comprehensive theory of biological functions is the "systemic account" (SA), first presented by Cummins in his paper "Functions" (Cummins 1975). Cummins claims that functions are contributions of certain parts or processes to the achievement of some systemic goal. According to this approach, functions are causal effects or dispositions of a trait, i.e., means–end relations contributing to some distinctive capacity of the global system.

Therefore, and contrary to the interpretation of many other approaches, Cummins' interpretation holds that functions have no explanatory power regarding the existence of the functional trait. In Cummins words:

> Teleological explanations and functional analyses have different *explananda*. The *explanandum* of a teleological explanation is the existence or presence of the object of the functional attribution: the eye has a lens because the lens has the function of focusing the image on the retina. Functional analysis instead seeks to explain the capacities of the system containing the object of functional attribution. Attribution of the function of focusing light is supposed to help us understand how the eye, and, ultimately, the visual system, works. In the context of

> functional analysis, a what-is-it-for question is construed as a question about the contribution "it" makes to the capacities of some containing system. (Cummins 2002: 158)

For Cummins, this teleological interpretation of functions is mistaken. It is a vestige of a pre-scientific conception of nature that cannot take place in a naturalistic theory[4]. By rejecting the teleological dimension, Cummins' conception has the consequence of lacking definite criteria to determine which systemic capacity is the legitimate goal for a functional ascription. At most, this theory can say that a function is a contribution to a systemic capacity that is determined by the pragmatic interests of the researcher (Cummins 1975: 78)[5]. Cummins' approach considers that functions refer to current relations between parts and capacities in a wide range of systems and consequently dissolves the problem of teleology of functions by reducing these to any causal contribution to a systemic capacity.

This approach argues that any trait's effect can be considered as a function if it is a contribution to a systemic capacity and consequently it provides no clear theoretical grounds to distinguish between the notions of "function" and "effect". This is the reason why many authors have argued that the causal role account is "too liberal" (Cfr. Davies 2001: 73-75). According to this criticism, Cummins does not provide any clear criteria for identifying the relevant systemic goal or capacity. Once the teleological dimension of functions had been left aside by the causal role account, other dispositional approaches appeared which focused on providing criteria which are naturalized, i.e., grounded in some constitutive features of the system and not related to an extrinsic evaluative decision of the observer and appropriate, i.e., in accordance with both scientific and everyday usage, to identify what counts as a target capacity of a functional relationship, from which the legitimate norms could be deduced. The different causal role approaches have proposed various criteria to identify these target capacities.

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[4]In a recent work, P. S Davies defends that the act of considering functional ascriptions as teleological and normative corresponds to a "conceptual conservationism," with psychological and cultural roots, which should be avoided to build proper, objective knowledge (Davies 2009).

[5] Cummins' analysis can be understood as an epistemological proposal: a functional analysis is interesting when the analyzed system has a remarkable organizational complexity. Thus, Cummins specifies three necessary conditions for this functional analysis:

(a) The analyzing capacities are "less sophisticated" than the analyzed capacity;

(b) The analyzing capacities are "different in type" from the analyzed capacity;

(c) The analyzing capacities exhibit a "complex organisation" such that together they explain the emergence of the analyzed capacity (Cummins 1975: 759)

All this led to new theoretical formulations of this ‘systemic approach’ (SA), directly derived from Cummins work, which tried to defend a more sophisticate definition of the notion of function. These formulations restrict functional ascriptions to behaviors of parts of *hierarchically organized systems* (Davies 2001, Craver 2001, Garson 2013). This version of SA fits the following definition:

A is a valid functional ascription for a systemic item I of a system S iff:

(i) I is capable of doing F,

(ii) A appropriately and adequately accounts for S's capacity to C in terms of *the organized structural or interactive capacities of components at some lower level of organization,*

(iii) I is among the lower-level components cited in A that structurally or interactively contribute to the exercise of C,

(iv) A accounts for S's capacity to C, in part, by appealing to the capacity of I to F,

(v) A specifies the physical mechanisms in S that instantiate the systemic capacities itemized. (Davies 2001: 89. Emphasis added)

Consequently, by restricting functions to hierarchically organized systems, the new SA approaches attempt to offer criteria for differentiating between every potential effect of a trait and the real function of this trait, thus avoiding the "liberality problem" of Cummins definition. However, there is still a problematic characteristic in this SA strategy: it under-specifies functional ascriptions (Wouters 2005). The different formulations of the SA, even when only considering hierarchical systems, are not restrictive enough to offer a specific definition of function. In fact, at least three problems arise with the SA interpretation of functionality. First, there is not a principled criterion to distinguish between systems whose parts have functions and systems whose parts do not (Bigelow & Pargetter 1987, Millikan 1989). There are many examples of non-biological hierarchically organized systems whose parts are not subjects of functional ascriptions. Second, the SA is not able to adequately distinguish between functional contributions and dysfunctional or irrelevant effects (Millikan 1989, Neander 1991). The normative dimension of functions is missing in this approach. And third, the SA does not draw an appropriate distinction between effects that contribute to the achievement of a systemic goal in a ‘proper’ functional way and accidentally useful effects, and consequently, the important distinction between "function" and "accident" is not grounded (Millikan 1993, 2002).

These fundamental weaknesses of the SA are precisely what the "Goal Contribution Approach" (GCA) has attempted to solve. This approach links the concept of function to the idea of goal-directedness. Accordingly, this approach introduces in the systemic framework more specific restrictions on what makes causal relations functions. Thus, according to the GCA, a function is a causal contribution to any (higher-level) capacity that constitutes a 'goal state' of the analyzed system (Adams 1979, Boorse 1976, 2002).

The theorists of the GCA adopt a cybernetic definition of "goal-directedness" (Rosenblueth et al. 1943, Sommerhoff 1950). In Boorse's terms:

> A system S is 'directively organized' or 'goal directed' toward a result G when, through some range of environmental variations, the system is disposed to vary its behavior in whatever way is required to maintain G as a result. Such a system, it is said, shows 'plasticity' and 'persistence' in reaching G: when one path to G is blocked, another is available and employed. (Boorse 2002: 69)

This cybernetic characterization of "systemic goal" allows them to identify the goal states of a system in a naturalized and non-arbitrary way. In particular, theorists of the GCA describe biological systems as systems whose behavior is internally directed to achieving survival and reproduction and, accordingly, biological functions would be the internally generated contributions to these goals.

This perspective substantiates the causal relationship involved in functional behaviors, but at the cost of introducing norms whose application is, in fact, not restricted to the relevant kinds of systems and capacities. Cybernetic criteria may interpret dysfunctional behaviors of goal-directed systems as functional (cfr. Bedau 1992, Melander 1997). Every internal regulation leads the system to a concrete state that can be interpreted as a goal in cybernetic terms, independently of any other considerations as, for instance, the relevance or implications of achieving this state for the systemic viability. For example, a mammal that, due to a defect in its regulatory system, tends to maintain a constant fever can be considered as a system cybernetically directed to this state (fever) and its fever should be interpreted as a systemic goal. The same can be said of many other cases of poor or wrong regulation, such as the case of autoimmune diseases. Identifying regulation with normativity involves considering many goal-directed states as legitimate systemic goals relevant to the theoretical grounding of functional ascriptions. Accordingly, the GCA still seems to under-specify functional attributions, and in some cases it appears to be an even less satisfactory account than the SA.

To sum up, I conclude that the causal-role approach, both in its SA and in GCA formulations, defines functions as current means–end relationships, and more specifically as current contributions of components to the emergence of a specific capacity of the containing system. Therefore, according to this view, functions are not teleological to the extent that they do not refer to any causal process that would explain the existence of the function bearer. I claim that this interpretation has many virtues for the scientific practice but in the end fails to provide a fully satisfactory ground for the normativity of functional attributions because it underdetermines the conditions for functional ascriptions. Causal role definitions turn out to be systematically under-specified: they do not restrict functional ascriptions to the relevant classes of systems and/or capacities.

IV. Functions as evolutionary causes of existence

As I have explained, the causal role approaches reject the teleological dimension of the notion of function and are incapable of providing definitive criteria for the theoretical grounding of the normativity involved in the notion of function. Significantly, this teleological character is precisely what enables us to account for the normative dimension of functional explanations. By restricting the term "function" only to those dispositions that explain the presence of the trait, teleological theories offer a clear criterion to determine the goal to which functional traits must conform. According to these theories, a function would be, ultimately, a disposition to contribute to the existence of the functional trait, and this contribution to the perpetuation of the trait is also the norm of its functioning. This teleological notion is at the basis of the mainstream approach in the current debate on functions: the Evolutionary Approach.

Most of the existing literature has favored this view, according to which an adequate understanding of functional attributions has to deal with the problem of teleology. In particular, both the teleological and normative dimensions are conceived of as being inherently related to the evolutionary role of the functional trait. Within this Evolutionary Approach, the most predominant view is the etiological approach (Wright 1973; Millikan 1984, 1989; Neander 1991; Godfrey-Smith 1994). These evolutionary-etiologic theories identify functions with the *causes of existence* of the functional trait. The etiological approach defines a trait's function in terms of its etiology (i.e., its causal history): the functions of a trait are past effects of that trait that causally explain its current presence.

In order to ground the teleological dimension of functions without adopting an unacceptable interpretation of the causal loop described by Wright, mainstream evolutionary accounts, usually called "Selected Effect Theories" (SET), have appealed to natural selection as the causal process that would adequately explain the existence of the function bearer by referring to its effects. In fact, according to the SET, functional processes are not produced by the same tokens of which they are supposed to explain the existence. Instead, the function of a trait is to produce the effects for which past occurrences of that trait were selected by natural selection (Godfrey-Smith 1994, Millikan 1989, Neander 1991).

Selection explains the existence of the current functional trait because the effect of the activity of previous occurrences of the trait gave the bearer a selective advantage.

The main consequence of this explanatory line is its historical stance: what makes a process functional is not the fact that it contributes in some way to a present capacity of the system, but that it has the right sort of selective history. By interpreting functions as selected effects, the SET is able not only to deal with the problem of teleology, but also to ground the normativity of functions. SET identifies the norms of functions with their evolutionary conditions of existence: the function of a trait is to produce a given effect because, otherwise, the trait would not have been selected, and therefore would not exist. To contribute to the existence of the functional trait, through natural selection, is the functional norm.

One of the weaknesses of the SET is that natural selection cannot guarantee functionality to structures that have been selected in a historic moment for a certain reason and have been selected again for another distinct reason at another later time. These situations are very frequent in biology and have led writers like Gould and Vrba (1982) to propose the term "exaptations" for them [6.]

Another problematic point of SET is the presupposition that a trait is always selected against other alternatives because of its achievement of a concrete effect (i.e., the function). As some authors claim, this consideration is too strong. A biological trait can be interpreted as functional from an evolutionary stance simply because this trait contributed to the fitness of the organism and, consequently, to the perpetuation of this kind of organism and of the trait itself. The trait cannot be considered independently of the whole organism.

The Weak Etiology theories (WET), championed by Buller (1998) and Kitcher (1993), claim that the function of a trait is the contribution of this trait to the natural selection through time of the kind of organism which has this trait. The key

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6 To avoid this problem, many evolutionary theories specify that this selection has to occur in a period which is relevant for the current activity of the trait. Theorists such as Godfrey-Smith (1994), Griffiths (1993) and Schwartz (1999) have introduce new temporal restrictions to the SET. The so-called Modern History Theories consider that only recent history is relevant for functional ascriptions. According to this approach, the function of a trait is the effect that has caused this trait to be selected in the most recent period of time. Thus, it does not matter that bones had a metabolic function during a certain evolutionary period, because the reason for the current presence of bones is that they support the body, and that is now their proper function.

This kind of theory is able to account for the cases of exaptations, and includes the contribution to the fitness of the system as a condition to consider a concrete effect as a function. However, even when restricting the period of time, many of the objections for SET, such as their inability to address the origin of functional behaviors or the emergence of functional diversity in biological systems, are not satisfactorily answered.

strategy of this approach is to shift the focus from the evolutionary history of the trait to the evolutionary history of the system. The criterion for determining if a trait is functional is not whether this trait has contributed by a given effect to its own preservation, but to the fitness of systems of the type to which this trait belongs, regardless of whether any other potential biological alternatives have been removed in the process of natural selection (Kitcher 1993, Buller 1999).

Thus, WET is less restrictive than SET. All these proposals appeal to the evolutionary history of the function bearer in order to ground functions, but WET does not specify that a trait has been selected *because of* its function. This allows it to account for many cases of functional traits that the other evolutionary theories let aside.

Within this evolutionary framework, there is also a non-historical evolutive approach: the Propensity View (Bigelow and Pargetter 1987; Canfield 1964; Ruse 1971). This approach identifies functions with current causal contributions of components to the life chances (or fitness) of the current systems. A function is a trait's effect which causes the trait to be evolutively selected in the future. In Bigelow & Pargetter terms:

> What confers the status of a function is not the sheer fact of survival-due-to-a-character, but rather, survival due to the propensities the character bestows upon the creature. (Bigelow & Pargetter 1987: 187)

This is a forward-looking evolutionary approach. A function is a current contribution to the fitness of the organism, which is an evolutionary cause of the existence of future instances of this organism type. According to PV "something has a (biological) function just when it confers a survival enhancing propensity on the creature that possesses it" (Bigelow and Pargetter 1987: 188). Thus, a function of a trait depends on the ways in which this trait will behave in future selective regimes: the biological function F of a trait Y in an organism S is the current effect of T which (presumably) will be the cause of the natural selection of S and, consequently, of the future existence of organisms like S with traits like T.

The main problem of the evolutionary perspective is that every evolutionary account is *epiphenomenal:* according to this historical-evolutionary view, functional attributions have no relation to the current contribution of the trait to the system, since they point solely to the selective history of the trait (Christensen & Bickhard, Mossio et al 2009: 821). As Mossio et al. hold:

> [The evolutionary] theories provide an account that is problematically epiphenomenal, in the

> sense that it maintains that the attribution of a function does not provide information about the 'phenomenon' (the current system) being observed. From the perspective of the SE theories, a function does not describe anything about the current organization of the system being analyzed. (Mossio et al. 2009: 821)

This epiphenomenal character is problematic because it is at odds with the fact that functional attributions seem to have a relation —captured by the causal role approaches—to what function bearers currently do, and not only to the causes of their current existence.

Even the forward-looking Propensity View is also epiphenomenical, but in a different sense to the historical theories. In this case, a function ascribed to a token trait does not explain this token trait, but the future existence of other tokens of the same type. Accordingly, the current heart pumping may explain why this trait type will be evolutionarily selected, allowing the existence of offspring with hearts that pump blood in the future, but the current pumping of blood has no explanatory power with respect to the existence of the current heart.

In conclusion, the Evolutionary Approach is able to address the teleological dimension of the concept of function avoiding the problem of the infra-determination of the causal-role theories. However, all these evolutionary approaches ground this teleological dimension appealing to different systems' token features. In trying to answer teleological questions such as "why a trait T exists?" or "Why a trait X will exist in the future?" both historical and propensitivist theories provide a characterization of "causal loop" that appeals to different trait tokens. By affirming that the function of a trait explains the existence of this trait, these explanations actually refer to the "type" and not to the "token" trait. That is why the evolutionary perspective is vulnerable to various criticisms and objections such as its inability to account for the origin or emergence of new functions.

V. Functions as *causal roles* AND *causes of existence*: the Organizational Approach

The recent Organizational Approach (OA) is an integrative proposal that adopts the opposite strategy to the RT. Instead of offering a splitting account considering different systems in order to justify the teleological loop that justifies that a function explains the existence of a trait, the OA aims to provide a unified definition of functions by extending the teleological dimension to the current activity of a trait.

Functional attributions to both past and current traits explain the presence of the very trait in terms of the effects of its contribution to the self-maintenance of the system to which it belongs. Biological beings are self-maintaining systems since they realize a specific kind of causal regime in which the action of a set of parts is a condition for the persistence of the whole organization through time. Thus, the organizational concept of function applies to classes of self-maintaining systems in current or past regimes of self-maintenance, by preserving in both cases its teleological and normative dimensions.

The notion of self-maintenance comes from a theoretical and mathematical framework developed over the past forty years by an increasingly rich body of scientific literature. In theoretical biology, complex systems theory, and far-from-equilibrium thermodynamics, self-maintenance refers to a specific causal regime, realized by various kinds of natural systems, by which a given system is able to exert a causal influence on its surroundings in order to preserve the boundary conditions required for its own existence. In its minimal form, this is shown in the so-called 'dissipative structures' (Glansdorff and Prigogine 1971, Nicolis and Prigogine 1977), i.e. systems in which a macroscopic ordered pattern (a 'structure'), emerging in the presence of a specific flow of energy and matter in far-from-thermodynamic equilibrium boundary conditions, exerts a constraining action on its boundary conditions that contributes to the maintenance of that FFE flow of energy and matter required for its own persistence. In nature, a very broad set of physical and chemical systems, such as Benard cells, flames, whirlwinds, hurricanes, and oscillatory chemical reactions can be pertinently described as self-maintaining dissipative systems (Chandresekhar 1961; Field et al. 1972; Field and Noyes 1974).

The different formulations proposed, among others, by Schlosser (1998), Collier (2000), Bickhard (2000, 2004), McLaughlin (2001), Christensen & Bickhard (2002), Delancey (2006), Edin (2008) and ourselves (Mossio et al. 2009, Saborido et al. 2011), base the grounding of the functional attributions in this self-maintaining organization of biological systems.

In a self-maintaining organization, functions can be interpreted as specific causal effects of a part or trait, which contribute to generate a complex web of mutual interactions, which, in turn, maintains the whole organization and, consequently, the part itself. Organizational theories argue that there is a causal loop at the basis of biological organizations, based in the processes of self-maintenance. This causal loop allows us to ascribe a function to a specific trait to the extent that, due to that trait's disposition that we label "function", the trait contributes to the maintenance of the biological organization to which it belongs.

Since self-maintenance of living systems is possible only insofar as the adequate boundary far-from-equilibrium conditions are maintained, and since the structure itself contributes to maintaining these conditions, the activity of the system becomes a necessary (even if not sufficient) condition for the system itself. The system has to maintain an appropriate interaction with its surroundings to maintain itself. Organizational approaches, such as the one defended by us, claim that organizational closure constitutes the relevant causal regime in which the teleological and normative dimensions of functions can be adequately naturalized. Therefore, that which a self-maintaining system does is relevant; it makes a difference in itself, since its very existence depends on the effects of its activity. An organizational function is therefore a condition for the existence (self-maintenance) of the function bearer. Moreover, such mutual dependence between existence and activity, which is specific to self-maintaining systems, provides an intrinsic and naturalized criterion to determine what norms the system, and its parts, are supposed to follow.

Elsewhere (Mossio et al. 2009, Saborido et al. 2011), I have defended my own version of OA. According to this account, the specific regime of self-maintenance that grounds functionality is what we call "organizational closure". This concept is of increasing importance in theoretical biology and philosophy of biology (see Chandler & Van de Vijber 2000 and Mossio & Moreno 2013) and it is a key notion to understand the specific kind of organization of living beings. In Mossio et al.'s words:

> Biological systems generate a network of structures, exerting mutual constraining actions on their boundary conditions, such that the whole organization of constraints realizes collective self-maintenance. In biological systems, constraints are not able to achieve self-maintenance individually or locally: each of them exists insofar as it contributes to maintain the whole organization of constraints that, in turn, maintains (at least some of) its own boundary conditions. Such mutual dependence between a set of constraints is what we call closure, the causal regime that, we claim, is paradigmatically at work in biological systems (Mossio et al. *In press*).

The most typical example of organizationally closed systems are biological systems, and the intimate association between complexity and integration at work in an organizationally closed organization is the relevant ground of functional discourse in Biology. The interplay between a set of mutually dependent structures acting as constraints, each of which makes a specific and distinct contribution, realizes self-maintenance by maintaining the boundary conditions at which the whole organization, as well as its various structures, can exist. In organizational closure, each process or part is, to use Bickhard's terms, *dynamically presupposed* by the other processes and parts in the overall self-maintenance of the system, such that the whole network must work in a specific and adequate way, for otherwise, because of its FFE nature, the system would disintegrate.

In this framework, functional ascriptions are explanatory because they refer to the net of mutually dependent constraints that contribute to the maintenance of an organization upon whose maintenance their own existence depends.

According to our organizational definition (Mossio et al. 2009, Saborido et al. 2011), a trait is functional if, and only if, it is subject to organizational self-maintenance in a system. This definition implies the fulfillment of three different conditions.

A trait T has (or serves) a function F if and only if:
C1. T contributes to the maintenance of the organization O of S;
C2. T is maintained under some constraints exerted by O;
C3. S realizes organizational closure.

> Accordingly, the heart has the function of pumping blood since pumping blood contributes to the maintenance of the organism by allowing blood to circulate, which in turn enables the transport of nutrients to and waste away from cells, the stabilization of body temperature and pH, and so on. At the same time, the heart is produced and maintained by the organism, whose overall integrity is required for the ongoing existence of the heart itself. Lastly, the organism is organizationally differentiated, since it produces numerous other structures contributing in different ways to the maintenance of the system. (Mossio et al 2009: 828)

In sum, living systems are characterized by the possession of different parts, produced within and by the system, that contribute differently to the maintenance of the organization and thus, of themselves. In this way, teleological and normative functional attributions to each biological trait participating in the organizational closure are justified and grounded.

VI. Conclusions: A new taxonomy of functions

In a paper by Walsh & Ariew published in 1996, they developed a "taxonomy of functions". There, Walsh & Ariew explain the different formulations of the different theoretical approaches as well as their mutual relations within the philosophical debate on functional explanations of that moment (Walsh & Ariew 1996). This taxonomy offered a panoramic review of the philosophical discussion and Walsh & Ariew used it to introduce their own proposal, the relational theory. Walsh & Ariew claimed that every function is a C-Function, i.e., a function according to Cummins definition, and distinguished between "Causal Role" and "Evolutionary" theories. Evolutionary Functions (E-Functions) are teleological and they are divided in Current (or Propensitivist) and Historial views.

I think that the taxonomy of Walsh & Ariew is still essentially right and does a good job at showing the state of the theories on functions at that time. However, the philosophy of biology has changed significantly in recent years and new approaches and theories have emerged in the philosophical debate on functions. Thus, a different contemporary taxonomy of functions should be formulated in order to account for the current state of the art, by taking into account the new approaches in the etiological and dispositional views and integrating this new organizational perspective.

In this paper, I have introduced an update of this description, emphasizing the novelties of the last years. These new approaches have changed the "geography" of the philosophical debate on the concept of biological function.

According to the current state of the philosophical discussion, I propose the following taxonomy of functions:

Figure 1 here

This taxonomy shows that all theories are dispositional. There are two main kinds of theories: causal-role theories (which include SA, GCA and the new OA) and evolutionary theories (where we find the historical approaches of SET and WET and the forward-looking perspective of PV). This taxonomy shows that both evolutionary approaches and the organizational approach are teleological. Moreover, OA, SET and WET are etiologic. Let me clarify this in more detail.

As I have explained, in a general sense every function is a disposition and there are two main ways to ground the kind of disposition that can be interpreted as a function. On the one hand, the different causal-role approaches base the theoretical grounding of functions on the disposition of a specific trait to contribute to achieve a concrete systemic goal or capacity. On the other hand, evolutive functions are also dispositions. According to the evolutionary account, a biological trait's effect is a function if it entails a disposition to contribute, either in past instances or in current organisms, to the selection of the trait via natural selection (as defended by the SET) or to the fitness of the past (WET) or present (PV) organisms.

Besides this dispositional character, the concept of biological function is interpreted by some theories as a teleological one. The Evolutionary Approach claims that a function has an explanatory role, in evolutionary terms, with regards to the present or future existence of the function bearer. And the same teleological character is present in the case of the Organizational Approach, a systemic approach that grounds functional adscriptions in a non-historical and, consequently, non-epiphenomenal causal-loop.

As noted, the explanatory strategy of historical evolutionary theories (SET and WET) is etiological. And, from a non-historical perspective, the same applies to OA. SA and GCA approaches are neither teleological nor etiological. And PV is evolutionary and teleological but, by having a forward-looking strategy, it is not etiological.

In conclusion, this paper has tried to offer a panoramic view of the current state of the debate on biological functions, emphasizing the relevance and novelty of the new organizational strategy. In a discussion that can be mainly understood as a confrontation between two principal stances, the OA perspective introduces itself as a half –way route capable of gathering the best of each of these approaches.

Thus, on the one hand, there are the classic systemic approaches (SA and GCA) that are unable to adequately ground the normative dimension of functional explanations and underdetermine the conditions for the adscription of biological functions because they reject the teleological character of functions. On the other hand, there is the evolutionary approach, which is, in the historical or current alternatives, problematically epiphenomenal.

The organizational approach aims to combine the etiologic and systemic approaches in a teleological and non-epiphenomenal definition of biological functions, since OA. As is stated in the taxonomy described in this paper, the new OA is a causal-role, teleological and etiologic approach. This way, it is able to provide clear criteria for the ascription of functions. However, unlike the historical evolutionary approaches, OA avoids the problem of epiphenomenalism. OA appeals to a causal-loop present in the current living systems, focusing therefore on the biological properties of current organizations[7].

[7] See Saborido et al. (2011) for an organizational answer to the challenge of the ascriptions of biological functions to

Therefore, according to organizational formulations, a function has an explanatory role with regards to the very existence of the functional trait. The reasons for the existence of the functional traits are naturalistically grounded in the organizational features of biological systems, interpreted as self-organizing and self-maintaining entities.

In this sense, a trait's effect that contributes to the self-maintenance of the organization is a normative function that is *at the same time* a biological trait's disposition and a cause of existence (in organizational terms) of such trait. Thus, OA reflects the Kantian interpretation of living beings as "natural purposes" by arguing that, indeed, biological functions are both cause and effect of a biological trait. The integration of the concepts of dispositional effect and cause of existence in this new approach opens the way for a naturalized grounding of the notions of teleology and biological normativity and has some important theoretical implications that seem to go beyond the realm of the philosophy of biology.

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