Teleological Explanations and Selective Mechanisms: Biological Teleology Beyond Natural Selection

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Abstract From a naturalistic approach, several attempts have been made to justify teleological explanations by appealing to the action of selective mechanisms. In philosophy of biology, natural selection has often been assumed to be the paradigmatic case of selective mechanism, and, on this basis, different generalized biological selective explanations have been proposed in an attempt to substantiate natural teleology. In this paper we use a different strategy. Starting from a general definition of selection as differential reinforcement, we interpret the different types of teleological explanation, both biological and non-biological, as specific cases of selective explanations, of which evolutionary explanations would be only a specific subset (rather than the only ones). We illustrate this by analyzing teleological explanations that make reference to biological regulatory processes.

Keywords Teleology · Selection · Function · Evolution · Regulation

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1 Introduction

According to what is perhaps the most popular account of biological teleology, biological purposes are introduced by natural selection (Millikan 1984, 1989; Neander 1991; Griffiths 1993; Kitcher 1993; Godfrey-Smith 1993; Buller 1998, Artiga 2021). The function of a biological trait, in this type of view, is to do whatever previous tokens of that trait were selected for by natural selection. This account can be seen as an instance of selected-effects theories of teleology, which hold that purposes are effects for which an item has been selected.

Selected-effects theories, as we will see, offer an attractive account of many paradigmatic forms of teleology, such as the functions of artifacts, or goal-directed behavior in intentional, rational agents. Arguably, when there is selection, there is teleology. Thus, a promising way of vindicating biological teleology is to argue that there are biological processes, in particular evolution, that involve genuine cases of selection and then to appeal to selected-effects theories of teleology. This vindicatory strategy requires showing that the alleged biological selective processes share the distinctive features of paradigmatic types of selection and, therefore, should be considered as genuine forms of selection as well. This provides motivation to look for a generalized account of selection that covers both biological selection and paradigmatic instances of selection in other domains.

Further motivation for a generalized account of selection is that it opens the door to the recognition of new types of biological teleology. In principle, there could be biological processes other than natural selection that exhibit the defining characteristics of selective processes. If we have a generalized account of selection, which does not apply just to natural selection, we can check whether a given biological process deserves to be considered a form of selection.

When constructing a generalized account of selective processes, one approach is to take natural selection as our model. In this approach, a process counts as selective insofar as it is analogous or relevantly similar to natural selection. We want to argue, however, that this approach is on the wrong track. Natural selection differs in several significant points from many paradigmatic types of selection. Thus, modelling a generalized account of selective processes on natural selection has the risk of leading to an unduly restrictive account.

A potential negative consequence of this is that one may fail to count as forms of selection biological processes that, despite not fitting the mold of natural selection, closely resemble paradigmatic types of selection. We think that this is what happens, for instance, with biological regulation. As we will explain, biological regulation shows relevant dissimilarities with natural selection. One could claim that, due to this, it is a stretch to regard regulation as a type of selection. However, we will argue that, if anything, regulation is closer than natural selection to paradigmatic forms of selection.

Our claim, therefore, is that a lack of similarity to natural selection is not a reason to discard processes that are strongly analogous to more paradigmatic types of selection as nonselective. As a kind of selection that in important ways differs from many paradigmatic selective processes, natural selection should not be taken as the (only) yardstick to determine what counts as selection. Instead, we propose constructing a minimal, generalized account of selection that captures both paradigmatic forms of selection and more atypical cases. We suggest doing so by relying on the notion of differential reinforcement. Biological regulation, as we will see, fits this generalized account and, therefore, deserves to be considered a genuine type of selection—giving rise, according to selected-effects theories, to its own form of teleology.

2 Selected-Effects Theories

Teleological explanations involve a distinctive loop between causes and effects. Walsh (2008) describes this teleological loop as follows: "teleology is a mode of explanation in which the presence, occurrence, or nature of some phenomenon is explained by the end to which it contributes" (Walsh 2008: 113). In a series of seminal papers in the 1970s, Wright (1976) proposed analyzing this explanatory loop by appealing to the causal history of the items to which purposes are attributed. In this view, the existence of an item can be accounted for in terms of some of its effects insofar as these effects play a crucial role in the causal history of the origin or preservation of the item. Wright thus inaugurates the so-called etiological approach to teleology, grounding purposes in causal history.

According to etiological approaches, the function of something is identified as the reason why it exists in its present form. Thus, in these approaches, to say that "the function of X is Y" is to say that "X exists because it does Y." Causal history (etiology) explains the presence of a feature through one of its effects, that is, its function. For example, the blood pumping function of the heart in the past explains why hearts exist today, or the function of the peacock's tail to attract mates in ancestral specimens explains the current existence of this trait. Functions have an explanatory role in accounting for the presence of these traits because of their historical relevance.

However, even if it is granted that the continued presence of a trait is explained by its tendency to produce certain effects, it is not immediately clear why this, on its own, would entail that the trait has a purpose and is subject to standards of success. There are multiple examples in the literature of cases where an entity has certain effects that de facto determine the continued existence of the entity without these effects actually being understood as "goals." For example, Bedau (1991) describes the case of a stick floating down a river that remains pinned on a rock due to the backwash it creates. As Bedau points out, "the stick does not create the backwash in order to keep itself pinned on the rock" (Bedau 1991: 648).

Etiological approaches can avoid this type of counterexample if they make use of selected-effects theories of teleology (Millikan 1984, 1989; Neander 1991; Griffiths 1993; Godfrey-Smith 1993). In these theories, the relevant teleological loop between causes and effects is generated by selective processes. That is, certain effects explain the presence or proliferation of some traits because having these effects explains why those traits were selected in a relevant selective process. Accordingly, the purpose of a trait is doing whatever it was selected for.

In the example above, the position of the stick on the rock is not explained in terms of any selective process. Thus, selected-effects theories do not attribute purposes to the backwash of the stick. In general, it seems natural to employ teleological discourse whenever we find cases of selection. As Griffiths (1993: 420) claims, “where there is selection, there is teleology.” The connection between selection and teleology is also highlighted by Neander (1991: 463): “Teleological explanations (. . .) explicitly refer to a future effect of a trait for which that trait was selected. In doing so they explain the trait by implicitly referring to the causally efficacious selection process from which it resulted.”

Selection captures two of the central features of teleology: its evaluative nature and the existence of teleological loops. First, both teleology and selection have an evaluative dimension, understanding evaluative normativity as concerning what is good or bad (beneficial or detrimental) in some way (McLaughlin 2009). Purposes are associated with evaluative standards: a successful performance is good as an instance of purposeful behavior. Likewise, selection comes hand in hand with evaluation. We can think of selection as classification plus valence. Items selected *for* are positively evaluated with respect to the standards governing that selective process, while items selected *against* are evaluated negatively.

Moreover, selection gives rise to the type of teleological loop discussed in etiological theories like Wright’s (1976). In selective processes, certain items are preserved, promoted, or positively reinforced in some way, whereas others are inhibited or negatively reinforced in some way. The reinforcement of selected items is explained by those effects that led to their selection.

Selected-effects theories offer, therefore, an attractive account of teleology. These theories deal well with many paradigmatic types of teleology. Consider intentional, goal-guided decision-making. This type of purposeful behavior involves selecting a course of action that contributes suitably to the achievement of the relevant goals, while discarding alternative actions that are detrimental to it. Because the relevant actions were selected due to their tendency to have certain effects or consequences, selected-effects theories regard these effects as the goals of such actions.

A second example is that of the functions of artifacts. The creators of artifacts select their features because of their role in producing certain effects. Therefore, according to selected-effects theories, the purposes or functions of artifacts are to produce these effects. For instance, the designers and manufacturers of hammers choose their shape (a compact head with a flat impacting surface) because of its usefulness to produce effects such as driving in nails. These are, therefore, the functions that creators of hammers intend them to have. Of course, if users select a hammer rather than another tool for a different task (say, being a paperweight), performing this further task can become the (perhaps temporary) function of the hammer in relation to the selecting intentions of those users. In the next section, we consider views that apply selected-effects theories to biology in terms of natural selection. We discuss the possibility of using natural selection as a model for a general characterization of biological selection that covers other types of biological selective processes. We will argue that generalized accounts of (biological) selective processes modelled on natural selection are too restrictive and leave out legitimate kinds of biological selection, such as self-regulation.

3 Modelling Biological Selective Processes on Natural Selection

The vast majority of selected-effects theories in biology take natural selection as the basis of biological teleology (Millikan 1984, 1989; Neander 1991; Griffiths 1993; Godfrey-Smith 1993; Buller 1998, Artiga 2021). In this type of view, biological purposes are effects selected by natural selection. In this way, the existence of a current token of a purposeful trait is explained by the fact that past members of its lineage tended to produce certain effects, which led to their proliferation under natural selection.

An interesting question is whether selected-effects theories can be applied in biology beyond natural selection, that is, to other types of biological selective processes. One way to go here is to construct a general characterization of selective processes based on the features of natural selection (Darden and Cain 1989; Garson 2017). Natural selection would be taken as model for determining when a mechanism counts as selective and thereby grounds teleological explanations. The aim is then to find biological processes that fit this general characterization, by virtue of their being sufficiently analogous to natural selection. A reason to adopt this strategy is that natural selection is arguably the most studied and best understood biological selective process, so it makes sense to use it as a model to investigate further forms of biological selection.

Darden and Cain (1989) have proposed a generalized account of selection of this kind, inspired by the features of natural selection but applicable to other biological selective processes, such as clonal selection or immunological selection. In Darden and Cain's words:

> A selection process may be broken down into a series of steps from which a more abstract characterization can be developed.
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> (A) First are the preconditions before a selective interaction. These include a set of individuals that vary among themselves. Also, the individuals must be in an environment with critical factors that provide a context for the ensuing interaction.
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> (B) The actual step of selection involves an interaction between individuals and their environment. Because they vary, different individuals will interact differently.
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> (C) Several types of effects result from the differential interactions. In the short-range, individuals benefit or suffer. If the individuals can be located in a hierarchy (such as gene, organism, group), then there may also be short-range effects of sorting at other levels.
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> (D) Longer-range effects may follow the short-range effects of the interaction, such as increased reproduction of individuals with certain variations or reproduction of something associated with those individuals.

> (E) Even longer-range effects may also occur, such as accumulation of benefits through numerous generations to produce a lineage of individuals. (Darden and Cain 1989: 110)

Natural selection follows the steps of Darden and Cain's schema. In cases of natural selection, we have a population of individuals featuring variability in some of their properties (say, a population of peppered moths with different colors). Individuals in these populations interact with their environment in different ways depending on these variable properties (dark moths in trees darkened by soot are less visible to birds of prey). As a result of these different ways of interacting, individuals with some of the variable properties are more likely to survive and reproduce than others (dark moths are less likely to be eaten by said birds of prey). Thus, individuals with certain properties tend to proliferate. This leads to the formation of lineages in which some of the properties predominate (e.g., lineages of dark moths).

Darden and Cain argue that the core elements of evolutionary explanations can be generalized and applied in other selective explanations in biology. Explanations involving clonal or immunological selection, for instance, would be selective in the same way as explanations involving natural selection because they would share the same basic structure. As Darden and Cain (1989: 118–121) explain, in Burnet's (1957) clonal theory of antibody formation, we can observe the fundamental elements of selective processes: (A) There is a set of lymphocyte cells, with different reactive sites. (B) Different antigens activate lymphocyte cells with different reactive sites, making them produce clones of themselves. Thus, cells with different reactive sites interact in different ways with antigens in the environment. (C) In the presence of a given antigen, cells with a certain reactive site are activated and produce clones of themselves, while other cells are not activated. (D) Activated cells proliferate by cloning themselves and release antibodies of a specific type that attack the antigen that activated them. (E) More cells of this type are present after the antigen is eliminated, so that the immune system is able to respond more quickly to future invasions by that kind of antigen.

So, according to Darden and Cain's generalized characterization of selection, antibody formation involves selective processes which are different from natural selection, but with an analogous abstract structure. Darden and Cain's proposal clearly exemplifies what has been the most common strategy for investigating biological selective mechanisms. It is typical in philosophy of biology to assume that natural selection is the paradigmatic case of a selective mechanism in biology and, on the basis of this type of mechanism, to try to offer a generalization of the idea of selection that can be used to account for other biological processes. This strategy is followed, among others, by Griffiths (1993) and Garson (2017). We do not wish to deny that taking natural selection as a model can be useful in identifying and characterizing other types of selective processes in biology, such as immunological selection. However, we think that this approach leaves out interesting forms of biological selection that do not share some of the structural features of natural selection. The example we will focus on here is biological regulation. We argue that regulation deserves to be considered as a type of biological selection, at least as much as natural selection does, given that it shares the core features of paradigmatic forms of selection. Accounts of selection modelled on natural selection are too narrow insofar as they exclude these paradigmatic types of non-biological selection. If we construct a characterization of selective processes broad enough to include these paradigmatic types of selection, biological regulation would also be included.

4 Selection Generalized

Garson's (2017) generalized account of selective processes mirrors the structure of natural selection less closely than Darden and Cain's. In particular, Garson argues that the forms of selection giving rise to functions can be a matter of differential retention, and not just of differential reproduction (as happens in natural selection).[1] Garson's main aim is to examine processes of neural selection, such as synaptic selection. Synaptic connections do not reproduce, but they can be differentially retained or eliminated in competitive processes, depending on their levels of activation. According to Garson, this form of competition can ground a form of selection, even in the absence of differential reproduction.

We consider Garson's view to be going in the right direction. There are many paradigmatic forms of selection without reproduction. Think of someone choosing apples in the supermarket. Obviously, the selected apples will not reproduce; they are just taken home by the buyer. Our proposal, however, is to go further than Garson and take selection to be more generally a matter of differential reinforcement. We understand reinforcement broadly, as including reproduction, retention, and different forms of promotion or enhancement. For instance, a way in which a process can be positively reinforced is by being stimulated or intensified. So, in glycemia regulation the release of insulin stimulates the absorption of glucose into muscle, adipose, and liver cells while suppressing the production of glucose through glycogenolysis. This is an example of differential (positive and negative) reinforcement of certain processes without reproduction or retention.

Our claim, therefore, is that selection involves the differential reinforcement of certain effects or traits, where this reinforcement may be a matter of being promoted, reproduced, preserved, stimulated, or intensified somehow (or, alternatively, inhibited, suppressed, or eliminated). The notion of reinforcement, we think, is sufficiently flexible to cover the great variety of cases of selection, including its most paradigmatic forms. It makes sense to consider natural selection a selective process precisely because it involves differential reinforcement, in the form of differential reproductive rates. Learning by trial and error is another example of selection based on reinforcement. In this case, the learner develops dispositions to repeat some behaviors and not others depending on whether they are observed to produce certain outcomes reliably.

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[1] An account of selection in terms of retention can also be found in Campbell (1960).

There are other ways in which Garson's proposal remains, in our view, too attached to the model of natural selection. Garson (2017) requires that selection operates on a population of (actual) entities engaged in fitness-relevant interactions. This is certainly a feature of some forms of selection, but it is absent in many paradigmatic selective processes. Thus, a generalized account that includes this condition remains too restrictive and may leave out genuine cases of biological selection. Consider a process of selection of candidates for an academic distinction. Such a process may consist of an individual exam, without interactions among the candidates. Indeed, the process does not need to be competitive. Imagine that there is no limit to the number of distinctions that can be awarded. Then, whether a candidate gets the distinction is a matter of whether their exam results meet a given standard, regardless of how their performance compares to that of the other candidates.

It can be argued that selection does not always operate over a preexisting population of items featuring variability in their features. Go back to the academic distinction example. Think of a case where there is only one candidate. Still, it makes sense to say that, if the candidate passes the exam, they have been selected for the award. The important point is that the candidate has been selected for certain features or effects of their performance (in particular, their results in the exam) and would not have been selected if those effects had been different. Thus, selection has a modal dimension: selective processes involve dispositions to reinforce items with certain effects, so that the selection of some item is explained by its tendency to have those effects. This does not require there to be an actual population of items with different features. What matters is that should there be an item without the relevant effects, then it would not have been selected by the selective process in question. It is irrelevant whether such an item actually exists in any given population.

We can now sketch a rough generalized characterization of selective processes as driven by mechanisms with the disposition to differentially reinforce certain items by virtue of some of their effects or features. We are relying here on a basic notion of selective mechanism in line with most contemporary mechanistic approaches, such as that of Illari and Williamson (2012), for whom "a mechanism for a phenomenon consists of entities and activities organized in such a way that they are responsible for the phenomenon." It also fits what Glennan (2017) has called Minimal Mechanism: a mechanism for a phenomenon consists of entities (or parts) whose activities and interactions are organized in such a way that they are responsible for the phenomenon. In the case of selection, the relevant phenomenon is the reinforcement of certain effects or traits over possible alternatives. Selective mechanisms are those entities and activities responsible for this type of phenomenon.

This is then our proposed general characterization of a selective mechanism:

> A selective mechanism is a mechanism by which the behavior of a system and its relationship with its environment are modified in such a way as to reinforce the presence of certain effects or traits over other alternatives.

We want to use this general abstract characterization to address in what sense certain explanations show a teleological dimension, making use of a selected-effects account of teleology. We will argue that an explanation is teleological if it appeals to effects of a trait that explain its reinforcement through a *selective process*.

We will therefore sustain this thesis about the selective character of teleology[2]:

> T1: A trait can be teleologically explained if it is structured as the result of a selective process.

We argue that a general characterization of the notion of selection provides a valuable abstraction of teleological explanation in all its diversity. This abstraction will help us not only in the task of naturalizing controversial teleological explanations but also in understanding how these explanations must be construed in order to be useful to current researchers in elaborating new theories.

In the next sections, we examine how our minimal, generalized account of selection applies to paradigmatic cases of intentional selection and also to natural selection. After that, we discuss biological regulation as an example of a biological process that is considered as selective according to our generalized account, despite not meeting some of the conditions of characterizations of selection modelled on natural selection. Our conclusion is that biological regulation should therefore be considered a selective process, giving rise to its own form of biological teleology.

5 Intentional Selection

Perhaps the most paradigmatic form of selection is that in which the relevant selective mechanism is constituted by an intentional agent who chooses among several possible options. This type of selection is found in explanations of typical human behavior, artifact design, and intentional selective breeding. Think, for example, of a customer selecting pieces of fruit in a supermarket, a committee selecting candidates for a position, or a family choosing a film to watch on TV. Similarly, the shape of a tool can often be explained by referring to the intentions of its designer. In this way, we can explain why a hammer has the shape it has (a compact head with a flat impacting surface) in terms of its intended use: the designer of the hammer intended it to perform tasks such as driving nails, so they selected a tool with a fitting shape for those purposes.

Methodical selective breeding (also known as artificial selection) is another paradigmatic example of intentional selection, studied in detail by Darwin (1868). In this type of intentional selection, a breeder chooses animals or plants with certain

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[2] Note that this type of selected-effects theory posits sufficient, but not necessary, conditions of teleology. We leave open the possibility of teleology without selection.

phenotypical traits to reproduce together, promoting in this way the presence of those traits in their offspring.

In cases like these, an agent, or group of agents, makes intentional decisions by virtue of which certain options are selected. Given that these are paradigmatic instances of selection, they should be counted in by accounts that aspire to offer a generalized characterization of selection. If an analysis of selective processes imposes conditions that are not met in these paradigmatic instances of selection, then we have reason to think that such an analysis does not cover all central forms of selection. The fact that a mechanism does not satisfy the conditions of this analysis would not mean that it cannot count as selective.

Many cases of intentional selection fail to fulfil the conditions of characterizations of selective processes modelled on natural selection. In particular, intentional selection does not presuppose a preexisting population of items to be selected, nor fitness-relevant interactions, as Garson's (2017) account does. For instance, when choosing whether to go for a picnic or take a walk by the river, one does not select among preexisting picnics and walks, but rather chooses an option among possible (non-actual) alternatives. If I choose the walk, the picnic will remain an unrealized possibility. Moreover, intentional selection can involve a wide variety of forms of differential reinforcement, beyond differential reproduction or retention (we can also have, for instance, differential repetition or differential increases in the intensity or rate of a process).

But, of course, intentional selection does not stop counting as a selective process just because it does not fit in with generalizations of the notion of selection modelled after natural selection. Intentional selection is, if anything, a more paradigmatic type of selective process than natural selection. So, rather than denying the existence of intentional selection, authors like Darden and Cain tend to treat it as the basis of a different type of mechanistic explanation that deserves a separate analysis.

We grant that a pluralistic approach to selection mechanisms can be fruitful—after all, it is to be expected that these mechanisms will present a great degree of heterogeneity. However, in light of this pluralism, one should not assume that all relevant forms of biological selection share the distinctive structure of natural selection. Accounts based on natural selection are too narrow when taken as generalized characterizations of selective processes. That is why it can be useful to find some core characteristics of selection mechanisms that feature not just in natural selection but also in other central selective processes. Our proposal is that the notion of differential reinforcement allows us to develop just such a general characterization of selection mechanisms.

In particular, intentional selection can be perfectly captured by a characterization of selection in terms of differential reinforcement. In this case, an intentional agent (or a group of them) would be responsible for the differential reinforcement of the relevant items and would therefore act as a selective mechanism. We can now have intentional teleological explanations that are a variant of T1, where the selective mechanism is constituted by intentional agents:

T2: A trait can be teleologically explained if it is reinforced as the result of the selective process performed by intentional agents. [3]

6 Natural Selection

Intentional explanations have been very influential in the history of the life sciences. In particular, what we can call the intentionalist approach tries to account for biological teleology by appeal to the intentions of some agent. This type of approach is reflected in the famous design argument, wielded from deistic positions and vehemently defended for centuries by promoters of Natural Theology. In Natural Theology the Creator has devised the conformation and activity of living things. This powerful demiurge has "chosen," from a potentially infinite variety of alternatives, the design of the concrete organization of each biological individual with all its particularities. Thus, natural organizations are teleological because they respond to a specific purpose, which would be the purpose for which their creator has designed them in such a way. [4]

In naturalistic approaches to biological teleology, the action of a supranatural intentional selector is left out of the explanation, but the primary role of selection in grounding biological teleology has been, to a large extent, retained. In etiological-evolutionary views, predominant in the current philosophy of biology, it is the action of natural selection that confers purposes to biological traits. Thus, biological purposes would no longer be the impositions of an external intentional selector, but the result of a long evolutionary history in which certain effects have been preserved and others have disappeared. Natural selection "chooses" biological purposes.

Consequently, from a completely different starting point than intentionalist approaches, etiological-evolutionary theories also consider selection to be the basis of teleology. In this case, the relevant selective mechanism is natural selection (see Barros 2008 for a defense of the view of natural selection as a [stochastic] mechanism). Differential reinforcement here takes the form of differential reproduction, so that selected traits are those that proliferate under selective pressures. It is thus

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[3] This formulation of teleological intentionalism has clear precedents in Broad's classic proposal (Broad 1925: 82).

[4] For a detailed analysis of the "design argument," see Sober (2018). Put forward by Hume in his *Dialogues Concerning Natural Religion*, and famously expounded in the the early nineteenth century by William Paley, this argument has been pervasive in the history of biology up to the present day.

possible to speak of a "what for" [5] in biology because we can identify a selective mechanism, natural selection, that explains the actual existence (more specifically the proliferation) of certain traits and their effects. In this way, etiological-evolutionary approaches can be seen as a particular case of T1:

T3: A (biological) trait can be teleologically explained if [6] its proliferation is the result of natural selection.

Natural selection is the key to grounding teleology in a naturalistic approach because it is understood to be a selection mechanism, in the same way that intentional, mentalistic selection mechanisms can be identified in cases of intentional purposive behavior. Nature selects an effect of a trait in the analogous way that we intentional agents choose from among different alternatives (we choose courses of action, friendships, or supermarket products). To be sure, these two types of selection mechanisms are very different in their specific details, but both exhibit the core, characteristic feature of selective processes: differential reinforcement. Take, for example, the standard etiological explanation that the function of the heart is to pump blood because this is the effect responsible for the preservation of this trait throughout the evolutionary history of mammals under the pressure of natural selection (Buller 1999: 1–7). This explanation treats natural selection as the selection mechanism underlying ascriptions of functions. In our proposal, natural selection can be considered as a selective mechanism insofar as it involves a historical form of differential reinforcement. So, hearts that fail to pump blood tend not to proliferate; their presence in future generations tends to be inhibited.

One could try to argue that, when investigating biological teleology, we can focus on those forms of selection typical in biology. What kinds of selection are paradigmatic in non-biological domains would not be relevant, so there would be no need to find a generalized account that covers non-biological selective processes. So, we could have a splitting account that distinguishes different types of selective mechanisms, giving rise to different types of teleology, without a general account of selection unifying them.

This splitting account, however, is problematic. First, it may undermine the application of selected-effects theories of teleology in the biological domain. The connection between selection and teleology is especially clear in paradigmatic cases of non-biological selection, in particular in intentional selection. If one holds that biological selection does not belong to a common kind with other types of selection, then the idea that biological selection introduces teleology may be questioned. One

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[5] A classic discussion of the distinction between finalistic "what for?" questions, as opposed to historical "how come?" ones, can be found in Mayr (e.g., 1961).

[6] Again, this is only a sufficient but not a necessary condition. A trait can be explained teleologically in relation to its selective history, but not only so, as shown, for example, by teleological explanations based on biological regulation.

objection could be that we are equivocating different notions of selection: we start with a connection between teleology and non-biological selection, and then we export it illegitimately to the biological domain, despite the fact that biological selection and non-biological selection are different types of phenomena. It could even be claimed that the term “selection” is used in biology only in an extended or metaphorical sense, which should not carry teleological implications that are only warranted in genuine cases of selection. All these worries will be assuaged if we can show that biological selection shares the central features of those forms of selection in which the connection with teleology is undeniable. So, a generalized characterization of selection covering biological and non-biological cases puts biological selected-effects theories on a firmer footing.

Moreover, as we have already pointed out, there are interesting biological selective processes that do not fit the mold of natural selection, such as biological regulation. So, even if we are only interested in biological teleology, a characterization of selection with natural selection as its model will remain too restrictive. We need a more general account that also captures these other types of biological selection.

In the next section, we discuss biological regulation as an example of a biological selective process that satisfies our generalized characterization of selection, despite not mirroring the structure of natural selection. We will argue that, in many respects in which the features of regulation and of natural selection diverge, the former is closer than the latter to paradigmatic forms of selection. So, discussing selection in relation to regulation is not more of a stretch (if anything, less) than doing so in relation to natural selection.

7 Regulation

Besides the evolutionary approach, there is another etiological tradition in philosophy of biology: the so-called cybernetic approach, based on ideas introduced by Rosenblueth et al. (1943) and developed, among others, by Sommerhoff (1950, 1959). The cybernetic theorists locate a teleological loop *á la* Wright in concrete dynamics that occur in the framework of the current organization of living beings. In particular, authors in this current have tended to consider that the feedback mechanisms that guarantee the stability of biological systems, such as homeostasis, provide the basis for the attribution of biological functions and, consequently, for teleological discourse in biology (Adams 1979; Boorse 1976; Edin 2008). Cybernetics is also one of the pillars on which the current organizational approach to biological teleology is based (Christensen and Bickhard 2002; Mossio et al. 2009; Saborido et al. 2011; Schlosser 1998). According to this approach, a trait function would be the effect of this trait that makes a contribution to the dynamic maintenance of the conditions, both internal and relational, which allows the living system to continue existing. For example, the function of the heart would be the pumping of blood because this pumping of blood has effects that have a direct impact on biological self-maintenance, such as the transport of nutrients to the cells, the stabilization of temperature and pH, and so on. The cybernetic approach allows for a naturalized explanation of certain teleological statements of biological systems based on the properties of their organization.

In recent years, the notion of biological regulation has become particularly relevant for the study of the organization of living beings, offering a more sophisticated approach to biological self-maintenance processes than other notions traditionally used by cybernetic approaches. In line with Bich et al. (2016), [7] regulation can be characterized as the capability to actively modulate the internal dynamics and behavior of a system in relation to variations in internal and external conditions. Regulation is the result of specialized mechanisms that evaluate disturbances and operate accordingly. These regulatory subsystems are "sufficiently independent of the dynamics of the controlled processes, and which can be varied without disrupting these processes, but it is still able to be linked to parts of the mechanism controlled system [the regulated subsystem] so as to be able to modulate their operations" (Bechtel 2007: 290).

Regulatory mechanisms are central to biological organization and are discussed in detail in the biological sciences, as the example of lac operon shows. Thus, as described by Bich et al. (2016), in the case of lac operon, two subsystems are identified: "the regulatory subsystem (consisting of the DNA sequence -promoter, operator, genes- plus regulatory proteins) and the regulated one (metabolism, or parts of it)" (Bich et al. 2016: 261). The lac operon is a concrete mechanism of regulation of protein synthesis, i.e., a process by which a cellular regulatory subsystem of an organism is able to choose what proteins or enzymes to produce given certain environmental characteristics, such as the availability of specific amino acids. Therefore, a system with adaptive regulation is capable of actively modulating its internal dynamics and behavior. It is not simply a matter of resilience or robustness, in which an organism passively "resists" the pressure of the environment. Regulation, instead, enables the organism to actively engage with the environment through selective processes: regulation involves a mechanism of selection—the regulatory mechanism—of the appropriate operations that a biological system must perform given specific circumstances.

Some simple types of regulation take the form of homeostatic stability. Homeostasis refers to the capacity of certain systems to maintain their internal dynamics in a stable attractor in the face of external perturbations or internal variations. Regulatory mechanisms can sustain homeostasis by adjusting the behavior of the system to these perturbations and variations, so that the stability of the system is preserved.

For example, mammals are able to maintain blood sugar levels within fairly narrow limits. If there is a rise in blood sugar, the beta cells of the pancreatic islets

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[7] In this paper we focus mainly on the characterization of regulation developed by Bich and collaborators and presented in Bich et al. (2016), Bich et al. (2020), and Bechtel and Bich (2021), because it is a particularly well-developed analysis of biological regulation, particularly well suited for conceptual and philosophical analysis (see also Winning and Bechtel 2018).

respond by secreting insulin into the blood and, at the same time, preventing their neighboring alpha cells from secreting glucagon into the blood. The combination of a high level of insulin in the blood and a low level of glucagon triggers the action of the effector tissues, mainly the liver, fat cells, and muscle cells, which—through different physiological mechanisms of inhibition and glucose uptake—manage to correct the excess glucose in the blood. On the other hand, if the perturbation faced by the mammal is a drop in blood glucose, this causes the interruption of insulin secretion and glucagon secretion from the alpha cells into the blood. Here, the uptake of glucose from the blood by the liver, fat cells, and muscles is inhibited, and, instead, the liver is strongly stimulated to produce glucose, which is discharged into the blood, thus reversing the hypoglycemia.

In the case of glycemia regulation, the relevant regulatory subsystem would involve beta and alpha cells in pancreatic islets, which detect significant variations in blood sugar levels and carry out actions that have an impact on other parts, such as the liver, fat cells, and muscles, ultimately leading to homeostasis, that is, the return to the original state in which the blood sugar level is within certain variables (Bich et al. 2020: 9).

This example shows that homeostasis can be an instance of regulation, insofar as it is achieved through the intervention of a regulatory mechanism. However, it is important to bear in mind that not all forms of regulation are homeostatic. Approaches that claim that homeostasis is a goal of the biological systems presuppose that the viability of the system depends primarily on its stability (Ashby 1956; Keller 2008). In this view, biological organisms would be systems that need to be brought back to their default state when they are affected by perturbations, as shown by the case of blood sugar levels. By contrast, regulatory adaptability does not necessarily imply a return to this default state. Adaptability implies change. Although the activity of regulatory mechanisms may result in the stability of some variables, this homeostasis cannot be considered as a goal in itself, but as a means to maintain the viability of the system. Indeed, in several cases, the viability of the system is achieved precisely by moving away from the original state. Considering that living systems are continuously interacting in a changing environment and undergoing internal transformations, regular behavior and stability might be the exception rather than the rule. Different organisms, or the same organism in different moments, may exhibit different set points for their physiological variables.

Let us consider a simple example. In a situation of danger, heartbeat and blood pressure change with respect to a situation of rest to provide oxygen and glucose for skeletal muscles. Regularity and stability in this case would not be beneficial but rather detrimental to the self-maintenance of the organism. An adaptive response to the situation of danger requires changes in the behavior of the heart, for instance, a faster heartbeat (Saborido and Moreno 2015).

Thus, instability can be more adaptive than stability, as the extremely large number of degrees of freedom it provides makes it possible for the system to carry out appropriate operations in extremely varied situations (Kitano 2007). Regulatory adaptivity focuses on engaging with, and taking advantage of, variability and change, instead of preventing them. Regulatory mechanisms do not only respond to perturbations that threaten the survival of the system or destabilize some variables in the system. A system endowed with adaptive regulatory mechanisms can implement new types of organization based on the environmental conditions. This is already observable in very simple cases of biological organization, for example, in bacteria, to actively exploit opportunities in the environment rather than merely react to it: to follow a gradient of concentration of nutrients, to synthesize different enzymes to metabolize different nutrients depending on their availability in the environment and their energy efficiency, to establish themselves in given locations or to move to others, etc.

The regulatory modulation of the dynamics of organisms constitutes a form of differential reinforcement. In general, regulatory mechanisms promote certain states or dynamic tendencies of the organism while inhibiting others. In some cases, this may be a matter of preserving the homeostatic stability of the organism, actively suppressing or counteracting deviations from such stability. Deviations, therefore, tend to be counteracted by regulatory mechanisms (for instance, in order to keep a certain level of blood sugar). But, as we have seen, regulatory mechanisms sometimes switch between different modes of operation of the organism, as when a heartbeat gets faster in response to danger. Here the regulatory mechanism triggers the realization of one possible mode of behaviors of the regulated system over the alternatives (in this case, different heartbeat frequencies).

In accordance with our characterization of selection, regulation can be regarded as a selective process, by virtue of the role that differential reinforcement plays in it. Regulatory subsystems act as selective mechanisms that are disposed to differentially reinforce certain states and tendencies of the organism. In a selected-effects approach, therefore, biological regulation grounds teleological explanations based on the organizational properties of living beings.

Note that this is so even if regulatory selection does not satisfy the conditions of accounts of selection developed by generalizing the structure of natural selection, such as Darden and Cain's (1989). Among other things, regulation does not typically operate over a preexisting population of different items with variable features (for instance, a population of different heartbeats). Despite this, it makes sense to count regulation as a form of selection mechanism, since it exhibits the core features of selection, in particular differential reinforcement leading to a loop between effects and causes.

It is worth mentioning one aspect in which regulation is closer than natural selection to central instances of selection. In most paradigmatic cases of selection, it is possible to identify a selector, a concrete agent or system responsible for the reinforcing pressures driving the selective process. One can point to such selectors in order to answer the question about who performs the relevant selection. For example, in a recruitment process, the selector is the hiring committee. Likewise, regulatory subsystems play the role of selector in biological regulation. Remember that regulatory mechanisms are constituted by concrete, physically realized systems in the organism. By contrast, in natural selection it is not clearly the case that one can find a concrete, individuated selector. To the question of who selects in natural selection, one can only offer vague answers—perhaps nature—but it is hard to find a concrete entity responsible for such selection. We do not intend this to discredit natural selection as a selective process. We grant that there is a well-defined notion of mechanism according to which natural selection can count as a (selective) stochastic mechanism (see Barros 2008). However, this example shows that biological regulation is in some ways more similar to paradigmatic selective processes than natural selection.

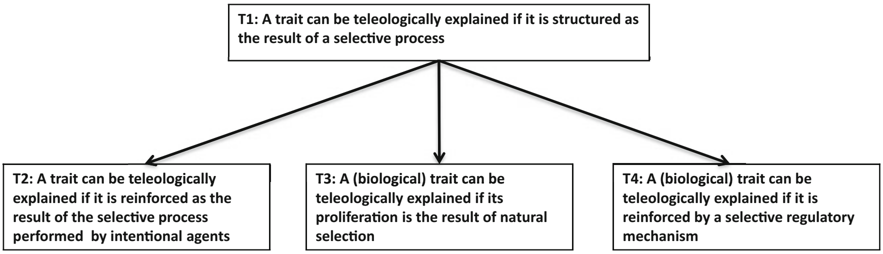
Our claim, therefore, is that it is possible, on the basis of the notion of biological regulation, to develop a naturalistic, etiological account of biological teleology that is different from (even if compatible with) evolutionary approaches. Regulation grounds teleological explanations because it is a selective process, by which biological systems modulate the conditions of their interaction with the environment in order to continue to maintain themselves. Regulatory selective mechanisms allow us, therefore, to naturalize certain teleological explanations that appeal to the functioning of biological organizations "here and now" (appealing to what Mayr (1961) defined as "proximate causes"). In this way, we get a further application of our selected-effects schema T1, this time associated with regulatory selection mechanisms:

> T4: A (biological) trait can be teleologically explained if it is reinforced by a selective regulatory mechanism.

8 Conclusions

In the selected-effects approach we have pursued here, teleological explanations are justified by their appeal to minimal selective mechanisms, that is, mechanisms that involve differential reinforcement. The existence of a mechanism that selects certain effects gives rise to teleological loops, in which the presence of a trait is explained by some of its effects. Selection, consequently, is a source of teleology in all domains in which it takes place.

In this way, teleological explanations based on the intentions of rational agents (T2), on the action of natural selection (T3), and on the regulatory mechanisms of biological organizations (T4) are particular cases of selective teleological explanations (T1), focusing on different selective mechanisms.



T1: A trait can be teleologically explained if it is structured as the result of a selective process

T2: A trait can be teleologically explained if it is reinforced as the result of the selective process performed by intentional agents

T3: A (biological) trait can be teleologically explained if its proliferation is the result of natural selection

T4: A (biological) trait can be teleologically explained if it is reinforced by a selective regulatory mechanism

T2 has no place in naturalistic explanations in biology—at least, unless we give a naturalistic account of the relevant intentional selectors. On the other hand, biological traits can often be explained from the perspective of both T3 and T4, given that the same trait can be under the scope of both natural selection and regulation. These explanations are compatible in a strict sense, since they just focus on different selective regimes to which the item is subject to. In many cases these different selective processes will promote the same effects, so that the function ascribed to a trait will be the same from both approaches. For example, pumping blood is the function of the heart both because it is an evolutionarily selected effect and because it is also the result of organismic regulation. In other cases, this is less clear. For example, functions can be identified and teleological explanations offered for traits that have not yet undergone the action of natural selection (emergence of new functions) or that have changed their function at some point in their evolutionary history (exaptations).

The selective actions of regulation and of natural selection are interdependent: natural selection acts on traits whose behavior is modulated by the regulatory mechanisms of individual organisms, and, at the same time, these regulatory mechanisms and the traits they regulate have been shaped by natural selection.

Teleological explanations based on regulatory mechanisms are therefore not intended to replace teleological explanations based on the mechanism of natural selection. Both share the same logical structure: the action of a selection mechanism justifies the ascription of purposes. If teleological explanations have any scientific value, it should be their contribution to increasing knowledge about biological phenomena. A naturalistic approach to biological teleology will therefore benefit from the inclusion of explanations that take into account selective mechanisms other than natural selection which, like regulation, serve to provide a better insight into the reasons why certain biological structures and processes originate and are preserved.

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